Intelligent Roads

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Deliverable D1.2: Report on Scenarios, Structure and Potential Short-Term Trends relating to Road Transport in Europe
EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

Introduction

The INTRO (Intelligent Roads) project is aimed at demonstrating how safety, capacity, road operation and maintenance problems can be alleviated by the use of existing sensor technology in a harmonised way, to add “intelligence” to road networks. It is a three-year R&D activity with funding under the 6th Framework Programme of the European Commission (Directorate-General for Research).

Further information can be found on the overall aims and activities of the project at the INTRO website: http://intro.fehrl.org

Work Package 1 (WP1) of the INTRO (Intelligent Roads) project deals with current knowledge and implementation strategies for intelligent road systems, related to safety and capacity improvements. It is a “horizontal” strand of the project, interacting with the three technical work packages (WP2: Novel concepts for surface safety monitoring; WP3: Pavement conditions from intelligent pavements and intelligent vehicles; and WP4: Traffic and safety monitoring) and with the work package on clustering, dissemination and implementation (WP5).

This Deliverable constitutes the second report of WP1. The task focused firstly on examining possible scenarios for road transport and looking at future needs in Europe for private and commercial transport on road networks. It explores the core challenges in safety, capacity and economy and short term and long term trends.

Most transport commentators and experts, including partners within the INTRO project, generally accept that the expected overall trend and future scenario for roads will be:

- Increasing traffic on the one hand, combined with higher costs for fuel and road operation on the other; and
- More awareness and higher necessity for improved safety and economy.

Although the degree to which these things will happen is open to debate, and is subject to many social, political and economic factors, these developments will generally lead to a situation whereby road networks will evolve from being an “inactive” pavement or concrete layer to an “interactive and communicative combined material and information road layer” including sensing and intelligence in cooperation with traffic in general and intelligent vehicles in particular.

This review also covers:

- Financial aspects: increasing financial constraints for public authorities responsible for building, maintaining and operator transport infrastructure;

- Trends, including chained dependencies for safety and capacity issues;
- Future visions, in terms technology trends, future needs and potential solutions and their innovations.

This report, as part of INTRO WP1, represents a scoping study exploring possible scenarios and likely trends. It feeds into a separate, later, task within the INTRO project in which a report on visions will be produced. This Visions report will use the present report as a base and go on to develop a range of more concrete scenario mixes and visions on intelligent roads.

Although this report draws on some existing information, such as existing trends and policies, it is largely the product of its authors own thinking, particularly as the concept of visioning and scenario building for intelligent road systems on a macro scale has received relatively little attention in previous research efforts. Much of the content of the report emanated from in-depth discussions in a two-day brainstorming meeting in Warsaw in December 2005, in which six INTRO partners participated.

Overview of Scenarios and Trends

"Scenarios and trends" means the perception and (short) description of different situations and related parameters and their dynamics and changes over the time and space.

