

FEHRL



VISION:
Road Transport
in Europe 2025

FEHRL OVERVIEW

FEHRL is a registered International Association with a permanent Secretariat based in Brussels. Formed in 1989 as the Forum of European National Highway Research Laboratories, FEHRL is governed by the Directors of each of the national institutes. At present, FEHRL comprises twenty-seven national laboratories from the member states in the European Union, the EFTA countries and the rest of Europe.

Under the day-to-day management of the Executive Committee, FEHRL is engaged in research topics including road safety, materials, environmental issues, telematics and economic evaluation.

Research capacity is provided by the national institutes and makes use of the wide range of test facilities available.

AIMS AND OBJECTIVES

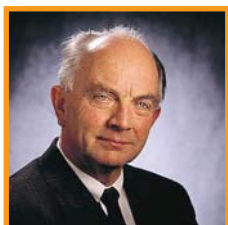
The mission of FEHRL is to promote and facilitate collaboration between its institutes and provide high quality information and advice to governments, the European Commission, the road industry and road users on technologies and policies related to roads.

The objectives of collaborative research are:

- to provide input to EU and national government policy on highway infrastructure
- to create and maintain an efficient and safe road network in Europe
- to increase the competitiveness of European road construction and road-using industries
- to improve the energy efficiency of highway construction and maintenance
- to protect the environment and improve quality of life



FOREWORD



Jørgen Christensen
President

The FEHRL Vision for roads in Europe, which is now in your hand, was developed to provide perspective for the Strategic European Road Research Programme (SERRP), which FEHRL developed and maintained over the last 15 years and has defined in a series of detailed plans with the full support of the national Road Directors.

In implementing the current SERRP plan, FEHRL has taken a long-term view of the process and adopted a more integrated approach to the conduct of the research arising from it. This has resulted in a clustering of the projects and strengthened consultations with the stakeholders. The process is now underpinned by a vision of the longer-term future of roads and of the research needed to realise this vision.

The development of the Vision began as a contribution to the European Commission's Barcelona Conference on Energy and Transport in 2002. The then Commissioner for Research and Development, Mr. Philippe Busquin, encouraged FEHRL to continue the process and invited us to arrange a workshop on the topic for the launch event of the Commission's 6th Framework Programme.

FEHRL brought together a range of actors for the workshop, including the developing European Road Transport Research Advisory Council (ERTRAC). The potential key role of ERTRAC was soon obvious, and FEHRL became a partner along with colleagues from the automobile and the fuel industry. We have since worked with many experts from the wider road transport sector to develop ERTRAC's year 2020 vision for the road transport system as well as the strategic research agenda needed to deliver that vision.

At the same time, FEHRL has continued to develop our Vision that is specific to road needs, and, with the support of the Commission, we have already instigated projects that seek to develop discrete elements of that Vision. One such project, New Road Construction Concepts (NR2C), is, for example, specifically aiming at the construction aspects. Each of these elements are reflected in the Vision and will become cluster centres in our research.

The Vision is also important for the development of our organisation. FEHRL operates on sound business practices and must anticipate the type of business we expect to conduct over the next 20 years. Further, in developing the human resources in our member institutes it is important to share common goals and aspirations. Organisations that are able to present in clear terms their sense of purpose and their view of their future are those with the most motivated people and the most attractive for potential recruits.

FEHRL and its member institutes play a unique role in the development of Europe's future roads, and together we have the means and aspirations to deliver our Vision of that future.

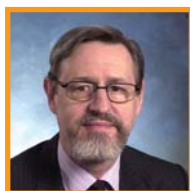


PREFACE

Because roads are so vital to Europe and because the next twenty years offer profound opportunities and challenges for their development, we need to think very carefully about how we can make greatest progress. FEHRL therefore decided to draw up a Vision for 2025 to guide the thinking and to help focus actions. This report summarises that Vision. It has been developed from the input of a Working Group of representatives from nine of the FEHRL establishments, and in conjunction with the Secretariat.

All visions of the future involve speculation. How well they work depends on how informed that speculation is, how well the inevitable uncertainties are recognised, and how robust the assumptions are on which it is based. We have therefore taken some trouble to lay out the reasoning and to explain how we conclude what the future is most likely to be. We believe the result is robust and reasonable, in that it concentrates on conclusions that are common to a range of scenarios. Time will tell.

It is very clear that if we are to realise the potential benefits of a number of key developments - which could be huge - we need first to gain an essential knowledge base. Road transport in 2025 will depend strongly on how well the policies and developments of coming years are actioned. The knowledge base is on the critical path and is key to our future.



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TABLE OF CONTENTS

1 INTRODUCTION	4	5 VISION 2025	24
Road Transport: Reality and Perception	4	What Emerges from the Scenarios and Requirements?	24
Futures	5	2025: What will it be like?	26
Our Approach	6	Roads	26
Relationship with the ERTRAC Vision	7	Road-Vehicle-Driver Linkages: the IT and Communications Infrastructure	30
2 CURRENT TRENDS	8	Finance	35
Transport Demand	8	A Cautionary Note	38
Modal Split	9	6. GETTING THERE: WHAT DO WE NEED TO KNOW?	40
Social	10	Design and Production Systems	41
Environment	11	Environment, Energy and Resources	42
Economic	13	Safety and Security	44
Political	13	Mobility, Transport and Infrastructure	45
3 TECHNOLOGICAL ADVANCE	14	Appendix A: Members of the Working Group	48
Construction	14	Appendix B: Users' and Stakeholders' Requirements	49
Network Management	14		
Traffic Management	15		
Demand Management	15		
Multimodal Trips	16		
Vehicle Engineering	16		
4 CONSTRUCTING THE VISION	18		
Scenarios	18		
Fulfilling Users' and Stakeholders' Requirements	21		

1 INTRODUCTION

This document is to set out a vision for Europe's road transport in 2025: 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 2004.

The Vision needs to capture the key elements of road transport, and these 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 these aspects in order to take proper account of the full impact of road transport.

Road Transport: Reality and Perception

Roads are, by any reckoning, the lifeblood of European trade and social utility. For most European countries they carry the majority of land freight and passenger traffic by a long way, and they enable wealth to be generated and enjoyed. But this provision for traffic movement brings big challenges in terms of the investment, organisation and maintenance needed. Road traffic generates large 'external' effects including death and injury and environmental pollution, and the freedom of movement roads offer is constrained by the congestion and delay generated by demands beyond their working capacity. As an asset, their replacement value is huge. The maintenance regimes are correspondingly expensive; and these regimes themselves impede or interrupt the delivery of free movement.



SCOPE OF THE VISION

Moreover, the benefits of effective road systems are frequently not perceived in themselves by the travelling public. Instead, road users simply judge the service levels available to traffic; and in turn tax payers judge the cost of maintaining and operating the asset within the larger tax picture. Neither perceives the total benefit of the operation.



So politically there is a distinction between the direct perception of users (with respect to convenience, efficiency of movement, and freedom from risk of accident and pollution), and the indirect effects realised in the national wealth generated net of the operating, maintenance, and investment costs. Most people do not connect the two, with the result that the enormous overall benefits provided by roads are often overlooked by the public under the weight of the day-to-day experience of delays, accidents, pollution, and general frustration.

We believe that there are two morals to be drawn. Firstly the public's perception of the day-to-day experience of road travel matters greatly; and secondly, more needs to be made of the benefits of road transport, and the national and individual wealth that they help generate, and can generate in the future.

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.

The first of these is visionary in a rather fanciful way; the second is at most a simple extrapolation of the present. Both, however, would be subject to big changes in the demand for travel as compared to now. So in both cases the future would look very different; since even in the second case, we would see the effects of big differences in the volume of operation, and in the externalities.

Practically speaking, we feel that neither is realistic, though the real future is likely to contain elements of both. What seems to us 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.



In whatever form this happens, there are likely to be very substantial changes in technology-driven communications and financial transfer systems. These will undoubtedly be deployed widely in many aspects of everyday life, and it would be a surprise and a lost opportunity if they were not incorporated into road travel. How effective this proved, however, would depend on how well the future has been anticipated - the needs and desires - and how well the implications for the actions needed to get there were recognised and acted upon.

Our Approach

It is increasingly clear that the vision needs to be Europe-wide. The need for movement within and between member states will be crucial to the development of Europe's economic activity and to the well-being of individual states. 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 we work towards a single future judging the likely technological, societal and policy options, and concentrating on those we think most likely to come about. This provides us with a rational framework for conceptualising.

We begin with a brief overview of the current position across the wider EU and of the known time trends at present. That enables us to draw out likely future changes given current conditions in the form of a simple projection to the future. We then define the broad features of the five supply-side scenarios: the policy and practical bases according to the five different types of approach. We go on to consider future technological and financial possibilities. This we do 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.

We believe this future will only be accessible via a growing knowledge base. The process of building such a base needs to be pursued proactively. Accordingly, we note the main themes needed in future research programmes.

Transport in general and road transport in particular involve huge resources, and generate huge benefits. We believe that it is more than ever important to treat the future seriously, to move forward with rational programmes, and to anticipate needs and opportunities, rather than waiting reactively, and then proceeding without a coherent direction. We hope that this Visioning exercise helps to set the scene for genuine exploitation of the rapidly growing set of opportunities that technological and institutional change offer.

Relationship with the ERTRAC Vision

As FEHRL's President points out in his Foreword to this document, there is a relationship between the present Vision and that being prepared by ERTRAC (European Road Traffic Research Advisory Council). Both address a period of a couple of decades or so ahead. And whilst the FEHRL Vision starts from the perspective of highways and their operation, we argue that in twenty years time they will be intimately linked with both the road-vehicle communications and IT infrastructure and the financial infrastructure.

Accordingly, in Chapter 6, we conclude by identifying the same four categories of enquiry and development as in ERTRAC's Vision. This enables cross referencing between the two whilst also highlighting those areas of enquiry at present more strongly associated with physical highways. The four categories are:

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



2 CURRENT TRENDS

We start by sketching current trends, in outline technological developments are considered in Chapter 3.

