ASSET Road

Integrated
System Solution
for Safety

Advanced
Safety and Driver
Support for
Essential Road
Transport

Fp7 Sp1 Cooperation
Grant agreement 217643
www.project-asset.com

Deliverable 1.2

DEL1.2 ASSET-Road Safety Theory and Integrated Architecture

Date of delivery:
24/03/2011

Revision:	1.6
Dissemination:	Public

Project information

Project Duration:

01/07/2008 – 31/12/2011

Project Coordinator:

Walter Maibach (walter.maibach@ptv.de)

PTV Planung Transport Verkehr AG

Kriegerstr.15

70191 Stuttgart Germany

Technical Coordinator:

Rigobert Opitz (rigobert.opitz@rocgmbh.com)

ROC Systemtechnik GmbH

Elisabethstr. 69

8010 Graz Austria

Version	Date	Action	Partner
0.1	11 July 2009	Original draft	ROC
0.2	21 Oct 2009	Main Chapters added	ROC/TUI
0.3	22 Dec 2009	Discussion results with UTBM	UTBM
0.4	13 Feb 2010	Restructuring and completion of section 1-2	ROC
0.5	13.March 2010	Integration Sustainable Transport	VTT
0.6	22.April 2010	Integration Swarm Theory	USTT/TUI
0.7	06.July.20010	Integration UTBM contribution	UTBM
0.8	07 July 2010	Integration State of the Art TUI	TUI
0.9	25 July	Revision I	VTT/PTV/TUI
1.0	25 July	Revision II	UCD
1.1	30 July	Draft Submission	ROC/TUI
1.2	01.Feb.2011	Draft final version	ROC
1.3	04.Feb.2011	Internal check	ROC
1.4	15.Feb.2011	Distribution to partners for comments	By ROC to Authors
1.5	18. March 2011	Final version reviewed	UCD/ROC
1.6	24. March 2011	Proof Reading	PTV

Title: ASSET-Road Safety Theory & Integrated Architecture

Authors: Rigobert Opitz, ROC Systemtechnik GmbH Graz

Christian Fessl, ROC Systemtechnik

Prof Barsanescu, University of Iasi

Matti Kutila, VTT Technical Research Centre of Finland

Jaafar Gaber, Technical University Belfort Montbeliard

Mohamed Ba khouya, Technical University Belfort Montbeliard

Bernd Eckstein, University Stuttgart

Internal reviewers:

Content:
Tapani Mäkinen, VTT Technical Research Centre of Finland

Proof reading:

Prof. Eugene O’Brian, University College Dublin

Dr. Walter Maibach, PTV Stuttgart

Content

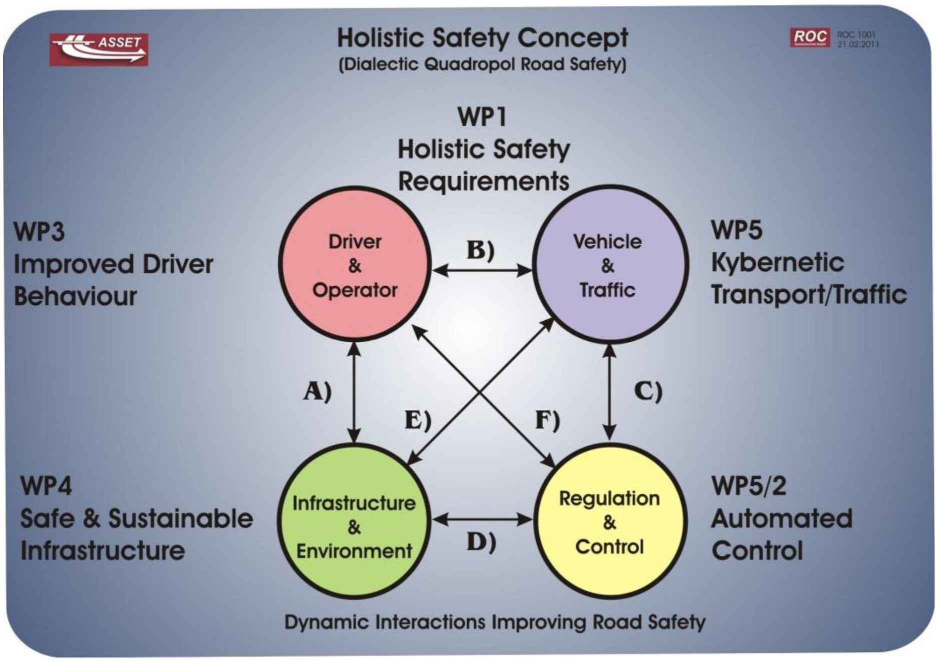
1 Executive summary 8
2 Vision, Strategy and Theory 12
2.1 Vision 12
2.2 Natural Mobility Performances 12
2.3 Mission of ASSET-Road 13
2.4 Road Safety Theory 14
2.5 Strategy 14
2.6 Specific Objectives 15
2.7 Challenges to reach the overall Objectives 15
2.8 Policies for Implementation 17
3 What is a Road Safety Theory? 18
3.1 Status “Road Safety Strategy” 18
3.2 General Definition of a Theory 18
3.3 Elements of a Theory 19
3.4 Theories Formally and Generally 20
3.5 Scientific theories 21
4 State of the Art: Road Safety Theory 22
4.1 Introduction 22
4.2 The analysis state of the art “Road Safety Theory” 22
4.3 Video processing systems 25
4.4 Geographical information systems 26
4.5 Road safety improvement measures 28
4.6 Strategic highway safety plans 29
4.7 Performance indicators in road safety 36
4.8 Macro road safety indicators 41
4.9 Conclusions on State of the Art 44
5 Road Safety Approach 45
5.1 Complexity and Complication 45
5.2 “Holistic Safety Methodology” (Road Safety Wheel) 46
5.3 “Holistic Safety Methodology” 50
5.4 Socio Economic Integrity 54
5.5 Safety Issues: Dialectic Interactions 56

5.6 “Dialectic Multipole” as extension 60
6 Methodology (Five “E” Programs) 61
6.1 Engineering and Traffic Environment 62
6.2 Education & Information of Road Users 70
6.3 Enforcement and Legislation 72
6.4 Emergency Response 73
6.5 Evaluation & Other Actions 74
7 Natural Mobility 75
7.1 Swarm Theory Definition 75
7.2 Natural Mobility” versus “Vehicles Mobility” (case study) 77
7.3 From Ants to vehicles’ communication 78
7.4 The Dissemination strategy 81
7.5 Preliminary simulation results 83
7.6 Conclusions and future work 85
8 Sustainable Transport 85
8.1 Sustainable transport as a concept 85
8.2 Biomechanics in nature 87
8.3 Implementing Sustainable Transport methodologies (Finnish Test Site) 87
9 Safety Performance Indicators 88
9.1 Performance and Effectiveness Indicators 88
9.2 How to Measure Safety 89
10 Integrated Architecture for Safety 90
10.1 Introduction 90
10.2 High level architecture guidelines 91
10.3 Architecture scenarios 91
10.4 The FRAME Architecture recommendations 97
10.5 Communication Architecture 101
11 Architectures of the test sites 105
11.1 German test site 105
11.2 Finnish test site architecture 116
11.3 French test site architecture 117
11.4 Conclusions 120
12 Automatable Use of Traffic Regulations 122

12.1 Introduction 122
12.2 Statistics, needs and requirements 124
12.3 General Statistics 124
12.4 HGV-Statistics 127
12.5 Needs and Requirements 129
13 Case studies – Hungary 134
13.1 Higher speed limits cause more accidents 136
13.2 Severe penalties decreased the number of traffic accidents 138
13.3 Scoring system for traffic violations was ineffective 140
13.4 Public outrage taught a politician that laws apply not only to common people 142
13.5 Drunk chief police officer crashes with a train 144
13.6 "Relative" speeding is more dangerous than exceeding "absolute" limits 146
13.7 A motorcycle enthusiast switched back to car for fear of accidents 147
13.8 Pedestrian crossings are unsafe in Hungary 149
13.9 Even bicyclists should know the rules 150
13.10 Theft prevention considerations at freight carrier 151
13.11 Tired or sleepy drivers pose significant danger on the roads 153
14 Case Study Finland: Traffic enforcement 155
15 Automatable Traffic Regulations 156
15.1 Safety Equipment 156
15.2 Snow Chains 159
15.3 Traffic Rules 159
15.4 Vehicle Characteristics 169
16 Automated Support Levels and Systems for Drivers 173
16.1 Information 173
16.2 Warning 174
16.3 Interaction 174
17 Technology & Regulations – Matrix 175
17.1 Introduction 175
17.2 Evaluation of physical knowledge delivery mechanisms 176
18 Appendix 178
18.1 Annex – HGV statistic Bavaria, Germany (2007) 178
18.2 References natural mobility section 179

18.3 General References 180
18.4 Web sites 181

1 Executive summary



This document describes the ASSET safety theory and integrated system architecture and how its architecture is compatible with the European ITS Framework Architecture.

However, this report is not a detailed description of the sub-system level architecture since these are already described in the other ASSET deliverables which are more focused on test site construction.

"Road Safety is a complex and complicated domain and requires a holistic and dialectic approach for understanding the involved interactions and interlinked processes for reaching best results of measures" therefore we elaborate, design and recommend a "Road Safety Theory"

The ASSET report is based on three internal deliverables

- Safety Theory and Holistic (D1.3),
- Integrated architecture for safety (D1.4) and
- Review and evaluation of automatic traffic regulations (D1.5)

prepared as reports by ROC, VTT and USTUTT.

The most important interests, needs and visions for integrated road safety were discussed, formulated and compared with natural mobility.

A road safety theory, in the scientific sense of the word, is an analytic structure designed to explain a set of empirical observations concerning road safety. It does two things:

1. *Identifies this set of distinct observations as classes of phenomena, and*
2. *Makes assertions about the underlying reality that brings about or affects this class.*

As part of a road safety theory with different hierarchical universes a safety strategy can be developed subsequently. The road safety theory should be considered as an analytic tool to understand the elements, interlinks and interactions related to road safety and their implications for optimizing the overall safety of road traffic.

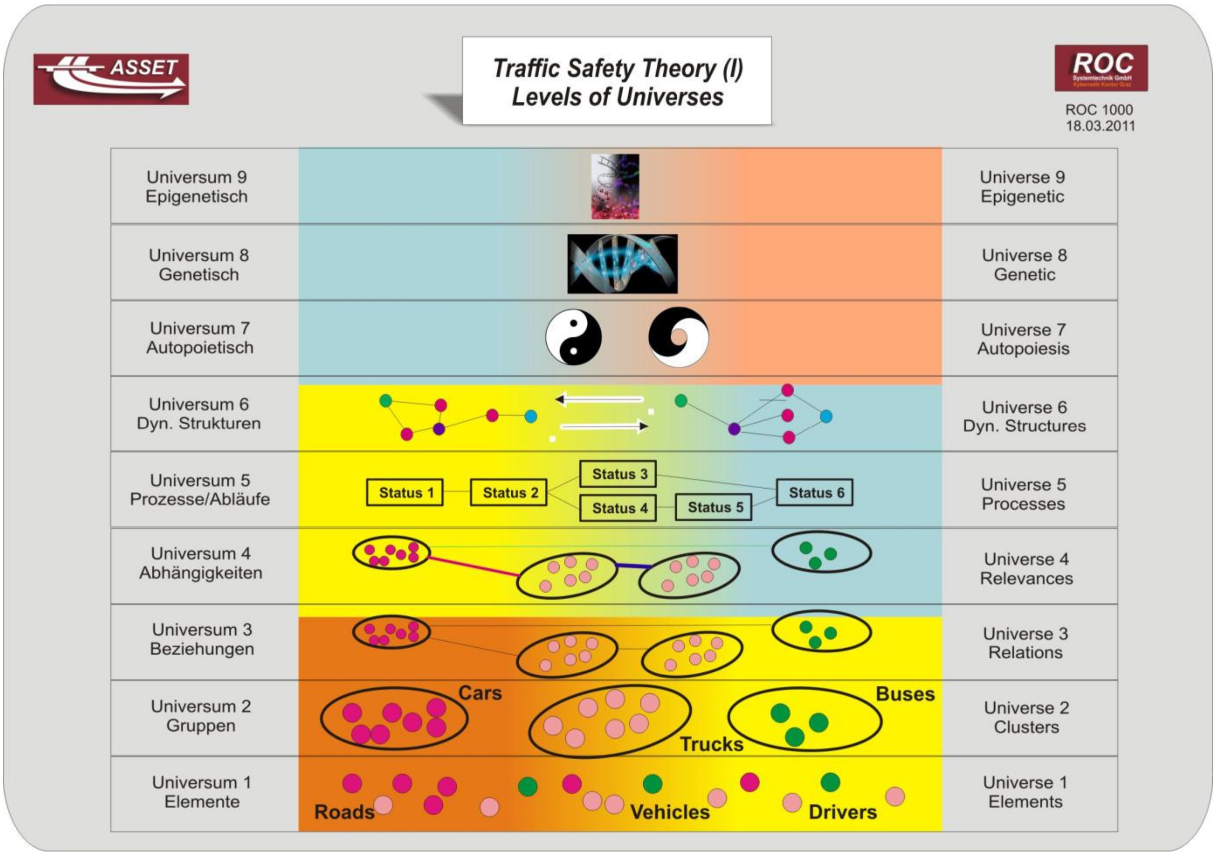


Figure 1: Traffic Safety Theory Levels and Universes (ROC)

With the aim to achieve targets of enhancing road safety the "Road Safety Theory" maps out the realization of the following concrete actions:

- Describe, discuss and investigate the elements, its clustering and dialectic interactions of road safety
- Describe and investigate the different processes and its relevancies
- Analyze the key elements for a best total solution
- Give recommendations for an operative and permanent "Road Safety Agency"
- Create a competent and integrated "Overall Safety System Framework"
- Initiate a "Key Action and Implementation Program" and implement measures
- Monitor safety improvements

There are many investigations, papers and handbooks available - related to the topic road safety. The problem is they are investigating and analyzing mainly single aspects or areas and don't provide a fully holistic and integrated approach of the different entities, domains and universes of road safety. Definitions of an overall theory, interactions and its elements are often missing.

ASSET-Road investigated and formulated therefore first time an integrated holistic approach and methodology. The findings and conclusions are the following:

Integrated Architecture

The current available FRAME Architecture is a high level reference ITS Architecture supported by European Commission to ensure that European ITS Systems implemented nationally or regionally have compatible high level 'backbones'. This promotes more open market for services and equipment reducing implementation, maintenance, and upgrade costs.

However, when ASSET-Road is implemented on national or regional level, more detailed functions and interfaces need to be specified and realized, since every practical ITS system always has extra user needs and extra functions to satisfy. Integrated functions considering many specific parameters are required.

This document does not handle these specific national or regional issues. Even if the ASSET-Road test sites are heterogeneous and concentrate of different applications with different technologies, the general observation is that they are well in line with the Frame recommendations.

However, the ASSET-Road technical objectives lie more in the monitoring and future surveillance, guidance and enforcement side whereas the pre-existing ITS architecture does not state clear sensor, monitoring or control specifications. The existing architectures influence more in the traffic data management side and the information delivered to the end users (vehicle drivers, road operators, authorities, traffic centers, etc.). The Frame architecture is huge due to compatibility requirements concerning different types of traffic management systems.

Recommendation: Supervision and enforcement should be integrated as being very effective for road traffic safety and transport economy.

Therefore, the specific data fields relevant for the ASSET-Road system have been selected in this deliverable in order to keep the report readable and consistent. The ASSET-Road German test site as a main result of the project includes a major part of the investigated technologies and integrated architectures for sensing, data communication, data storage and processing, monitoring and presentations for involved users.

Moreover, some end users like environment authorities, which are relevant in the Finnish test site concept, but are not included to the architecture recommendations has been added to ASSET-Road architecture concept.

Automatic Traffic Surveillance and Enforcement

For the future a strongly growing traffic capacity and higher safety demand is expected. This will be caused by increasing numbers of cars, trucks and public traffic on motorways. It is strongly related with thenations economy.

Because of expected growth and change of motorization combined with more driving stress and economic pressure by high operation costs, these problems will become even worse for human and nature in the future. Regulation and following the rules is requiered. The ASSET-Road investigations include therefore a traffic rules study, exemplary case studies of Hungary and a section, where all traffic rules will be presented and examined in terms of the possibility of automatable recognition of violations against those rules. It is very obvious, that in road traffic the driver and the driving behaviour plays a key role concerning traffic safety.

As a consequence of this development, it has been decided to improve safety by an integrated and efficient highly automated enforcement system, finally installed in a nationwide distributed network, including black spot areas for safety. Objectives are to make road traffic smoother, safer and to decrease traffic emissions and travel times.

2 Vision, Strategy and Theory

2.1 Vision

As base of a theory the most important interests, needs and visions have to be discussed, formulated and published. A vision for road safety is "A mental model of the improved future state of road safety in urban and interurban road traffic networks within an unpredictable and uncertain future". Vision change is the adaptation of our vision to major challenges of a perceived future.

Several categories for vision statements for road safety are operated today:

Vision	"Zero Fatalities and zero Accidents"
Vision	"50% reduction in a certain time frame (EC)"
Vision	"Achieving Natural Mobility Performance"
Vision	"Enabling Environmental safe and green transports"

The vision is to generate and operate a safe traffic environment in accordance with internationally best achieved standards, to create a future holistic traffic safety and to reach in long term the impressive performance levels "Natural Mobility Safety" called further on "NMS" which is accident free".

Figure 2: NMS Natural Mobility is Accident Free

2.2 Natural Mobility Performances

Very interesting is the result of long term evolution related to natural mobility. The performances and features of natural mobility related to safety, efficiency, self-producability, reproducibility, sustainability and adaptability are impressive.

Natural Mobility Entities (animals) are created and self-produced in temperature ranges around 0 to 40 degrees Celsius and require as production material sometimes only grass and water.

It means we can learn a lot from natural mobility concerning safety, efficiency, materials and the use of resources for self-production or energy for transports and the car industry. It is a big challenge and industry has to leave current approaches for higher performance and efficiency.

Figure 3: Natural Mobility Features

2.3 Mission of ASSET-Road

The mission of ASSET-Road is a succinct and concentrated statement and a supporting the theory for road safety that articulates main important purposes, needs, structures and functions as a these, support the strategy development, enable process conception, activity planning and evaluation of values and beliefs. As an international research group we define the guiding mission statement as follows:

"Our contributions are focused on improving the quality of the living and working environment to enhance the sustainable development of local as well as global economies (purpose)".

By doing so, we create value for the society (safety, economy, function, and tasks). In pursuing this mission, we have identified three core values (basic values, beliefs): Integrity, Entrepreneurship, Implementing programs and agility. A road safety theory is here a core element.

2.4 Road Safety Theory

Based on the Road Safety Vision, the Road Safety Theory followed by a Mission is “To analyze, describe interactions and parameters and to stop (and in some countries reverse the increasing trend) the number of road crashes, number of deaths and number of injuries through comprehensive measures covering engineering, enforcement, education and emergency care”.

A road safety theory, in the scientific sense of the word, is an analytic structure designed to explain a set of empirical observations concerning road safety. It does two things:

1. *Identifies this set of distinct observations as a class of phenomena, and*
2. *Makes assertions about the underlying reality that brings about or affects this class.*

As part of a road safety theory a safety strategy can be developed.

2.5 Strategy

The next step is the development of a strategy. A strategy consists of our choices made in an effort to best accomplish future missions within an unpredictable or complex dynamic context. Strategy is thus a general and integrative intention to support the addressed actors to:

- formulate and reach objectives
- allocate and use its resources
- analyze, define and choose fields of action
- intelligent and sustainable interaction considering environment

We created a Road Safety Theory to improve road safety, to support reform and decision making, reform action programs and managing structures and initiating directly enforcing traffic law and regulations.

With the aim to achieve targets of enhancing road safety (and to stop the permanent increase or to high level in accident and fatality figures), the “Road Safety Theory” maps out the realization of the following concrete actions:

- Recommend a methodology to analyze, define and optimize road safety
- Cluster and selected main actions
- Recommendation for an operative and permanent “Road Safety Agency”
- Create a competent and integrated “Overall Safety System Framework”
- Initiate a “Key Action and Implementation Program” and implement selected measures
- Monitor and report safety improvements

The research society and responsible governments have to prepare and develop in future a holistic and integrated Road Safety Strategy for the future years.

The general objective of road safety theory is to allow the formulation and establishment of an updated road safety strategy concept and to initiate concrete initiatives for the next years regarding a road system based on needs, in order to improve safety on roads and safeguard vital road facilities from damage by overloaded vehicles and the traffic in general. ASSET-Road was concentrating on motorways leading to the development of a comprehensive Road Safety Strategy aiming at a systematic and sustained improvement in road safety.

The overriding goal than is the development of a comprehensive Road Safety Strategy aiming at a systematic and sustained improvement in road safety and development of a holistic strategy to implement Road Safety. The policy and the strategy incorporate and reflect best practice to provide guidance regarding the accomplishment of road safety.

2.6 Specific Objectives

Specific objectives are statements, in general terms, of what will be achieved in a particular sector by a selected course of actions over the period of time of the framework contract and beyond.

Regarding the particular assignment of ASSET-Road, the 3 main specific objectives are

> **O1**: To define the elements, systems and interactions principally relevant for a future improved Road Safety which aims to reduce the loss of life, physical suffering and economic costs associated with traffic and road accidents
>
> **O2**: To built functional test systems and prototypes for road safety and to investigate and demonstrate the possible integration of technologies and its benefits
>
> **O3**: To disseminate the findings and motivate responsible actors, stakeholders and ministries for future initiatives and actions.

The range of action areas out of the theory and their applicability has to be adapted over time and space depending on relevant parameters. In a subsequent strategy it has to be identified a menu of action areas and key action initiatives that are recommended for implementation in the next years.

2.7 Challenges to reach the overall Objectives

In order to attain the envisaged overall objective, the road safety technology creators, providers and stakeholders face several, major challenges. The challenges correspond directly to the identified key road safety problems:

1) Public and political awareness and commitment

It is a challenge to create and maintain full political attention and support to the road safety sector, as a reflection of the high value that the leaders and communities place on human beings and human life.

2) Adequate coordination and overall management of regulations, actions and techniques

It is a challenge to establish and support a relevant structure that can initiate, steer, coordinate and evaluate road safety activities effectively.

3) Sufficient funding for road safety

It is a challenge to create a sustainable and sufficient source of funding for road safety activities.

4) Responsive Legislation to the present conditions

It is a challenge to revise and update the legislation and regulations and thereby create a sound base for future road safety activities.

5) Supervision and Enforcement has to be sufficient

It is a challenge to increase the presence, coverage and effectiveness of enforcement, to target the enforcement at the major road safety problems and ensure that they are properly coordinated with awareness campaigns.

6) Lack of awareness among road users

It is a challenge to integrate road safety in education for drivers, children and raise awareness among road users in general.

7) Accident-prone spots and sections

It is a challenge to ensure that these locations are identified and improved quickly and effectively.

8) Poor driver and vehicle standards

Mainly in developing countries, it is a challenge to streamline driver and vehicle examination and licensing, first of all for professional drivers and vehicles where the impact on human lives is most significant.

9) Insufficient accident data and information

It is a challenge to create a reliable, effective accident data reporting and analysis system that can provide the necessary statistics for road safety activities, research and evaluation.

10) Insufficient research and international cooperation

It is a challenge to institutionalize and increase research and international cooperation activities that can provide knowledge and experience for effective future road safety activities and avoid "reinventing the wheel".

2.8 Policies for Implementation

Policies are necessary measures of implementation by the virtue of which the overall objective is attempted to be achieved. Political awareness and commitment are necessary. A key measure of ASSET-Rod was therefore to increase public and political awareness and commitment to fund road safety issues also at governmental level to assure adequate resources for road safety activities and measures:

- Increase priority for road safety by the government and governmental institutions to secure adequate funding for road safety in sector programs and decision-making.
- Mobilize the public to support road safety initiatives as a reflection of the high value that the community places on human beings and human life.
- Create awareness about road safety problems and opportunities in different levels through information and discussions.

The fulfillment of the challenges and overall objective requires the implementation of mutually reinforcing Policy Statements on EC and on national levels in a harmonized and effective way. The clustering of measures for a possible Road Safety Policy can be grouped as follows (used in diverse road safety strategy papers, e.g in the ASSET-Road partner country Tanzania

- Engineering and Traffic Environment
- Education and Information
- Enforcement and Legislation
- Emergency Response and Rescue Service
- Evaluation and other comprehensive actions

3 What is a Road Safety Theory?

3.1 Status "Road Safety Strategy"

There are many investigations, papers and handbooks available - related to the topic road safety. The problem is they are investigating and analyzing mainly single aspects or areas and don't provide a fully holistic and integrated approach of the different entities, domains and universes of road safety. Definitions of objectives, structures, elements and its interactions or interlinked processes are often missing or are fragmentary.

Main reason may be the complicatedness and complexity of road safety as a whole, its interdependencies and multifold dynamic processes in addition to a very often practiced "very narrow minded view".

3.2 General Definition of a Theory

The term theory has two widen sets of meanings, one used in the empirical sciences (both natural and social) and the other used in philosophy, mathematics, logic, and across other fields in the humanities according general definitions, e.g. given in "Wikipedia":

A theory, in the scientific sense of the word, is an "Analytic structure designed to explain a set of empirical observations. A scientific theory does two things:

1. It identifies this set of distinct observations as a class of phenomena, and
2. It makes assertions about the underlying reality that brings about or affects this class.

In the scientific or empirical tradition, the term "theory" is reserved for ideas which meet baseline requirements about the kinds of empirical observations made, the methods of classification used, and the consistency of the theory in its application among members of the class to which it pertains.

These requirements vary across different social and scientific fields of knowledge, but in general theories are expected to be functional and parsimonious: i.e. a theory should be the simplest possible tool that can be used to effectively address the given class of phenomena.

Theories are distinct from theorems: theorems are derived deductively from theories according to a formal system of rules, generally as a first step in testing or applying the theory in a concrete situation.

Theories are abstract and conceptual, and to this end they are never considered right or wrong. Instead, they are supported or challenged by observations in the world. They are 'rigorously tentative', meaning that they are proposed as true but expected to satisfy careful examination to account for the possibility of faulty inference or incorrect observation.

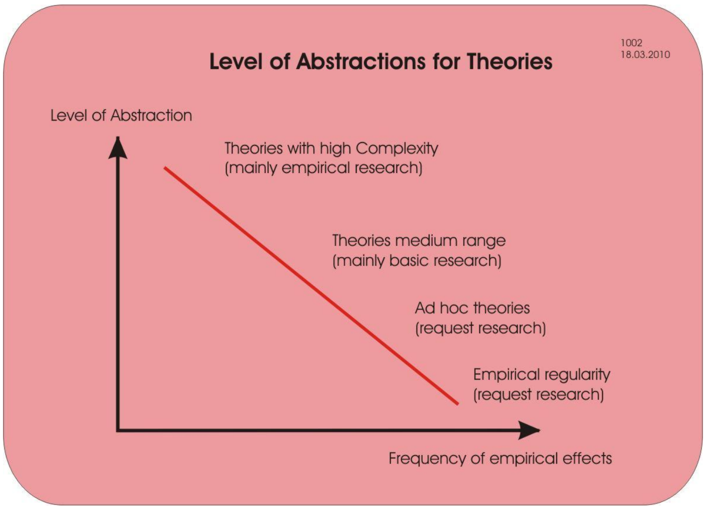


Figure 4: Level of abstraction versus empirics (Wikipedia)

The word 'theory' is generally considered to derive from Greek θεωρία theoria (Jerome), Greek "contemplation, speculation", from θεωρός "spectator", θέα thea "a view" + • ρ• ν horan "to see", literally "looking at a show". A second possible etymology traces the word back to το θείον to theion "divine things", reflecting the concept of contemplating the divine organization (Cosmos) of the nature. The word has been in use in English since at least the late 16th century.

3.3 Elements of a Theory

Normally - based on a scientific theory- the following possible elements of a theory are distinguished:

- **Basic Assumptions** describing the basic structure of the reality and how it should be analyzed. The total of these basic assumptions can also be called “Paradigm“.
- **Basic Terms of Definitions** are the building blocks of a theory, being theoretical terms like physical dimensions and entities.
- **Theory Core** consisting of a descriptive and explanative statements and declarations. The declarative statements are also called “Hypotheses” (as if than condition or even stronger formalized). A theory can include prognostic and recommendation statements.
- **Concepts for Measurement and Approval** “Hypotheses” will be measureable by using indicators (operationalised) for empirical check, even by using a questionnaire.
- **Empirical Proves**: Observations, verifying or disprove a theory.
- **Descriptive Statements**: descriptive statements and explanations can be considered with different priorities and in different ways. Some theories prefer descriptive methods; on

others the explanation and again others use both approaches in combination. New theories use to a high degree descriptive statements.

- **Prognosis and Recommending Statements:** Scientists are using prognostic and recommendation statements either very carefully or as main aspect (political consulting). Some scientists are rely strict on empirical proves, others don't do this. It means there are great differences between the scientists using and operating theories, with or without clear hypotheses and indicators.

3.4 Theories Formally and Generally

Theories are analytical tools for understanding, explaining, and making predictions about a given subject matter. There are theories in many and varied fields of study, including the arts and sciences. A formal theory is syntactic in nature and is only meaningful when given a semantic component by applying it to some content (i.e. facts and relationships of the actual historical world as it is unfolding).

Theories in various fields of study are expressed in natural language, but are always constructed in such a way that their general form is identical to a theory as it is expressed in the formal language of mathematical logic. Theories may be expressed mathematically, symbolically, or in common language, but are generally expected to follow principles of rational thought or logic.

Theory is constructed of a set of sentences, which consist entirely of true statements about the subject matter under consideration. However, the truth of any one of these statements is always relative to the whole theory. Therefore the same statement may be true with respect to one theory, and not true with respect to another. The form of theories is studied formally in mathematical logic, especially in model theory. When theories are studied in mathematics, they are usually expressed in some formal language and their statements are closed under application of certain procedures called rules of inference.

A special case of this, an axiomatic theory, consists of axioms (or axiom schemata) and rules of inference. A theorem is a statement that can be derived from those axioms by application of these rules of inference.

Theories used in applications are abstractions of observed phenomena and the resulting theorems provide solutions to real-world problems. Obvious examples include arithmetic (abstracting concepts of number), geometry (concepts of space), and probability (concepts of randomness and likelihood).

3.5 Scientific theories

Theories whose subject matter consists not in empirical data, but rather in ideas are in the realm of philosophical theories as contrasted with scientific theories. At least some of the elementary theorems of a philosophical theory are statements whose truth cannot necessarily be scientifically tested through empirical observation.

3.5.1 Scientific theories

Theories are intended to be an accurate, predictive description of the natural world.

In science, generally, theories are constructed from elementary theorems that consist in empirical data about observable phenomena. A scientific theory is used as a plausible general principle or body of principles offered to explain a phenomenon.

A scientific theory is a deductive theory, in that, its content is based on some formal system of logic and that some of its elementary theorems are taken as axioms. In a deductive theory, any sentence, which is a logical consequence of one or more of the axioms, is also a sentence of that theory.

3.5.2 Theories as Models

The aim of this construction is to create a formal system for which reality is the only model. The world is an interpretation (or model) of such scientific theories, only insofar as the sciences are true.

Theories are constructed to explain, predict, and master phenomena (e.g., inanimate things, events, or behavior of animals and human beings). A scientific theory can be thought of as a model of reality, and its statements as axioms of some axiomatic system.

3.5.3 The term theoretical

The term theoretical is sometimes informally used in place of hypothetical to describe a result that is predicted by theory but has not yet been adequately tested by observation or experiment. It is not uncommon for a theory to produce predictions that are later confirmed or proven incorrect by experiment. By inference, a prediction proved incorrect by experiment demonstrates the hypothesis is invalid. This either means the theory is incorrect, or the experimental conjecture was wrong and the theory did not predict the hypothesis.

4 State of the Art: Road Safety Theory

4.1 Introduction

Road Safety should become an important issue in the design and more safe operation of roads and traffic. All over the world, traffic engineers are permanently engaged in working to ensure that the road system is designed and operate such as crash or accident rates can be reduced, to ensure safety for motorists and pedestrians. This is one element of road safety.

More important is the use of new technologies and to work with law-enforcement officials and educators in a team effort to ensure that the traffic laws, such those regarding speed limits, drinking, overloading, are enforced, and that motorists are aware about their responsibility to drive preventively, to understand and obey traffic regulations.

Each country has also particular aspects regarding road safety, and it is necessary to identify its key safety needs such that investment decisions can be made resulting in significant reductions in road and highway fatalities and serious injuries on public roads.

It is desirable to replace the word “ACCIDENT” (the commonly accepted word for an occurrence involving one or more transportation vehicles in a collision that results in property damages, injury or death) with the term “CRASH”, because this term implies that the collision could have been prevented or its effect minimized by modifying driver behavior, vehicle design, roadway geometry or the traffic environment.

4.2 The analysis state of the art “Road Safety Theory”

There are many investigations, papers and handbooks available related to the topic road safety. The problem is they are covering mainly single aspects or areas and **don’t provide a fully holistic and integrated approach for a road safety theory.**

Main reason may be the complicatedness and complexity of road safety as a whole, its interdependencies and dynamic processes.

4.2.1 Road Safety Improvement Process

The road safety improvement process involves planning, implementation and evaluation. The planning process requires that engineers collect and maintain road traffic safety data, identify hazardous locations, perform engineering studies, and establish project priorities. The quality of geometric design will also influence the safety of roads and highways. Roadways should be designed to provide adequate sight distance, to separate through traffic from local traffic, to avoid speed variations and to ensure that the driver is aware of changes occurring on roadway and has adequate time and distance to change speed or direction without becoming involved in a collision with another vehicle, a fixed object, or a pedestrian. Road safety is also dependent on a well-educated population who drive courteously and preventively; it requires enforcement of the traffic laws.

4.2.2 Main factors for road safety

While the causes of crashes are usually complex and involve several factors, it is possible to elaborate a general list of the categories of circumstances that could influence the occurrence of traffic accidents. If the factors that have contributed to crash events are identified, it is possible to modify and improve the transportation system. Those factors can be considered in **four separate categories**: actions of the driver or operator, mechanical conditions of the vehicle, geometric characteristics of the roadway, and the physical or climatic environment in which the vehicle operates.

4.2.3 Driver or Operator Actions

The major contributing cause of many crash situations is the **missing performance of the driver** of one or more (in multiple vehicle crashes) of the vehicles involved. Driver errors may occur in many ways, such as insufficient attention to the roadway and surrounding traffic, failure to yield the right of the way, and/or obey the traffic laws. These “failures” may occur as a result of unfamiliarity with roadway conditions, travelling at high speeds, drowsiness, drinking, and using a cell phone or other distractions within the vehicle.

4.2.4 The Vehicle Condition

The mechanical condition of the vehicle can be the cause of transportation crashes. Faulty brakes in heavy trucks have caused crashes. Other causes are the failure of the electrical system, worn tires, and the location of the vehicle’s centre of gravity especially in the case of heavy trucks.

4.2.5 The Roadway Conditions

The conditions and quality of the roadway, which includes the pavement, shoulders, intersections, and the traffic control system, can be a factor in producing crashes. Highways especially must be designed to provide adequate sight distance at the design speed or motorist will be unable to take remedial action to avoid a crash. Traffic signals must provide adequate decision sight distance when the signal goes from green to red. Railroad grade crossing must be designed to operate safely and thus minimize crashes between road and rail cars.

4.2.6 Analysis of Accidents (Video Recording)

One of the technological problems related to accidents occurrence and adverse road geometry encountered was the lack of available technology to collect data in an exhaustive and accurate way. Computer vision involves the automatic digitizing, processing and interpretation of the images from roadside TV cameras. The key feature of the video sensor is that it conveys spatial and temporal information. Not only can a single camera survey several lanes simultaneously, but a continuous length of road is also under surveillance. It enables a broader description than the classical technologies based on electromagnetic loops, radars, photography, etc.

TV cameras and image processing permit one to accurately and automatically measure lane positions, speeds and lateral and longitudinal accelerations. These three measures permit a complete cinematic description of the vehicle. Another advantage of TV cameras and image processing is that they permit an access to new measurements related to vehicle behavior: spacing of vehicles, directional movements and their interferences in intersections, as well as locating and quantifying lane changes. Therefore, it is possible to obtain relative and absolute measures regarding vehicle evolution and global measures about the traffic stream. Firstly an automatic tool for modeling vehicle evolution at critical locations, based on artificial vision techniques is described, and secondly, the way of obtaining a methodology for the evaluation and improvement of black spots is presented. These two objectives imply the following partial topics and tasks:

- To revise, analyze and evaluate the current road geometric design standards;
- To develop a software tool based on artificial vision to obtain cinematic vehicle data;
- To design and carry out specific field trials;
- To parameterize, characterize and model local vehicle evolution at critical locations from the data obtained in the different field trials;
- To develop, evaluate and validate a new tool for the automatic diagnosis of black spots;
- To determine the safety margins of the current road geometric design standards;
- To propose improvements and harmonization

4.2.7 Environment

The physical and climatic environment surrounding a transportation vehicle can also be a factor in the occurrence of road crashes, the most common being the weather and the road topologies. All transportation systems function at their best when weather is sunny and mild and the skies are clear. Weather on roads can contribute to road crashes; for example the pavement reduces stopping friction and can cause vehicles to hydroplane. Many severe crashes have been caused by fog because vehicles travelling at high speeds are unable to see other vehicles ahead that may have stopped or slowed down, creating a pile-up.

4.3 Video processing systems

The main functions of the video processing systems are: on the one hand, to measure, in an automatic and sufficiently accurate way, lateral placements, vehicle velocities and accelerations along its movement, and on the other hand, to reconstruct the vehicle trajectories, using image processing techniques. The images are previously recorded by video cameras installed at each defined location. These above mentioned variables permit a complete description of the vehicle cinematic. The system also permits the determination of relative and global variables, that is, variables that not only depend on the vehicle but on the traffic stream. Those are: confluence of trajectories, velocities and accelerations variations, lane changes etc.

Evaluation methodology

The objective is to obtain a methodology for the diagnosis of critical situations. The evaluation methodology is divided in the following parts:

Road Geometric Design Parameters and Accidents

The objective of this part is to analyze what the factors are and how they affect accident occurrence, from the point of view of road geometric design. The first task to be done is to identify the geometric and functional parameters affecting vehicle evolution. This task concerns:

- Road alignment: horizontal and vertical alignment, sight distances, components of the roadway;
- Functional characteristics of road pavements: skid resistance, smoothness;
- Equipment: lighting, signs, barriers;
- Weather conditions: rain, fog, ice, wind.

The parameters will be classified according to their influence upon: vehicle behaviour, technical performance of the road and the outcome of the accident event. Once the road geometric design parameters that affect accident occurrence have been identified, they will be analyzed to determine how they influence vehicle cinematic and behavior in general [4].

Vehicle Evaluation Model

The speed, radius and lateral placement data, obtained from the video image processing system, will be analyzed, to produce: plots of vehicle speed, lateral placement, centreline and edge line encroachment; and cumulative distributions of vehicle speed, path radius and side friction demand. The required side friction, when compared with the available side friction, gives an objective estimate of the margin of safety against the vehicle sliding towards the outside of the curve.

The final goal of this part is to obtain a model that describes the behaviour of the vehicles. This model will be developed from the geometrical characteristics of the specific location and the above-mentioned physical variables [4].

Methodology for the Evaluation of Black Spots

The objective is to develop a methodology to evaluate high accident locations in order to analyze the limit situations near accidents occurrence that will allow the causes of accidents to be extrapolated. This process is divided into two phases:

Proposing a Model for Evaluating Black Spots

The model will consist of a tool for the automatic diagnosis of the black spots according of their geometry. It is based on the idea that "in places where accidents often occur, there must be a considerable number of vehicles that circulate near the critical or limit safety conditions; it is possible to obtain the final causes of the accidents that occur, by analyzing and extrapolating the evolution of these vehicles".

Model Evaluation and Validation

The model will be evaluated by carrying out several field trials in different critical points. It is possible that videotapes recorded include accident situations, thus allowing us to validate if the extrapolations and conclusions regarding the causes of accidents are correct [4].

Improving Road Geometric Design Standards at Critical Points

This last part consists in comparing the experimental vehicle evolution model obtained and the one expected from the actual road geometric design standards in order to determine safety margins, and as a consequence of the work carried out, in the above activities, adaptations, improvements and harmonization of the different worldwide road geometric design standards shall arise [4].

4.4 Geographical information systems

A Geographic Information System (GIS) important as base for traffic safety is a computer system for capturing, storing, querying, analyzing and displaying geographic data. GIS represents a new paradigm for the organization of the information and the design of information system, the essential aspect of which is the use of concept of location as the basis of structuring of information systems. GIS technology can be viewed as an offshoot from two major software technologies i.e., database management system (DBMS) and computer aided design (CAD), with the addition of specialized functions for managing and analyzing spatial data i.e., data that can be referenced to a geographical location. The objective of any GIS system is to capture, store, manage, analyze, and visualize geographical data.

GIS is a powerful computing tool for managing large amounts of heterogeneous data. A GIS can be effectively used to identify accident black spots on roads. The capability of GIS to link attribute data with spatial data facilitates prioritization of accident occurrence on roads and the results can be displayed graphically which can be used for planning and decision making. The process of rasterizing, which involves conversion of vector data into raster data, helps in determining the suitability of horizontal curves provided on the roads. The results thus obtained can be combined using spatial and aspatial queries to obtain the desired results [5].

The model requires a map of the desired road network digitized in a suitable form and certain specified road attributes to carry out prioritization The analysis then identifies accident black spots on the given road network. While carrying out the analysis the model only incorporates the road related factors such as road geometries, which lead to accidents. The factors considered for evaluating accident prone locations on road are as follows:

- Road width.
- Number of lanes.
- Approximate number of vehicles per day.
- Type of road.
- Drainage facilities.
- Surface condition of the pavement.
- Frequent vehicle type.
- Presence of shoulders, edge obstructions, median barriers and ribbon development.
- Radius of horizontal curve.

In order to model the mentioned factors and achieve the desired result, a step-by-step procedure as given below is adopted.

- Scan the map containing the desired road network and input this image to ARC VIEW for digitizing.
- Digitize the road network with due considerations for separation of every link and assign id number to every link.
- Specify the attributes for every road link using the questionnaire provided.
- Export the road attribute table generated in dbase format so that Arcview can import it.
- Join the road attribute table to the digitized road map and prioritize the road network for accident occurrence using total weights assigned to every link.

- Rasterizing the road-network by assigning the absolute minimum radius of curvature as cell values.
- Export the rasterized image (known as Grid in Arcview) in ASCII raster format to obtain a text file.
- Input the text file obtained above to an executable file to determine the suitability of the provided horizontal curves.
- Combine the results obtained by prioritization and curvature analysis to determine the accident black spots on the given road network [5].

As a technological alternative open-source street data based on vectorized mathematical models (like openstreetmap.org) can also be used for computations.

4.5 Road safety improvement measures

Road safety improvement measures can be classified as laws and government regulations, enforcement, education and engineering. Each of these actions is necessary if road safety is to be improved. However, in order to effectively apply a particular safety improvement, it is necessary first to determine the outcome of each measure, which could be either to prevent the accidents or to minimize the effect of traffic accidents, once it happens. The primary goal of any road safety program is to prevent traffic accidents. Clearly, if a traffic accident is prevented, it never happens. No one is injured or killed.

The second approach is to design the vehicle - roadway system for safety in such manner that, if a traffic accident occurred, the effect on the occupants would be minimized. Minimizing the effects of traffic accident is a strategy that is effectively used in road and highway transportation, with its large annual death and injury rate and extensive property damage. The designer seeks to eliminate obstacles near the roadway so that, if the vehicle cannot be controlled, it will have a clear zone (free of obstacles) or, if impact occurs; the occupant’s injuries will be minimized.

The traffic participants are not so compliant and consider the traffic regulation laws as optional or to be obeyed only when there is a possibility of being caught. Thus, the drivers exceed speed limit, use cell phones while driving, drink and drive, park illegally and demonstrate aggressive behavior. Furthermore, the public (and more of their elected officials) are not interested in new technology that monitors their driving behavior, and many screening techniques are deemed illegal due to privacy concerns and constitutional issues regarding securing of evidence about an individual’s behavior by remote means.

Traffic safety experts have recognized that, because of many incontrollable factors, is impossible to prevent traffic accidents completely. Instead, focus is being placed on creating a safer vehicle, one in which the occupant will have a lower likelihood of an injury or fatality if a crash should occur. This strategy has been successful in saving lives. For example, by adding lap and shoulder safety belts, installing air bags, increasing the structural strength of the vehicle, and installing energy absorbing fenders, traffic accident deaths or injuries victims have been reduced.

One road safety goal is to reduce the crash rate for young drivers. It is well known that one of the major causes of death and injury for youth, aged 18-23, is traffic related. There are many reasons for this situation, including inexperience, driving high speeds, drinking and recklessness. Consequently, many young drivers exceed safe speed limits in curves and drive too fast for road conditions, resulting in the inability to stop or control the vehicle.

Activities regarding road safety is also focused on driver tiredness this being another cause of traffic accidents. The effect of driver tiredness occurs because human beings are constituted such that they perform at their best when rested and on normal schedule. For the driver of a personal vehicle, no laws exist that mandate stopping periodically to rest or limit driving to a maximum time period. For this reason, some drivers exceed their physical limitations. Research studies have demonstrated conclusively that drivers perform better on a schedule that includes a full night's rest. It is also well known that a lengthy period of driving without a break induces boredom and tiredness. For commercial vehicles, while regulations exist regarding the allowable number of hours of work, there is often a lack of training regarding the importance of including rest schedules in travel plan. The usefulness of the "black box" for re-creating the conditions immediately prior to crash has been clearly demonstrated. Recording devices are necessary on other commercial vehicles as well, particularly large trucks. The purpose of these devices is to provide information such as speed, direction of vehicle, operator comments, eventually wind speed and temperature. In addition to providing information that might be helpful in reconstructing an accident and identifying that may help to correct deficiencies before accident happens.

