FEHRL Vision 2025
For Road Transport In Europe

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Synopsis

The Forum of European National Highway Research Laboratories (FEHRL) was formed in 1989 by the National Highway Research Laboratories in EU and EFTA countries. The mission of FEHRL is to promote and facilitate collaboration between its institutes and provide high quality information and advice to governments, the European Commission, the road industry and road users on technologies and policies related to roads. To promote common research activities a five-year Strategic European Road Research Programme (SERRP) is usually defined through detailed implementation plans. In implementing its fourth version of SERRP, FEHRL has taken a long-term “ Vision” of the future of roads and of the research needed to support their development and operation. The aim of the Vision 2025 is to illustrate the current position and key trends of road transport, propose a range of possibilities for the future, draw out differences, identify decision areas and ultimately consider consequences for 2025.
The “Vision 2025” begins with a brief overview of the current position of road transport across Europe and of the known time trends at present. Based on that knowledge, likely future changes were drown out and a number of possible scenarios constructed, starting from two extremes: an ideal future supply-side and a do-nothing or do-minimum supply side. Three other scenarios between these extremes were examined: a government-driven scenario, a market driven scenario and a sustainability scenario. From them a single future based on the likely technological, societal and policy options was drawn up. Future technological and financial possibilities were considered with respect to seven primary “desirables”: that travel should be smart, safe, clean, comfortable and reliable; that access to business and leisure activities should be available in proportion to value and need, and that each part of the network should be suitable for its function.
Accordingly to the previously mentioned analysis, four categories of enquiry and development were identified to fulfil future needs: design and production systems; environment, energy and resources; safety and security; mobility, transport and infrastructure. For each category a series of desirable research matters were suggested.
The results arisen from this “Vision” were carried out capturing those elements of the projection with a reasonable level of probability, leading to conclusions that are common to a range of scenarios. How these scenarios will develop and which of the issues emerged in this study will prevail depends on the policies that are pursued in the coming years.
One of the most relevant issues of the Vision is the linkage between road, vehicle and driver, enabled by the continuous progress in communications and IT systems, which constitutes the core of the Intelligent Transportation Systems (ITS).
Initiatives in ITS field begun in the 1960s led to many implementations that introduced automation and real time information in the traffic management and culminated in the automated highways initiative, which represents the most fascinating and debated vision of future road transport.
Several field experiments demonstrated automated highways are technically feasible. However, there are many barriers to their actual development that include costs, liability, psychological and institutional issues.
A more practicable alternative, which many studies predict being largely implemented by 2025, is a partial application of automation that leaves the driving task to the driver and assists him or her by continuously verifying safety conditions.
In the paper a survey of experiments carried out in USA, Europe and Japan will be presented and the main technical issues to integrate road condition detection sensors, traffic monitoring devices and vehicle control sensors will be discussed.

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INTRODUCTION

This paper summarizes a synthetic view of a document drawn up by FEHRL to create a reasonable vision for Europe's road transport in 2025. 2025 should represent a date far enough into the future not to be overly constrained by incrementalism, but not so far as to become science fiction or whimsical speculation. The intention is to capture the key features of a foreseeable future and to ask what steps would be needed to move to it from present days.

The key elements of road transport go beyond the physical roads themselves: they also include the vehicles, the drivers, the suppliers and operators, the governments, and all of those affected directly or indirectly by road traffic. Whilst our perspective is rooted in the European road transport institutes, the scope of this exercise extends to all those aspects previously mentioned in order to take proper account of the full impact of road transport.

Futures

There are at least two radical views of the future. The first is a future in which technology totally transforms travel; where communities and work places are clustered 'optimally' with high efficiency systems for communications and activities; where they are spaced geographically to minimise the demand for physical movement; where such movement is efficiently priced in economic terms; where it takes place by means of a complementary set of high tech and low energy systems incorporating road, rail, maglev, urban underground and overground shared systems ('public transport'); and where movement is co-ordinated by demand-responsive real-time systems. Such a future would incorporate social inclusion as an integral part of its provision and pricing. The impact on the environment would be minimised. Decisions would be firmly based on sustainability principles.

The second radical future is a future whose supply side is quite simply the same as the present, to all intents and purposes, with little change in the types of roads or rail, etc, or in vehicles, or operating systems, beyond a limited continuation of the normal (i.e. historic) patterns of development. This is seen as radical because of the lack of change at a fundamental level, rather than in spite of it. It is radical because it goes against common expectations.

Practically speaking, we feel that neither is realistic, though the real future is likely to contain elements of both. What seems much more likely to come about is that governments and commerce, both national and Europe-wide, will take a series of steps over the next twenty years (to 2025), that bring about some middle ground between the extremes - a mixture of the fundamentally new combined with more conventional updating, so achieving a reasonable economic balance between investment and benefit.

FEHRL's approach

The Vision described here applies to the "wider Europe", meaning the expanded EU of twenty-five member states plus the EFTA countries (Switzerland, Norway and Iceland). Much of the argument will also apply more widely still - to aspects of road transport in Russia for example - but we do not develop it in those terms. The only broad distinction we make is within the wider EU and is between Eastern and Central Europe on the one hand and Western Europe on the other; these differ in the extent of their roads infrastructure, motorisation, freight movement, and the balance between public and private transport.

To envisage the future we have examined the possible types of change, and to do this we have constructed a number of "scenarios" or possible policy approaches to the currently-growing demand for movement. The extremes of these are the two above: an ideal future supply-side and a do-nothing or do-minimum supply-side. In addition we have examined three others between these extremes: a government-driven scenario, a market-driven scenario and a sustainability-driven scenario. These we believe map out the principal possibilities. From them a single future judging the likely technological, societal and policy options was developed, concentrating on those aspects we thought most likely to come about. This was done with respect to seven primary "desirables": that travel should be smart, safe, clean, comfortable and reliable, and that access to business and leisure activities should be available in proportion to value and need, and that each part of the network should be suitable for its function. The consequences constitute our vision for 2025.

CONSTRUCTING THE VISION

To arrive at a vision for the road network in 2025 we have to make assumptions about the political and social climate over the next twenty years. First we consider possible policy scenarios relating to road transport and then we test the likely response in each scenario to a set of user or stakeholder requirements.

Scenarios

We first use scenario planning building on existing knowledge to develop plausible futures. Given the impossibility of knowing precisely what form the future will take, a good strategy to adopt is one that plays out well across several possible futures. To find such a robust strategy, a number of distinctive scenarios have been examined. These are specially constructed models of the future, each representing a distinct plausible world in which we might someday live and work. The purpose of doing this is to not to pinpoint future events but to highlight large-scale forces that might push the future in different directions.

The scenarios are identified by considering broad societal values on transport provision, examining how they cluster and how the clusters point towards a particular view of the future. What actually happens over the next twenty years will depend on the kind of models that develop for forming policy - not only from government choices but also by how much other organisations and players come forward to influence the way the future develops. The range we have chosen is anchored in five scenarios and concentrated around three middle scenarios: one led predominantly by governments, one led predominantly by market forces, and one led predominantly by aspirations towards sustainable operations. These are bracketed by the ends of the range, which we see at one extreme as Do Nothing - i.e. as little as possible is done by way of strategic decision making - and at the other by an Ideal World.

The Do-Nothing Scenario

This first scenario revolves around caution, an aversion to taking risks, and a reluctance to invest without certain short-term returns. There is a public expectation of improvement and a reluctance to pay for it.

Governments and other major players do not set out with any particular plan in mind; or alternatively they do have a plan or outline of where they intend to be going but do not in practice actively implement it. This scenario is therefore characterised by incremental change at the minimal level required to avoid immediate political consequences. The result is: a very limited growth in the physical network (and this growth would be mainly be confined to the new member states); little capitalisation of new mass-technology and fragmentary application; an increased car dependency as car usage continues to grow; increasing congestion; limits on the use of the network caused by blockage and congestion; and, importantly, economic growth constrained by inefficient transport, continuing damage to the environment, and social division.