Transport Demand

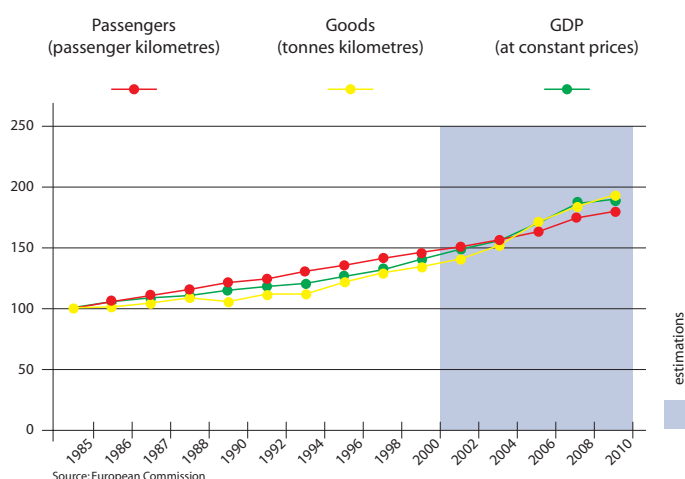


Figure 2.1 Transport growth in the European Union (EU-15)
1985 - 2010 (2001 - 2010 estimates)

The demand for road transport has grown continuously over the last 50 years and although populations in some member states are declining, the demand for road transport is still predicted to increase. For the ten new European Union Member States, it is forecast to grow by 4% a year (see Figure 2.1).

There will be pressure for these countries to move towards Western European standards of infrastructure development, road safety and environmental

protection. According to ERF estimates, the average motorway density in Central European Countries (CEC) is 6.3 times lower than in the western EU countries (EU-15) and 14,000 km of new motorways need to be built within the next 10 years simply to offer similar levels of network accessibility to Central and Eastern European citizens. These countries are already investing heavily in building new infrastructure. For example, Hungary spends 90% of infrastructure resources on the construction of new motorways. Similarly, in Slovenia, 27% of all bridges on the main road network, comprising 48% of the entire bridge deck area, have been built in the last 15 years. However, a consequence of such policies is insufficient budget provision, for maintenance of existing infrastructure.

The profile of the driver population is changing; people are living longer, especially in developed western economies. It is predicted that a fifth of the population of Europe will be aged 65 or over in 2020. This is coupled with the increase in the number of female drivers, who have historically been strongly under-represented in the driving population.



Modal Split

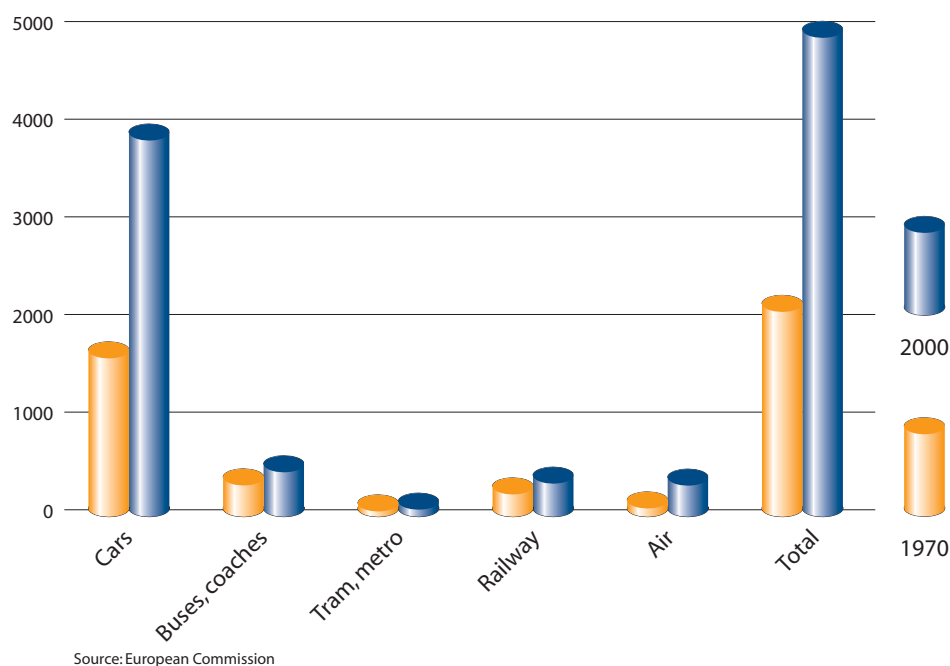


Figure 2.2 Performance by main modes of transport (EU-15) - Comparison 1970 / 2000 (1000 million passenger kilometres)

Overall, roads are the dominant transport mode (see Figure 2.2). They carry 44% of the goods transport market compared with 41% for short sea shipping, 8% for rail and 4% for inland waterways. The predominance of road transport is even more marked in passenger transport, accounting for 87% of the market, while air has 6% and railways 7%. See Figure 2.2.

There are exceptions within the overall picture. While roads have already acquired a dominant role in the transport of goods in the Czech Republic and Hungary they remain outweighed by the rail sector in the Baltic States and Slovenia. In Cyprus and Malta, road haulage is dwarfed by sea-shipping.



Social

Road Safety

In 2002 there were around 39,000 deaths and 600,000 serious injuries on the roads of the original 15 EU member states (EU15) and another 11,000 road deaths in the 10 new EU member states. Safety levels vary widely across Europe (see Figure 2.3). While the number of deaths in EU15 countries has on average decreased by 2% in 2002 compared to 2001, the number in the remaining 10 countries has increased by 5%. Improving road safety is generally seen as a high priority and many countries have set targets for reducing the number of deaths and serious injuries. The European Commission is committed to a 50% reduction in road deaths by 2010, compared to 2000.

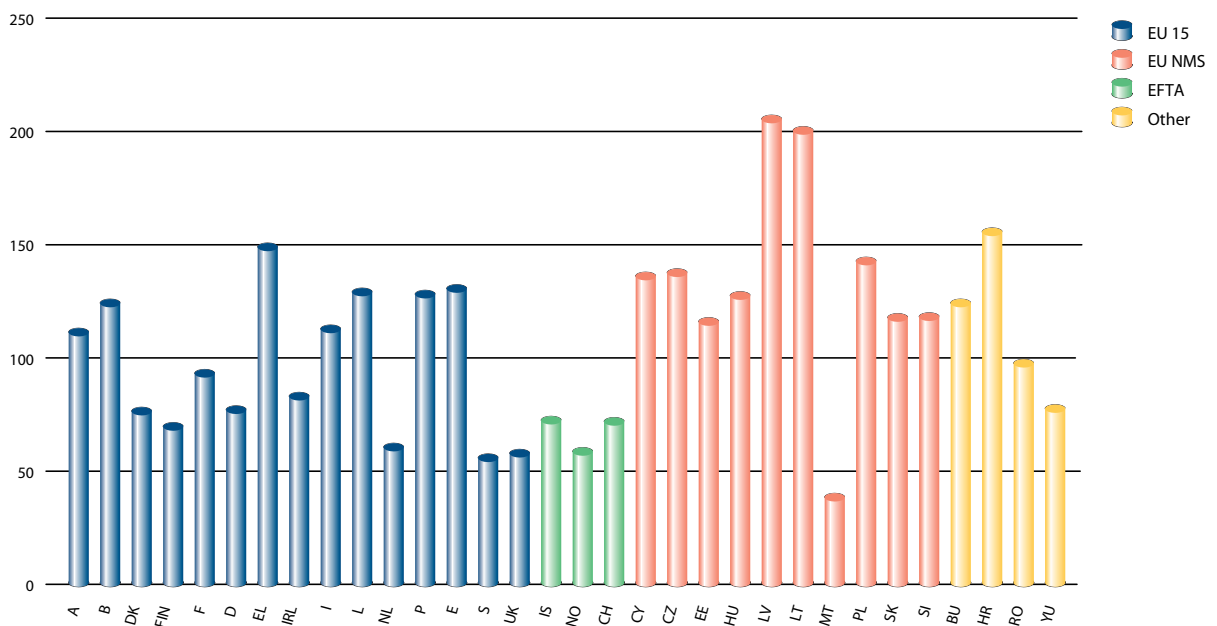


Figure 2.3 Number of road fatalities per million population - 2003

Lifestyles

Changing lifestyles are contributing to the increasing demand for travel. In particular:

- The number of households per head of the population is continuing to increase.
- Higher disposable incomes are generating demand for more leisure and holiday travel.
- People are generally spending more time on leisure activities assisted by flexible working patterns.
- Increased opportunities for economic activity beyond retirement age will increase demand for mobility among the elderly. Tourism is continuing to grow, with faster long distance travel. Travel in non-peak hours may increase, at a greater rate relative to commuting travel, as a result of increased leisure time.
- Career paths and opportunities for employment will take people further from their home towns and national and international travel will become increasingly common.
- The developing picture is of traffic congestion spreading spatially, outwards from the major conurbations, and temporally, leading to more extensive periods of regular congestion within the day.

Transport and Land Use

Populations and employers are continuing to decentralise from city centres to the suburbs across Europe. Infrastructure development will need to take into account the larger numbers of elderly people. If distances to facilities and services increase, people will become more dependant upon their cars.