Ongoing research is done in developing video systems based on eye tracking to identify if the drivers are getting tired and to signal such dangerous situations to them acoustically.

4.6 Strategic highway safety plans

Road Safety priorities have been established at the European level these priorities relies on the concept of "Sustainable Safety", meaning that in order to provide an increasingly safer road traffic system, not only for the present but also for its future users, an approach is needed which encompasses combined, multidisciplinary and integrated actions leading to long lasting safety improvements.

For example, local enforcement by more police on the road is not an economic viable action sustainable on the long-term (when the number of controls is decreased the accidents will return), whereas electronic and automated means of enforcement can be considered as sustainable measure. In this context, the actions proposed in this document aim exactly to reach (all together) a sustainable safety traffic system.

Road safety needs more priority in the transport policies of EU Member States and the EU, because 97% of all transport fatalities in the EU are caused by road transport. Road transport accounts for 88% of all passenger transport in the EU, but accounts for over 100-times more deaths than all other modes together.

We have come a long way in reducing road deaths in the European Union (EU) over the past fifteen years. In 1995 in the fifteen Member States of the European Union there were around 45,000 reported deaths and 1.5 million casualties as a result of road traffic accidents (ETSC, 1997). This figure is higher than the current total for a larger EU now of 27 Member States. Nevertheless in 2007 around 43,000 people were killed in road traffic collisions in the European Union (28,791 in the EU-15).

The year 2010 is a deadline for both reaching the EU's target of halving road deaths (set in 2001). The momentum of preventing further deaths and disablement is in danger of being lost and new impetus is needed in considering a new European Action Program for the period of 2010 to 2020.

The following figure shows where we are and where we're going in relation to fulfilling the 50% fatalities reduction (ETSC).

Furthermore, the figure below shows how the real reduction is moving in relation to the planned one (CARE).

To be on course to reach the EU target in 2010, a reduction of at least 37% between 2001 and 2007 corresponding to an annual average reduction of at least 7.4% is needed. Between 2001 and 2007, however, road deaths have been reduced by 20% only. The European Union's yearly reduction in road deaths is no more than 4.2% on average.

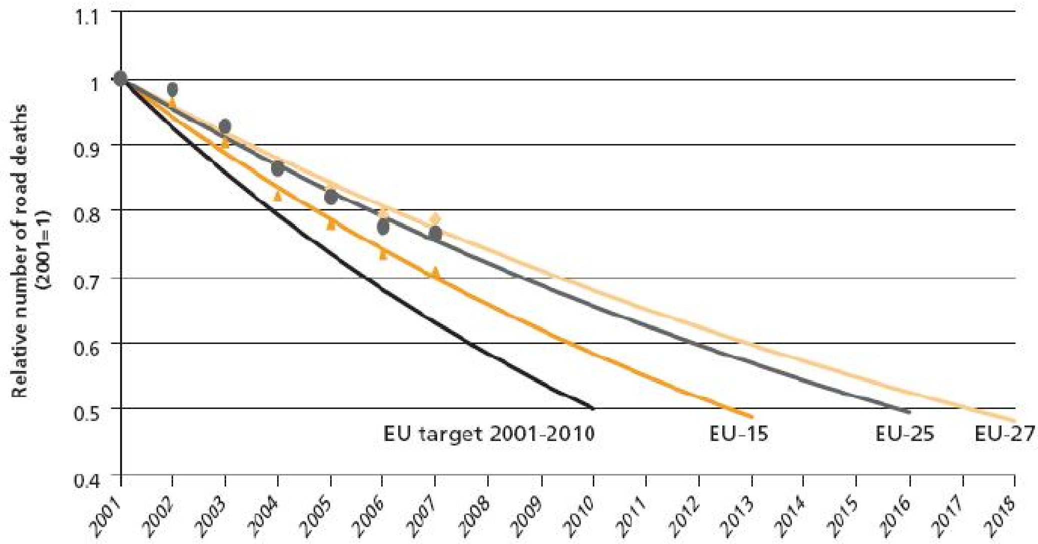


Figure 7: Estimated Trends in road deaths in EU 27 [6]

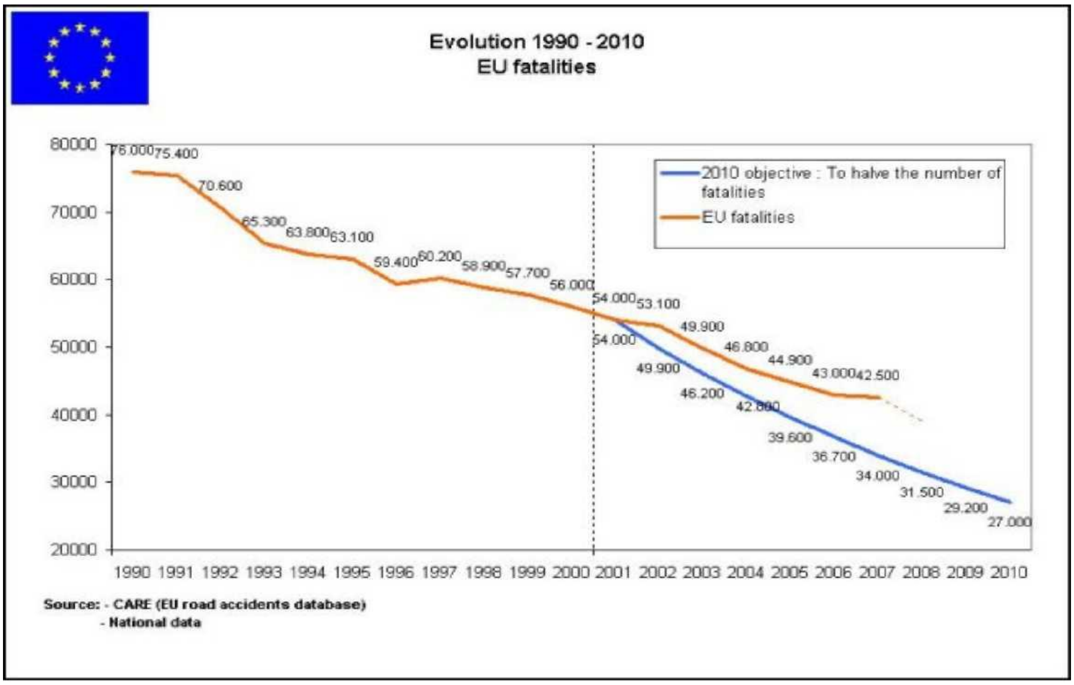


Figure 8: Reduction of EU road accidents between 1990 and 2010 [8]

To be on course to reach the EU target in 2010, a reduction of at least 37% between 2001 and 2007 corresponding to an annual average reduction of at least 7.4% is needed. Between 2001 and 2007, however, road deaths have been reduced by 20% only. The European Union's yearly reduction in road deaths is no more than 4.2% on average.

Also, new targets and measures beyond 2010 have been proposed. Indicatively, ETSC proposes a shared target of 40% reduction of deaths with a further target to reduce injuries with lasting effects in each Member state by 20%.

However, the overall issue is much more complex and there are clear areas (transportation means and traveler cohorts), where the need for research and intervention are much more pressing, namely:

- Emphasis should be put not on to deaths reduction, but also on injury prevention. The annual monetary valuation of road injury prevention in EU countries has been estimated to exceed 180 billion Euros, less than half of which is accounted for by deaths, and this figure may well undervalue the prevention of injuries leading to permanent impairments (ETSC, 2003).

- In the EU 27 in 2006 at least 1,000 children died in traffic collisions. Children in cars or taxis account for more than two-fifths of child deaths, whilst child pedestrians account for just over a quarter (ERSO, 2007). Thus, Great Britain set a target in 2000 reduce by 50% the number of children aged 0-15 killed and seriously injured by 2010 (and is well on target), whereas ETSC recommended the EU to adopt a target of 60% reduction **between 2010 and 2020.**

- In 2006 at least 6,200 Powered Two Wheeler (PTW) riders were killed in road collisions in the EU25 representing 16% of the total number of road deaths while accounting for only 2% of the total kilometers driven (ETSC, 2008a). For the same distance travelled, the risk for PTW riders to be killed in road accidents is on average 18 times the risk of being killed in traffic for car drivers.

Correspondingly, the risk of being killed in traffic per kilometer travelled is more than 9 times higher for pedestrians than for car occupants and more than 7 times higher for cyclists than for car occupants (ETSC, 2003a).

In the European Union 60% of citizens live in urban areas of over 10,000 inhabitants (Eurostat). Moreover about two thirds of the accidents and one third of the road deaths are in urban areas and affect the most vulnerable road users. In 2008 the EU adopted a Green Paper: "Towards a New Culture of Urban Mobility". Thus, urban safety is clearly a priority area for actions.

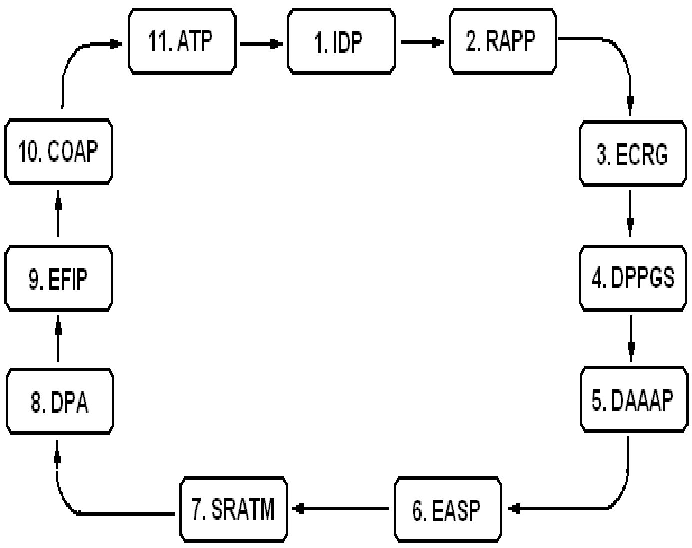
Traffic collisions are the single largest killer of 15-24 years olds (ERSO, 2006b). Thus, effective novice drivers training and retraining schemes, merged with appropriate and sustainable enforcement policies, need to be in focus.

The risk of an elderly road user being killed in a road accident is on average 16 percent higher than the corresponding risk for a younger road user. Elderly people are more vulnerable to trauma than other age groups, taking into account both their increased accident exposure and their higher vulnerability (AGILE, 2005).

The differences in road safety levels between various EC countries are as big as 500%, thus focused research measures per European area need also to be supported.

In conclusion, both accident prevention and mitigation should be focused. According to ERTRAC Strategic Agenda of December 2004, accident prevention could contribute 55-65% and mitigation 35-45% of the overall gain in fatalities and injuries reduction.

The American Association of State Highway and Transportation Officials (AASHTO) applying road safety theory has developed and implemented a strategic highway safety plan, with the goal of reducing highway fatalities by 5000-7000 lives each year and reducing injuries and property damages. The elements of the ASSHTO plan place in perspective the major areas of concern in highway traffic safety and, by extension, the safety of others models. The plan recognizes that improvements in runway design, systems operations, and infrastructure maintenance, while important, are not sufficient to achieve progress in safety.



Legend:

1. Identify and Define the Problem
2. Recruit Appropriate Participants of the Program
3. Establish Crash Reduction Goals
4. Develop Program, Policies, Guidelines and Specifications
5. Develop Alternative Approaches to Addressing the Problem
6. Evaluate the Alternatives and Select a Plan
7. Submit Recommendations for Action by Top Management
8. Develop a Plan of Action
9. Establish the Foundations for Implementing the Program
10. Carry Out the Action Plan
11. Assess and Transition the Program

Figure 9: AASHTO Strategic Highway Plan model implementation process

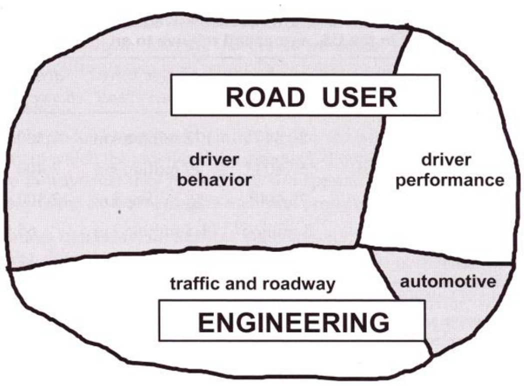
The quantities that can be measured in traffic safety are nearly always rates. That is, some measures of harm (deaths, injuries, or property damage) divided by some indicators of the risk of this harm. Simple counts are almost never used. The annual count of fatalities is a rate, namely, the number of driver deaths per head of population, per registered vehicle, per licensed driver, or per same distance of travel.

There is no rate superior to others in any general sense. The rate to be selected depends on the question being asked-and often also on what data are available (on available data). What is important is to specify exactly what rate is measured and how is related to the problem being addressed.

Properties of a hypothetical population of identical drivers all having the same risk of crashing every day can be computed using the Poisson distribution. Due to randomness alone, some drivers will have two, three, even more crashes at the end of the year, while other "identical" drivers will be crash free. Removing the high – crash drivers from such a hypothetical population has no effect on average crash risk next year. All drivers do not have equal crash risk, but the expected random variation in numbers of crashes (if they provoked any crash) makes license revocation based solely on above – average crash experience a relatively ineffective countermeasure.

The large number of factors relevant to road safety can be conveniently divided into the following categories:

- Engineering
  - Roadway and traffic engineering
  - Automotive engineering
- Road user
  - Driver behavior
  - Driver performance



(Source: Evans L, Traffic Safety)

Figure 10: Factors relevant to road safety

Given the enormity of losses from traffic crashes, all factors are of immense importance, but some are more important than others. Road user (or human) factors are more important than the engineering factors. The human factor that plays the largest role is driver behavior is one of the main keys to changes in road traffic safety. Behavior-change theories may offer guidance that could contribute to harm reduction. In 1949, the comment *"a man drives as he lives"* entered the road traffic safety literature. The things that affect driving behavior almost as diverse and those that affect life in general; they include family, personality, the era in which one lives, socio – economic status, religion, beliefs, traditions, etc. Four areas of influence on driver behavior are addressed below:

- Fear of adverse consequences
- Social norms
- Mass media
- Legislative interventions.

These all interact with each other.

Given that roads are generally in good condition and vehicles come equipped with a variety of safety devices, is the operator of the vehicle that has become the major causal factor of traffic accident. In today's stressful world, with increase congestion, longer driving times and multiple destinations reached by car, it is not surprising that the phenomenon of "road rage" has developed and cell phone is comparable to alcohol consumption as a major cause of crashes.

For example, to improving driver performance AASHTO (American Association of State Highway and Transportation Officials) proposes:

- Graduated licensing for younger drivers.
- Reducing the number of drivers on the road whose privileges have been revoked or suspended.
- Improving the safety of older drivers.
- Controlling aggressive driving behavior.
- Reducing or eliminating driving while under the influence of alcohol (drugs).
- Reducing driver tiredness to assure that drivers are alert.
- Increasing the awareness of the motoring people about the importance of road and highway safety.
- Increasing the use of seat belt.

Among these are enacting laws to ensure driver competence, improving driver education and training programs; developing means to identify problem drivers who are repeat offenders; designing highway signs and signals for greater visibility by older drivers; increasing law enforcements of speeders and seat-belt violators; implementing safety-related intelligent transportation system and technologies; increasing driver checkpoint programs to identify impaired drivers; retrofitting highway shoulders and bike lanes with rumble strips to alert drivers; revising hours-of-service regulations to reduce truck driver fatigue; and developing national public awareness of road safety issues.

4.7 Performance indicators in road safety

Countries develop, establish and implement systems for managing road traffic safety such as:

- Coordinating and integrating broad-based safety programs, into a comprehensive management approach for road traffic safety;
- Identifying and investigating hazardous road safety problems and road way locations and features and establishing countermeasures and priorities to correct identified or potential hazards;
- Identifying safety needs for special user groups (old drivers, pedestrians, bicyclists, motorcyclists, hazardous materials car, commercial motor carriers, etc.) in the planning, design, construction and operate road system;
- Routinely maintaining and upgrading safety hardware (including road and highway-rail crossing warning devices), road and highway elements, and operational features.

It is a common perception among the public that traffic accidents are a problem, resulting in death, injury or property damage.

Unfortunately, many people do not fully realize the size of the problem.

It is clear that while many people, especially in the developing countries, have the general idea that driver error is the main cause of the problem, they have no idea that a several causes and factors contribute to the problem as well. Their understanding, in most cases, is limited because they have no clear measurement(s) that can show them the size of the problem in a simple and adequate way.

When a policymaker decides which actions need to be taken nationally, it has to be based on some sort of statistical measurements. When road users want to know their accident risks, this should also be based on understandable statistical measurements.

Unfortunately, most present measurements that are used to address the scale of road safety problem in a country or city are mainly based on death rates (deaths per vehicle or per person). These rates are often too complex to be understood by ordinary people and, in some cases, by policy makers since the scale of these measurements is not uniform, and vary from one study to another and the results are mostly in a decimal number.

Furthermore, the death rates say little about achievement of a country or its progress towards a certain goal. Therefore, it has always been of interest to researchers to develop a measurement that provides public and policy makers with a clear understanding of the causes and magnitude of traffic accidents in their countries. All countries suffer from the road accident problem. Yet the size of the problem is different from one country to another, because countries vary widely in their development levels, road safety systems and experiences. According to Jacobs *et al.* (2000), the majority of road deaths and injuries occur mostly in developing and transitional countries. *Highly Motorized Countries* (HMCs) have sixty percent of the total motor vehicle fleet but their contribution of the total global road accident deaths is only fourteen percent. Several studies have shown that the total number of road deaths in HMCs has been declining or establishing during recent decades, whereas the situation in *Less Motorized Countries* (LMCs) remains severe and the total number of deaths continue to increase.

An international comparative study across different regions in terms of motorization (vehicles per person), personal risk (deaths per person), and traffic risk (deaths per vehicle) show that highly developed countries have the lowest risk records and high motorization, while Africa has the lowest motorization and a high traffic risk. Southeast Asia, Africa and the Middle East run the highest risk of being killed in terms of personal safety.

However, such comparison should not be taken too seriously, since there are differences within the same region concerning for instance: motorization, population, education, health, investment level on road safety measures, etc. In order to achieve adequate results in comparisons, international comparisons have to be carried out between similar countries or regions at the same level of development, motorization and with similar type of transport system as much as possible.

Additionally, the characteristics and nature of the road safety problem differs between countries. For instance, the majority of road accident injuries and deaths in LMCs are the vulnerable road users (pedestrians, cyclists, motorcyclists), whereas, due to the high number of car owners, car occupants account for most of the victims in HMCs. Therefore, road safety priorities are different from country to country and from region to region in accordance to their accident characteristics, nature, causes and challenges.

In terms of road safety, many countries recognize the importance of international benchmarking to measure their own achievements with similar countries or countries that have already passed through similar stages of challenges and development. This comparison allows countries to identify their problems and improve their performance in road safety based on existing practices and lessons in other countries. In general, these benchmarking models intended to answer:

- Which country performs better than another?
- Why is a specific country more successful than others?
- How and what measures a successful country has used to improve its road safety work.

- Which actions have to be taken to improve road safety performance in a country in future?

A number of benchmarking models in road safety have already being developed and they range from relatively simple to highly complex models depending on the number of indicators involved, details of data and complexity of methods used in calculations and analysis. These benchmarking models in road safety can be classified into four broad categories as follows:

- Product benchmarking is used to compare death rates.
- Practices benchmarking is used to compare activities related to human - vehicle road performance (e.g. seat belts use, crash helmets use, motorways level etc.).
- Strategic benchmarking is used to compare National Road Safety Program (NRSP), management and organizational framework.
- Integrated benchmarking is used to compare countries in terms of the three previous types of benchmarking altogether.

Road safety performance in a country is seen and perceived within a holistic context. Although numerous research and applications have been carried out in the first three types in macro benchmarking of road safety, little research has investigated the fourth type (Integrated Benchmarking). The major possible obstacles in constructing an integrated benchmarking model are:

- Misunderstanding what integrated benchmarking means.
- The lack of data from different countries, especially in LMCs.
- May be very expensive in terms of money and the time taken to collect and analyze data from many countries.

However, today data is more accessible. Faster computers are developing rapidly as well, which simplifies the work and analysis of a large amount of road safety data that was not available before. This development makes the work in the integrated benchmarking easier, bringing it closer to reality.

Additionally, the term "*Sustainable Development*" has become more popular and applied in different sectors of research. This term simply means integrating several efforts at the same time for maximizing the development of a specific sector. Examples are "*Sustainable Transport*", "*Sustainable Environment*" and "*Sustainable Health Care*".

To date, important researches have been reported on "*Sustainable Road Safety Development*", which needs to be emphasized in research.

One of the major challenges to sustain road safety in a country is that the traditional measurements used regarding the first three types of benchmarking are not powerful enough to model the complexity of road safety situation in a country. Therefore, an integrated benchmarking tool can contribute to a sustainable improvement in road safety in the country and bring all relevant concepts together. The benchmarking models in general are mostly based on two types of measurements, from a statistical point of view, for the overall performance of a country.

The first type is to develop a set of national Key Performance Indicators (KPIs) that measure the country performance from different aspects; and the second type is the composite indices that combine many key indicators KPIs into a single value. There is a considerable number of studies (beyond road safety sector) that has highlighted the importance and usefulness of having composite indices as a tool for making integrated benchmarking, Many composite indices have been developed internationally and used in different aspects of life to indicate progress or achievements between countries. Such examples are: Human Development Index (HDI), which was developed by the United Nations and the Overall Health System Index by the World Health Organization.

Business, in general, has also recognized the importance of having a multi-dimensional index for managing, assessing, controlling and sustaining the performance of the company/organization.

This has led to the development of quality benchmarking and excellence models, which are today quite popular and are widely accepted and used in modern economic and business benchmarking research at national and international levels. Such examples are Total Quality Management and the European Foundation for Quality Management (EFQM, 2006).

To date, no similar multi-dimensional (composite) index has been developed and used for benchmarking road safety issues. Most attempts in past research have focused on improving and implementing KPIs in road safety. Simple safety indicators have been used and developed by a number of international institutions and databases such as International Road Federation (IRF) and International Road Traffic and Accidents Database (IRTAD).

However, unfortunately, many databases overlap to a large extent and they are not so detailed enough since many important indicators and data are not available for a large number of countries in the world. One reason for the lack of data, among many others, is that there is no single list of performance indicators in road safety, universally accepted, collected and used.

A master-list of macro-performance indicators in road safety.

The indicators are classified into three classes according to their data availability in different countries, quality and type.

A high availability of data means that enough data is always available to access. Medium availability means that data is under development and there is a call for data collection in these indicators.

A low rating means that data is currently not available and they require further development and collection of data in the future for a large number of countries, especially from developing countries. For instance, one acceptable indicator is "*deaths per vehicle kilometer"* and it is an important element in road safety, but this measure is still not available in most countries. In fact, there are several macro indicators that may play a role in road safety development in a country, but unfortunately some indicators are hard to measure for now and they will be kept for further and future development.

A high quality of data means that data comes from reliable sources with minimum errors. Acceptable data means that it is fairly reliable and accurate. Poor quality means that we have a data quality problem and the results are questionable and should not be fully trusted.

Not rated means indicators are not identified for now and there is no indication of what the quality could be in future. For instance, the indicator "*percentage of motorways per road network"* has poor quality of data and there is difference of definitions of road standards across countries. The size of quality and availability of the indicators have been estimated based on a sample of countries from different parts of the world.

The indicators, as mentioned earlier, may either be quantitative/objective or qualitative/subjective. In some indicators, there is lack of quantitative information and it will be better if subjective indicators are included.

Subjective indicators can be considered as complementary indicators if they are translated to a quantities rating system. Both "*organizational structure*" and "*enforcement measures"* are based mainly on subjective assessments and at this stage it is a major problem to gather experts' assessment regarding both dimensions and to measure subjective indicators. However, both dimensions can be developed and become more concrete indicators for the future.

4.8 Macro road safety indicators

Core Dimensions and Indicators	**Availability**	**Quality**	**Type**
Traffic Risk:			
Death rate (per vehicles-km)	Low	Good	Objective
Death rate (per person-km)	Low	Acceptable	Objective
Deaths per vehicles	High	Good	Objective
Personal Risk:			
Death rate per population	High	Good	Objective
Death rate per population age	Medium	Acceptable	Objective
Changing trend in the number of deaths (%)	Medium	Acceptable	Objective
Road User Behavior:			
Percentage of seat belt use	Medium	Acceptable	Objective
Percentage of crash helmet use	Medium	Acceptable	Objective
Percentage of drivers above the legal BAC limit in police checks Percentage of all drivers exceeding speed limits in police checks	Low	Poor	Objective
Objective Consumption of alcohol per capita (liters)	Medium	Acceptable	Objective
Minimum age for driving	Medium	Acceptable	Objective
Vehicle Safety:			
Index of national crashworthiness (vehicle crash performance)	Low	Acceptable	Objective
Distribution of vehicles by age: Percentage of new cars	Low	Acceptable	Objective
Mass classes of car fleet (%)	Low	Acceptable	Objective

Percentage of buses and coaches in total vehicle fleet	High	Acceptable	Objective
Percentage of vehicles excluding motorcycles	High	Acceptable	Objective
Roads Safety:			
Percentage of roads paved	High	Acceptable	Objective
Total paved roads (km) per capita/vehicles	High	Acceptable	Objective
Total motorways/freeways (km) per capita/vehicles	Low	Poor	Objective
Km of motorway per km of paved road	Low	Poor	Objective
National expenditure on roads (engineering /maintenance) % GDP	Low	Poor	Objective
National expenditure on roads (safety measures) % of GDP	Low	Poor	Objective
National expenditure on roads per total vehicles	Low	Poor	Objective
Socioeconomic indicators:			
Percentage of urban population	High	Acceptable	Objective
Percentage of 15-24 years old in the total population	Medium	Acceptable	Objective
Population density (people per km^2)	Medium	Acceptable	Objective
Life expectancy (years)	Medium	Acceptable	Objective
Population per physician	Medium	Poor	Objective
Average acute care days related road accidents in hospital	Low	Poor	Objective
Severity index (number of deaths per total casualties)	Medium	Acceptable	Objective
Illiteracy: percentage of persons over 15 years unable to read	Medium	Acceptable	Objective
Gross National Product (GNP) per capita	High	Acceptable	Objective
Percentage of people in unemployment	Medium	Poor	Objective

Traffic Police and Enforcement:			
The annual number of random breath tests (per vehicles)	Low	Acceptable	Objective
The annual number of speed-violation notices (per vehicles)	Low	Acceptable	Objective
The annual number of seat belt violation notices (per vehicles)	Low	Acceptable	Objective
The technical means/equipment available to the traffic police	Low	Not Rated	Subjective
Organizational structure:			
The development of the 'National Road Safety Council'	Low	Not Rated	Subjective
How far the cooperation between the key stakeholders and NGO's	Low	Not Rated	Subjective
The funds level are spent on road safety measures	Low	Not Rated	Subjective
Legislations level, data collection level and statistics	Low	Not Rated	Subjective
Inspection of vehicles	Medium	Not Rated	Subjective
Number of national campaigns in the last three years	Low	Acceptable	Subjective
Number of driving licenses delivered per total vehicles fleet	Low	Acceptable	Objective

Table 1 The master list of macro road safety indicators and dimensions

The increase in availability of data will improve the quality of data. In other words, the quality of indicators is good when data is available. At the same time, the importance of each indicator depends on its type, availability and quality. Thus, for increasing the usefulness and applicability of the indicators and dimensions, efforts have to be made to enable a high quality data delivery, especially to those indicators which are considered important and vice versa. This selected master-list is useful for different benchmarking purposes. The selected indicator should be clearly defined, measured, and regularly available and to be comparable over time.

4.9 Conclusions on State of the Art

Road Safety is an important topic in the design and operation of roads and highways. All over the world, traffic engineers are permanently engaged in working to ensure that the road system is designed and operate such as crash or accident rates can be reduced, to ensure safety for motorists and pedestrians. Supervision and enforcement is underrepresented as measure in the reports related to road safety.

Each country has also particular aspects regarding road safety, and it is necessary to identify its key safety needs such that investment decisions can be made so that will result in significant reductions in road and highway fatalities and serious injuries on public roads.

Road safety improvement process involves planning, implementation, regulation and evaluation. The planning process requires that engineers collect and maintain road traffic safety data, identify hazardous locations, perform engineering studies, and establish project priorities.

If the factors that have contributed to crash events are identified, it is possible to modify and improve the transportation system.

Those factors can be considered in four separate categories: actions of the driver or operator, mechanical conditions of the vehicle, geometric characteristics of the roadway, and the physical or climatic environment in which the vehicle operates. A complete evolution methodology of the black spots has been presented.

Countries develop, establish and implement systems for managing road traffic safety such as:

- Coordinating and integrating broad-based safety programs, into a comprehensive management approach for road traffic safety;
- Identifying and investigating hazardous road safety problems and road way locations and features and establishing countermeasures and priorities to correct identified or potential hazards;
- Identifying safety needs for special user groups (old drivers, pedestrians, bicyclists, motorcyclists, hazardous materials car, commercial motor carriers, heavy goods transports, etc.) in the planning, design, construction and operate road system;
- Routinely maintaining and upgrading safety hardware (including road and highway-rail crossing warning devices), road and highway elements, and operational features.

Road Safety priorities have been established at the European level; these priorities relies on the concept of "Sustainable Safety", meaning that in order to provide an increasingly safer road traffic system, not only for the present but also for its future users, an approach is needed which encompasses combined, multidisciplinary and integrated actions leading to long lasting safety improvements.

5 Road Safety Approach

5.1 Complexity and Complication

Road crashes are likely to increase as economic activities accelerate unless road safety is radically improved. Road crashes have now become a major public health issue and the victims are mainly vulnerable road users. The road safety situation in many countries is alarming specially compared to industrialized and highly motorized countries in the world.

"Single de-synchronized and isolated actions for safety are not effective", a whole interlinked safety action package with key elements must be initiated and managed.

Safety Issues are complex and complicate.

Road Traffic Safety is a complex and complicated domain. Many actors, interlinked processes, regulations and safety elements are involved and shall be considered. A holistic and integrated approach is required. The overall effects and behavior of interactive processes (cybernetic) has to be considered. As used often, this is called the "Famous Triangle of Road Safety" (created by ROC)

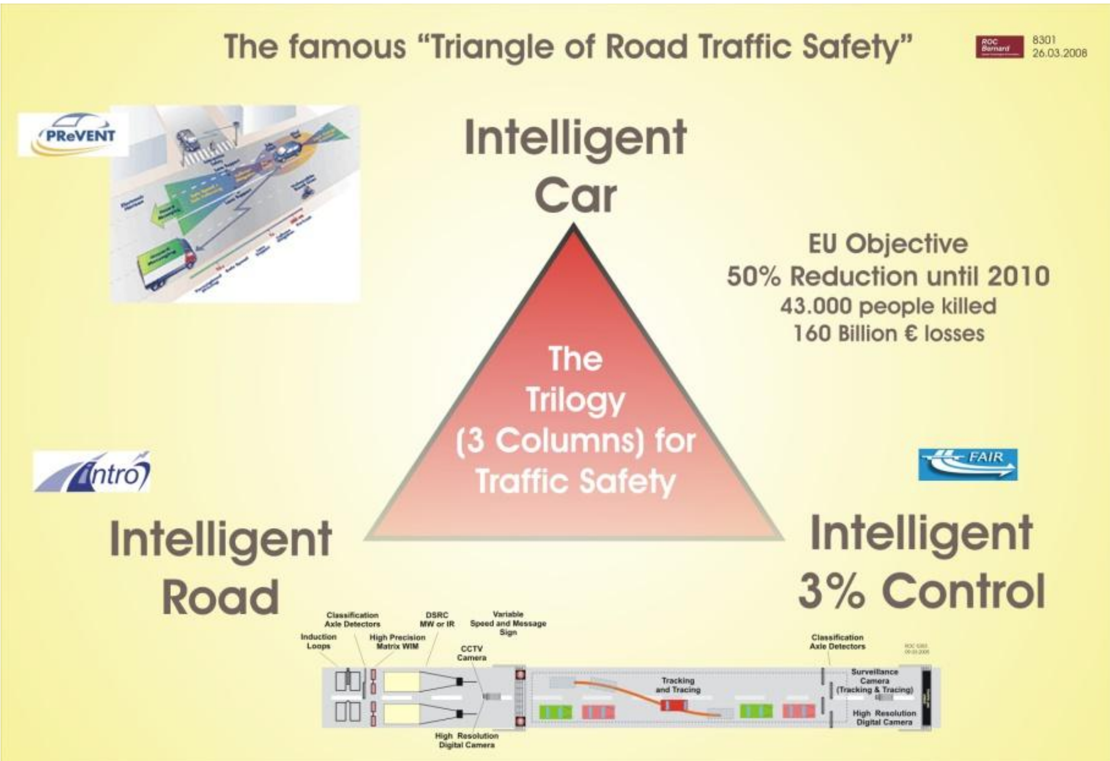


Figure 11: The famous Triangle of Safety

After this first step it was very clear, that a triangle is not sufficient for an integrated and holistic system description, analysis and optimization - an extension of the elements and a wider system approach was necessary.

To achieve the goal of a holistic safety a "Quadro-Pole" with 4 entities inserting the "driver" was created and used, consisting and describing a set of the most relevant elements needed. The interactions can be firstly treated on a dialectic dipole level. Dialectic dipoles can be used to represent, analyze and evaluate the impacts of the elements, solutions and technologies on safety parameters.

The main elements (dialectic dipoles) influencing road traffic safety and their interactivity - important for achieving safety - improvements can be described in dialectic interactive multipoles:

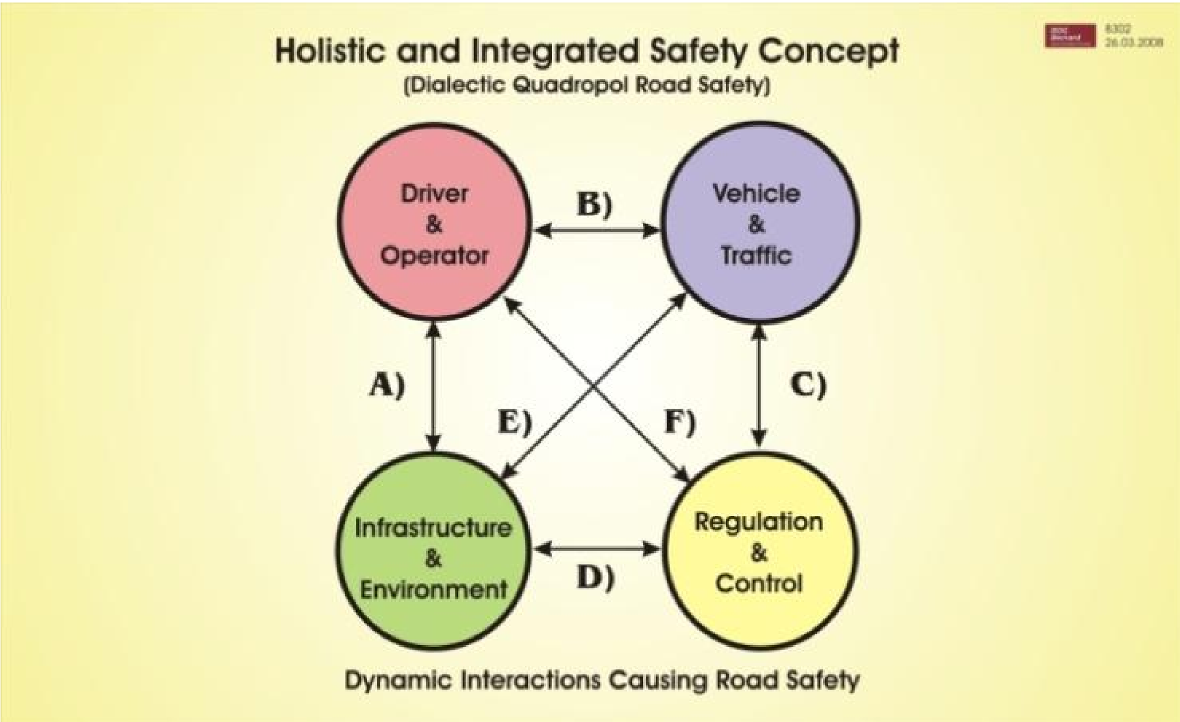


Figure 12: Holistic Road Safety Approach

To improve the safety situation a practical strategy and relevant recommendations for a holistic (covering the whole system) and integrated (linked together) approach were analyzed and are recommended.

5.2 "Holistic Safety Methodology" (Road Safety Wheel)

To apply experience concerning traffic safety initiatives and know-how from a control system is a key factor. To benefit from existing successful implemented and operated projects and approaches are important and save time and resources. This is an initial element for restructuring and strengthening the measures and administrative processes for road safety and its future operation. The consideration of national and local parameters is important.

5.2.1 Integrated Safety System Concept

The concept and methodology of an integrated system and holistic approach concerning traffic safety on roads has to be based on the following elements and measures:

- Integration of the main traffic and transport elements for increased safety (Driver, Vehicle, Infrastructure and Control)
- Discussion, specification and introduction of a clear, transparent set of requirements (general, operational, functional and technical) and main objectives and its monitoring concerning road safety improvement (Task of one of the committees)
- Creation of a practical holistic approach (including an overall safety concept and methodology), helping to solve and manage the complex interactions of the transport elements
- Combining and applying emerging and new technologies (Monitoring, Supervision, Sensing, Communication, Identification, Knowledge- and Databases, Data Mining, Image processing, Data security)
- Integration of road users, public stakeholders and administrations in the processes of identification of needs through to evaluation of initiative and measures results
- Building a competent team of experienced and multidisciplinary experts.

Growth in computing power and new technical equipment, simulation and optimization tools and technologies continues to create opportunities to improve safety in transport. However, the implementation of new concepts is often sporadic at best and there is at present a major gap between what is possible and what is implemented in practice. The concept of the proposal is to exploit this opportunity in a pragmatic way to greatly improve safety and sustainability of transport concerning individual drivers and at a holistic level. A “Holistic Safety Methodology” will consist of different levels for describing and representing a system, discussion and evaluation of the complex interlinked elements, situations, processes, interactions and its dynamics.

5.2.2 Step 1 Holistic Concept and Key issues

Four “A” steps can characterize the holistic approach and are recommended for an integrated road safety methodology:

- “Anticipation” of visions, trends and effects of possible and useful measures.
- “Analysis” of safety elements, processes, cybernetics and their interactivity.
- “Agency” generated, established, financed and operated for road safety.
- “Actions for Progress” interlinked program of key actions to be undertaken.

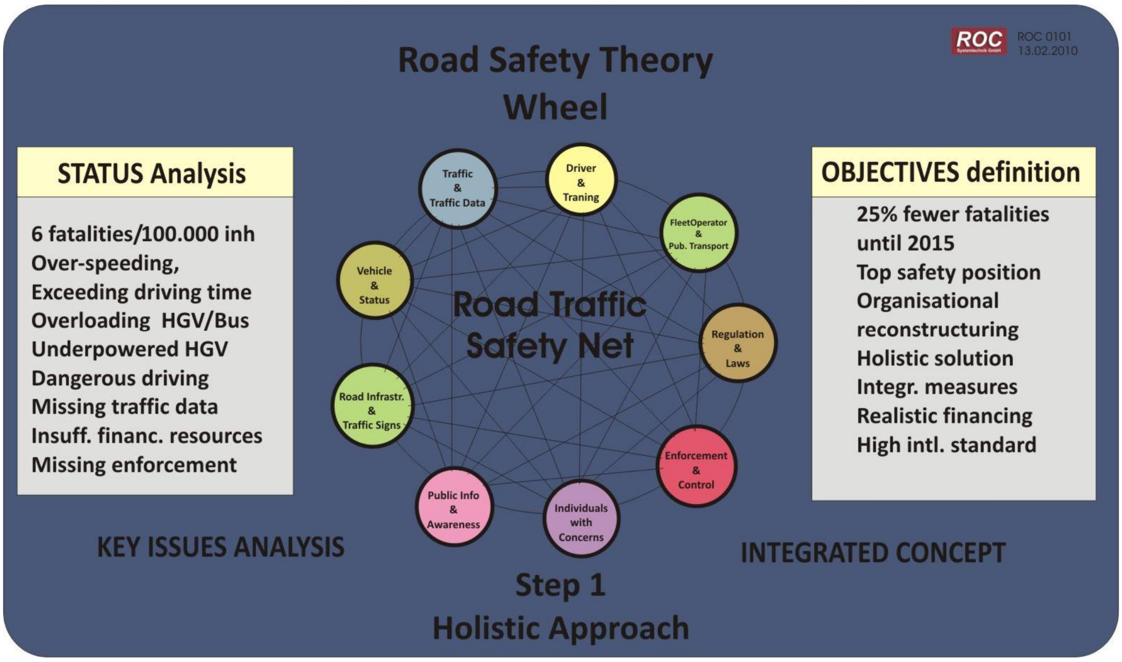


Figure 13: Road Safety Strategy 2010/2015: "A" Step 1

Step 1 is to elaborate and consider the most important safety and control elements, to develop an integrated and holistic approach and a full coverage of the main elements and processes of the road safety system complex. A concept considering these key aspects and dynamics will be developed and the implementation strategy by relevant activities and measures will be supported.

5.2.3 Step 2 Road Safety Situation Analysis

Figure 14: Road Safety Strategy 2010/2015: "A" Step 2

Step 2 is to analyze traffic safety situation and organizational relationships, followed by the third synthesis step to propose and create the organizational framework and its composition.

5.2.4 Step 3 Road Safety Agency

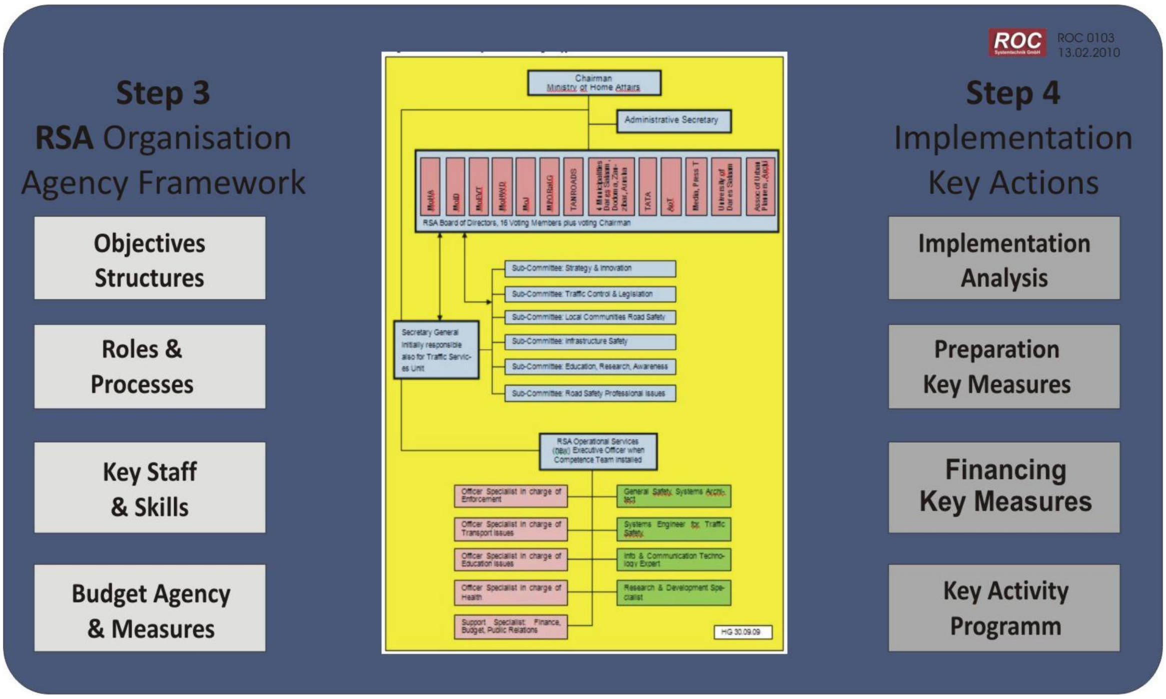


Figure 15: Road Safety Strategy 2010/2015: "A" Step 3

Step 3 is to propose and create the organizational framework of a Road Safety Agency (RSA) and its composition.

5.2.5 Step 4 Road Map and Key Action Program

Step 4 is to prepare a road map, prepare key actions and realize key actions including its financing.

5.3 "Holistic Safety Methodology"

For improving road safety it is necessary to understand the "Reality of Road Safety" and its phenomena by an analytic structure and to elaborate the best prognoses and recommendations to react for improvements.

A "Holistic Safety Theory" will consist of different levels for describing and representing a system, discussion and evaluation of the complex interlinked elements, situations, processes, interactions and its dynamics.

5.3.1 Universes of Safety Theory Elements

A professional "Holistic Safety Theory" is necessary for analyzing and improving road safety as a complete system.

This safety theory will consist of different hierarchical universes, besides giving and describing the dialectic interactions, of the main safety related elements and levels below.