The Government-Led Scenario

In striving for a society in which the talents and skills of individuals are blended for the good of all, and the weaker members of society are protected from exploitation, there is a balance to be struck between individual freedom and the need for rules and central (i.e. Government) direction. This balance may tend towards governments leading and individuals, groups and organisations following. Here the state, rather than individuals or groups, is responsible for the major decisions. This is the Government-Led scenario.

Governments set out with strong plans and tend to implement them by commissioning them directly. The result is a form of strategic vision and a progressive move towards it. It is, however, characterised by a slow response to market needs - there are lags between the appearance of market pressures and the final government adoption of the plan to accommodate them. The priorities tend to be political and funding tends to be slow and subject to contingent delay. Despite strong planning, inevitably there is some focus on the short term, as political contingencies set in. However, pollution and safety targets are likely, in this scenario, to be sustained and held to.

The Market-Led Scenario

Here governments choose to encourage a more market-responsive system in which the restraints on private investment are kept to a minimum, as are those on hybrid investment between the public and private sectors and on some types of public investment. By its nature, this is a demand-led scenario and would tend to have faster responses to market needs. The financial viability of particular investments are more directly tested in this case, but are subject to a large element of risk off-setting in the private investment. Task for task therefore the costs may be higher, but the barriers to more rapid development lower.

This scenario is less likely to produce coherence across the transport system (and certainly across the land use/transport systems taken together) and there may be some fragmentation of systems. Similarly, with less government involvement to apply constraint, social divisions would open up more.

The Sustainable-Society Scenario

Individuals have become increasingly aware of their surroundings, the fact that the resources available are finite and that their use is beginning to have an impact on the planet.There is therefore an increasing pressure to preserve resources for future generations and to structure society in such a way that its needs are catered for at minimum cost to the environment. In future, ecological awareness and concerns over sustainability will have a stronger influence over the way in which society is structured. There will be pressure to develop new and sustainable energy sources.

In the Sustainable-Society scenario growth in mobility would be limited and traffic and transport would be controlled by government, with the main focus on providing or encouraging as much collective or shared-use transport as possible, and the sustainable application of high-quality, government-controlled technology in transport systems.

This scenario is perhaps the most future-orientated and the solutions it aims for are long term. As an example, here one would be more concerned to minimise the whole-life costs of roads or structures, taking into account the environmental costs, than to minimise the initial and medium term funding requirements. The result is that raising finance is likely to be more challenging in the short term and the approach as a whole to require more collective innovation.

Local materials are used more. There may be some restrictions in movement (in relation to the perceived cost of those movements in the longer-term environmental and sustainability sense). Fully implemented, it would result in a movement towards new styles of community.

The Ideal-World Scenario

This last,extreme, scenario is not realistic. It has features that people often talk about when they become a little starry-eyed, and which they often use - without realising it - to benchmark the performance of real systems.Unlike the previous scenarios it recognises neither practical constraints nor trade-offs between different groups within society. An ideal world would satisfy everyone's values.

What this means in practice is that it is unconsciously assumed that there is no financial restraint or limitation, little restraint on construction, and that a very rapid reorganisation of the way people and societies move about and interact could be engineered. Thus an Ideal-World would contain fully integrated land use and transport where people live near their work and their leisure,where trips are only made when highly necessary or for real pleasure, where the network is highly connected, both between the roads themselves and with other modes, where the journey times are minimised, where the environment is more or less undamaged, where clean energy is unconstrained and where safety is fairly complete. This would lead to comfortable and enjoyable travel when needed.

Summary

These scenarios are chosen to provide reference frameworks. The Do-Nothing and the Ideal-World scenarios are extremes. The Government-Led, Market-Led and Sustainable-Society scenarios each have elements that are likely to come about in reality.

The three "middle" scenarios, whilst for simplicity presented as particular clusters of assumptions, in practice have some elements in common but present to different degrees. A market-led society would still depend on government controls to some extent, in order to constrain and direct the effects of the markets. Future government-led societies would always encompass markets of some sort, but under a higher degree of control. A sustainable society would only be achieved by articulating sustainability goals through governments and their influence on markets. It is in any case unlikely that any one of these scenarios will be played out in full. What is more likely is that the actual futures will fall somewhere between the Ideal-World and the Do-Nothing scenarios, and will be mainly characterised by a mixture of the three broad approaches between.

Future objectives

The scenarios map out a range of possible approaches to the future. In each case the actual provision of transport will be driven by the requirements of users and stakeholders in relation to the cost and to the potential effect of provision on the overall economic and social good. The Vision for 2025 will be determined by how society responds to the requirements. Whilst the response will be specific to each scenario, those features which emerge over several scenarios will provide the principal components of the Vision.

We believe users and stakeholders want travel to be smart, clean, safe, reliable, comfortable and accessible, and for the parts of the infrastructure to be suitable for their relative functions. Here we find the definitions of the requirements:

- *SMART Travel*: The transport system should provide good information and it should be managed responsively and efficiently,making full use of available technology.
- *SAFE Travel*: The infrastructure and operations should be inherently safe. They should provide as much protection as possible against driver error and aberration.

- *CLEAN Travel:* There should be no net damage to the environment; health impairing pollutants should be eliminated or minimised.
- *COMFORTABLE Travel:* Strictly-speaking the concept of comfort is not separate and independent; it contains many of the key elements of clean, safe, and reliable travel.Travelling should be comfortable and pleasant, not unpleasant.The quality level should be acceptable.Travellers should feel at ease.Maintenance workers on the infrastructure should expect a safe and predictable working environment.
- *RELIABLE Travel:* For the infrastructure to be reliable there should be no surprises. Any disruptions that occur should be predicted in advance and measures taken to mitigate their effect on users.
- *Availability of ACCESS:* Travel should provide full access to destinations in relation to need and economic value; it should be socially inclusive.
- *Suitability of road FUNCTION:* The capacity, safety, and level of service of the components of the road infrastructure should be proportional to need and function. The form and appearance of roads should complement their respective functions and should be environmentally empathetic.

Probable Consequence: Paths to Implementation

When we consider the developments relative to the requirements and the pre-conditions necessary to achieving them, the overall picture that emerges is of a tension between the tendency towards piecemeal but rapid progress in some areas under market-dominated circumstances contrasted with more coherent but slower, more expensive and politically difficult progress under government-led circumstances. The first pulls towards a user-optimum (without regard for social inclusion or other constraints arising out of sustainability) and the second towards a systems-optimum (taking account of social inclusion and other "non-market" factors).
The sustainability scenario influences development by applying sustainability constraints through government control on the one hand and consumer preferences, public demand and attitudes on the other. Between the scenarios and the requirements a 'real-world' picture begins to emerge.

VISION 2025

The objective of good visioning is to identify the patterns both of change and continuity over time. Given the time it takes to plan, design and construct roads, much of the road network in twenty years time will not in fact differ greatly from that in use today. But whilst the physical infrastructure in 2025 will in many respects look like that in 2005, there will also be some substantial changes whose rolled-up effect is likely to be bigger than one might be tempted to expect. Europe enlargement, technological development, IT and communication growth, intermodality increase will play an important role in changing future patterns.
Among the patterns of change several simple themes emerge from the scenarios and requirements: maximum existing network exploitation; available information increment; new financial models. In addition, two big themes seem in particular likely to grow in importance: the user as consumer and the profound requirements of sustainability.
In fact roads are intended for the users. Roads are provided because movement allows wealth and social good, so users needs to be satisfied. What users perceive and the choice they make are therefore very important. Increasing weight of user perceptions over coming years are expected. This leads to an important principle: that users' perceptions of transport should be well informed both in the sense of enabling reasonable choices to be made and of understanding how these choices relate to the overall economic, environmental and safety aspects of transport provision.
On the other hand, governments and voters are increasingly concerned about the sustainability of policy and investment choices. People in general are more likely to be aware of sustainability arguments and that in itself will influence government thinking of a greater extent than at present. What is certain is that issues surrounding the quality of life, especially with regard to urban living, will have much greater prominence.
We have generally become accustomed to thinking of the road infrastructure as comprising roads, interchanges and structures that support them. But it is already clear that by 2025 three pillars of the road based infrastructure will be required for the effective operation of the network, rather than one:

- The physical roads themselves
- The communications and control systems that link roads, vehicles and drivers
- The financial systems.