Environment

Climate Change

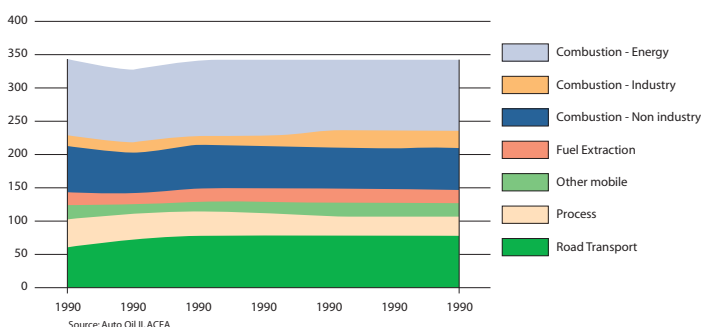
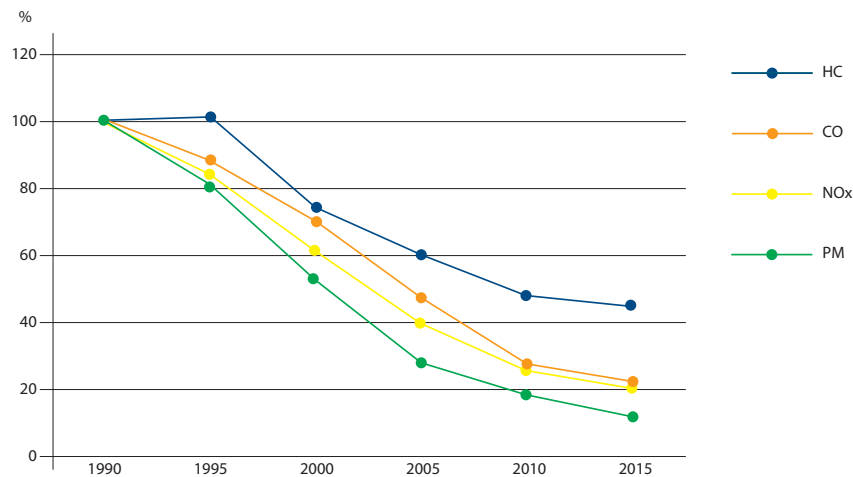


Figure 2.4 Carbon dioxide emissions (Mt) from the EU-15

There is an increasing scientific consensus that global warming is underway, linked at least in part to human economic activity. Carbon dioxide (CO₂) is the main greenhouse gas. Emissions of CO₂ from transport are the second largest single source of greenhouse gas emissions in the EU accounting for 20 % of total greenhouse gas emissions in 2001. Road transport is by far the largest emission source from transport accounting for 92 % of total transport related CO₂ emissions. Between 1990 and 2001, CO₂ emissions from transport increased by 20 % in the EU (Figure 2.4). The main driving forces were the increasing volumes of passenger and freight traffic.



Air Pollution



Source: Auto Oil II, IRU

Figure 2.5 Emissions 1990-2015 road transport (EU-15)

Road transport is a major source of air pollutants and the dominant source in many urban areas. According to the latest estimates, provided by the World Health Organisation European Office, about 80,000 deaths per year in Europe can be attributed to long term exposure to road traffic generated air pollution. The health costs of traffic-related air pollution are very high; they include premature deaths, hospitalisation and loss of production. However there has been significant progress in reducing air pollution in recent years (see Figure 2.5).

Noise and Nuisance

In Western Europe the population exposed to noise levels above 65 dB (A) increased from 15% in the 1980s to 26% in the early 1990s. It is estimated that some 80 million EU citizens suffer from unacceptable levels of noise while another 170 million live in "grey areas" where sound is a major nuisance, much of it caused by the transport sector as a whole. The resulting sleep disturbance, loss of productivity and decreases in property value cost the EU an estimated EUR 38 billion. Despite progress in reducing noise from individual vehicles, as traffic volumes increase, noise pollution, particularly from road and air transport, is expected to rise and become an issue of growing concern.

Energy - Resources

In 1998 fossil fuels met 90% of global commercial energy demand. Crude oil accounts for over 98% of transport fuel consumption. There are a number of new technologies that promise an alternative to fossil fuels but most are at an early concept stage.

Economic

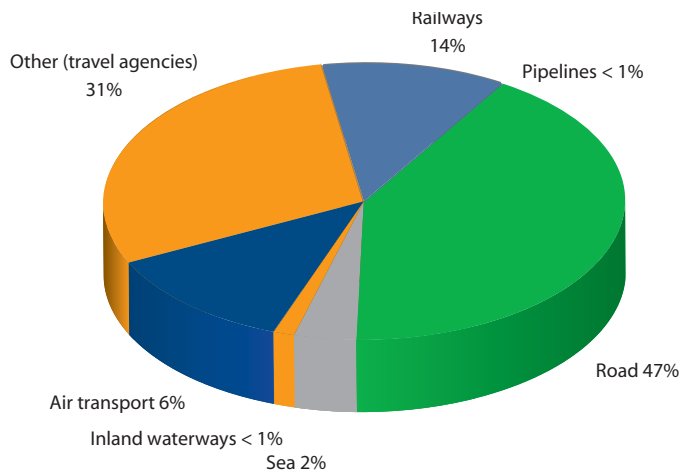


Figure 2.6 Employment by mode of transport in Europe 1999
(% of total transport)

The road transport sector makes a major contribution to the economies of Europe. As elsewhere, there has been a strong correlation between transport and economic growth, with each 1 per cent growth in GDP being concomitant with a 0.9 per cent growth in freight transport and 1.2 per cent growth in passenger transport.

Employment in the transport sector in 1999 is shown in Figure 2.6. These figures only relate to haulage and passenger transport performed by companies, not to the overall transport employment share as they do not include own-account transport, motor trade maintenance & services, automobile & equipment manufacturing, road related civil works, motorcycle industry nor insurance related employment.

Political

The liberalisation of road freight combined with the opening of markets in Central and Eastern Europe has led to a steady increase in road transport compared to other modes. However, there is a tendency to think that within liberalised competitive markets there need to be specific provisions, regulatory or fiscal, for environmental protection.

Public expenditure on roads is generally covered by road-user taxes. Most governments have abandoned road funds incorporating a direct link between road taxes and expenditure. Despite a growing belief that pricing for road use should be a central part of sustainable policy-making, very few cities have introduced any form of road pricing.



3 TECHNOLOGICAL ADVANCE

There has been, and is, a great deal of technological advance across the whole range of road transport.

Construction

The construction materials and procedures for the planning, design and construction of roads and their associated structures have remained largely unchanged over the last century. However in recent years there have been pressures to reduce the timescales for the whole process and to take account of environmental impacts both during and after the construction operation. This has resulted in a much greater use of recycled and secondary materials in construction, developments to lessen the intrusion of the infrastructure on its surroundings, such as improved landscaping and quieter road surfaces, and the application of the principles of whole-life costing. Whilst these developments have contributed to reducing environmental impact and improving sustainability there has been little progress in reducing timescales. Fast construction techniques and modular construction are likely to develop over the next few decades.

Highway maintenance can cause considerable disruption to traffic. However, recent advances are enabling maintenance activities to be planned to minimise the disruption to traffic. These include advances in the understanding of the long-term performance of pavements, developments in traffic speed surveying techniques to determine the condition of roads, and maintenance techniques such as crack and seal.

The need to construct smooth, long-lasting pavements that maximise highway investment and are more user-friendly to highway users is leading to improved ways of evaluating highway construction products. There has been a move away from specifications for end-product quality towards performance-related specifications for quality in terms of desired performance over the long term. This will allow for a greater choice of materials and greater scope for innovation which should in turn accelerate change.

Network management

In recent years there has been considerable interest in Europe, the US and Japan in intelligent transport systems (ITS). In the USA, Japan and the UK research on automated highway systems (AHS) - a lane, or set of lanes where specially equipped cars, trucks and buses could travel together under computer control - has been underway. The French programme, "La Route Automatisée", incorporates preliminary studies on the application of vehicle-highway automation to improve travel in rural areas, commercial trucking, city-to-city corridors, and commuting.

Whilst technically feasible, there are a number of barriers to the development of ITS systems; these include cost, liability, societal and institutional issues.



Traffic Management

Physical measures include modifications to the infrastructure either to improve road capacity (road building) or to enhance road safety (traffic calming). Traffic control measures employ sensors, computers and actuators that monitor traffic flow and regulate traffic by means of signals at road junctions.

Traffic monitoring and surveillance systems have been extensively applied in many urban road networks and interurban expressways. Modern traffic detectors can now provide extensive data that characterise traffic flow. In addition, video sensors can be used for automatic traffic counting which enables prompt detection of incidents and the application of appropriate measures.

Many European cities have installed urban network traffic control systems that dynamically adjust traffic lights according to real-time traffic flows. On urban and metropolitan motorways, dynamically coordinated ramp metering systems, widely applied in United States during the last decade, are now being introduced in some European Countries. Speed regulation by means of variable message signs has been introduced in some countries to ensure a more stable traffic flow.

To-date, variable message signs and radio broadcasts are the most common sources of real-time information. However, they cannot provide driver specific information.

On-board information systems are at present generally limited to providing only static information, supplied by a location device and a digital map. Although the first electronic route guidance systems were experimented on several decades ago, their application to-date has been limited to the motorway networks of a few EU Countries and Japan. They have not yet been implemented generally in urban areas because of the high investment cost. Some urban and interurban real-time traffic information is now available on the internet.

Route Guidance

On-board navigation systems now use global satellite positioning (GPS) and odometer sensors to track the car position along the route and display the current location on a digital map. Radio information systems, such as Radio Data System/Traffic Message Communication (RDS/TMC), provide updated information on non-recurrent congestion detected by a still sparse network of monitoring detectors. Simple dynamic route guidance systems have been recently introduced into the market in Europe, USA and Japan to provide drivers with updated information collected by specific detectors located on the motorway network.

Demand Management

Measures to manage demand - i.e. to control or constrain demand - include encouraging travellers to use their cars more efficiently (e.g. car sharing), limiting traffic access into city centres (e.g. pedestrian areas) and encouraging a modal shift to public transport by introducing differential road pricing schemes (e.g. parking



charges, road tolls, congestion charging). Other policies aimed at reducing demand include encouraging the introduction of flexible time working and, at a grander level, integrating transport-land use policies.

The recent technological advances allowing tele-activities (teleworking, teleshopping and so on) also seem, *prima facie*, to offer to substitute for some physical trips and so reduce demand for travel. However, experience so far indicates that this tends to be complementary rather than wholly substitutional, and that tele-activities in general mostly tend to add a further level of activity. Teleworking may however induce temporal shifts in travel.