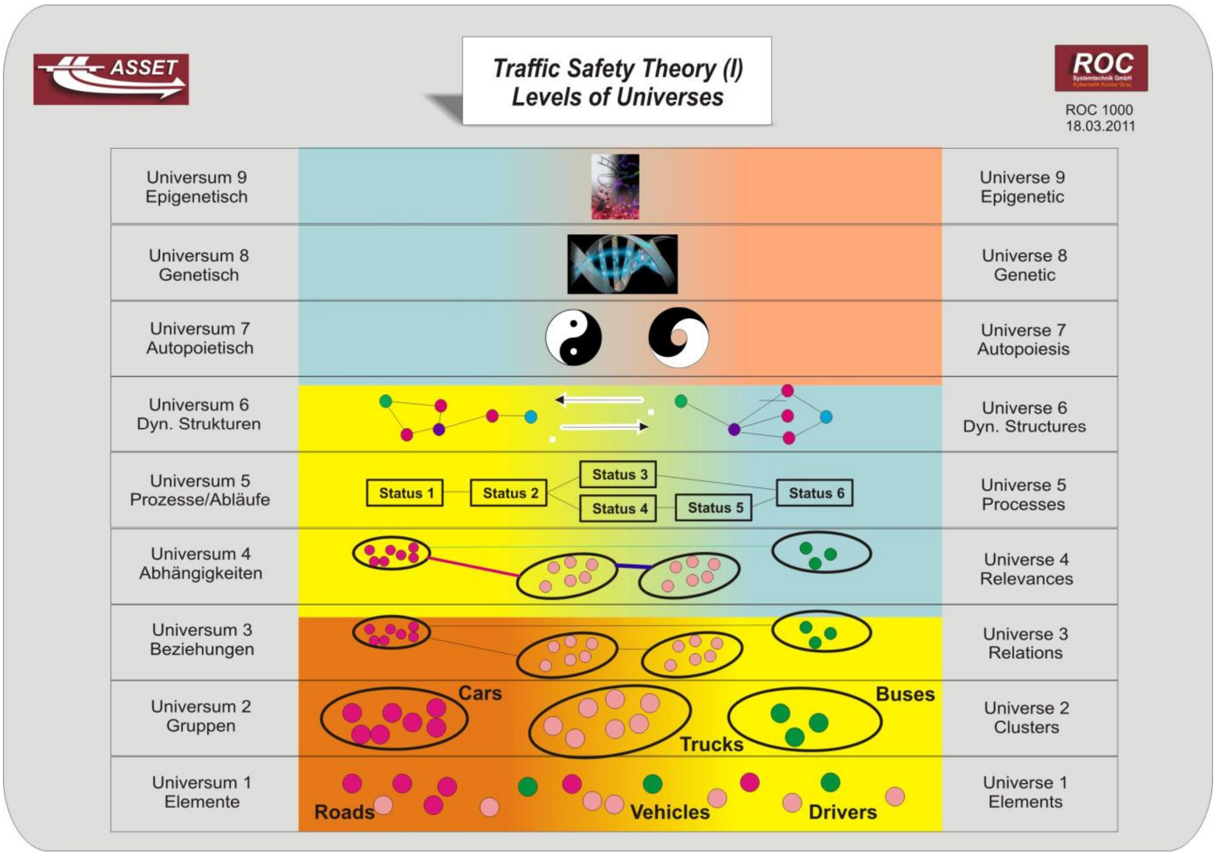


Figure 16: Theory of Safety Levels (ROC)

The safety theory will define different levels (universes) for representing the whole safety system. This is facilitating discussions of stakeholders and users and the evaluation of the complex interlinked elements, situations, processes, interactions and its dynamics.

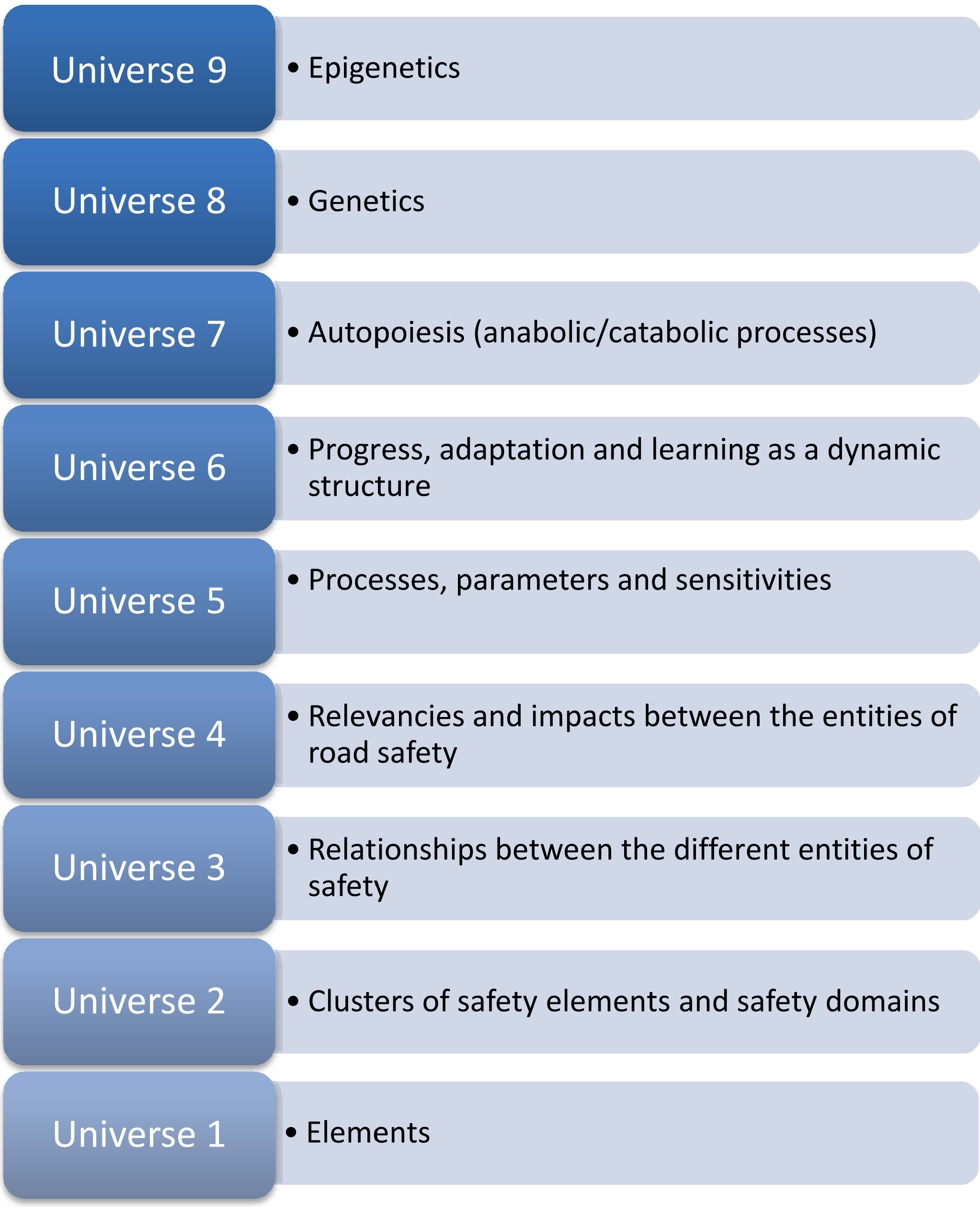


Figure 17: Road Safety Theory Elements and Universes

An additional important step of the methodology is to consider and evaluate the developments and the contribution of the different parameters in a structure or during a process for enhanced safety applications describing the future holistic approach.

5.3.2 Chains of Effects for Safety (Cybernetics)

Road Traffic Safety is based on multiple interlinked dynamic processes and the involvement of many actors and elements. Processes are non linear.

As example of the Traffic Safety Cybernetics (linked processes and the chain of effects) the impacts of overloaded heavy trucks/axles on the different traffic and safety domains are analyzed and involved stakeholders are described.

Vehicle Overload has a strong direct and indirect, short- and long-term impact on driving and traffic safety.

Vehicle axles very often exceeding the legal permitted load create unacceptable wear and tear of the road surfaces and road structures. Road damage with the 4th (or even more under specific conditions and parameters) power of the overload is the result.

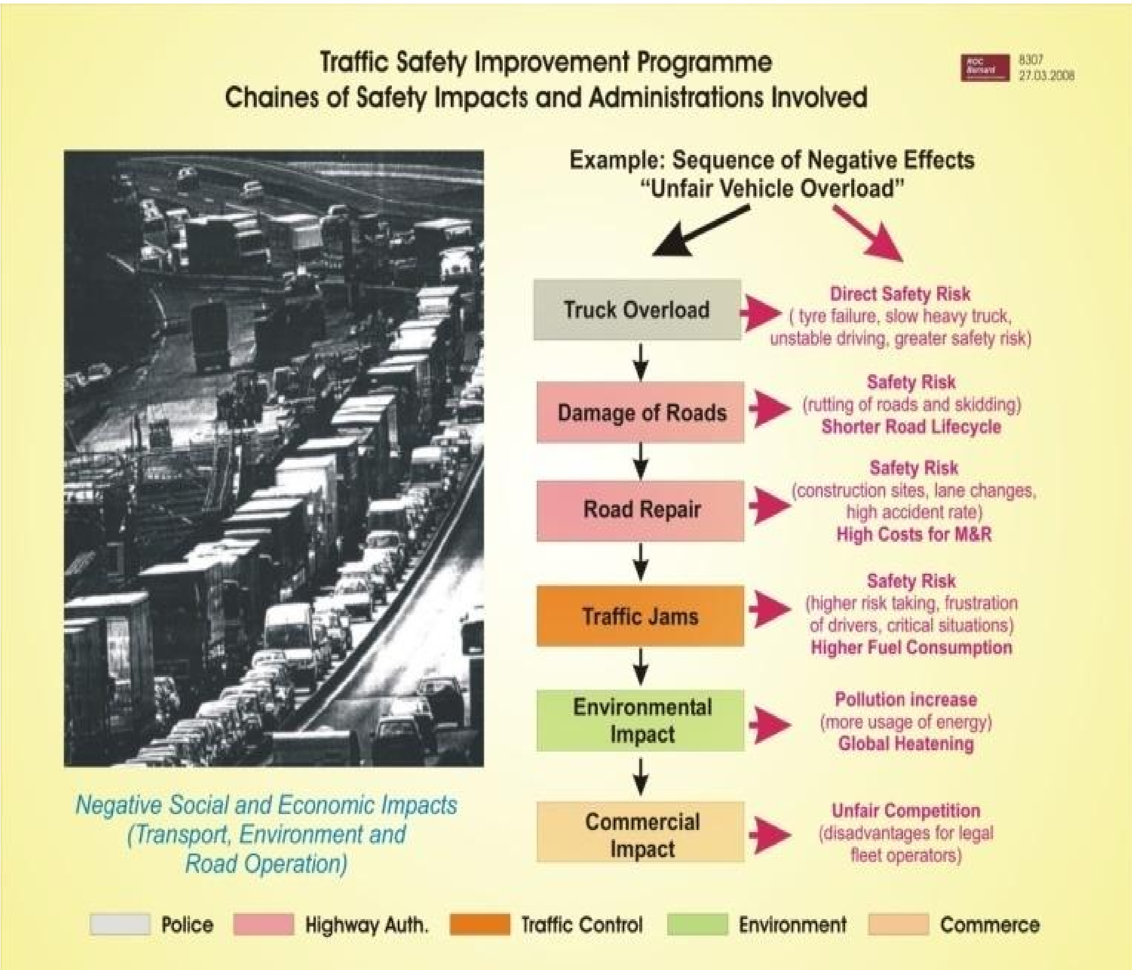


Figure 18: Goods Truck Overload: Cybernetic Processes

Road infrastructure has to be repaired or maintained with much higher costs and additional traffic problems during the construction time and higher accident rates on the construction sites. Accidents with involvement or causation by overloaded or heavy trucks are frequently severe or with fatalities, due to the high mass, high kinetic energy and/or long stopping distances. The end of the chain of negative effects is the unfair situation for haulage operators legally driving their HGV fleet.

5.3.3 Violation Enforcement Economy

Enforcement is one of the primary transport safety means today.

Some key aspects of effective enforcement by the police (retrieved from the conclusions of the ESCAPE-project) are as follows:

- The mechanism of enforcement is based on deterrence. Ample empirical evidence shows that the deterrence principle works. Enforcement based on deterrence is cost effective.
- The problem of enforcement studies is that they are experiments only.
- Drink driving enforcement shows (especially in Nordic countries) that long-term, durable and combined methods (high risk of detection, education, and information) bring about good results.
- Interference by the police is important in influencing speeds.
- There is widespread support for enforcement among the public.
- Automated methods are effective; current solutions are outdated; the adoption of automated methods is slow and in some countries, authorities are hesitant or reluctant.
- Automated enforcement will be arranged so that maximum deterrence is achieved through a minimum number of notices indicating the camera areas clearly, ensuring that drivers are aware of the areas covered by camera installations.
- Efforts shall be made to manage long stretches of roads/large areas with camera technology instead of spots; black spots need structural changes.

The next diagram is presenting the different parameters and there functionality for achieving enforcement success and economy.

Key parameters are:

- Violation rate
- Control rate
- Costs of measures
- Fining rate

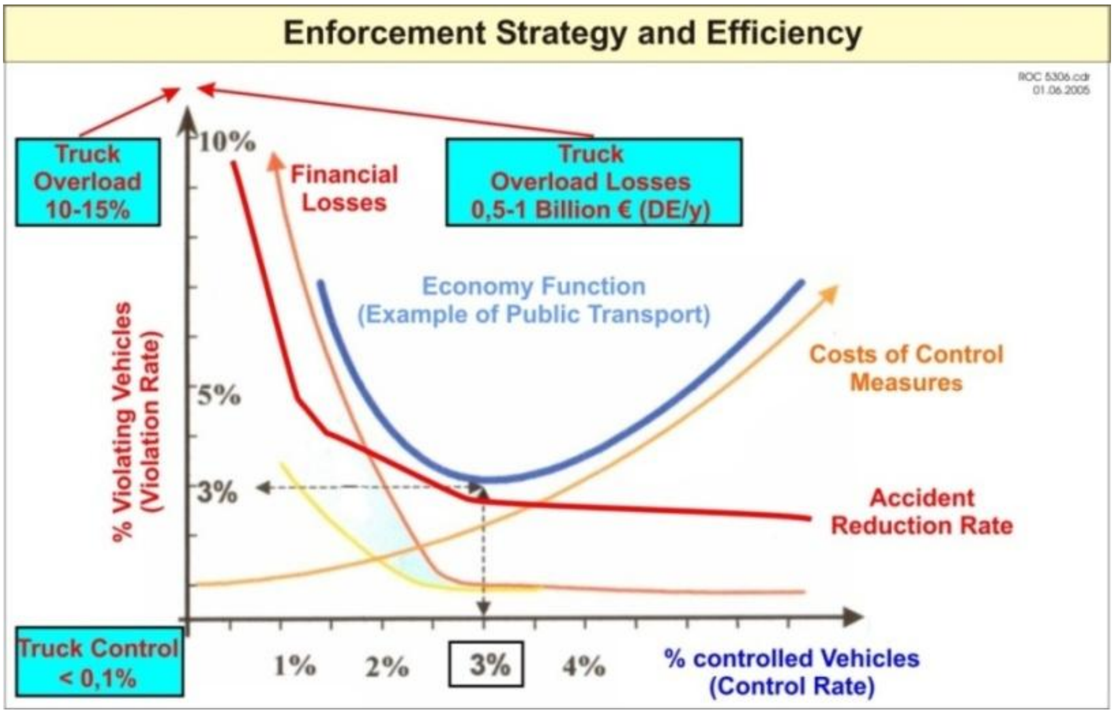


Figure 19: “Multi Purpose Efficiency Function”

5.3.4 Approach of Services (Automation)

Findings of various international research projects and successfully implemented strategies make clear statements about the use of automated methods in traffic management and control for improving safety. The European Commission launched for already in 2003 a recommendation on enforcement in the field of road safety:

- Automated methods are effective; current solutions are outdated; the adoption of automated methods is slow in most countries and authorities are reluctant to use them.
- Enforcement needs commitment and dedication; innovation is needed above all in persuading decision makers of the need for effective enforcement strategies.
- Surveys of needs reveal that more technological help is needed and more simplified methods must be found for recognizing and fining violators.

5.4 Socio Economic Integrity

Improving road safety has strong impacts on social life and economics of the individual as well as for the whole nation. Main domains and factors are described in the diagram below.

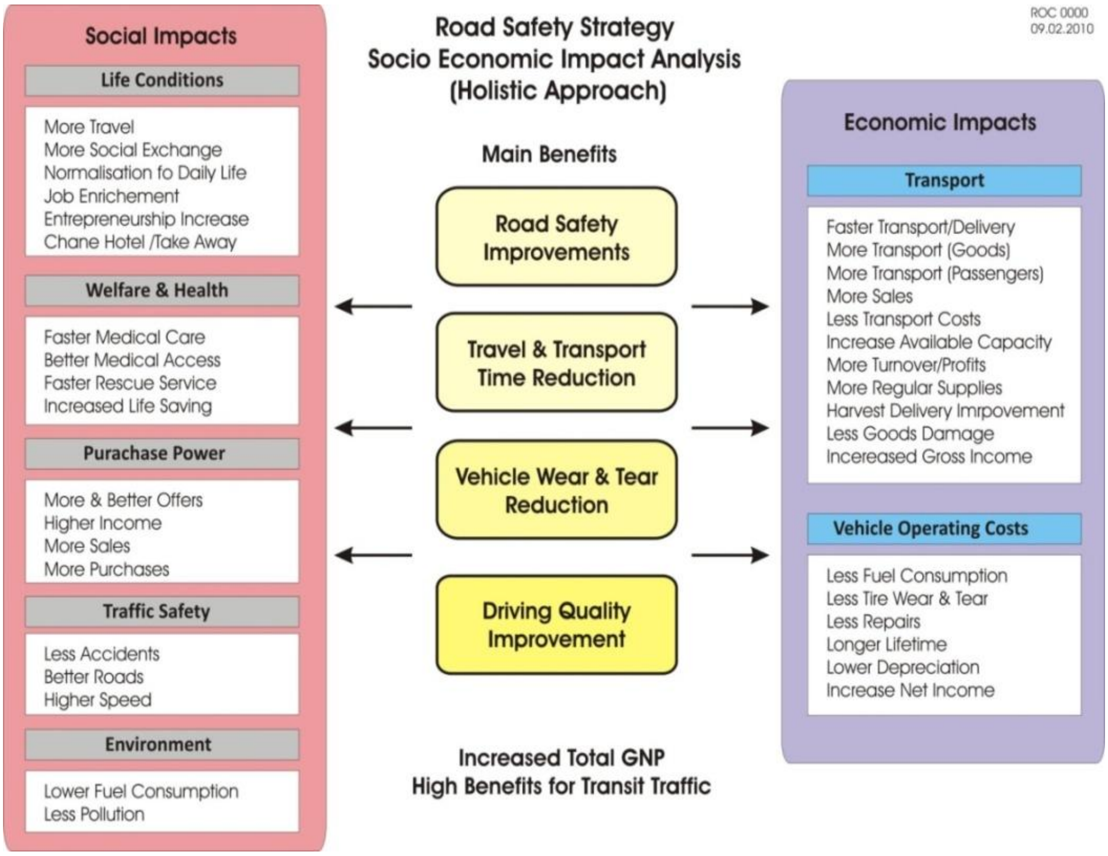


Figure 20: Socio Economic Impacts Analysis

Road safety has a wide scope of impacts on society and the economy:

- Life Conditions, Welfare & Health
- Purchasing Power, Infrastructure,
- Traffic Safety, Transport efficiency, Environment

Besides the direct and indirect costs of accidents, persons injured and fatalities have many influences on the overall economy of a country. This includes traffic jams and many delays based on accidents, rescue actions and insurance costs. Better and safer traffic flows are important for life conditions, welfare and health, purchasing power and environment too.

On the economic side, the costs of transport and the vehicle operation costs (energy consumption) are influenced. To reduce fuel consumption is a mayor necessity as a basic element of the productivity of a road haulage system. Pollution due to traffic jams and congestion influences the environmental conditions to a great extent.

A further key element in transport policy will be that, whatever the damage suffered by roads or other infrastructure, the costs will be borne by the relevant user. A similar approach will be the common rule and principle for the allocation of infrastructure costs to the relevant road users.

5.5 Safety Issues: Dialectic Interactions

Road Traffic Safety is a complex and complicated issue. Many actors, processes, regulations and safety elements are involved. A holistic and integrated approach is required. Cybernetics of interactive processes has to be considered. The main elements (dialectic dipoles) influencing road traffic safety and their interactivity - important for achieving safety - improvements are:

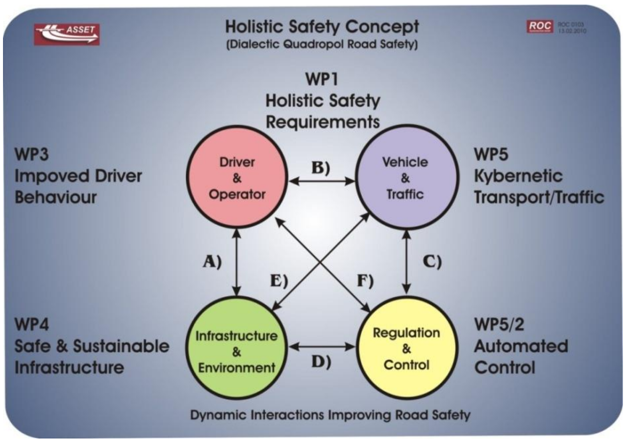


Figure 21: Holistic Road Safety Approach

To improve the safety situation a practical strategy and recommendations for a holistic (covering the whole system) and integrated (linked together) approach will be applied:

The concept and methodology of an integrated system and holistic approach concerning traffic safety on roads has to be based on the following elements and measures:

- Integration of the main traffic and transport elements for increased safety (Driver, Vehicle, Infrastructure and Control) and extend these elements for most relevant ones.
- Discussion, specification and introduction of a clear, transparent set of requirements (general, operational, functional and technical) and main objectives and its monitoring concerning road safety improvement (Task of one of the possible committees).
- Creation of a practical holistic approach (including an overall safety concept and methodology), helping to solve and manage the complex interactions of the transport elements.
- Combining and applying emerging and new technologies (Monitoring, Supervision, Sensing, Communication, Identification, Knowledge- and Databases, Data Mining, Image processing, Data security).
- Integration of road users, public stakeholders and administrations in the processes of identification of needs through to evaluation of initiative and measures results.
- Building a competent team of experienced and multidisciplinary experts.

Growth in computing power and new technical equipment, simulation and optimization tools and technologies continues to create effective opportunities to improve safety in transport. However, the implementation of new concepts is often sporadic at best and there is at present a major gap between what is possible and what is implemented in practice. The concept of the road safety strategy is to exploit this opportunity in a pragmatic way to greatly improve safety and sustainability of transport concerning individual drivers and at a holistic level.

A “Holistic Safety Theory” will consist of different levels for describing and representing a system, discussion and evaluation of the complex interlinked elements, situations, processes, interactions and its dynamics.

One step of the methodology is to consider and evaluate the developments and the contribution of the different parameters for enhanced safety applications describing the future holistic approach. It became very clear, that a simple triangle as used in the previous studies is not sufficient for an integrated and holistic system description, analysis and optimization - an extension of the elements and a wider system approach was necessary.

To achieve the goal of a holistic safety a “Quadro-Pole” with 4 entities was created and used, consisting and describing a set of the most relevant elements needed. The interactions can be firstly treated on a dialectic dipole level. Dialectic dipoles can be used to represent, analyze and evaluate the impacts of the elements, solutions and technologies on safety parameters.

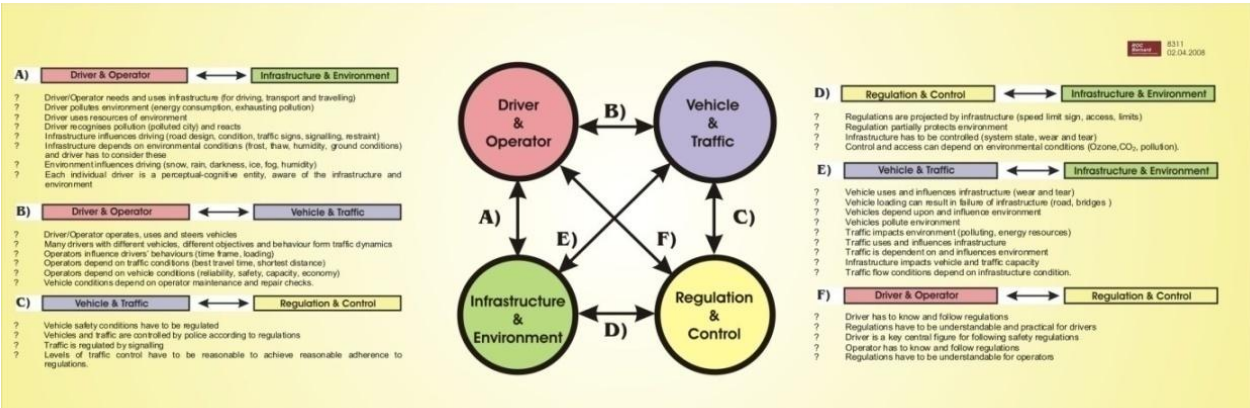


Figure 22: The Dialectic Quadro Pole of Safety Holistic Road Safety Approach

Important, critical and considerable relationships between each of the safety-related categories can be identified and described.

- Number of elements (n) means
- Dialectic Safety Interactions DSI = n *(n-1)/ 2

5.5.1 Dialectic Road Safety Discussion (example n=4, DI =6)

Some examples are given below, even not being complete, described in detail and scored according their relevance, implications and impacts:

A) Driver & Operator ⟷ Infrastructure & Environment

- Driver/Operator needs and uses infrastructure (for driving, access, transport and travelling), Infrastructure can be used under different parameters: shortest way, fastest way, and most convenient way. Road infrastructure may be used if the public transport infrastructure is not developed, is too expensive or timing is not adequate.
- Driver with his car pollutes environment (energy consumption per distance, exhausting pollution) based on the car on his and cooperative traffic driving behavior and passengers. Driver uses resources of environment for the car production material, factories and infrastructure, car production energy, car driving energy and fuel consumption, car and car material disposal.
- Driver recognizes pollution (polluted city) and reacts or not.
- Infrastructure influences driving: road design, road condition, weather condition, traffic condition, access of desired locations (shopping centers, hospitals...) traffic signs, signaling, restraint), new roads create more traffic, new roads may create more severe or fatal accidents.
- Infrastructure depends on environmental conditions (rain, floods, frost, thaw, humidity, ground conditions) and driver has to consider these occurring temporary or permanent.
- Environment influences driving (heavy rain, water on the roads, snow, darkness, ice, fog, etc.).
- Each individual driver is a perceptual-cognitive entity, aware of the infrastructure and environment but not behaving homogeneous.

B) Driver & Operator ⟷ Vehicle & Traffic

- Driver/Operator buys, operates, maintains and uses vehicles on roads interurban and cities.
- Many drivers with different vehicles, different objectives and behavior form traffic patterns, OD distributions and driving dynamics.
- Transport and fleet operators influence drivers' behaviors (time frame, loading).
- Operators depend on traffic conditions (best travel time, shortest distance, cost of transport and road usage).

- Operators depend on vehicle conditions (approval, reliability, safety, capacity, economy).
- Vehicle conditions depend on owner or operator maintenance, overload of wheels, axles, axle groups and gross weights, road conditions and repair checks.

C) Vehicle & Traffic ⟷ Regulation & Control

- Vehicle safety conditions have to be regulated.
- Vehicles and traffic are monitored and controlled by police according to regulations.
- Traffic is regulated by signaling.
- Levels of traffic control (distribution, detection rate, fining rate) have to be reasonable to achieve reasonable adherence to regulations and safety in prevention and accident reduction.

D) Regulation & Control ⟷ Infrastructure & Environment

- Regulations are projected by infrastructure (speed limit sign, lane markings, road network access limits in weight, vehicle class and time, height limits, geofencing of vehicles or vehicle types).
- Regulation partially protects environment (upcoming measures, EC regulations).
- Infrastructure has to be controlled (system state, wear and tear).
- Control and access can depend on environmental conditions (Ozone, CO_2, pollution).

E) Vehicle & Traffic ⟷ Infrastructure & Environment

- Vehicle uses and influences infrastructures (wear and tear).
- Vehicle loading can result in failure of infrastructure (road, bridges).
- Vehicles depend upon and influence environment.
- Vehicles pollute environment.
- Traffic impacts environment (polluting, energy resources).
- Traffic uses and influences infrastructure.
- Traffic is dependent on and influences environment.
- Infrastructure impacts vehicle and traffic capacity.
- Traffic flow conditions depend on infrastructure condition.

F) Driver & Operator ⟷ Regulation & Control

- Driver has to know and follow regulations.
- Regulations have to be understandable and practical for drivers.
- Driver is a key central figure for following safety regulations.

- Operator has to know and follow regulations.
- Regulations have to be understandable for operators.
- Control should achieve compliance with regulations - driver has to be controlled reasonably.
- Control should achieve compliance with regulations - operator has to be controlled.

5.6 "Dialectic Multipole" as extension

An interesting methodology and innovative concept creating a holistic approach, an integration of the elements for traffic and safety and interdependent processes will be presented and proposed (also part of the ASSET project introducing a new traffic safety methodology). Major different innovation areas (or areas not yet existing or sufficiently considered) are identified:

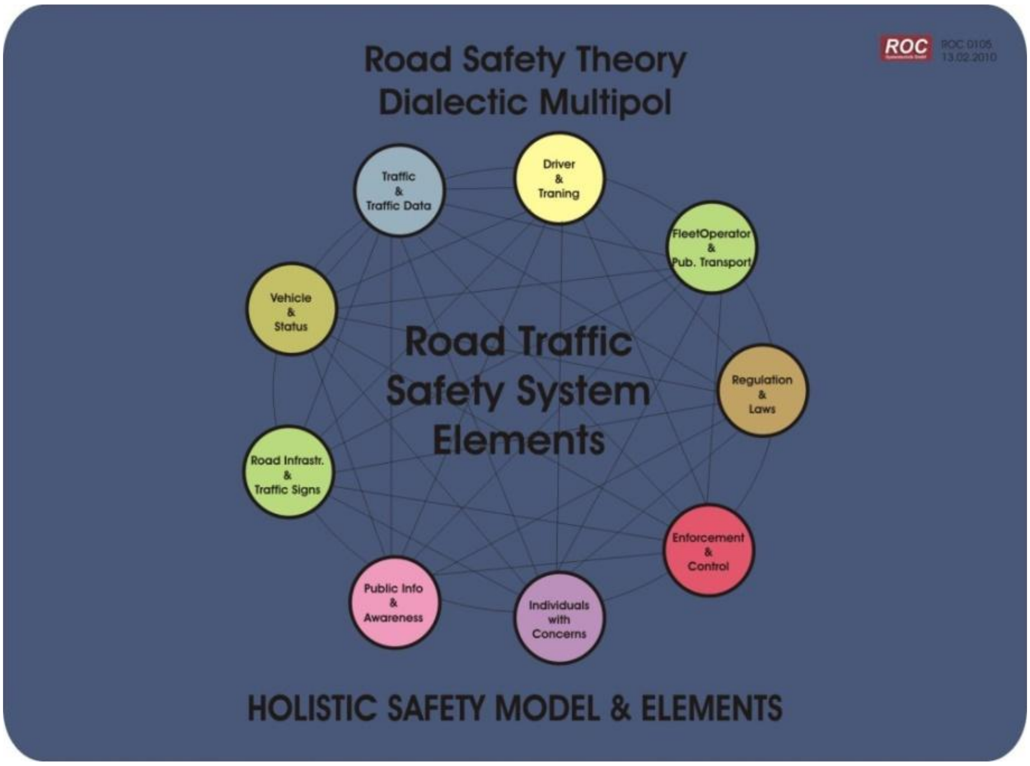


Figure 23: Dialectic Multipole (Road Safety Wheel)

1. Implementation of a holistic approach base on a system theory of safety advancing existing traffic safety theories with a view that accidents and safety need to be regarded as the interactions of -and here more than four - basic entities: (I) Driver and operator (ii) Vehicle and traffic (iii) Infrastructure and environment and (iv) Regulation and control. These areas create a number of different inter-relations for optimization.

2. A lack of integration/cooperation is currently present between the relevant parties and stakeholders in traffic safety. Analysis of the interdependencies suggests that similar sources of information and data can be used for several purposes. This will promote greater cooperation of key authorities – especially the police, municipalities and road operators – facilitating cooperation in the form of automatic data exchange, accident prevention and avoidance and common traffic and especially incident management strategies/tactics and shared technology solutions resulting in efficient and effective operations.

3. Technically the emphasis will be on functional competence establishment, data fusion and databases and an adequate sensor network used for the traffic sector. The principle of use and fusion of multiple information sources (multiple sensors) is that of integrating the information from vehicle behavior, road surface-based sensors and traffic infrastructure information for supervision and driver support.

6 Methodology (Five “E” Programs)

A common practice in international consultancy in analyzing and managing road safety is the five “E” approaches (Source: Road safety strategy Tanzania). First step is to recommend and outline a comprehensive policy to efficiently promote safety in a cluster of 5 programs. Different professional disciplines are required to work together.

Five “E’s” are formulated for reduction and prevention of road crashes and for improving road transport.

Engineering & Traffic Environment	• Road Design and Engineering, • IT, Databases, Traffic and Parking Management • Training, Control, Vehicle and Load Permission , Inspection
Education & Information	• Public Awareness, Driving Behaviour, Road Safety Publicity • Road Safety for Children • Land use planning, Crash Databases, Monitoring &Research
Enforcement & Legislation	• Enforcement as Key Factor, Legislation • Main Enforcement Cases and Processes • Enforcement Technologies and Equipment
Emergancy & Rescue	• Integrated Service Management System • Medical Response • Rescue Services
Evaluation & Comprehensive Actions	• System Monitoring & Evaluation • International Cooperation • Other Comprehensive Actions

Figure 24: Five "E" Programs

In the following sections the content of the 5 elements are described.

6.1 Engineering and Traffic Environment

Engineering & Traffic Environment	•Road Design and Engineering, • IT , Databases •Traffic and Parking Management •Training, Control, Vehicle and Load Permission , Inspection

For improving road safety, very often road infrastructure has to be improved considerably. However, especially in developing countries there are often road safety problems along the main roads in both trunk, regional, rural roads and ferries. Also road safety in urban areas continues to deteriorate as urbanization expands.

The main problems include different involved local authorities, different design and planning principles, non-harmonized signs and markings, lack of competence, and different objectives in the different city and town authorities. It should be noted that the traffic situation in urban areas is very complex compared to rural roads.

Most accidents are reported in urban areas and the road safety situation is more alarming for vulnerable road users, particularly the pedestrians, pedal cyclists, motorcyclists, and passengers.

To this effect, it is necessary to review and improve the design of new roads and rehabilitated roads and to effect regular maintenance of ferries to ensure safety.

Possible measures to ensure:

- The number of black spot improvements has to be increased.
- Road infrastructure deterioration and furniture vandalism is reduced.
- Facilities for vulnerable road users are integrated early in the road planning and investment process.
- Introduce and enforce a general speed limit for all vehicles in urban areas, and one for all vehicles outside urban areas.
- Develop and implement common guidelines for functional classification, safe design, and proper signs and markings.
- Introduce proper management of parking spaces. Proper and timely maintenance of road safety facilities including regular inspection must be assured.
- Introduce improved safety aspects and design systems in ferries.
- Procure modern pontoons and install safety gears in all pontoons

6.1.1 Enhanced Road Safety Engineering and Design of Safe Roads

The road safety strategy will be based on a combination of infrastructure improvements and measures aiming at developing an institutional framework.

To achieve this, it is necessary to assess and integrate a number of activities related to the development of rail, road and port infrastructure as well as the corresponding legal and administrative framework governing the financing and management of the corresponding operations. Examples of recommended projects:

Standards and Safety audits

For road and pavement design considering the national conditions. Establishment and operation of a pavement test center and laboratory.

Black Spot Management

Elaboration of a "Black Spot Hit list" and analysis, evaluation and preparation of adequate measures for achieving safety improvements.

Design of Bypass Road

Design a Bypass Road complete with Junctions for Radial Access Roads to City Centres.

Urban Road Safety Audit

Conducting a systematic and technical audit of urban transport conditions with respect to Internationally Accepted Performance Indicators; Identifying urban road safety, by safety items, and proposing related implementation solutions; establish priority-ranking lists on the basis of road safety performance indicators.

Multi-modal Transport Project

The core objective is to propose a strategy to optimize multi-modal transport systems and interfacing.

6.1.2 Professional IT and Data Base Systems

IT technologies and automation are employed for communication, data collection, information transfer, and analysis and remote operation. Different data collection and interactive databases have to be established and operated. Types of systems are:

- Accident Reporting Scheme
- Road Accident Database
- Traffic Data Collection system and Traffic Database
- Weigh station/overload Database
- Road Infrastructure Database
- Road Safety Monitoring Database
- Violators and Fining Database
- Optimization of an accident data registration and analysis system.
- Extend the use of a standard accident registration form.
- Produce and publish accident statistics to decision makers and the general public

Reliable accident and traffic data is an important prerequisite for identifying road safety problems and subsequent analysis of the problems and possible solutions.

Relevant data also comprise statistics on driver and vehicle licenses, police enforcement activities and the number and nature of traffic offences and registered injuries at hospitals.

Example: “ePermission for Abnormal Loads”

The overall goal would be the implementation of a modern, time- and cost-efficient internet-based system for handling requests for permissions to transport abnormal loads to achieve a safe and uncomplicated transport. The system supports the freighters requesting permissions for abnormal load transports, officers at the Ministry granting the requests, and later on also all citizens planning their routes to avoid traffic jams based on abnormal transports.

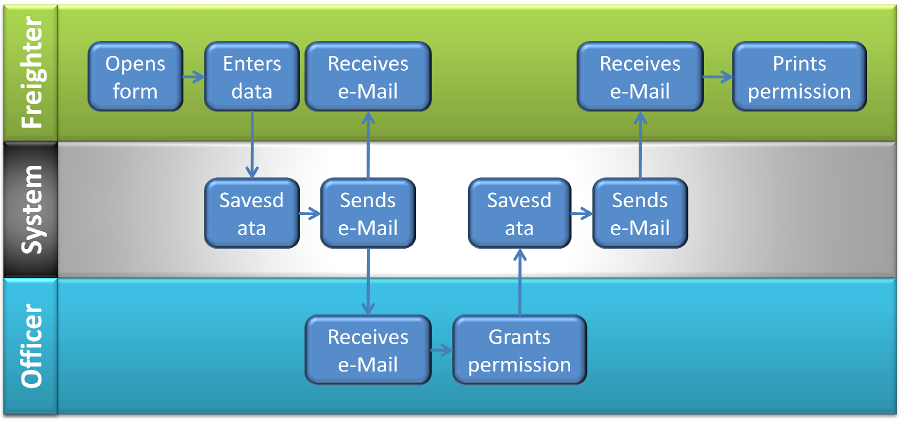


Figure 25: System structure “ePermission for abnormal loads”

Advantages: There are multiple advantages of such a system for various types of user

- The system is simple to learn and fast to use for all types of users.
- There exists one harmonized procedure for requesting and granting permission for all freighters and officers.
- All communication is based on e-mail
- The system is accessible on each computer connected to the Internet

Advantages for the Ministry

- The system helps reducing time and costs because the complete workflow for granting permission can be done within minutes in a few straightforward and simple steps.
- All data is collected and preserved in a database located in the Ministry to review and analyze all abnormal transports.
- Officers at the Ministry can share and exchange the incoming requests from the freighters to balance the workload with their personal demands.
- All data and all actions are documented and archived in a database for later use.

Advantages for all Freighters

- The system helps reduce time and costs for filing a request for an abnormal transport.
- The freighters do not need to manage an account in the system. They only fill-out the form and then get the results by e-mail.
- In later versions the freighters can use it as a route planning tool containing detailed data regarding obstacles on their planned route.
- Advantages for all Citizens
- Abnormal transport routes can be made available to the public to allow citizens the planning of their route depending on ongoing abnormal transports.

6.1.3 Improved Traffic Management and Control

Technologies, control algorithms and automation will be used also for analyzing, predicting and control of the traffic flow. Possible actions and measures:

- Traffic signalization
- Intersection control
- Section Control and Detouring
- Special event management
- Traffic and Safety Control Center
- Integrated Transport and Interactive Service Management

Example for introducing of an integrated and effective traffic safety and service management system and tool: There are emerging technologies and software tools under development concerning a new methodology and initial application to aggregate secure information involved in TransportML collaboration platform. A Service Oriented Architecture (SOA) platform provides a set of methods for the development and integration of road transport services and systems where functionalities are packaged as independent interoperable services. A SOA infrastructure enables information sharing between applications.

SOA's strength lies in the loose coupling of services with operating systems, programming languages and other underlying technologies. SOA splits and packages features in distinct entities – services – that developers make accessible on a network so that they can be reused and combined to develop new applications. Services can exchange information using messages. They also expose their functionalities using an interface, which can be easily understood by other applications or services, providing an abstraction layer hiding all underlying complexity. A user is then able to access a wide variety of services without worrying about their different implementation platforms.

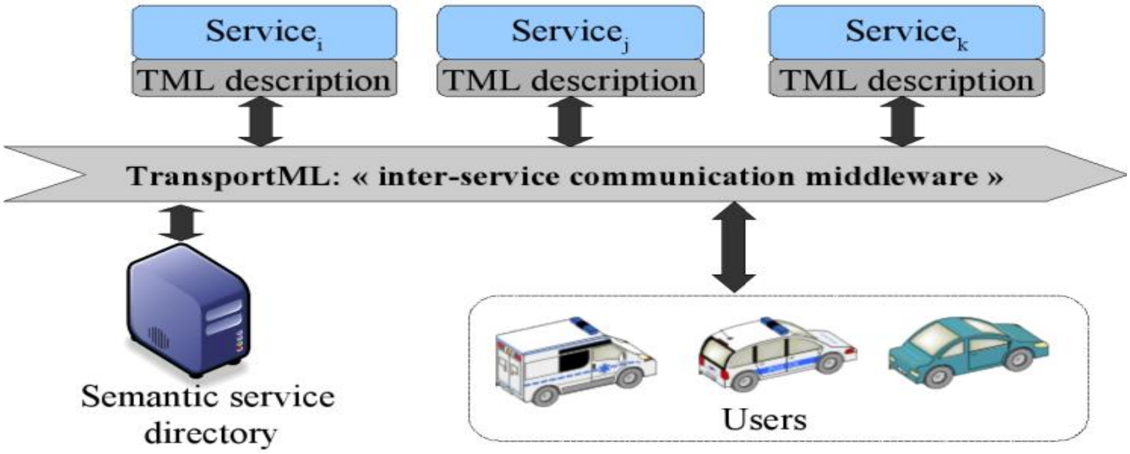


Figure 26: Integrated Road and Rescue Service Management

The TransportML platform was developed according to SOA principles. SOA meets the requirements for intelligent interactive services, namely the reusability and combination of functionalities packaged as distinct interoperable services.

6.1.4 Efficient Vehicle Weight, Freight and Overload Control

Heavy vehicle road safety strategy is important. Overloaded vehicles deteriorate road infrastructure to a high extend and create severe safety problems. It includes the main aspects: load and overloading, driving time, abnormal load protection, load and load fixation, allowed driving corridors and geofencing for dangerous goods and abnormal loads.

The 4 main objectives of controlling the overloads of vehicles are to:

- (a) Ensure safety for heavy goods transports and buses.
- (b) Ensure that roads do not suffer unnecessary distress due to gross vehicle weight, axle weight or combination of the two while serving their need for transportation.
- (c) Protect the public's safety and preserve the investment while serving the need for transportation.
- (d) Ensure that road pavement and bridge design are suitable to safeguard the interests of both the road user cost and investor cost.

Possible Actions and Measures:

- Integration of the new/existing weigh stations and remote monitoring.
- Introduction of axle overload control to protect road infrastructure.
- Introduction of semi automatic weighing systems with pre-selection scales.
- Preparation of fully automatic overload control systems and remote enforcement.
- Inclusion of main stakeholders and fleet operators in a safety campaign.

6.1.5 Professional Vehicle Safety Inspection and Higher Road Worthiness

Often the responsibilities for vehicle control licensing and safety is divided among several institutions.

All these functions could be streamlined into a one–stop centre to ensure coordination and observance of adequate driver and vehicle standards through the strengthening of vehicle and driver examination and licensing procedures.

6.1.6 Better Driver Training, Testing & Licensing

To enhance road safety, there is a need to ensure that vehicles operating on roads are in good mechanical condition and meet the requirement of body construction and roadworthiness.

The objective is to have appropriate and acceptable vehicle design, standards and specifications to cater for the needs of various groups and to deter the use of unsafe vehicles on public roads through the enforcement of proper vehicle standards and inspection procedures.

The triple objective is to

- produce safe drivers trained in defensive driving techniques and attitudes;
- streamline driver testing and licensing in order to have competent drivers on public roads;
- comply with regional protocols.

A “Driver and Vehicle Examination and Licensing Agency” in collaboration with the “Road Safety Agency” could initiate better driver education and testing for certification in view of exposing learner drivers to the principles of road safety.

These principles will include or consider

- defensive driving; licensed driving
- the roles of speed, alcohol and drugs in crashes;
- the value of using safety devices;
- road rage coping skills;
- night driving;
- the importance of route planning and time scheduling.

6.1.7 More efficient Transport of Passengers and Goods (Modal change)

The objective is to encourage safe transport of passengers and goods, use of a higher share of high occupancy vehicles instead of private cars for public transport, e.g. articulated bus transport, railway transport, and marine vessels, with the goal of reducing congestion and minimizing emotional responses of drivers.

Private transport of passengers and commercial transport of goods on roads are not safe enough today. There is a general lack of driving skills, awareness, spare parts, maintenance expertise, and competent professional workshops in developing countries.

Moreover, the demand for transport is less than the available supply, which results in inappropriate competition between customers for places and overloading. According to available statistics the commercial vehicle fleet is involved in 30 – 50% of heavy road accidents, and among these are the most serious accidents with several fatalities.

Recommended measures:

- Improved standards, regulations and awareness for public transport to ensure the safety of passengers and goods.
- Improve transport quality standards for commercial transport operators and ensure that the users, especially passengers, are made aware of such standards and know what to demand from the operators.
- establish sustainable standards and mechanisms for the management and follow-up of transport operators, training of professional drivers and enforcement of regulations.