ROADS

Physical Network in Europe

Physical infrastructure development is expected so as to provide the major links and corridors needed for transport within Europe, particularly for the new member states to connect them better with the west (linkage

to EU Trans European Network). Motorization in eastern and central Europe is likely by 2025 to approach similar levels to those in western Europe. The corridors, whilst road based, will increasingly become integrated multi-modally for passenger transport, and provide logistic connections for freight. These corridors would form the basis of multi-modal linkages with heavy road traffic movement and some cross-scheduling.
In contrast, road building in western Europe will be restricted and, despite the new corridors, the capacity available will struggle to meet the demand. The emphasis will therefore be on:

- Getting the most out of the existing infrastructure, i.e. ensuring that is available for use when required and that its use is managed to maximum effect
- Measures to limit demand or shift in time within the day in selected areas of high demand in relation to capacity.

Construction in western Europe is likely to concentrate on area where congestion relief is needed. Where new roads are required or existing roads replaced, novel design and methods of road construction are likely to be developed and used in some applications, in order to provide improvements in capacity and traffic disruption. There will include modular construction that enables roads to be constructed off-site. Once in position novel methods of overlay such as asphalt carpets, which can be rapidly laid, will be employed. Those units might also include voids for utilities, built in drainage systems and sound absorbing characteristics, thus reducing the impact of vehicles on the surrounding community.
Recycling will be the norm. Replacement of roads at the end of their life will involve substantial re-use of the existing material, possibly being cast into the modular units described above, and the use of raw materials will be minimized.
Thus, to summarize, a significant physical construction in central and eastern Europe, and rather more limited supplementing of networks in western Europe is expected. Overall, the growth of road-based multimodal corridors coupled with growing hubs of urban and suburban development will begin to reconfigure surface transport to some degree. In twenty years the advancement in this direction cannot be complete, but coupled with changes in communications it will have significant impact on both mass movement and on the traveling experience of individuals.

Changes in land use and development

There is likely to be a net movement towards urbanisation and the growth of city dwelling, especially perhaps in eastern Europe, accompanying a relative decline in the availability of services, employment opportunities and transport supply in rural areas. Cities will see some re-urbanisation with a relative shift in the location of activities (housing, industries, retail and other services) towards the peripheries, exacerbating urban sprawl.
Land use could be significantly reconfigured and controlled in order to reduce the growth of transfers by car. In other words, the need for some car trips would be reduced by bringing work, households and leisure closer together in settlements with balanced living patterns.
However, the scope for such reconfiguration is limited in practice to eastern countries in Europe, where there is in principle more scope for creative land-use development because car dependency is at an erlier stage. But in either case, the pace of significant change in land use is slow, and instruments for incentivisation and control are generally difficult to handle, and have consequences that are not always easy to predict.
Given all of this, it is likely that within a twenty years period some progress will have been made towards a configuration of some urban and suburban living hubs which are better integrated with business and retail activities and toward a greater inter-modal transfer. These hubs are likely to grow up in conjunction with the corridors referred to above.
Finally, in this respect, electronic substitution for some road travel might also play a role in reducing demand albeit a small one overall. The main effect of tele-activities, however will be add a new set of means for access, operating in parallel and in conjunction with physical travel.

Road construction and maintenance

Knowledge of the structure and performance of road pavements has increased substantially over recent years, and by 2025 we shall know significantly more about how to optimize performance using whole life costing techniques. A good understanding and knowledge of deterioration processes will enable maintenance requirements to be predicted and maintenance works to be planned in advance. Maintenance techniques will be quick to apply, suitable for application at times when demand is low and long lasting. This will enable maintenance to be scheduled such that disruption to users is minimized.
Long life roads and more durable structures will both reduce the cost of road works and reduce the traffic disruption they cause. Monitoring of road condition will be achieved by the use of conditioning monitoring vehicles traveling at traffic speed, and by implanted sensors in road pavements and structures that register and record condition automatically. Sensors will be used to give advance warning of structural deterioration and enable inspection interval to be increased thus reducing the associated traffic disruption. Monitoring will

also be used to control the loading on structures thus enabling their lives to be extended and replacement to be undertaken at the optimum time.
Temporary structures using new light-weight materials will be deployed to relieve congestion during maintenance and reduce the need for diversions.
As a consequence the “down-town” of roads will be minimized. Road capacity will be deployed more dynamically, in conjunction with traffic management; roads will be operated by adopting variable configurations of lanes in relation to traffic demand volumes as these vary within the day. Variable road marking will also enable wheel tracks to be moved sideways thus increasing the life of the pavement. In areas of high business and housing density, special bridges and tunnels will be deployed for particular user types so as to optimize user capacity (taxi o truck only lanes, high occupancy vehicle lanes, etc.).

ROAD-VEHICLE-DRIVER LINKAGES

In the last years, many “visions” on the future of transportation system have been proposed both in Europe (Vision 2030, 2003; Fehrl, 2004) and in USA (ITS America, 2002). All these treatises aim at sketching possible scenarios of future transport systems, starting from current critical issues and envisioning feasible solutions, where the research efforts should be addressed.
The classic framework used to define the transport system was based for many years on the distinction among the following three main components: road, vehicle, driver.
In the late ‘70s, the so relevant problems affecting the large development of the automobile-society, like the unexpected oil crisis, the continuous increase of traffic congestion, the huge amount of road accidents, the spreading of urban areas and the deterioration of the air quality, induced transport scholars to criticise such a classic technology-based approach and emphasise the transport system as a whole, in order to search for a new mobility model that could make it possible a more sustainable development.
In the 90’s, a new interest in a better exploitation of technology to improve road traffic efficiency, reliability and safety was due to the dramatic progress of electronic, telecommunication and computer science. The applications of these technologies to the transportation system have been identified as Intelligent Transportation Systems (ITS), as they enable users and operators with an additional knowledge about the close and the far (both in time and space) environment. ITS include several applications, which in USA are usually distinguished as in the following: Advanced Information Systems, Advanced management Systems, Intelligent Vehicle Control Systems, Commercial Vehicle Operations.
Even if also this classification is based on the classical distinction among car, vehicle and driver, in recent years it has become evident worldwide that vehicles alone, or infrastructure alone, are limited in what they can do to realize greater safety and environmental goals. Therefore still greater expectations are being placed on research in network management and in cooperative vehicle-highway systems.
In Europe, the White Paper (2001) points out that technological innovation provides an excellent opportunity to integrate the transport modes, optimise their performance, make them safer and help make the European transport system compatible with sustainable transport development. The potential impact of intelligent transport systems has been assessed both during research and in the early stages of deployment. Journey time reductions of up to 20% and increases in network capacity of 5–10% have often been achieved in various combinations. Safety improvements have often been estimated at around 10–15% for certain specific types of accident (rear-end collisions) thanks to coordinated information and control strategies, while survival rates have also increased thanks to automatic incident detection systems for the management of emergency situations.
Initiatives begun in 60s led in these years to many implementations that introduced automation and real-time information in the traffic management culminated in the automated highways initiative, which represents perhaps the most fascinating and debated vision of future road transport.

