ASSET Road

Integrated
System Solution
for Safety

Advanced
Safety and Driver
Support for
Essential Road
Transport

Fp7 Sp1 Cooperation
Grant agreement 217643
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Project Final Report - Publishable summary -

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1 Final publishable summary report

1.1 Executive summary

The overall objective of the ASSET-Road project was to develop and test a holistic and integrated safety system incorporating driver support and control, economic road transport, infrastructure protection and cooperation between authorities to lead to an enhancement of traffic safety.

The project used existing sensor technologies in an innovative way, developed new sensor modules also putting emphasis on the fusion of data from multiple sources. In addition to the development of sensors different innovative acquisition methods were integrated allowing the automated detection of traffic offences and warning of hazards as well as driver assistance tools. Both focus on heavy goods vehicles (HGVs) representing a major hazard potential on motorways. Their potentially destructive impact of any traffic rule violations in terms accident consequences and deterioration of the road infrastructure emphasizes the need of such developments.

The developed sensors include a new matrix high-speed weigh-in-motion sensor detecting passing overloaded HGVs prepared for future automated overload enforcement (e.g. overweight of axles, axle groups, truck, trailer or gross weight), an RFID reader which can reads the technical data stored on RFID tags of passing vehicles, a new thermal image monitoring system to check vehicles and to detect defective brakes, tyres, bearings, shafts and other elements of the drive train system in an efficient and effective way at reduced costs and less time, a new generation of multi-purpose pavement sensors for measuring pavement loads and environment conditions to reduce pavement life cycle costs, a system using a special near-infrared camera to detect ice and water on the road surface as well as an automatic seat belt monitoring system checking seat belt compliance.

The developed driver assistance systems is based on a "Regulation Knowledge Base Framework" enabling a fully automatic observation system, a virtual multi-agent system aiming at the automatic detection of rule-violating driver behaviour by video surveillance and an interactive intelligent human-machine interface (LISA) alerting drivers of road scenarios and regulations. Above all, a TransportML middleware for intelligent interactive services was developed to allow road operators and administrations to share their information using Web services that interact to fulfil common tasks. Four different test sites were established in Germany, Finland (mobile), Austria and France to demonstrate and test the project developments.

Technically, the focus is on road monitoring, vehicle and driver monitoring and the integration of this information. At the practical level, ASSET-Road added value by developing methods and practices of close co-operation and data fusion with different users: drivers, TMC, emergency centre, police and rescue authorities, in order to prevent incidents and hazards and to increase road safety. See also the project website: (www.project-asset.com).

1.2 Summary description of project context and objectives

Ten years ago, almost 50,000 fatalities per year were counted on the roads of the EU-25 territory. A number that is equal to the number of inhabitants of a medium-sized town. The European Union has set the goal to halve that number within 10 years. During the past few years, safety on European roads has improved continuously, but it still leaves a lot to be desired. The ambitious target has not been reached yet.

Road traffic safety was a key element of the ASSET-Road project. Utmost priority was attributed to accident prevention by improved driver awareness and early warning procedures in case of incidents and hazards and control of violations. Therefore, the primary goal of the ASSET-Road project was the enhancement of traffic safety, whereby cleaner traffic was a by-product of more fluent traffic flow and enhanced safety. It was to be achieved mainly by the following main objectives:

1. Development of sensors and innovative acquisition methods allowing the automated detection of traffic offences and of hazards
2. Development of driver assistance tools
3. Create a road safety theory including practical recommendations

Both, developed sensors as well as the driver assistance systems, particularly focus on heavy traffic, as heavy goods vehicles (HGVs) represent a major share of the hazard potential on motorways. Above all, the potentially destructive impact of any traffic rule violations in terms accident consequences and highlighted the need of such developments.

The ASSET-Road project had a number of scientific, technological and procedural objectives:

1. To develop an innovative, holistic, integrated safety approach to improve the safety and fluency of traffic flow. The theoretical approach leads to the design and implementation of solutions for three main application areas:
   - ► Direct driver support measures
   - ► Infrastructure condition and monitoring and
   - ► Traffic surveillance and control.
2. To promote cooperation and data sharing between different safety authorities on their infrastructure. Until now, this possibility has not been optimally used in traffic safety. The cooperation of key authorities needs to be accelerated, ensuring that automated data exchange, common traffic incident avoidance strategies/tactics and shared technology solutions are realised.
3. To adopt and tailor potential existing sensor and processing technologies for traffic and infrastructure monitoring, control and surveillance needs:
   - ► Regulation knowledge bases and driver co-pilot agent systems

- ► Vehicle safety condition monitoring by enhanced Weigh-in-Motion (WIM) and thermal imaging
- ► Tracking and identification using advanced video technology and Galileo
- ► Advanced human-machine interface for driver awareness and human driver support
- ► Advanced infrastructure protection, modelling and life cycle optimisation

4. To develop a sensor data fusion method to interpret and analyse vehicle and infrastructure use-related data collected by different transducers. By creating an overall view of conditions and behaviour influencing traffic, integrated traffic operation and driver support strategies are possible.
5. To introduce and apply a novel, secure and scalable many-to-many (M2M) communication concept and identify technologies for
   - ► Managing traffic data
   - ► Securing data
   - ► Providing traffic, vehicle and driver information to various users.
6. To set up three European test sites to demonstrate and validate system functionality.
7. To disseminate the project concept – possibly in a tailored form – to countries outside the consortium, including the promotion of the concept in developing countries.
8. To draw up guidelines to implement a European wide automated traffic supervision and control network.

This included techniques for monitoring traffic safety incidences and enforcement offences had to be explored, methods for monitoring vehicle and axle load/overload, road conditions and driver behaviour on dedicated road sections developed and secure communication ensured, integrated safety management solutions based on the information of driver, road, vehicle and regulations developed, situations analyzed and predictions of incidents and hazards made as well as methods for driver information, warning and, ultimately, for traffic enforcement developed.

Moreover, it comprised the minimization of road infrastructure wear and the improvement of sustainability, the reduction of the number of interventions and repairs of road surfaces by accurate tracking of damage initiation and progression, the development, application and testing of new technologies to measure load flow on roads and road conditions as well as the application of advanced technologies for infrastructure design/assessment and last but not least the development and implementation of the advanced co-operation between traffic management centres, emergency rescue and police in emergency situations.

Based on existing and previous work in traffic safety applications at vehicle, infrastructure and system level, the consortium considered it necessary to push development towards a more holistic approach – exploiting the progress that has been made in individual domains of transport safety. Therefore, within the framework of the ASSET-Road project all these developments were embedded in a holistic approach to road traffic safety. A professional "Holistic Safety Theory" was necessary for analysing and improving road safety as a complete system. This safety theory consists of different hierarchical universes, giving and describing the dialectic interactions of the main safety related elements and levels.

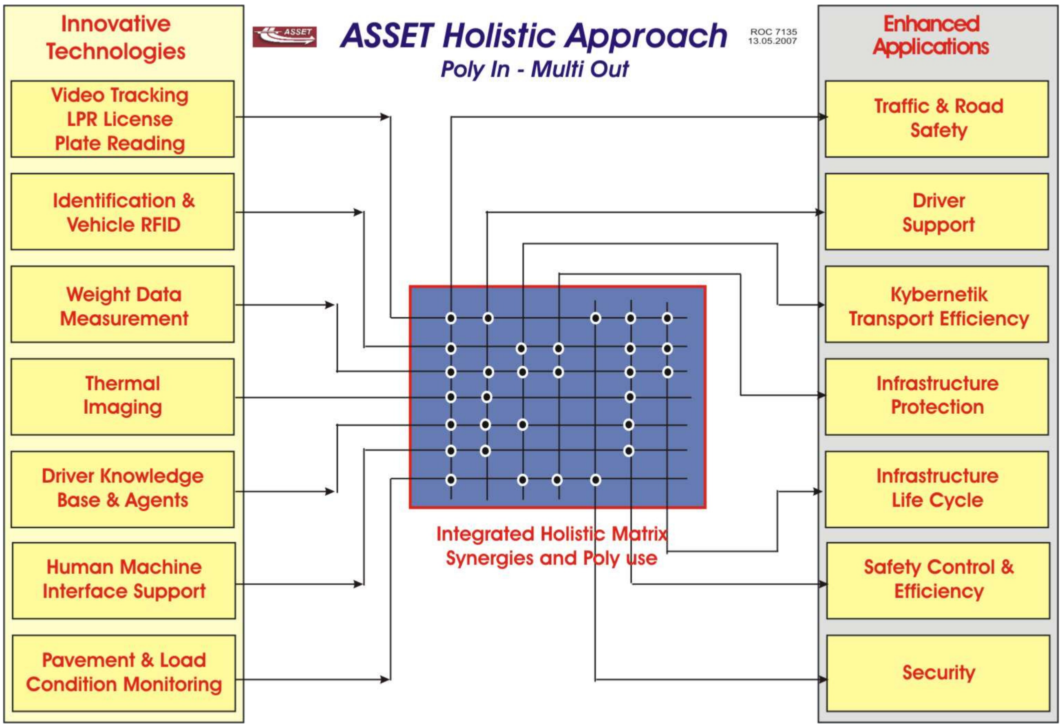


Figure 1: ASSET-Road integration matrix

Examples for the development of sensors allowing the automatic detection of offences and warning of hazards, which may be mentioned here, are in particular:

1. High speed Weigh-in-Motion sensor with its requisite software, which was developed for future automatic overload enforcement (overweight of axles, axle groups, truck, trailer or gross weight). The system can detect weight and overload of heavy goods vehicles in traffic while running on the motorway.
2. An RFID reader which from the carriageway reads the RFID tags of passing vehicles.
3. A new thermal image monitoring system to check vehicles and to detect defective brakes, tyres, bearings, shafts and other elements of the drive train system in an efficient and effective way at reduced costs and taking less time.
4. A new generation of multi-purpose pavement sensors for measuring pavement loads, conditions and environment conditions for analyzing and optimizing pavement behaviour and to reduce life cycle costs enabling better pavement and traffic load modelling.
5. A system which is able to detect ice and water on the road using a special near-infrared camera including a software to detect whether road is wet, icy, snowy or

dry comparing the polarization from reflected light and graininess values. Via image analysis the different road states are distinguished.

6. An automatic seat belt monitoring system with detection algorithms to check the seat belt compliance.

To assist the driver the following systems were developed:

1. A "Regulation Knowledge Base Framework" serving as an enabler of a fully automatic observation system
2. A virtual multi-agent system aiming at the automatic detection of rule-violating driver behaviour. Vehicle monitoring is achieved by a video surveillance system which tracks and traces the vehicles
3. A "Life In-vehicle Smart Assistant" (LISA) with an interactive intelligent human-machine interface which alerts drivers regarding road scenarios and regulations.