Multimodal Trips

At present there is little co-ordination between different transport modes for users making multimodal journeys - bus, train, tram, car etc. Advances in Information Control and Technology (ICT) will provide the means to make this possible. The effective up-take of such technologies will depend very much on organisational issues and any financial incentives to operators.

Vehicle Engineering

Although the vision we are seeking is about roads in 2025, vehicles and vehicle technology bear strongly on it. This will become clear in Section 6 below. Here we briefly summarise vehicle technology development. Considerable progress is being made in vehicle engineering to address safety, pollution and energy saving, and to provide the driver with more information.

Safety

In recent years, the design and marketing of motor vehicles have been strongly influenced by the European New Car Assessment Programme (EURO NCAP). This is leading to improvements in the quality of information provided to consumers and to better protection of the occupants of vehicles. The trend over the next few years is likely to be towards better protection of vulnerable road users.

Many active safety devices now available on the market improve vehicle stability in braking/traction and help drivers to keep safe distances among moving and fixed obstacles. Anti-lock Braking Systems (ABS) are now installed on most cars on the EU market, while newer electronic devices such as Electronic Stability Programmes (ESP), Electronic Brake-force Distributors (EBD), and Traction Control (TC) are now available on many cars and trucks. ESP uses sensors to determine the steered path and help the driver keep it under control by applying appropriate brake pressure to individual wheels or reducing engine output to correct understeering or oversteering. Programmes to develop independent tests of the claims made for each system are currently in progress.

Side obstacle detection and lane-departure warnings are available on a few luxury cars and some lorries. They use radar or video sensors to detect frontal and side obstacles respectively, or to avoid involuntary over-running of the lane border. Tyre pressure monitors use piezoelectric sensors to obtain real-time measurements of tyre

pressure and warn 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.

Advanced cruise control and collision warning systems that enable the driver to maintain a safe distance from the vehicle ahead or resume the desired speed by automatically acting on the braking system or on the engine were introduced in Japan in 1995 and in Europe in 1999. They are now available on a number of models produced by a variety of car and lorry manufacturers in Europe, Japan and the USA. Other innovations include sensors, on-board computing and communications that provide systems to enhance road visibility, particularly at night. Headlight distribution control varies light intensity and direction according to car speed and trajectory. Experimental night vision systems have employed an infra-red camera and a heads-up display to show a thermal image of the front scene to the driver.

Technology is moving towards the state where road-vehicle and vehicle-vehicle communication systems could improve current safety systems, and help the driver to maintain a safer speed profile, dependent on actual road and traffic conditions.

Power Sources

There is likely to be an increase in the use of alternative fuels as new technologies are developed, if they can be made affordable. Promising prototype technologies already exist but most are at an early concept stage. These include fuel cells, biofuels and hydrogen.

Electric vehicles are being developed whose driving ranges are several times higher than earlier versions. They are starting to capture a small part of the passenger and urban car market. The most promising application of electric power is the hybrid vehicle which uses a combination of electrical and combustion energy.

Energy Consumption

Conventional vehicle development still has some way to go. Vehicle weight has a major effect on fuel economy. The most promising lightweight materials are aluminium and carbon fibre and several aluminium-based vehicles with a weight reduction of 40% are already available on the market. The latest research on hypercars is producing vehicles with 3-5 times better fuel economy, virtually no emissions and technologies that are almost completely recyclable and reusable (www.hypercar.com).

Emissions

Catalysts have reduced engine pollutant emissions as standards have been progressively tightened. Natural gas and liquid petroleum Gas may reduce emissions of some pollutants. Although they have been available for many years, their market penetration is still low.



4 CONSTRUCTING THE VISION

So far we have talked about the present and changes that are identifiable within it. The immediate future will be shaped by the trends outlined in the previous section, the transport system requirements, the resources available, and unforeseen future events. 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. In this chapter we outline this process before going on in Chapter 5 to the Vision which follows from it.

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.

Fulfilling Users' and Stakeholders' Requirements

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.

Appendix B discusses these requirements, the preconditions necessary for the developments to take place, and how they may be implemented under the different scenarios. Here we summarise the indicators to emerge. Let us begin with definitions of the requirements.

Definitions

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

Appendix B considers the developments relative to the requirements and the pre-conditions necessary to achieving them. The overall picture to emerge 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. It is this picture that we go on to explore in Chapter 5. In forming it two questions need to be considered: (a) do some developments occur in some scenarios but not in others? (b) for those developments which occur in all scenarios, is the pace of progress different according to which scenario would apply?

With one or two notable exceptions the answer to the first question is that developments are mostly common to all of the three practical scenarios. But with regard to the second question, the answer is that the pace of progress is likely to be different.

The most notable example of a development unlikely to take place in one scenario but more likely in another is the achievement of multi-modality. In an extreme market-led scenario, multi-modality is unlikely to be achieved to a significant degree unless there are distinct financial incentives for the operators of the different modes, incentives not only to exchange information but also to adjust scheduling and interchange facilities so as to enable users to make multi-model trips easily and efficiently. There is no obvious market-based source for such incentives. In contrast, in a government-led scenario a degree of multi-modality could be achieved according to the extent governments influence the operators and the relationships between them.

But we believe that in practice such completely separate scenarios are unlikely. What is much more likely is that those two scenarios would overlap strongly. That is, even in a Government-Led scenario, governments would seek to use market forces to shape transport operations by mode, and could inject a degree of control sufficient to generate some improved linkages between modes. Similarly, in a Market-Led scenario, the stability of market operation for a given mode would still depend on government controls to some extent, and such controls could again be manipulated to generate a degree of multi-modality. This is not to say that the achievement of multi-modality would be easy, or in any sense guaranteed. We believe it still remains a difficult problem.

As a result, the paths to implementation follow a range, according to the scenarios, as detailed in Appendix B. The degree of commonality between these paths is quite strong. The differences are mainly in the likely rate of progress and the extent of the developments within the next 20 years.

Broadly speaking, progress will depend on the degree of stability in government programmes in all scenarios and the extent to which markets respond. Innovation and progress with mass-production technology will be crucial. In general there are few strong qualitative differentiators between the responses to the requirements in different scenarios. What is likely to differ most, and is most uncertain, is the rate at which change occurs. In all cases, clearer well-informed policy frameworks, with stable indicators for the markets, are most likely to produce successful change.

We go on now to consider the consequences of this analysis so as to formulate a Vision for 2025.



5 VISION 2025

What Emerges from the Scenarios and Requirements?

The objective of good visioning is to identify the patterns both of change and of 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 2004/2005, there will also be some substantial changes whose rolled-up effect is likely to be bigger than one might be tempted to expect.

Our reason for saying this is that there are some strong economic and social forces at play. Europe is a very big player in world economics, and EU enlargement involves fundamental change, with the potential for large developments in the coming decades. Technology is developing rapidly, and that will continue, particularly for mass-production technology systems - those applied across the whole population, rather than limited high-tech subsets like those in defence technology. Natural resources are under pressure and there is a growing recognition that we must improve our husbandry of them. Road travel and IT and communications are already dominant and their relative dominance over other access modes is likely to grow rather than decline. The connections between physical transport modes will become increasingly important and our capacity to improve them will grow.

Amongst the patterns of change several simple themes emerge from the scenarios and requirements: governments will continue to seek ways of getting the most out of the existing network; the amount of information available on all aspects of the road network will increase dramatically; new financial models offer the potential for fundamental change in the way roads are financed; and a greater willingness to encourage innovation and implement new ideas will increase the likelihood of step changes occurring.

In addition, two big themes seem in particular likely to grow in importance: the user as consumer, and the profound requirements of sustainability.

The User as Consumer

Roads are self-evidently to enable movement. They are intended for the user; as are the vehicles, the control systems, the safety devices and so on. We provide them because movement allows wealth and social good to be generated, and user needs to be satisfied.

Users exercise pressure for change through their economic and political choices. But they do not generally perceive where the greatest benefit lies for society as a whole. They will as a rule seek to maximise their own personal benefit net of cost. Aligning the options for user choice with the generation of the greatest good for society as a whole, is the ultimate task of governments and administrations.



What users perceive and the choices they make are therefore very important. We expect user perceptions to gain increasing weight over coming years. This leads to an important principle: that users' perceptions of transport (in all respects) 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.

Sustainability Arguments

Governments and voters are increasingly concerned about the sustainability of policy and investment choices. Whilst the full sustainability scenario is unlikely to sweep everything before it, none the less some of the sustainability arguments themselves are increasingly likely to influence decision making. At the least this will lead governments to avoid too much short-termism in investment and to pay some homage to ecological concerns. In any event, people in general are more likely to be aware of sustainability arguments, and that in itself will influence government thinking to 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. In assembling the Vision we have been mindful of the likely effects of the EU Directive on environmental assessment.

As more has become known about the whole-life costs of roads, so it will become more important to make proper assessments and to build, monitor and maintain roads with considerably greater regard for the lifetime cost of provision. We believe that the analytic apparatus for such appraisal and decision-making should become a key ingredient in developing the future. This can go together with the greater use of recycled and local materials. The exposure of potential waste - unnecessary future expense in maintenance and rebuilding, and ecological neglect - depends on having quantitative knowledge for both the initial construction and for assessing the present and likely future condition.

Themes:

- Growing pressure to get the most out of existing networks, particularly in Western Europe
- Greater attention to the user as consumer
- The case for sustainability will grow
- Information will increase dramatically
- New financial models will enable change
- Innovation will increase the likelihood of step change



2025: What will it be like?

We have generally become accustomed to thinking of the road infrastructure as comprising roads, interchanges and the structures that support them. But it is already clear that by 2025 there are likely to be three pillars of the road-based infrastructure, rather than one:

- the physical roads themselves
- the communications and control systems that link roads, vehicles and drivers
- the financial systems that pay both for the physical and communications, infrastructure and the services that they support.

To discuss the physical road infrastructure in isolation would thus beg too many questions about how it will interact both with vehicles and drivers and with the underlying funding mechanisms. By 2025 all three pillars will be required for the effective operation of the network. The way in which this develops will be strongly influenced at least by the common themes in the scenarios.