Automated highways

An automated highway consists of a road equipped with magnetic devices that provide an immaterial guide to specially equipped cars, provided with two pairs of complementary magnetometers. Automated cars are also equipped with other sensors and actuators for longitudinal and lateral control. Vehicle-to-vehicle communications allow vehicles cooperating within the traffic stream when performing manoeuvres as car following and lane changing.
Several field experiments demonstrated automated highway is technically feasible. Indeed, a working model of an automated highway was the hit of the General Motors pavilion at the 1939 World's Fair in New York City. On 1958 Ford built the Firebird III, which included an automated guided system called “Autoglide” (Litman, 2005).
Several experiments have been conducted in the ‘90s in the USA within Path Program, which launched the Automated Highway System (AHS) project, in Europe (Chauffeur program) and in Japan, within the Smartways Project.

In the most extensive experiment, conducted in California on 1997, a platoon of 8 cars ran at 105 km/h on a 12.2 km segment of a fully automated highway. The cars maintained a fixed spacing of 6.5 m between themselves at all speeds up to full highway speed. This means that assuming 4.5 m long cars, the capacity of one lane could increase, theoretically, up to about 9.500 veh./h. The spacing was maintained with an accuracy within 10 cm during cruising and 20 cm during manoeuvres like acceleration and deceleration. Indeed, safety conditions should limit the capacity to much lower values. During the Demonstration on 1997, if any vehicle in the platoon misses just 10 consecutive "packages" of information usually sent 50 times each second, the platoon automatically goes into the fault management mode, and the vehicles extend their interval to about 15 m. This limits the capacity to not exceeding 5.400 veh/h per lane in realistic operation conditions. Capabilities of the automated guidance on winding roads have been tested by making several steering manoeuvres at transversal acceleration up to 6 m/s^2 within a very narrow lane.
Several different approaches to lateral control were demonstrated using cameras, magnets, radar-reflective tape, and lasers.
The camera or vision-based system uses a small television camera. The camera works in concert with an onboard computer, an image processing software, and vehicle control actuators to guide the vehicle to stay within the lane markings. A major advantage is that this system works without any structural changes to the highway and can be operated easily in mixed (automated and non-automated) traffic. A recent application of such a system has been carried out within the research program CIVIS, jointly developed by Irisbus and Siemens, which equipped a bus with a video-based automatic guidance system that tracks the lateral white strip and automatically acts on the steer to follow it.
The magnet-based system of AHS relies on magnets embedded along the centre of the lane 1.2 meters apart to define the roadway. The car tracks the magnets with less than 7.5 cm of error. The life of the magnets is 30 to 50 years.
The major advantages of the magnet-based system are that it is very reliable in all weather conditions even when the roadway is covered with snow.
In spite of the demonstration of technical capabilities, there are many barriers to its actual development that include costs, liability, psychological and institutional issues. Technical problems are almost related to interchange between ordinary and automated roads, which would prevent exploiting the huge increase of capacity that would be theoretically provided by this system. On the other hand, relevant legal questions could arise in case of accidents, when it would be very difficult to establish if the responsibilities were up to the car-maker, the car owner or the system operator.

Automated driving aid systems

A more practicable alternative, which many studies predict being largely implemented by 2025, is a partial application of automation that leaves the driving task to the driver and assists him or her by continuously verifying safety conditions. In first stage of introduction of the system, automatically assisted vehicles will coexist with manually driven vehicles. Thus, the automated driving aid system should integrate several components that control the traffic stream, like in current management systems, and the single vehicle by means of on-board and roadside sensors and communications devices.
In Europe, several programs on both automated and assisting driving systems have been developed in the ‘90s and are still continuing, at both Community and National levels. European Commission has defined a focus area called the Information Society Technologies Program (INFOSO), which is active in the area of Advanced Driver Assistance Systems (ADAS), a combination of telematics and vehicle control systems that assist drivers and reduce driver error rates (programs Chauffer, IN-ARTE, Save, Radarnet, Carsense). A fundamental principle of ADAS is that the driver remains responsible for the vehicle at all times and can override any automatic controls.
The critical applied technologies that fall under the European ADAS umbrella are:

- computer vision;
- range measurement sensors;
- sensor fusion;
- road geometry monitoring and positioning;
- vehicle-vehicle and vehicle-roadside communications;
- human - machine interaction;
- traffic situation analysis and monitoring;
- control algorithm development and simulation;
- vehicle control systems.

National initiatives have been undertaken by several Countries like France, which launched “La route automatisée” and Civis Programs, and The Netherlands, where the Intelligent Speed Adaptation involved several equipped cars in the town of Tilburg.
Sweden is taking a worldwide lead in evaluation of the benefits of Intelligent Speed Adaptation, with over 7.000 vehicles currently participating in an operational test. ISA is sponsored by the Swedish National Road Authority (SNRA), who is investing 9 millions of US $ in the project, as part of a vision for achieving zero traffic fatalities and injuries. During 1999-2002, cars were being equipped with voluntary speed adaptation

systems to help motorists keep to speed limits. Systems are being deployed in four cities. Two approaches are used: the advisory system, in which the driver is notified if his or her speed is too high, and an “active accelerator”, in which resistance is activated in the accelerator if the driver attempts to speed up when his or her speed is at or above the speed limit. The accelerator force can be over-ridden, if necessary. For the road information, both digital maps and GPS are being used in three cities, as well as roadside beacons using dedicated short range communications in one city.
In the first years of the 21th Century, the greatest research efforts in developing applications of advanced technologies to road traffic are being undertaken in Japan. After first applications mainly focused on the route guidance experiences (ITS Hand Book, 2005) in the ‘70s (CACS), ‘80s (RACS) and ‘90s (VICS), a more comprehensive ITS Program has been launched by Advanced Cruise-Assist Highway System Research Association (AHSRA), which brings together the key automotive, infrastructure, and electronics companies in a partnership with the Ministry of Land, Infrastructure and Transportation within the Japanese government (AHSRA, 2003a).
The main concept on the basis of AHSRA is that ITS represents an integrated approach to studying the elements of people, vehicles, and roads. To provide a solid basis focusing on road development, the concept of Smartways was introduced that entails road-to-vehicle cooperation. In the U.S., the Safe, Accountable, Flexible and Efficient Transportation Equity Act (SAFETEA) describes many similar concepts.
AHSRA defined three levels of focus: AHS-i (information to the driver), AHS-c (control assist for the driver) and AHS-a (fully automated operations). Work since then has focused on cooperative intelligent vehicle-highway systems for crash counter-measures, culminating in the Demo 2000 experiment conducted on 2000 in Tsukuba City.
Current activities are now focused on developing and testing single technologies to realize a complete system that performs both traffic and aid driving information by means of a road monitoring system and a telecommunication system among roadside devices and vehicles.
The architecture of the automated aid driving system is based on the following components:

- Road surface monitoring system;
- Road vehicle detection system;
- Vehicle positioning system;
- Communication system;
- On-board system;
- Control centre.

In the following, the main features of the most innovative technologies (namely: road surface, vehicle detection, communication system and on-board system) are shortly described and discussed. Readers interested in a state-of-the art review of positioning systems and control centres can refer to Zhao (1997), Drane and Rizos (1998), Klein (2001), FHWA (2003).