Within the ASSET-Road project a new model to accurately simulate vehicle-pavement dynamic interaction gives new insights into the pavement damage progression through its life. A “Numerical Integration” approach was developed to find the statistical distribution of force patterns due to the vehicle fleet, and hence the changing road profile. Also the structure and the initial working version of software for predicting long-term pavement performance was developed that allows users and researchers to modify the simulation depending on their needs and their expertise.

A TransportML middleware for intelligent interactive services was developed to allow road operators to share their information using Web services which interact to fulfil common tasks. It is an extended XML platform based on Services Oriented Architecture (SOA) principles to recognize, monitor and collect service information and description over the network.

And at least, new concepts for traffic and axle load monitoring, including Weigh in motion (WIM) innovations and their implications for maintaining and management of an efficient and sustainable road infrastructure in the frame of DBOT/PPP project schemes were developed and presented.

The ASSET-Road project was result-orientated structured and driven (management by objectives). The project was prepared and organised by experienced partners from all relevant domains, such as research institutions, industry, SMEs and road/traffic authorities with high interest and motivation. The project also supported cooperative driving – a concept requiring communications standards of WLAN technologies – as well as rescue support.

1.3 Description of the main S&T results/foregrounds

1.3.1 Holistic safety and road safety theory

Road safety is a complex, dynamic, interactive and complicated universe of events and processes. However, so far a comprehensive "Road Safety Theory" has been missing. The next ideas and recommended methodology should help to have a better understanding, allow a better analysis and finally lead to the "optimum overall solution". Based on a 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".*

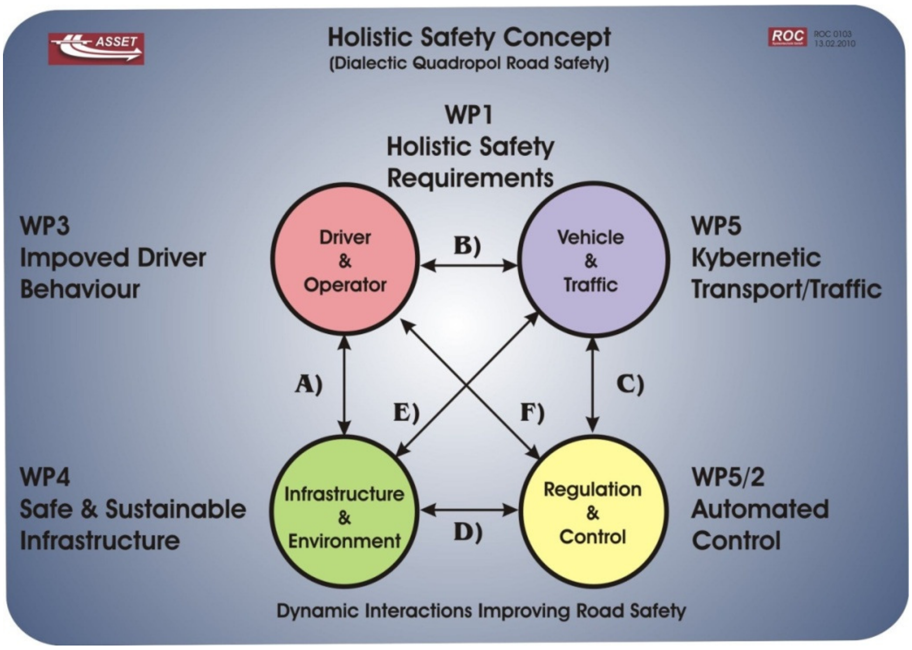


Figure 2: Holistic safety concept

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
- ► Creation of a practical holistic approach (including an overall safety concept and methodology) helping to solve and manage the complex interactions of 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 into the processes of identification of needs and evaluation of initiatives and measures

► Building a competent team of experienced and multidisciplinary experts.

Universes of safety elements

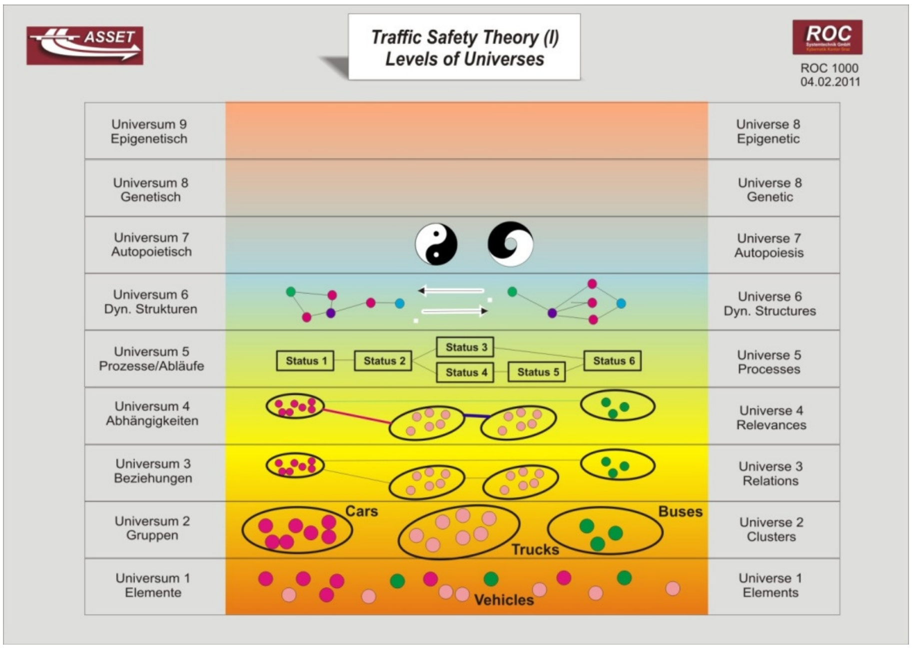


Figure 3: Levels of the Traffic Safety Theory

A professional holistic “Traffic Safety Theory” is necessary for analysing and improving road safety as a complete system. This safety theory will consist of different hierarchical universes, giving and describing the dialectic interactions of the main safety related elements and levels.

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.

1.3.2 WIM sensor technologies

High-speed Weigh-in-Motion or HS WIM) with its requisite software was developed for automatic overload enforcement (overweight of axles, axle groups, truck, trailer or gross weight). The developed system can detect heavy goods vehicles in the traffic running on the motorway (see Figure 4).

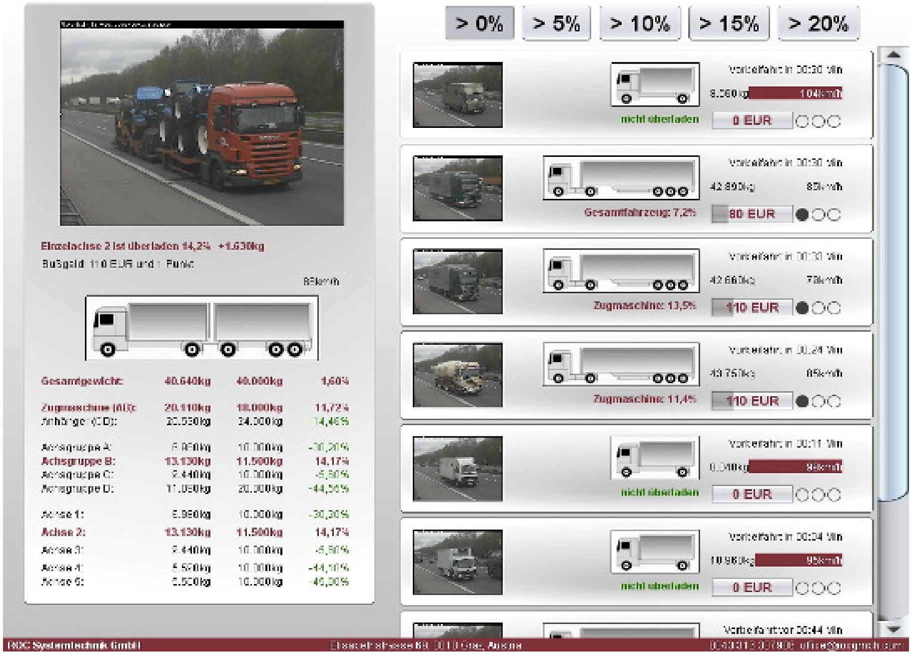


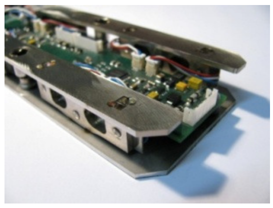
Figure 4: Weigh-in-motion measurement application

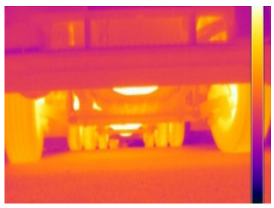
The vehicle data is transmitted to the sensor using the Radio Frequency Identification (RFID) system. The installed system features a passive measurement part – the RFID measurement probe does not need a power source, but power is inducted by the RFID reader.

A new generation of high-tech weigh-in-motion sensors using reliable and precise strain gauge technology and embedded microelectronics for signal processing and Ethernet interfacing was developed. It is available with a simple and intuitive 3D user interface for weighing all types of vehicles, detecting overloaded trucks in free-flowing traffic on the highways in real-time and also detecting technical issues of the measured trucks.

ROC WIM

Compared to state of the art of the WIM sensor can offer

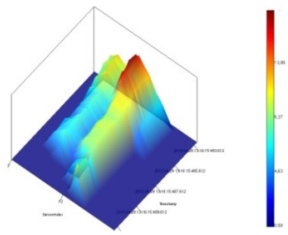




- Higher static and dynamic sensor system accuracy
- Long-term stability of measurements
- Easier and transparent calibration
- Simpler installation and replacement leading to shorter road closures due to flat sensor design
- High-speed WIM for dynamic enforcement: High-speed WIM for fully automated enforcement providing legally valid data
- Possibility of combining additional sensors with WIM (thermal imaging, RFID readers, tire profile measurements…).

The WIM system is able to

- ► Measure all available weights of any vehicle starting with the wheel, axles, axle groups, truck, trailer and gross weight with a sampling rate of up to 8.000Hz and 80 Measurement points/sensor
- ► Measure the footprint of each tire (size and pressure distribution on load) and calculate the tire pressure



- ► Detect the vehicle type based on its dimensions and tire configuration (single or twin tires)
- ► Measure the width and spacing of each axle and the centre of gravity and imbalance of the vehicle
- ► Analyse the plausibility of each measured value and automatically detect all manipulations done by the drivers such as accelerating, braking or driving sideways.