Bearing these in mind, and working to the common themes of the scenarios, we expect the main features of the roads infrastructure in 2025 - the three pillars - to be along the following lines.

Roads

Physical Networks in Europe

We expect some physical infrastructure to be developed 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. These will link with the EU Trans European Network (TENs). The corridors, whilst road based, will increasingly become integrated multi-modally for passenger transport, and provide logistic connections for freight, including routine scheduling and enabling real-time decisions in both freight and passenger movement. These corridors would form the basis of multi-modal linkages with heavy road traffic movement and some cross-scheduling. They would connect to the hubs described below under changes in land-use and development. In both cases, 2025 would be a relatively early stage in this development rather than an endpoint.

We expect road building in Central and Eastern Europe to continue along currently planned lines, and thereafter at a rate determined by economic demand. Motorisation in eastern and central Europe is likely by 2025 to approach similar levels to those in Western Europe.

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 (a) getting the most out of the existing infrastructure i.e. ensuring that it is available for use when required and that its use is managed to maximum effect, and (b) measures to limit demand or shift it in time within the day in selected areas of high demand in relation to capacity. We take this up later.

The limited construction in Western Europe is likely to concentrate on areas where it can make a major impact in terms of relieving congestion. It is likely also to be associated with more novel design, including limited facility bridges or tunnels to provide local improvements in capacity, extended also to the provision of separate lanes for cars and trucks. The smaller and lighter cars will have the use of car-only lanes on double decks either above the road surface or in tunnels. This will be made possible by advances in tunnel technology and by the inclusion of all costs in scheme appraisal which will make tunnels relatively more attractive. Where new roads are required or existing roads replaced, novel methods of road construction such as those currently being investigated in the Netherlands are likely to be developed and used in some applications. 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. The units may contain preformed voids for utilities which are accessible without disrupting traffic and built in drainage systems. They will also be designed to absorb noise thus reducing the impact of vehicles on the surrounding community. A further potential capability is to incorporate a facility for collecting and storing energy from solar radiation.

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 minimised.

Thus, to summarise, we anticipate significant physical construction in central and Eastern Europe, and rather more limited supplementing of networks in western Europe by targeted and sometimes novel additions to physical capacity. 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 travelling 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, as previously derelict or low-quality inner areas are refurbished and gentrified, but overall there will be a relative shift in the location of activities (housing, industries, retail and other services) towards the peripheries of cities, exacerbating urban sprawl.





Land-use distributions in member states in Western Europe have generally been built up on the basis of a heavy and growing car dependency, and trends in eastern Europe are developing similarly. In principle, if land-use could be significantly reconfigured and controlled, it would be possible to reduce the growth in some kinds of journeys: the 'need' for (or more strictly, the value of) 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 placing constraints or incentives on future development, rather than attempting to undo past developments on any great scale. For the more eastern countries in Europe, there is in principle more scope for creative land-use development because car dependency is at an earlier stage although it may already be too late in some countries. 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 20 year 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 towards 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 to add a new set of means for access, operating in parallel and in conjunction with physical travel.

Roads:

- Significant road construction in Eastern/Central Europe
- Development of East-West corridors, road-based with multi modal connections
- Public transport services and freight logistics will be highly optimised and real time responsive
- Urban/Suburban hubs beginning to develop, connected to corridors
- Intelligent deployment of road space in relation to demand (tidal systems, lane allocation, and light weight temporary structures in areas of dense development)
- Fast, off-site construction methods developing
- Long-life roads and more durable structures
- Investment for construction/maintenance on basis of whole-life costs and low maintenance disruption
- Intelligent monitoring of roads and structures
- Electronic means of access (tele-working etc) to grow and to complement travel, but to provide only partial substitution
- Minimised "down time" for maintenance and accident clearance

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 optimise 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 minimised. It will also enable engineers to prolong the life of the network where this can be justified both economically and sustainably.



Long life roads and more durable structures will both reduce the costs of road works and reduce the traffic disruption they cause. Incident clearance will be much quicker, aided by high speed data gathering equipment to record the scene and to provide legal evidence where it is needed.

Monitoring of road condition will be achieved by the use of condition monitoring vehicles travelling 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 intervals 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-time" of roads will be minimised. Road capacity will be deployed more dynamically, in conjunction with traffic management (see below); roads will be operated by adopting variable configurations of lanes in relation to traffic demand volumes as these vary within the day. Variable road markings 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 optimise user capacity (taxi-or truck-only lanes, high occupancy vehicle lanes, etc).



Road-Vehicle-Driver Linkages: the IT and Communications Infrastructure

The second pillar of the infrastructure will be the communications and IT systems linking the driver, vehicle and road. These will develop rapidly in relation to intelligent communications and "ambient" computing: the use of ether-interconnected small local computer systems. The costs of these are expected to fall rapidly and could be recovered from drivers through payment for new or improved services. They will enable a range of facilities to enhance information transfer and efficiency and safety of movement.

Information

There will be continued growth in the collection, manipulation and dissemination of information on the performance and operation of the network. Advances in sensor technology, the use of wireless sensors and reductions in their cost will have made it possible to install sensors into the infrastructure during construction and into the vehicles that use the infrastructure.

The road operator will be better informed on the condition of the network which will assist in predicting and planning maintenance needs and will enable maintenance to be scheduled such that it minimises both disruption to users and damage to the environment. The data will be provided from a variety of sources including sensors installed in vehicles using the network, specially designed survey vehicles and sensors installed in the network itself.



Vehicles will be very thoroughly linked by telematics to the infrastructure. The exchange of information between "intelligent roads" and vehicles will correspondingly influence driving patterns, and offer a degree of control over them.

Managing road capacity

To squeeze the most out of the existing network a variety of traffic management techniques will be in place to increase capacity. In principle, significant benefit may be achieved through the use of measures such as automated highways. What is uncertain is the degree of automation that will be in use in 2025. Full automation would require a number of barriers to be overcome. A more likely outcome is partial application, where sensors and control devices provide an aid to drivers and enhance the performances of the car-driver system. The system would exploit a network of sensors that monitor the state of the road surface, detect the presence of unexpected obstacles on the road, and recognise traffic breakdown and the occurrence of congestion. The on-board system will benefit from detailed digital road maps containing data on road geometry such as

curve radii and road geometry. Such systems will also be integrated with traffic signal management systems to coordinate traffic signals and drivers' route choices dynamically and to exploit the overall network capacity better. There will be a good deal of real-time management of vehicles including lane control, ramp metering at interchanges, and controls over the close following of vehicles. The balance of benefit from these systems will be between increased safety and increased capacity. It is a matter of debate how big the effects will be by 2025. Capacity increases are unlikely to be radical: large increases will be difficult to achieve, and smaller increases are likely to stave off the worst effects of overload rather than providing extra capacity equal to a new road or the widening of an existing one.

There is also likely to be a degree of in-vehicle control, derived from infrastructure-based information (such as selective speed control), but this will probably be subject to voluntary interruption from the driver to cope with driver liability requirements.

The Vehicle

Vehicles are likely to change substantially during the period; and although in our present way of thinking they are not part of the physical infrastructure, they will in effect become part of it by 2025.



Operating conditions will be different. At the most basic, it seems extremely likely that the certainty of oil supply will be substantially lower than at present. This will have a strong effect on vehicle design. Coupled with a need for environmental cleanliness, it will drive up the fuel efficiency of vehicles substantially, provided that suitable further technological development is possible, which we believe is the case. There is a fundamental question of whether, and at what stage, a hydrogen based fuel system might substantially be in place, but we believe that it will not be before the 2020s. Whilst hydrogen fuel-cell technology is likely to have developed significantly, we believe that most vehicles will still be using hydro-carbon fuels; but there will be much more by way of hybrid operation, for example diesel/electric. Biofuels will have been developed significantly and, from an environmental viewpoint, zero-carbon balance operation will reduce global carbon dioxide impact (i.e. that part of hydrocarbon fuel use is balanced exactly by the production of fuel from purely biological sources, and thus ensures as much carbon dioxide is consumed from the atmosphere as is generated into it).

The extensive telematic linking of vehicles with the infrastructure will give some influence and control over driving patterns. Sensors within the vehicle will be able to record and communicate vehicle position and condition and some aspects of the environment around the vehicle (for example whether it is stuck in a



traffic jam, whether it is experiencing particular weather conditions such as rain and so on). They will also be able to communicate their speed and direction to the infrastructure and to other vehicles in the vicinity, and this will have direct consequences for vehicle safety (see Controls and Restraints below).

Information transmitted to the vehicle about the circumstances pertaining on other parts of the network, particularly including the route which the vehicle is travelling, will enable the driver to assess options whilst driving: for example, to choose the best route according to the state of congestion on the alternative routes ahead. Similarly, systems are likely to be in place that would enable various forms of charging (for road use, or for on-line services) or for applying constraints to vehicle movement (for example, to prevent or warn of accessing one-way streets the wrong way, or of an accident or incident on the road ahead). Traffic may also be controlled to achieve acceptable environmental conditions.

It is possible also that some vehicle sensor systems might be used to assess some of the simpler aspects of the road condition itself. Moreover, systems of this kind would enable a range of user-specific services to be implemented - including for example mileage-based insurance where the user would be charged a premium in relation to their mileage driven according to type of road (each carrying a different risk), the time of day, and the conditions (for example the risk in bad weather may well be different from that in good) (See Insuring Against Accident Risk).

Lorry cabs will be designed so that drivers have greater vision; sensors will prevent drivers from colliding with vehicles travelling along-side them. Companies will be able to track and monitor their fleet using satellite navigation systems.

As for safety, active intelligent occupant restraint will reduce injury and death to vehicle occupants, as will collision avoidance systems from telecommunications links between vehicles. Vehicles will be subject to speed control (see Controls and Restraints).