Road surface monitoring system

Road surface monitoring system detects and tracks road surface conditions as dry, wet, snow, freezing or water film by means of a network of sensors that apply different technologies like laser radar, optical fibres or video processing (AHSRA, 2003b).
Video sensors exploit image processing algorithms to characterize the pavement conditions. The main advantage of video sensors is that they can adopt the visible image cameras that are presently in widespread use for road surveillance. Requirements for operations are: visibility at least 200 m, rain of no more 200 mm/h, illumination of at least 30 lx. The main disadvantages are the high sensitivity to shadow and sunlight and, over all, the need of artificial illumination in the night.
Laser radar sensors use pulsed laser beam to scan the road surface in two dimensions and use the time lag and reflection intensity of the beam to distinguish road surface conditions.
Each sensor is mounted in vertical position with respect to the road and can monitor a 4×7 m area with a resolution of 25 cm or more, longitudinally and laterally. The main advantage of laser technology is that it is quite independent of environmental influences (visibility of 50 m is sufficient) and then it is capable of continuous day and night operation. Moreover, it can utilize the sensor module usually applied to measure the headway between vehicles.
Optical fibre sensors measure road surface temperature and are joined to meteorological sensors to distinguish road surface conditions from the presence or not of thermal phenomena, like evaporation or freezing, that occur on the road surface. Optical fibres have to be buried under the road surface and this is their main disadvantage. Each fibre can detect one lane for 1 km.
Experiments conducted in Japan on 2001 and 2002 (AHSRA, 2003b) showed that, in standard conditions, all these systems achieve an appreciable detection accuracy, ranging in the worst cases from 81% (freezing for laser, water film for optical fibres) to 88% (water film for video sensors).

Road vehicle detection system

Road vehicle detection sensors required by AHS services differ from usual traffic monitoring devices because they were developed with the capabilities to detect position and speed information on individual vehicles and based on that information to identify the phenomena of standing vehicles, slow vehicles, and congestion. Three types of sensors were developed and tested for vehicle detection in the Japanese AHSRA program (AHSRA, 2003c): visible image type sensor, which utilize images from visible television cameras, infrared image type sensor, which utilize images from infrared cameras, and millimetre-wave radar type sensor, which utilize millimetre waves. Laser type sensor was also developed for detection of pedestrians, bicycles, and so on in intersections.

Visible image type sensors can be identified as the second generation of usual automatic video traffic monitoring systems, which in the first one are usually applied to determine macroscopic characteristics of traffic flow, as vehicle counts and average speed. Second generation systems have the additional relevant feature to individuate and track each single vehicle. To do this, they can apply two typical methods of vehicle isolation: the background discrimination method, which isolates vehicles by means of differences in the background image, and the time subtraction method, which isolates vehicles by comparing images captured at different time intervals. To overcome the well-known difficulties of usual video image processing in low visibility conditions, infrared image type sensors have been developed that identify vehicles by detecting their far-infrared radiation and conducting image processing. The results are used to derive position and speed information, from which standing vehicles, congestion, and so on are detected.

These sensors generally recognize vehicles by pairing the background (road surface) with vehicle characteristics (high-temperature points such as muffler and radiator, and low-temperature points).

In experiments, performances were determined to be reduced when rain reduced vehicle temperatures. However, these sensors yielded high detection rates even at night without illumination.

Millimetre-wave radar type sensors emit frequency modulated continuous millimetre-waves (in the order of about 70-80 GHz) onto the road being monitored and then measure the target vehicle's speed from the Doppler shift of the reflected waves and the vehicle's position from the lag time of the reflected waves.

These sensors can detect vehicles in multiple lanes by emitting waves while scanning across the width of the target road. They are also capable of detecting vehicles under environmental conditions that make detection difficult for image sensors, even including, for example, dense fog and falling snow (snowstorms). Since they are active sensors, they can positively differentiate vehicles under conditions of overlapping in which image sensors are unable to separate them, so long as the sensors can receive waves reflected from the vehicles. However, since they are usually installed at a low height, they may be completely unable to separate some overlapping vehicles when there are large numbers of vehicles overlapping (shadowing) in heavy traffic environments. Accuracy in detecting vehicle is 5 m and 1 m as for the longitudinal and lateral positions, respectively. A major drawback for real-time applications of this technology is the longer time required for data acquisition, due to the scanning movement of the sensor head, which requires about 0.4 s for a 3 lane-road.

Communication system

Communication system enables the exchange of information between vehicles and road side equipments as well as between vehicles.

Road-vehicle communication transmits data collected by the monitoring systems and regarding surface conditions, road layout, presence of obstacles, weather and occurrence of congestion.

Vehicle-to-vehicle communication system is often associated to automated highway system. However, it could greatly improve road safety as it would make it possible cooperative driving, where breaking or steering manoeuvres would be promptly communicated to near vehicles, allowing on-board control systems verifying safety conditions.

Two possible configurations of the road-vehicle system include either a continuous or a spot communication system (AHSRA, 2003d). The first forms a radio zone of continuous communication by means of multiple roadside units in order to periodically provide information on standing vehicles and other such constantly changing conditions to vehicles in zones up to the one immediately before the zone where a phenomenon is detected. The spot communication system, on the other hand, forms a radio zone with a single roadside unit.

AHS in the early phase of practical application of spot communication will be configured with two road-to-vehicle communication functions. One is the starting beacon, which provides AHS service reference points and starting information, and the other is the information beacon, which provides cruise-assist information.

The vehicle uses position information obtained from the starting beacon together with cruise-assist information sent from the information beacon to judge the content and timing of services, and provides that information to the driver. The combination of information from the two beacons (the starting beacon and the information one) allows the vehicle to find out the direction in which services are provided and judge whether to accept the services. This arrangement makes that possible, and also serves as a countermeasure against radio wave leakage to oncoming lanes. In addition, the information beacon and starting beacon both use one-way broadcast transmission from roadside units to vehicles in order to provide information to all vehicles within the communication area.

Services for road sections of uninterrupted flow field transmit cruise-assist information repeatedly in order to be certain of providing the information. Moving vehicles take the position where they received starting information as the relative AHS service distance origin point, after which they receive information on phenomena such as the presence of a standing vehicle from the information beacon. In services for intersections, moving vehicles receive starting information, then every 0.1 second they receive information on the position of vehicles entering the intersection from the information beacon, and assist drivers with their driving.

Future issues for used in AHS are shown below:

- Conceptual approach of safety of information provision for intersection services where shadowing occurs frequently due to oncoming vehicles, etc.;
- Problem of provision of multiple applications and standardization of communications protocol;
- Problem of deterioration of signal reception characteristics due to oblique reception when on-board unit is installed indoors.

On-board system

On-board system processes all data received and provides the driver with information on road traffic conditions.

Automated vehicle control systems are already in use to assist the driver in controlling the vehicle by measuring operational variables of the vehicle itself (its speed, acceleration) as with anti-lock braking, anti-rollover devices, electronic braking systems, traction control.

Many active safety devices now available on the market improve the vehicle stability in braking/traction and help drivers to keep a safe distance among moving and fixed obstacles. Anti-locking Braking Systems (ABS) are now installed on the most cars on the EU market, while relatively newer electronic devices as ESP, EBD, and traction control (TC) are now available on many cars and trucks. ESP uses various sensors to determine the steered path and helps driver keep it under control by applying appropriate brake pressure to individual wheels or reduce engine output to correct understeering or oversteering.

Active suspensions can be adapted automatically to the conditions of the road and allow the driver selecting various options of rigidity according to the desired comfort.

Collision warning system, side obstacle detection and lane departure warning, available on few luxury cars and several lorries, apply radar or video sensors to detect frontal and side obstacles, respectively, or to avoid involuntary overtaking of the lane border. Tyre pressure monitor applies piezoelectric sensors to obtain real-time measures of tyre pressure and warns to the driver when low values occur. Brake assistant monitors how the brake force is applied and applies maximum brake force for potentially shorter stops if it detects an emergency braking situation.

Intelligent cruise control (NHTSA, 1999) integrates collision warning, brake assistant and traction control and assists the driver to maintain a safe distance from the vehicle ahead or resume the desired speed by automatically acting on the breaking system or on the engine. This function was introduced in Japan on 1995 and in Europe on 1999. It is now available on around 20 models by different car and truck manufacturers in Europe, Japan and USA.

Different electronic technologies, based on sensors, on-board computing and communications, provide systems to enhance road visibility, particularly in the night.