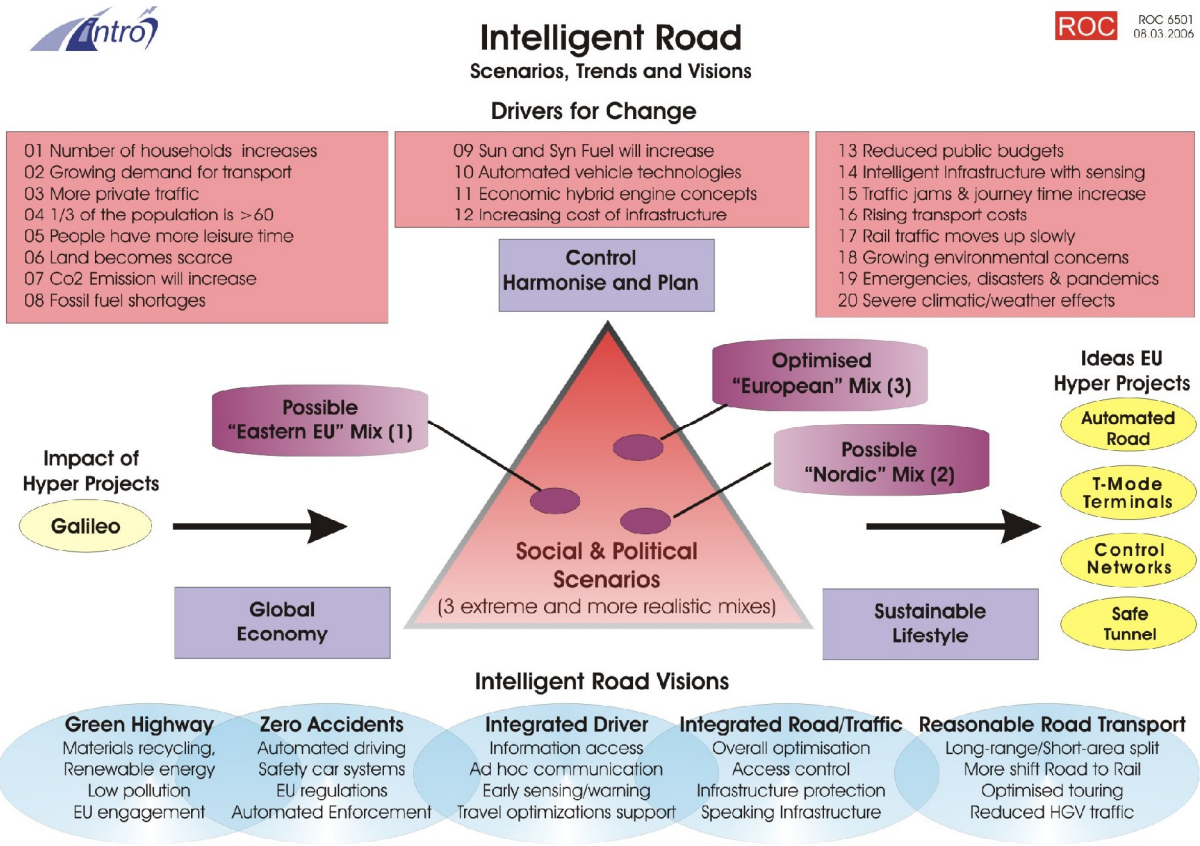
Scenario planning is a method for learning, developed in order to train military leaders for Cold War contingencies in the 1950s, through constructing a range of distinct narratives about the future, each scenario representing a different reality.

Trends, on the other hand, are based on current and future developments in society, the economy, technology, the environment, etc, and can be used as a base for which to develop scenarios and predict their effects.

One important reference project was the Vision 2030 project[1] for the Highways Agency in the UK, which is responsible for motorways and trunk roads in England. This project had the objective of developing visions for the future mobility needs of people and goods for a 30 year time horizon, as it was recognised by the Highways Agency that issues such as traffic congestion, global warming and environmental sustainability required forward planning beyond the typical 5-10 year horizon. This project developed three main scenarios which, although attainment of any of them is unlikely, indicate a direction in which society and governments could go in the next two to three decades. These scenarios were named "Control, Harmonise and Plan", "Global Economy" and "Sustainable Lifestyle". These three scenarios have been used in this INTRO report as a base from which to explore possible structures and trends. Figure 1 summarises the scenarios, trends and visions covered in this report, with the three Vision 2030 scenarios shown as the corners of the triangle. Realistically, the future will not be one of these "extremes", but somewhere in-between them, within the triangle. Feeding into

[1] A more complete outline of this project is provided in Appendix 2 of the main report. See also the Vision 2030 project website: http://www.transportvisions.org.uk

these visions at the top of the figure are the drivers for change and at the bottom are a set of visions for intelligent road which emanate both from the from the drivers and from the socio-political scenario mix.



Intelligent road solutions – effects, circumstances, visions and solutions

Trends and Drivers of Change

"Trends" looks at drivers of change. Different trends in different domains have to be considered in the anticipation of future:

- Technological developments on a microscopic level (sensors, processors and interfaces);
- Technological developments on a system level (vehicle design, automated vehicle systems, intelligent infrastructure, wireless short and medium range communication, etc);
- Lifestyle and population changes;
- Economic developments and management of energy (consumption and its sources) combined with changes in costs;
- Environmental issues, including renewable energy use, as well as increasing temperature (Greenhouse effect), pollution controls and climate change;

- Safety issues, including accident rates and severity, control measures (technological and legal), education and attitudes, etc;
- Changes in production processes (single-location in depth production, to dislocated production spread across different geographical locations) and freight transport in general.