The 'Plugged-in' User

Journey management will be, we believe, commonplace. Drivers will get much more information on conditions on the network both before and during their journey, and will be very thoroughly plugged in to communications networks. They may even come close to being personally wired in via headphone/hearing aid type connections. We expect by 2025 that good standards of information filtration and presentation will be achieved, so as to avoid driver overload.

Data on traffic flows will enable operators to respond to changes in demand and users to be advised of the optimum route to their destination using software that takes account of existing and predicted conditions on the network. This could be the quickest or the most fuel efficient depending on the users preference and will be updated as the journey progresses. There will be improved sharing of information between modes allowing better planning of intermodal travel and making modal shift from the road more attractive. This will enable the

user to make informed decisions or at least understand the cause of any delays.

It will be feasible for drivers and freight operators to book journey 'slots' as part of a multi-modally coordinated total journey. This might include walking, car, bus, train.

Data

Taken as a whole, the data capture capability of the systems providing road-vehicle-driver linkages will be extensive. This will range from data on the physical state of the roads themselves, through to the movements of individual drivers, their trajectories, and their environment. Such data, taken together, will provide an enormous step forward in our capability of managing traffic movement and the externalities that it generates.

Data on traffic flows will enable journey times to be predicted with much greater accuracy. The availability of such data will enable operators to manage traffic flows and users to be advised of the optimum route to their destination. There should be improved sharing of information between modes allowing better planning of intermodal travel and making modal shift from the road more attractive. The ability to plan journeys in advance and to obtain through-ticketing between different modes will be particularly beneficial to the increasing number of elderly travellers.

Controls and Restraints

Most of the foregoing is about enablement: enabling free movement by providing road capacity or enhancing existing capacity, managing it better, and providing better information and options for users. But the new systems will also allow more sophisticated restraint of individual actions contrary to the common good. These fall into three broad categories: demand restraint, risk restraint, and environmental restraint.

The first, demand restraint, sets out to limit the number of low value trips so as to reduce demand to match available capacity. This is most commonly conceived in financial terms - as road pricing or congestion pricing or via deliberate capacity limitations, e.g. parking restrictions. The new IT and communication systems linked to the roads infrastructure will in principle provide all the apparatus for charging users for their use of the road, if necessary as a function of the operating conditions at the time (for example if the road is heavily loaded or not) and a number of other factors. There are already a number of charging systems world-wide, although they are at present still very uncommon. Governments generally believe that if traffic growth continues as expected some form of restraint by charging is highly likely to be needed. By 2025 we expect charging within cities to be well established in Western Europe and probably more widely across Europe as a whole. The possible conditions and rules applied to such charging could vary widely. Inter-urban charging may also be in place, and this would help to balance transport costs between modes in the Government-Led scenario or to set the conditions of operation in the Market-Led scenario. Charges could be supplementary to existing fuel tax and vehicle charges through general taxation, or they could in some circumstances replace them. By 2025 we expect vehicle recognition systems and financial collection systems to be well established. How the revenues are used is considered later.



By risk restraint we mean limiting the risk of collisions between vehicles and other vehicles, other road users and the road side infrastructure.

The fact that vehicles will be very thoroughly linked by telematics to the infrastructure will have safety benefits, for example providing the user with information on road geometry and conditions, and warning the user when the vehicle is being driven outside safe limits or when there is a danger from adjacent vehicles on the network. Active intelligent occupant restraint will reduce injury and death to vehicle occupants, as will collision avoidance systems from telecommunications links between vehicles. By 2025 speed control of vehicles according to road and traffic conditions will be in place. Vehicle interlocks will limit or prevent vehicle movement if the driver is impaired, by alcohol or fatigue, or if seat belts are not properly in use. Insurance interlocks will prevent vehicles from being driven by anyone except those properly insured to drive.

Sensors in vehicles will support crash avoidance systems which will prevent accidents when possible. The impact on road users will be minimised when accidents are unavoidable. Pedestrians and cycles, in particular, will be protected. Such automatic systems will aid the driver in avoiding collisions or mitigate the effects. The driver will retain full responsibility, however, for any collision or other act resulting in damage to persons or property. In the event of a collision, sensors within the vehicle will determine the severity and the likely injury to the occupants and will automatically call the emergency services, giving details of the types of injuries to be expected and the degree of urgency.

Vehicle-road-driver infrastructure: IT and communications:

- Information on structural condition of network will grow greatly; maintenance programmes will be optimised.
- Network access and management and maintenance operations will be optimised so as to maximise network availability
- Intelligent vehicle-road communications will increase traffic management capability, including inter and intra urban operation
- Vehicle-vehicle communication will enable the development of collision avoidance systems, and of the mitigation of effects on occupants when collisions do happen
- Vehicle speeds will be constrained by telematic links to the infrastructure, according to road and traffic conditions
- Driver-impairment interlocks (for alcohol, fatigue etc) will limit or prevent vehicle movement when risk is too high
- Users will draw on multi-modal journey management systems
- Time-variable demand restraint will be in place by controls and, in key areas, by pricing
- Environmental impacts will be minimised by increased fuel efficiency, engine management and traffic management

The third area is environmental: the data available on the impact of the network on its surroundings will enable traffic flows to be controlled so as to limit air pollution and noise levels to acceptable levels in sensitive areas and allow a balance to be achieved between those needing to travel and those living adjacent to the road network.

Sensors across the road network, and in sensitive areas in particular, will monitor environmental conditions. These fall into two categories: real-time monitoring of variations in pollution levels according to the type and intensity of use, and assisting traffic control systems in limiting solutions and the monitoring of long term secular trends where the accumulation of pollutants over a period is determined as an input to wider environmental policies.

The overriding policy will be to maximise the efficiency of resource use whilst minimising any adverse effect. All works undertaken will be assessed in terms of their impact on the environment ie energy use, water consumption, emissions, noise etc. Recycling of materials will be the norm with emphasis being on level recycling (for example, by recycling the old base-course into the new sub-base).

Security

Plans to manage the consequences of hijackings and terrorism will be further developed, including the increased use of technology for protection purposes, for example, improved load tracking, and cross-border sharing of intelligence.

As well as increased use of theft deterrent systems, trackers will be found in all vehicles. Black box technology will enable police investigations to be more detailed. Video-based surveillance and image-recognition systems will guard major junction crossings and transport links against uninsured or threatening circumstances.

Finance

Finally, we feel it is important to talk about finance because in 20 years the patterns may change substantially.

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.

Financial Infrastructure:

- Growth of public/private hybrid funding, including shadow tolling and 'pay-at-the-point-of-use'
- Electronic cash flow principles will become well established in transport, both for priced road use and multi modal transactions with through-ticketing
- Pricing for road use will become established in areas of Western Europe and be beginning in Eastern/Central Europe; most cities will employ pricing in key areas
- Usage-based insurance against accident risk will become the majority operation
- Services in tandem with the pricing/insurance ether infrastructure will develop; there will be a high degree of cross-coupling with mobile phone, internet infrastructures and operations

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).

The key question is when all of this will happen. We believe the answer is before 2025 for areas of much of Europe, particularly Western Europe. There is no certainty, but it seems highly likely.

Other changes are less difficult to predict. Whilst all have uncertainty associated with them, we believe that, taken as a whole, our Vision captures 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.



6 GETTING THERE: WHAT DO WE NEED TO KNOW?

The Vision for 2025 developed in Chapter 5 is not a recipe. It does not set out machinery which if operated would cause a particular future to come about. Neither is it a political manifesto of things we want to happen and are laying out in order to persuade constituencies to adopt and own them. Neither is it solely a matter of prediction, although it does have a strong element of prediction in it.

Rather, it is a statement of what we believe is broadly likely to happen, given what we know of advancing trends, requirements and opportunities. Its main function is to point out these opportunities and where they could lead. In most cases it is clear that to realise them we need to know things that we do not currently know. The key to moving forward strongly is first to gain the necessary knowledge.

Therefore we feel the most pressing need is to identify the areas of enquiry that are crucial to achieving the Vision. The following sections do that. In drawing them up, we have adopted a simple classification deliberately aligned with those that FEHRL developed in parallel with its partners for the ERTRAC VISION and consisting of four themes: Design and Production Systems; Environment, Energy and Resources; Safety and Security and Mobility, Transport and Infrastructure. This enables cross reference.

Here, we are concerned with road transport, and in particular with the implications of the 2025 Vision for the roads infrastructure. A major theme for the future is asset management - how to assess needs and benefits and how to ensure proper, sustainable management of the infrastructure. This theme runs through many of the subject areas which follow. As we have argued, in 2025 we believe the roads infrastructure will go much wider than the physical roads themselves and will include the road-vehicle ether infrastructure and financial infrastructure as well. Therefore in the following we have set out all of these parts. But to help relate the areas of enquiry to the present (2004) conception of the roads infrastructure we have identified three themes with specific relevance to FEHRL's activities and interests. From this, we have:

- those that have direct relevance to road infrastructure (for example, understanding the physical processes that cause road deterioration);
- those that have indirect relevance to road infrastructure (for example, development of data management systems for road condition monitoring); and
- hybrid themes that for implementation require complementary development in road and in other transport fields (for example, cooperative vehicle-highway systems).

Directly relevant themes are indicated with ■, indirect themes with ►, and hybrid themes with ●. Other themes are complementary - they set the context for road transport - these are highlighted with ◆.



Design and Production Systems



Developments in Infrastructure 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 structures 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 scanning) 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 conditions 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 (ie collision avoidance systems, hazard warning systems).
- Determine the type of information that is required by the driver to optimise safety, minimise 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.

This then is our view of which areas need to be investigated if the knowledge gaps are to be closed sufficiently to allow the Vision to come about. Knowledge should precede action. The agenda is pressing.

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 enable 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 accident spillages.
- Develop concepts for roads that reduce the creation of particulate and other pollutants through, for example, tyre wear, and in situ cleansing methods.
- ▶ Understand 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 concepts 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, vehicle 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.



- Investigate the cost and environmental balance between using local resources and materials from possibly more distant but more sustainable sources in road construction and maintenance

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 (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 systems 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 Infrastructure



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 'transshipment' 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

- ▶ Develop traffic management and capacity models in relation to real time demand profiles 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

- Design the connections between physical transport modes 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 options 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.