6.1.8 More Parking Facilities

The objective is to alleviate the problems of inadequate parking space and thereby improve road capacity and road safety. Review parking policies to ensure that travel demand management principles are taken into account, especially in terms of limiting the growth of all-day parking.

Roadside parking that is compelled to walk on the carriageway, as most of the walkways are full of parked vehicles and petty traders, has reduced Road capacity. When the road capacity is exceeded, efficiency is reduced and the traffic flow becomes impeded.

The government will identify parking places, rest centers and an agent to remove defective vehicles in the road network.

6.2 Education & Information of Road Users

Education & Information

- Public Awareness, Road Safety Publicity, Driving Behaviour
- Road Safety for Children
- Land use planning, Crash Databaes, Monitoring &Research

6.2.1 Improving Public Awareness and improving Driving Behavior

Young road users have to be educated in road safety in order to develop the knowledge and attitudes that lead to responsible behavior on the road. This process includes parents, school-based programs and novice driver training. The behavior of experienced road users will be improved through an ongoing series of coordinated public information initiatives.

Local government has to provide local advocacy for road safety and be a catalyst for community involvement and participation in local road safety projects: "Speed, Alcohol, Driving time and Drugs are the key aspects". Reasonable speed limits and seat belt usage will be analyzed and introduced.

These campaigns, in conjunction with better training and licensing practices and automated enforcement will lead to better attitudes and knowledge among road users, including greater:

- Ability to perceive hazards
- Publicity of Enforcement Campaigns and Safety checks
- Awareness of safe and responsible practices including seat belt usage
- Penalties for serious cases and violations
- Sensitivity to all road user groups
- Knowledge of, and compliance with, road rules

6.2.2 Better Road Safety for Children

Not all road users enjoy the same level of safety. There are particular issues of concern for vulnerable road users such as:

- Youth
- Older people
- Inhabitants of rural and remote areas
- Some occupants in crashes between vehicles of different mass and features
- Pedestrians
- Cyclists and Motor cyclists

- People with disabilities
- Tourists, and those persons facing socio-economic disadvantage

6.2.3 Extended Road Safety Publicity

The objective is to improve road user behavior through increased awareness of traffic law, regulations, rules and crash risks.

A Road Safety Agency (RSA) could be created road safety knowledge and awareness amongst the population through education, training and publicity campaigns. RSA could conduct regular national and local publicity campaigns designed to promote safe behavior amongst target groups. RSA could organize, on a sustained basis, campaigns and orientation programs for all categories of road users and make them aware of their respective responsibilities and place special emphasis on safety of vulnerable groups like school children, the disabled and senior citizens. Private sector participation will be sought in conducting specific safety campaigns, e.g. “anti-drink & drive” campaigns.

6.2.4 Practical Crash Data System

Evidence from road safety outcomes must be collected and analyzed so that more effective road safety programs and policies can be developed. The objective is to develop and maintain an accurate and comprehensive crash data system with powerful analytical capabilities, and make it available to key stakeholders.

6.2.5 Improved Research and Monitoring

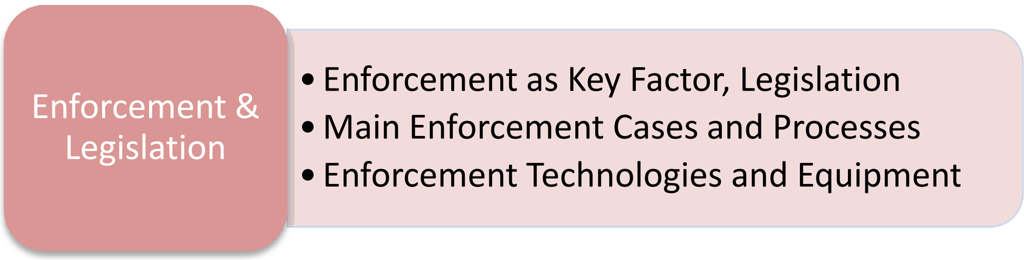
Since the easier gains in road safety tend to be made first, future gains may become increasingly hard, and require a more informed approach. Research will provide the foundation for a new generation of road safety measures and will ensure that the road safety effort is not misdirected into ineffectual strategies.

Well-focused research effort is required to support the target of the Road Safety Strategy. Through comprehensive, well resourced research a more thorough understanding will be available of

- The causes of road crashes.
- The consequences of road crashes.
- The effect of existing counter measures in reducing the number and severity of road crashes.
- The likely effect of potential counter measures in reducing the number and severity of road crashes.

A better understanding of these factors will assist in identifying and targeting high-risk and high-incidence groups.

6.3 Enforcement and Legislation



The road users generally show little respect for laws and regulations and the Traffic Police do not have the vehicles to pursue an offender. But effective police enforcement coordinated with information and education activities is crucial to change the behavior of the road users.

There is therefore an urgent need to strengthen Traffic Police enforcement on the roads and streets. Moreover, the strengthening must be supported by appropriate legislative improvements to ensure adequate sanctions to offenders.

The existing organization of the Traffic Police is a good base for effective enforcement activities. The manpower available for traffic surveillance is also on an acceptable level in most places. However, there is an obvious need of training and equipment. The Traffic Police must therefore be provided with sufficient and sustainable funding, equipment and skills to carry out its duties.

It is also important to ensure that enforcement is targeted at problems that can have a direct and quick impact on road safety.

6.3.1 Enforcement as "Key Factor" for Road Safety and Main Enforcement Cases

Enforcement is a key factor for monitoring and improving road safety and driving behavior. The list of different enforcement cases important for road safety was analyzed and clustered in priorities as follows (priorities are listed in the first section are the most serious violations):

6.3.2 Main Enforcement Systems

A list of different enforcement systems and necessary equipment has to be elaborated by the road safety agency to control the most important enforcement issues effectively and efficiently.

Most Serious Road Safety Violations

- **Speed control**
- **Driving time and rest time control**
- **Vehicle Overload control (axles and gross weight)**
- **Alcohol and Drugs**
- **Distance keeping**
- **Right Lane driving**
- **Red Light Violation**
- **Vehicle Safety Status**

6.4 Emergency Response

Emergancy & Rescue Services

- Integrated Service Management System
- Medical Response
- Rescue Services

6.4.1 Better Emergency Medical Response

While prevention will always be the ideal solution to the problem of road trauma, an effective trauma care system is essential to treat the injured. Trauma care in rural areas is particularly difficult and therefore needs to be addressed with priority. The urgency is a consequence of the following evidence

- Rural crashes involve higher speed and are therefore more severe.
- The time taken for emergency services to be notified and to reach the site is greater.
- The standard of initial care at the site is lower as rural ambulances are less well equipped to deal with severe trauma.

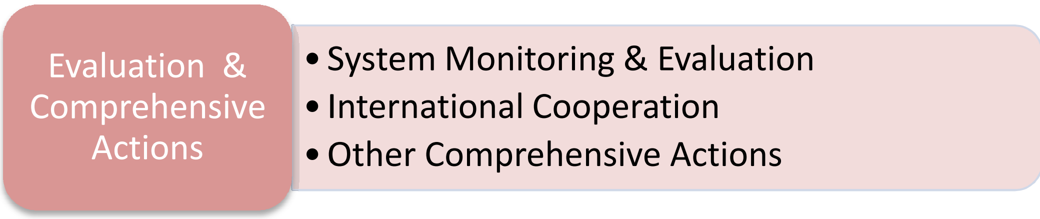
Rural hospitals are less well equipped to provide appropriate care to severe trauma cases.

6.4.2 Professional Rescue Services and fast Emergency Medical Response

The physiological consequences for victims of road crashes will be reduced through more rapid notification and provision of primary treatment, and through more effective retrieval, medical and rehabilitation services. The improvement of communications and transport systems will deliver medical attention to crash victims more rapidly. Measures proposed are to

- Provide better training of doctors and paramedics in early management of severe trauma.
- Improve training of general public in first aid.
- Conduct joint planning with emergency services and health agencies to improve planning of trauma management systems.
- Utilize new technology to enable earlier notification of serious crashes.
- Develop and implement systems to provide reliable and timely data on serious injuries that systematically links crash types with injury and treatment outcomes in order to underpin research and decision-making.

6.5 Evaluation & Other Actions



New technologies and systems will be applied to monitor, evaluate and report the success of the different safety and economy improvement measures.

- Cost Benefit Simulators
- System analysis tools
- Joining international programs, R&D Projects and cooperation
- Installation of a road pavement laboratory

A multidisciplinary expert team should be established (part of the RSA). Additional measures are:

- Higher usage and promotion of “In vehicle car safety systems” and ADAS “Advanced driver assistance system” technologies.
- The usage of “Low fuel consumption vehicles” will be promoted (for higher energy saving and higher transport economy).
- Promotion of “clean air and reduced pollution vehicles”.

7 Natural Mobility

(Picture source Google)

7.1 Swarm Theory Definition

Figure 27: Bird swarm

Nature evolved a brilliant mobility with high efficiency and effectiveness. An example is swarm and swarm behavior. A swarm is a homogenous set of entities that seems to move as one unit. In nature an entity can be an animal (a bird, a fish, a bison) but also human beings can move in a swarm-like manner. The movement of its neighbors influences each entities movement. The reaction on movements of neighboring entities is very fast; every entity tries not to collide with its neighbors (repulsion). Hence if a predator (e.g. a shark) tries to catch an entity (e.g. a fish) the movement at one side of the swarm propagates through the whole swarm and leads to the impression that the whole swarm reacts on the predator as if it was one organism. These movements of the swarm look very smooth and cause the fascination of watching a swarm in movement. The reason why the swarm stays together and does not spread apart is an attraction within the swarm. As predators usually catch entities at the boundary, the middle of the swarm is the safest position. Hence each entity tends to be in the middle of the swarm.

7.1.1 Swarm Intelligence

Swarm intelligence is a collective intelligence of groups of entities. Communicative and specific actions of individuals can create an intelligent behavior of a so-called “Superorganismn” in a social scenario. First formulations and basic ideas of collective intelligence can be found by Aristoteles: “Summierungstheorie”.

Recent investigations show, that swarm intelligence is based on behavior schemes of single entities and becomes active if more than 6 units are in a certain distance area.

7.1.2 Self Organization

The movement of the swarm is not directly coordinated by a central entity and there are no distinct leaders in the swarm. But a swarm nevertheless reacts in an intelligent manner, which is in literature referred to as swarm intelligence (SI). SI emerges from the interaction of the entities with each other. In a recent paper [] it is shown that some hungry bird in a swarm can make the whole swarm move into a different direction. This is due to the fact that most of the entities in the swarm are indifferent about the direction they are going, as their main goal is to stay within the swarm. This way a few entities can influence the direction of the whole swarm.

7.1.3 Emergence of Structures

The third important parameter is the alignment of the entities. It describes whether the direction each entity moves compared to the direction of the neighboring entities.

Figure 28: Self-organized structure of a migrant bird swarm

The parameters depend on the utility of each entity in the swarm and different parameters lead to different structures emerging in a swarm. A bird swarm, where the utility is to be safe has a completely different structure than a migrant bird swarm where the utility of each entity is to fly energy efficient. As the entities are homogenous and all have the same behavior, a self-organized structure emerges that is solving the problem. The interesting thing in this is that pretty primitive behavior of the entities leads to complex macroscopic structures of a swarm.

Often these structures have self-similar properties. But the emerging structure can have all properties which attractors in nonlinear dynamic systems can have, including chaos. In a swarm of mosquitoes for example, the entities don’t have an alignment, so the emergent structure is chaotic.

7.1.4 Perception

The reaction time an entity in a swarm has to avoid accidents is very low, especially if we consider for example a shark attack at a swarm of fish (fish school). Fish, as all amphibians, have so-called lateral line organs. This organ enables a fish to measure water pressure differences very fine. This way not only an attacking shark is detected pretty early by the fish but also small differences in the motion of the neighbors. This way, the fish can swim close together and still be reactive enough not to crash into each other.

7.2 Natural Mobility" versus "Vehicles Mobility" (case study)

It is believed that natural mobility (e.g. birds flying in the sky in the form of groups, the movement of bees, and ants' movement) follow some predetermined principles and is free from unusual conditions like accidents. Therefore, more bio-based principles are working their way into the automobile industry's new designs, as consumers increasingly desire "green" features in their vehicles. However, one biggest challenge is to find those natural mobility patterns, which closely resemble with the mobility of vehicles. While talking about vehicles movement on the roads, there are three major goals: traffic efficiency, safety, and comfort, influencing the design of vehicles mobility principles. To achieve these goals vehicles should be informed about up to the minute bulletins on the roads, which require a mechanism to propagate required information in a more natural way.

Biological principles have been exploited in a variety of computationally based learning systems such as artificial neural networks and genetic algorithms. Also, the emergence of complex collective behavior from the local interactions of simple agents is illustrated by many natural systems, like immune system and bee colony that exhibit capabilities of complex distributed problem solving. Ant colony receives similar attention like other biological-inspired approaches. They are a great source of inspiration in different areas e.g., route optimization, wireless network routing, scheduling problems, vehicles routing, etc.

With the growth and expansion of wireless communication technologies, considerable research efforts have done in the area of Inter-Vehicle Communications (IVC). Keeping in mind the above three major goals for vehicles mobility design, two types of applications can be distinguished, comfort applications and safety applications. The comfort applications can improve passengers comfort by updating them about route optimization and increase the traffic efficiency e.g., weather information, gas station or restaurant location information, etc. Whereas safety applications increase the safety of passengers by exchanging safety data via inter vehicle communication. For example, a vehicle detecting an icy road could inform other vehicles intending to use the same route.

By relying on the participation of vehicles' community and wireless communication, a high-quality Context-Aware Information System (CAIS) can be deployed. The smart vehicles equipped with advanced sensors (e.g., ABS - Automatic Braking System) and capable to be aware of specific abnormal conditions can share this information with other vehicles lacking this technology. For example, once the ABS within a vehicle is activated to indicate an icy road, strong rainfall or snow, the CAIS module will notify the driver. This information will be further sent to other surrounding vehicles in order to be informed and eventually take preventive actions before getting into same dangerous situation. Another important scenario concerns exchanging information between vehicles to prevent traffic jams from growing too fast. For example, a vehicle having an embedded traffic detection sensor can send the traffic state to its following vehicles that can take preventive actions to avoid the congested areas.

Numerous applications have been proposed that require Vehicle-to-Vehicle (V2V) and Vehicle to Roadside unit (V2R) communication in order to increase driver safety and comfort. Applications such as road condition monitoring, information on traffic jam/accident need safety data dissemination among concerned vehicles within critical geo-graphic area. Being inspired from ants direct and indirect communication to disseminate information about food source, we are proposing a self-organized approach to disseminate information about safety critical incidents on the roads.

7.3 From Ants to vehicles' communication

We see social ants' colonies as the inspiration to develop self-organized, emergent, and decentralized CAIS systems to propagate safety data among relevant vehicles. In this section, we will first provide a short description of the Ants colony principles. Then a mapping is made between Ants communication paradigm and the proposed dissemination strategy. To enable V2V and V2R communication, we introduce a CAIS module that would be the part of each vehicle or RSU. Finally, we propose an information dissemination strategy.

7.3.1 Ants' System (AS)

Ants are very simple insects but collectively they can perform complex tasks with good consistency. Examples of such complex problem solving behavior include: building nests, co-operating in carrying large prey, and finding the shortest routes from the nest to the food. In Ants' colony, two types of communication can be distinguished: ants' indirect and direct communication.

Ants use stigmergy to communicate indirectly. Two distinct types of stigmergy are observed within ants. One is called sematectonic stigmergy that represents a change in the physical environment characteristics e.g., nest building wherein an ant observes a structure developing and adds its ball of mud to the top of it. Another form of stigmergy is sign-based, which is used for indirect communication between ants through chemical messages known as pheromones. Ants foraging for food lay down some pheromone, which marks the path that they follow. An isolated ant moves at random but an ant encountering a previously laid trail will detect it and decide to follow it with a high probability and thereby reinforce it with a further quantity of pheromone. Since the pheromone will evaporate, the lesser-used paths will gradually vanish. Now if the shorter path is blocked or unavailable, then in this scenario the longer route may still be used and made the preferred route by repeated use. Hence, the pheromone concentration here gets stronger that leads to that path being used. This is how ants develop a solution when a path is blocked. This illustrates how swarm intelligent systems adapt with changes in the environment. Ants' direct communication has also been observed when two ants come closer to each other; they exchange some information (e.g., food source). This is just like we say 'hello' when we meet each other.

These key points then in turn can be summed up for an AS as very simple rules: lay pheromone, and follow trails of other ants. Now we will describe about the design of our AS inspired solution.

7.3.2 AS and the proposed solution

Within our problem area, we are treating each vehicle like an ant. When a vehicle perceives an abnormal environmental change on the road surface, it creates a safety message to inform other vehicles and roadside units along its way. This is similar to an ant behavior i.e., when an ant observers a food source; it creates pheromone to convey indirectly to other ants about route information of that food source. It is also interesting to note that in some ant species the amount of pheromone deposited is proportional to the quality of the food source found: path that lead to a better food sources receive a higher amount of pheromone. Similarly, in our ants inspired information dissemination method, the relevance or significance of the safety messages will depend upon the severity and type of the event took place on the road.

Another important characteristic of ant's pheromones is that these are evaporated with the passage of time. Taking the concept of pheromones decay from the AS, we defined the relevance of safety messages (similar to pheromone values), which evaporate by the function of time and distance, and finally are vanished from the system. Ants are also seen adaptable when they face obstacles in their current preferred route; they just select the next available path and will follow that path in the same fashion described previously. Similarly, vehicles can optimize their itineraries by receiving safety messages. In short, by following the swarm intelligence of AS, vehicles can build an intelligent cooperative vehicular network. Table 2 presents the mapping between ants' behavior and the proposed decentralized system for information dissemination.

Ants Behavior	*Proposed dissemination method*
Ants use pheromones to communicate indirectly.	Vehicles use messages to update roadside units (OBU to RSU communication).
Food sources	Event location (e.g., accident)
Ants' thrown pheromones evaporate with the passage of time and the distance to the food location.	The relevance of messages stored within RSUs and OBUs is automatically decreased based on the time and distance to the location of the emergency event. The message will be deleted when its relevance value reaches 0.
Ants communicate directly to exchange useful information.	Vehicles communicate directly (OBU to OBU communication) using DSRC/WAVE technology to exchange safety information about their routes.
Awareness to decide next actions: ants use alternate route when the current route is blocked	Drivers, by receiving information from CAIS module, take preventive actions.

Table 2: Mapping AS and proposed system

7.3.3 The structure of CAIS module

To enable V2V and V2R communication we are proposing a special device named as CAIS module, which is illustrated below. The detail of each CAIS module component is given by:

- *GPS receiver*: is available in modern cars and will be used to get position information.
- *Sensors*: different sensors will be used to monitor roadside conditions, vehicles' states, and drivers' behaviors. These sensors will be part of each vehicle and RSU taking part in dissemination process.
- *Knowledge base*: will be used to store messages received from other vehicles/RSUs. This knowledge base will also be used to store and transmit new safety messages.
- *Data Processing Unit*: will be used to analyze the data stored within knowledge base unit and will pick up useful data chunks for next transmission.

- *Generation of messages*: This module will generate complete messages along with timestamp, and spatial component.
- *Communication interface*: will be used to transmit and receive safety messages. We recommend DSRC/WAVE technology for this purpose that is specially designed for automotive use and supports mobility.

Hence, CAIS module will be the part of each vehicle and RSU involved in information dissemination process in this decentralized system. The following dissemination strategy will be used to spread information within the related geo-graphical area.

7.4 The Dissemination strategy

The dissemination protocol is composed of four phases: data generation, data dissemination, data reception, and data evaporation.

7.4.1 Data generation

When any vehicle or RSU1 observes an event/phenomenon p_j that needs to be reported to other vehicles in order to increase their safety information about that particular event, it will generate a safety message m_{p_j}. This message should include the timestamp (t), spatial information (X_{p_j}, Y_{p_j}) about the event to be informed, the description of the event (d_{p_j}), and the relevance of the message R_{p_j}

7.4.2 Data dissemination

Two modes are distinguished: dissemination through V2R communication and dissemination through V2V communication. In the first mode, when a vehicle passes through a RSU and one/both have some new message(s) to exchange, they will update each other's knowledge base by using communication medium. This is just like an Ant throws pheromones alongside its route. A vehicle throws new message to RSU such that other vehicles could get this information. Similarly, vehicles can also get information from RSU that has been provided by previous vehicles or RSU itself. In the second mode, when two vehicles (moving in opposite direction or same direction) approach within the communication range of air interface and one/both have some new message(s) to exchange, they will update each other's knowledge base by exchanging new messages. This is quite similar to direct communication between Ants.

[1] RSUs correspond to stationary vehicless

7.4.3 Data reception

When any message m_{p_j} is received from other node (i.e., vehicle or RSU), if receiving node doesn't have an entry of the message, it will simply store that message into its knowledge base. Otherwise, received message will be analyzed and compared with current available information. The old message will be replaced only if the new one is still relevant and more accurate. Suppose $m_{p_k}(t_2)$ is the new message received by vehicle v_i, that was generated for event p_k at time t_2, and its corresponding previously stored entry is $m_{p_k}(t_1)$, which was generated for the same event, p_k, but at time t_1, then $m_{p_k}(t_1)$ will be replaced by $m_{p_k}(t_2)$ if $R_{p_k}(t_1)$ is less than $R_{p_k}(t_2)$. This relevance value is described later in this section.

7.4.4 Data evaporation

Since the pheromone trials laid by ants evaporate with the passage of time. The lifetime of these pheromones also depends upon the number of ants that follow such trail and throws pheromones to further enhance the effect of pheromones. Taking the concept of pheromones decay from the ants system, we defined the relevance of safety messages similar to pheromone values, which evaporate and finally be vanished from the system. Furthermore, using relevance value, vehicles can anticipate about phenomenon further up the road.

Similar to pheromone evaporation in ant's colony, the relevance value of each message decreases as the distance increases from the current position of the vehicle to the phenomenon location. Let's consider $R_{p_i}(t)$ is the relevance of the received message m_{p_i} related to the phenomenon p_i received by a particular vehicle. The relevance value can be calculated at step $t+1$ as follows:

$$R_{p_i}(t+1) = R_{p_i}(t) - \Delta R_{p_i}(t) \qquad (1)$$

Where the value of $\Delta R_{p_i}(t)$ cab be calculated with the following logistic function as follows: $\Delta R_{p_i}(t) = 1/(1+\exp(-l\,d(t)))$, where l is an adjusting factor and its value is between 0 and 1. The value of $d(t)$ is a function of the vehicle distance to the phenomenon (in meters) and the transmission range T_r, which can be calculated as follows: $d(t) = d(t)/T_r$.

It is worth noting here that the importance of safety related information to a vehicle is increased when the distance is decreased between the vehicle and the place where safety data was generated, and vice versa. This is quite similar to the pheromones, as pheromones lifetime is also decreased as the distance between nest and food sources is increased. Finally, the message will be deleted from knowledge base when its relevance is reaches 0.

To evaluate the performance of proposed solution, we introduced another important metric known as driver awareness that measures the driver knowledge about road conditions and is derived from relevance value. The driver awareness value at step t: $A_{v_i}^{p_i}(t)$ about a phenomenon p_i can be calculated using the phenomenon relevance value at step t $R_{p_i}(t)$ and the relevance value at time t_0, i.e., the time of message generation i.e.,

$$A_{p_i}(t) = \frac{R_{p_i}(t)}{R_{p_i}(t_0)} \times 100 \quad (2)$$

The awareness value can help drivers to decide next actions such as decreasing/increasing speed, finding an efficient route, and avoiding traffic jam, etc.

7.5 Preliminary simulation results

Simulations have been conducted using Starlogo. Starlogo is a programmable modeling environment for exploring the workings of decentralized systems such as biological and natural phenomena. Starlogo provides the ability to program a system that is composed of thousands of Pathes and Turtles. Turtles are agents that run in the environment composed by Pathes. Both Turtles and Pathes can execute commands and procedures. Turtles and Pathes can interact with each other, for example a Turtle can move and execute some commands or procedures to change the states of the Pathes it pass by. Starlogo provides a very simple language to describe the behaviors of Turtle and Pathes. It also provides a run-time environment to run thousands of Turtles and Pathes in parallel. Turtles simulate represent active elements such as vehicles and RSUs and the environment represents passive elements such as the road.

To evaluate the dissemination strategy presented above, we enhanced the traffic simulator developed using Starlogo. In this simulator, the vehicles follow two very simple rules: If there is a car ahead, then slowdown. If there is no car ahead, then speed up. In this evaluation, we consider information dissemination in a highway scenario. The scenario simulated is a straight section of a road with 50 vehicles moving in both directions as depicted in Figure 29. The scenario would just consist of two lanes of vehicles entering the road section at the one end, and leaving it at the other. At both ends of the road section, vehicles initialized them to behave as new vehicles, i.e., vehicles arrived to end of the first lane are treated as a new vehicles and vice versa. In addition to speed-up and slow down rules when introducing an accident, nearby vehicles to the accident location slowdown and start dissemination/evaporation process as described above. When a vehicle receives a message it first calculates it awareness value, if this value is greater than 0.5 (50%), the vehicle slowdown, otherwise speed up.

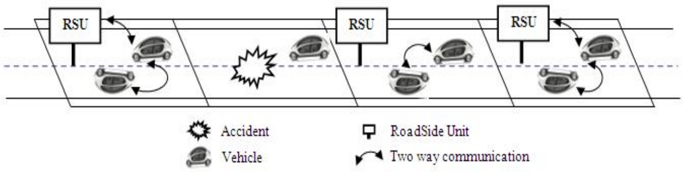


Figure 29: The simulated scenario

For a particular phenomenon, a given vehicle will receive messages from vehicles passing the location that have information about the location before getting to it. At each step, based on the awareness value, the driver can decrease or increase the speed. In the simulation, the speeds limit decreases 30% when the information relevance is below 0.5 and set to speed limit otherwise. Figure 3 illustrates the average awareness vs. average speed. As shown in this figure, the protocol achieves better information awareness of the accident introduced at time 50. As the information awareness increases (i.e. relevance increases) vehicles drivers become aware of the accident and therefore decrease the speed. Furthermore, as the information becomes not relevant, the drivers increase the speed to the speed limit. For example, at time 250, the accident effects are removed from the road and its information is cleared from vehicles knowledge and therefore the speed increases to be the speed limit.

As we can see in Figure 30, the average value of drivers' awareness decreases when the distance increases between the accident (phenomenon) location and the current position of his vehicle. The darker an area is, the more awareness about the phenomenon, and white areas indicate that no knowledge is available.

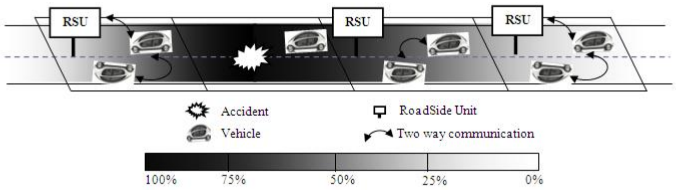


Figure 30: Awareness during information dissemination process

The main advantage of using this dissemination strategy is that the geographical area is not defined in advance. When a vehicle detects a danger (e.g. an accident) it will issue an emergency message.

The message will have a relevance value specified according to the corresponding safety application reliability requirement (by analogy to ants' this value corresponds to the quantity of the food). Vehicles stop disseminating a message when its relevance value reaches 0. To enable drivers to decide next actions more efficiently, the awareness value can be computed (equation 2) using the message relevance. This value is used by CAIS to help drivers make an appropriate decision that is best suited to a particular context.

7.6 Conclusions and future work

Natural mobility principles always inspired researchers to use them for computational purpose. Being inspired from ants colony system, we proposed a self-organized and decentralized information dissemination method exploiting signed based stigmergy and direct communication between ants. An architecture of the Context Aware Information System (CAIS) is presented to inform each vehicle with the necessary information about its surrounding and to assist drivers to be aware of undesirable road conditions. Simulations are conducted and preliminary results are reported to show the benefits of using Ants' principles for information dissemination in IVNs.

Simulations with NS2 to evaluate the robustness and performance of the proposed approach, such as the network load, latency, and the percentage of messages received is an ongoing work. Future work addresses the comparison of the proposed dissemination strategy with other work from the literature.

8 Sustainable Transport

8.1 Sustainable transport as a concept

Sustainable transport is an essential part of the sustainable development –concept or ideology. As a movement it aims to for efficient transit of goods and services, and sustainable freight and delivery systems. It also aims to make transport systems of urban and suburban areas greener and more fuel-efficient. Any mode of transport that has a low impact on environment can be considered sustainable, but currently and in the near future it usually means low-carbon fuelled vehicles, vehicles using any kind of renewable energy sources and various types of zero- and low-emission vehicles.

When sustainable transport is taken into account in transport planning, the main focus of improvements shifts from simply improving mobility of vehicles (which is important as well in reducing congestion) to improving the overall access. Access can be simply defined people's ability to reach desired goods, services, activities and destinations. It is affected by the effectiveness of the public transport system, amount of congestions near the locations or services that people try to reach, distribution of the desired destinations and many other things. It is also quite difficult to measure. It is, however, usually considered that a sustainable transportation system also provides good accessibility.

European Union Council of Ministers of Transport defines a sustainable transportation system as one that:

- Allows the basic access and development needs of individuals, companies and society to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations.
- Is affordable, operates fairly and efficiently, offers a choice of transport mode, and supports a competitive economy, as well as balanced regional development.
- Limits emissions and waste within the planet’s ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes, while minimizing the impact on the use of land and the generation of noise.

Some methods that are already used in realizing these definitions include road space rationing, congestion pricing and fully car-free city centers. Road space rationing is usually implemented by restricting vehicle access to city centers or urban cordon areas, for example by the last digits of license number. The method has been used in some large Latin American cities in since 1997. In Beijing, before the 2008 Olympics, half of the cars were banned from entering the city centre on alternate days. In some cities in Germany, variable limitations for car traffic in city centers are used. The limitations are adjusted based on the air quality in the city centre.

In London, a Congestion Charge system has been implemented. Since the Congestion Charge scheme started, it has produced at least the following results:

- Traffic entering the zone is 21 per cent lower than pre-charge levels (70,000 fewer cars a day).
- There has been a six per cent increase in bus passengers during charging hours.
- £137m has been raised, in the financial year 2007/08, to invest back into improving transport in London. (By law, all net revenue raised by the charge has to be invested in improving transport in London.)

8.2 Biomechanics in nature

Recent research is analyzing the movements of animals in relation to their body structure, speed and weight and trying to formulate a common theory of mobility processes and optimized movement patterns.

Figure 31: Wind hounds: low energy consumption for long-term performance

They created to formula: Speed, Frequency and Force depend on the mass of the animals. Bejan and Marden analyzed two kinds of moving:

- Soft ground moving and swimming.
- All others and flying.

Additional they defined a "constractual law" as basic principle in a constructual theory (Website Duke University). Projections and consideration of this principle for the car industry could be interesting.

8.3 Implementing Sustainable Transport methodologies (Finnish Test Site)

Implementing these methodologies in car traffic could be eased by methods available at the Finnish Test Site of ASSET-Road. The 3D camera system used at the test site (developed by KRIA) provides a few methods for traffic monitoring including vehicle type identification, vehicle counting and speed measurements. These can be used for modeling CO2 emissions and to provide information and statistical data on traffic density and congestion, average vehicle speeds, vehicle type distributions and similar metrics. In the Finnish Test Site, the camera system will be mounted to a Road Side Unit (RSU). The RSU used in the project provides also traffic enforcement services. It is portable and it can be almost freely placed on spots where the enforcement or monitoring is mostly needed.

Modeling of CO2 emissions in traffic flows can be used for statistical analysis on motorways, highways and on urban as well as suburban roads and streets. On the motorways, highways and suburban roads, the traffic statistics provided by the RSU can be used as grounds to perhaps limit speeds on roads that have high amounts of CO_2 emissions. The vehicle speed has an important role on fuel savings and with comparatively high velocities, also CO_2 emissions. The most economical speed for current vehicles is approximately 80 km/h. When driving at 110 km/h, the fuel consumption is up to 25% higher. Too short distances to the vehicle driving ahead increase not only the risk of collision but means also more braking and acceleration. Harsh acceleration and braking can use up to 30% more fuel.

Lowering of average vehicle speeds also improves general road safety in addition to lowering the emissions. One way to lower average speeds of vehicles on a single road without lowering the speed limit is a speed monitoring system based on average speeds. This kind of system has been proven effective in lowering the otherwise quite high average speeds closer to the speed limit on some British motorways. In the future the speeds could also be further reduced by ISA (Intelligent Speed Adaptation) systems.

In the urban and suburban areas, the data can be used to help in traffic planning and to find the most polluting or most congested areas that may be candidates for vehicle rationing or other measures. Urban speed limits may also be adjusted to lower emissions in certain areas.

While there already are numerous solutions for traffic monitoring available, a mobile RSU makes the monitoring solution flexible and the monitored spot can be changed on demand, on the fly. The Finnish test site is also the ASSET-Road response to the EU’s agreement to cut greenhouse gas emission by at least 20 % until 2020. The idea is to measure the actual CO_2 foot print of traffic in order to provide people measured data concerning influence of road traffic and make them think if they could change their driving habits to a more environment friendly direction.

9 Safety Performance Indicators

9.1 Performance and Effectiveness Indicators

Key factors for the often urgently required increase of safety and transport efficiency by administrations and in general are:

- Implementation and operation of a road safety institution addressed to the objectives for road safety, current existing organizations and experience.
- Improving driver knowledge and human behavior aspects.
- Increased use of modern technologies and automation for support and supervision.

- Introduction of innovative measures for safe and sustainable infrastructure.
- Application of modern traffic control and networking.
- Achieving effectiveness in the analysis and management of system complexity and very large data sets.

9.2 How to Measure Safety

Starting point for achieving necessary and impressive safety improvements (e.g. until 2015 by 25%!) are the major needs and objectives as guideline for the design of a future full size advanced traffic enforcement system. It must be stated, that normally a separate study would be necessary to elaborate the listed requirements and performance indicators in a more profound and systematic way.

9.2.1 General needs

The most important needs can be summarized, also in accordance with the 3rd action program of the EU White Paper as follows:

- Drastic reduction of casualties and severe accidents.
- Achievement of more fair and legal driving behavior with safety consciousness.
- Environment protection.
- Preservation and protection of the roads infrastructure.
- Efficient and unified control measures and methods with enforcement.

9.2.2 Traffic and Safety Requirements

A main element of achieving safety on roads is to define and operate clear and measurable objectives and deducted requirements (some examples given below), covering the key issues of improving road traffic safety and enabling the improvement process and success:

- Drastic reduction of accidents (serious accidents).
- Reduction of accident consequences.
- Full spectrum or maximum coverage of the scope of detectable types of violations.
- Priority and levels for violation treatment according to settings and vehicle classes (car, bus, trucks, hazardous goods).
- Efficiency of enforcement operations with high impacts on safety.
- Maximum violation detection rate per single enforcement site.
- Maximum violation detection rate for network and hot cells.
- Strategically optimized spatial distribution of detection and control areas.

- Repetitive violators detection on network base.
- Successful execution rate of violator's enforcement (detection, recognition, identification, transmission and recording, process, notify).
- Integration of permanent and temporary measures.
- Integration of mobile and fixed site enforcement.
- Sectional and in-depth driving behavior surveillance and enforcement.
- Higher traffic safety for HGV heavy goods vehicles (demarcation the max. kinetic truck energy, tire protection from overload, braking ability and reactions, less grooves in the pavement).
- Measured reduction of severe accidents.
- Measured reduction of other accidents.

10 Integrated Architecture for Safety

10.1 Introduction

Information architecture describes systematically how its applications and services interact and share information, covering technical but also some organizational, legal and business issues.

This ensures that the system meets its needs and objectives from the viewpoint of all involved bodies. It usually ensures open market for services and equipment, consistency of information and reduces technology dependency.

An important benefit of a well designed architecture usually comes up after the first implementations, when the computer system/database/etc needs to be extended or changed: Without well designed overall architecture it may turn out to be a surprisingly huge effort.

Road traffic is one complex area where various non-compatible information systems can be implemented over the years. Making larger and more effective systems by combining regional or national legacy systems may be tedious.

European Commission has focused efforts to reduce and avoid these kinds of problems by recommending well-considered model architectures.

This document shows how the ASSET-Road architecture follows the European ITS Framework Architecture that is currently maintained by the EC Funded Project E-FRAME (2008-11), which will extend the Framework Architecture for Cooperative Systems [1]. The European ITS Framework

Architecture is based on the work done in KAREN (Keystone Architecture Required For European Networks) EU-project (01.04.1998 - 30.09.2000) [KAREN 2011].

This document does not handle the additional national or regional ITS issues.

10.2 High level architecture guidelines

Framework architectures like the European ITS Framework Architecture above defines and describes what needs to be included in a system – in this case ASSET-Road System – that can fulfil the requirements of a set of User Needs. The system is expressed in the Framework Architecture in the following parts:

- Functional Architecture describes the needed functionality to fulfill the User Needs.
- Physical Architecture is the way in which the functionality can be implemented as applications to fulfill the User Needs. These applications may also fulfill the User Needs in ways that cannot be expressed in functional terms, such as physical characteristics.
- Communication Architecture describes the links that enable data to be exchanged between the applications in the physical architecture, and between the applications and the surrounding world.

10.3 Architecture scenarios

ASSET-Road project promotes an integrated Holistic Traffic Safety approach, which includes the four basic domains:

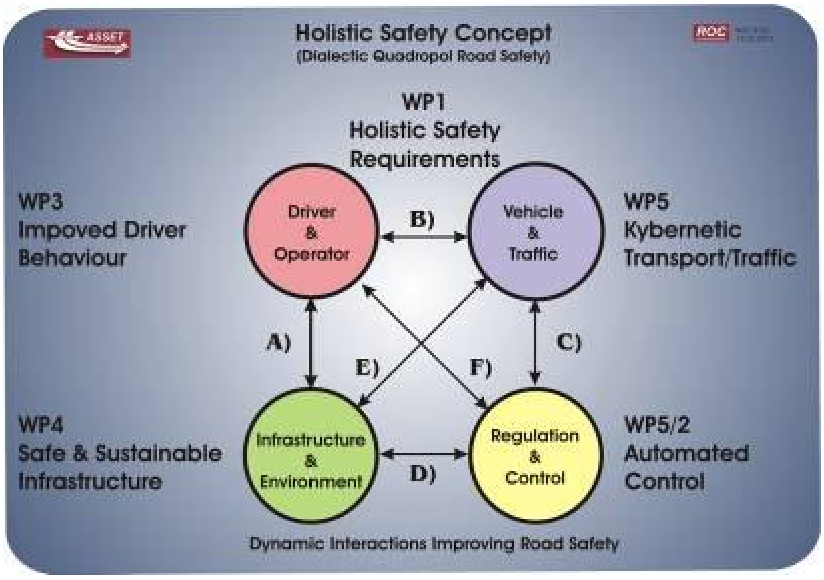


Figure 32: Socio Economic Impacts Analysis

The project vision of ASSET-Road is to:

> "… substantially contribute to safe and sustainable transport by linking road traffic and safety information from all essential system elements."

The objectives of the project relates to an integrated safe and secure road transport system, which has been synthesized by the following main aspects:

- The road and traffic system will be effectively monitored by the exchange and fusion of data from different sources; to ensure that high safety standards are fulfilled.
- The road infrastructure will be regularly verified and maintained according to safe and sustainable methods; this will reduce the number of accidents and disruptions of traffic.
- Advanced techniques for vehicle tracking and identification will support the recognition of dangerous or unstable driving.
- New recommendations and enforcement methods for overloaded and unsafe vehicles will be applied to promote proactive observation of traffic rules.
- The ASSET-Road system will support drivers by enhancing their awareness of traffic situations, and the existing traffic regulations across different countries.
- Intelligent roads and intelligent vehicles will communicate and contribute to improved solutions for transport/traffic monitoring and control.
- The transport system will reduce impacts on the environment through enhanced safety and optimized traffic flows.

The reference of these seven aspects in terms of the four domains of the holistic approach is represented in the following:

Main aspects of the ASSET objectives	Domains of holistic approach			
	Driver and operator	Vehicle and traffic	Infra-structure/ environ-ment	Regu-lation and control
A. Road and traffic monitoring (data fusion)		**P**	**P**	
B. Sustainable road infrastructure			**P**	
C. Vehicle tracking and tracing		**P**		**P**
D. Recommendations and enforcement methods		**P**		**P**
E. Context awareness and early warnings for drivers	**P**	**P**	**P**	**P**
F. Intelligent vehicles / intelligent roads	**P**	**P**	**P**	**P**
G. Reduced environmental impacts		**P**	**P**	

Table 3: The ASSET technology contribution to the application domains

Table 3 is used as a base for detecting the necessary components from the European ITS Framework Architecture (FRAME) to be included in the ASSET-Road architecture, which is a sub-set of the FRAME. Table describes the functional areas supported by the ASSET-Road system.

FRAME functional areas	Supported by ASSET-Road
Provide Electronic Payment Facilities	
Provide Safety and Emergency Facilities	Minor support
Manage Traffic	P
Manage Public Transport Operations	Minor support
Provide Advanced Driver Assistance Systems	
Provide Traveler Journey Assistance	
Provide Support for Law Enforcement	P
Manage Freight and Fleet Operations	Minor support

Table 4: The European ITS functional areas supported by the ASSET-Road system

With this scheme in mind, a number of research topics have been judged more significant for the ASSET-Road objectives, and therefore chosen for a specific focus. The following tools in order to meet the ASSET-Road vision has been considered in particular:

First, a number of **key technologies** are required to implement the ASSET-Road vision, such as:

- Vehicle identification
- Vehicle tracking and control
- Road condition monitoring
- Vehicle brake and tire monitoring
- Weigh in motion measurement
- Vehicle-to-Infrastructure (V2I) communication
- Data channel encryption
- Data security
- Geo-corridors
- Agent based driving behavior analysis
- Sensor data fusion

Then, a fundamental role is played by systems, which can support drivers and operators. These systems are generally covered by initiatives addressing the following areas:

- Driver behavior
- Knowledge representation technologies
- Roadside traffic enforcement
- In-Vehicle Human Machine Interface
- Holistic Road safety

Finally, the underling theories and methods commonly applied must be considered, in term of basic issues such as:

- Integrated safety theories
- Road safety methodologies
- Sustainable infrastructure
- Interaction and control of road transport
- Practices of road authorities

For these three groups of research topics, the following table lists a number of relevant projects, together with the areas of main relevance. Further considerations of the status and perspectives of research are given in chapters 1.3 to 1.5.

The ASSET-Road architecture can be seen as part of European ITS Framework Architecture.

Table describes how the ASSET-Road system addresses the documented user needs of the European ITS Framework Architecture [FRAME tool 2011].Table describes how the ASSET-Road system could also assist other user needs of European ITS Framework Architecture, especially if minor software updates are carried out.

