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New Transport Technologies to be Implemented in 10–20 Years Perspective

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EXECUTIVE SUMMARY

New technologies will have a profound effect on the operation and structure of European transport over the next 10-20 years. The aim of the HINT project is to assess the human and organisational impacts of the expected technological developments and make recommendations on the best approach for managing the changes that will occur.

The present report summarises expected applications of new technologies within the different transport modes, i.e. in road, rail air and maritime transport. National and international forecasts on new transport technology expected in a 10-20 years perspective have been used as sources of information, together with reports on European and national R&D projects. The most important area of new technology that reaches implementation is information technology in each transport area. There is an other important area of new technological development, the need to decrease negative environmental impacts caused by transport. It seems to be specifically strong in road and rail transport.

The often stated aim of implementing new technology in road transport is to improve efficiency, safety and the environmental quality of road transport. Road transport is, however, the transport mode in which the most independent actors function and in which interests are the most divergent. It means that development and implementation of new technology is less coherent in this area than in other transport areas. New technology in road transport can be applied in the traffic infrastructure, such as the different urban and inter-urban traffic management and control, demand management and traffic and travel information systems; or in vehicles, such as the different driver assistance systems (or both). Public transport applications and new technology as a means of monitoring and enforcement is also covered by the report.

Aircraft manufacturers, airlines, air traffic control and airports are driven by different interests to implement available new technology in air transport. The main areas where new technology is implemented in air transport are aircraft manufacturing, new flight decks i.e. new means of communication, navigation, displays, cognitive aids, etc. and air traffic control. Most of the technologies that are expected for implementation in air transport are information and communication technologies.

Rail transport is a specific area with many characteristics different from other transport modes. Current research efforts for railways are concentrated on high speed lines, combined transportation issues, environmental and sustainable growth issues and the separation of infrastructure management and operation. From the point of view of the HINT project intermodality, pricing and ticketing, passenger information, automation, train safety and control systems and security issues are the most important areas of new technology implementation in train transport.

In maritime transport the main areas of new development are navigation, manoeuvring and collision avoidance, new bridge systems and new maritime transport management systems. Global Positioning Systems, electronic chart and intelligent autopilot are the main technological developments in the navigation support area. Manoeuvring and collision avoidance support is based on Advanced Radar Plotting Aid technologies and these can also provide integrated bridge systems. New traffic management systems in maritime transport attempt to exert some external influence on route choice and timing of vessels.

A separate chapter describes new transport technology applications and forecasts for new technology implementation in some Central and Eastern European countries. A detailed list of information sources (relevant projects and references) in each transport area give help to the reader to go deeper in topics selected.

1. INTRODUCTION

New technologies will have a profound effect on the operation and structure of European transport over the next 10-20 years. The aim of the HINT project is to assess the human and organisational impacts of the expected technological developments and make recommendations on the best approach for managing the changes that will occur.

One of the first tasks within the project was to identify expected new technologies, covering all areas of transport, i.e. road, rail air and maritime. The present report gives a summary of expected applications of new technologies within the different transport modes. Intermodal transport both of passengers and goods is one of the important areas of the application of new technology which is not covered in this report as a separate part, but is treated in chapters of the separate transport modes.

The present report stresses application areas of new transport technology rather than technology itself, as applications will have human and organisational impacts, not mere technology. The same technology, as we have seen when collecting information for the report, can be applied in very different areas of transport, with different impacts. As this report will be the base for the broad review of human and organisational impacts of new transport technology (WP7), large groups of applications have been selected, so that the number of applications to be assessed will be manageable, and the assessment be not bound so much to details of present technology

The structure of the report follows the different transport areas, i.e. road air rail and maritime transport. The team that has worked in this work package consisted of experts from each transport mode and they prepared the specific chapters of the report. Road transport, as the most diverse transport mode has been covered by more than one partner so that different geographical areas of Europe can also be surveyed.

The team consisted of

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2. APPLICATION OF NEW TECHNOLOGY IN ROAD TRANSPORT

2.1 INTRODUCTION

The often stated aim of implementing new technology in road transport is to improve efficiency, safety and environmental quality. Road transport is, however, the transport mode in which the most independent actors function and in which interests are the most divergent. It means that development and implementation of new technology is less coherent in this area than in rail, air or maritime transport. Two European R&D programmes, DRIVE and PROMETHEUS have provided, however, a framework for co-ordinated and co-operative action within Europe in this area. Although both programmes covered many areas of road transport, PROMETHEUS was stronger in applications based on vehicle technology and information technology within the vehicle, and DRIVE has put more emphasis on application of information technology in the infrastructure. Most of the information presented in the subsequent chapter comes from those programmes.