Typical use cases for a high-speed WIM

We are able to deliver real-time surveillance of the typical situations on the highways without disturbing the free-flowing traffic. HS WIM can also automatically detect:

- ► Excess of legal permitted weights and speeds

- ► Tailgating, elephants racing or left lane driving
- ► Driving prohibition violations based on date, time, vehicle type, weight or vehicle dimensions
- ► Vehicle problems like unbalanced axles, trucks or trailers, and lurching
- ► Tires with insufficient pressure, excessive weight or even unbalanced twin tires
- ► Driving in wrong direction ("ghost-driver-detection") and inform the highway police.

Future innovations and sophisticated features and applications

- ► Manual, semi-automatic and fully automatic enforcement systems

- ► "Weight-based tolling" with individual fees
- ► Surveillance and automated security based on weight, vehicle type and vehicle dimensions.
- ► Monitoring and securing tunnels
- ► Detection of upcoming and existing traffic jams
- ► Prediction of upcoming road maintenance issues long before they appear
- ► Very detailed statistics and predictions of current and future traffic flow.

3D real-time monitoring and evaluation software

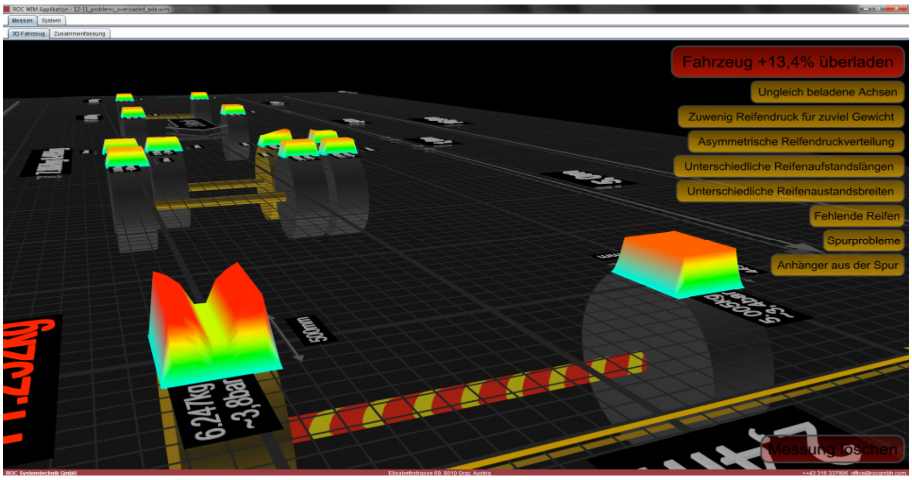


Figure 5: 3D real-time monitoring and evaluation software

Figure 6: Mini double Shear-beam sensors arranged in a 80 measurement point matrix

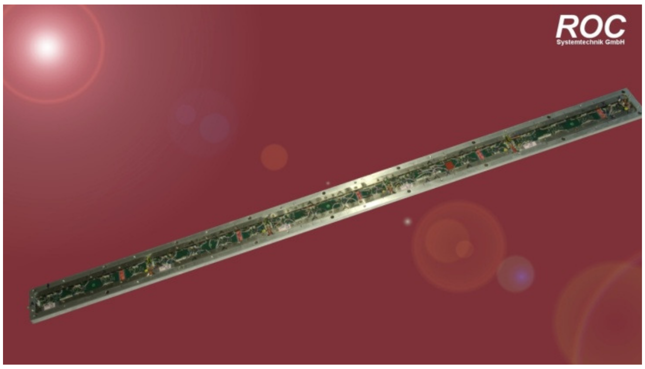


Figure 7: Sensor embedded electronics and micro controller (Master/slave hierarchy) with Ethernet interface

1.3.3 Data processing

Within the ASSET-Road project one of the tasks was to develop the key technologies for monitoring and processing data on the ASSET-Road test sites. Several software and hardware solutions were implemented to achieve the planned goals (see Figure 8). A holistic system was devised covering several traffic monitoring operations. It was realized via a sensor data fusion platform which integrates the data from the sensor units (see Figure 9).

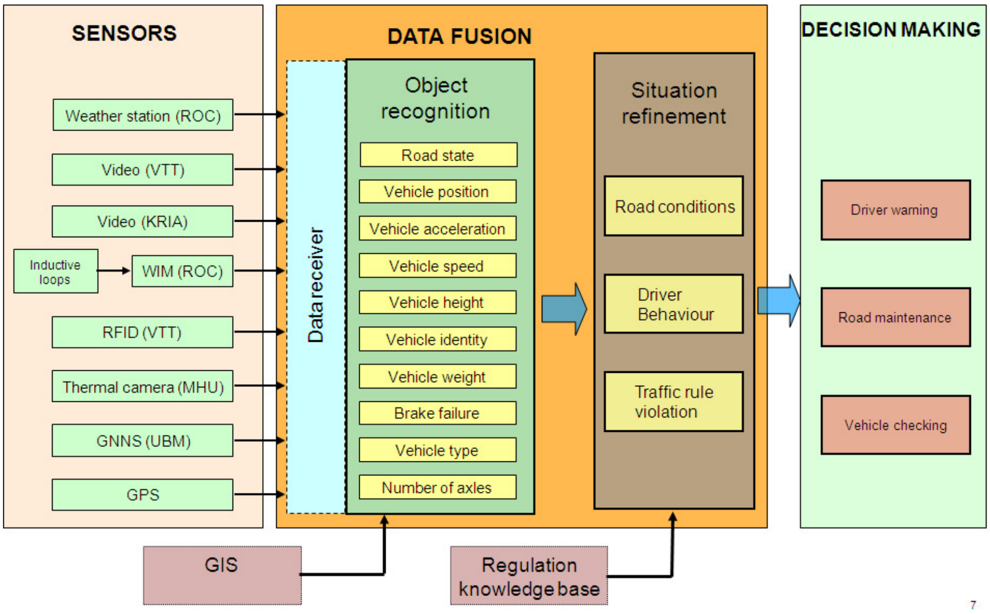


Figure 8: Architecture of the implemented data fusion process

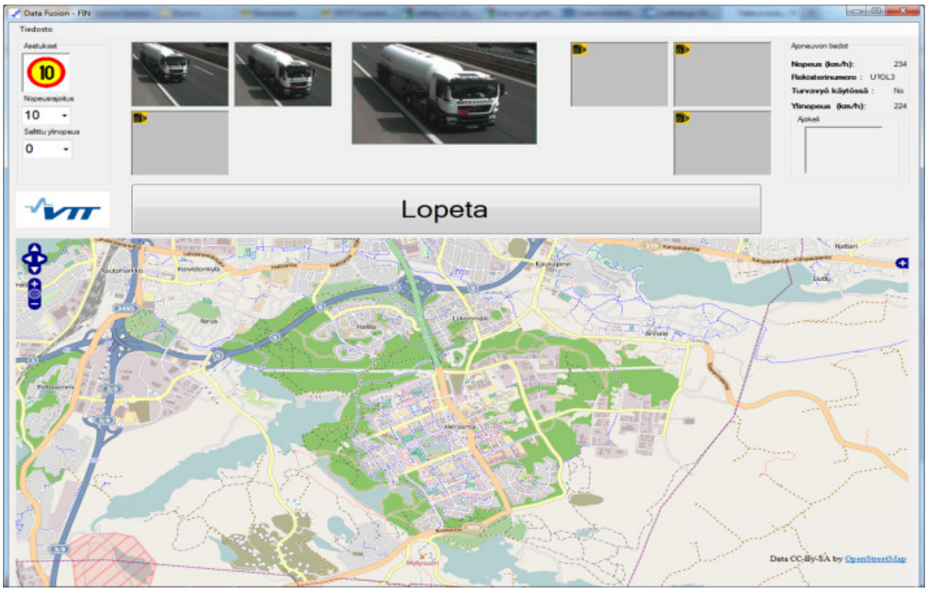
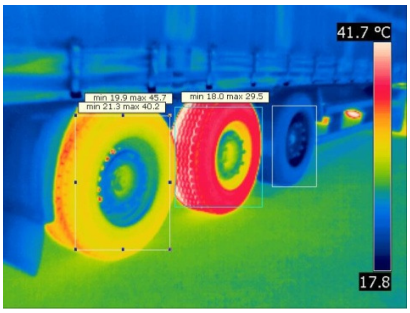


Figure 9: User interface of the data fusion software

1.3.4 Vehicle inspection technology by IR

Many trucks and buses do not operate properly or safely. Vehicle inspection is needed to detect malfunctions.



The main goal was to develop a new thermal image monitoring system to check vehicles and their active components in an efficient and effective way with reduced costs and control time.

The hardware solution involved the development of a sensor system, a wireless communication system and a thermal imaging system. The sensor system

"Thermal imaging" was used to detect defective brakes, tyres, bearings, shafts and other elements of the drive train system. The idea of using an IR camera to detect defective brakes is based on the fact that friction causes heat. If the brake does not heat, it does not work. Different IR camera systems, portable and fixed ones, were used. The IR camera system was used laterally and also installed into the road surface to monitor the vehicles rolling over. A monitoring system for the operator was developed.

1.3.5 Road friction monitoring

Slippery roads cause fatal accidents throughout the Europe and are especially great concern in northern Europe. Currently there are no ways of informing traffic about reduced friction.

Aim was to develop and improve detection of ice and water on the road using a special near-infrared camera.

A Software has been developed to detect whether road is wet, icy, snowy or dry. Comparing the polarization from reflected light and graininess values achieved via image analysis the different road states are distinguished. In the ASSET-Road the NIR camera was used but a stereo camera pair has been proved to work successfully, too.

A unit was developed to avert road operators to take necessary maintenance services (salting or snow ploughing). The measurement unit is based on a near-infrared camera and the software algorithm was developed.

Software solutions were worked out for different tasks: measurements, sensor data pre-processing, communication between sensors and systems, database storage, data analysis and data mining, automated system operations, data visualization and representation, graphical user interface, data fusion and traffic control.

1.3.6 Multi-agent system

One of the three main results of software development was the virtual multi-agent system (see Figure 10). It aims at the automatic detection of rule-violating driver behaviour. At its current stage it can detect hazardous traffic situations in real-time, e.g. too short distance between vehicles, it can provide information for the driver, record rule violations and finally fine, too.

