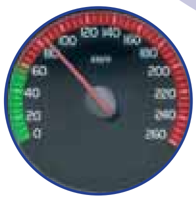
INTRO is supported by funding under the Sixth Research Framework Programme of the European Union

INTRO PROJECT

The unacceptably high number of accidents on European roads together with an increasing public demand for improved road capacity and comfort sets entirely new demands on road infrastructure. The costs of maintaining and developing the capacity of European road networks is ever increasing due to anticipated increases in freight transport demand and increased axle loads and traffic volumes.

The INTRO project addressed the problems of road safety and capacity combining sensing technologies and local databases with real-time networking technologies. The ambition was to improve both road safety and capacity by providing rapid feedback of emerging problems to maintenance authorities and road users.



http://intro.fehrl.org

INTRO Activities

The INTRO project focussed on applying and combining existing and new sensor technologies in a holistic way in order to significantly increase capacity and safety as well as improving the well-being of road users.

The results achieved by the INTRO project will have effect on several areas of road and traffic research and management.

The INTRO project was a € 3.5 million project, supported by the European Commission. The project started in March 2005 and ended February 2008. Participants in the project were both public European road engineering and road safety institutes as well as private companies within the ITS sector.

Intelligent Road Systems: Current Knowledge and Implementation Strategies

For effective implementation strategies, a state-of-the-art overview of intelligent roads is essential. This provides feedback on user needs. Structured interviews with a selection of road operators and traffic managers in Europe allowed INTRO's outputs to be focused on the needs of these users. To prevent duplication and avoiding "reinventing the wheel", INTRO gives an overview of selected relevant related projects, their activities and key results. This overview also helps to identify potential issues, findings and experiences related to INTRO's work. INTRO provides an overview of key technologies and systems related to intelligent roads.

INTRO identified and analysed scenarios and short term trends were identified. INTRO developed an INTRO Vision considering technology trends, financial constraints of road authorities and other circumstances. INTRO also provides an analysis of potential implementation strategies, issues and examples of possible costs and benefits.

Infrastructure

Floating Car Data

INTRO experimented with a method for using a dedicated fleet equipped with the CAN bus readers and GPS functionality, with added sensors. Results showed this is a good set up to obtain up-to-date information of road surface defects.

In situ sensors

A range of in situ sensors and possible applications were identified by INTRO. Examples of these are (traditional) strain gauges and fibre optics, temperature sensors and accelerometers. Special attention has been given to 'Mote' technology. This technology combines some of the identified sensors with wireless communication technology.

Pavement health monitoring system

Measurements showed that by measuring the strain at the bottom of the asphalt layer, it is possible to get information about the load of a passing truck. By using this information about the load and the measured deformation, the residual lifetime of the pavement could be calculated and compared with the threshold fixed by the road administration. This method will help road operators of highways with very important load information and results in better road management.

Determination of bearing capacity due to frost heave

INTRO found a very good correlation between relative strain and frost thaw. This kind of correlation is a first step to a general model for predicting the seasonal variation of bearing capacity on minor low volume roads. This model and the information about frost thaw together helps road authorities with making a more objective decision about load restrictions on minor roads in winter.

Bridge health monitoring system

Wireless sensor networks have the potential to change the perception of structural health monitoring, because there are many advantages. For the technology to be able to monitor structurally, a specific level of sensor sensitivity and available sampling rate is needed. Permanent monitoring of bridges by use of in situ sensors is a promising technique to support maintenance and guarantee safety and reliability.

Safety

Pavement skid-resistance versus vehicle stopping distance

Pavement skid-resistance is an essential factor of road safety. The INTRO project aimed to link pavement skid-resistance to vehicle stopping distance in summer and winter conditions. A procedure to estimate the braking distance of a passenger vehicle using a reference friction value as input has been developed. The procedure has been tested and validated on both high and low friction surfaces (summer and winter conditions) using two different types of vehicles. The results show that the values of the parameters for low and high friction cannot be directly compared, because different test vehicles have been used. Additional input regarding the road conditions (ice, snow, wet or dry) is needed. More testing is needed, using surfaces with a friction level somewhere between pure polished ice and packed snow, as well as very low friction asphalt surfaces. This will lead to a conclusion whether a reference friction value is enough for braking distance estimation or not.