Related sets of User Needs within Fundamental Services within KAREN Groups	Reference Number	Description of the User Need	Addressed by ASSET	Comments
3 Law Enforcement		*This group contains the activities associated with the enforcement of traffic laws and regulations, and the collection of evidence.*		
3.1 Policing/Enforcing Traffic Regulations				
3.1.0 Objectives	3.1.0.1	The system shall enforce the traffic laws and regulations of the region automatically (where possible).	y	
	3.1.0.2	The system shall be able to collect the evidence of a violation of the traffic laws and regulations in a manner suitable to justify the application of a legal punishment	y	
	3.1.0.3	The system shall be able to provide support for the enforcement of safe driver behaviour and the provision of vehicle priorities.	y	
	3.1.0.4	The system shall not obstruct or slow down traffic in any way, except when it is part of access control.	y	
	3.1.0.5	The system shall be able to communicate with Police Command and Control Systems.	y	
3.1.1 Evidence Collection	3.1.1.2	The system shall be able to collect evidence on vehicles that exceed a local (variable) speed limit.	y	
	3.1.1.3	The system shall be able to measure the characteristics (e.g. length, weight etc.) of a vehicle automatically, whilst the vehicle is in motion ("Weigh in Motion").	y	
5 Emergency Services		*This group contains 'May Day' and stolen vehicle management (for any vehicle), the prioritising of emergency vehicles, and hazardous goods (i.e. goods that need to be tracked)incident management.*		
5.1 Emergency Notification and Personal Security				
5.1.1 Stolen Vehicles	5.1.1.2	The system shall be able to detect a vehicle when it has been stolen.	y	Assuming the original number plate is untampered
	5.1.1.4	The system shall be able to provide the location of a vehicle when it has been stolen and/or to indicate when it passes a certain point.	y	Assuming the original number plate is untampered. Only the location of passing by vehicle is possible
7 Traffic, Incidents and Demand Management		*The activities associated with traffic control, incident management and demand management, including monitoring, planning, flow control, exceptions management, speed management, lane and parking management, HOV, road pricing and zoning, and VRUs*		
7.1 Traffic Control	7.1.0.2	The system shall be able to implement identified control strategies that conform with specified policy.	y	
7.1.0 Objectives	7.1.0.3	The system shall not do anything to reduce road safety.	y	
	7.1.0.4	The system shall manage road traffic in such a way that levels of environmental (i.e. atmospheric and noise) pollution may be reduced.	y	Provides info; mgmt not included
	7.1.0.10	The system shall be able to control urban roads and traffic.	y	Provides info; control not included
	7.1.0.11	The system shall be able to control inter-urban roads and traffic.	y	Provides info; control not included
7.1.1 Monitoring	7.1.1.1	The system shall be able to monitor sections of the road network to provide the current traffic conditions (e.g. flows, occupancies, speed and travel times etc.) as real time data.	y	
	7.1.1.2	The system shall monitor urban roads and traffic.	y	If installed permanently
	7.1.1.3	The system shall monitor inter-urban roads and traffic.	y	If installed permanently
	7.1.1.6	The system shall be able to monitor and record weather conditions, e.g. wind, fog, rain level, ice, etc.	y	Road surface conditions at locations where it has been situated
	7.1.1.7	The system shall be able to monitor and record environmental (atmospheric and noise) pollution conditions, and provide an alarm when a certain threshold is exceeded.	y	Based on vehicle flow and vehicle type distribution
7.1.8 Roadside-Vehicle Communications	7.1.8.1	The system shall be able to transmit information to a vehicle to update its on-board database.	y	E.g. 802.11p
7.2 Incident Management	7.2.0.2	The system shall not do anything to reduce road safety.	y	
7.2.0 Objectives	7.2.0.3	The system shall not do anything that might aggravate, or cause, an incident.	y	
7.2.5 Pre-Incident Management	7.2.5.1	The system shall be able to detect "non-vehicle" incidents before they can escalate into traffic accidents, e.g. bad weather conditions, objects on the road, ghost drivers, etc.	y	Road surface conditions and speeding detected
	7.2.5.2	The system shall be able to provide local warnings on dangerous sections of the road network.	y	Road surface conditions detected
7.3 Demand Management				
7.3.1 Zoning	7.3.1.3	The system shall be able to control the access of vehicles into a zone using a form of identification, e.g. electronic tags, number plate readers, etc.	y	Can identify number plates
8.2.4 Short Range Communications	8.2.4.1	The system shall be able to communicate with other equipped vehicles, and/or the infrastructure, to exchange data for automatic vehicle control.	y	The system is equipped with 802.11p

Table 5: The user needs listed of FRAME addressed by the ASSET-Road system

Related sets of User Needs within Fundamental Services within KAREN Groups	Reference Number	Description of the User Need	Assisted by ASSET	Comments
3 Law Enforcement		*This group contains the activities associated with the enforcement of traffic laws and regulations, and the collection of evidence.*		
3.1.1 Evidence Collection	3.1.1.1	The system shall be able to collect evidence on vehicles that commit traffic signal violations.	y	Interface to traffic sign system and violation recognition SW currently missing from ASSET
7 Traffic, Incidents and Demand Management		*The activities associated with traffic control, incident management and demand management, including monitoring, planning, flow control, exceptions management, speed management, lane and parking management, HOV, road pricing and zoning, and VRUs*		
7.1 Traffic Control	7.1.0.5	The system shall manage road traffic in such a way that congestion (travel time) may be reduced.	y	Provides info; mgmt not included
7.1.3 Traffic Control Centres	7.1.3.1	The system shall enable a TCC operator to control, possibly remotely, infrastructure elements (e.g. traffic lights, VMS).	y	Information of traffic flow, violations etc from the monitoring location can also be provided to other data bases than the current ones
7.1.4 Traffic Flow Control	7.1.4.1	The system shall be able to control the entries and exits to motorways.	y	The system can provide pointwise information for these purposes also from motorway entries and exits
	7.1.4.6	The system shall be able to provide control measures for bridges so that warnings of weather conditions, vehicle restrictions and closure can be provided.	y	The system can provide pointwise information for these purposes
	7.1.4.7	The system shall be able to provide control measures for "tunnel" environments i.e. vehicle restrictions, fire detection, atmospheric pollution and closure.	y	The system can provide pointwise information for these purposes
	7.1.4.8	The system shall be able to provide co-ordinated traffic management operations during periods of mass movement across (many) regions.	y	The system can provide pointwise information for these purposes
	7.1.4.9	The system shall be able to provide specific traffic management for exceptional vehicles (e.g. very dangerous cargo, wide loads, etc.) when requested.	y	The system can provide pointwise information for these purposes
7.1.5 Exceptions Management	7.1.5.1	The system shall be able to provide control measures to protect road maintenance work and workers.	y	The system can provide pointwise information for these purposes
	7.1.5.6	The system shall be able to command certain classes of vehicle (e.g. heavy vehicles or tourist traffic) to take an alternative route for a period of time.	y	The system can provide pointwise information for these purposes
7.1.7 Speed Management	7.1.7.2	The system shall be able to set variable speed limits on parts of the road network.	y	The system can provide pointwise information for these purposes
	7.1.7.3	The system shall be able to calculate recommended speed limits for given traffic and weather conditions, and road network characteristics.	y	The system can provide pointwise information for these purposes
7.1.9 Adaptive Traffic Control	7.1.9.2	The system shall be able to minimise delays of all vehicles using adaptive signal control	y	The system can provide pointwise information for these purposes
7.2.1 Emergency Services	7.2.1.1	The system shall be able to locate and identify emergency vehicles on the road network.	y	Needs a system update (SW) before the system can provide pointwise information for these purposes
7.3 Demand Management	7.3.0.2	The system shall receive up-to-date information on those factors that will influence the demand management strategy, e.g. traffic levels, car park usage, other modes usage, fares, tolls, etc.	y	Can provide pointwise traffic flow data
7.3.1 Zoning	7.3.1.1	The system shall be able to create a "traffic collar" and limit the entry of all vehicles into a defined area according to (a set of) criteria.	y	Can provide information on vehicle height and length
7.3.2 Pricing Management	7.3.2.1	The system shall be able charge for the use of a section of road, or facility (e.g. bridge, tunnel etc.), based on given policy decisions, e.g. duration, distance, congestion etc.	y	Can provide information on number plate, and vehicle height and length
	7.3.2.2	The system shall be able to adjust toll fees according to a given pricing strategy.	y	Can provide information on number plate, and vehicle height and length
8.2.4 Short Range Communications	8.2.4.1	The system shall be able to communicate with other equipped vehicles, and/or the infrastructure, to exchange data for automatic vehicle control.	y	The system is equipped with 802.11p
10 Public Transport Management		*This group contains the activities associated with public transport (PT), demand responsive PT, Shared PT, on-trip PT Information and Traveller Security. It includes management, scheduling, monitoring, information handling, communications and PT priority.*		
10.1.2 Monitoring	10.1.2.1	The system shall be able to receive information about the identity, location, status and occupancy all vehicles in the fleet in real time.	y	Can provide pointwise information based on vehicle number plates.
10.2.1 Information Handling	10.2.1.6	The system shall be able to locate and identify the Demand Responsive PT vehicles.	y	Can provide pointwise information based on vehicle number plates.

Table 6: The user needs listed of FRAME assisted by the ASSET-Road system

As noted in the above, the relevant areas of the European ITS Framework from ASSET-Road viewpoint are

- Provide Safety and Emergency Facilities (only minor support by ASSET-Road)
- Manage Traffic
- Manage Public Transport Operations (only minor support by ASSET-Road)
- Provide Support for Law Enforcement
- Manage Freight and Fleet Operations (only minor support by ASSET-Road)

These are studied further from functional, physical, and communication architecture viewpoint, see below.

10.4 The FRAME Architecture recommendations

10.4.1 Provide Safety and Emergency Facilities

(Only minor support by ASSET-Road)

The ASSET-Road system can provide information if a vehicle - which has been notified as stolen, and whose license plate is untampered – passes the ASSET-Road monitoring location.

FRAME function [FRAME Tool 2011]	**Output data flows generated**
2.2 Manage stolen vehicle notification	tes-stolen_vehicle_information

10.4.2 Manage Traffic

The ASSET-Road system can provide various information about traffic speed, density and distances between vehicles etc. It can also collect data about the amount of exhaust gases being released and weather conditions, especially if the road is getting icy.

FRAME function [FRAME tool 2011]	**Output data flows generated**
3.1 Provide Traffic Control	mt_collected_urban_traffic_data mt_urban_current_traffic_data_for_demand mt_urban_traffic_data_for_incident_detection mt_collected_inter-urban_traffic_data mt_inter-urban_current_traffic_data_for_demand

	mt_inter-urban_traffic_data_for_incident_detection mt_bridge_urban_inputs mt_bridge_inter-urban_inputs
3.4 Provide Environmental Information	mt_weather_condition_data_inputs mt_atmospheric_pollution_data_inputs
3.5 Manage Road Maintenance	mt_icing_incident_data

10.4.3 Manage Public Transport Operations

(Only minor support by ASSET-Road)

Since the ASSET-Road system can recognize license plates, it could be used to collect information, when a certain public transport vehicle has passed the monitoring site. Extra confidence can be achieved by utilizing the vehicle classification provided also by ASSET-Road.

FRAME function [FRAME tool 2011]	**Output data flows generated**
4.1 Monitor PT fleet	trrs-real_time_info

10.4.4 Provide Support for Law Enforcement

The ASSET-Road system implements relevant instances of the following key functions (the function number refers to the numbering used in FRAME database) for protecting the databases and corresponding data flows:

FRAME function [FRAME tool 2011]	**Output data flows generated**
7.1 Detect Fraud	psle.padas_vehicle_ID_request psle_fraud_type_CC psle_user_image psle_violator_ID td-psle_record_request
7.2 Identify Violator	psle_fraud_type_AI psle_fraud_type_DV

	psle_user_data_request psle_vehicle_ID_CC psle_violator_ID_DV
Process Fraud Notifications; especially 7.3.1 Sort Fraud Notifications	psle.mt_inter-urban_violator_ID psle.mt_urban_violator_ID psle_fraud_notification_AI psle_violation_notification_SF

10.4.5 Manage Freight and Fleet Operations

(Only minor support by ASSET-Road)

The ASSET-Road system can provide information if a vehicle - which has been notified as stolen, and whose license plate is untampered – passes the ASSET-Road monitoring location. Extra confidence can be achieved by utilizing the vehicle classification provided also by ASSET-Road.

FRAME function [FRAME tool 2011]	**Output data flows generated**
8.2 Manage Commercial Fleet	mffo.psle_fraud_notification

10.4.6 Physical Architecture (Sub-system level components)

In the FRAME description the above Functional Architecture of ASSET-Road is complemented with its Physical Architecture description below.

Environment Monitoring Agency monitors the environmental impact of traffic, usually the amount of exhaust gases produced along a certain road segment.

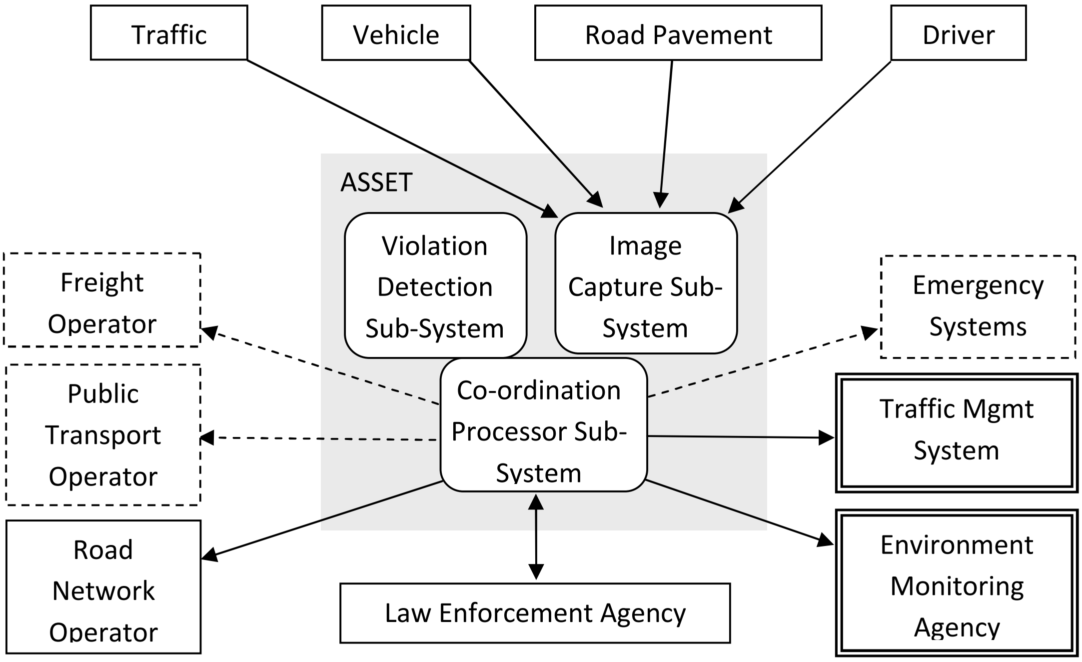


Figure 33: **Context Diagram of the ASSET-Road system [KAREN D3.2 1999]. Minor support is shown with dash lines. Terminators new to FRAME have double line.**

Traffic Management System is usually presented in FRAME Architecture as a System, not a terminator. However, from the ASSET-Road viewpoint the Traffic Management System is very similar to a terminator, and described as one. This approach also avoids describing all the non-relevant terminators of TMS.

Sub-System		**Function**		
Name	Location	No.	Name	User Needs
Violation Detection	Roadside	7.1	Detect Fraud	3.1.0.1; 3.1.0.2; 3.1.0.3; 3.1.0.4; 3.1.1.2; 3.1.1.3
Image Capture	Roadside	7.2	Identify Violator	3.1.0.1; 3.1.0.2; 3.1.0.3; 3.1.0.4; 3.1.1.2; 3.1.1.3
Co-ordination Processor	Roadside communication units, back office servers	7.3	Process Fraud Notifications; especially Sort Fraud Notifications	3.1.0.1; 3.1.0.2; 3.1.0.3; 3.1.0.4; 3.1.0.5; 3.1.1.2; 3.1.1.3
		2.2	*Manage stolen vehicle notification*	*5.1.1.2; 5.1.1.4*
		3.1	Provide Traffic Control	7.1.0.2; 7.1.0.3; 7.1.0.4; 7.1.0.10; 7.1.0.11; 7.1.1.1; 7.1.1.2; 7.1.1.3;

				7.1.8.1; 7.2.0.2; 7.2.0.3; 7.2.5.1; 7.2.5.2; 7.3.1.3
		3.4	Provide Environmental Information	7.1.1.6; 7.1.1.7; 7.1.8.1; 7.2.0.2; 7.2.0.3; 7.2.5.1; 7.2.5.2
		3.5	Manage Road Maintenance	7.1.0.2; 7.1.0.4; 7.1.1.1; 7.1.1.2; 7.1.1.3; 7.1.1.6; 7.1.1.7; 7.1.8.1; 7.2.5.1; 7.2.5.2
		4.1	*Monitor PT fleet*	*10.1.2.1; 10.2.1.6*
		8.2	*Manage Commercial Fleet*	*5.1.1.2; 5.1.1.4*

Table 7: Sub-Systems and Functions of the ASSET-Road system [KAREN D3.2 1999]

10.5 Communication Architecture

10.5.1 Communication

The project utilizes three different types of communication methods due to specific requirement in each test site:

- The German test site uses a FOC backbone for combining the different elements of the test site: High speed WIM (P1), Sorting Point (P2) and Control Center (P3). This enables high data rates due to many video signals and data security for transmission of the information on roadside.
- The Finnish test site uses mobile IP communication to exchange data between the mobile platform and data pool. TCP protocol is used for its reliability while transferring the data. The wireless broadband is based on Flash-OFDM (Fast Low-latency Access with Seamless Handoff Orthogonal Frequency Division Multiplexing) technology and it is available all over Finland. The connection downlink speed is 2 MBit/s and uplink speed is 512 kBit/s. 3G networks are used for backup connection. Wireless Flash-OFDM communication network covers over 99,9% of Finland.
- In addition, the Finnish test site utilizes 3G cellular networks in the areas where the Flash-OFDM service is not reliable. This makes also the communication protocol feasible when considering using the concept abroad. The selection whether the Flash-OFDM or 3G networks are used is done manually.

- In the trailer, the computers share the data with using the Ethernet protocol. The three PCs are connected between each other via the Ethernet hub, which allows the measures to be synchronized. In the Finnish test site case the standard cabling is sufficient whereas in the German test site amount of image data is huge and therefore, fiber optical cables are needed.
- The centralized database for recording the measures of the trailer is located in computer centre. Therefore, the Internet connection to the data pool has been established. This enables chance to for all user groups (police, road authorities and environment authorities) to access to the data remotely with having suitable authentication method to prevent illegal use of data.

10.5.2 Data security

The crucial issue is that all the data is well protected to maintain the credibility of the system. The Finnish test site database includes data, which is restricted only for police use and hence, road or environment authorities are not allowed to use that data see Table:

Subsystem	Data	Purpose
Mechanical and electronic platform	none	-
3D camera system	• Pictures of the vehicles • Time stamp • Licence plate number • Vehicle dimensions: Height / length / width • Vehicle category • Vehicle speed • Distance to previous vehicle	The 3D camera data is used for traffic violation detection and traffic logging
Road state monitoring system	• Road state	Monitoring the road state and detecting possible low-friction conditions
Seat belt compliance	• A Boolean value of seat belt compliance estimation result	Monitoring seat belt usage violations
Data gathering, fusion system and data pool access	• All the data collected by the 3D camera and the road state monitoring system • GPS location data	Gathering, fusioning and packaging the data and sending it to the database
Servers for service applications	• All the data available in the database	Providing a service / services for presenting the data to the end users

Subsystem	Data	Purpose
Terminals for the end users	• Pictures of the vehicles • Time stamp • License plate number • Vehicle dimensions: Height / length / width • Vehicle category • Vehicle speed • Distance to previous vehicle • RSU location • Speed limit at the location	Presenting the data to the end user.

Table 8: Data of the subsystems

In order to meet data protection requirements, all data acquired are transmitted via SSH encrypted wireless link. The operation concept for RSU in the piloting phase requires that RSU is manned and monitored constantly. This gives reasonable protection for both the physical parts of the RSU and the data in the unit.

The data flows in the system consist of flows between three different actors: data from the RSU to the database and data from the database to the terminals for the end users. The data is available only at the RSU, the database and at the terminals. The data is not stored in the RSU, as it is immediately transmitted to the database after acquisition via an SSH encrypted connection.

The database access is restricted by PostgreSQL user authentication mechanism. The database has different roles for different kinds of users, i.e. read-only accounts for the terminals and a write-only account for the RSU data acquisition. The database accepts connections only from a pre-defined range of IP addresses and all other connections must be made via an SSH tunnel from these addresses.

Accessing the database from the Internet requires the username and password for the database server and for the database. Neither one of these can be breached using brute force through the use of modern encryption methods as well as strong passwords. The most likely way of obtaining these usernames and passwords is through social engineering. Thus, it is of crucial importance not to disclose any passwords or usernames to unauthorized personnel.

Accessing the database from user device requires the physical device, which in turn requires stealing of the device or looking at it at the same time as an officer. While stealing from an officer is risky, it can be done. It is easier just to look at it at the same time. However, this limits the access to the data quite dramatically.

Data modification on the database remotely requires the username and password for the database server and for the database. Neither one of these can be breached using brute force through the use of modern encryption methods as well as strong passwords. The most likely way of obtaining these usernames and passwords is through social engineering. Hence, it is important not to disclose any passwords or usernames to unauthorized personnel.

11 Architectures of the test sites

11.1 German test site

11.1.1 System architecture specification

The integrated ASSET system and subsystems consist of 3 primary categories and elements:

Sensor systems

- High-speed weigh-in-motion system on the first lane of the highway for pre-selecting overloaded trucks.
- Low speed weigh-in-motion system on the parking lot for enforcing overloaded trucks detected by the high-speed weigh-in-motion system.
- New prototypes of beyond state-of-the-art weigh-in-motion sensors who are able to detect not only the axle weights, but also the speed, type of tires (single, double, super-tire), track width, footprint of each tire, air pressure in tires, unbalanced load or improper working twin-tires.
- Tire profile measurement for detecting tires with too less profile (< 1.6mm)
- Vehicle type detectors to distinguish between different types of trucks to enable vehicle specific observation and enforcement.
- Vehicle type dependent speed surveillance of vehicles to detect suspicious reason of tachograph manipulations on trucks.
- RFID-reader enabling the electronic license plate reading for better identification of vehicles.

Cameras

- Thermal cameras for detecting overheated or not-working brakes, problems with tires and the power train.
- 3D Cameras for identifying all vehicles entering the test-site and for measuring the dimensions and speed of each vehicle.
- 2D Cameras for tracking and tracing all vehicles passing along the 3km test site on the highway.
- Video camera for sending live video-streams of the current traffic situation on the test site and for taking pictures of trucks with suspicion reason of being overloaded or driving too fast.

Computer systems

- Various servers and databases to collect measured data and to fusion the raw data to a stringent information stream of all vehicles not obeying the traffic rules within the test site.
- Various notebooks (so-called tough books) used by the police forces to detect and observer possible violations and to pre-select them to a control station for further investigations.
- Various large-sized and high resolution displays in the control station to enable the users a good and comprehensive overview of the current traffic situation on the test site.
- Security systems to prevent access to the saved data for persons which are not allowed to use them (strong passwords, encryption of data, no data storage outside the secured container, no public internet access, no WLAN, infrared or Bluetooth access to the computers).

11.1.2 Architectural overview

The layout of the pre-selection of overweighed trucks on the highway A8 in Rosenheim consists of 3 primary elements see Figure 34:

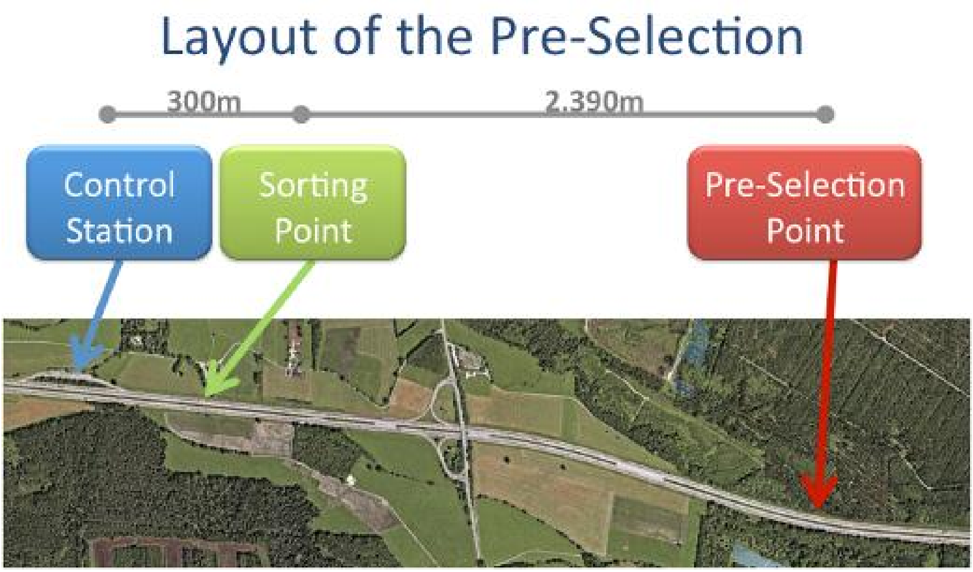


Figure 34: Layout of the German test site setup

The pre-selection point measures the speed, vehicle type and weight of each truck entering the test site. These data are transferred via fibre optics to the computers at the control station where possible violations are computed.

These results are then transferred to the sorting point where a police officer equipped with a notebook gets informed when a truck with a suspicious reason of overload or over-speeding is passing the sorting point. When the trucks arrives (typically 2-3min after detection) the police offers sorts the out to the control station where further investigations are done.

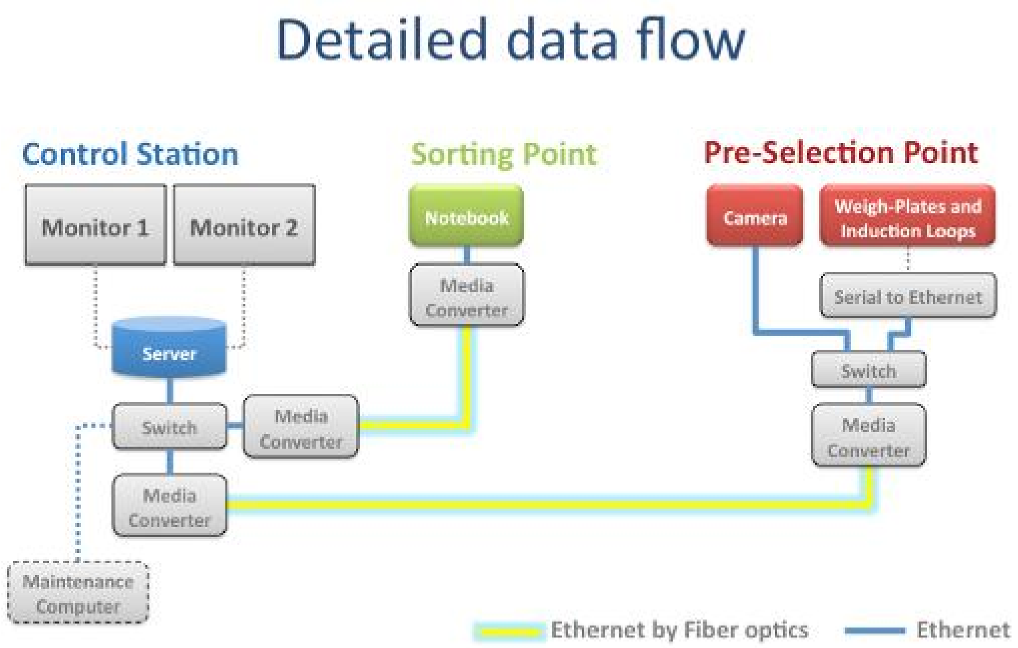


Figure 35: The physical architecture of the surveillance system on the test site.

The overall architecture of the software is based on a three-tier architecture consisting of a relational database storing the traffic rule violations, a persistence and business layer for managing the algorithms for detecting violations and a user interface for the police officer to display the found violations:

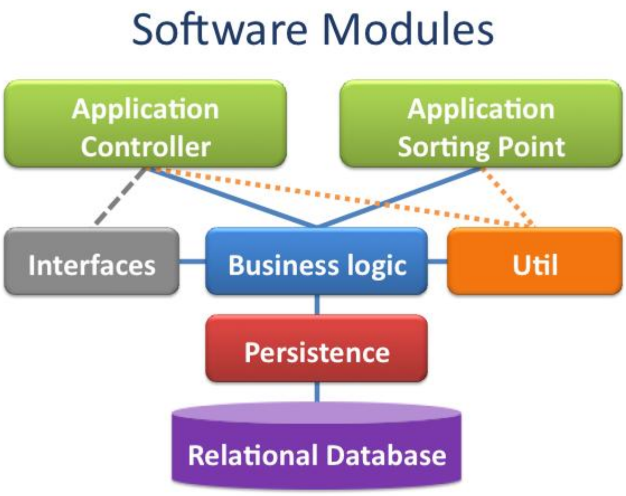


Figure 36: Software modules in the German test site

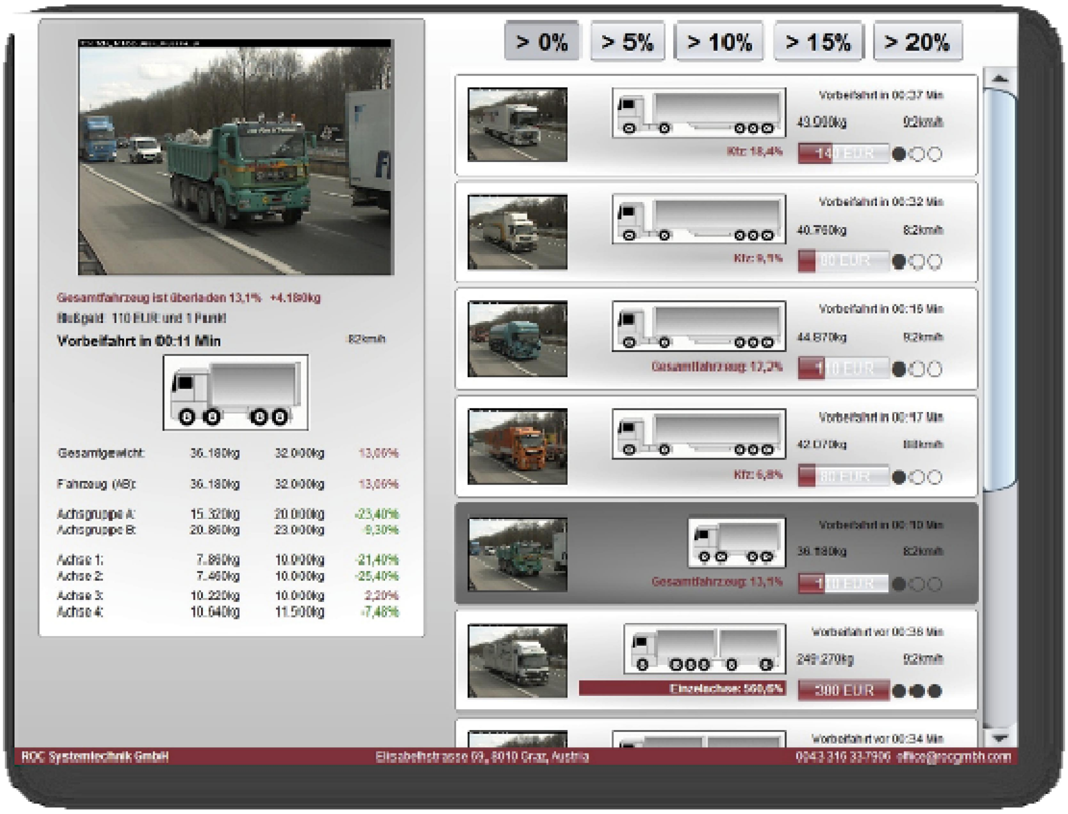


Figure 37: Screenshot of the application at the sorting point used by the police officers to select overloaded trucks to the control station.

Figure 38: Example of possible fines per day based on overloaded trucks on a typical month (October 2010) computed from the weigh-in-motion system.

11.1.3 Pictures of the system elements used on the test-site

Figure 19: Truck passing the pre-selection point on the highway.

Figure 40: Container at the Control station where all servers, services and monitors are installed and used by the highway police officers.

Figure 41: Installation of the high-resolution traffic monitoring system for observing the current situation on the highway.

Figure 42: Integration of the prototype of the new weigh-in-motion sensor combined with an RFID-tag reader to the pavement at the control station.

Figure 43: Installed prototype of new weigh-in-motion sensor.

Figure 44: Thermal camera for observing all trucks regarding brakes, tires and power line conditions from below while they are passing the control station.

Figure 45: Tire profile measurement system for detecting too less profiles of all trucks passing the control station.

11.1.4 Detailed technical description

The ASSET-Road German test site is set up on the federal motorway A8 between Inntaldreieck motorway interchange and the Bavarian capital of Munich. It begins on the northern carriageway of the A8 at km 51,600 in direction of Munich and ends on the parking facility „Im Moos“, at km 48,500. The tracking and tracing system is intended to monitor the motorway section between km 51,700 and km 49,300 and it is composed by two 3D Camera systems and 14 cameras spaced along the monitored road, each one mounted on prepared poles. The T&T cameras sit on top of 10m poles and the 3D cameras on 6m poles.

The 3D Camera systems are positioned at the two opposite extremes of the section, in order to identify the vehicles, determining their speed and classification. The 14 cameras are positioned on 7 poles, each pole hosting 2 systems looking in opposite direction.

Poles are spaced about 250m along the right side border of the motorway. Each T&T unit performs the same base function, vehicle tracking, inside its field of view.

The final aim of each unit is to maintain a list of vehicles, evaluating for each one of them the dynamical attributes (position and speed), and communicating such data to the supervising system when required. Those advanced techniques for vehicle tracking and identification will support the recognition of dangerous or unstable driving.

Figure 46: KRIA's camera system

Both the two 3D Camera systems and the 14 T&T cameras send data to the Road Supervisor. This software links the information received from the different devices creating a global view of the traffic in the monitored road.

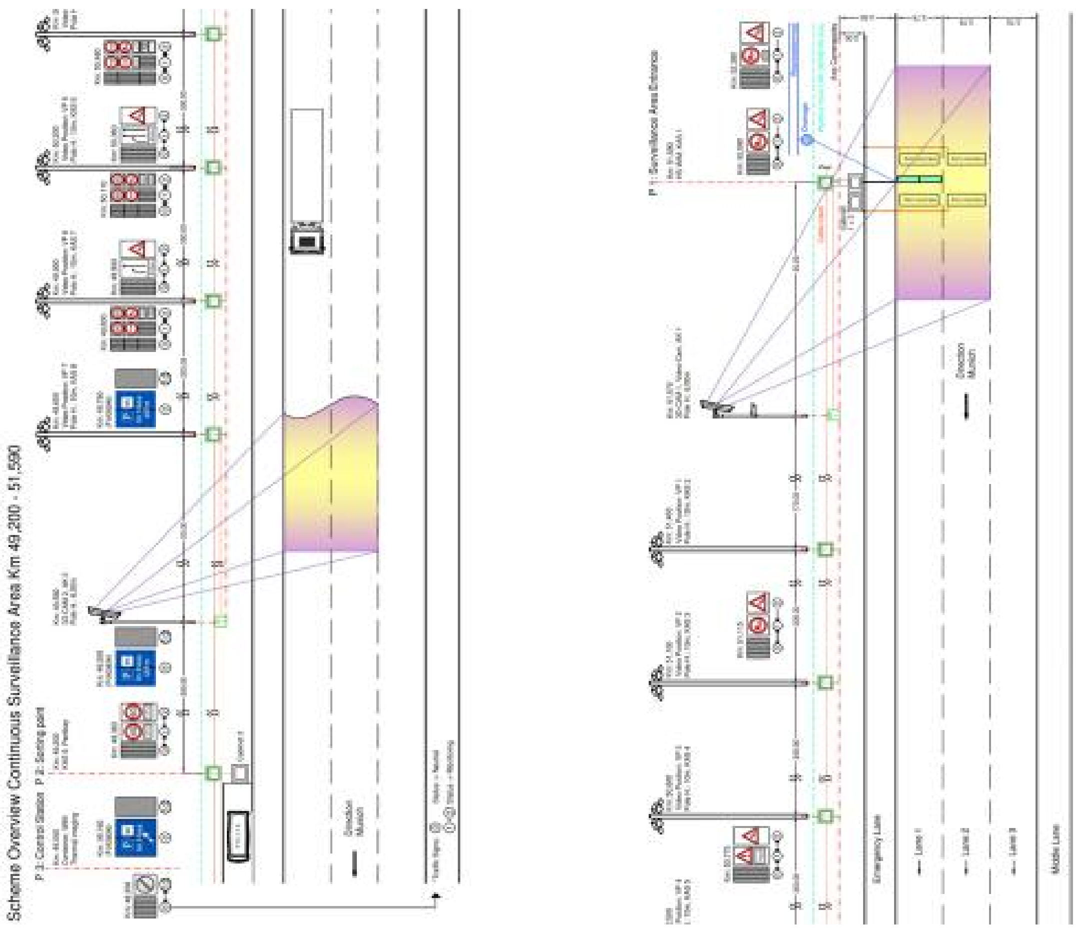


Figure 47: Drawing of the cameras system in the German test site

All video are gathered the central unit located into an integrated control, which covers a reference system, a trial and operation container with the necessary computers to evaluate all these information and a fiber optic cable communication network.

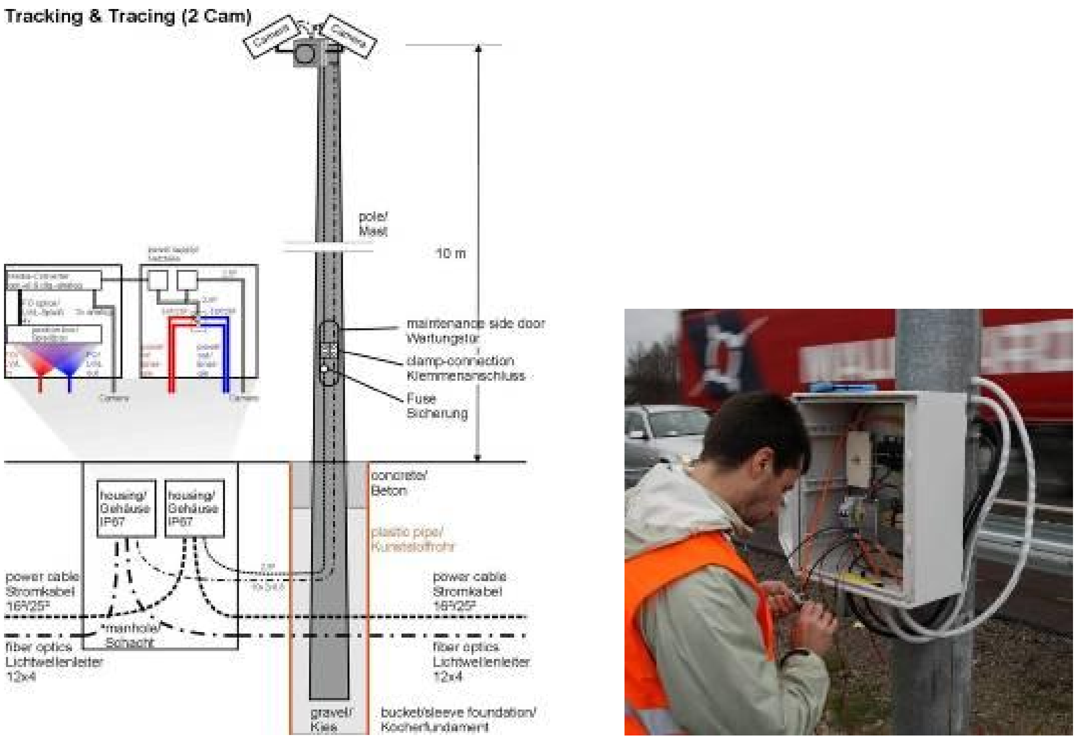


Figure 48: Example of cable access for a tracking and tracing pole

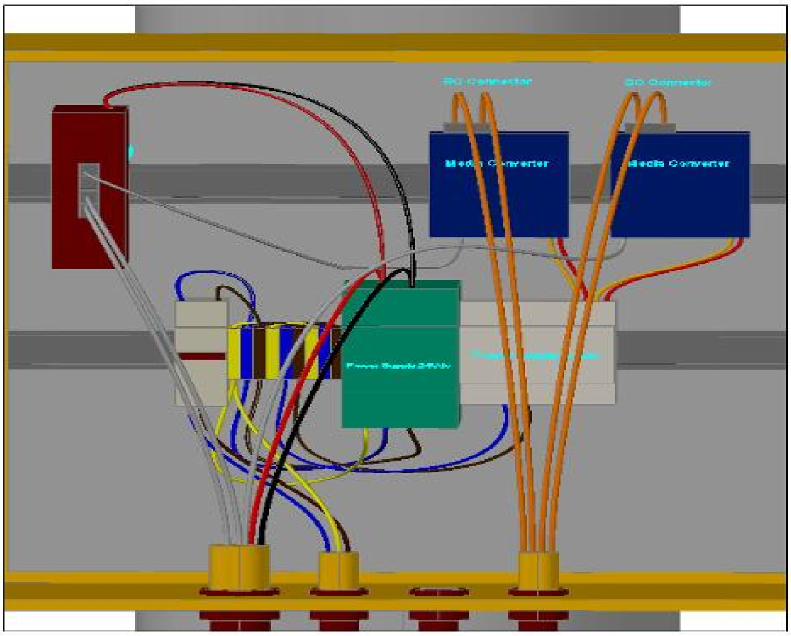


Figure 49: 3D camera system junction box cabling

The video system has been implemented by connecting all PC units and media converted inside a rack as showed in the picture (see Figure 44):

- The full map of the connections is reported below. We used 7 units, each one with its own IP address, to connect the different camera in this way:
- the two 3D cameras are connected to 2 dedicated PC units
- the 14 T&T cameras are distributed over five PC units, with a maximum of three cameras/unit

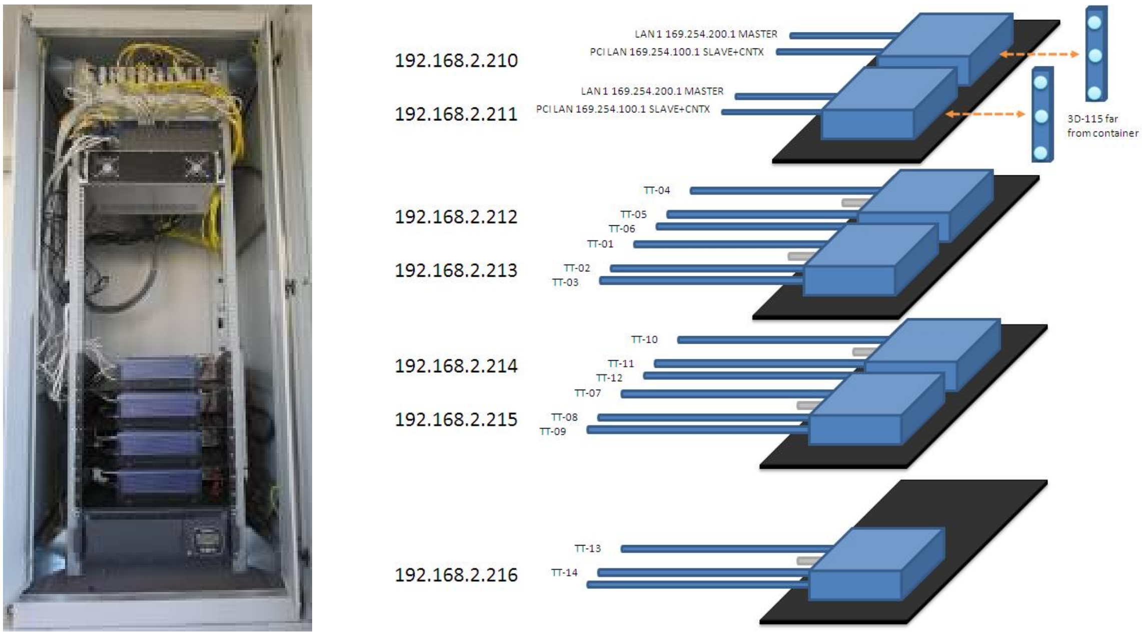


Figure 50: Rack shelter in the container

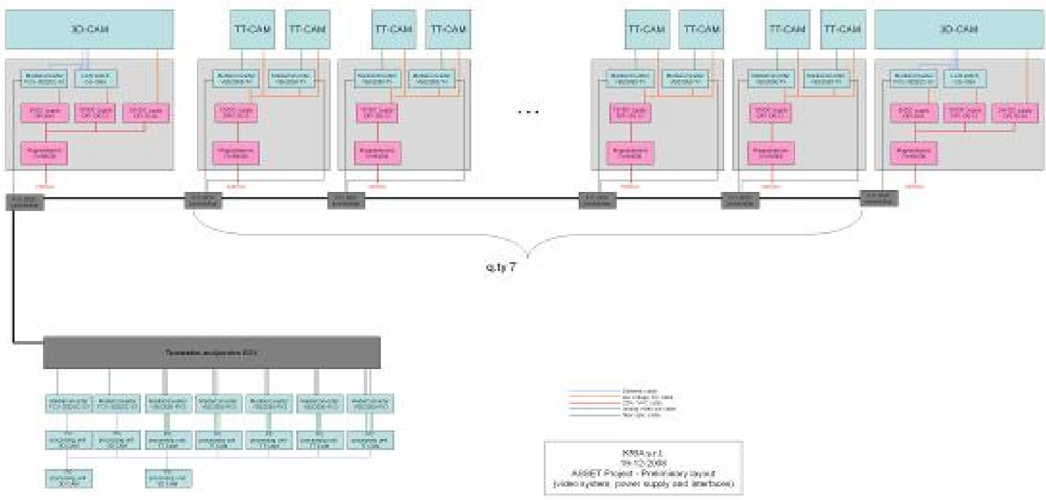


Figure 51: Project layout (video system, power supply and interfaces)

11.2 Finnish test site architecture

The Finnish test site implementation is distributed to the components in multiple locations [Maibach et al. 2010]. The traffic monitoring units have been implemented to a trailer, which can be moved from one place to other relatively easily. The data is gathered to one centralized database, which can locate hundreds of kilometers away from the users (traffic management centre, environment authorities and police officers).

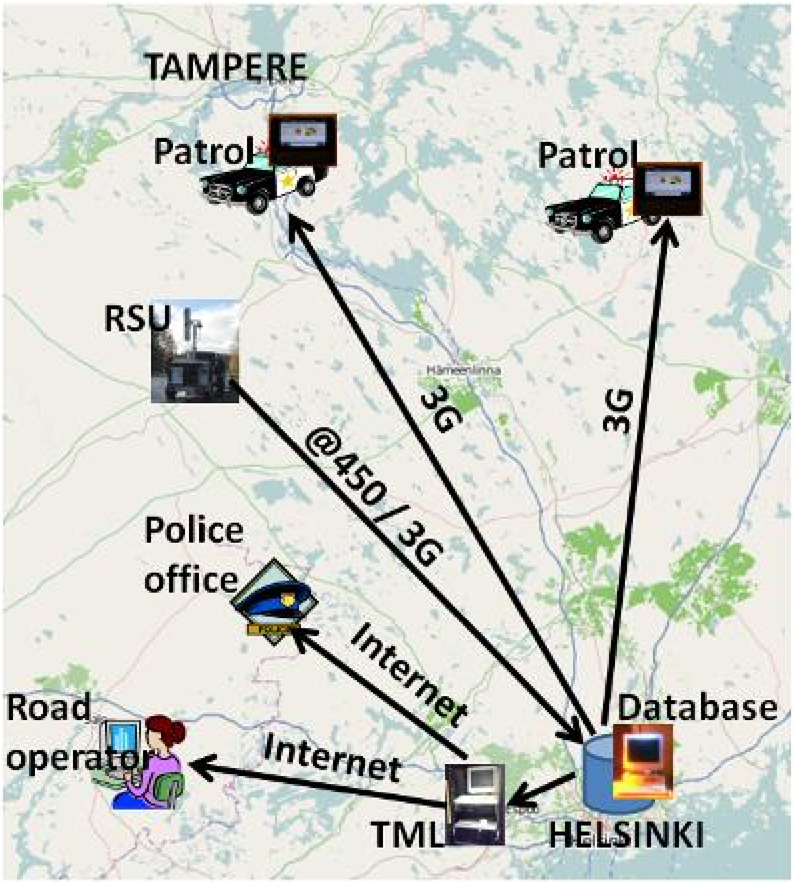


Figure 52: The Finnish test site concept

The original plan was to store all data to the server and save the energy and CPU power in the roadside unit to acquire data from the camera units. However, the first user tests revealed, that the traffic rule violation data needs to be analyzed on site for keeping data consistent in the database. Moreover, this is beneficial approach when thinking about future co-operative ITS scenarios that enable opportunity of traffic infrastructure to communicate and exchange data between infrastructure and vehicles. Therefore, the Finnish test site communication protocol follows the CEN TC278, ISO TC204, ETSI TC ITS standard drafts.