Headlight distribution control varies light intensity and direction according to car speed and trajectory.

The first electronic night vision system, introduced in the US market in year 2000, is based on an infrared camera and a head-up display to show to the driver a thermal image of the front scene. It allows him or her so to recognise the presence of obstacles as pedestrians in front of vehicle when the street light is poor.

Developments are also taking place in tyre technology that will allow automatic measurement of inflation pressure, temperature and tread. Future tyres will be able to distinguish between dry, wet and icy roads.

These features could improve current safety systems based on feedback control that maximises the performances of breaking applied by the driver avoiding wheel blocking, but can not warn the driver if he or she must start breaking because his or her speed is unsafe with the respect of road characteristics ahead. Road-vehicle communication system, however, could help the driver to always keep a safe speed profile and could greatly improve their performances.

In the future the safety system will also benefit of the very precise location performance enabled by the implementation of Galileo satellite system, as well as of very detailed digital road maps that should contain also data from road registers as road layout (curve radii, longitudinal and transverse profiles), signs (enabling in-vehicle signing) and usual pavement conditions.

Thus, such on-board stored static information will make it possible to exploit precise location provided by the navigation system not only for route guidance, but also to develop a driving aid system that can warn the driver if his or her speed is incompatible with characteristics of the road ahead.

Congestion and information

The large amount of data collected and processed by the traffic control centre can be transferred to users through traffic information systems. Until now, variable message signs and radio data broadcasting are the most common sources of real-time information. They are both collective systems, which provide the former a space discrete information and the latter generic information related to a wide area. As they cannot provide specific information to each individual driver, an optimal distribution of traffic across the road network cannot be achieved.

However, on-board information systems are generally limited to provide only static information, supplied by a location device and a digital map. Although first electronic route guidance systems were experimented in 1968, their application until now is limited to implementations on the motorway network of few EU Countries as well as in Japan, where about 10 millions of cars are now equipped with VICS information system, but they have not yet been implemented on urban areas because their centralised architecture still require high investment cost for fixed roadside devices.

In spite of the application of the numerous mentioned tools to improve the performance of the road network, traffic congestion continues to grow in all European Countries as well as overseas. Attempts to make more efficient use of the existing road capacity are often made fruitless by the overwhelming increasing of traffic demand, which grew as intensity and also assumed a more distributed pattern as a consequence of the continuing urban spread. Facing these problems requires an entirely new approach that, on one hand, applies long-term comprehensive land use-transport policies to take under control the complex of phenomena that generate mobility needs and, on the other hand, looks for a completely different kind of transport system that should be able to react to changes in mobility needs and realise a safe, sustainable and high performance system.

In a partially automated system it is expected that the network efficiency will continue to require real time traffic flow management. In the short-term this will be through variable message signs but there will be an increase of in-vehicle information, which can assist drivers with journey planning and advise him or her on alternative routes using software that takes account of existing and predicted conditions on the network to minimise journey times.

Early experiments undertaken on many European, American and Japanese towns involving dynamic route guidance systems will continue in the next future and it is expected that they will be integrated with road-vehicle communication experiments conducted within the automated highways field, which will largely increase their efficiency. On the other hand, integration with traffic signal management systems will improve their effectiveness, because it will make possible dynamically coordinate traffic signals and drivers route choices and better exploit the overall network capacity.

As these systems will improve mainly road safety providing only limited benefits in terms of the road capacity, they will be combined with measures to reduce the demand and control the traffic flow access to congested facilities or areas. A low cost way to optimise the traffic flow on crowded freeway as dynamic coordinated ramp metering will be largely applied. Long freeways operating at high speed are needed to allow long distance trips across large metropolitan areas.

FINANCE

Public-Private Operation

The traditional approach to roads finance is by government funding from general taxation. But already the practice is beginning to move towards more specific charges for activities (in London there is now a congestion charge, in France, Italy and Slovenia tolled motorways and Austria has an automatic system on motorways for charging lorries based on distance travelled and their size, and so on).We believe that this will move more closely to an operation based on pay-at-the-point-of-use. A second source of finance is from the private sector, mostly in some sort of hybrid with government. Growing pressures on government across Europe will mean that they will continue to seek alternative methods of funding the infrastructure required to take advantage of the technological developments described in previous sections. This will be achieved by encouraging the private sector to invest in the infrastructure required and then charging users for the improved service that it provides.There are a wide variety of services that could be made available. These range from payment for information before and during journeys, to payment for road space and congestion charging.

Handling Mechanisms

There is the overwhelming fact that electronic cash flows have now replaced physical transactions very substantially across whole populations in many European countries. These electronic cash flows have not yet penetrated far into transport transactions (except for some electronic toll systems and attempts with parking, e.g. by mobile phones, but these are very limited compared with other financial transaction systems and banking).But we believe that they could, and will. That would lead to closer integration between real-time use, payment, and planning. And, of course, these would need to be linked together telematically. So the telematics of car and infrastructure communication and control will also incorporate cash flow, to the extent that government and private finance organisations move in that direction. By 2025 we believe that they could move quite a long way.

Charging for Use

At present Governments predominantly charge motorists for their use of the roads infrastructure by means of fuel taxation and vehicle-specific charges. It has been realised for a long time that this is not as economically efficient as more specific charges levied in close relation to actual vehicle usage. Whilst fuel duty is a good instrument for targeting carbon emissions and incentivising the development of fuel-efficient vehicles, other costs are less well targeted, or not at all. Thus for the individual user, the time, the discomfort, and the risk of accidents are not targeted; for the infrastructure provider the wear and tear and the marginal cost of use are not targeted; for other users the congestion delay and increased accident risk are not targeted; and for the rest of society, the contribution to climate change, the pollution, the noise, and the community-borne accident costs and visual intrusion are not targeted.

By 2025, the mass technology needed to charge all motorised road users for their use of roads by kilometres driven, according to time and place, can certainly be available. In limited production, all of the elements already exist now. Similarly, "backroom" administration systems for data handling and so on can be set up.

Both we believe could happen in 10 years - i.e.by 2014/2015. A big question is: to what extent will EU countries have such systems in place by 2025?

Two issues are critical for this: achieving popular acceptability, and devising a tractable system for migrating the present taxes in whole or in part to the charges for use by motorists. Governments have tended until now to the view that individual cities might, if suitably empowered, implement their own systems, and that this could lead to a progressive take-up, although not necessarily a migration of national taxes. Experience, however, has not supported this - only in relatively few cases are systems in place in individual cities and they are not generally fully specific systems (e.g. London's is a cordon based system with single unit charge). The reason may be fear by city authorities of putting their business base at a competitive disadvantage with respect to geographically near neighbours. In contrast national systems could avoid that difficulty, although setting prices would be a complex process.

We believe this is likely to produce a mixed picture for Europe by 2025. Some member states, will have adopted national or nationally-based systems. Most individual high density cities will have adopted some kind of charging regime within them.

What is of most significance for our Vision is that the systems for vehicle location and movement monitoring will probably be thoroughly with us by 2025, and they will be used as parts of systems to control large cash flows (comparable with cash flows for mobile phones operations). These systems will have begun to marshal a transformation in the economics of road travel. In 2025 we do not believe the new charging models, with the consequent economically efficient restraint of trips (and constraint on routes) will have come to full development; but in the subsequent decades they will; and that will in due course produce a different transport/and land use interaction and a more advanced shaping of our settlements and living patterns.

Insuring Against Accident Risk

The cost of insurance against accident risk is currently borne by motorists usually on the basis of annual (or similar) premiums, which vary from country to country, and which are usually charged with respect to personal factors (age, sex, etc) and broad patterns of usage (business/non-business use; location; and so on). However, satellite positioning systems and in-vehicle units can now be used to monitor how far, how often, where, and when vehicles are driven. In conjunction with records of collisions, damage, and injuries (some of which will be derivable from the records from the in-vehicle technology) this will allow much more specific determination of risk, resulting in more efficient pricing. It will also, by sending price signals to the user, encourage behavioural change away from the riskier (and therefore more costly) behaviours.