Data model for road safety related data

The INTRO project aimed to increase the safety of European roads with the help of an intelligent combination of sensor technologies and central databases utilising real-time networking technologies. This will enable road maintenance authorities to react more flexible to unfavourable road conditions.

The creation of a data model for road safety posed an innovative challenge for all parties concerned. With all information and data quality checks, INTRO made a valuable contribution to the safety of all road users as well as a possible reduction of traffic related fatalities.

Simulator study

In a simulator study the INTRO project investigated how a low friction warning system in vehicles would influence traffic safety. For this purpose it was essential to identify the interface with the highest potential to increase traffic safety in low friction conditions. The results indicate quite clearly that the recommended speed display in combination with a timing of six seconds leads to the most favourable driving behaviour with respect to traffic safety.

Traffic Management

Traffic data: single source and data fusion

An investigation of data fusion methodologies on combining data from multi sources to predict travel time and traffic safety has proven to be very useful for estimating and predicting traffic indicators. A main innovation here is the use of alternative traffic data sources such as toll collection data combined with more general data, such as traffic sensor data.

Weather and traffic forecasting

INTRO had the objective to quantify the relationship between weather and traffic flow variables. Studies clearly showed that there exists a strong connection between weather and traffic parameters. Experiments in the driving simulator tested the parameters of time headway and time to collision for different drivers and fog situations. These experiments also showed the necessity to take visibility in inclement weather into account when considering parameters such as overtaking and lane changing.

Safety indicator for monitoring traffic safety

INTRO addressed the development of safety indicators to monitor traffic safety using traffic sensor data. Motorway accident databases were analysed. The INTRO project has developed safety indicators (both microscopic and macroscopic) and demonstrated the application. When the traffic condition is deemed to be risky, drivers could be warned of the risk and take actions to reduce and mitigate the risk.

Future (Vision)

INTRO worked on a vision on intelligent roads. This INTRO Vision depicts the most probable world in which we might travel in 30 years; it is based on the extensive analysis of existing visions and on the experience of INTRO partners. Strongly based on the current trends, the INTRO Vision pictures a realistic future of our road networks and how they will be used and managed.

Intelligent road systems: Current knowledge and implementation strategies

The principle

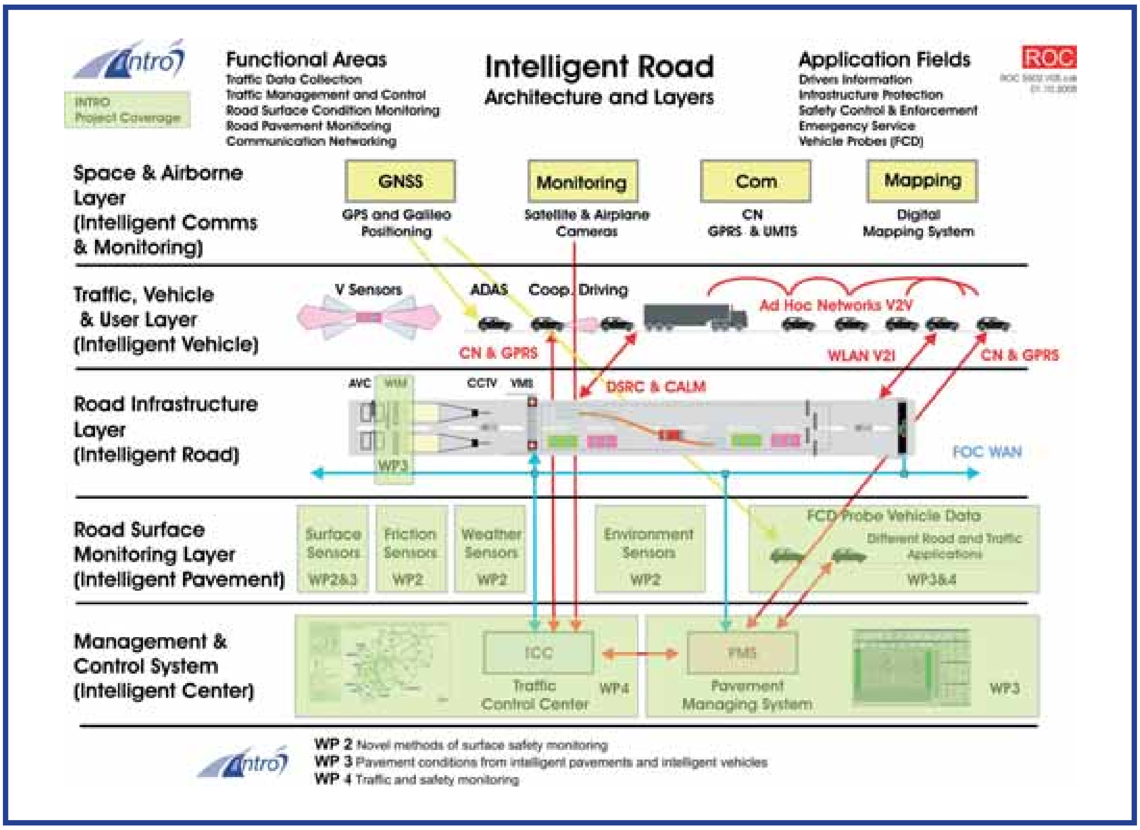
This research strand of the INTRO project was a "horizontal" activity, feeding into the technical parts of the project. It aimed to bring together previous experience, to examine user needs, to provide scenario investigations and to investigate implementation issues and benefits.