The Finnish test site architecture is presented. The system is completely modular which makes it relatively flexible for integrating new sensors. Sensor, monitoring and communication layers are part of the roadside unit whereas the transport middleware and database are installed remotely to the server in the fixed location which is accessible via internet. In addition to the original Finnish test site objective, the platform includes full support for the future cooperative safety applications and is able to warn drivers directly via the IEEE 802.11p wireless link if the passing vehicle is communication equip.

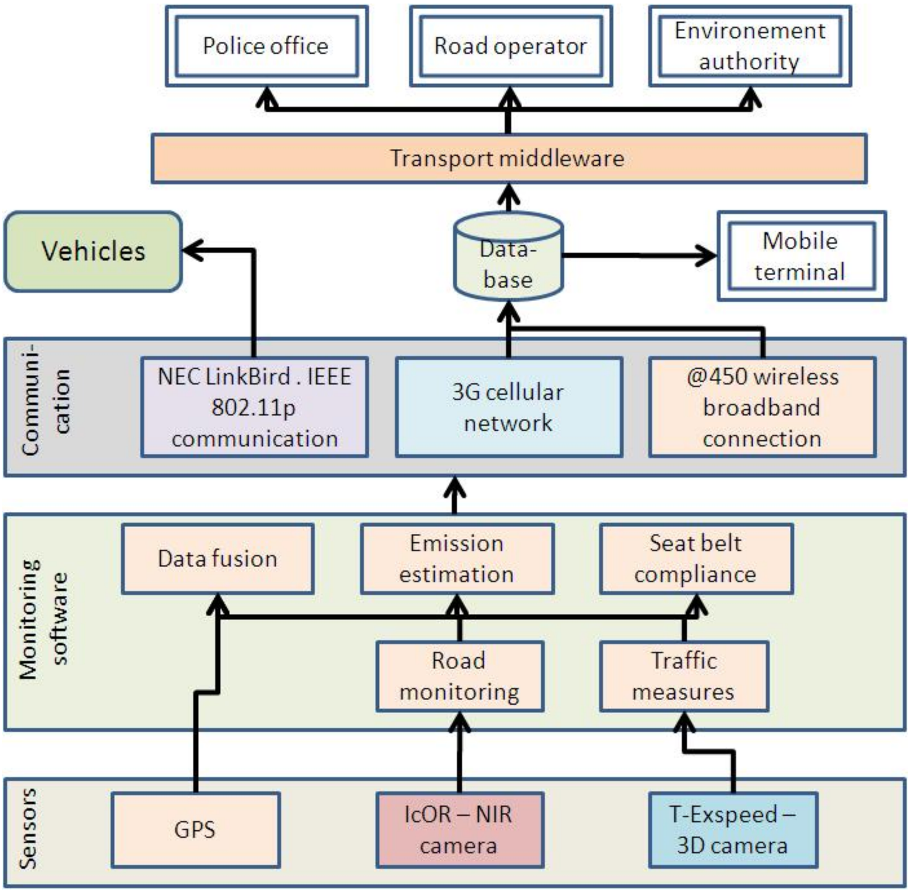


Figure 53: Architecture of the Finnish test site

11.3 French test site architecture

In the French test site, many demonstrations around the solutions developed by the French partner UBM have been presented. The TransportML collaboration platform has been developed with the aim to make the best use of information issued from multiple distributed services in order to provide a composite service. The platform development is based on SOA principles, web services standards, service discovery and composition. It provides a common communication language (TML) for client-service interactions. A mobile communication library is developed to allow V2I2V communication through the platform. Using this middleware, experiments have been conducted on the motorway and in urban environments, while invoking many web services which are road status, snow clearance, geofencing, and itinerary computation services. The obtained results show that the average travelling time is around 27% less when using TransportML. The TransportML architecture is given.

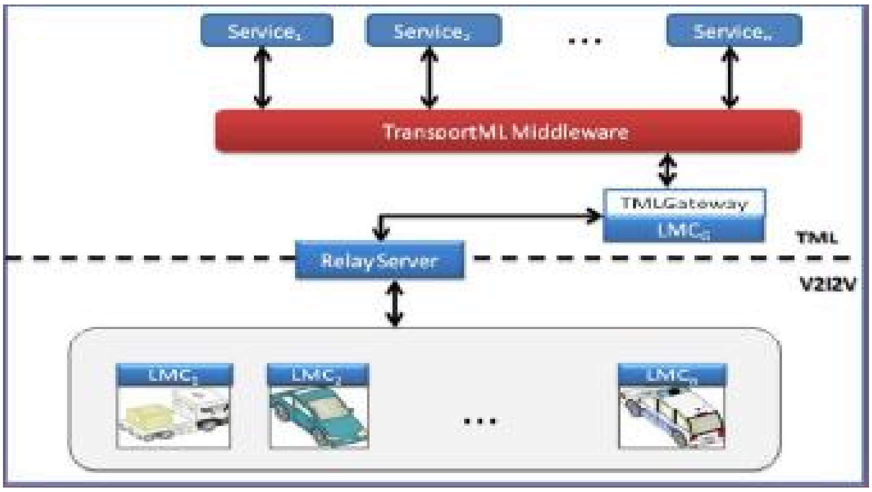


Figure 54: TransportML architecture

A context-aware embedded application has been developed and implemented. A diagnostic interface to plug into the vehicle's CAN is developed to extract internal context information such as seat belt, ABS activation, engine temperature and speed, fuel level, etc. The architecture of this application is given.

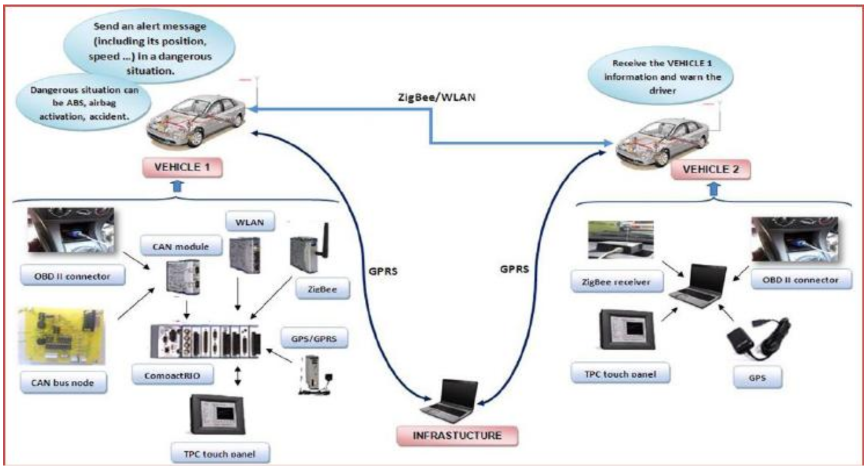


Figure 55: Context-aware embedded architecture

The collected information is displayed on the touch panel into the vehicle, to warn the driver. In addition, this information can be communicated through a communication mean (such as GPRS, WIFI and Zigbee) to the infrastructure or other surrounding vehicles.

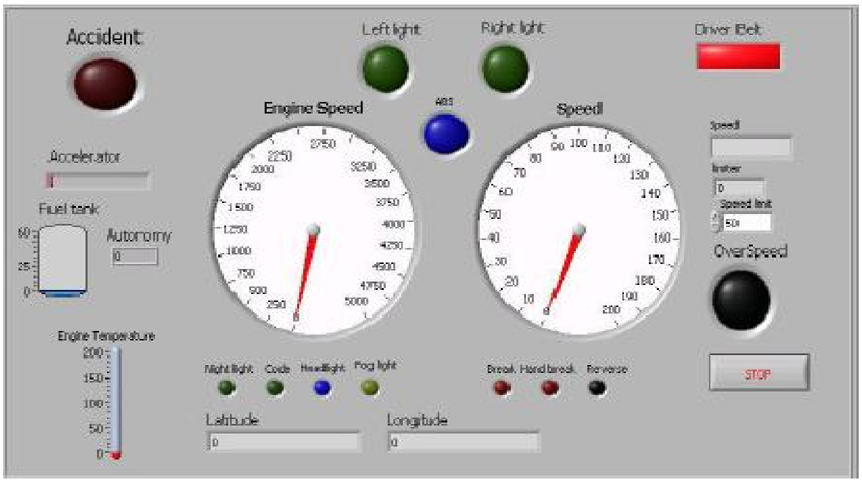


Figure 56: Diagnostic interface

For the monitoring and tracking of vehicles, especially for dangerous goods transportation or crisis management for example, a geofencing application is developed and implemented. The application allows defining and drawing geofences and storing them in MySQL database, representing the geofences on the Map defining the characteristics of the geofences (e.g. max weight, forbidden vehicles).

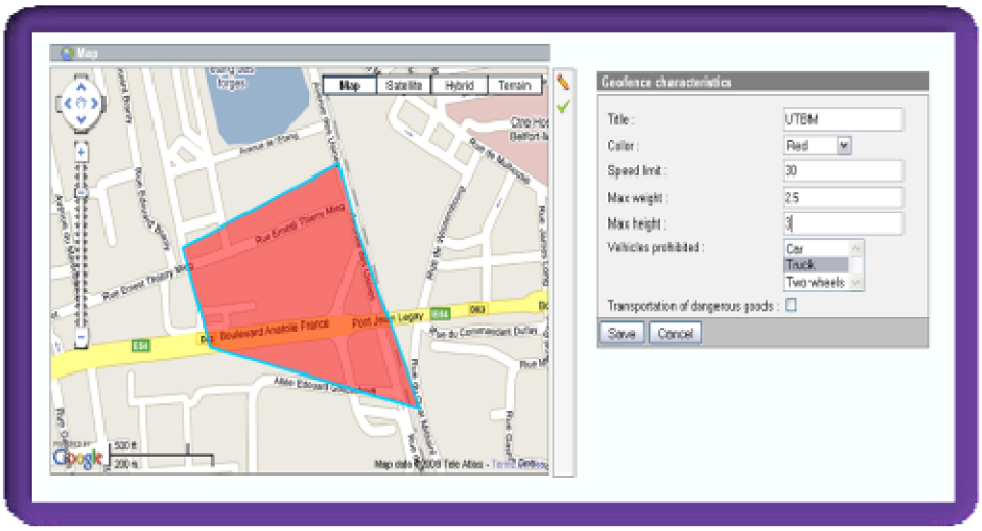


Figure 57: Representation of a geofence on the map

For the monitoring of snowplows and the display of plowed roads on a map, the snow clearance application has been developed and implemented. Its architecture see discribtion.

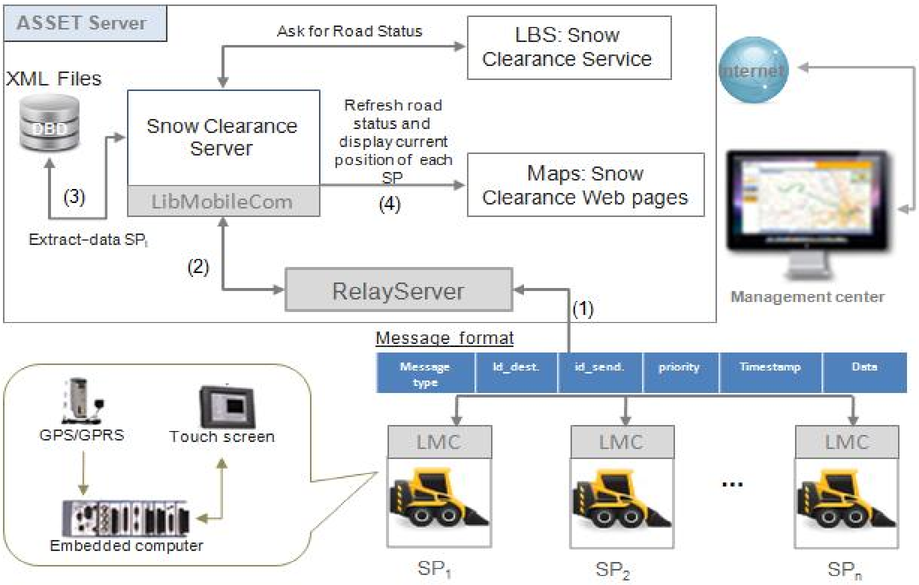


Figure 58: Snow Clearance Architecture

The snow clearance application provides several functionalities:

- Track and display in real time the position of snow plows
- The roads to be cleared are known in advance, stored in database or XML
- Snow clearance service gets the road status whenever is invoked
- The road status (cleared or not) are based in an algorithm which from the snow plow position computes the unclear part of the itinerary
- As depicted, red lines represent the unclear roads. As long as the snowplow is in motion, its trajectory becomes green to show that this part of road is cleared.

Figure 59: Real time position of snow plow with plowed roads

11.4 Conclusions

The ASSET-Road System is compatible with the European FRAME Architecture on the upper level: it supports many User Needs and Functional Areas with its Data Flows, and it can be connected to the defined Physical Architecture.

When ASSET-Road is implemented to some existing national or regional system, more detailed functions and interfaces need to be specified and implemented. This is because every practical ITS system may have some legacy issues, but mainly because they always tend to have extra user needs and extra functions to satisfy.

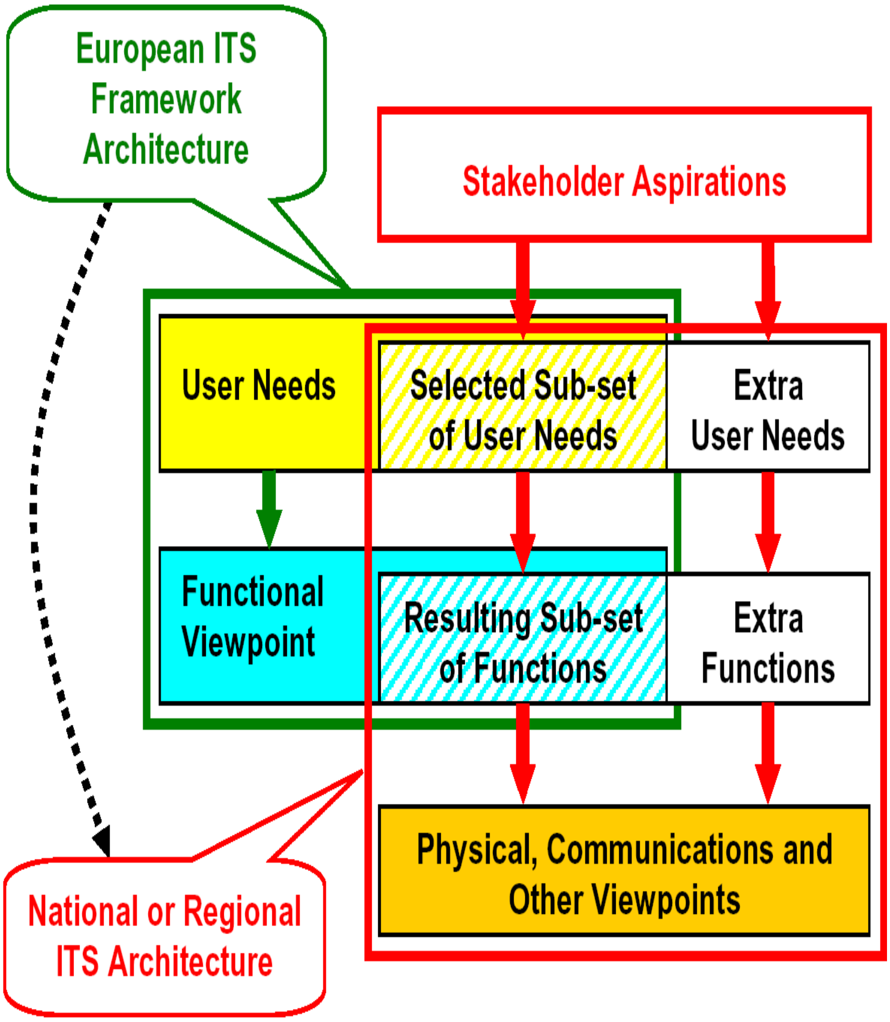


Figure 60: National or Regional ITS Architecture has often additional features that extend it beyond the FRAME Architecture. [FRAME Guide 2011]

12 Automatable Use of Traffic Regulations

12.1 Introduction

The traffic in the European road network shows today an unacceptable high rate of violations which lead quite often to severe accidents; reasons are beside general uncontrolled driving behaviour problems in the network operation that no instance (authority or continuously automated system) is assuring driving according to the legal framework on a 24/7 basis.

For the future a strongly growing traffic capacity and higher safety demand is expected. This will be caused by increasing numbers of cars, trucks and public traffic on motorways. Because of expected growth and change of motorization combined with more driving stress and economic pressure, these problems will become even worse for human and nature in the future.

It is very obvious, that the in road traffic the driver and the driving behaviour plays a key role concerning traffic safety.

As a consequence of this development, it has been decided to improve safety by an integrated and efficient highly automated enforcement system, finally installed in a nationwide distributed network, including black spot areas for safety. Objectives are to make road traffic smoother, safer and to decrease traffic emissions and travel times.

The European Commission launched already in 21 October in 2003 a recommendation on enforcement in the field of road safety including the following statements.

- Automated methods are effective; current solutions are outdated; the adoption of automated methods is slow in most European countries and authorities are reluctant to use them
- Enforcement needs commitment and dedication; innovation is needed above all in persuading decision makers of the need for effective implementation of enforcement strategies
- Surveys of needs reveal that more technological help is needed and more simplified methods must be found for catching and dealing with treating violators

Upcoming new ambient technologies, integrated system architectures, new sensor technologies, communication and processing technology with high performance, modular and standardised equipment for professional control and enforcement operation are required in future as the most determination factors to decease accident rates dramatically and to improve safety.

The study project “FAIR” Fully Automatic Road control (DG TREN) already investigated enforcement applications and the possibility for high or fully automation and the relevance for the different vehicle types versus applicable technologies.

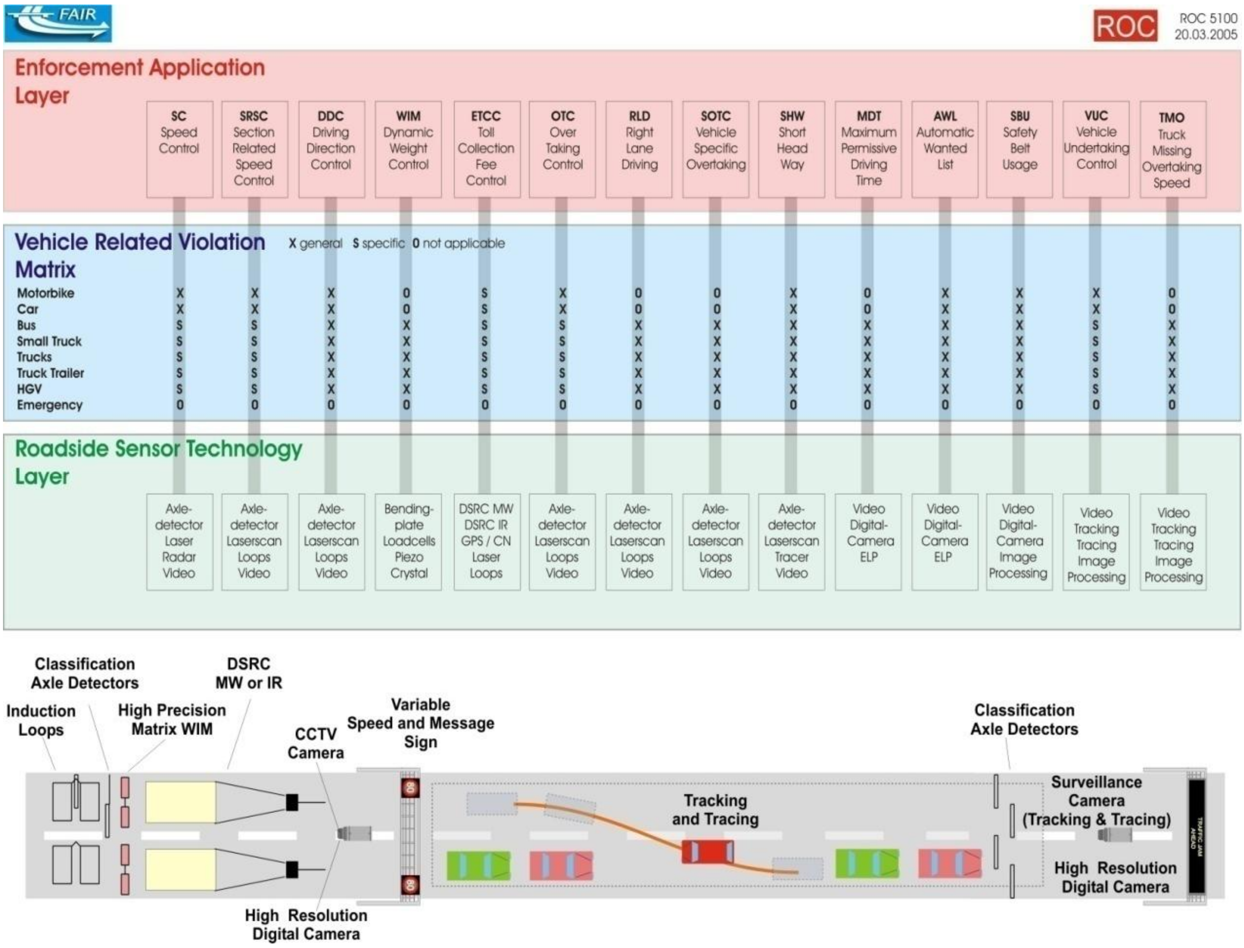


Figure 61: FAIR Initial Application Matrix

Automation of enforcement for better and secure following the rules will be a key factor for improving road safety in future transferred to highly automatic driving or cybernetic driving.

Driver

For the drivers to achieve maximum awareness and safe driving they must know and drive according the traffic rules in effect. Within this project, we want to support the driver to improve his awareness of traffic regulations and of dangerous situations. To be able to do that, we need an mechanism to store traffic regulations in a way, a computer can read and use it to detect rule violations and to support a HMI system that interacts with the driver and makes him aware of his violations so the driver can react to it and correct his behaviour.

Traffic Rules Study

The traffic rules throughout the 27 states of the European Union are quite diverse and are not easily to unify. The European Committee (DG TREN) initiated a traffic rules study which will be used as basis for the regulation base of this project. In this study the 15 member states of the EU at that time (2003) where considered and the rules of each country where examined and compared to one another.

Due to the date at which that report was created and as traffic rules are always a subject to changes, we cannot be sure that the information presented in that study is completely up to date. However, as the report contains reference to planned changes of the rules we will be able to update the rules according to the current state.

Case Studies Hungary

In Hungary we performed different case studies which help us finding key performance indicators leading to traffic safety.

Automatable Traffic Regulations

12.2 Statistics, needs and requirements

In this chapter we present interesting statistics that will provide useful information about the importance of certain traffic rules in terms of traffic safety. We concentrate at statistics that point out the traffic accidents that caused fatalities, not only because these accidents are most important to avoid but also because the statistics are most unified in Europe.

The test site where the automatic traffic rules will be implemented is at the motorway A8 in Bavaria/Germany. Hence we will then take a look at statistics from Germany and especially Bavaria.

12.3 General Statistics

In this section general statistics based on fatality rates are presented. We first take a look at European statistics. Then we will show statistics from Germany and will finally present statistics from Bavaria, Germany where the main test site will be installed.

Europe

In the European Truck Accident Causation Study (ETAC) which was funded by the European Commission and the International Road Transport Union, the goal was to find out the main causes of accidents involving trucks.

As one can see from the figure, Human factors play the most important role in collisions on the road. The most important factor leading to accidents is speed (27,0%) and Accident in a queue (20,6%), followed by accidents due to lane departure (19,5%) and accidents after an overtaking manoeuvre (11,3%). The most important human factors leading to these accidents involving Trucks are: not adapted speed (22,1%), Insufficient safety distance (16,2%) and Inattention (12,8%). Where one has to make clear that "inattention" is often used as excuse when fatigue (6%) is the real cause. The difference is that "inattention" does not have consequences to the driver, while tired driving is enforced similar to driving under the influence of alcohol. From accidents where fatigue is the main cause, 90% take place on the highway due to the more monotonous driving compared to urban areas (ETAC, 2006).

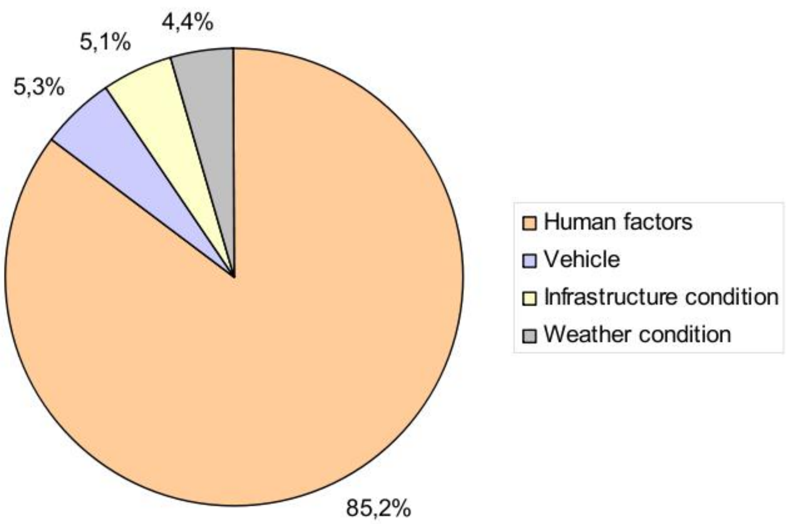


Figure 62: Main cause for all road users(ETAC, 2006)

Germany

In the last 60 years the number people killed in traffic reached a peak value in the late sixties. At that time about 22,000 fatalities occurred in Germany. As one can see from the next figure, this number is decreasing since then, although the traffic is increasing. This is founded on three important factors: global influences, the development of more secure vehicles, and the adjustment of legal issues.

Global influences where the oil crisis in the 1973 and is currently the ongoing financial crisis, which leads to less road transport for the next months or years we could already detect from our test site in Rosenheim.

The car industry improved the vehicles in great manner the last 50 years. Beginning from side impact protection, three-point seatbelt, airbag, anti-lock breaking system (ABS) to the electronic stability program (ESP), car manufactures have great importance in making traffic safer. However, some of their achievements would not have had an impact without the legislation.

The three-point seatbelt for example, introduced 1959 by Volvo and standard now, could not make a big difference until the drivers were forced to use their seatbelts 1984 (in Germany). Other traffic rules like slower maximum speeds and the reduction of the maximum alcohol allowed when driving further reduced accidents and fatalities.

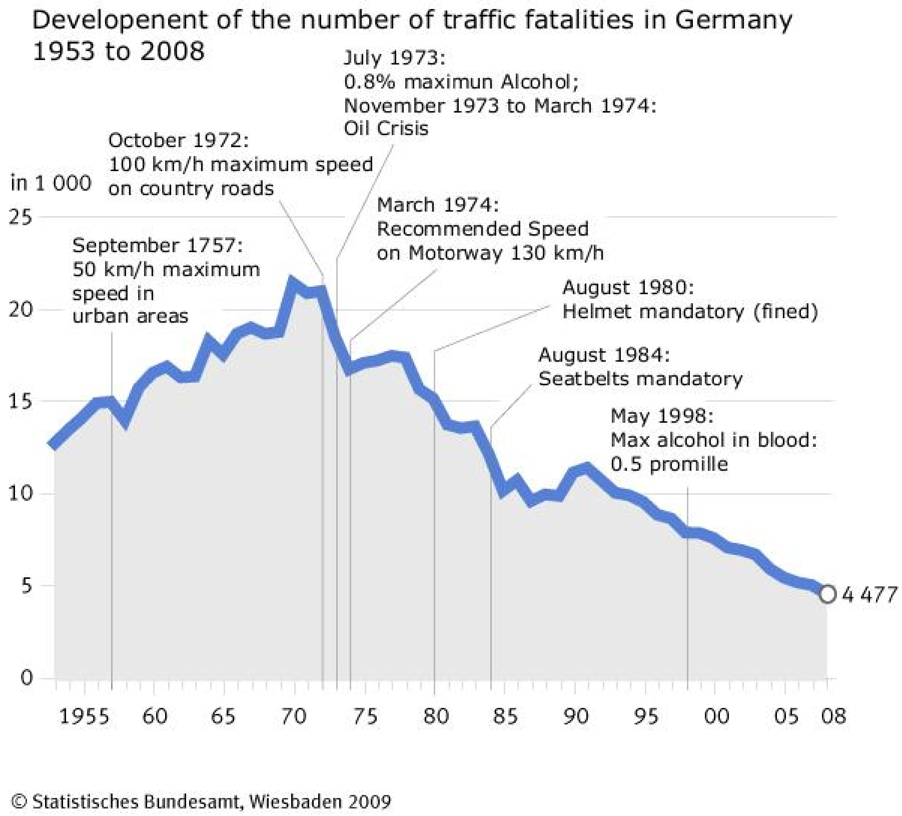


Figure 63: Development of the number of traffic fatalities in Germany

According to the provisional statistics of the Federal Statistical Office in Germany (Destatis), the number of fatalities on German roads went down to 363 in July 2009. Compared with July 2008, that was a decrease by nearly 18%. The number of persons injured decreased slightly by 0.9% to 39,000 persons. Unfortunately this trend does not come from less traffic accidents. In fact, in July 2009 there were approximately 195,200 accidents, which is 3.6% more than in July 2008. This increase is due the increase of accidents where only material damage occurred, which increased by 4.6 percent to 164,000 in July 2009.

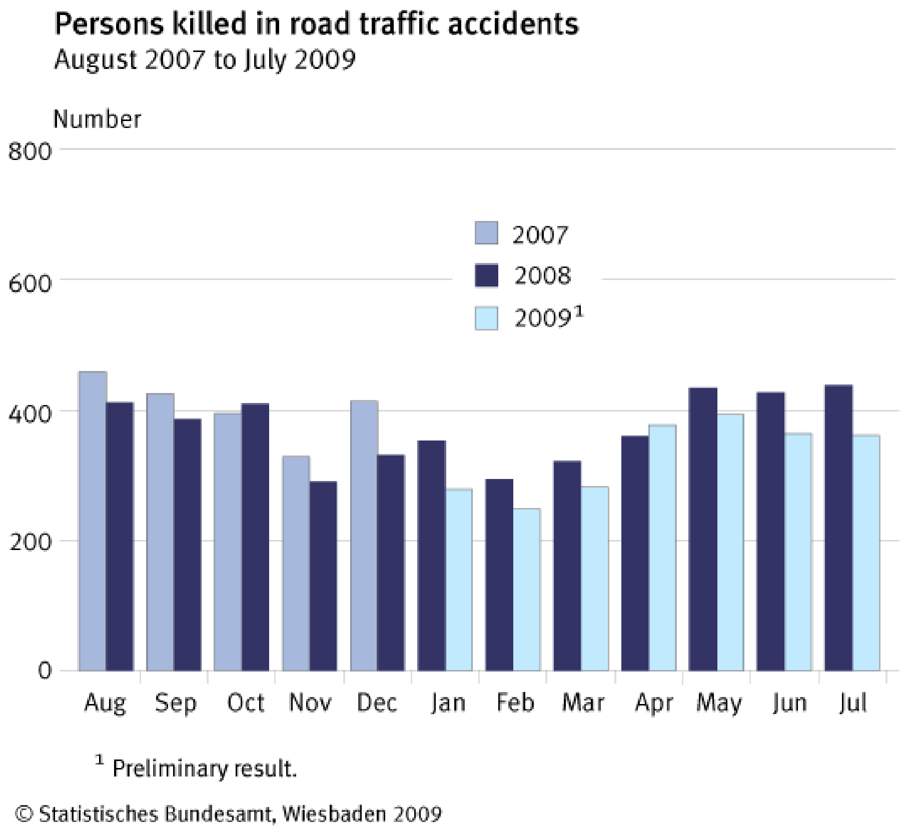


Figure 64: Fatalities in Germany in the years 2007, 2008 and 2009

Bavaria, Germany

In Bavaria we cooperate with the IMB which allows us to access their traffic accident database. This gives us the opportunity to present statistics that are fitted to our needs. In the following we want to focus on the test site and therefore select a statistic that is filtered by Motorway (Autobahn), fatalities in respect to the cause of the accident. Unfortunately we have to admit that certain points in the statistic may be underrepresented. For example the cause "tired / micro sleep" is not easy to prove by the police, hence this cause is often transformed to "inattention".

This protects the driver, as "fatigue" would have the same consequences to him as if he was under the influence of alcohol.

12.4 HGV-Statistics

Here we will focus on statistics incorporating heavy goods vehicles (HGVs). We also use the accident database of the Bavarian police.

However, statistics do not always tell something about the true nature of the problem, as there are many parameters that play a role in setting up the statistics. For example, technical problems that lead to an accident are often not detected correctly. This happens often due to the fact that it is for the sake of security much more important to clean the accident site and let the subsequent vehicles continue to drive as fast as possible. This avoids traffic jams and thereby the probability of further accidents. However, often the real cause of the accident cannot be determined when cleaning the accident site is the top priority. Furthermore an examination is also expensive in personnel costs. So if a sufficient individual mistake is found that can explain the accident, no further investigation is made. For example, if the driver tells the police that he was tired, and drove too fast, the police may not find out, that the breaks of the HGV where not working properly. This affects the statistics, which is the reason why in traffic statistics, the cause "technical failure" is underrepresented. Furthermore, in Germany for example it is the duty of the police to review an accident only in the case of a criminal act. That's why many accidents are not counted in accident statistics.

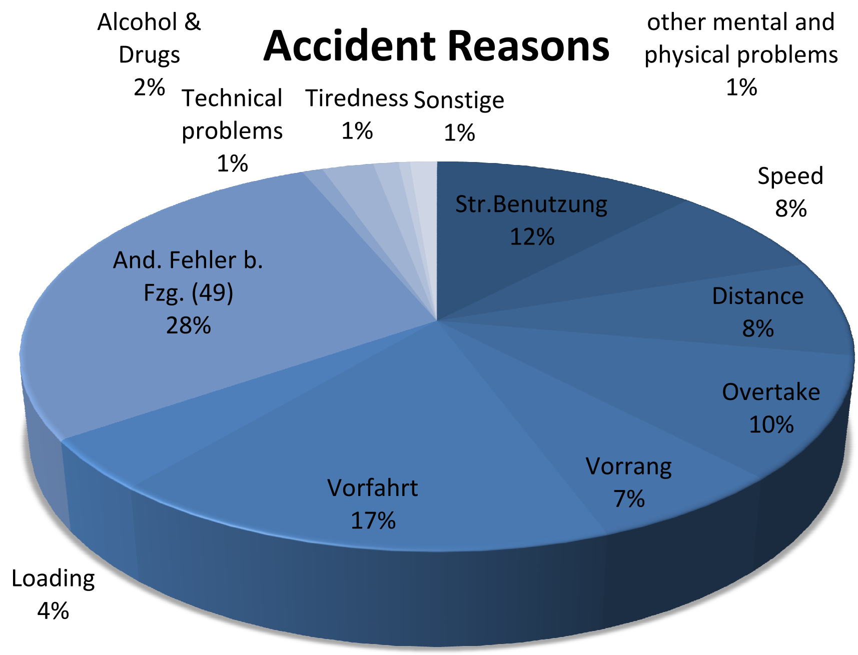


Figure 25: Accident reasons

12.4.1 Accident Reasons

The above diagram the reasons for accidents are visualized. As expected Speed and Distance are main factors as well as overtaking. Due to the fact that the focus of this statistic is not only on motorways but on all types of streets including inner city streets, there are also accidents because of right of way, loading and others included.

In this statistic, technical problems only represent 1% of the Accident reasons but “And. Fehler b. Fzg.” which means “other failures of the vehicle” is the reason in 28% of the accidents.

12.5 Needs and Requirements

The most significant needs and requirements regarding road safety, sustainable transportation and effective infrastructure are analyzed in the following, based on the interviews conducted with the Hungarian key players in the road transportation sector. These are the State Accident Prevention Board, Federation of International Private Transporters, Hungarian Road Transport Association, State Motorway Management Co. Ltd, Hungarian Public Road Management non-profit cPlc., State Police General Headquarters - Traffic Division, Ministry of Transport, Telecommunication and Energy.

12.5.1 Needs and requirements regarding road safety:

Regulatory needs and requirements:

- Finding a solution to the objections related to the handling of personal data in various enforcement, regulatory and control actions and systems
- Obtaining the support of the parliament and the general public in various legislative issues
- Feedback on the effects of legislation on traffic conditions (e.g. how a certain legislation altered the rate of accidents)
- Possibility to consult on planned legislation for the various key players in the sector (e.g. road users’ associations, enforcement organizations, road management companies)
- Stricter and simpler regulatory background
- Prevention of accidents by stricter driver license requirements and by the removal of dangerous drivers from the roads (e.g. by an actually operated scoring system)
- Clearly defined responsibilities for authorities, with the minimum possible overlap
- Laws and national policies need to be clear and easily applicable
- Government approach that emphasizes both prevention (e.g. education, safety equipment usage) and final results (accident rate, mortality etc.)
- Harmonization of the weekend HGV traffic restrictions and road toll systems in the European Union^

Statistical, information share and data management:

- Statistical data on the origins of traffic accidents
- Improving the data exchange between EU states and authorities about various enforcement related issues (rest times for truck drivers, ADR and oversized routes, export regulations, etc.)
- Data on compliance to traffic-related legislation
- Statistics on traffic accidents (by location, causes etc.)
- Online database accessible on the field to support the enforcement activities
- Access to relevant statistical data on the EU level
- Current, accurate and complete information on road and traffic conditions (e.g. accidents, inoperative safety equipment, traffic jams)
- Cooperation and data exchange with foreign research institutions in and outside of the European Union
- Cooperation of authorities in research programs
- Information on technical developments that may improve road safety
- Improved traffic education, possible as part of the state educational system
- Improved medical and first aid training in public schools and during drivers' trainings (to decrease the harmful consequences of accidents)
- Follow-up on health conditions of injured persons requires coordination between police and healthcare providers (otherwise there is a possibility of underestimating traffic mortality rates)
- Scientific data on the effectiveness of prevention measures (e.g. safety equipment)
- Possibility to monitor the effectiveness of preventive activities (e.g. the effect of advertising campaigns on traffic accident rates)
- Finding effective means to promote safe driving
- Fast notification on events requiring police intervention (e.g. accidents with personal injuries)
- Instant and easy access to EU warrants (Schengen Information System)
- Finding effective means to reach the general public
- Data on compliance (e.g. usage of safety equipment, observing speed limits)
- Fastest possible notification on conditions influencing traffic conditions (accidents, non-functional safety equipment, traffic jams, damages in the infrastructure etc.)

- Advance information on pre-planned activities influencing traffic conditions (e.g. scheduled reconstructions, events that require closing roads, slow convoys)

Financial needs and requirements:

- Receiving sufficient financial resources from the central budget for the traffic police in order to be able to perform their tasks (e.g. funding to increase the staff dedicated to road controls) and to improve the personnel and technical background of the police
- Effective state financial incentives (tax allowances) besides the legislative measures to support the implementation of the various road safety regulations, e.g. the installation of reflective contour foils on HGVs
- Effective state financial incentives (tax allowances) besides the legislative measures to support the implementation of the various environmental friendly technologies

Enforcement related needs and requirements:

- Immediate initiation of the fining actions
- Increase the presence of law enforcement personnel on the roads
- Traffic police activity concentrated on the most dangerous localities and times
- Fair and predicable treatment in case of violations (e.g. fines should be proportional to the seriousness of the offence, to the past record of the violator and consider the financial capabilities of a typical Hungarian company or driver; vehicles should not be seized or significantly hindered in case of minor violations)
- Effective programs to decrease corruption among law enforcement
- Finding the balance between enforcement and education

Application related needs and requirements:

- Fully automated overload control
- Virtual driver agent system – put road signs and warning messages into the vehicle
- Installing the Variable Message Signs on the motorways
- Replacing the conventional intersections with roundabouts
- Continuous maintenance of the road surface markings
- Ensuring the visibility of the road signs (upholding the vegetation alongside the roads)
- Safe parking compounds for buses and HGVs along the main roads in Europe (not only along the motorways), sufficient in frequency and quality

12.5.2 Needs and requirements regarding sustainable transport and infrastructure:

Regulatory needs and requirements:

- Terminating the frequent reorganization of the institutions in the governmental sector and within the state institutions
- Minimizing the unnecessary changes in the leadership
- Starting a dialogue on reconsidering certain EU regulations, such as the abolishment of the weight measurement stations at the country borders, which had to be moved away from the border
- Political stability and support
- Stable environment to operate in, including institutional framework and leadership at government institutions
- Roles of government agencies must be unmistakably defined
- Lack of transportation conception on the political level
- Legislative background has to be completely rebuild and updated
- Transparent and stable taxation and toll collection, preferably proportional to usage and road wear
- Reasonable and enforceable speed limits

Statistical, information share and data management related needs and requirements:

- High level road usage data
- Statistical data on registered vehicles
- Data on the origins of traffic congestions
- Infrastructure development plans of neighboring countries
- Detailed data on the origins of traffic problems (e.g. by location, vehicle type)
- Available and skilled specialists and engineers
- Set up a registration system for the full life-cycle of the vehicles
- International data exchange related to registration and enforcement activities
- Scientific data on effects of road usage (e.g. wear caused by different types of vehicles)
- Road users' and transporters' representation in infrastructure-related development decision-making bodies
- Harmonization of data collection methods among different regional police departments

Financial needs and requirements:

- Receiving sufficient financial resources from the central budget in order to be able to promote the sustainable transport and efficient infrastructure
- Sufficient funds for transport infrastructure related development
- Recirculation of the fines to the system
- Adequate and transparent funding for transportation-related research

Enforcement related needs and requirements:

- No multiple stopping of drivers by different authorities (this relates to professional drivers)
- Due to the uniqueness of the Hungarian regulatory environment the Police have only limited options checking the technical parameters of the vehicles, and because of this situation certain enforcement activities like the weight control of the trucks are preformed jointly with the National Transport Authority.

Application related needs and requirements:

- Creating locations on the existing and planned road system to perform the necessary road side checks
- Building of the infrastructure should be done "right for the first time" by the government agencies. (The M0 expressway ring around Budapest was cited as a counterexample; the completed sections are practically useless – the road is too narrow, congestion is commonplace, accidents are frequent.)
- Development of accompanying infrastructure outside of, but related to roads (e.g. safe parking locations)
- Special attention to children and bicyclists in the regulations and infrastructure development.
- Using effective and up-to-date technology
- Consideration of traffic safety implications in infrastructure developments projects
- Hands-on demonstration of technological or other developments in traffic infrastructure affecting traffic safety
- Efficient channels to broadcast messages to road users (e.g. electronic boards)

12.5.3 Most important road traffic regulations

- Speed restriction regulations
- Regulation related to seat belt and child seat usage
- Priority regulations (in intersections)
- Regulations related to alcohol consumption
- Regulations related to drug consumption
- Regulations related to compulsory rest times for bus and HGV drivers
- No entry regulations for various vehicle types

12.5.4 Problematic road traffic regulations

- Traffic regulations related to the most vulnerable participants (pedestrians and two-wheeled vehicles) of the traffic
- Sanctions regarding vehicles participating in traffic without license plate
- Regulations forbidding HGVs to overtake on certain motorway sections, full impact studies needed on the effects on the cargo transportation
- Placing and removing the temporary road signs (e.g.: in case of road works) in a timely fashion
- Speed limits regarding the railway crossings in Hungary are unnecessarily strict and in conflict with the Geneva Protocol on Road Signs and Signals
- Certain no stopping and no waiting restrictions are prohibiting the loading of cargo

12.5.5 Recommended road traffic regulations to implement

- Upon approaching the pedestrian crossings limit the maximum speed to 30 km/h when pedestrians are in the proximity and their probable intent is to cross
- Implement stricter fines and administrative measures for vehicles participating in the traffic without license plate

13 Case studies – Hungary

The Republic of Hungary is situated in the centre of Europe, in the Carpathian Basin. Its territory is 93,030 square km, the population amounts to 10,200,000. The capital city of Hungary is Budapest. From an administrative point of view, the country is divided into 20 regional units – namely into the capital city and 19 counties.

In Hungary the Police comes under the supervision of the Minister of Interior, there are no police organisations run by local authorities. The total number of the police is 38,000 persons, the traffic on public roads is controlled by the traffic enforcement service branch with about 2,500 persons, in addition to that the Motorway Police was established on 1st July 2004 the current strength of which is 292 persons.

The Hungarian Police is a full member of TISPOL (The European Traffic Police Network) organisation since May 2004.

Road - system of Hungary

- Due to its geographical location, Hungary acts as a „bridge" between the Western and Eastern part of Europe, thus several important international routes cross its territory, among others the 2 continental Helsinki corridors, corridor IV and V.
- The road-system - particularly the freeways and major roads- has a basically radiant structure, whose focal point is Budapest. The length of the national public road-system (including motorways) is 30.545 km, while the local road network is 139.800 km long. The maintenance and management of public roads belong to the central government's competence, while the tasks related to local roads is the responsibility of local authorities.
- The length of motorways are 679 km, they can be used on payment of road charge (sticker/vignette). The density, capacity and condition of the road network falls behind from the average of older EU members. 34 % of the national public road-network does not reach the actual EU capacity requirements.