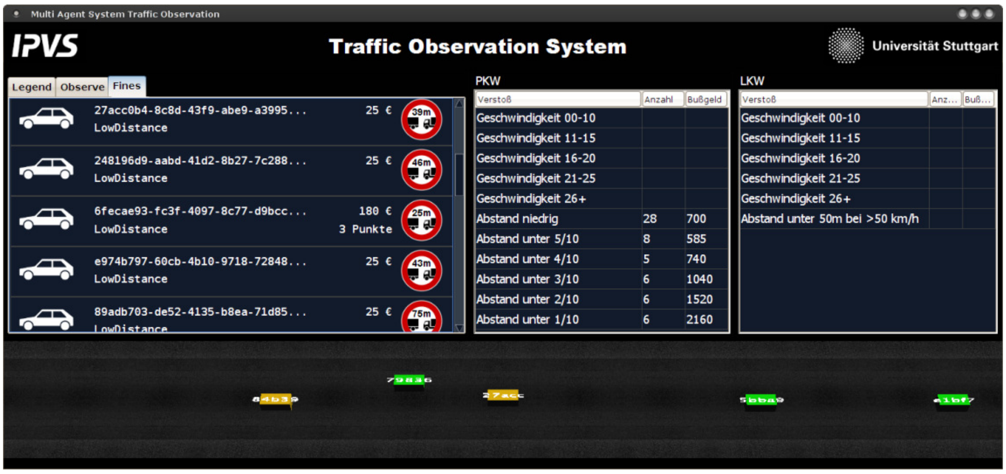


Figure 10: Agent-based system to follow behaviour of drivers

Vehicle detection is achieved with a video surveillance system which can track and trace the vehicles. The implementation of the system allows determining vehicle types based on their dimensions, vehicle speed and position. It can also be used to read vehicles number plates.

Regulation knowledge base framework is a new, automatic XML database for traffic rules. As design features, it has easy data entering and conversion. The database contains traffic rules of the European countries (incl. traffic rule violations, fines and defined traffic situations). The seat belt compliance monitoring module was subjected to extensive testing. The detection results of the algorithm were compared with the results of a human operator, which were taken as a ground-truth reference.

1.3.7 Improved driver behaviour compliance

Considering drivers' occasional inattention to the warning outside stimulus, LISA really represents a useful instrument for traffic regulation support systems.

The global vision of the ASSET-Road project is that drivers have the ability to improve safety the most. As a key success factor their behaviour when driving is analyzed. On the basis of the tests carried out the LISA application, has achieved the following:

1. Investigation by means of questionnaire and surveys of driver compliance with road regulations and safe driving practices
2. Filling the gap between current and desired driver knowledge with regard to regulations using an informative approach
3. Design of LISA, an interactive intelligent human-machine interface (HMI), as a smart in-vehicle information system which alerts drivers to road scenarios, regulations
4. Design and conduct of a simulator study using LISA prototype devices to observe driver behaviour and performance when interacting with the smart information system
5. Testing of LISA in real context, i.e. during a field trial on the German test site.

This part of the ASSET-Road project focused on drivers of heavy goods vehicles because the potentially destructive impact of any violations in a road scenario in terms accident consequences and the data collected by questionnaire surveys carried out in the previous tasks highlighted the need of such support. The system is highly scalable and open to the integration of a lot of new information provided by the infrastructure.

The design and development framework is strongly reliable with state-of-the-art devices; it could effectively be used to implement the same application and the same communication modalities also on any kind of smartphone or tablet PC, independently from the specific operating system. Even more important, this framework is well-engineered enough to match future telematics trends and requirements.

The above activities represent an efficient and effective implementation of the user-centred design and model-based design approach consisting of a logical loop of analysis and technical activities including

- User needs and requirements collection and analysis
- Scenarios analysis and definition
- System design and implementation
- Tests with user
- System improvements
- Integration into infrastructure and field trials.

Figure 11: LISA driver support and its all support elements

1.3.8 Optimal road pavement/bridge monitoring

Within the ASSET-Road project a new model to accurately simulate vehicle-pavement dynamic interaction and give new insights into the pavement damage progression through its life. A “Numerical Integration” approach is developed to find the statistical distribution of force patterns due to the vehicle fleet, and hence the changing road profile.

The improvement in computational efficiency from the numerical integration approach is of two orders of magnitude (about 100 fold). The road surface profile is modelled in 3-D and allowance is made for variation in the transverse position of the wheel on the road. The damage caused in pavements by millions of passing wheels is predicted using a mechanistic-empirical model that explains the way in which pavement damage progresses and the importance of the natural frequencies present in the wheels of the vehicle fleet. The wavelet transform is used to identify critical frequencies in an existing road profile and hence to predict which sections of road are susceptible to future damage.

The pavement model is extended to provide an early indicator of pavement vulnerability to damage. This is a valuable tool that can be used by road owners and managers to optimise pavement maintenance budgets. Figure 12 shows the pavement profile predicted after 20 million wheels have passed.

Bridges are subject to continuous degradation. Most developed economies require the monitoring of this infrastructure to provide adequate maintenance and guarantee the required levels of transport service. Current ambient vibration techniques that extract modal data require lots of measurement points and also accurate numerical models of the structure to allow the identification of damage. The studies undertaken contribute with an easy-to-implement empirical-based damage detection algorithm. The algorithm utilizes traffic load on the bridge as a source of excitation and a wavelet approach to analyze the bridge's acceleration signal induced by the traffic crossing it. It is based on the ability of the wavelet transform to capture small singularities within a signal.

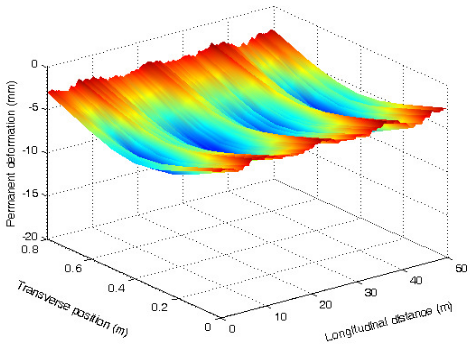


Figure 12: Predicted pavement profile after 20 million wheels

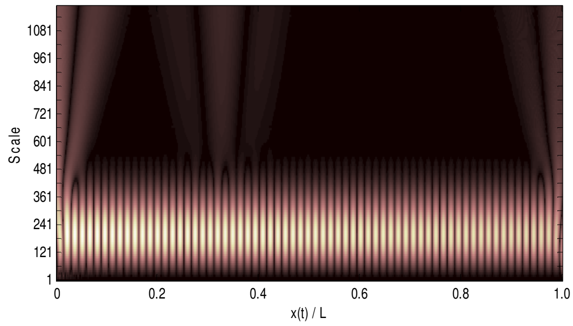


Figure 13: Wavelet transform of signal

The proposed technique uses fewer sensors than existing mode shape based detection methods and is less sensitive to environmental conditions than natural frequency based methods. The source of singularities in the acceleration signals of damaged bridges has been investigated for a wide range of scenarios and this information has been exploited to improve the sensitivity of the algorithm to damage.

Existing monitoring procedures are expensive, requiring installation of sensors and data acquisition electronics on the bridge. Therefore, a new method that uses a moving vehicle fitted with accelerometers on its axles to monitor bridge condition is presented.

An advantage of this method is that all measurement equipment is contained within the vehicle, and bridges within a driving distance can be easily checked in a relatively short period of time. The frequency of a bridge can be extracted from the spectra of vehicle accelerations, and an algorithm which enables the identification of the structural damping of the bridge using the vehicle accelerations has also been developed.

As bridge frequency and damping can indicate deterioration in bridge condition, this method can be implemented as a tool for the periodic monitoring of structural condition of bridges.

1.3.9 Pavement deterioration model

For road authorities in responsibility of road infrastructure design, planning, building and maintenance it is essential to know mechanical pavement and bridge performance and failure mechanisms in order to develop appropriate and efficient maintenance strategies and calculate and evaluate repair costs.

Road infrastructure construction, maintenance and repair are important factors concerning road network operation and traffic management for European countries and their economies. To have information about the “health” of pavements and bridges there are available several investigation procedures and analytical pavement design methods. Due to complex material behaviour and alternating boundary conditions, structural designs are not sufficiently validated yet and future research is necessary.

In the ASSET-Road project the structure and the initial working version of software for predicting long-term pavement performance has been developed that will allow users and researchers to modify the simulation depending on their needs and their expertise. The software will be modular and open source in order to allow the community of users to build a library of modules to test and compare different approaches and ultimately to be able to always use the most up to date state of the art model within the framework of one single software.

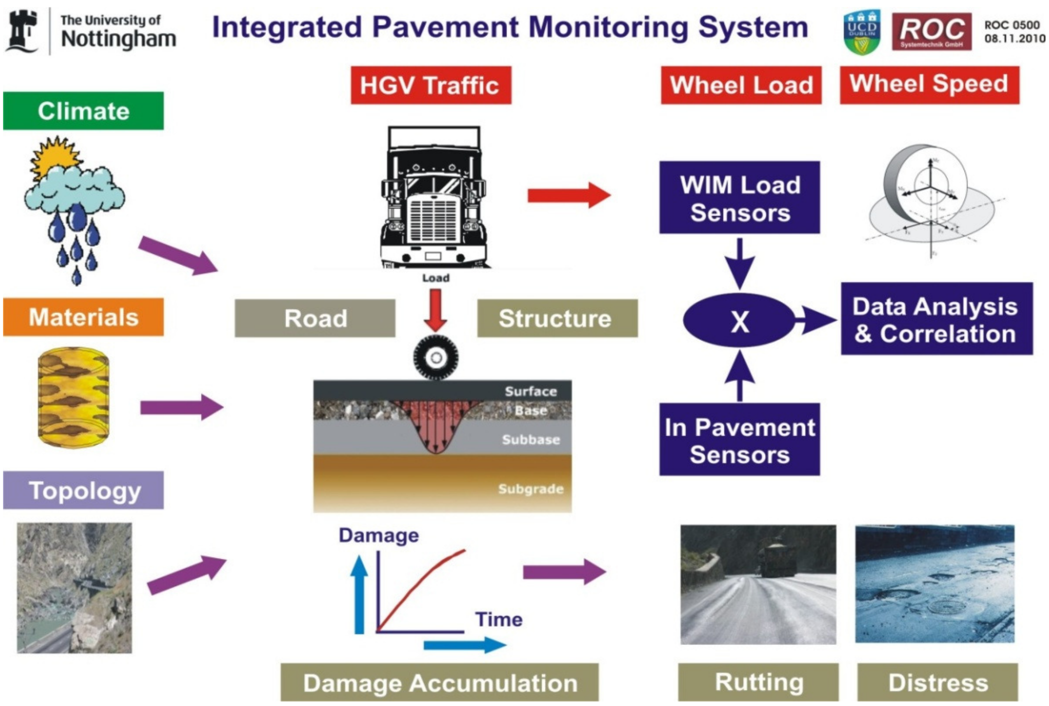
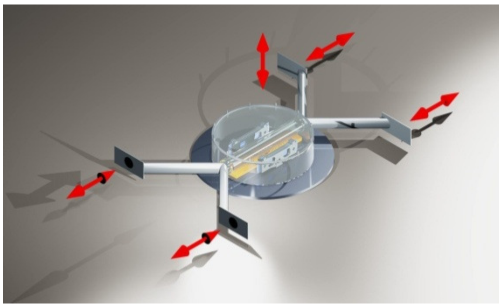


Figure 14: Integrated pavement monitoring system

The software is currently being referred to as “VPI – Vehicle-Pavement Interaction” and its initial prototype (alpha version) is being tested at the universities of Nottingham and Cambridge. It has been employed on a few studies. A first release of the software is expected to be made available for beta testers (a selected group of field experts and researchers) by the end of 2011. This will be followed by a period of scrutiny during which the suggestions and recommendations from the testers will be developed and implemented. After this final stage the full version of the VPI software will be released to the public (expected date August 2012).