The rationale

Rather than developing new technology, the aim of INTRO was to better use existing technology in an integrated way in order to provide realistic and cost-effective solutions to road safety, infrastructure management and maintenance issues. Thus there was a need to review existing practice in the form of previous and ongoing studies and deployments. Because the project's outputs are mainly targeted at road authorities and operators, a comprehensive overview of the needs of these stakeholders was particularly important.

The technical output and results produced by other strands of the INTRO project needed to be set in the context of the real world in order to facilitate further work towards implementation and enabling road operators (and thus all road users) to effectively reap the benefits of INTRO. This involved issues such as costs, benefits and implementation strategies, depending on different needs and circumstances.

The following diagram shows the "layers" present in an intelligent road. Areas shaded in green were covered by the INTRO project.



The practice

The first task was a state-of-the-art report (released in autumn 2005), focusing on the use of sensor technologies to deliver highway safety and capacity improvements. A section on user needs is included, focusing on the needs of road operators. A limited number of road operators in different parts of Europe were interviewed in order to assess where their priorities lie and their approaches towards the deployment of sensor technologies.

Following this, a review of current and future trends affecting road transport in Europe was undertaken and released in 2006. This included a review of drivers of change, intelligent road policies and of scenario planning, the development of scenarios and expected trends related to the three technical streams of INTRO. This task fed into a report on Visions, produced in 2007, which reviewed current visions related to Intelligent Transport Systems and developed a 30-year vision for intelligent roads based on five example road types ranging from busy urban motorways to rural secondary roads. A wide consultation has been undertaken to obtain feedback on these visions.

Finally, towards the end of the INTRO project, an analysis was made of potential implementation strategies for the project's outputs, looking at the potential cost-effectiveness of larger-scale deployment of the main concepts developed and demonstrated in INTRO and proposing future steps.

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Novel Methods for Surface Safety Monitoring

The principle

Sustainable pavement management and efficient road maintenance are becoming more and more important for road operators and road authorities. Measures to be taken and warnings to be issued strongly rely on up to date and accurate data concerning road conditions.

The rationale

Low friction road sections often cannot be perceived by drivers, thus constituting great danger in everyday road traffic. Although modern cars (equipped with "stability programs") provide advanced security and even issue warnings to the driver, this does not yet include a warning prior to the affected road section or even to succeeding drivers, nor information to road maintenance authorities, who could mitigate the given situation for the sake of all road users. The terms road friction and skid resistance are of minor use for the road user and have to be translated in order to make them generally understandable for drivers. The technically important value is expected stopping distance and the communication to the driver could be a simplified classification, which is a matter that still needs investigation.