As visible from today's point of view, several trends (some definite, others likely) can be firstly summarised. These are presented in the figure on the previous page.

The key trends are as follows:

- ***Energy Change:*** Conventional fuel resources are finite and sometime in the future petrol and diesel for road transport will become increasingly in short supply, leading to dramatic increases in costs. Scarce fossil fuels could be partially replaced with bio-fuel and synthetic fuel ("Sun and Syn" fuel). In its Green Paper: Towards an European Strategy for the Security of Energy Supply (2000), the European Commission expressed its aim of a 20% substitution of traditional automotive fuels by alternative fuels by the year 2020. Vehicles must use alternative energy sources and be more and more efficient, however although major advances have been made in fuel efficiency, mass production of road vehicles running on alternative fuel is not yet the case and is unlikely in the short-term. These developments are not yet promoted as necessary.
- ***Vehicle Change:*** Single vehicles have already evolved from being purely "mechanical" to being "electromechanical", with computer control. This is likely to evolve further to become an "interactive information, communication and sensor/actuator controlled driving system", increasingly supporting the driver and automating the driving process on different levels (from trip planning to real time driving control). First projects with "Cyber cars" which drive themselves automatically have been tested and are under further development.
- ***Road and Traffic Change:*** Road infrastructure, at least for key parts of the network with heavy traffic flows, are likely to change to intelligence-embedded layers, and infrastructure will be more protected from deterioration (life cycle cost reduction) if automated nation-wide HGV control networks are implemented, together with optimised pavement status supervision and maintenance systems.
- ***Interactivity between vehicles and the whole dynamic traffic flow*** on different levels will increase step by step to achieve more safe and co-operation controlled driving. The current traffic management centres should be complemented by in-situ and ad hoc traffic co-ordination and control systems, including enforcement of violations.
- ***Infrastructure Operation Change:*** Infrastructure cost allocation and schemes will change: in the future, users are likely to be increasingly charged according to driving patterns, time slots, demand and supply of road space and infrastructure maintenance and operation costs. Marginal cost pricing for infrastructure is part of EU policy and several national

governments are already investigating electronic road pricing (beyond that which already exists on toll motorways).

- ***Goods Transport (HGVs on roads):*** If current trends continue, freight transport and quantities of HGVs on road networks will dramatically increase, unless considerable measures for stabilisation are introduced. It is clear, that a multi scope regulation has to be undertaken on EU level to reduce the negative effects, make road transport reasonable, and shift more long distance transport to other modes (e.g. rail). Stabilisation and achieving the EU's aim of "modal balance" will be a long term task.

- ***Driving Access Change (Restrictions and/or Tolling):*** Availability and access to the road networks, or at least the busiest parts, will eventually change from a more or less open unlimited road system to a limited, rationed or pay-by-use access system. Governments and administrations may in future limit the number of vehicles (e.g. as is done in Singapore) and introduce personal driving contingents e.g. in km/year, in addition generally restricting the road use in terms of allocated amount of mileage or time slots per person on busy roads (motorways, urban roads, etc) and/or at peak times – such rations or rights to use certain networks at certain times could possibly be bought and sold as tradable benefits.

- ***Safety Change:*** Road safety is a key political issue and the EU White Paper on Transport gives a stated policy aim to halve the number of deaths on the roads between 2000 and 2010[2]. While there has been some reluctance by some countries to implement automated control and enforcement in the past, the reductions in accidents and casualties brought about by increased control and enforcement systems have proved their worth and there is increasing public recognition that some "freedom" needs to be sacrificed in order to significantly reduce accident rates. Increased control and traffic management is almost certain in the future, which will result in traffic flow becoming smoother and safer. Driving would thus become more homogeneous and efficient, and a convergence of main international traffic rules is possible in the future. Co-operative driving and platooning of vehicles are likely to be introduced on a higher level. Road traffic safety improvements through ITS-based measures may come from intelligent road infrastructure (such as applications within the scope of the INTRO project), from intelligent vehicles and from intelligent control. The optimal solution is to combine all three.