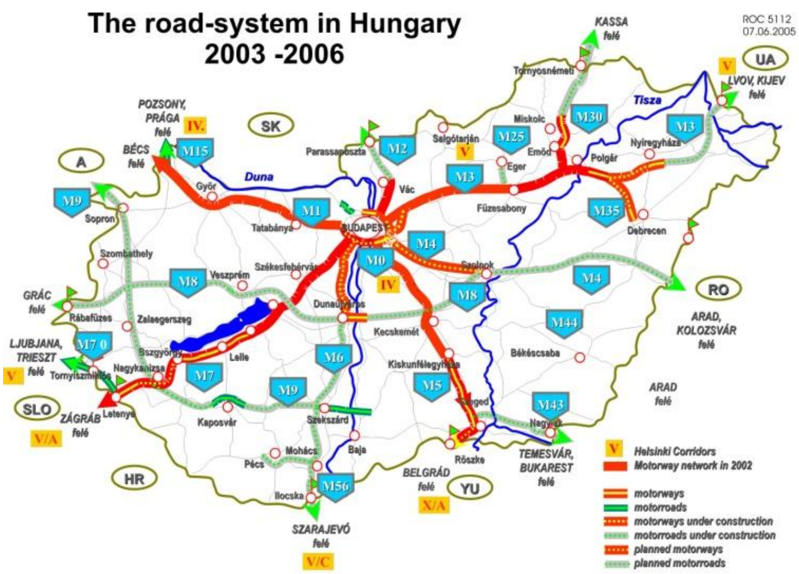


Figure 66: The current road system in Hungary

The development of road-system forms priority in the programme of the Hungarian Government. In the frame of this programme, more than 100 km of new freeways (motorways, and motor-roads) will be build until 2015 and the existing highways will be modernized upon the requirements. According to the plans, the total length of freeway network will reach 2500 km by 2015.

Case consideration

In the following we present case studies related to traffic offenses and their sanctioning in Hungary. The following cases are considered in this section.

- Higher speed limits cause more accidents
- Severe penalties decreased the number of traffic accidents
- Scoring system for traffic violations was ineffective
- Public outrage taught a politician that laws apply not only to common people
- Drunk chief police officer crashes with a train
- “Relative” speeding is more dangerous than exceeding “absolute” limits
- A motorcycle enthusiast switched back to car for fear of accidents
- Pedestrian crossings are unsafe in Hungary
- Even bicyclists should know the rules
- Theft prevention considerations overrule traffic safety regulations at freight carrier
- Tired or sleepy drivers pose significant danger on the roads

For each case it is shown why this case is considered and which background there is. Furthermore the involved Safety regulations are presented. After that, there is a description of each case and which lessons can be learned regarding the case.

13.1 Higher speed limits cause more accidents

13.1.1 Background

It is common sense that at higher speeds, accidents can be more dangerous. But do also more accidents happen, when the speed limits are increased? In Hungary there was a nation-wide change of the speed limits in May 2001. Hence the Hungarian statistics can be used to answer that question.

13.1.2 Safety regulations involved

Speed limits outside inhabited areas were raised in Hungary effective May 1, 2001. The changes in the maximum allowed speed (for passenger cars) are show below:

Type of road	Previous speed limit	New speed limit
Rural highways	80 km/h	90 km/h
Expressway	100 km/h	110 km/h
Motorway	120 km/h	130 km/h

In urban areas the speed limit was left unchanged.

13.1.3 Description of the case

Between 1990 and 2000 the number of persons killed or injured in traffic accidents in Hungary significantly declined in spite of the increasing number of vehicles on the roads. This trend clearly reversed in 2001.

Several different explanations were offered for the increase, including decaying traffic discipline, political changes (elections were held in 2002), etc.

Two experts analyzing the data came to the following conclusions:

- The number of accidents in urban areas did not increase significantly in 2001, and it declined in 2002 and 2003.
- The growing number of total accidents was clearly attributable to accidents outside urban areas.
- With statistical analysis it can be shown that after May 2001 the actual number of accidents were higher than the trend line predicted from earlier data.

It is unreasonable to assume that drivers' attitudes worsened when they were driving outside urban areas, while the discipline of the same drivers did not change within city limits. The only logical explanation is that the increased average speed allowed by the new limits was the reason for the higher number of accidents. (The effect verified by the analysis was predictable from the results of earlier studies.)

The study analyzed data until 2003. It must be remarked that the number of accidents further increased in 2004, remained more or less constant until 2006 and started to decline from 2007.

The detailed analysis (in Hungarian) may be found in: Dr. habil. Holló Péter – Zsigmond Olivér: Gyakorlati előrejelzési tapasztalatok emelt sebességhatárok közlekedés-biztonsági hatásvizsgálatakor: www.kti.hu/uploads/2009/kozlekedesbiztonsag.doc.

13.1.4 Lessons learned

The obvious connection between the number of accidents and speed limits should have made policy-makers reconsider the regulation. This unfortunately did not happen. Legislators chose the less popular – although definitely more profitable – approach of raising penalties for violations. (See Severe penalties decreased the number of traffic accidents.)

13.2 Severe penalties decreased the number of traffic accidents

13.2.1 Background

Between 1990 and 2000 the number of persons killed or injured in traffic accidents in Hungary significantly declined in spite of the increasing number of vehicles on the roads. This trend, however, reversed in 2001. Between 2001 and 2006 the number of fatal incidents grew by 5% and the number of people injured increased by over 13%. The number and rate of accidents caused under the influence of alcohol rose significantly. Government officials attributed this phenomenon to decaying traffic discipline.

(Remark: we have seen earlier that the growth of accidents occurred between 2001 and 2004, and practically stopped afterwards. Consequently the introduction of higher speed limits in 2001 offers a more feasible explanation. See 'Higher speed limits cause more accidents'.

It is also worth remarking that the "increase" in fatal accidents is a statistical trick rather than an actual tendency: if we choose 2002 as the basis instead of 2001, then the number of fatal accidents actually decreased by 7% in the period. Considering that the total length of the roads and the number of vehicles increased, there is hardly any evidence of "decaying discipline" on the roads.)

Punishment of perpetrators not identified on the spot was difficult due to a stipulation in the Hungarian laws: the owner or operator of the vehicle could refuse to identify the person driving at a given time if it would have meant accusing his or her close relative. As this loophole became widely known, more and more drivers abused it – claiming that the violator was a relative that they would not name.

13.2.2 Safety regulations involved

The violations of several traffic regulations are detected by automatic devices that recognize license plate numbers but do not make it possible to recognize the person driving the vehicle. In many cases, evaluation of the measurements and notification of the vehicle operator takes days.

The possibility of accusing an unnamed family member of the violation made it possible to avoid legal consequences in a wide range of cases, the most common ones being:

- exceeding the allowed speed limit,
- failure to slow down at railroad crossings,
- ignoring traffic lights,
- driving in the wrong direction,
- parking violations.

Driving under the influence of alcohol has been strictly regulated in Hungary: the allowed blood alcohol level is low, legal consequences of violations are strict in international comparison, but before 2008 violators could utilize several methods to avoid or delay penalty. (E.g. policemen detecting such violations were given significant room to consider their seriousness and to choose the penalties accordingly. This incited a number of drivers to perform touching scenes or offer fines.)

Often the driver's license was seized only several months after the blood alcohol level was determined to be over the allowed limit. This meant that he or she could legally drive in that period.

13.2.3 Description of the case

In 2008 a new law was introduced in Hungary, introducing two new elements in the system of traffic regulations:

- "Objective responsibility": the operator of the vehicle is declared to be responsible for any violation committed with the vehicle, unless he or she can produce written evidence that another person was the driver at the given time. Should the perpetrator not pay the fine, it may be collected from the operator.
- "Zero tolerance": Police is given little room for consideration when it may be reasonably suspected that the driver is under the influence of alcohol. If a driver's blood alcohol level is determined to be over the legal limit (usually measured with a breathalyzer), the offender's driver's license must be seized on the spot. Should the driver refuse to undergo the breath test or dispute its result, the police are required to ensure that urine and blood tests are performed, by applying coercive measure if necessary.

In addition, the fines imposed for a number of violations (e.g. significantly exceeding the speed limit) have been significantly raised and applied without any consideration of the circumstances.

According to police statistics, after the introduction of objective responsibility and zero tolerance, the number of injuries caused by traffic accidents, the number of fatal accidents and the number of accidents caused by drivers under the influence of alcohol decreased by 16 – 27%. (The numbers cited vary depending on the type of the accident and on the length of the time periods compared.) If the effects prove to be lasting over 200 lives will be saved by the new law yearly.

In spite of the obvious benefits, the law has been challenged by many. Some find it unconstitutional, as it presumes the operator of the vehicle to be guilty without appropriate evidence and may even penalize persons who are clearly not guilty (in case the fine cannot be collected from the perpetrator). Others believe that the rigor is excessive, especially if the blood alcohol level is close to the legal limit, that is, the driving ability is not seriously impaired by the alcohol consumed.

Another counter-argument is that the enforcement of the law is unfair, as police road checks in Hungary are sporadic and unevenly distributed, thus perpetrators in certain areas or time intervals may still be considered “exempt”.

Although the government originally planned to extend the applicability of objective responsibility to other traffic violations in 2009, this modification has not been enacted yet, probably due to the widespread popular opposition.

13.2.4 Lessons learned

Stricter penalties for serious violation of traffic regulations and removing legal loopholes lead to increased compliance and to a reduction in the number of accidents. This is true even if the enforcement is sporadic.

However, constitutional and other basic legal issues must also be considered before imposing severe penalties (e.g. presumption of innocence, proportionality of the punishment to the crime).

Methods other than excessive rigor may and should be considered to decrease the number of accidents. A simple one would be reducing speed limits back to their pre-2001 values.

13.3 Scoring system for traffic violations was ineffective

13.3.1 Background

In 2001, a scoring system was introduced to keep track of drivers regularly committing traffic violations. Every violation admitted by the driver or judged by a court was punished with a given amount of points, without consideration of the circumstances.

- Drivers collecting a given amount of points within a two-year time interval were punished with suspension of their license.

- Drivers over a certain score could decrease the number of points collected by participating in traffic safety training.
- The new system did not replace, rather supplemented the already existing other penalties, such as fine or prison time.

13.3.2 Safety regulations involved

Most of the dangerous traffic violations were punishable with points, including excessive speed, driving under the influence of alcohol, unsafe overtaking or turning, breaching railroad crossing regulations etc.

13.3.3 Description of the case

In the first three years of the scoring system (2001 – 2003) not one driver’s license was suspended for reaching the upper limit. This is not surprising, considering the low scores for violations and the high allowed limit. (E.g. 1 point was given for excess speed or not giving the right of way, while 18 points were necessary for suspension of the license. Drivers reaching 14 points could go back to 5 by attending safety training.)

The system has been aggravated several times: points for certain dangerous violations were raised; the time interval considered was changed from two to three years etc. This increased the number of drivers reaching the limit; however, the number of licenses suspended still remained low (about 350 in the first seven years of the system).

The majority of the drivers (about 75%) received their penalty points for exceeding the speed limit. Distribution of points for other violations has remained sporadic, meaning that the most dangerous actions are rarely punished with penalty points.

We found no credible evidence that the scoring system improved traffic safety. The number of accidents slightly increased during its application; however, this is most probably attributable to the increased speed limits. (See ’Higher speed limits cause more accidents’.)

13.3.4 Lessons learned

A scoring system with delayed consequences has little or no effect on traffic safety.

Lack of systematic, regular or automatic monitoring of the most dangerous violations on a wide number of road sections limited the scoring system to punishing mostly “absolute speeding” which is by far not the most dangerous offence. (See “Relative” speeding is more dangerous than exceeding “absolute” limits.)

13.4 Public outrage taught a politician that laws apply not only to common people

13.4.1 Background

It is a widely held belief in Hungary that laws apply only to common people. There are a number of verbal – thus unverified – accounts and a few documented cases indicating that members of certain privileged groups may easily avoid, lessen or delay punishment for breaches of the law, including traffic violations. These groups include the following:

- high-ranking police officers,
- politicians, especially those belonging to the parties ruling at the time of offence,
- high-ranking government officials,
- family members of the above,
- people having close relationships to the above through friendship, work or hobby (e.g. lawyers working for the police, managers of insurance companies).

(The list may not be complete.)

Although not known by most of the public, some people are legally exempt from being examined by the police at road checks. They may refuse participation in a blood alcohol test or any similar procedure. These privileged citizens include members of the parliament, judges, prosecutors and "ombudsmen". According to some reports, members of the parliament regularly refuse to undergo the breathalyzer test, not only in routine checks but also after violating traffic rules or causing an accident.

Traffic violations caused by "privileged" persons are regularly suppressed in the mainstream media. (Remark: according to some interpretation of the Hungarian laws, immunity of politicians, judges etc. do not apply to traffic checks by the police or to traffic violations. But the majority of legislators have a different opinion. In 2005, a Member of the Parliament at a committee meeting discussing the issue called it "forgivable" to exceed the speed limit and then use the immunity clause to escape punishment.)

13.4.2 Safety regulations involved

In 2008, a law was passed introducing "objective responsibility" and "zero tolerance" rules and significantly increasing fines for several traffic violations, including exceeding speed limit and driving under the influence of alcohol. (A more detailed description of the law is given in a previous case: Higher speed limits cause more accidents).

13.4.3 Description of the case

Shortly after "zero tolerance" was introduced by the ruling Hungarian Socialist Party against drunk drivers, a locally elected representative of the very same party obviously thought that traffic regulations did not apply to him.

In March 2008, a police officer was driving his car under the influence of alcohol, when police tried to stop him. As he kept driving, the police officers were forced to chase him for several kilometers before managing to stop his vehicle. According to eye witnesses, the politician drove dangerously while he was trying to escape and could easily have caused accidents.

The police officer refused to identify himself to the police, resisted arrest, fulminated and verbally threatened the police officers. When taken to a nearby hospital for urine and blood test, he further resisted and tried to destruct the samples. After his release, he urinated on a wall of the hospital – probably trying to express his dissatisfaction in this peculiar manner. Subsequent measurement determined that his blood alcohol level was over 8 times the legally allowed limit.

According to the "zero tolerance" law, his driver's license should have been seized, but he refused to hand it over to the police, claiming that it had been "stolen".

(It must be remarked that the previously mentioned immunity does not apply to locally elected representatives.)

As may be expected by anyone acquainted with the Hungarian media, the case did not receive widespread publicity, probably due to pressure by the Socialist party. We know of only one major newspaper and one national TV channel that reported about it. The majority of the local media also remained silent.

However, the few media reports that did appear sparked a wave of public outcry. Blogs on the Internet denounced the behavior of the ruling elite in general and that officer in particular. The political opposition also started a campaign against him.

Although the unruly representative originally intended to stay in his position – apparently believing that he committed no serious offence –, mounting public pressure eventually forced him to resign.

His attitude, however, probably has not changed; though his driver's license was suspended, he has been seen to drive his car, according to several Internet accounts, which we could not verify.

13.4.4 Lessons learned

Improving voluntary compliance to traffic regulations will be difficult in Hungary, as even some of the country's first people openly ignore the very rules they are imposing on others. Given this situation, only more severe enforcement may improve the situation, as evidenced by the success of "objective responsibility" and "zero tolerance".

Public pressure – facilitated by the Internet – may be a significant factor in achieving equal treatment of citizens and in abolishing privileges.

13.5 Drunk chief police officer crashes with a train

13.5.1 Background

See in the previous case (Public outrage taught a politician that laws apply not only to common people).

13.5.2 Safety regulations involved

In 2008, a law was passed introducing "objective responsibility" and "zero tolerance" rules and significantly increasing fines for several traffic violations, including exceeding speed limit and driving under the influence of alcohol. (A more detailed description of the law is given in a previous case: Higher speed limits cause more accidents.)

13.5.3 Description of the case

Lieutenant-colonel Z., the chief police officer of a Hungarian city was reputed to be a strict officer. In local media he warned citizens on the importance of ethical behavior while on the road. According to a union source, when one of his subordinates was found driving under the influence of alcohol, he declared that such a person is unworthy of being a police officer.

In March 2008, shortly after the "zero tolerance" law was introduced on driving under influence, Lt Col Z. was driving his car after consuming alcohol. At a railroad crossing, he crashed into a train. He and another drunk police officer travelling in the car suffered only minor injuries due to the lucky fact that the train was going at a reduced speed.

As usual in the case of violations committed by high-ranking officers, no further details of the accident were disclosed by the Hungarian police. (As different news reports repeat the same few sentences mechanically, it seems that representatives of the media did not ask any questions from the authorities. Interviews with the eye witnesses, reconstruction of the events or even photos of the scene – usual in case of other accidents – were also "forgotten" by the reporters.)

According to unverified accounts, the “stop” signal was properly operating at the crossing. Several drivers stopped their car, forming a line. The Lt Col overtook the other cars, drove around the barrier and then collided with the train arriving.

We found little information in the media regarding the consequences of the violation. It was widely publicized that Lt Col Z. was “terminated” from his position. While to the average reader this may sound as dismissal, actually it only meant that the Lt Col was offered a lower position within the police force. This important fact was not communicated in the vast majority of the news reports we analyzed. According to one media report, the police, “considering his injuries”, did not seize Z. license on the spot. This information, however, is not corroborated by other sources.

From correspondence between a police union and a chief police officer further details may be concluded: the police chief was removed from his position “without justification” instead of “improper conduct”, which allowed his superior to offer him a lower position. After he refused to accept the position offered, he was entitled to collect a significant severance payment – contrary to earlier cases, when lower ranking officers were dismissed for similar violations, instead of being rewarded as Lt Col Z. was.

A wide range of relevant facts remain unknown to the public, including:

- Was “zero tolerance” exercised in the case of Lt Col Z.?
- How high was his blood alcohol level at the time of the accident?
- Is it true that he intentionally ignored the stop sign at the railroad crossing?
- Was he ever charged and sentenced as “ordinary” citizens would have been in a similar case? If yes, was his driver’s license suspended and for how long?

According to several posts on different web sites, a significant percentage of the Hungarian police leaders are addicted to alcohol. As these people rarely cause such spectacular accidents under the influence and the police probably suppress the less conspicuous ones, this case is probably just a tip of the iceberg.

13.5.4 Lessons learned

Improving voluntary compliance to traffic regulations may be difficult in Hungary, as some leaders of law enforcement consider themselves “above the law”. Police chiefs should be carefully selected to be of high moral characters, able to show example.

The poor to mediocre reputation of Hungarian police (compared with other institutions and other EU member states) could be significantly improved if violations perpetrated by high-ranking officers were persecuted and disclosed instead of being covered up.

13.6 "Relative" speeding is more dangerous than exceeding "absolute" limits

13.6.1 Background

The leading causes of traffic accidents in Hungary are:

- Excessive speed
- Violation of priority rules
- Illegal change of direction, steering or turning

(Based on data by the Hungarian Central Statistical Office, on accidents causing personal injuries in 2007)

Each of these three major groups is responsible for about one fourth of all the accidents (23% – 26%), all the other causes (overtaking, pedestrian's fault, technical defects etc.) contributing significantly less to the total number.

International comparison is difficult, since in other countries different categories are used. However, excessive speed seems to be among the primary causes in most developed countries.

A closer look at the Hungarian data reveals an important and interesting fact: less than 6% of all accidents are attributable to exceeding the maximum allowed speed for the particular road ("absolute speeding"), while in almost 20% of all the accidents the drivers chose a speed within the legal limit, but inappropriate for the weather and road conditions ("relative speeding"). This indicates that "relative" speeding is over three times more dangerous than "absolute" speed violation.

While exceeding "absolute" limits is easy to prove and penalize, "relative" limits are subjective, and their enforcement seems to be practically absent from the practice of Hungarian police.

13.6.2 Safety regulations involved

According to the Hungarian regulations, the driver must consider a number of factors beside the "absolute" speed limit when choosing the vehicle's speed. Such factors include: visibility conditions, breaking distance, signs indicating danger, road surface, movement of other vehicles etc.

In practice, drivers often do not know what the safe speed would be under the given conditions.

13.6.3 Description of the case

Icy roads predictably increase the number of accidents, even though authorities regularly warn drivers of the dangers through different media channels whenever weather conditions warrant it. These types of accidents are mostly caused by exceeding the “relative” speed limit.

We present just one sample news report from among the many similar ones:

January 7, 2006

Black day in Fejér County

Seven persons died in two accidents on the icy roads in Fejér County. Ambulance treated 25 injured.

A scheduled bus was travelling on Road 7 near Emmaróza, when its driver noticed an automobile that had slipped into the roadside ditch. When the bus driver tried to break, the bus slipped on the icy road, collided with a pylon and tipped to its side. A crane was needed to lift it. Three passengers died, eighteen suffered injuries.

On Road 63, near Bodakajtor a passenger car overtook a bus. After ending the maneuver, it returned to the right lane, but on the icy road it slipped back to the left lane and collided with an oncoming van. Three people died at the scene of the accident, three others were hospitalized, one of whom later died.

13.6.4 Lessons learned

Drivers should be aware that legal speed limit is only one of the factors to be considered when choosing their vehicle’s speed.

Although more difficult to evaluate than “absolute” speeding, police should pay more attention to violators of “relative” speed limits. This could most probably prevent more accidents than the present practice of penalizing mainly the “absolute” violators.

13.7 A motorcycle enthusiast switched back to car for fear of accidents

13.7.1 Background

Traffic accidents involving motorcycles are common in Hungary. The number of such accidents starts to increase in March, but the “black month” is usually April, when a large number of motorcycle drivers appear on the road who have not used their vehicle for months. Car drivers not used to bicycles and motorcycles during the winter months are often unprepared and cause a significant number of the accidents.

Many car drivers and motorcyclists mutually accuse each other of recklessness.

13.7.2 Safety regulations involved

Hungarian traffic laws stipulate that overtaking by any motor vehicle is allowed only if the driver overtaking maintains a safe distance to the left of the other vehicle and can return to the lane after his or her vehicle is safely clear of the overtaken vehicle. The laws do not specify any minimum side distance.

Usually neither the theoretical, nor the practical training of drivers include the vulnerability of bicycle and motorcycle drivers if appropriate side distance is not kept. Penalizing drivers for passing too close to a motorcycle or bicycle is practically unheard of.

Naturally, priority rules (e.g. priority to the right) apply to bicycles and motorcycles also, however, in practice these vehicles are often ignored by car and van drivers.

13.7.3 Description of the case

We found an interesting confession on a Hungarian web page dedicated to motorcycle driving and accident prevention (http://www.akmt.hu/balesetek.html).

A short summary of the post is given below, with the original expletives rephrased.

Let me tell you why I gave up the habit of motorcycling even if I have always loved it.

I grew up riding a motorcycle, first behind my father, then on my own. I fell many times, just as others did. Once I almost got killed by a tram.

After my marriage the motorcycle was not enough, I had to buy a car. Then 15 or 20 years have passed and I realized that it is difficult to travel by car in Budapest. I decided to buy a motorcycle for my daily trips.

After a few days of practice with my new bike I joined the city traffic. I realized up front that today's car drivers pay no attention to bikers. They pass you frighteningly close and behave as if bikers never had the right-of-way.

I felt as if everyone had been out there trying to hunt me down.

The last straw was when I stopped at a red light. A van stopping beside me knocked me to the ground. After getting back on my feet I complained to the driver. His answer was:

"Shut up, bugger, or I'll drive through you, back and forth!"

After this I stopped motorcycle riding, at least in Hungary.

13.7.4 Lessons learned

Lack of consideration for other participants and unwillingness (or inability?) to behave in a cultured manner are significant obstacles to accident prevention in Hungary.

Besides following distance, side distance to the right should also be an important factor to monitor, with proper sanctioning of the violators; especially in case of larger vehicles overtaking bicycles or motorcycles.

13.8 Pedestrian crossings are unsafe in Hungary

13.8.1 Safety regulations involved

The driver of any vehicle must approach pedestrian crossings ("zebra crossings") with appropriate speed to ensure that he or she may stop if necessary.

Drivers are required to stop before the crossing if

- there is a pedestrian on the crossing or
- another vehicle has stopped before the crossing.

13.8.2 Description of the case

According to posts in web forums and blogs, many Hungarian drivers do not stop before pedestrian crossings. Our personal experience confirms this observation.

A particularly dangerous situation is when one vehicle stops for the pedestrians, then another one tries to overtake it on the left. In such cases pedestrians (especially children and short people) cannot see the coming danger because their view is blocked by the stationary vehicle.

It is not surprising therefore that many are injured or killed on pedestrian crossings.

A personal account from a web site (http://www.gumibiznisz.hu/nem-fordulhat-elo):

Driving a car I had to blow my horn on two occasions to stop the pedestrians on the crossing as a car travelling straight in the "left turn" lane could have hit them. Once I stopped school children this way.

Pushing a stroller, often we could cross the road at a pedestrian crossing only after I stepped in front of the cars holding my hand up. Drivers coming at speeds of 50 - 60 on a section with a 30 km/h speed limit sign often cursed me, including mothers carrying their children.

13.8.3 Lessons learned

Zebra crossings in Hungary do not seem significantly safer for pedestrians than other, regular sections of the roads.

Ensuring safety of zebra crossings should be a primary goal of Hungarian police. Sensors, cameras, personal police presence and speed limit signs should be used for this purpose.

13.9 Even bicyclists should know the rules

13.9.1 Background

Unfortunately it is a "tradition" in Hungary to use bicycles without the minimal safety equipment. For example, it is customary in villages to ride a bicycle in the evening without headlights, wearing dark clothes, often under the influence of alcohol.

No license is required for cyclists. Although in principle they are mandated to know the traffic regulations, due to the lack of examination, they often do not have even the minimal knowledge of the rules.

13.9.2 Safety regulations involved

All bicycles used on public roads must be equipped with yellow headlights, red tail lights, at least one reflector on the back and one on the front wheel.

The riders must wear reflective clothing outside inhabited areas, at night or in poor visibility conditions.

Bicycles must use the right side of the road, with a few exceptions (e.g. before left turns).

Overtaking by any motor vehicle is allowed only if the driver overtaking has made certain that the lane to be used for the maneuver is clear such that oncoming traffic will not be disturbed. (Consequently, an adequately long section of the road must be visible to the driver.)

13.9.3 Description of the case

On a March 2009 evening, on a road near Ajka, the driver of a Fiat passenger car tried to overtake a Mercedes. During the maneuver the Fiat hit one of the two bicyclists travelling opposite it in the left lane. The vehicle pushed the bicyclist for several meters.

The victim was a 19 year old man, who died on the scene of the accident. The other rider "disappeared" and could not be identified subsequently.

Investigation concluded that the speed of the Fiat was 94-96 km/h. (The allowed limit on that road is 90 km/h.)

The bicycle was not equipped with a headlight, however, the road was lighted, and consequently, visibility was good. Police established illegal overtaking as the primary cause of the accident. (The visible section of the road was too short to start the maneuver.) Another significant factor was that the bicycle was not travelling on the right side of the road but near the center. The lack of bicycle headlight played only a minor role.

According to unverified sources, the 20 year old driver caused an accident a year earlier, but the injured persons survived then.

13.9.4 Lessons learned

Bicyclists are vulnerable even when they are well equipped. Lacking appropriate safety equipment and knowledge of traffic rules, they are likely to become victims.

Increased awareness of the regulations and more regular checks by law enforcement could easily save a number of lives.

13.10 Theft prevention considerations at freight carrier

13.10.1 Background

According to experts, one of the most important root causes of accidents by professional drivers is fatigue. As a rule, commercial drivers in Hungary are considered experienced, well trained in traffic regulations and committed to safe driving. However, when they become fatigued due to excessive work hours, the risk of serious accidents substantially increases.

Cargo theft is a significant problem in many countries, including Hungary. Several companies contract with freight carriers only on condition that trucks carrying their goods must be guarded while parked. However, the number of guarded parking facilities for trucks is inadequate.

It is customary in Hungary to subtract from the drivers' salary the company's losses due to theft, accidents or fines, although this practice is illegal. (Legally, the company should first prove that the driver is accountable for the damage, and demand payment only after that.)

13.10.2 Safety regulations involved

In Hungary, the maximum amount of working hours and minimum length of rest times is strictly regulated for professional drivers. The regulations are complicated, and here we only summarize the most relevant ones for truck drivers.

Drivers are not allowed to work more than 10 hours on any day, and only on two days per week are they allowed to exceed 9 hours. After 4,5 hours of work it is mandatory to take a rest time of at least 45 minutes. After a day's work the driver is entitled to a minimum of 9 hours' rest. During rest time, the driver is not obliged to perform any work, even other than driving (e.g. administrative duties).

The maximum total amount of working time is 90 hours per two weeks. Rest time cannot be spent in a moving vehicle.

The work and rest times must be measured with an appropriate apparatus (tachograph). Drivers must keep in the vehicle the tachograph data for the last 28 days. Police is entitled to check the data and violators face severe fines.

13.10.3 Description of the case

A freight company, a significant player in the Hungarian market operates trucks transporting goods both within the country and internationally.

Many clients insist on contractual terms ensuring that the carrier provides appropriate guarding of the trucks while they are parked. This in practice could be accomplished either by using only guarded areas for parking or by escorting the vehicles with guards. Of these, the second would mean significant added cost. Consequently, the carrier provides escorts only in the case of exceptionally high freight value. In general, the company makes it the drivers' responsibility to park the vehicle only in guarded areas – this is stipulated in company policy.

As there are few guarded facilities in the country, and their location is sporadic, distances between them often cannot be covered within the allowed working time, especially if the driver spends significant times in traffic jams or waiting for loading or unloading of goods – this is also counted as working time. When there is not enough time left to reach the closest guarded facility, the driver is forced to choose between breaching company policy on parking (thus assuming liability for any theft) or not conforming with legal regulations regarding rest time (facing severe fines and a risk of causing accidents). Since the value of the cargo is typically high, they rarely choose the first option.

Consequently, drivers employed by the freight company regularly drive longer than the allowed legal limit. To avoid fines, they either try to bribe the police or alter the data in the tachographs. (The latter was relatively easy in the case of the older models, but the newer digital devices are difficult to tamper with.)

The management of the carrier is aware of the situation, but refuses to find solutions for it, claiming that it is the drivers' problem.

13.10.4 Lessons learned

In some organizations considerations such as cost saving, prevention of property loss or satisfying customer demands (delivery times) have higher priorities than traffic safety. In such cases breaching safety regulations may become institutionalized and communicated as company policies.

Building a supporting infrastructure may help increase safety, but only if the underlying motives of the participants are discovered and taken care of. (In this case, mandatory use of tachographs does not solve the problem until measures against theft are inadequate.)

Fines do not always punish the real perpetrators. Care must be taken in assigning responsibility. (In this case, the fine will be paid directly or indirectly by the drivers, while primary responsibility rests on company's management.)

13.11 Tired or sleepy drivers pose significant danger on the roads

13.11.1 Background

There is no statistics on the rate of accidents caused by the drivers' fatigue, as it is difficult to determine it by subsequent investigation. However, several sources indicate that it is an important root cause of accidents.

Professional drivers tend to be aware of the importance of breaks and rest times, but they are often not allowed to take the necessary time to refresh themselves (see Theft prevention considerations at freight carrier).

Nonprofessional drivers, on the other hand, could more easily afford to take the necessary rest times; still, they often keep on driving when they get sleepy or tired, ignoring its risks.

13.11.2 Safety regulations involved

Hungarian laws only stipulate rest times for professional drivers. There are no mandatory rests for non-professionals.

13.11.3 Description of the case

Many drivers admit that they have been involved in dangerous situations because of sleepiness. Both in private conversations and on web forums, an innumerable number of cases may be heard or read.

Here is a typical example from the Internet (http://autozz.blog.hu):

People need to learn from their own experience when they need just a little bit of gymnastics and when sleep is necessary.

On longer trips I recommend rolling down the windows. Having a conversation did not work out for me.

Although I had a partner to talk with, I still fell asleep just before a bend. When I woke, it was too late *to get back to the road; I only had time to avoid hitting the oncoming vehicle and the road signs. The car stopped in the ditch. Fortunately we were not injured.The person sitting next to me did not believe that I had fallen asleep, as he was talking to me continuously.*

13.11.4 Lessons learned

To prevent accidents caused by sleepiness of non-professional drivers, the only feasible solution seems to be increased awareness.

Roadside posters urge drivers on some Hungarian motorways not to drive when they are tired. Hopefully, these have already saved several lives, but the topic would deserve more attention in the media.

14 Case Study Finland: Traffic enforcement

Traffic enforcement by the police in Finland is shared by two bodies: Local police and National Traffic Police (NTP). When characterising Finnish traffic enforcement, it can be stated that there are areas that are internationally well taken care of. These are enforcement of drink driving, speed enforcement and the overall organisation and work of NTP.

A more problematic area has been the decrease of enforcement resources throughout the 1990's and the early 2000. The input of the local police in traffic safety has strongly decreased and is not at the level needed today. Moreover, legislation has been a bottle-neck for the development of more effective camera enforcement. Also R&D concerning novel enforcement methods has been retarding during the past years.

The weighting of the police input in various areas of traffic enforcement can be illustrated through the following table of NTP.

Type of enforcement activity	Number of activity
Traffic crime	6 087
Fine	100 095
On-the-spot-fine	62 039
Parking	599
Warning	36 394
Over-weight report	3 787
Vehicle weighting	8 873
Breath test	1 057 418
Drink drivers caught	4055
Driving- / rest-time check	38 513
Temporary driving ban	10 957

Table 9: Enforcement distribution in Finland

The distribution of traffic enforcement activities by the NTP is such that almost 50 % of the input is put in speed enforcement, some 20 % in overall driver behaviour such as reckless driving, overtaking or close-following, and somewhat less than 20 % in drink driving. The rest of the enforcement is targeted to heavy vehicles and the use of safety equipment.

15 Automatable Traffic Regulations

In this section, all traffic rules will be presented and examined in terms of the possibility of automatable recognition of violations against those rules. Secondly also those regulations will be taken under consideration which cannot be detected by our system but still could/will be provided to the drivers as useful information.

Thereby the inherent constraints of this project have to be taken into consideration.

As the ASSET-Road project is focused on motorways where high vehicle speeds occur and accidents with HGVs often cause fatalities, we will concentrate on rules that apply to those kinds of roads.

In the following each rule is examined. Some rules are only addressed very briefly as their violation cannot be detected automatically. For the other rules the following points will be addressed: First the rule is described briefly then the importance in terms of traffic safety is stated.

After that we briefly list some differences in the rules of the countries of the European Union and create a table containing the rules of the counties where test sites will be created: Finland, Germany, France and Austria for the main vehicle types: passenger cars and heavy goods vehicles. We describe the current techniques used in European countries to enforce the rules briefly. Then we make suggestions how the rule can be detected within the ASSET-Road roadside detection system; which is the base of communicating information to the drivers. Then we describe the differences between the ASSET-Road and the usual techniques. After that, the possible representation of the rule in a Regulation Database is presented.

15.1 Safety Equipment

Detection of correct usage of safety equipment is not part of the automatic detection in the scope of the ASSET-Road project. However, the presence of safety equipment could be detected in the future when the safety equipment has embedded RFID-Chips.

A sensor in the street pavement could detect the presence of the safety equipment on board of each passing vehicle. Most of these rules can be written to a rule base as true/false-value. Another possibility is the use of image processing algorithms, which are able to detect missing safety-equipment by analysing real-time video-streams from the vehicles passing the video camera. Within ASSET-Road a research project by a partner is done regarding an automated detection of the usage of seat belts of the drivers in the front row.

15.1.1 Safety Helmets

Safety helmets have to be used on motorcycles and mopeds in all European countries. There are exceptions however for motorcycles with a rigid cabin, which also use a restraining system. Wearing of Safety Helmets can currently not be detected automatically and will not be in the ASSET-Road scope.

15.1.2 Fluorescent Clothes (Warning Vest, High Visibility Jacket)

The existence of fluorescent clothes can't be controlled automatically yet. However, it would be useful to inform the drivers that they should have fluorescent clothes, especially when a border is crossed to a land where these clothes are mandatory. Furthermore when drivers stop on the emergency lane they should be informed to use the warning vest.

15.1.3 Use of Safety Belts

The use of safety belts is mandatory in all European states. However, there are exceptions which cannot be regarded (e.g. pregnant women, taxi drivers, special medical reasons). It is possible to detect the use of safety belts on the front seats. However, there could be false detections. For example: false negatives, e.g. "driver not using the seat belt", when the driver wears black clothes, or false positives when there is a shadow on the driver.

15.1.4 Use of Child Restraint Systems

This rule cannot yet be detected automatically. The parents are responsible to secure their children correctly. Of great importance is the deactivation of the front seat airbag when a child restraint system is used in the front seat.

15.1.5 Warning Triangles

Like the usage of fluorescent clothes the possession of warning triangles is not yet detectable. However, drivers should be informed upon crossing a border about the necessity of the item or when stopping in the emergency lane how to setup the warning triangle correctly. There are different rules for each country about the distance to the car, where the triangle has to be placed on the street.

15.1.6 First Aid Kits

First aid kits are mandatory in all European states. However, drivers should be informed about the need to check the kit regularly.

15.1.7 Fire Extinguishers

Fire Extinguishers are mandatory for some vehicle types in European countries.

15.1.8 Vehicles Breakdowns and Accidents Signaling

On a vehicle breakdown which can be detected, when the system detects a not moving car on the emergency lane. The driver can be informed to turn on the warning lights and sometimes the head light, setup the warning triangle correctly. Also the driver could be informed which emergency numbers he could call in the specific country.

15.1.9 Child Seats on Bicycles and Mopeds

Not automatable.

15.1.10 Winter Tyres

Winter tyres are a safety critical point when driving a vehicle in winter. Below 7 degrees of Celsius the rubber mixture of summer tyres gets too hard, so the traction decreases. Therefore winter tyres should not only be used on snow but already when the temperature falls below 7°C. Winter Tyres are not mandatory, however in most countries in Europe. Some countries, like Finland, Estonia, Latvia, Lithuania and Slovenia define time spans, where winter tires are mandatory, usually from the middle of November until March or April.

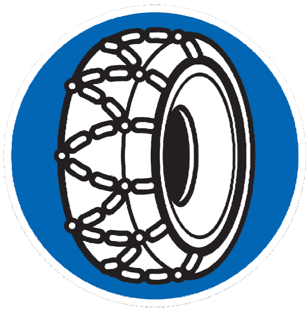
In Germany for example, a driver get's problems with his insurance company when it can be shown that an accident could be avoided using winter tyres. The German "Straßenverkehrsordnung" (StVO) says that "the car equipment must be adapted to the weather conditions, especially the tyres". However, rented cars often don't have winter tyres if the user does not explicitly ask for it.

For HGVs the rules seems to be stricter. From the 15th of November to 15th of March vehicles over 3.5t have to be equipped with winter tyres on their driven wheels.

In the ASSET-Road scope the automatable detection of those tires is in principle possible. The company ProContour (www.procontour.com) has developed a system that can detect the tyre types and the current wear level of the tyre. This system will however not be part of the fully automatic detection on the A8 in Germany, but it is planned to incorporate that system on the parking area.

15.2 Snow Chains

Under certain weather conditions snow chains may be mandatory. Usually these signs can be found on mountain passes in the winter. On a motorway it is not used usually. The detection of a violation is currently complete done manually by police officers. It will not be possible to detect this violation in the ASSET-Road scope – but induction loop clusters on the driving lane could recognise magnetic detuning and the presence of metal.



Firgure 67: Snow chain sign

15.3 Traffic Rules

In this section all traffic rules are considered which could be automatically observed. The main aspect of ASSET-Road is road transport on motorways so the rules that don't apply on motorways are listed in the next section. After that the rules are examined, which play a role on motorways.

15.3.1 Rules which are not relevant on motorways

As the ASSET-Road project is aiming on motorways we do not consider the following rules, as they are not relevant in this environment. For example, pedestrians are not allowed on the motorway. Hence there are no rules for boarding passengers or pedestrian crossings. However, the system should be able to detect obstacles on the motorway, such as cars standing on the emergency lane.

The following rules do not apply to motorways

- Pedestrian Crossing
- Level Crossings
- Standing and Parking
- Boarding and Alighting Passengers
- Loading and Stowage

15.3.2 Application of Local Restriction on Road Traffic

Almost no road is free from local restrictions. Hence for an automatable use of traffic regulations, it is important to be able to check local restrictions. These restrictions can limit or extend almost all traffic rules. Local speed limits are the most usual but also minimum speed, overtake restrictions or for example the use of snow chains can be part of a local restriction. To fulfil that requirement, a data structure has to be developed that makes it possible to store local restrictions, so the automated system can use them to be enabled to enforce the local restrictions. This representation should be able to store all relevant rules combined with a longitude position where this rule is in effect. If no such rule is in effect the system should use the general rules that apply on that road depending on the vehicle type, road type and the country, where the road is located.

15.3.3 Direction of Traffic

The direction of traffic in almost all European Countries on the continent is on the right side. In the United Kingdom and Northern Ireland as well as in Ireland the direction of traffic is on the left side. The automated system should be able to work with both directions of traffic.

15.3.4 Driving in the wrong direction

On motorways there are separated roads for each direction. There exists the rare situation when a driver drives very wrong onto a motorway, for instance when he is old and lost the overview, and starts to drive down the motorway in the wrong direction. In Germany this is common enough that it is denoted as “ghost driver”. The big problem is that once, a vehicle is driving on a motorway in the wrong direction, there is no save way to get of the motorway anymore. And with the high speeds you are allowed to drive especially on the German Autobahn, this is very dangerous for all drivers on the motorway. The common way to react to that situation, when it is detected, is to inform the police and radio stations. The radios broadcast the information and hopefully the drivers driving on that route listen to the radio. At the same time a police vehicle tries to catch up with the “ghost driver” on the correct side of the motorway and try to stop him.

Detecting such a situation with an automated system in this project is possible. The vehicle driving in the wrong direction can be identified by a velocity which has negative values. In this case a warning message to all upcoming vehicles has to be sent. The reaction of the drivers should be to drive slow on the right lane and be prepared to perform an evasion manoeuvre.

15.3.5 Priority Schemes

Priority schemes are important on motorways mainly at the acceleration lane. Here, the vehicle which is already on the motorway has priority. But each vehicle should make it possible for the vehicle on the acceleration lane to change the lane safely. Also in construction sites often two lanes merge to one and the vehicles should drive one by one to the new land (zip-merge).

15.3.6 Use of Lights

In many countries in the European Union it is mandatory to use the headlights also at daylight. In Austria, for example using the headlights was mandatory from November 15th 2005 until December 31st 2007. The law was revoked because there was an increase in accidents. This comes from the fact that the cars could be seen well but the pedestrians and bicycle drivers where less visible, when all vehicles were using the headlights at daytime. Some countries don't have that rule but many people use their headlights on the motorway nevertheless. Many new cars are now equipped with special daylight headlights, which also increases the use of daylights.

The driver should be informed when he enters a country where the use of the lights at day is mandatory. However, it is not planned to detect the correct use of the daylight within this project as the cameras will not be able to detect it failsafe.

15.3.7 Special Lanes

Special lanes are not allowed to be used by all vehicles. Most common special lanes can be found in cities, which are only allowed for bus, taxi, fire engines, ambulance and police. On the motorway the most common special lane is the emergency lane, where a vehicle is only allowed to be located in case of an emergency.

In Bavaria (Germany) a new kind of traffic influence system exists on the A 73 motorway. It allows the emergency lane to be used as normal driving lane when the traffic volume is high in the rush hour. It consists of several observation cameras for that lane and a system that automatically detects breakdown of vehicles and accidents. Then the emergency lane is immediately closed. The system is a big success, as the traffic jams where reduced dramatically and the number of accidents was also cut by half. But it is also stated that it is not a desirable permanent solution and that the motorway should better be extended to 6 lanes.

Not all vehicle types are allowed on all lanes. HGVs (precisely vehicles with more than 3.5 tons maximum loaden mass or a length of more than 7 meters) for example are not allowed on the leftmost lane on German motorways with three lanes, except for the purpose of turning left. In case of a "no overtaking" sign for HGVs, they are also not allowed to use the middle lane.

Overtake allowed on motorway with two lanes

Rule	AT	DE	FI	FR	H
Car	Y	Y	Y	Y	Y

Use of the left lane on motorway with 3 lanes

Rule	AU	DE	FI	FR	H
Car	Y	Y	Y	Y	Y

15.3.8 Use of Mobile Phones

The use of mobile phones when driving is forbidden in most countries of the European Union. Often it is allowed to use a hands-free set instead. Currently the police detect this violation manually. In Germany in 2007, 392.000 violations were fined. VTT is checking the possibility of automatically detecting this violation within this project. However, this system is not expected to work fail-safe. There can be mirroring effects on the windshield and other circumstances that lead to false positives as well as false negatives. Hence a violation cannot be fined based on that system. However, the information could be sent to driver.

15.3.9 Speed Limits

Speed limits are the standard rule to keep safety on the road. Also, it is the rule which is most often violated against. Many drivers are not aware that they risk their license and also their and other people's lives. State of the art in increasing the awareness of the drivers concerning their speed is a navigation device, which can inform the drivers when they drive too fast.

Speed limits are the most important rule concerning traffic safety. When there is an accident, double speed causes four times energy which leads to much worse traffic accidents. Also the ability to break decreases the same way: As we can see on the left figure, the correlation between breaking distance and velocity is not linear but quadratic. A vehicle driving 100 km/h breaks in about 40 m. A vehicle driving 200 km/h has breaking distance of about 160 m which leads to a higher likelihood of an accident. And the reaction time is not even included in this calculation.