The software will be made freely downloadable from the following web pages:
www.pavementsimulation.com
www.pavementsimulation.org.

1.3.10 Pavement and bridge sensor



Increasing traffic volumes and climate changes have led to higher wear and tear on road infrastructure networks and pavements. Modelling must be improved.

Objective was to develop a new generation of multipurpose pavement sensors for measuring pavement loads, conditions and environment conditions for analyzing and optimizing pavement behaviour, and to reduce life cycle costs enabling better pavement and traffic load modelling (Correlation WIM with pavement sensing).

New, integrated pavement sensor measuring stress and strain, shear beam sensors, embedded electronics and Ethernet interface. Also measures acceleration in two axes, acoustic noise, temperature and humidity; designed for application in different layers. Synchronization of WIM systems for considering real world load flow forces by tires and vehicles with the pavement sensor data and correlation of effects.

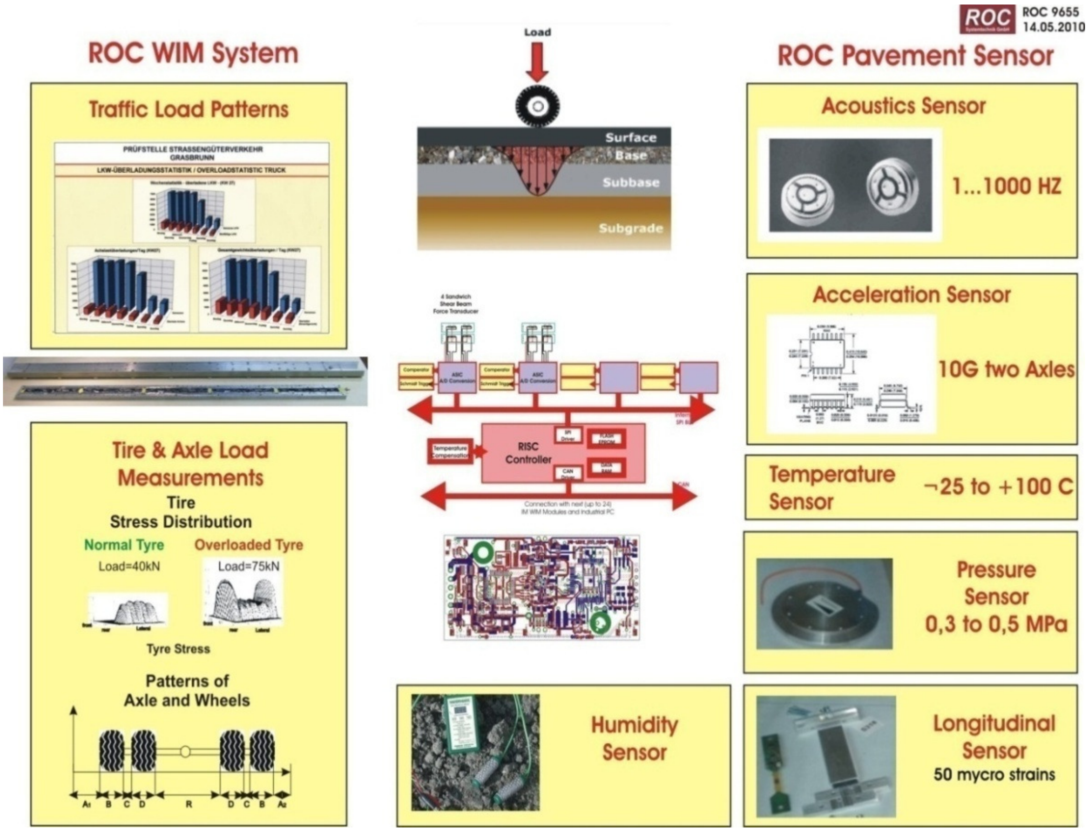


Figure 15: Pavement and bridge sensor

1.3.11 TransportML and Geofencing services

The GNSS localisation and vehicle communication technologies were tested and optimised in the project to create cooperative traffic services. As vehicle communication is based on cellular networks, capacity limitations had to be taken into account.

A TransportML middleware for intelligent interactive services was developed to allow road operators to share their information using Web services that interact to fulfil common tasks. It is an extended XML platform based on Services Oriented Architecture (SOA) principles to recognize, monitor and collect service information and description over the network. It can be directly accessed by mobile users using any technology allowing an Internet connection. Figure 16 describes the architecture of TransportML platform.

A software tool was developed and integrated within TransportML platform. It allows the definition of the characteristics of geographical areas as well as techniques to restrict access or exit to a given type of vehicles (see Figure 17). It also allows defining appropriate routes for a certain type of vehicles and ensuring that each concerned vehicle follows its assigned route from origin to destination. To allow vehicles exchanging information with other vehicles nearby as well as with the infrastructure, a V2I and V2V communication library was developed and integrated. The obtained results showed that the average travelling time from the emergency location to the incident location is around 27% shorter when using TransportML and Geofencing services.

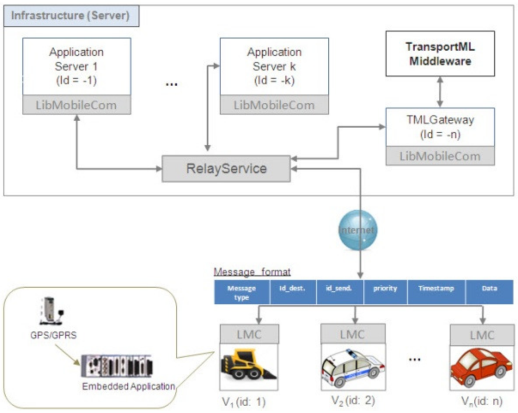


Figure 16: TransportML architecture

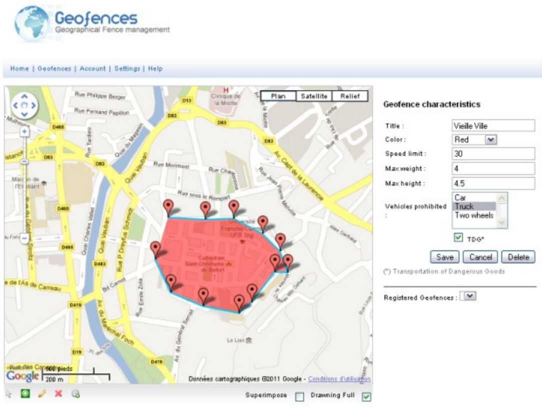


Figure 17: Geofencing tool

1.3.12 Transport force models including" Load flow"

There are different purposes for traffic modelling available and models in use. A clustering of possible categories of models could be: models for traffic management, driver warning and information system, infrastructure planning and maintenance, safety improvement, enforcement tolling and road and traffic infrastructure planning. We recommend and practised the following methodology for analysing new algorithms in four steps:

- Cluster the recommended and proposed innovations for algorithms according existing application areas and requirements for improvements
- Investigate and define the new parameters and data which are required or will be available in future
- Formulate and recommend new algorithms for better modelling of the reality and its effects and processes, analysis and investigation of improvements
- Evaluate and validate the models and algorithms for practice

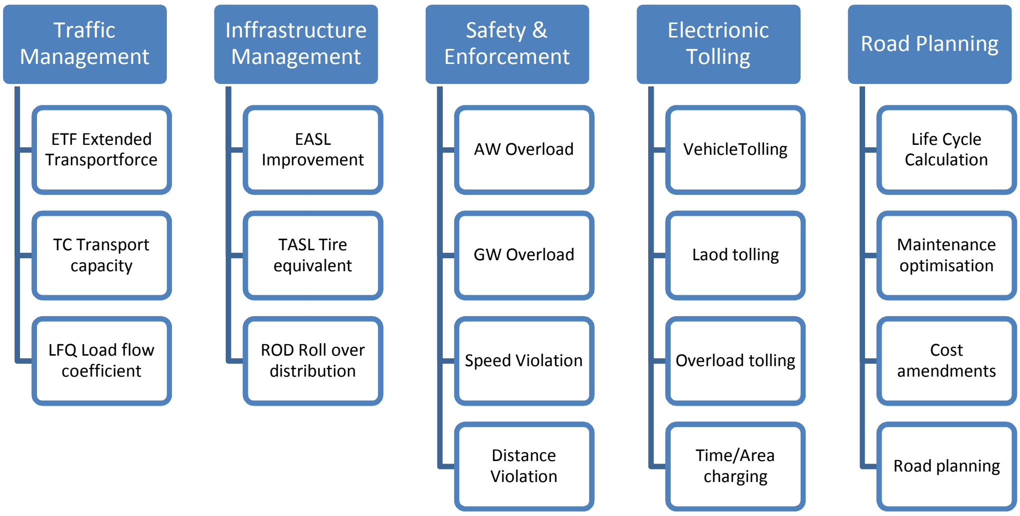


Figure 18: Clusters of areas for new algorithms and innovative approaches

Investigation Vehicle Transport Force model (VTF)

The *Transport Force* ("Transportkraft") model has been conceived in 2000 by *Lothar Franke* (Straßenverkehrstechnik, 44, no. 11, 2000, 596-600) and it is focused on the vehicle gross weight. The *transport force* equation proposed by Franke for the (*i)* vehicle is:

$$p_i = \frac{G_{T_i} \cdot v_i}{t_{b,i}} [kN / vehicle] \qquad (2)$$

Vehicle Transport Force using bumper to bumper time gap (VTFb-b)

Analyzing the VTF model proposed by Franke, we can see that the time base of 1 sec. or 1 min. is not necessary. The transport force will be computed below for each vehicle using Eq. (2), and then pT will be computed by summing pi for all vehicles crossing the WIM sensor in one hour:

$$p_T = \sum_{i=1}^{n1\,veh.} p_{v.i} \ \ [kN/h] \qquad (4)$$

where n1 is the number of vehicles crossing the WIM sensor in one hour.