- ***Environment and Climate Change:*** There is a two-way relationship between roads and the environment. The first is well-documented: the ways in which roads and traffic affect the environment. Issues include air pollution and associated global warming, noise pollution, severance, visual effects, groundwater and water run-off pollution, unburnt fuel, particle matter (from exhaust, tyres, brakes, etc), the destruction of natural habitats, landscapes and ecosystems by road building, and the depletion of energy resources. These issues are considered by all European governments and a range of government legislation or

[2] European Commission, "White Paper – European transport policy for 2010: time to decide"

incentives are foreseeable in the future to deal with this by encouraging mode-shifting, more fuel-efficient driving, etc (e.g. road user charging, traffic restrictions, more taxes on polluting vehicles or banning them from certain sensitive areas, stricter enforcement of speed limits and traffic management and control measures). The second part of the relationship is how the environment and climate can affect transport, and in particular roads. Many parts of Europe are subject to severe winter conditions and roads need to be designed, constructed, maintained and managed accordingly in order to prolong the life of the infrastructure and uphold the safety of users. Global warming is causing climate change, one effect of which is more frequent severe weather, such as storms, heatwaves, etc. The implications of climatic changes may include road surface drainage failures, more flooding, deformation of road surfaces due to high temperatures, damage to roadside infrastructure (signs, gantries, etc, including ITS infrastructure) due to high winds, etc. In certain locations therefore, intelligent infrastructure itself could be damaged or destroyed. The appropriate infrastructure therefore needs to be chosen for the conditions and adequately protected.

- ***Technological Drivers of Change:*** Technological change is usually developed either to satisfy user desires (e.g. improved specification of cars, including on-board services) or government objectives (such as enforcement or pricing). The different effects of current and expected technologies, developed in general or specifically for traffic and ITS are expected to be higher data rates and better access, more precise positioning and navigation, individual connectivity in real-time and covering all road areas, cheaper and better sensors and automated operations supporting drivers.

Scenarios and Policies

High Level Scenarios

Scenario development is not about predicting the future, but by looking at a range of plausible future frameworks (concerning transport, government, society in general, the environment, etc) and exploring what the impact of each scenario would be on the road transport sector in general, and the role of intelligent road systems in particular. Scenarios try to describe all the possible situation of external and internal factors influence on the “intelligent road” systems and try to give an answer how the systems demonstrated and recommended by the INTRO project can adapt or react to each of the scenarios.

The question is, how developments caused by mankind and nature, and their interdependencies will influence or promote intelligent roads and their expected functions and performances.

A new and more open thinking is required: Information technologies including new micro scaled sensors, wireless and more powerful communication (even between single vehicles and infrastructure) and highly integrated and low cost processing technologies are entering and dominating the road with strong impacts and opportunities for improving safety, capacity, driving economy and infrastructure management. The availability and costs of petrol and diesel will also play

a more and more important factor and hopefully initiate alternative energy sourcing for vehicles and driving.

The role of intelligent road systems in the future could vary enormously according to degree of control society is willing to accept in order to reduce the negative impacts of transport, and thus whether societies and governments adopt more controls and regulation, or go down a more liberal and laissez-faire route.

Public awareness concerning over 40 000 people killed per year as an ongoing annual disaster has to be raised and its acceptance compared to other man-made or natural disasters (terrorism, earthquakes, floods, etc).

The UK project Vision 2030 (see Appendix 2 of the main report for further details) aimed to identify the potential roles of strategic highways in meeting future mobility needs, by identifying the key drivers and factors that will influence them, specifically social issues, technology, political and regulatory aspects, and macro-economic drivers. This project produced three rather “utopian” scenarios, as follows:

- **"Global Economy"** - a highly capitalist, market-driven approach where all services and infrastructure are privatised and government regulation and control is minimal. Transport supply is based on ability to pay, thus motorways might have separate priority lanes with a high toll, enabling those who are willing to pay to avoid congestion.
- **"Sustainable Lifestyle"** - a community based way of living which leads to an increased quality of life and a reduced need for travel, with more local working or e-working. Most urban and suburban trips are by collective transport (shared minibuses, etc) or slow modes (walking and cycling), whilst the interurban road network is mainly used for leisure trips. Multimodal journeys are the norm, leading to a high degree of interchange for passengers and freight.
- **"Control and Plan"** - based on greater regulation of movement, which has become a political necessity in order to manage congestion, energy use, competitiveness, safety etc. This leads to widespread driver assistance, speed controls, electronic road pricing, rationing of road space, zero emission zones, etc.