The practice

The INTRO strand "Novel Methods for Surface Safety Monitoring" focuses on data that is available in standard cars with ABS/ESP sensors. By merging these data and data from standard measurements (as carried out in many countries on a regular base), a system is designed and demonstrated in a pilot, that detects warnings and causes for local road surface insufficiencies of temporary and permanent nature. This affects winter maintenance topics as well as low friction road sections in summer.

The data collected by the probe vehicle was analysed in different ways, thus deducing relevant information for road authorities on one hand and road users on the other. The results are processed and conveyed in a way that road authorities can take immediate countermeasures (e.g. black ice sections, leaves/mud on the road) and road users (having a unit issuing advanced warnings at their hands) can adapt their speed and way of driving to the oncoming hazardous area.

The contribution to active road safety of such a driver warning system was assessed in one of the world's leading driving simulators.

The results

Fundamental research measuring stopping distance as well as skid resistance on different surfaces supported the development of a stopping distance model. These results built the foundation for the next developments and research activities. One was to analyse the impact of different low friction warning systems (Figure 1) in a driving simulator (see Figure 2).

Figure 1. Recommended speed interface used in the driving simulator study

Figure 2. VTI Driving simulator used for INTRO WP2 tests

In the extended evaluation the system components, like client server communication, GPS localization, micro slip measurements, etc. were tested. Finally two pilot applications were developed and presented. One was to inform the road operator on the road surface condition with the innovative system concept (Figure 3). The second application was the implementation of the optimal road user warning (the recommended speed interface under real conditions in the Austrian test area (Figure 4).

Figure 3. GIS for road authorities and operators (Pilot 1)

Figure 4. Driver low friction warning system with recommended speed (Pilot 2)

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Pavement condition from intelligent pavements and intelligent vehicles

The principle

The efficient operation and maintenance of the road network relies on the availability of accurate and up to date information on pavement condition. As traffic levels continue to increase, it has become essential that the acquisition of this information be made with little or no disruption to traffic flow.

The rationale

The INTRO research strand focussing on «pavement condition from intelligent pavements and intelligent vehicles» has aimed to provide new methods of predicting the deterioration process and condition of pavements and structures in unobtrusive ways, and make this information accessible at low cost. The long-term benefits provided by this work will be the effective targeting of road maintenance, resulting in reduced traffic disruption, increased accessibility, reduced accidents and better value for money. Further benefits include increased effectiveness of current measurements, improved identification of defects, and hence reduction of the time between the development of the defects and the reporting of their presence to the road operator.

The practice

First, the in-situ measurement of pavement condition was considered. Both current and emerging sensors were identified and a number demonstrated for the provision of information on the structural capacity of highway pavements and structures, during trials at targeted sites. These investigations included the use of sensors for providing a continual record of road strength; instantaneous vehicle weighing, to prevent overloading of trucks; highlighting abnormalities in the strain placed on bridge decks or supports; and in areas suffering from road damage due to the spring thaw cycle, moisture and temperature sensors embedded in a road have been shown to predict the load-bearing capacity of the road, thus enabling automatic setting of load restrictions on these roads.

In-situ sensors:

Weigh-in-motion (WIM) station

Strain gauges at Kindsjön

Moisture gauge at Kindsjön

Secondly, the measurements provided by the sensors fitted to standard production vehicles ("probe vehicles") were investigated, in order to demonstrate a method for (potential) real-time monitoring of areas of the network having conditions that affect user well-being, and the identification of locations that may present a non-friction related hazard. This investigation found that it is possible to pinpoint locations of pavement unevenness, using data collected by a standard, unmodified passenger car, and this information could be relayed in real time to a road operator.

Strain gauges on a bridge deck

Finally, methods were identified whereby data obtained from in situ measurements can be enhanced by those provided by probe vehicles, to provide network managers with a more complete picture of the condition of the network. It was demonstrated that dynamic loading measurements, obtained from a truck, could be used to enhance measurements from in situ strain gauges, used to measure road strength.

Probe vehicles:

Probe Vehicle sending condition data to road operator.