Knowing the type of vehicle (indicated by the WIM station), the distances between the first axle and the front bumper, CBF, and between the last axle and the back bumper, CBB, respectively, have to be estimated for each vehicle, in order to compute tb.i (Figure 19).

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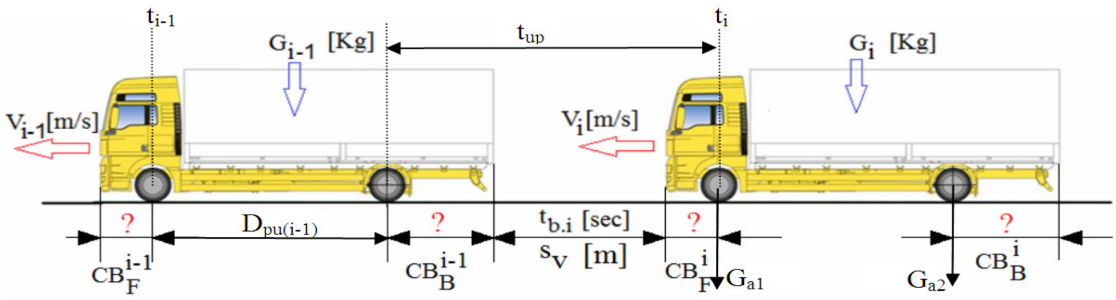


Figure 19: Notations used for VTF model

Axle Transport Force Model (ATF)

This model, proposed by R. Opitz, is focused on axles, not on vehicles. The basic idea in this model is to apply the Transport Force computed with equation (5) for each axle of the vehicle (i), and then to evaluate the Transport Force of vehicle (i) by adding all Transport Forces calculated for its axles:

$$p_i = \frac{G_{a1} \cdot v_i}{t_{up}} + \frac{G_{a2} \cdot v_i}{t_{up} + \frac{D_{1,2}}{v_i}} + \frac{G_{a3} \cdot v_i}{t_{up} + \frac{1}{v_i}(D_{1,2} + D_{2,3})} + \frac{G_{a4} \cdot v_i}{t_{up} + \frac{1}{v_i}(D_{1,2} + D_{2,3} + D_{3,4})} + \ldots \quad (7)$$

$$t_{up} = t_i - t_{i-1} - \frac{D_{pu(i-1)}}{v_{i-1}} \quad (8)$$

where

- G_{a1}, G_{a2} etc. are the axle weights of the vehicle (i);
- $D_{pu(i-1)}$ is the distance between the first and the last axle of the vehicle (i-1);
- $D_{i,j}$ is the distance between axle *i* and axle *j* of the vehicle (i);
- v_i is the instantaneous speed of (i) vehicle and, of course, it is the same for all its axles.

The ATF model is more accurate and more appropriate for pavement damage prediction than VTF model.

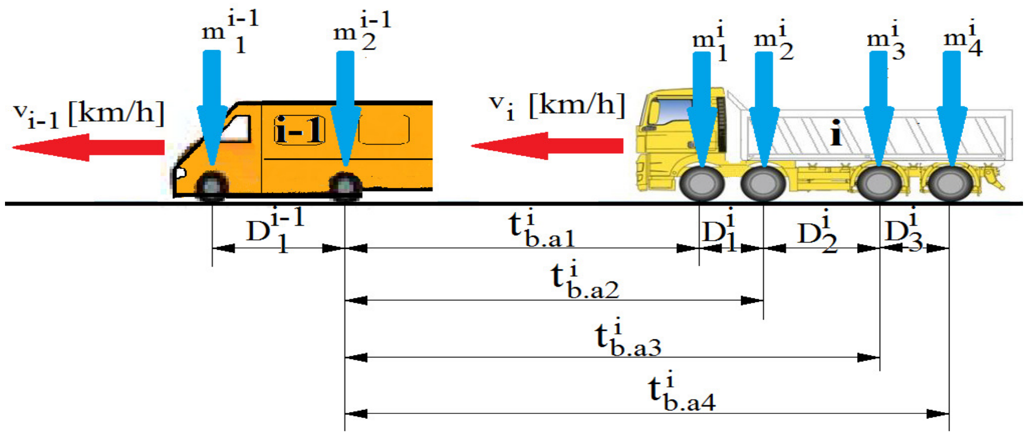


Figure 20: ATF model presented for vehicles D and E

The average distance between the last axle of one vehicle and first axle of the next vehicle is

$$s_a = \frac{L_{1\min} - D_T}{k-1} = \frac{1543 - 46.09}{4} = 374.23[m]$$

Although small differences has been obtained for the vehicle E, ATF model is more accurate than VTF because it works only with distances between axles, which are measured by WIM station and has no need to estimate the total length of every vehicle. It is also more realistic for pavement damage prediction. A comparison between all three models presented (TI, VTF and ATL) is presented in Figure 21.

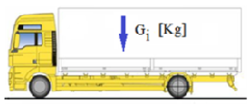
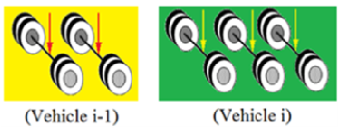
Traffic model	Model is focused on	Schematic representation	Conclusions
Traffic Intensity - *TI* [no.vehicles/h]	No. of vehicles		*TI* model, focused only on no. of vehicles/hour, is not realistic for pavement damage.
Vehicle Transport Force - *VTF* [kN/h]	Vehicle gross weight		*VTF* model is realistic for pavement damage, but the total length of every vehicle must to be ***estimated***.
Axle Transport Force - *ATF* [kN/h]	Load on axle		Instead of total length of every vehicle *ATF* model use the axle-to-axle distances, which are measured by the *WIM* stations. The accuracy of *ATF* is better and it is more realistic for pavement damage.

Figure 21: Traffic models (discussions)

1.3.13 Data security management

Technologies and techniques to perform efficient monitoring and enforcement were developed and deployed on the French and the German test site, e.g. T&T and 3D cameras, WIM sensors for load/weight control, infrared camera. Results showed that these technologies increased the fining efficiency to 32.78% compared to 4.37% with standard control technologies. For the Finnish test site a model was developed with a corresponding tool to estimate CO_2 emission according to the actual traffic flow (traffic density, number of vehicles, speed, and vehicle type) gathered from roadside unit camera system (Figure 23).

However, different data base applications and data sets and timing are used to supply the input vectors for the models and algorithms (see Figure 22). Therefore, data security concepts were prepared for all test sites as well as for the use of the realized systems in real world. Emtele Security Hub implements the main security concept designed for the ASSET-Road project, and includes authorization, encryption, user authentication and device authentication for data security management.

Figure 22: Hardware/software framework for capturing real-time traffic data for German test site

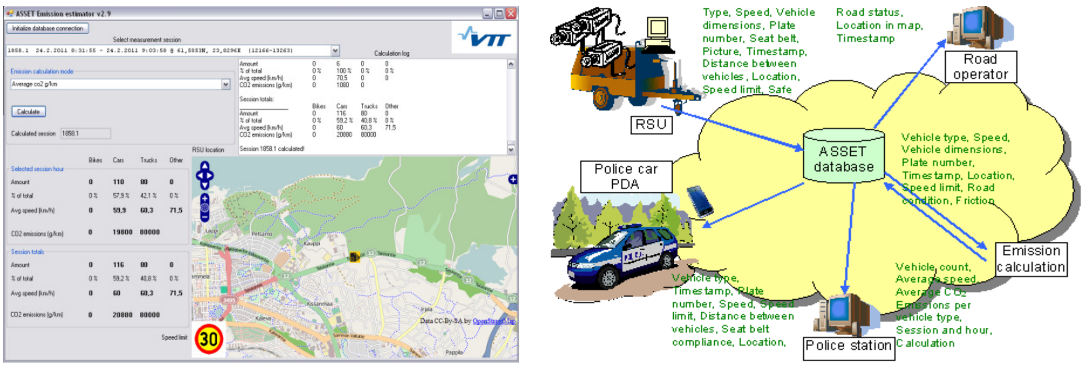


Figure 23: CO_2 emission tool

Complete Control of one single Truck						
	Classic Controlling			ASSET based Controlling		
Controlling Type	Nr of Persons	Time per Person	Time in minutes	Nr of Persons	Time per Person	Time in minutes
Paper	1	10	10	1	10	10
Digital tachograph	1	30	30	1	30	30
Overload	3	45	135	3	5	15
Technical conditions	2	30	60	1	10	10
Load protection	2	20	40	2	20	40
Selection of vehicle	1	20	20	1	2	2
Overall time for Control		**155**	**295**		**77**	**107**
Benefit in %			100,00%			36,27%

Figure 24: Enforcement measures using ASSET-Road and traditional technologies

1.3.14 Results of test site development and operation

Within the ASSET-Road project four test sites in Germany, France, Finland and Austria were built up under real world and life traffic situation. The design of the four ASSET-Road test sites is different in location, seize, layout, basic functionalities and integration of applications. Their joint feature, however, is the purpose of testing and further developing the different sensors, the algorithms, the software and the sequence of operations developed within ASSET-Road project.

1. At first, there is the **German test site** situated on the motorway A8 near Rosenheim, which is called an "Integrated safety station". Here, high-speed scales and slow-motion scales are installed, which acquire total weight and weight per axle, and undertake a vehicle classification. Furthermore this site includes a newly developed high-precision weigh-in-motion system, an RFID reader which is embedded in the pavement, an infrared camera for monitoring

status of brakes, tyres and bearings. And there is a surveillance area with a video-based tracking & tracing system monitoring vehicle trajectories, vehicle gaps and overtaking manoeuvres, as well as a high-resolution 3D camera system for licence plate number reading, vehicle classification, speed, height and distance measurement.

2. The **Finnish test site** is a “Mobile safety application”. A mobile enforcement platform set up on a trailer has been developed. It is not fixed to one place but can be moved easily at any location where traffic offences are expected. Seat belt compliance is performed. Vehicle speed, height and the distance between two vehicles is measured and - in case of offences - a picture is taken and the licence number plate is recorded for vehicle identification and the information is transmitted to the hand held terminals of the police.
3. The third test site, called **“R&D test bed module” is situated in Austria** on an urban road in Graz. Its purpose was to develop and pre-test the sensors in the carriageway, which later were installed on the other test sites.
4. Another **test site has been established in France**. It is called “GNSS based safety applications”, where several safety aspects and integrated technologies have been tested. A newly developed middleware (called TransportML) is used as a basis for connecting different services like snow clearance service, road status monitoring service, waste collection service and emergency service. The overall architecture of the TransportML middleware is designed as open system. Such architectures allow providing value-added services, resulting from the collaboration between existing services maintained by different entities. On the French test site these services are provided with applications like real-time GPS tracking, navigation and geo-fencing. A context aware embedded system was developed and tested.