Policies

The likelihood of various scenarios depends to a large extent on the policies of governments and road administrations. There is no policy or vision at EU level relating specifically to intelligent roads (including intelligent infrastructure, intelligent traffic and reasonable transports), although there are

some policy references to ITS for road traffic and automotive applications in general, for example in the 2001 Transport White Paper[3].

Besides the extensive R&D into ITS for road sponsored by the European Commission, the main focus of the EU's approach towards deployment of intelligent road systems is within the seven "Euro-Regional projects" within the TEMPO programme (part of the European Commission's Multi-annual Indicative Programme). While there are some overall guidelines for European added-value and continuity service for these projects, they do not really constitute a clear policy or vision at the EU level, but rather as a funding stream to assist road administrations and operators deploy ITS on the Trans-European Road Network (TERN) and to take into account certain trans-European factors. This is exemplified by the fact that proposals for deployments come from the national and regional road operators (administrations or toll companies) and the financial contribution of the EC is limited to 10-20% for ITS deployments.

Policies in 9 national administrations were studied in the report (Belgium [Wallonia], France, Germany, Latvia, the Netherlands, Poland, Slovakia, Slovenia, Sweden, Switzerland and the United Kingdom). Little specific strategic information was found for most countries although in some cases there were overall goals and milestones for ITS contributions to safety, reliability, efficiency of commercial transport and information services.

Policy and Scenario Mix

The figure "Intelligent road solutions – effects, circumstances, visions and solutions" on page 4 of this Executive Summary gives an overview of the approach to scenario building. It starts from the three "extreme" scenarios developed by the UK project "Visions 2030": "Global economy", "Control, harmonise and plan" and "Sustainable lifestyle".

In the centre of the triangle are three more realistic mixes reflecting the ways in which different parts of Europe are developing. It should be noted that these are only speculative, and neither scientifically predicted nor necessarily recommended. These are:

- ***Possible Eastern EU Mix :*** this lies somewhere between the "Global economy" and "Control, harmonise and plan" scenarios. This reflects the fact that the economies of the eastern countries are rapidly moving towards an open free-market system, perhaps becoming more free-market than some Western European economies, which are seeking to protect themselves and their social model from cheap labour and imports from abroad. Roads in several New Member States are already being built on a private finance basis and the shortage of state funds indicates that more road building, financing, operation and even control could be let out to the private sector. Emphasis is more on economic growth then environmental or sustainability issues (at present). On the other hand, there is still a control

[3] European Commission, "White Paper – European transport policy for 2010: time to decide", Luxembourg: Office for Official Publications of the European Communities, 2001.

element left over from the communist era and a certain amount of strict enforcement is likely (e.g. most Eastern European countries have a very low or zero blood-alcohol limit).

- ***Possible Nordic Mix*** : this comes closer to the "Sustainable lifestyle" scenario, reflecting the fact that social and environmental considerations are important in the Nordic countries, whereas privatisation of infrastructure is less important (social ethos and also greater availability of public funds than in poorer European countries, largely due to high taxes). There is however a strong "Control, harmonise and plan" element, due to the importance attached to safety in the Nordic countries, thus a high degree of enforcement is expected to be maintained.

- ***Optimised European Mix :*** this could be a goal towards which most of Europe will eventually move. This places importance on sustainability issues but also with a high degree of control, planning and enforcement. The role of the free-market could be reduced, as BOT infrastructure schemes revert to the public sector after their concession period and there is increasing recognition that the state should intervene more in order to promote modal shift, enforce environmental and safety regulations and generally ensure traffic and mobility is managed for the benefit of society. Limited space, environmental and safety concerns and depleting fuel resources could mean that unbridled competition in transport provision, including competing toll roads operated by private companies whose interest is in seeing more road traffic on their networks rather than less, could mean that the current move towards privatisation and deregulation in transport would at some future point be reversed.

The future INTRO WP5 report on Visions would investigate likely moves towards, and preconditions for, these scenarios and other possible scenarios, and look at how Intelligent Road Visions might develop in different parts of Europe.