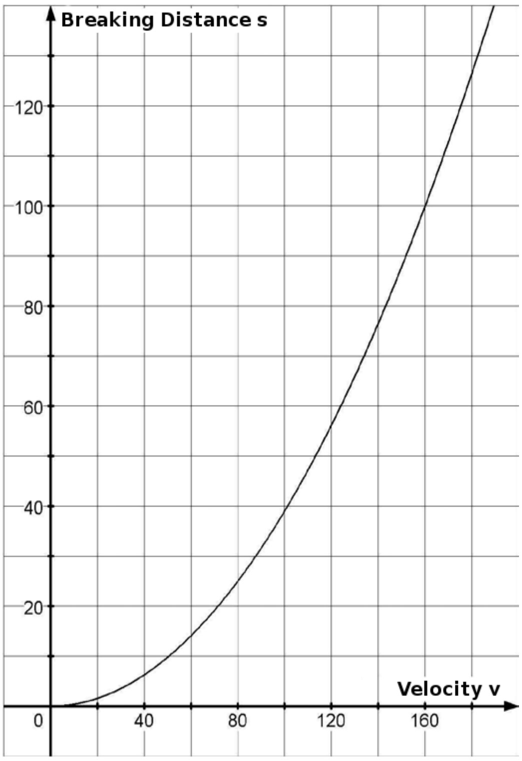


Figure 68: Breaking distance in relation to velocity (Ewert, 2005)

In the European countries, the speed limit is quite similar. On urban roads, usually 50 km/h are allowed for all vehicles. Outside urban areas up to 100 km/h and on motorways up to 130 km/h, whereas Germany is the only country, where motorways exist that have no general speed limit. However it is recommended to drive 130 km/h on the "Autobahn". For HGVs, the maximum speed is 80 km/h in most European countries. Current Enforcement Techniques

The classical detection method for speeding is the use of radar traps which can be stationary or mobile. The stationary traps (often induction loops) are very effective to secure a dangerous point of the road. As the local drivers will know the spot pretty quick, they will drive slower and slow down the whole traffic at this point. But some meters after the trap they often accelerate to their previous speed again. Therefore mobile radar traps are used, so the drivers never know where they could be detected. Laser speed measuring devices are another method which are mobile and are operated by specially trained police officers.

A different method is “section control”, where with only two control units, usually video-monitored with number-plate recognition, are sufficient to control the complete section between those units. Thereby not the actual speed of the vehicles but the average speed in this section is observed. This method works very effective in terms of violation reduction and it is also cost efficient. Additionally, in combination with a weigh-in-motion system, it is possible to observe the obeying of speed limit rules depending on the type of the vehicle (e.g. trucks and busses have a speed limit of 80kmh and passenger cars have 130km/h).

Detecting rule within ASSET-Road roadside system

There are two types of speed surveillance and control: on short areas and on sections between 1-2 km or even longer.

The system that will be developed within the ASSET-Road project will consist of two number plate detecting cameras at the start and the end of the controlled section. Therefore it is equivalent to the section control approach, but additionally there will be surveillance cameras on the whole section. Hence the speed of the vehicles at each point of the section can also be controlled.

The speed rule can be saved in a lookup-table (LUT) but as there are differences in the countries of the EU, which lead to increased number of dimensions. For example, in France the speed limit depends on the weather situation. When it is raining, a general speed limit of 110 km/h is in effect, whereas 130 km/h is the speed limit for good weather. Also there are different speed limits for HGVs, depending on the maximum weight.

Rule	AT	DE	FI	FR	IT	H
Car	130	130	120	130 (110)	130	130
HGV	80	80	80	90 (>12t) 110 (<12t)	80	80

15.3.10 Minimum Speed

Figure 69: Minimum speed sign

Sometimes there are lanes where it is not allowed to fall below a certain speed. For example when there is a hill on a motorway, the left and the middle lane often have signs that indicate a minimum speed. A vehicle that cannot keep that speed is considered dangerous on this lane, as there are large speed differences; hence it has to move to the rightmost lane. Right now minimum speed is not checked by any automatic system. On German motorways the minimum speed is 60 km/h. But the recommended speed is 130 km/h. For traffic safety it is important to decrease the speed differences on the street. Therefore each vehicle should go about 130 km/h and not less than the trucks are allowed to drive (80 km/h) because this would force the trucks to overtake these vehicles as they often drive under time pressure and are not willing to go slower that they are allowed.

The automatic detection of this rule is not as easy as it might appear. First, one has to take into consideration that the vehicle goes slow because the traffic is dense and the vehicle in front is slow, too. A possibility is to check the distance to the driver in front. If this distance is for example twice as high as allowed, the driver could go faster. An increasing distance to the front driver is an even better indication of too low speed. The second point is that in bad weather situations it is allowed to go slower than the minimum speed. In rain or fog the minimum speed should therefore not be checked.

15.3.11 Distance between Vehicles

The distance between vehicles (dependent also on weather conditions and visibility!) plays a major role in traffic safety. Often, drivers try to press the vehicle in front, flash their headlight to further force the driver in front of them to move from the left lane. This aggressive behaviour always comes in conjunction with following distance violations. But when it comes to a traffic jam or another unattended situation which causes an abrupt breaking of the vehicle in front, an adequate distance to the vehicle in front is most important to avoid a collision.

Importance of the rule

Low distance driving is one of the most important factors concerning traffic safety. The safety distance is correlated to the current vehicle speed. But there is no system onboard of a vehicle that can tell the driver the correct safety distance. HGV-Drivers can use the reflector poles that have a distance of 50 m on motorways to determine the correct safety distance. Drivers of vehicles that can drive much faster have to estimate the correct distance. This estimation often turns out to be wrong.

Currently there are research developments of major car manufactures that are checking the usefulness of distance/speed measurements based on laser beams or high frequency radar.

Rule Differences in EU Countries

In the following "distance" is usually defined as the stopping distance of the vehicle under the current conditions. It is one of the most important safety rules. It depends on many parameters, where the most important one is the speed of the vehicle. But different vehicles have different breaking distances due to different technology (e.g. with ABS/without ABS), the slope of the road can increase the stopping distance and the friction of the surface, which changes under different conditions (rain, snow, ice) and is also dependent on the type of tires mounted on the vehicle which has a great impact on the breaking distance. Therefore it would be absurd to define the security distance physically correct.

Hence, most countries of the European Union have chosen to make a rather lax definition. The following distance is defined in most countries as "enough distance, so that no crash occurs in case of a sudden break of the car in front" (* in the table below). This definition is based on the driver's estimations about how their vehicle would react and how fast it could stop under the current conditions. However, in reality there are not many situations where the car in front is suddenly comes to a full stop. Hence, many drivers don't seem to have much interest in keeping the following distance. They often use the fear of other drivers to "push" them to the right lane by intentionally tailgating another vehicle. Therefore, for example in Germany the distance that leads to a fine is not defined in the traffic rules of the state (here "StVO") but in the fine catalogue of the police.

Rule	AT	DE	FI	FR	H
Car	*	* (Speed/2)	*	2 sec, > 7m	*
HGV	50	50	*	50	One passenger car has to be able to fit in front of the HGV

Current Enforcement Techniques (briefly)

There are two different kinds of surveillance, stationary and mobile. In Germany, the stationary method uses cameras mounted on bridges. Therefore no expensive poles need to be mounted and the system can be used nomadic. On the pavement there have to be lines to calibrate the system correctly. The system works automatically, but some conditions have to be verified manually to impose a fine. The first condition where tailgating does not lead to a fine is when the vehicle in front is breaking. In this case the driver is not guilty of tailgating because he has no other chance. The second condition is when there is a car changing the lane directly in front of the driver. If none of the conditions is satisfied the driver is fined of intentional tailgating.

The mobile detection of tailgating and aggressive driving is carried out completely manually by police officers driving an unmarked car which is equipped with a surveillance camera. They follow suspicious drivers and check their behaviour.

Detecting rule within ASSET-Road roadside system

In the ASSET-Road project, the distance of the cars is measured by using the positions of two vehicles which drive behind each other. Therefore we need the position, the speed, the length and the lane information for each car. Then for one car X, we can filter out all cars that are on other lanes and take the car Y which is closest in front.

Then, if we assume that the position is in taken at the front of each car, the distance is

X.dist = Y.pos - Y.length – X.pos.

Difference between ASSET and usual Technique

The technique we use is based on structure from motion, which will not be able to produce really precise distance data (for example the shadow of a car might be interpreted as part of the car). Therefore, the data will not be used to automatically fine the driver. However, the technique will be used to alert the driver so he can react to the situation and will be aware of the danger he causes by not keeping the safe following distance. Secondly, we will check the possibility of automatic detection of intentional tailgating.

Representation of the rule in the Regulation Knowledge Base

The security distance is most often determined by the speed of a vehicle. Hence in the regulation knowledge base, a formula has to be places which can be used to calculate the correct safety distance. Physically correct it should be about speed^2/250, which would approximate the break distance curve in Figure on page 162 pretty good.

Rule	AT	DE	FI	FR
Car	?	Speed/2	?	2 sec, > 7m
HGV	50	50	50	20? 10?

Situation Recognition

To detect intentional tailgating, complex situation recognition has to be developed, which also complies with the facts described above: it has to be clarified, whether the driver in front of the vehicle did break in a certain time span or if there was a line change in front of the driver, meaning that the security distance was decreased by that situation.

15.3.12 Overtaking

Overtaking is to approach behind another vehicle, which drives in the same direction and to pass it. An overtaking manoeuvre does not necessarily include a lane change, so simply by driving faster in one lane than another vehicle in a different lane is considered as an overtaking manoeuvre. When an overtaking manoeuvre is initiated by a lane change, in all European Countries the manoeuvre is indicated with the turn indicator. In and outside urban areas in some countries, the indicator has to flash for the complete manoeuvre. There are different conditions where overtaking is not allowed in some countries, for example at road bottlenecks, humps, junctions, bends or pedestrian crossings. On motorways the situation is different, as there are multiple lanes in one direction. Here the indicator is used for the lane change and an overtaking manoeuvre is not as dangerous as there is no oncoming traffic. However, the speeds are usually much higher on the motorway, especially in the leftmost lane where very fast cars can be driving. Therefore, the driver should overtake as fast as possible and afterwards go to the rightmost lane again if the traffic situation allows it. In all European countries it is usually not allowed to overtake on the same side of the direction of traffic, but there are exceptions in some countries. When the volume of traffic is so high that convoys are moving in each lane, in most countries it is allowed to drive faster on the right lane. Also, on the acceleration lane leading to motorways in Germany it is allowed to overtake on the right side.

Overtaking manoeuvres can be dangerous. Often they are carried out in an illegal manner. Illegal overtaking often also includes short distance and over speeding.

Overtake on the right lane.

Detecting an incorrect overtaking is a challenging task. There are different violations drivers can commit, which have to be dealt with separately. There is correct and incorrect right overtaking as well as correct and incorrect left overtaking. To be sure that a right overtaking manoeuvre is incorrect the following points must be made clear (rules for Germany only): If the overtaken vehicle is driving in a column with less than 60 km/h and the overtaking vehicle has a speed of not more than 20 km/h above the speed of the overtaken vehicle or the overtaking vehicle is on an acceleration lane, then the manoeuvre is correct.

Slow Overtaking (Elephants Race)

A driver should only overtake when he is driving much faster than the vehicle he wants to overtake. HGVs with speed limits implemented often try to overtake with only low speed differences of about 2-5 km/h. This leads, expecially on a 2-Lane Highway to big speed differences to the cars approaching on the left lane. They have to break down to 90km/h and while the truck is overtaking, a long queue may emerge, even a traffic jam is possible in a high traffic situation. Hence slow overtaking should be detected and the driver should be warned. Therefore the system has to calculate the speed difference of the vehicles. If it is below 10 km/h, the overtaking is too slow. But a driver may overtake slow because he is following a slow vehicle. In this case, he should not be told to drive faster. Therefore the distance and speed difference to the leading vehicle has to be checked too.

Undertaking

When a vehicle on the left lane suddenly gets slower than vehicles on the right lane, without having a vehicle in front that gets slower, a undertaking manouvre may be happening. This vehicle is forcing all vehicles behind and even on the right lane to adapt to his speed. Such a driver should be warned and change his lane or drive faster again and not be an obstacle on the road.

15.3.13 Changing Lanes

The regulation of changing lanes is connected to the overtaking rules and is therefore defined in the same article of law as the overtaking rules in most European countries. Changing lanes is forbidden when a continuous line separates the lanes. Sometimes lanes are allowed to be crossed in one direction but not in the other one (e.g. within the accelerating lane). In all European countries the turn signal indicators have to be used to signal the intent. When the traffic allows it to change the lane safely (no fast subsequent vehicle, no vehicle in the blind spot), the lane can be changed. The vehicle changing lanes is not allowed to endanger subsequent vehicles. That means that if a subsequent vehicle has to break sharply or deflect, the manoeuvre is forbidden. However, the driver of the subsequent vehicle should enable the lane changing vehicle to perform the manoeuvre safely, which means that he should ease of the accelerator and not (what unfortunately happens sometimes on motorways) accelerate and claim the lane for his own.

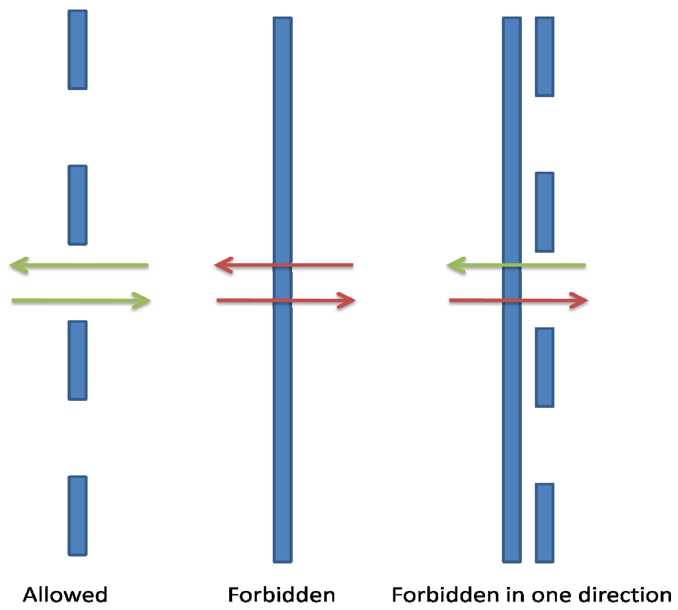


Figure 3: Lane crossing

15.4 Vehicle Characteristics

15.4.1 Classification of Vehicles

An elementary point of the automatable usage of traffic regulations is the classification of the vehicles. To know which traffic rules to use for a vehicle it is necessary to recognize the type of it, because different rules apply to different types of vehicles.

The directive 2007/46/EC of the European parliament and the council establishes a “framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles” [2007/46/EC].

There is a vehicle classification which will be used by all European countries in the future.

Today, many countries have different vehicle classifications, but some have already created links to the EU classification.

In this directive, the vehicle categories are defined according to the following classification: (Where ‘maximum mass’ in the following definitions means ‘technically permissible maximum loaden mass’).

Category M: Motor vehicles with at least four wheels designed and constructed for the carriage of passengers.

Category M_1: Vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver’s seat.

Category M_2: Vehicles designed and constructed for the carriage of passengers, comprising more than eight in addition to the driver's seat, and having a maximum mass not exceeding 5 tonnes.

Category M_3: Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass exceeding 5 tonnes.

Category N: Motor vehicles with at least four wheels designed and constructed for the carriage of goods.

Category N_1: Vehicles designed and constructed for the carriage of goods and having a maximum mass not exceeding 3,5 tonnes.

Category N_2: Vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 3,5 tonnes but not exceeding 12 tonnes.

Category N_3: Vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 12 tonnes.

Furthermore there are the categories O for trailers, G for off-road vehicles of type N or M (For example N1G). For the automatic rule detection, only those types are relevant to which different rules apply. It may not be possible to distinguish between all different vehicle types by camera vision only. Therefore, in the future RFID tags could be integrated in the badge placed on the vehicles number plate. In this project we will do a test using an RFID-Sensor integrated in the pavement for reading those tags. In this way, even a vehicle that has a technically permitted maximum mass of 40 tonnes, but its weight limit is decreased administratively to 20 tonnes, can be handled correctly. A further indication of the vehicle types can be achieved by a weigh-in-motion system, which is able to deliver the number of axles, the axle distances and the truck width as additional parameters for detecting the type of a vehicle.

15.4.2 License Plates

License plate recognition plays an important role in traffic surveillance. In Europe all newer license plates have a blue stripe on the left side with the yellow stars of Europe and the abbreviation of the country. However, the style of the number plates still varies. Many countries use black on white and a combination of characters and numbers. The font of the text also differs. Within this project, KRIA will use their number plate recognition system which is based on high definition cameras. Also, a system that can read RFID-Tags on the license plate will be tested.

15.4.3 Dirty or missing license plate

It may happen that a license plate is not present or dirty and cannot be read. In this case, the driver cannot be warned, as he cannot be identified. The authorities may be alerted.

15.4.4 Special Vehicles

Special vehicles are a new kind of vehicles, which don't use the usual diesel or petrol motor as well as vehicles, which are limited to 30 km/h. Some of those vehicles are not allowed to drive on the motorways due to that limitation. The new kinds of vehicles are those vehicles that will be standard in the future. They include cars with electric motors, hybrid motors and liquid gas powered cars (LGP). Those LGP vehicles are often not allowed to park underground for security reasons, but concerning motorways no special rules apply for those vehicles.

15.4.5 Use of Trailers

The main violation of the rules for the use of trailers are overloading, missing the under run protection device, trailers of inadequate size and weight and trailers with insufficient lighting. The weigh-in-motion sensors would be able to measure the load of a trailer, but only combined with a RFID tag containing the maximum allowed loaden mass of an overloaded trailer could be detected.

15.4.6 Tyres

Tyres are one of the most important parts of the vehicles but are often not in correct condition. The main safety aspects are the correct type of tire (summer/winter), the remaining profile and the correct tyre pressure. Low pressure on the tyres not only increases the amount of gas needed to travel and decreases the lifetime of the tyres, but it also has great impact on safety. Low pressure leads to a tyre warm-up, inside the tyre the material is exposed to more stress which can in conclusion lead to a blowout. Furthermore it has a bad influence on aquaplaning, breaking and leads to a more unstable car when changing lanes or driving around curves. Due to the heat dissipation of low pressured tyres the pressure can be controlled by the infrared camera used in the ASSET-Road project; however this camera can only control the right tyres of the vehicles driving on the right lane. For HGVs also the left tyres may be checked. There is also the possibility of checking the tyre profile which will be implemented in the parking area of the A8 but not on the road. However this could be possible in future too. In future it may be possible to implement the thermal camera between the weigh-in-motion sensors to allow a view of all tyres, all brakes and the power line to detect overheated tyres or brakes. Additional it would be possible to detect non-working brakes due to their low temperature. Finally in combination with new weigh-in-motion sensors it could be possible to detect tires with too low air pressure (due to a larger footprint than the other tyres of the vehicle).

15.4.7 Vehicle Documentation

In some countries in the European Union it is necessary to carry the vehicle documentation on board while driving. In others it is compulsory for HGVs only. In Spain it is even necessary that the identification card and the technical card of the vehicle, the roadworthiness certificates, the insurance contract and the last insurance receipt as well as the driver's personal ID and driving licence are on board. Of course the presence of the documentation cannot be automatically detected.

15.4.8 Roadworthiness Tests

For the roadworthiness of the vehicles all countries have their own regulations. The key point to do those tests is to ensure a safe vehicle that is no threat to the owner and to other road users. In most countries vehicles have to be inspected every 12 or 24 months. In principle it could be possible to check the roadworthiness badges by camera (although it is not planned to do that within this project), but using badges with embedded RFID tags would be much more fail-safe. However, having a valid roadworthiness badge doesn't ensure that the vehicle really is in good condition.

Especially HGVs are in focus of ASSET-Road. The pure mass of HGVs can lead to immense destruction when they are involved into an accident. Many fatalities on the roads in Europe are caused by HGVs, twice as much regarding the driven kilometres than in accidents where no HGVs are involved. In fact, a driver of a HGV has seven times greater risk of being killed at work in an accident .

HGVs are often not in the condition they should be. Because there is a great financial pressure in the transport industry, necessary maintenance work is often not carried out. Many HGVs have defective brakes, which leads to overheating, which can cause vehicle fires. Defective brakes are also often the root cause of accidents but in the accident statistics this is not necessarily documented because other factors (for example driver micro sleep) find their way into the statistics.

All those factors lead to decreased safety. Certainly, we cannot check the complete vehicle on the fly, but using infrared cameras defective or missing brakes can be detected. These HGVs can then be sorted out to do a manual check of the functionality of the brakes.

15.4.9 Noise

There are rules in effect indicating how much noise a vehicle is allowed to emit. This could be checked in principle by a microphone; but on the motorway, the tyre sound is louder than the motor noise, making it impossible to test it. Furthermore, it would be hard to separate the sound of a specific vehicle in dense traffic. Maybe in future a combination of directional microphones and Fourier analyses of the different spectral distribution of the noise may lead to measureable indicators for noise.

16 Automated Support Levels and Systems for Drivers

Here, we give an overview of the rules that have the potential of automated recognition. We order them by their significance in terms of safety issues on the road. Some of the rules are obviously important for road safety, like speed and distance keeping. Others are often not monitored in the statistics correctly like failures of brakes.

16.1 Information

One key aspect of ASSET-Road is to inform the driver of the rules he might not be aware of. It has to be identified which rules are the ones, the drivers are not aware of. Often truck drivers drive though many European countries and the rules change in each country. Candidates for those information rules are all general rules that only change when entering a different country. These properties may be different for various vehicles types and are listed in the following sections.

16.1.1 Vehicle Measures

These vehicle measures are Maximum Height, Maximum Width, Maximum Length, Maximum Weight and Maximum Axle Weight. These measures are usually global valid but there are also streets where the maximum width may be lower, bridges which have a low maximum weight or tunnels with a low maximum height. The driver has to be informed, when his vehicle doesn't comply with the maximum measures. In some cases the driver would have to change the lane, driving route or stop the vehicle completely.

16.1.2 Safety Equipment

The safety equipment that has to be carried in European countries is still not harmonized. Warning triangles and a rescue kit have to be carried in all European countries, but for Fire Extinguishers and High Visibility Jackets, the rules differ in various countries within Europe.

16.1.3 Tyre Properties

The Minimum Profile for summer tyres is 1.6mm in all European countries. However, for winter tyres it is different. The countries which are used to snow on the streets have realized that 1.6mm is not enough profile for winter tyres to maintain their quality characteristics. These countries sometimes have a Start Date and End Date for Winter Tyre usage. These dates may be recommended or strict and may be adapted to the current weather situation.

16.1.4 Other Safety Properties

The Maximum Blood Alcohol allowed differs in the countries of the European Union and the driver should be aware of that. Furthermore the use of Daylight is becoming popular and in some countries is mandatory the whole year or for a specific time span. So the Start Date and End Date for the use of daylights should be provided to the driver.

16.1.5 General Tempo Limits

Most important, the general tempo limits have to be known by the driver for the following street types: Inside Urban Areas, Outside Urban Areas, Expressways and Motorways.

Furthermore he should be warned if the country has different general maximum speed like in France.

16.2 Warning

Warning signals are displayed to the driver when there is a situation that needs all his attention. However, it is crucial, that the warning does not distract the driver but alarms him in time, so he has more time to react than he would have without the system. This could be of various factors:

Dangerous Situations

- Traffic Jam
- Slow Traffic ahead
- High Speed Differences
- Blind Spot check

Rule Offence

- Speed Limit Exceeded
- Low Distance
- Right Overtaking
- Slow Overtaking

16.3 Interaction

The definition of the interaction of an on-board traffic support system with the driver is an important factor. This system (“LISA” – Live In-vehicle Smart Assistance system) is the interface between the driver and the roadside system. The data of driver behaviour, which is processed on the roadside and evaluated by a multi-agent system, is transmitted to the LISA device and provided to the driver. As different dangerous traffic situations and different rule offences as well as the current driver status affects the way of information provision and the interaction of the driver with the system, these aspects will be evaluated in WP3. These main aspects are:

- How to provide information to the driver in a certain situation
  - Visual
    - Graphical icons designed like traffic signs allow the driver to check the current traffic rules in effect.
    - May distract the driver in dangerous situations
  - Auditory
    - Standard non-visual information provision which does not distract the driver as he still can pay attention to the current traffic situation.
  - Tactile
    - May warn or wake up the driver of very dangerous situations
    - Must be integrated into the vehicle, not possible with just an onboard-unit.
- When to provide information to the driver
    - The driver should not be distracted. So in dense traffic situations where the driver has to pay attention all the time the HMI should not try to tell him information that is not important at that time.
    - Warning the driver in time can prevent accidents. It is important to find out, when the driver has to be informed of dangerous situations and how. This information can then be used to tune the multi-agent system so it can deliver the information in time.

17 Technology & Regulations – Matrix

17.1 Introduction

In this section, the technologies (currently used, ASSED-Road and future Technology), which can be used for the automation of traffic regulations, are shown.

An “x” means fully automated detection, an “(x)” means half-automated detection. An “s” means that his technology can be used to support fully automatic detection.

The Regulations shown here may all be included in the automatic detection. However, it may be possible that the system mixes up vehicles, when they drive close to each other and the precision of this new technology has to be tested. Using a multi-agent system is a good approach evaluating the tracking and tracing data of the vehicles and finding out the rule violations. However, as the system is designed primarily to support the driver, also dangerous traffic situations like “traffic jam” can be implemented.

Technology / Traffic Regulation	Speed Limit	Distance	Minimum Speed	Overweight	Right Overtake	Slow Overtake	Right driving rule	Brake Failure	Tyre Profile	Safety Equipment
Radar	x									
Section Control	x									
Bridge Distance Measuring		(x)								
Number Plate Recognition	s	s	s	s	s	s	s	s	s	
Weigh in Motion Sensors	x	s	s	x	s	s	s			
Infrared Camera				s				x		
Tyre Profile Detector				s					x	
Tracking & Tracing					x	x	x			
RFID on Number Plates	s	s	s	s	s	s	s	s	s	
RFID on Everything										x

Table 10: Application Matrix
(Current technology: green, ASSET-Road Technology red, future RFID Technology blue)

17.2 Evaluation of physical knowledge delivery mechanisms

The idea is to create a mechanism that the regulation knowledge base can be easily delivered, for example with a “European Regulation Memory Stick”, an e-mail attachment or via download from the internet.

The problem is that there must be a program on the other hand, which can make use of that knowledge. So the goal is to make it easy for other programmers to access the data. Usually, if much structured date has to be saved, one makes use of a database.

To access the data from a database with a program that needs that data, one needs to connect to a database service (for example MS Access or SQL-Server) that creates access to the database via SQL-Commands. Secondly, a database should be free of redundancy, so accessing linked data would imply to access different database tables what makes it costly to program the data access.

When the structure of the database changes a bit, the program would have to be changed. Today in computer science the object-oriented view is state-of-the-art, which brings together function and data. So, when the rule data is stored into a “Regulation Object”, this object can be used to access the data in a much easier way.

To improve the access to the data, one may introduce redundancies. However, there should be also a database without redundancies from which the regulation Object” is created. For deployment of the regulation knowledge base, the object can be written to a file. This process is called serialization and the result is an XML-representation of the object. It is not a binary file but a human readable text document, which can be easily exchanged.

The structure of the XML can be defined as XML Schema Description. This description is also an XML-file which can be used to automatically generate code to parse a serialized rule file and reconstruct the “Regulation Object”. This object can then be used by the programmers to access the data in an easy way. For ongoing research and development where more and more regulations may be checkable fully automatic a versioned XML-scheme can be developed.

18 Appendix

18.1 Annex – HGV statistic Bavaria, Germany (2007)

Polizeipräsidium Mittelfranken

V e r k e h r s u n f a l l s t a t i s t i k

Nürnberg, 18.02.09
Uhrzeit : 05.37
Turnus : S
Auswertung: Z/02/3
Seite : 12

*** Kollektivauswertung 'Schwerverkehr' ***
Zeitraum: 01.01.2008 - 31.12.2008 (bzw. 01.01.2007-31.12.2007) Z/02/3
Bereich : VU im Zuständigkeitsbereich von Dienststellen - Bayern gesamt

VU mit Beteiligung Schwerverkehr	19.208	(19.940	-3,6 %)
- mit Personenschaden	5.144	(5.440	-5,4 %)
- mit schwerwiegendem Sachsch.	14.064	(14.500	-3,0 %)
- Anzahl Verletzte gesamt	6.988	(7.438	-6,0 %)
- - davon Führer Schwerverkehr	1.373	(1.543	-11,0 %)
- - davon Mitfahrer Schwerverk.	285	(339	-15,9 %)
- - davon so. Beteiligte/Mitf.	5.330	(5.556	-4,0 %)
- - - davon Fußgänger	257	(254	+1,1 %)
- - - davon Fahrrad	495	(417	+18,7 %)
- - - davon motor. Zweirad	413	(408	+1,2 %)
- - - davon Pkw	4.016	(4.328	-7,2 %)
- - - davon Sonstige	149	(149	+-0,0 %)
- Anzahl Getötete gesamt	168	(235	-28,5 %)
- - davon Führer Schwerverkehr	27	(38	-28,9 %)
- - davon Mitfahrer Schwerverk.	2	(4	-50,0 %)
- - davon so. Beteiligte/Mitf.	139	(193	-27,9 %)
- - - davon Fußgänger	15	(19	-21,0 %)
- - - davon Fahrrad	14	(15	-6,6 %)
- - - davon motor. Zweirad	19	(26	-26,9 %)
- - - davon Pkw	89	(129	-31,0 %)
- - - davon Sonstige	2	(4	-50,0 %)
- Sachschaden (in tsd. EUR)	129.578	(142.616	-9,1 %)
- durch Schwerverkehr verurs. VU	14.076	(14.479	-2,7 %)
- - VU mit Personenschaden	3.494	(3.612	-3,2 %)
- - - getötete Personen	92	(125	-26,4 %)
- - - verletzte Personen	4.579	(4.751	-3,6 %)
- - - - schwer verletzt	776	(738	+5,1 %)
- - - - leicht verletzt	3.803	(4.013	-5,2 %)
- - VU mit Sachschaden	10.582	(10.867	-2,6 %)
- - Sachschaden (in tsd. EUR)	90.336	(98.538	-8,3 %)
- - Alleinbeteiligung	3.413	(3.623	-5,7 %)
- - innerhalb geschl. Ortschaft	8.156	(8.594	-5,0 %)
- - außerhalb geschl. Ortschaft	5.920	(5.885	+0,5 %)
- - - auf Autobahnen	2.813	(2.794	+0,6 %)

- Anzahl Beteiligte gesamt	37.386	(38.983	-4,0 %)
- - davon Schwerverkehr	21.609	(22.253	-2,8 %)
- - davon Verursacher	20.137	(20.944	-3,8 %)
- - - davon Schwerverkehr	14.250	(14.627	-2,5 %)
- - - - Alleinverursacher	12.928	(13.239	-2,3 %)
- - - - Hauptverursacher	722	(766	-5,7 %)
- - - - Mitverursacher	600	(622	-3,5 %)

	gesamt			davon bei Schwerverkehr		
- Hauptunfallursachen	18.906	(19.605	-3,5 %)	13.650	(14.005	-2,5 %)
- - Alkoholeinwirkung (01)	341	(369	-7,5 %)	182	(180	+1,1 %)
- - Drogeneinwirkung (02)	21	(23	-8,6 %)	11	(12	-8,3 %)
- - Übermüdung (03)	177	(169	+4,7 %)	122	(115	+6,0 %)
- - so. körperl./geist. M. (04)	79	(67	+17,9 %)	39	(37	+5,4 %)
- - Str.Benutzung (10/11/66-68)	1.835	(1.813	+1,2 %)	1.333	(1.323	+0,7 %)
- - Geschwindigkeit (12/13)	1.170	(1.446	-19,0 %)	734	(886	-17,1 %)
- - Abstand (14)	1.213	(1.324	-8,3 %)	897	(958	-6,3 %)
- - Überholen (16-23)	1.527	(1.535	-0,5 %)	1.006	(985	+2,1 %)
- - Vorrang (24/25/26/32/33/37)	977	(1.082	-9,7 %)	721	(778	-7,3 %)
- - Vorfahrt (27-30)	2.535	(2.640	-3,9 %)	1.137	(1.204	-5,5 %)
- - Rotlicht/pol. Weisung (31)	146	(168	-13,0 %)	94	(110	-14,5 %)
- - Abbiegen/Wenden (35/36)	3.573	(3.688	-3,1 %)	3.088	(3.189	-3,1 %)
- - Fehlverh. ggü. Fußg. (38-42)	77	(67	+14,9 %)	75	(66	+13,6 %)
- - Beladung (47/48)	640	(686	-6,7 %)	613	(660	-7,1 %)
- - and. Fehler b. Fzg. (49)	4.292	(4.227	+1,5 %)	3.398	(3.316	+2,4 %)
- - technische Mängel (50-55)	143	(129	+10,8 %)	120	(115	+4,3 %)
- - Fahrbahn überschr. (60-65)	25	(41	-39,0 %)	0	(0	+-0,0 %)
- - andere Fehler (Fußg.) (69)	10	(19	-47,3 %)	0	(0	+-0,0 %)
- - sonstige Ursachen	125	(112	+11,6 %)	80	(71	+12,6 %)

in Klammern: Vorjahreszahlen sowie prozentuale Veränderung vom Vorjahreszeitraum zum Auswertungszeitraum ('+999,9 %' = Zunahme um 999,9 % oder mehr)

18.2 References natural mobility section

[1] K. Dar, M. Bakhouya, J. Gaber, and M. Wack, "Towards a decentralized architecture for information dissemination in Inter-vehciles Networks", NatComp 2010, ACS/IEEE International Conference on Computer Systems and Applications, to appear in May 16 2010.

[2] Marrow, P., "Nature-inspired computing technology and applications", BT Technol J, 18(4), October 2000.

[3] Arora, Tamanna; Moses, Melanie, "Using Ant Colony Optimization for Routing in VLSI Chips", BICS 2008: Proceedings of the 1st International Conference on Bio-Inspired Computational Methods Used for Difficult Problems Solving: Development of Intelligent and Complex Systems. AIP Conference Proceedings, Volume 1117, pp. 145-156 (2009).

[4] M. Dorigo and T. Stützle, "The Ant Colony Optimization Metaheuristic: Algorithms, Applications, and Advances", Handbook of Metaheuristics, 2002

[5] Shubhendu Trivedi, "Adaptive Routing taking Cues from Stigmergy in Ants", http://onionesquereality.wordpress.com/2008/01/31/adaptive-routing-taking-cues-from-stigmergy/, Jan 31, 2008.

[6] M. Dorigo, E. Bonabeau, G. Theraulaz, "Ant Algorythms and Stigmergy", Future Generation Computer Systems, v.16 n.9, p.851-871, June 2000.

[7] L. Wischhof, A. Ebner, H. Rohling, "Information Dissemination in Self-organizing Intevehicle Networks", IEEE transactions on ontelligent transport systems, VOL 6, NO. 1, March 2005.

[8] C. Lochert, B. Scheuermann, M. Caliskan, M. Mauve, "The Fasibility of Information Dissemination in Vehicular Ad-hoc Networks", WONS 2007: Fourth Annual Conference on Wireless On demand Network Systems and Services, pp. 92--99, Obergurgl, Austria, January 2007.

[9] S. Fuchs, S. Rass, B. Lamprecht, "Context-Awareness and Collaborative Driving for Intelligent Vehicles and Smart Roads", Proc. 1st Int'l Workshop ITS Ubiquitous Roads, 1st Global Information Infrastructure Symp. (GIIS 07), IEEE CS Press, 2007, on CD.

[10] T. Nadeem, S. Dashtinezhad, C. Liao, "Traffic View: Traffic Data Dissemination using Car-toCar Communication", ACM SIGMOBILE Mobile Computing and Communications Review, vol. 8, no. 3, pp. 6–19, 2004.

[11] S. Biswas, R. Tatchikou, F. Dion, "Vehicle to vehicle wireless communication protocols for enhancing highway traffic safety", Communications Magazine, IEEE, Vol.44, No.1, pp.74–82, 2006.

[12] The Starlogo simulator, available at web site: http://education.mit.edu/starlogo/ANNEXES

[FRAME 2011] The FRAME architecture. available in [http://www.frame-online.net/]. cited on 5 Jan 2011

[KAREN 2011] KAREN Framework Architecture. available in [http://cordis.europa.eu/telematics/tap_transport/research/projects/karen.html]. cited on 5 Jan 2011
[KAREN D3.2 1999] KAREN Physical Architecture. Deliverable D3.2 of the KAREN project. See

[http://cordis.europa.eu/telematics/tap_transport/research/projects/karen.html]

[Kutila et al. 2009] Kutila, M., Alessandretti, et al. 2009. DEL1.1 State of the art, needs and current practice. ASSET-Road deliverable 1.1.

[FRAME tool 2011] The database of the FRAME Browsing tool. available in [www.frame-online.net/top-menu/the-architecture-2/the-browsing-tool.html}. cited on 5 Jan 2011.

[Maibach et al. 2010] Maibach, W. et al. 2010. DEL6.2 Test sites, set ups, tests and operation. ASSET-Road deliverable 6.2.

[FRAME Guide 2011] PLANNING A MODERN TRANSPORT SYSTEM

A GUIDE TO INTELLIGENT TRANSPORT SYSTEM ARCHITECTURE. available in [http://www.frame-online.net/top-menu/first-view/further-reading/PlanningGuide.pdf]. cited on 31st of Jan, 2011

18.3 General References

1. Johnston, I.R., Perry, D.R., Driver Behaviour Research: Needs and Priorities. Australian Road Research Board. Research Report ARR 108, 1982.

2. Wong, Y.D., Nicholson, A., Speed and Lateral Placement in Horizontal Curves. Road and Transport Research, Vol. 2, No. 1, Marh 1993, pp. 74-87.

3. Blosseville, J.M., Motyka, V., Video Sensors. Concise Encyclopedia of Traffic and Transportation Systems, Ed. By Markos Papageorgiou, Pergamon Press, 1991, pp.610-615.

4. Garcia, A., Diaz, E., Vehicle Tracking in Black Spots using Artificial Vision Techniques in order to Improve Road Geometric Design Standards. Proceedings of the International Symposium on Highway Geometric Design Practices, Boston, Massachusetts, August 30 - September 1, 1995.

5. Gupta, R., Mandloi, D., Evaluation of Accidents Black Spots on Roads using Geographical Information Systems (GIS). Thesis on OpenGis Standards and the Software of the Major GIS Vendors.

6. Road Safety as a right and responsibility for all. A Blueprint for the EU's 4th Road Safety Action Programme 2010-2020, ETSC, Brussels 2008, http://www.etsc.be/documents/Blueprint_for_a_4th%20Road_Safety_Action_Programme_ETSC_Sept%2008.pdf

7. Bourgeois, G., The Sustainable Safety Approach to Road Safety and Mobility. ECTRI-FERSI meeting, Brussels, Belgium, 18 February 2009. http://www.ectri.org/Documents/Publications/Strategic-documents/The-sustainable-safety-approach-to-Road-Transport-and-Mobility_Final.pdf.

8. Road Safety evolution in the EU. CARE - European Road Accident Database, 2008. http://ec.europa.eu/transport/roadsafety/road_safety_observatory/care_reports_en.htm

9. Al-Haji, G., Road Safety Development Index (RSDI) - Theory, Philosophy and Practice, Disertation, Linköping Studies in Science and Technology, Sweden, 2007.

10. Black, W., Sustainable Transportation-Problems and Sollutions, ISBN 978-1-60623-485-3, The Guilford Press, USA, 2010.

11. Elvic, r., Vaa, T., The Handbook of Road Safety Mesures, Elsevier Science, Oxford, UK, 2004.

12. Evans, L., Traffic Safety, ISBN 0-9754871-0-8, Science Serving Society, Bloomfield Hills, USA, 2004.

13. Hoel, L., A., Graber, N., J., Sadek, A., W., Transporting infrastructure Engineering. A multimodal Integration, ISBN 10:0-495-244392, ISBN 13:978-0495-24439-4, Thompson Pub., USA, 2008.

14. Hoel, L., A., Graber, N., J., Traffic and Highway Engineering, ISBN 10:0-495-43853-7, ISBN 13:978-0495-43853-3, Cengage Learning pub., USA, 2010.

15. Guidance for Implementation of the AASHTO Strategic Highway Safety Plan, National Cooperative Highway Research Program, NCHRP, Transportation Research Board, USA, 2003.

16. Roess, R., Prassas, Elena, McShane, W., Traffic Engineering, Third Ed., ISBN 0-13-91877x, Peassonn Education ing., USA, 2004.

17. Seaton, G., Active Traffic Management – Results from the Monitoring and Evaluation Project, Highways Agency, UK, 2008.

18.4 Web sites

www.aashoto.org – American Association of State Highway and Transportation Officials;

www.aaafts.org – American Automobile Association Foundation for Traffic Safety;

www.hwaysafety.org – Institute for Highway Safety;

www.highways.gov.uk/atm;

www.nhtsa.gov – National Highway Traffic Safety Administration;

www.ntsb.gov – National Transportation Safety Board;

www.trb.org – Transportation Research Board.

Glossary

ASSET	Advanced Safety and Driver Support for Essential Road Transport
CAN	Controller Area Network
CEN	European Committee for Standardization
ETSI	European Telecommunications Standard Institute
FRAME	European ITS Framework Architecture
GPRS	General Packet Radio Service
ITS	Intelligent Transport Systems
ISO	International Organization of Standardization
KAREN	Keystone Architecture Required for European Networks
SOA	Service-oriented architecture
TML	TransportML Middleware
Wi-Fi	Wireless Fidelity
XML	eXtensible Markup Language

List of Figures

Figure 1: Traffic Safety Theory Levels and Universes (ROC) 9

Figure 2: NMS Natural Mobility is Accident Free 12

Figure 3: Natural Mobility Features 13

Figure 4: Level of abstraction versus empirics (Wikipedia) 19

Figure 7: Estimated Trends in road deaths in EU 27 [6] 31

Figure 8: Reduction of EU road accidents between 1990-2010 [8] 31

Figure 9: AASHTO Strategic Highway Plan model implementation process 33

Figure 10: Factors relevant to road safety 34

Figure 11: The famous Triangle of Safety 45

Figure 12: Holistic Road Safety Approach 46

Figure 13: Road Safety Strategy 2010/2015: “A” Step 1 48

Figure 14: Road Safety Strategy 2010/2015: “A” Step 2 48

Figure 15: Road Safety Strategy 2010/2015: “A” Step 3 49

Figure 16: Theory of Safety Levels (ROC) 50

Figure 17: Road Safety Theory Elements and Universes 51

Figure 18: Goods Truck Overload: Cybernetic Processes 52

Figure 19: “Multi Purpose Efficiency Function” 54

Figure 20: Socio Economic Impacts Analysis 55

Figure 21: Holistic Road Safety Approach 56

Figure 22: The Dialectic Quadro Pole of Safety Holistic Road Safety Approach 57

Figure 23: Dialectic Multipole (Road Safety Wheel) 60

Figure 24: Five “E” Programs 62

Figure 25: System structure “ePermission for abnormal loads” 65

Figure 26: Integrated Road and Rescue Service Management 67

Figure 27: Bird swarm 75

Figure 28: Self-organized structure of a migrant bird swarm 76

Figure 29: The simulated scenario 84

Figure 30: Awareness during information dissemination process 84

Figure 31: Wind hounds: low energy consumption for long-term performance 87

Figure 32: Socio Economic Impacts Analysis 91

Figure 33: Context Diagram of the ASSET system [KAREN D3.2 1999]. Minor support is shown with dash lines. Terminators new to FRAME have double line. 100

Figure 34: Layout of the German test site setup 106

Figure 35: The physical architecture of the surveillance system on the test site. 107

Figure 36: Software modules in the German test site 107

Figure 37: Screenshot of the application at the sorting point used by the police officers to select overloaded trucks to the control station. 108

Figure 38: Example of possible fines per day based on overloaded trucks on a typical month (October 2010) computed from the weigh-in-motion system. 108

Figure 19: Truck passing the pre-selection point on the highway. 109

Figure 40: Container at the Control station where all servers, services and monitors are installed and used by the highway police officers. 109

Figure 41: Installation of the high-resolution traffic monitoring system for observing the current situation on the highway. 110

Figure 42: Integration of the prototype of the new weigh-in-motion sensor combined with an RFID-tag reader to the pavement at the control station. 110

Figure 43: Installed prototype of new weigh-in-motion sensor. 111

Figure 44: Thermal camera for observing all trucks regarding brakes, tires and power line conditions from below while they are passing the control station. 111

Figure 45: Tire profile measurement system for detecting too less profiles of all trucks passing the control station. 112

Figure 46: KRIA's camera system 113

Figure 47: Drawing of the cameras system in the German test site 113

Figure 48: Example of cable access for a tracking and tracing pole 114

Figure 49: 3D camera system junction box cabling 114

Figure 50: Rack shelter in the container 115

Figure 51: Project layout (video system, power supply and interfaces) 115

Figure 52: The Finnish test site concept 116

Figure 53: Architecture of the Finnish test site 117

Figure 54: TransportML architecture 118

Figure 55: Context-aware embedded architecture 118

Figure 56: Diagnostic interface 119
Figure 57: Representation of a geofence on the map 119
Figure 58: Snow Clearance Architecture 120
Figure 59: Real time position of snow plow with plowed roads 120
Figure 60: National or Regional ITS Architecture has often additional features that extend it beyond the FRAME Architecture. [FRAME Guide 2011] 121
Figure 61: FAIR Initial Application Matrix 123
Figure 62: Main cause for all road users(ETAC, 2006) 125
Figure 63: Development of the number of traffic fatalities in Germany 126
Figure 64: Fatalities in Germany in the years 2007, 2008 and 2009 127
Figure 25: Accident reasons 128
Figure 66: The current road system in Hungary 135
Firgure 67: Snow chain sign 159
Figure 68: Breaking distance in relation to velocity (Ewert, 2005) 162
Figure 69: Minimum speed sign 164
Figure 3: Lane crossing 169

List of Tables

Table 1	The master list of macro road safety indicators and dimensions	43
Table 2:	Mapping AS and proposed system	80
Table 3:	The ASSET technology contribution to the application domains	92
Table 4:	The European ITS functional areas supported by the ASSET system	93
Table 5:	The user needs listed of FRAME addressed by the ASSET system	95
Table 6:	The user needs listed of FRAME assisted by the ASSET system	96
Table 7:	Sub-Systems and Functions of the ASSET system [KAREN D3.2 1999]	101
Table 8:	Data of the subsystems	103
Table 9:	Enforcement distribution in Finland	155
Table 10:	Application Matrix (Current technology: green, ASSET-Technology red, future RFID Technology blue)	176