Table 1 gives an overview on the applications of the different test sites:

Subsystems & technologies	Data	Purpose	DE	FI	AT	FR
High-speed WIM sensor	• Time of weighing process • Axle-related weight • Total weight • Number of axles • Distance between axles • Vehicle length • Vehicle category • Axle overload / total overload • Vehicle speed • Vehicle classification	Monitoring vehicle and axle load and overload	X			
High-speed WIM camera	• Still image of the vehicle	To identify the vehicle in case of violation for pre-selection by police	X			

Subsystems & technologies	Data	Purpose	DE	FI	AT	FR
Low-speed WIM sensor (reference system)	• Time of weighing process • Axle-related weight • Total weight • Number of axles • Distance between axles • Vehicle length • Vehicle category • Axle overload / total overload	Monitoring vehicle overload and prepare fining protocol	X			
High-precision WIM	• Time of weighing process • Axle-related weight • Total weight • Number of axles • Distance between axles • Vehicle length • Vehicle category • Axle overload / total overload • Vehicle speed • Vehicle classification	Monitoring and enforcing vehicle and axle overload in future for fully automatic overload control and fining	X		X	
Pavement sensor	• Stress • Strain • Acceleration • Noise/Acoustics • Temperature • Humidity	Measurement of pavement and environment properties			X	
Thermal imaging	• IR camera picture with temperature gradient and algorithms / temperature pattern	Inspection of the state of brakes, bearings and tyres	X			
Embedded road side RFID reader	• Data readout of pavement properties and vehicle data	Verification of the technical feasibility	X		X	
3D camera	• Pictures of the vehicles • Time stamp • Licence plate number • Vehicle dimensions: Height / length / width/ overheight • Vehicle category • Vehicle speed • Distance between vehicles	Identification of the vehicles, detection of vehicle dimensions, speed and distance monitoring	X	X		
3D cameras	• Section control II	Re-identification of the vehicle at the end of the section	X			
Tracking & Tracing cameras	• Pictures of the vehicles	Monitoring driver behaviour	X			
Video camera	• Video image and LPR	Road friction monitoring		X		
Video camera	• Video image and LPR	Seat belt compliance monitoring		X		
Regulation knowledge base	• Driving behaviour data and analysis based on regulations (digitized)	Recognise driving behaviour concerning regulations and driver warning	X			
LISA HMI	• Safety and driving information for warnings	Support and warning of the driver	X	X		

Subsystems & technologies	Data	Purpose	DE	FI	AT	FR
Data bases	• Different kind of parameters and measurement data	Storage and processing of information and inputs for analysis and monitoring	X	X	X	X

Table 1: Overview of the test sites

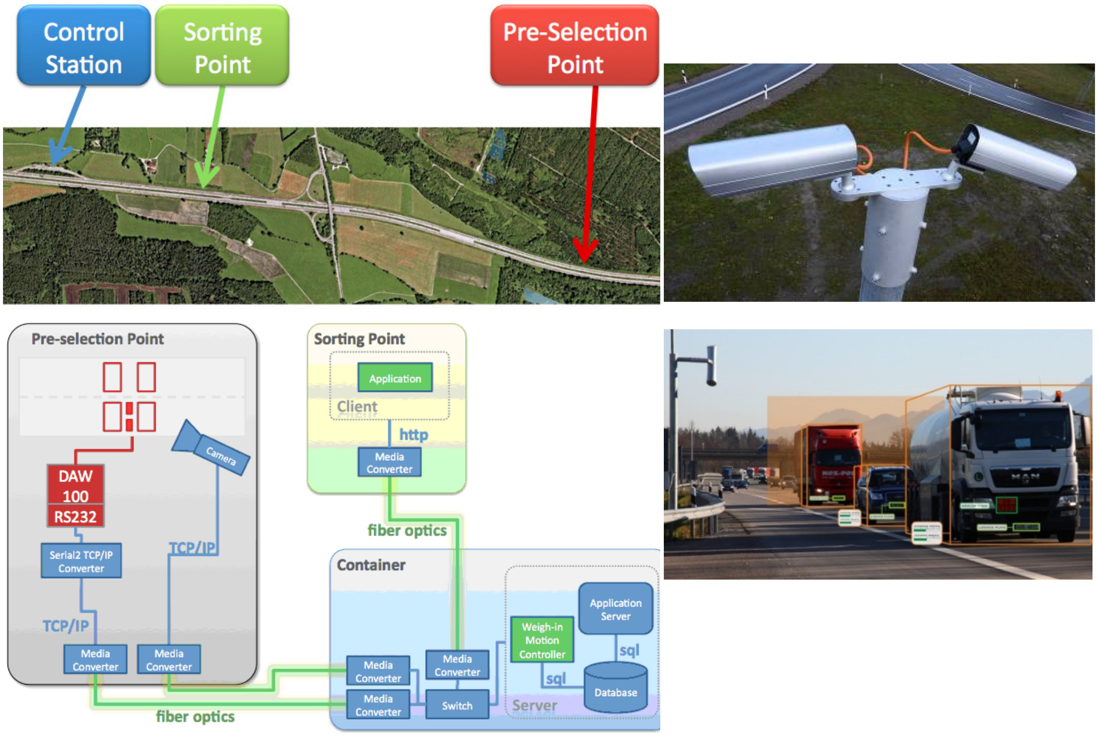


Figure 25: German test site

Figure 26: Finnish test site

Figure 27: Austrian test site

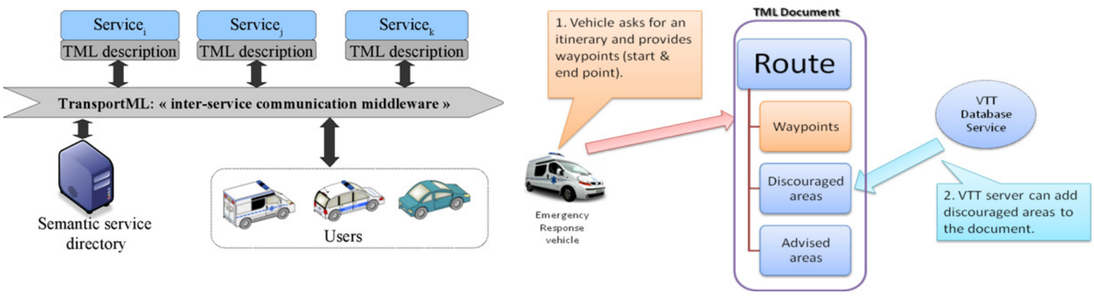


Figure 28: French test site

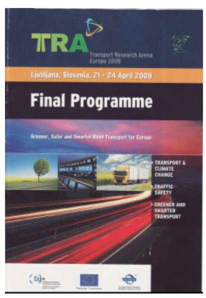
1.3.15 International co-operation and dissemination

A very successful international cooperation between the ASST-Road partners, ministries, industry and administrations could be established in conjunction with many different national and international workshops.

- Tanzania (very successful with several contracted consulting studies and further and ongoing cooperation)
- India (conference in 11/2011 with the road administration and ITS India)
- Hungary (cooperation concerning a integrated test station in preparation)
- Austria (cooperation concerning a integrated test station in preparation).

Bilateral cooperation between project partners could be established too for the future. The participation in conferences and exhibitions had a great variety in success rate, costs and efforts for preparation.

TRA 2008 Transport Research Arena Ljubljana



The very interesting conference and meetings were attended and supported by the ASSET-Road PO (at that time) Maria-Cristina Marolda and the Technical Coordinator of the ASSET-Road project. Two different presentations were given. There is available an

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excellent after conference service with online presentations and videos.

ECS (European City of Science) Paris

The preparation of the ECS participation was done in the period August until November 2008 and the venue was the Grand Palais in Paris from 14th to 16th November 2008. There was a strong international competition for being accepted for the ECS and ASSET-Road proposal was selected.

It was organized during the French Presidency of the European Union by the Ministry for Higher Education and Research. Over 60,000 visitors were registered.

The objective of this event was to provide the largest possible audience with a vision of European research that is more in keeping with the individual concerns and problems of our time; a framework for direct and lively dialogue between science and society.

ITS Stockholm 2009

The participation on ITS Stockholm on the EC booth, prepared by a contracted design company of the EC, was not successful:

- Provided ASSET-Road posters were modified and finally without sense.
- The boot was hidden in a second row.
- Big LCD projectors showed useless pictures of non-related content.
- Therefore, in the end there were less than 10 visitors.

International cooperation Tanzania

The main objective of the cooperation between ASSET-Road Project partners and stakeholders in Tanzania is a selective dissemination of ASSET-Road project research findings that adequately address the challenges of road safety and road infrastructure protection.

Figure 29: International conference Tanzania

ROC Systemtechnik GmbH Graz, Austria made an immense contribution in guiding and directing the WP7 dissemination activities to Tanzania and ADC-AfriDeut Consult Limited, Dar es Salaam acted as a country coordinator for ASSET-Road project in Tanzania, linking the dissemination efforts successfully to the stakeholders. This was greatly facilitated through the EC grant that made ASSET-Road project possible.

International cooperation India

Figure 30: International conference India

The international ASSET-Road India conference took place on 15th November in New Delhi, India, situated at the well-known IIC India International Centre.

The conference was very well prepared including the highlights of the ASSET-Road project and a professional handout submitted to the participants.

The conference program started with the welcome speech of Mr. Vinod Sher as Indian ASSET-Road partner followed by different presentation and intensive discussions. Further cooperation with ITS India and the Ministry of Transport is intended.

1.4 Potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and exploitation of results

ASSET-Road has different impacts on the “Socio-economic development” as the process of social and economic development in a society - measured normally with indicators, such as GDP, life expectancy, personal safety, literacy and levels of employment.

This will be caused for example by the new applied new technologies, changes in behaviour, control and regulations, changes in the physical system environment.