Links Between Scenarios and INTRO

Surface Safety Monitoring (WP2)

The Combination of different sensor data (infrastructure or in-vehicle based, weather, surface, etc.) will enable the estimations of entirely new real-time safety parameters and performance indicators to be used in traffic monitoring and early warning systems. This will result in better methods for accident prevention. The correlation between friction and stopping distance will in particular be emphasised for surface safety parameters. Due to real time data acquisition systems and dynamic information systems the road user's safety and the information about the pavement surface condition will improve.

The use of real-time weather data combined with road surface and accident data bases will be of use to prevent accidents due to dangerous sections during certain weather conditions. This data will be possible to utilise as a basis for enforced low speed limits during periods of adverse weather conditions. The parameters and calculations should not be obvious to the driver who should only get aware of sudden changes in road friction by a message or appropriate warning. The usability of a

driver information system, warnings against unforeseeable low friction and therefore increases of stopping distance shall be evaluated in this WP using simulator studies. Therefore an HMI has to be developed to provide this information in the best and less confusing way.

Intelligent Pavements and Vehicles (WP3)

Road status monitoring is expected to increase significantly by means of “in situ” measurements combined with floating car data (fleets of probe vehicles with vibration patterns and other vehicle/ driving indicators from modern in-car sensors) for distributed statistic patterns. Primary and secondary roads are expected to be covered. This is an important development as hitherto, comprehensive road monitoring infrastructure can normally only be justified on busy and strategic routes (motorway and major roads). On the other hand, secondary roads comprise the majority of most networks, and increased monitoring by means of floating vehicles will be a cost-effective measure, enabling more efficient targeted maintenance, leading to road authorities optimising their resources.

Traffic and Safety Monitoring (WP4)

The cost of installing fixed location sensors on road network is very high and the trend is moving towards using mobile sensors such as probe car which is of lower cost, and has the potential to provide a more comprehensive coverage of the road network. In the near future, with a high proportion of probe cars (floating cars) travelling on the road network, it will be possible to send all the data collected on-board each vehicle to a server. Algorithms could be developed to estimate the performance of the network such as congestion level, amount of emission and travel time. This information will be useful to the road operator to select the best management strategy to deal with the traffic demand.

More interesting would be the prediction of the traffic condition on a rolling time horizon of say 30 to 60 minutes. This will enable operators to take a proactive measure in managing the traffic. Obviously synergy of probe car data with fixed traffic sensors and other exogenous data sources such as data from weather monitoring stations, automatic de-icing stations and VIMS can be realised with the use of data fusion. The benefits from data fusion are more accurate information and a more comprehensive information.

Information derived from such a system is not only useful to the road operator but they are also useful to drivers as well. For example, information can be disseminated to driver to drive in a certain manner such as reduce speed further when the road is wet or icy, and when incident is detected ahead.

With high resolution probe car data that is data being collected at a high frequency, it may be possible to predict when a sharp drop in speed is about to occur a minute or so in advance. A warning message can then be displayed onboard to alert driver and such information could also be communicated to other vehicles in close proximity.

With a rich and comprehensive data it is also possible to monitor the level of safety on the road network. Situations where the traffic condition is judged as unsafe, measures can be taken to reduce the risks. For example scenarios such as high speed difference between vehicles, high density and high speed situation, and platoon of vehicles travelling at very small headways could mean unsafe situation; and alert could be send to drivers to take extra pre-caution.

Scenario Example Cases

This chapter of the main report creates and collects a list of topic examples for the use next INTRO project report on Visions, as recommendations:

- Access and Capacity Control;
- Monitoring and Steering Strategies;
- Infrastructure Life Cycle & Asset Management;
- Transport Mode Shift;
- Managing Emergencies and Disasters.

Final Comment

The important topic of “Intelligent road networks” is one which requires further analysis in future and in greater depth (including the risks of different trends, policies and developments), in order to support the EU and enabling it to create a future long-term vision (2030 or beyond) for road transport and the role of intelligent infrastructure and systems. The aim could be to avoid ongoing dislocated and divergent national or regional solutions at a general level and also to allow measures for regional optimisation at a secondary level.