There is potential for common use of such in-vehicle equipment with other applications - for example. Road pricing. Again, the cash flows could be handled electronically.

Because of the potential market advantage this will confer on companies employing such usage based charging, we expect it to penetrate the insurance markets very significantly by 2025, by which time most insurance will operate in this way.

A Cautionary Note

It is not difficult to speculate open-endedly on possible developments. In contrast, constructing a vision for twenty years time involves judgements about which things are likely to happen, when they could happen (perhaps the most difficult), and what hurdles would have to be overcome on the way.

Perhaps the best illustration of this is the introduction of road pricing. The theory was established forty years ago, and the economic principles are fundamental. Despite much consideration since then its use is still rare and exceptional. Does that mean that it will not happen in the next twenty years? No. The reasons why it could be deployed are very persuasive. But for implementation one needs a number of conditions to be satisfied:

- Popular assent, or at least acquiescence,
- Prototype or exemplar technology that is already available,
- Mass technology that is not yet available (but compare the situation with that for mobile phones over
    - recent years: it could become available if the incentives were present),
- Legislation,
- Backroom financial collection systems,
- A migration path for charges from fuel tax and vehicle duties to road pricing so as to ensure a new and publicly acceptable revenue stream (e.g. demonstrable neutrality in net revenue, or initial advantage to the user).

MAIN RESEARCH THEMES

The Vision 2025 described in the previous paragraph is a statement of what it is likely to happen, based on the information about advancing trends, requirements and opportunities. Its main function is to point out these opportunities and where they could lead. In most cases to realize them we need to gain the necessary knowledge, identifying the areas of enquiry that are crucial to achieving them. FEHRL adopted a classification of the areas to be investigated consisting of four themes, aligned with those developed for the ERTRAC VISION:

- Design and production systems
- Environment, energy and resources
- Safety and security
- Mobility, transport and infrastructure

DESIGN AND PRODUCTION SYSTEMS

Developments in infrastructures provision

- Develop novel methods of fast construction that minimise energy consumption and damage to the environment.
- Develop innovative construction methods for relieving congestion “hot spots”.
- Develop an understanding of how capacity can be optimised over the life of the infrastructure by selection of appropriate maintenance strategies
- Obtain a better understanding of the physical processes that cause deterioration and determine how these can be monitored and controlled.
- Develop improved maintenance techniques that are economically viable, have a longer life and can be applied quickly under all weather conditions
- Develop methods that can be used to undertake a more comprehensive appraisal of sustainable performance so that better inputs into whole-life cost models can be used.

Developments in sensor technology for operation and management of the network

- Develop systems for-real time condition monitoring of roads and infrastructures which enable their physical condition and the loads and temperatures to which they are subjected to be recorded.
- Develop methods for using the output from monitoring systems to control the loading on roads and structures.
- Understand how sensors installed in vehicles can be used to provide information on the condition of the road.
- Examine how new technologies such as remote methods for monitoring the network (eg satellite images, laser scanner) can be used to provide information on the condition of the network – both static (road geometry) and dynamic (temperatures, movements) – that is of value to the road operator.
- Develop systems that allow communication between vehicles and the road operator which give information on condition on the network (wet/dry, temperature) and location (road pricing, congestion).

Developments that enable a better service to be provided to users

- Develop systems that allow communication between vehicles (i.e. collision avoidance systems, hazard warning systems)
- Determine the type of information that is required by the driver to optimise safety, minimising journey times and maximise economy and how it can be provided.
- Develop systems that allow communications between vehicles and third parties such as fleet owners to enable them to track and monitor vehicle movements.

ENVIRONMENT, ENERGY AND RESOURCES

Pollution and environmental control

- Understand the links between transport, lifestyles, education and health, and their costs and benefits, to assist in the development of a holistic approach to urban development and liveability.
- Research is needed to address the understanding of the relationships between traffic management, driver behaviour, vehicle operation, emissions and environmental impacts. In particular, methods are needed for predicting and managing high pollution episodes in urban areas, the development of appropriate emissions and air quality modelling techniques, and understanding public perception, and hence the acceptability of traffic management and calming schemes.
- Develop models that enables the prediction and control of traffic flows to achieve environmental and other targets.
- Develop systems to reduce the generation and dispersal of chemical pollution in road, run off, vehicle spray, winter maintenance and accidents spillages.
- Develop concepts for roads that reduce the creation of particulate and other pollutants through, for example, tyre wear, and in situ cleansing methods.
- Understanding how sensors installed in vehicles, at the roadside and in the built infrastructure can be used to monitor environmental conditions, and to provide information for the real-time management of traffic to limit environmental impacts.

Nuisance and societal/cultural impacts

- Investigate the use of new road surfacing materials and maintenance techniques that could produce significant benefits in terms of noise reduction.
- Develop vehicle tyre and road surface design concept which work together to produce less noise without sacrificing other desirable features such as safety, durability and economy.
- Techniques are needed to be able to assess and optimise the effectiveness of combinations of highway and land use noise control measures. Such measures include highway alignment, road surface design, land use and topographical considerations, and screening techniques including roadside planting.
- Concepts for road infrastructure that reduce both visual intrusion and severance for people and animals, and support the protection of cultural heritage (buildings and landscape).

Energy consumption

- Develop road concepts that reduce energy consumption for vehicles through better pavement design and maintenance, changes in road alignment and the provision of more energy-friendly infrastructure.
- Continue to investigate the use of new fuel systems and alternative and cleaner fuels for internal combustion engine powered vehicles.
- Continue research into vehicle and engine design, maintenance and operation to make them more efficient and to drive down pollution levels (both emissions and noise)
- Predict the response of the vehicle fleet and traffic characteristics to changes in charging methods (fuel prices, vehicles taxation, etc.): this will be an important part of future decision-making, and the effects on air quality.
- Consider concepts for energy generation in the road and road-side environment, including energy reclamation from pavements, use of roadside verges and other infrastructure

Sustainable construction

- Develop more economically efficient and more environmentally acceptable methods of construction and maintenance, taking full regard of the use of local materials and minimising cost and environmental impact.
- Investigate the use of waste products from other (non-transport) industries as the prime materials in the construction and maintenance of roads.

SAFETY AND SECURITY

Collision avoidance and mitigation

Opportunities should be developed for accident reduction (both frequency and severity) by means of new telematic systems; in particular:

- Influencing vehicle trajectories to avoid impact (collision avoidance) or lessen its severity, by means of driver warnings or control interventions. This should include both avoiding collisions with other vehicles and with road infrastructure, and would require roads-based information transmission.
- Influencing driver behaviour by intelligent warnings of risk factors relating to road layout, condition, ambient conditions including warnings of incident ahead, traffic proximity, etc and movement of the

subject-vehicle movement (speed, indications of driver impairment etc) and by control interventions (speed limitation, impairment interlocks etc).
- Develop lorry systems to identify persons and vehicles in close proximity (alongside, in blind spots etc) and issue warnings to driver or control interventions to prevent or lessen collision.
- Develop active intelligent systems for occupant restraint within vehicles, investigating (a) vehicle-autonomous systems (sensing occupant mass and shape and vehicle dynamics (impact speed/deceleration profile)) and deploying restraint in close relation to expected bio-mechanical forces, (b) the same systems but also deploying vehicle -vehicle communication prior to impact for additional dynamic information.

Changing behaviour by identifying risk
- Investigate achieving behavioural change by identifying the specific risk behaviours and exposure patterns of individual drivers, and providing for (a) information feedback to the driver (b) linkage to insurance premiums.