When work has been started in this work package we had an expectation that different new technology applications can be foreseen in different areas of Europe, according to specific needs of the area and the level of its economic development. We have found, however, that most of the work within the EU has been carried out as a co-ordinated activity within either DRIVE or PROMETHEUS, and there have been very few independent national initiatives. We could not, therefore, indicate how new transport technology implementation can be foreseen in different geographical areas of Europe, especially because national forecasts have been missing in this area in most of the EU countries.

The structure of the road transport chapter follows the main application areas of new road transport technology i.e. infrastructure-based and vehicle-based applications, applications in public transport and monitoring and enforcement as a separate area. There is another area of possible application of new technology in road transport i.e. information and communication technology that has not been developed for in-car use, but is brought into the car and is used by the driver during driving. The use of that kind of office technology (phone, computer, fax, etc.) may disturb the driving task and increase the risk of an accident. Regulation regarding the use of that kind of equipment will be needed in the near future.

2.2 INFRASTRUCTURE-BASED APPLICATIONS

2.2.1 Urban and inter-urban traffic management and control

Traffic management and control both in urban and inter-urban areas is one of the most complex fields of new technology application in road transport. Its main aim is to improve efficiency, safety and environmental quality of traffic, where the main emphasis is usually put on improving efficiency by on-line monitoring and forecasting of state and use of infrastructure, and provision of services to users.

The main areas of Urban Traffic Management and Control are road section control, intersection control, and parking control. Urban traffic management and control is not a new function, but it is continuously improved and made more flexible by introducing new technologies. It includes all measures designed to control the flow within urban areas i.e. network state monitoring, demand prediction, incident/accident detection, control computation and actuating, etc. Parking control deals with the management of parking facilities and the provision of information to drivers about the availability and location of parking space.

The monitoring of inter-urban road network from regional traffic control centres includes road status (friction, infrastructure, etc.) and weather (visibility, wind, etc.) conditions monitoring and forecasting. Provision of services consists of emergency and rescue service, information on weather, road conditions, etc. and road maintenance. Fee collection and payment management is also part of inter-urban road management.

New technology applied in traffic management and control includes:

- real-time traffic monitoring by different traffic sensors
- road surface, temperature, wind, etc. sensors
- automatic incident detection by
    - video image processing or
    - radar and microwave sensors
- ramp metering
- electronic tolling systems, etc.
- different data collection, processing and exchange technologies
- means of message dissemination, such as:
    - Variable Message Signs
    - RDS/TMC
    - Dedicated Short Range Communication System

Urban and inter-urban traffic management and control systems are already in use in many parts of Europe. The main direction of future development is that while today vehicles are mainly passive receivers of messages from management centres, two-way communication between roadside and vehicles can be expected in the medium term (10 years), and vehicle-to vehicle communication in the longer term. On the inter-urban road network systems that function first on the trunk roads will spread out to the whole road network. Two-way communication between roadside and vehicles can be expected in the medium term (10 years), and there is a vision of fully automated vehicle-highway system in the longer term.

2.2.2 Traffic and Travel Information

The objective of traffic and travel information is to promote optimal route and travel mode choice and improve the quality of travel and transport by that.

Traffic information provides dynamic traffic and traffic related information to drivers in the course of a trip via either collective means or individual in-vehicle terminals. Traffic information is usually specific and relevant to the actual driving task and the location of the vehicle in the network. Its aim is to influence on-trip route choice. Travel information provides information to travellers before the trip in order to facilitate travel planning, via private or public terminals.

New technology applied in urban traffic and travel information includes:

- different traffic sensors
- different data collection, processing and exchange technologies
- means of message dissemination, such as:
    - Variable Message Signs

- RDS/TMC
- Dedicated Short Range Communication System
- road-side beacons
- GSM
- Internet
- urban travel information centres, etc.

Traffic and travel information already exists in different forms and level of sophistication in several urban areas. Future development can be expected towards providing more specific information, more in an interactive way and real time. Inter-urban travel and traffic information via VMS and different radio messages is already functioning on smaller networks. One of the major problems to be solved in the near future is international data exchange and the language of information presentation for users of different languages. Wide use of in-car systems to convey information to users has a longer perspective and may solve the problem of information presentation, too.

2.2.3 Urban Demand Management

The aim of application of new technology in demand management is to improve the efficiency of spatial and temporal traffic redistribution in urban areas.