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APPENDIX B: USERS' AND STAKEHOLDERS' REQUIREMENTS

This Appendix discusses requirements in relation to developments as they are foreseen and sets out preconditions and conceptual features of the path to implementation by scenario.

SMART Travel

Requirement

The transport system should provide good information about what is going on; it should be managed responsively and efficiently, making full use of available technology.

Developments

Over the next twenty years there will be developments in collecting, interpreting and presenting information on the condition and use of the network and its impact on the surroundings. The huge increases in computing power and the capacity for storing large amounts of data coupled with advances in the different forms of communication will make it possible to provide all stakeholders with the information they need to get maximum benefit from the road network. Thus the users, operators and owners of the road network in 2025 could have much more information at their disposal than they do today.

Preconditions

Much of the technology required for the developments is in principle already available in limited form. The transition to full application will require the development of a range of technological systems for IT and communications for mass-production and application, so depressing the unit prices to economic levels, and the implementation of data gathering and processing, and institutional communication and data-transfer. Connecting together information from multiple sources will be important, as will the development of financial and institutional linkages to incentivise and enable delivery.

An area where further advances are required is in the development of improved deterioration models for the road infrastructure and the development of sensors for recording the performance data required as inputs to the models. Data on the condition of the infrastructure could come either from sensors installed in the infrastructure itself or from survey vehicles driving on the network. The latter have the advantage that they do not require sensors to be installed in the road infrastructure along with their supporting power supplies and transmissions systems etc, but also that they can be easily updated to take advantage of the latest advances in technology.

System architecture, technical specifications and common standards are necessary to ensure the system's efficiency. Users' reactions have to be well understood, modelled and predicted to avoid the over-reaction of the system.

Path to Implementation

The Do-Nothing scenario driven by short-termism is likely to produce the least progress. Projects that require longer-term investment and which do not produce immediate benefits are unlikely to be funded. Progress is likely to be fragmented with developments taking place on an opportunistic basis where immediate benefits can be obtained from a relatively small investment.

The Government-Led scenario would take a more holistic view of the road network and seek to take account of longer-term environmental issues as well as providing help to the road user. Whilst it might produce a more coherent approach, it would be slow to respond to changing needs, and funding would be an issue. Under such a scenario the emphasis would be on using the data collected to control or limit environmental damage and to produce generic improvements in construction, maintenance and operation. Co-ordinated information programmes would be developed; these would not necessarily produce user optima but would rather concentrate on achieving the optimal condition of the overall system.

The Market-Led scenario is likely to lead to the greatest advances in this area. However the advances are also likely to be fragmented and will be focussed on areas where there is a willingness to pay for a particular service. This is most likely to benefit travellers who might be prepared to pay for information and advice on traffic conditions that enable them to plan their journeys and reduce their travel times. There would be no obvious drive for 'universal' information provision.

The Sustainable-World scenario would seek to use the information additionally to quantify environmental damage and structure a charging regime on the principle that the "polluter pays". This would seek to cause changes in behaviour that favoured activities that were environmentally friendly. Information would also help the image of public transport, which is inherently more sustainable.

The Ideal-World scenario would seek to use all the information available to achieve a balance between the desire to travel and the desire to live in a sustainable world. For example journeys could be planned to minimise environmental damage.



SAFE Travel

Requirement

The infrastructure and operations should be inherently safe. They should provide as much protection as possible against driver error and aberration.

Developments

Most countries, and the EU, have targets for improving safety on the road network and this is an area that could see considerable advances over the next twenty years. A range of safety measures will act on the infrastructure, the vehicle and the road user. In most European countries the accident rate per kilometre has been declining. Actual casualty levels will depend on the extent of traffic growth in conjunction with these rates per kilometre. Casualties will continue to fall in Western Europe, provided that technological and societal changes continue. In Eastern and Central Europe there is a risk that increasing motorisation will drive casualty numbers upwards.

Methodologies for collecting crash data are important. Annually within the European Union, there are over 39,000 fatalities in road accidents and well over a million other casualties. The majority of these are either to the occupants of cars or are sustained by other road users in collision with a car. Accidents cost the European community over 160 billion annually more than twice the annual budget of the commission, and they are the leading external cost of road transport. Casualty reduction strategies need to be based on a full understanding of the real-world need under European conditions and their effectiveness developed and evaluated. A co-ordinated set of targeted, in-depth accident data systems exists to support new safety actions and to provide a resource for analysis.

Intelligent monitoring of the infrastructure could provide information not only on the maintenance, use and impact of the road network but could also be used to provide data on safety.

Consumer-driven safety programmes like EuroNCAP for car secondary safety and EuroRAP for the safety of road sections are likely to contribute to greater safety. In-car systems will use data on the conditions on the road and the interaction between the vehicle and the road to advise the driver on the safe speed and safe distance from the vehicle in front. The success of the EuroNCAP car secondary safety programme in recent years has shown that there is a market for improved safety. Thus manufacturers will be encouraged to continue to improve the design of cars so as to protect the occupants when the car is involved in a collision. By 2025 it is very probable that cars will be able to communicate to avoid collisions. In-vehicle restraint systems will be developed to anticipate and respond to collisions when they do occur so as to minimise injuries to occupants.

The safety of other road users will be improved by the increased separation of motor vehicles from vulnerable road users and by the adoption of better designs for pedestrian protection in impact. The safety of maintenance workers will continue to improve through increased mechanisation and better health and safety practices.

Preconditions

Safety is a strong driver and there will be pressure to make use of whatever technology is available to make road travel safer. As with SMART roads, much of the technology to implement the ideas discussed above is either currently available or could be developed given sufficient funding. The degree of implementation will depend on the balance between cost and safety.

Much depends on national will and public attitudes. Substantial change can be made if governments are prepared to promote and incentivise safety. There are big differences between the safety of road and rail travel; progress will depend on how far society is prepared to trade-off some forms of freedom (for example, to choose vehicle speed on the road) against safety. Intelligent speed control is an example where some relinquishing of the freedom to break speed limits could reduce casualties substantially.

Path to Implementation

In the Do-Nothing scenario government would rely on a societal belief that roads are in any case getting safer. The way forward would comprise contingent short term changes to existing practices. Significant improvements over the next twenty years would be unlikely. The biggest changes are likely to be in EU countries with a poor safety record who might adopt measures used in other EU countries with a strong safety record.

The Government-Led scenario would lean towards a balanced approach depending very much on government and public attitudes to what constitutes reasonable safety levels. Most governments are likely to take a positive, targeted approach. This would guide investment in infrastructure and tend towards using advancing technology to introducing enforcement and other measures to ensure that road users complied with legislation to maximise safety.

In the case of safety it is difficult to separate policies that are primarily market-led from those that are primarily government-led, since a strong element in achieving safety is the placing of societal controls and influences on individual road users by means of government action, and the selective placement of public investment. In the Market-Led scenario progress would be driven more strongly when users were prepared to pay for safety. This would be reflected in more expensive but safer cars that allowed drivers to travel at higher speeds and be protected from the consequences. This would not necessarily provide an improvement in safety because of the increase in risk for other road users; it may result in vulnerable road users switching to other modes of transport. However other measures such as the use of "black boxes" in cars that record driver behaviour and reward safe driving through reduced insurance premiums could have a beneficial effect on safety.



Whilst safety would be of importance in the Sustainable-World scenario, the emphasis would in any case be on using alternative modes of transport such as trains, light rail systems and buses, and in protecting the occupants of these vehicles. Since these modes are safer than cars, the effect of the net transfer would be to reduce casualties. However, the greater use of cycling and walking under sustainable policies would, unless accompanied by specific safety measures, be likely to increase casualties because of the increased exposure. This would be offset by net reductions in the distance travelled for these transfers of mode.

In the Ideal-World vulnerable road users would be separated from vehicular traffic wherever possible particularly where the risk was greatest, for example at junctions. Extensive help for drivers and other road users would come from telematic equipment, including limitations on aberrant behaviours. Collision avoidance and mitigation systems would be widely used.

CLEAN Travel

Requirement

There should be no net damage to the environment; health impairing pollutants should be eliminated or minimised.

Developments

It is likely that oil-based fuels will still be the main energy source for motor vehicles in 2025. There will be continual reductions in air pollution from vehicles through the increased use of technical devices which minimise the emission of particulates and pollutant gases. There are likely to be gradual improvements in efficiency rather than radical changes. Other measures to reduce pollution from vehicles will include the use of hybrid vehicles. However it is unlikely that altogether new cleaner fuels will have made a substantial impact.

There will be more emphasis on reducing the intrusion of roads on those living close by. There will be tighter restrictions on noise levels and air pollution from traffic particularly in urban areas. Innovations such as the use of solar panels on noise barriers that are currently being trialled in the UK will become commonplace, as a means of capturing energy cleanly.

Wherever possible, existing materials will be recycled when the parts of the infrastructure reach the end of their service life. An increasing proportion will be reused for the original application rather than at a lower level in the waste hierarchy. Sustainability indicators will play a major role in the construction process, and decisions will be based on the result of life-cycle analysis.

Preconditions

Public concern over the natural resources to maintain an oil based economy and a deteriorating environment will determine developments in this area over the next twenty years. The current over-reliance on oil and the susceptibility to an interruption in oil supplies will encourage governments to invest more heavily in alternative, and preferably clean, sources of energy. However a continued supply of cheap oil is likely to maintain the status quo, with fluctuations, for some time; but a growing concern over the question of supply and the possibility of a secular downward trend in availability and security of supply in the second decade, 2015-2025, will be offset by more efficient vehicles and restrictions (by price) on travel. Concern over the environment will depend on public acceptance that climate change and pollution present a genuine threat to our way of life.

This is therefore an area where there is considerable scope for developments in technology both to improve existing practices and develop cleaner fuels. Within the timescale of the Vision, the former is likely to be more significant than the latter. The use of zero-carbon balance biofuels will, however, develop over the period.