Deployment of emergency services
- Further develop systems to alert emergency services in the event of a collision by in-vehicle sensors recognising signature and communicating with infrastructure/emergency services (e-call).
- Investigate extension of such system to input to intelligent assessment systems for emergency services to prioritise response between incidents, and deploy according to traffic and weather and geographical conditions.

Capture of accident data
- Develop in-vehicle systems for recording accident events for post-hoc investigation.
- Develop scene surveying systems and image recognition and data extraction systems for rapid data capture of the scene following an accident.

Security
- Develop vehicle tracking and sensing systems within infrastructures to recognise major emergencies and terrorist acts.

MOBILITY, TRANSPORT AND INFRASTRUCTURES

Understanding and informing users
Understand user opinion on the use of transport services, better optimise those services and systems with respect to efficiency, safety etc, and understand how to summarise and present to customers/users the overall performance of transport systems with respect to efficiencies, safety and the environment, so that the user can make fully informed choices and improved decisions.

Travel behaviour and factors influencing it
- Understand how travel behaviour may be modified by packages of measures such as road pricing, improved public transport integration, better public transport vehicles, and innovative ticketing systems. Understand how the control of externalities would influence travel behaviour and travel patterns. Improve understanding of the demand/supply relationships, especially in complex and congested networks. Use the improved understanding of traveller behaviour and capacity limiting processes to develop better real time management models for traffic and pedestrian movement.
- Develop detailed models for international passenger and freight travel that take account of travel demand across the EC and all the driving forces but that are also capable of identifying and appraising the impacts of network improvements at a relatively local level.
- Investigate opportunities and requirements for freight ‘transhipment’ near city boundaries from ‘heavy’ to lighter vehicles (lorries to vans etc).
- Develop better option models for predicting the effects of planning strategies.

Land use and Information and Communications Technology (ICT)
- Understand the effects of restraints and incentives on land use and trip making.
- Understand locational behaviour and develop functional relationships for predictive purposes. Improve and extend land use/transport models, especially for the assessment of new and more efficient settlement configurations for living, working, shopping, leisure.
- Understand behavioural drivers and technological developments better in order to determine the scope for substitution of physical trips by electronic access.

- Determine the potential opportunities for new types of transport-telecommunication substitution and complementarity.
- Determine influence of new technologies such as satellite tracking on fleet management systems and delivery patterns, and the influence of non-transport regulation such as working hour directives on delivery patterns and industrial and business activity.

Traffic management

- Traffic management and capacity models need to be developed in relation to real time demand profile s and in relation to recurrent traffic patterns, in order to allow more intelligent understanding of the effects of restraints and incentives on land use and trip making.
- Understand how to limit demand, especially at peak time of the day, by use of restraints and incentives, and determine the full range of impacts.
- Develop novel methods for achieving local increases in capacity including electronic and telematic means.
- Extend the range of measures that regulate and control highway traffic – which currently include ramp metering, speed controls, HOV lanes, etc, and understand their contribution to reducing congestion and delay.

Public transport; and the parking of vehicles

- The connections between physical transport modes will become increasingly important and our capacity to improve them will grow. Interchanges must be designed so that they optimise traveller flow and throughput, and encourage use by and of multiple transport modes.
- Determine how to configure, design and operate such interchanges. Investigate coach-and-ride systems for medium and longer journeys to complement rail.
- Develop real-time parking management systems, linked directly to journey planning – for both passenger and freight journeys.
- The scope for extending the use of less conventional transport services needs to be examined and innovative approaches for the supply of transport services identified, piloted and assessed.

Data management

- Development of tools to interpret the data for highway operation.
- Determine how best to acquire, filter and disseminate data for timetabling in real time by mode and location; this will include understanding how real-time changes to service schedules interact and synchronise with complementary modes.
- Design efficient travel and traffic data collection and management systems that are able to deal with real time processing and are suitable for prediction.
- Establish management protocols for the rationalisation of information collection and sharing. Investigate the functional requirements and market opportunities for the storage and access of historic and real-time traffic data.

Road user charges

- Investigate the potential benefits, costs and impacts of different structures, levels and geographic coverage of road user charges. Determine how to inform the user of the charge in a meaningful way, and its relation to the trip, in order to bring about appropriate behavioural change.
- Explore how models of financial management will impact on the type of charging system that is actually implemented - the structure and level of charges and how they relate to use - and what elements of use are actually charged for.
- Investigate and establish the criteria for charging - environmental effects, effect on the road, effect on other road users, for time saved, targets, constraints, desirables etc. - and the relation between objectives and behavioural response.
- Devise a system for migrating from the current approaches to travel taxation to a system based on road user charges.
- Investigate potential interactions and interfaces between local and national road user charging systems and how to ensure that revenues are equitably distributed. Investigate how to harmonise potential systems between towns.
- Understand the potential impact of road user charging on residential and commercial land use distributions.
- Develop intelligence processing and contingency plan selection for such events; provide intelligent coupling to emergency services' operations.
- Develop database systems to record patterns of traffic etc events and permit recognition of unusual or threatening (pre-terrorist) activity; develop processing and warning systems for emergency services.
- Develop video based surveillance and image recognition systems to input to safety and security systems (as well as monitoring traffic flows). Develop vehicle theft and traffic systems.

CONCLUSION

This paper reports the results of an European level coordinated effort aimed to build a reasonable vision for Europe's road transport in the future. The purpose of this work was to capture the key features of a foreseeable future and define the steps necessary to move to it from present days.

We believe that, taken as a whole, this Vision catches the principal elements of road transport with a reasonable level of probability. Of greater significance, we believe that the knowledge needed to realise this Vision is common to a range of futures, of which this Vision is simply a representative one, and that that knowledge lies on the critical path. This means that it is important to plan now for how we are to achieve that knowledge. It is also well to remember that no-one has universal control over the influences and determinants of the future. For a given future to come about many groups and interests have to act. Road transport in 2025 will depend strongly on how well the polices and developments of coming years are put into action.

REFERENCES

AHSRA (2003a), *Overview of Reports at the 7th AHS Research Seminar*, Tokyo, Japan.

AHSRA (2003b), “Development of Road Surface Detection Sensors”, *7th AHS Research Seminar*, Tokyo, Japan.

AHSRA (2003c), “Development of Positioning Technology”, *7th AHS Research Seminar*, Tokyo, Japan.

AHSRA (2003c), “Development of Road Condition Detection Sensors”, *7th AHS Research Seminar*, Tokyo, Japan.

AHSRA (2003d), “Development of Road-to-Vehicle Communication Systems”, *7th AHS Research Seminar*, Tokyo, Japan.

DRANE, C. and RIZOS, C. (1998), *Positioning Systems in Intelligent Transportation Systems*, Artech House, Boston, USA.

FEHRL (2005), *VISION: Road transport in Europe 2025,* Technical Report, Forum of European Highways Research Laboratories.

FHWA (2003), *Freeway Management and Operations Handbook - Final Report*, FHWA Report No.: FHWA-OP-04-003.

ITS America (2002), *National Intelligent Transportation Systems Program Plan: A Ten-Year Vision*, Intelligent Transportation Society of America.

ITS Hand Book (2004), Japanese Ministry of Land, Infrastructure and Transport.

KLEIN L. (2001), *Sensor Technologies and Data Requirements for ITS*, Artech House, Boston, USA.

LITMAN T. (2005), *The Future Isn’t What It Used To Be*, Technical Report, Victoria Transport Policy Institute, Canada.

NHTSA (1999), *Evaluation of the Intelligent Cruise Control System*, Volume I – Study Results, Technical Report, National Highway Traffic Safety Administration.

Vision 2030 (2003), *Final Report*, Vision 2030 Consortium, WSP Civis Ltd, www.transportvisions.org.

White Paper (2001), European transport policy for 2010: time to decide, European Communities.

ZHAO Y. (1997), *Vehicle Location and Navigation Systems*, Artech House, Boston, USA.