Spatial traffic redistribution focuses on the geographic diversification of activities to even out or reduce mobility demand. Temporal redistribution aims at redistributing traffic demand to avoid overloading the road network at peak hours. New information technology provides means to make demand management more flexible, adjusted to actual situation. Demand restraints include measures like area access restriction, route diversions, road pricing, parking strategies, priority for public transport, high occupancy lanes, etc.

New technology applied in urban demand management includes:

- Variable Message Sign,
- RDS/TMC,
- smart cards,
- sensors for special vehicles, etc.

The first applications of urban demand management on smaller areas are already functioning in several countries in Europe, e.g. in the Netherlands and in Norway, and experiments are planned in the UK. Remote sensing of occupancy and vehicle type will allow variable road charging and controlled access within the next 15 years. The development of smart, contactless card technology will allow a wide and flexible use of urban traffic management in a longer perspective.

2.3 VEHICLE-BASED APPLICATIONS

2.3.1 Driver Assistance

Several driver assistance functions are under development or in an experimental phase all over Europe. Their aim is to give help to drivers in some aspect of the driving task, and increase driver comfort, reduce driver workload and improve traffic safety.

Navigation and route guidance

The objective of navigation and route guidance systems is to help drivers in the navigation task and provide them with the necessary information so that they can arrive at their destination in an efficient and safe way.

Navigation systems provide drivers with information so that they can locate their vehicle in the network and find the optimal route to their destination. Navigation can be either static or dynamic, using either autonomous on-board equipment or external infrastructure. Optimal route can be computed by autonomous or infrastructure-based systems which may use either static or dynamic information.

New technology applied in navigation and route guidance includes:

- different in-car navigation systems working in
  - autonomous, or
  - an interactive way
- Global Positioning System for autonomous systems
- digital road network data base in car computers
- traffic control centres for real time, dynamic information
- road-side transponders, etc.

Several autonomous route guidance systems are already commercially available which are linked to GPS via satellites. Small-scale experimental application of infrastructure based dynamic systems has also been carried out within the DRIVE programme. Wide application of autonomous systems in new cars can be expected in the near future. Dynamic navigation systems, that need interaction between vehicles and infrastructure are of somewhat longer perspective.

Collision warning/avoidance

The objective of collision warning and avoidance systems is to help drivers by warning or intervening when the car is on a collision course with another vehicle. The main aim of these systems is improving traffic safety by preventing mainly rear-end collisions on motorways, but a secondary effect may be also improving efficiency by allowing higher density and increasing road capacity by that.

Collision warning/avoidance systems detect potential obstacles in relation to the dynamics and predicted trajectory of a moving vehicle by measuring the relative positions and dynamic status of neighbouring vehicles within the manoeuvring zone of the vehicle. An important part of collision avoidance systems is the determination of safety margin, and the timing and way of warning or intervention in case of danger of a collision.

The following basic types can be identified:

- Collision warning systems where the driver gets a warning but stays fully within the control loop.
- Assisting systems where haptic feedback is given when the headway becomes too short, e.g. by an increased accelerator pedal resistance.
- Semi-automatic driving, where control is exerted on the throttle and brakes in order to keep a set headway. The following distance may be pre-set by the manufacturer or by the user according to driving style.
- Automatic driving, where the control is exerted on both the throttle and the brakes in order to attain the set headway.

New technology applied in collision warning or avoidance systems includes:

- inter-vehicle distance measuring by
    - radar
    - infra-red beam
    - laser
- speed measuring, etc.

Experimental vehicles have been built by different car companies in Europe. Some of them were part of the PROMETHEUS and DRIVE programme. Although there are still several unresolved problems both technically and regarding the behavioural effects of the system, some car manufacturers expect the market introduction of their products within 5 years.

Dynamic vehicle control
The objective of dynamic vehicle control is to assist drivers in controlling lateral and longitudinal dynamic behaviour of the vehicle and stabilise driving in order to increase driver comfort, reduce driver workload and improve traffic safety.

Longitudinal vehicle control (adaptive cruise control) regulates speed and distance from the previous vehicle in accordance to the control strategy for the actual situation. Lateral control gives dynamic guidance of lateral movements of the vehicle with regards to lane or road side in order to maintain the appropriate trajectory. Assistance in both cases may range from warning or advice to fully automated control such as in platooning.

New technology applied in dynamic vehicle control systems includes:

- distance sensors
- video-cameras
- lateral sensors
- systems to correct vehicle dynamic, etc.

Several dynamic vehicle control systems have already been under development and in an experimental application, specifically in the frame of the PROMETHEUS programme. Vehicles equipped with dynamic vehicle control systems need, however, new type approval, and a development and testing of requirements for that may take more time. The first equipped, commercially available vehicles can be expected in 10 years perspective, but a wider market penetration needs longer time.