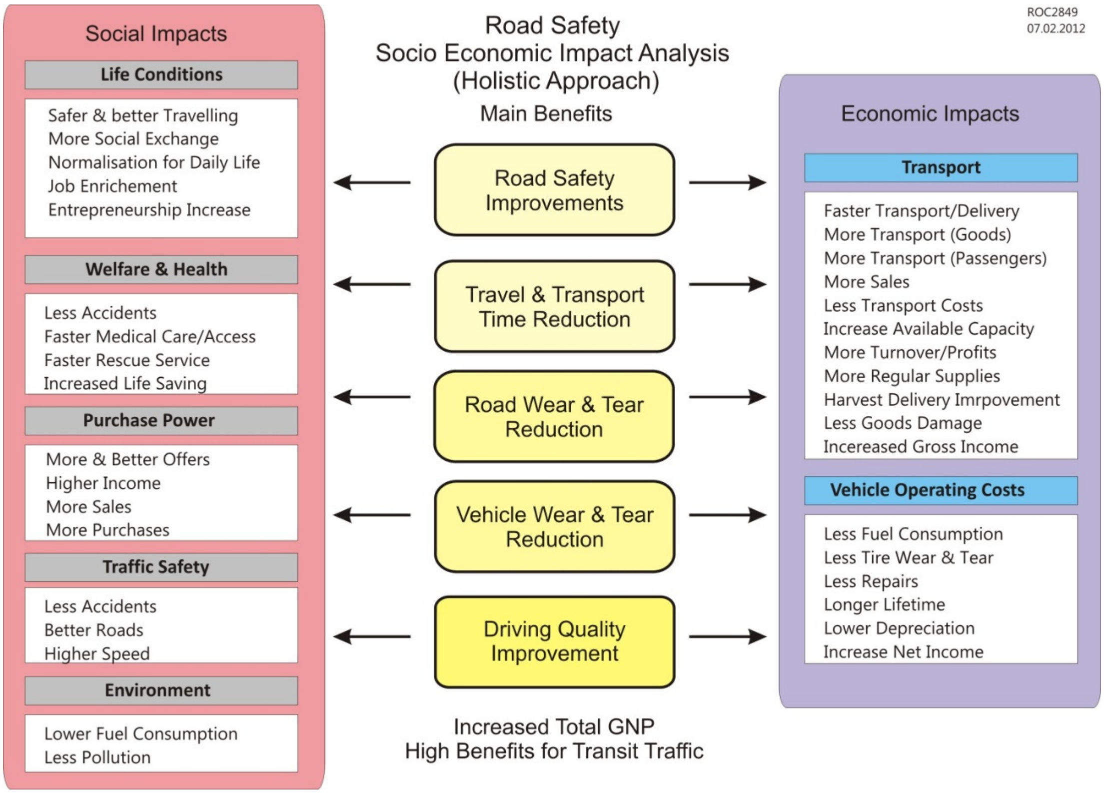

Figure 31: Road safety socio-economic impact analysis

Impacts of holistic safety and requirements

Item/Issue	*Before*	*After*
Methodology for increasing traffic safety	Currently there are ample of research work and studies concerning improvements for traffic safety. They mostly suffer on lack of holistic view, they are too closely related to a specific topic, technology or too ambition to take place in a real world.	This project will survey the methodology for increasing traffic safety in a way which is practically implementable. The holistic view and guidelines will be created not only for gathering pre-existing know-how but also generating holistic view and guidelines for developers when they designing new safety applications.

Item/Issue	Before	After
Architecture for road infrastructure applications	Projects dealing with road infrastructure based sensing or data management have been mostly initiated by road operators or vehicle manufacturers. Therefore they are mostly considered the problem from a vehicle or operator point of view.	The ASSET-Road architecture will take into account the preferences given by existing “vehicle” projects (e.g. FRAME, CVIS, Safespot, PReVENT, etc.) but will also investigate the architecture feasibility for emergency services, road administration, etc. The ultimate goal is to create a multi-purpose architecture which serves the needs of all end users (vehicle drivers, road operators, road administrators, police, etc.).
Traffic regulation knowledge base	At the moment, it is not easy to find documentation/resources where traffic regulations of countries are compared in a “simple” way (e.g. speed limits, warning signs, etc.) and it is even more difficult to find databases where such knowledge is easily available.	Data will be collected in a format which can be easily adapted to a knowledge base for providing the local traffic rules effectively in short glance. A common format is required since the collection will be directly used in the regulation data base developed in WP2.

Impacts of development of key technologies

Item/Issue	Before	After
SENSOR TECHNOLOGY		
Video image processing	The traffic surveillance (and enforcement) based on identification of vehicles and counting of traffic flow	Traffic cameras used for multiple different types of purposes, e.g. detecting seat belts, vehicle speed, ice on road, distance between vehicles.
RFID for dynamic vehicle applications	Tags used in many different kinds of identification applications. Future development will result in techniques for electronic licence plates	The RFID system will be integrated at hardware level with WIM sensors which provide real-time vehicle identification. The future electronic licence plate detection will be fused with an optical licence plate detection system.
GNNS	There are lot of GPS systems available in market, especially for navigating purposes	ASSET-Road will utilise GNNS technology (GPS and Galileo) for automatic localisation of surveillance equipment and for Geofencing, which will be demonstrated in the France test site.
WIM	In many European countries the feasibility tests for weigh-in-motion detectors have been performed recently and few WIM sensors are already available but there are problems with accuracy, installation and durability. Some sensor arrays are under investigation.	ASSET-Road will further develop the weigh-in-motion technique and will demonstrate its benefits for future automatic overload enforcement, the control station of the future and in estimating pavement wearing. New WIM sensing techniques will be used here and major development steps are focused for integrating sensors with RFID and thermal imaging technology in hardware level in order to provide real time measurement capability.
Tracking and tracing	Existing tracking and tracing systems are already in use for identifying and following vehicles on road. They still suffer low	Merging optical roadside tracking technology with a system which performs high resolution (continuous) tracking of online driving behaviour analysis, e.g.

Item/Issue	Before	After
	sampling rates and do no run in real-time.	detecting drunk and dangerous or non-economical driving. Moreover, optical and RFID based systems will be merged to provide robust vehicle identification even when visibility is degraded.
UTILISING ACQUIRED DATA		
Roadside data fusion	Data fusion has been topical in EU funded projects and scientific articles for 10 years. However, practical solutions have mostly resulted in rather low level fusion of raw data.	Taking the lesson of the existing data fusion propositions (e.g. PreVENT / ProFusion) and considering advanced ways of filtering, prioritising and taking care of data consistency, the ASSET-Road solution will use advanced fusion methodology (e.g. neural networks) and demonstrate their strength experimentally.
Regulation knowledge database	There are available some collections of the traffic regulations in written format mainly from automobile industry. However, ordinary drivers do not pay attention to regulations very intensively after driving school.	For tackling this serious problem of inadequate driving behaviour the ASSET-Road project will provide a database which rather adapts the driving environment for supporting driving behaviour which is in line with the local traffic rules. The database serves as an automatic guide for a driver.
Virtual driver agent system	The first offline analysers for modelling driving of single vehicles already exist. They are used for analysing and giving feedback concerning risky driving.	The virtual agent system will encourage drivers to modify behaviour, decreasing risky driving. Drivers will be encouraged to improve fuel efficiency for environment friendly driving.

Impacts of improved driver behaviour compliance

Item/Issue	Before	After
Driver behaviour analysis	There is a wide range of studies performed for analysis of drier behaviour. Despite the complex theories, a good basis exists for understanding and allowing for this behaviour.	The ASSET-Road study approach differs from the studies done in the EU projects HASTE, AIDE, HUMANIST, etc. This project approach is to provide information when necessary, but more emphasis is on infrastructure. ASSET-Road knowledge will be applied to encourage drivers to behave in a more infrastructure-friendly way.
Regulation knowledge base	No consistent information available, some studies by DG TREN	Framework for electronically representing traffic regulations for different applications (driver, roadside, ADAS). First content provision
HMI information provisions	Different HMI presentations for ADAS subsystems and applications	Integrated, scalable and adaptable HMI concept; will result in increased driver awareness.

Impact of safe and sustainable infrastructure

Item/Issue	***Before***	***After***
Load flow modelling	Various classical traffic flow models available, load flow is Currently not considered as necessary	Enhanced data integration for improved load flow modelling (high resolution WIM, environment conditions, and material properties). New algorithms were proposed and developed.
Life cycle Modelling	Various classical life cycle models available	Enhanced data integration for improved Life Cycle Modelling (high resolution WIM, traffic load flow and weight distributions, environment conditions, and material properties).

Impact of Kybernetic transport/traffic

Item/Issue	***Before***	***After***
Safety and security aggregation	Separately operated safety services and traffic management application	Structured and coherent integration of safety and security systems
Traffic flow representation	Mainly on quantities of vehicles and classes	Consideration of the physical mass and gaps of vehicles will lead to improved incident detection and cybernetic traffic flow optimisation.
Traffic control and enforcement	Various approaches and stand alone solutions for Traffic control and enforcement	Integrated efficient fully automatic or semi automatic safety control systems will be demonstrated for safety improvements.
Data security	Various approaches and stand alone solutions for equipment and systems	Integrated concept for the entities: vehicle, road side equipment communication and back end offices

1.5 Address of the project public website and relevant contact details

The project logo, the project website address and the list of beneficiaries including the relevant contact details are given below.

ASSET-Road project logo

ASSET-Road website

The project website can be found under the URL http://www.project-asset.com. It is designed in four languages (German, English, French and Italian). The website describes the project activities in detail. Its prime objective is the communication of the project concept, its outcomes and events realised in its context as well as provision of the contact details of project partners to the interested users to promote communication and possible collaborations with other companies or organisations outside the Consortium.

The website is considered as a very important dissemination tool, since it connects the ASSET-Road integrated project with the wide public (experts, related projects and research programmes, relevant authorities, policy makers, industry as well as the general public) via internet.

ASSET-Road list of beneficiaries and contact details

Partner	Institution	Partner code	Type	Country code	Postal code	Town	Address	Name	E-mail
1	**PTV Planung Transport Verkehr AG**	PTV	IND	DE	70191	Stuttgart	Kriegerstraße 15	Walter Maibach	walter.maibach@ptv.de
2	**VTT Technical Research Centre of Finland**	VTT	R-INST	FI	33101	Tampere	Tekniikankatu 1	Matti Kutila	matti.kutila@vtt.fi
3	**Statens väg-och Transportforskningsinstitut**	VTI	R-INST	SE	581 95	Linköping	Olaus Magnus Väg 35	Jan Andersson	jan.anderson@vti.se
4	**Università di Modena e Reggio Emilia**	UNIMORE	UNI	IT	42100	Reggio Emilia	Via Amendola, 2	Roberto Montanari	montanari.roberto@unimore.it
5	**Université de Technologie de Belfort-Montbéliard**	UBM	UNI	FR	90010	Belfort Cedex	UTBM, Rue Thierry Mieg Bat.D b.215	Jaafar Gaber	gaber@utbm.fr
6	**Universität Stuttgart**	USTUTT	UNI	DE	70569	Stuttgart	Universitätsstraße 38	Prof. Paul Levi	paul.levi@ipvs.uni-stuttgart.de
7	**University College Dublin, National University of Ireland, Dublin, Department of Civil Engineering**	NUID UCD	UNI	IE	14	Dublin	Earlsfort Terrace, Newstead Building, Richview	Prof. Eugene O'Brien	eugene.obrien@ucd.ie
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