Path to Implementation

In the Do-Nothing scenario there would be reaction to major public concerns about environmental issues on the one hand and increasing congestion on the other, but limited mainly to continued reliance on targets which aim to reduce the rate at which things get worse rather than seeking significant improvements.

In the Government-Led scenario a range of controls would be used, including those, for example, to limit vehicle emissions and to audit infrastructure specifications so as to maximise recycling and minimise ground contamination.

Market-Led developments would ride mainly on development to reduce waste, environmental and health impacts in response to consumer awareness, coupled by market-pull. As in the case of safety this is difficult to separate conceptually from government and EU controls, which would both set requirements and influence consumer attitudes. To the extent that minimally controlled market conditions would focus on point-of-sale margins, it is likely that the use of advanced SMART materials and systems would be non-optimal across the motorised population.

The Sustainable-Society scenario would see a reduction in the number of journeys leading to an increase in cleanliness as well as a reduction in the environmental impact per unit of travel.

In the Ideal-World scenario would be an extension of the Sustainable-Society scenario with improved land-use configuration a fundamental element of both.



COMFORTABLE Travel

Requirement

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.

Developments

The drive for a comfortable infrastructure will affect government policy and influence the developments that occur over the next 25 years. The need for seamless travel in multimode journeys to provide comfort and efficiency of movement for the user will drive a set of improvements towards better information and co-ordination.

Landscaping schemes should enhance the appearance of the environment adjacent to the road network and vulnerable road users would be separated from vehicles.

Preconditions

Achieving these standards of comfort would require a transport industry and institutions responsive to the needs of travellers and greater levels of integration between the different modes of transport.

Path to Implementation

Under the Do-Nothing scenario there would be little or no government role other than to set limits where individuals' health might be at risk and to protect the safety of those working on the road network.

The Government-Led scenario would seek to improve conditions on public transport and introduce further measures to protect construction and maintenance workers.

The Market-Led scenario would encourage, for example, in-car multimedia systems (e.g. entertainment for passengers and driving systems for drivers). There would also be developments in entertainment systems that could be used on other modes.

The Sustainable-Society scenario would provide integration between modes that made travel simple with good facilities at intersections between modes. Transport would be safe and comfortable; intrusion on those living adjacent to the road network would be minimised.

In the Ideal-World scenario user stress would be minimised through the provision of a well maintained comfortable transport system, offering seamless journeys by the most appropriate modes at a fair and efficient price.

RELIABLE Travel

Requirement

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.

Developments

Maintenance is likely to be planned in advance and traffic flows predicted. Maintenance works may involve the provision of temporary structures or temporary roads in heavily congested areas. Heavy traffic flows might be accommodated by reversing lane flows when the majority of the traffic is in one direction. Whilst individual accidents cannot be predicted, once an accident occurred it would be promptly detected and effective contingency measures should be put in place to minimise disruption. Prior plans on a 'what if?' basis should be developed for a wide range of possible accidents.

Preconditions

Increasing reliability can only be achieved if current models for predicting when maintenance is required to the road infrastructure can be developed further. Thus a number of conditions will need to be satisfied, as follows: the development of construction methods that enable replacement of road infrastructure at the end of its service life to be fast and effective, and of improved maintenance techniques that enable maintenance to be undertaken quickly and effectively; an understanding of user attitudes to reliability and uncertainty; and an ability to predict responses to network disruption and congestion.

Path to Implementation

Under the Do-Nothing scenario journey times would be unreliable. It would be left to individuals to avoid the worst conditions.

The Government-Led scenario would use traffic management measures to limit congestion such as advanced traffic surveillance and management systems for example lane markings to aid flow and speed management to prevent shock waves. There would also be incentives to encourage the use of public transport and the use of different modes.



Under the Market-Led scenario users would be required to pay for information on predicted journey times and for real-time information during the journey. They would also be required to pay for improved levels of service, for example more reliable routes would be available through the use of tolls. Wherever alternatives which involved payment were available, pricing would be instrumental in achieving a balance between traffic flows and reliability.

In the Sustainable-Society scenario the emphasis on durable infrastructure would reduce maintenance needs and consequent disruption. The more general move towards sustainable lifestyles - with the planned rebalancing of transport and land-use - would have the effect of limiting or reducing demand for certain journey types. As far as possible, alternative modes would be provided for those journeys that were required.

In the Ideal-World scenario fast construction and maintenance and highly desirable roads would minimise disruption. Real time information about network conditions will be available to users to enable them to plan their journeys.

Availability of ACCESS

Requirement

Travel should provide full access to destinations in relation to need and economic value; it should be socially inclusive.

Developments

The purpose of travel is to undertake activities such as work, school, shopping and leisure. These activities could be made more accessible through land-use planning that located the workplace near schools, shops and leisure activities and within easy reach of the home. Access to these should not discriminate by age, income or physical ability.

The use of IT and telecommunications to provide a growing network of connections for home working and business and workplace activities, along with retail supply-chain linkages, will constitute a profound increase in accessibility. This will complement physical travel. As we have already said earlier the evidence so far is that these activities do not automatically substitute for physical travel; rather, so far they have added to it, constituting an additional raft of activity driven by greater opportunities for accessibility.

It would, we believe, be possible to induce some substitution by selective policies aimed at some journey types, including the use of pricing mechanisms; but over the next twenty years it seems more likely that social and work patterns will absorb the new possibilities for access organically - much as they have so far for the internet and mobile phones. In other words, they will not remove a significant part of the need for the provision and management (in the broadest sense) for access by physical movement.

Preconditions

In the period to 2025, the availability of oil as a fuel will come under a number of downward pressures, including longer term secular trends in the volume of supply, and fluctuations because of world political shifts, threats of Middle East hostilities and terrorism. Together these are liable to make governments more cautious regarding consumption. Risk aversion to the likely economic effects of insecurity of world oil supply, both in the expected trends and the possibility of shocks, will be a strong incentive towards bringing in measures on manufacturers to improve vehicles' fuel efficiency. Environmental concerns will act in the same direction. Since accessibility is a function of value and cost, these same pressures will tend towards governments "tailoring" accessibility through a range of regulatory and fiscal measures. The out-turn in 2025 will be a product of all of these factors.

The technology is already in place to deliver home-working and home shopping. Up-take will be a function of customer demand and business and commercial practices, driven by perceived economic and social advantage. Changes in land-use planning and the subsequent changes in travel patterns will and are likely to take several decades to have an effect. Thus they will only begin to impact over the next 20 years. They are, however, our essential prerequisite for longer-term change.

Path to Implementation

Under the Do-Nothing scenario governments would provide and maintain the minimum level of accessibility. The lack of an overall strategy would lead to arbitrary decisions and a fragmented network.

The Government-Led scenario would encourage an integrated approach which would include subsidising routes where demand did not justify the commercial cost and provision of non-profitable public transport. This would produce a socially inclusive network at a cost borne by general taxation.

The Market-Led scenario would respond to rather than be led by demand. It would provide accessibility to those prepared to pay and exclude those who were not.

The Sustainable-Society scenario would use IT to reduce transport demand and encourage inter-modal travel, particularly using environmentally friendly modes, car share lanes and other incentives to encourage sustainable behaviour.

In the Ideal-World scenario there would be integrated transport networks; inter-modality; intelligent route diversion and other traffic management. There would also be inter-regional routes e.g. east-west across Europe.



Suitability of road *FUNCTION*

Requirement

The parts of the road infrastructure should be suitable for their functions. The capacity, safety and level of service should be proportional to need and function. The form and appearance of roads should complement their respective functions, and should be environmentally empathetic.

Developments

Most road networks have grown up to a large degree by evolution as, over long periods, land use and transport patterns have changed. Specific new construction progressively complements the existing networks.

The functions of roads range from , for example, the longer distance, high speed, high capacity motorways to urban streets providing low speed access for residential and business purposes with mixtures of motorised traffic, cycles and pedestrians on sidewalks. The provision of particular types of roads needs to be appropriate to the purpose, and the differentiation between them clear to the user. The condition needs to be maintained to a standard fully commensurate with function.

Developments in the practical definition of function in recent years have been clearest in the provision of motorways. For other roads in most of Europe there are specific hierarchies of type. However, the function of many roads is mixed and changes over time.

In moving towards more clearly defined functional hierarchies, there is scope for fast construction and maintenance. Prefabricated construction opens up the possibility of introducing the mass production of high quality units produced to high specification under factory controlled conditions. Deteriorated units could be easily replaced and then recycled and re-used elsewhere. To minimise journeys transporting the units it may be possible to set up temporary factories adjacent to the construction sites as currently done for larger segmental bridge structures.

The advantages of prefabrication are high quality, long-life and adaptability that would enable change of use if required during the life of the structure.

Preconditions

Aptness of provision is determined by many specific decisions. A clear communication of function - such that motorists can always recognise the type and level of provision and what to expect (pedestrian and cycle activity on urban streets for example, but not on motorways) is important. There should be no surprises. The main barrier is cost. For this to be overcome, the benefits of a clear overall approach need to be recognised.

Path to implementation

Whilst a functionally suitable network is a pre-requisite under all five scenarios, the degree of functionality would vary considerably. There would be little improvement under the Do-Nothing scenario and current practice would continue with any changes being introduced slowly.

In the Government-Led scenario road function would be differentiated by the traffic management and restraint. Fast construction techniques might be introduced through incentives if it could be demonstrated that there were wider benefits.

By contrast the Market-Led scenario would be driven by more specific (and parochial) cost benefit arguments driven by the returns on investment. Improvements in service would be provided for those who were prepared to pay. Roads that could be constructed quickly would provide quicker returns than those by more conventional methods.

The Sustainable-Society scenario would place more emphasis on the environmental issues; greater use of a holistic approach to provide a network that caused minimum damage to the environment.

In the Ideal-World scenario there would be: substantial flexibility and integration of the physical assets; integrated transport corridors; the integration between land-use and transport being well understood and planned for; and development planning.