In situ and probe:

Truck traversing strain gauge

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Traffic and Safety Monitoring

The principle

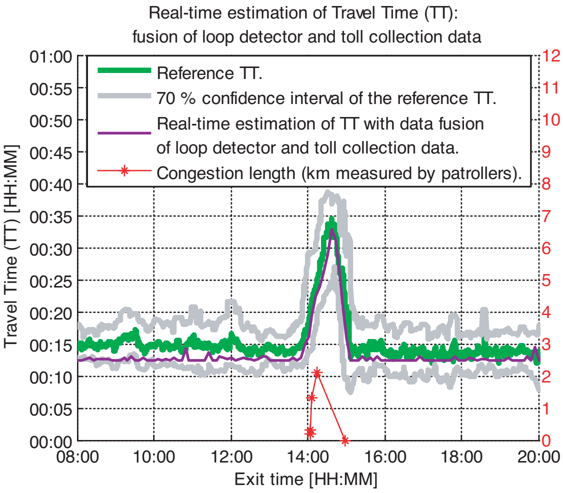
Efficient traffic management relies on up-to-date information about the state of the road network. As more traffic and other data sources become available, more accurate estimation and prediction of road traffic conditions utilising all data sources is becoming essential to reduce congestion and increase traffic safety.

The rationale

Increasing amount of data are being collected and often for one specific application. If these data are converted into useful traffic indicators describing the traffic conditions, appropriate traffic management plan can be activated. Pro-active traffic management actions can be taken more efficiently if traffic conditions are predicted a short time ahead. The INTRO "Traffic and safety monitoring" strand focused on developing methodologies for predicting traffic conditions and for monitoring traffic safety using data measured from traffic sensors and probe vehicle data. The effect of weather on traffic conditions is also an important factor to be taken into account. Furthermore, knowing when traffic conditions are unsafe and acting on this information to warn drivers still needs investigation. The outcomes from this research will improve prediction of traffic conditions and evaluation of traffic safety, leading to safer driving condition and better use of road network.

The practice

First the most relevant traffic indicators characterising traffic flow conditions for different applications were evaluated and selected. Methodologies for dynamic traffic indicator estimation using probe vehicle data from Vienna were developed; and the methodologies were evaluated using traffic simulation.



Fusion of traffic loop data and toll collection data

Traffic data collected by different sensors, both fixed and mobile were investigated in order to demonstrate a method for fusing data to provide a consistent and comprehensive picture of network traffic conditions. The data fusion technique takes into account the qualities and imperfections of each source and combined the data to generate a single estimate of traffic conditions in areas of the network where data is available.

Inclement weather conditions affect driving behaviour, traffic safety and traffic capacity. To investigate the weather effects, quantitative analysis on the changes in traffic characteristics under various weather conditions, and study on the effect of fog using driving simulator were carried out.

Finally, relevant safety indicators to estimate the safety level at different locations on the road network were formulated. Sensitivity analysis of the safety indicators formulated using observed individual traffic data was carried out and methods to set threshold values the safety indicators' parameters were proposed.

The results

INTRO developed a new method for estimating travel time from unidentified probe vehicle data. The results based on simulated data showed that the method generally performs better compared to existing piecewise constant vehicle profile method. Results for identified probe vehicle method, validated against Automatic Vehicle Identification data, showed the mean error for speed estimated is low (5.1 – 5.8 km/h).

Data fusion is an appealing data processing technique to take into account data qualities and imperfections of each source. INTRO demonstrated that the fusion of traffic loop data and toll collection data, improves both the accuracy and the robustness of travel time estimation.

Weather conditions influence how drivers behave. INTRO research showed on Polish roads, free flow speed decreases during rain and snow conditions. However, speed difference on Swiss motorways during fine and inclement weather is relatively small. One reason could be the quality of the road. It also raised the question whether Swiss drivers are keeping sufficient safe distance during inclement weather.

INTRO driving simulator study of fog showed that drivers' time headway when following a vehicle at 30m visibility is less than when the visibility is 60m. One of the reasons is that drivers are looking for a visual frame i.e. the tail light of the lead vehicle, and at 30m visibility it means that following vehicles are driving too close.

If a system could monitor traffic risk and inform drivers to the appropriate action to take, it would reduce accidents and road fatalities. INTRO has developed safety indicators for monitoring traffic risk and preliminary results on the sensitivity of the safety indicators using field data have been encouraging.

INTRO driving simulator study of fog

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