Vision Enhancement
The objective of vision enhancement is to assist drivers' vision in suboptimal visibility conditions and prevent accidents that would be effected by decreased visibility. A secondary effect of improved vision in those conditions may be higher driving speed which in fact can cause a deterioration of traffic safety, but improve efficiency.

Vision enhancement improves the visibility of the driving scene by autonomous means in subnormal visibility conditions by providing direct visual information to the driver.

New technology applied in vision enhancement includes:

- Near Infra-Red (NIR) headlights (operates in the infra-red region near visible light)
- Ultraviolet based headlights
- Thermal Imaging or Far Infra-Red (FIR), etc.

Volvo has investigated ultraviolet based headlights, while Jaguar and Renault have developed demonstrator vehicles with NIR systems. The behaviour modification effects of vision enhancement, i.e. increasing speed in bad visibility, need to be evaluated before wide application.

Driver and Vehicle Status Monitoring

The objective of driver and vehicle status monitoring is to detect on time any deterioration of driver or vehicle performance and prevent accidents that would be caused by this deterioration.

Driver monitoring observes the driver's control of the vehicle, the psychological condition of the driver, and evaluates a possible major deviation from normal safe behaviour. Similarly, vehicle monitoring collects and processes data on vehicle dynamics and operational status to diagnose and predict vehicle failures and improper vehicle dynamic behaviour. In case of deterioration warning or intervention may be initiated within the vehicle, or information may be sent out to relevant body outside of the vehicle.

New technology applied in driver and vehicle status monitoring includes:

- sensors of driver status of
    - physiological functions
    - vehicle control functions
- sensors of vehicle status and functioning
- systems for intervention, etc.

Experimental systems are being designed within the DRIVE programme to monitor a driver's control of the vehicle and give a warning if performance falls below a certain level. Diagnostic networks for vehicle status and functioning are technically possible, but the condition of commercial use is that cost effectiveness is guaranteed and customers are willing to pay for it.

Speed Control

The objective of speed control is to ensure that appropriate speed is kept on each part of the road network. As inappropriate speed is a major factor in accidents, improving traffic safety is the main aim of speed control.

Speed control can function at different levels, from flexible speed limits, posted by Variable Message Sign gantries, to a speed limiter built in the vehicle that restricts vehicle speed according to actual speed limit. A speed limiter may function in an infrastructure dependent way, getting information from road-side transponders, or as an autonomous system with its own data-base and local positioning system.

New technology applied in speed control includes:

- Variable Message Signs
- Global Positioning System
- digital road network data base with speed limit information
- speed limiter in vehicles, etc.

Time perspective and first application areas:

- Advisory and mandatory speed control systems based on VMS have been functioning on shorter road sections in several European countries. This form of flexible advisory speed control can widely be introduced in Europe in the near future.

- Experiments with in-car speed limiter have also been started. This form needs a longer time perspective for technology development and public acceptance before wide introduction in Europe.

2.3.2 Environmental friendly car of tomorrow

The aim of developing new technologies for the car of tomorrow is to mitigate negative effects of road traffic on the environment.

Car manufacturers concentrate substantial efforts on developing new materials and car technology that makes road traffic sustainable in the long term by reducing its energy consumption and pollution. The main areas of development are:

- light-weight vehicles
- alternative fuels
- electric car
- cost-effective recycling techniques
- emission diagnosis systems

New technology applied in the car of tomorrow includes:

- electric car batteries
- fuel cells
- improved engine efficiency
- electric and hybrid vehicles
- cost-effective recycling techniques
- new materials, etc.

Time perspective and first application areas

1. Short to medium term:
    - energy efficient, competitive ultra low and near zero emission vehicles for both urban and regional use,
    - radically new, competitive, safe, intelligent, energy efficient, zero emission vehicle concepts, such as ultra compact electric vehicles for urban use.
2. Long term:
    - radical, fully sustainable, negligible or zero emission propulsion systems (for example fuel cells), which have the prospect of exploiting renewable primary energy sources.

2.4 MONITORING AND ENFORCEMENT

2.4.1 Speed and Violation Monitoring and Enforcement

The objective of speed monitoring and enforcement is to eliminate inadequate and excess speed from the road network, as high speed is an important factor in accidents. Violation monitoring and enforcement is going to detect and eliminate traffic violations on the road network in order to improve the quality of co-operation between road users, and prevent accidents caused by violations. New information technology makes it possible that authorities monitor the road network regularly and detect speeding and violation of traffic rules, identify violators and enforce them in a large scale.

New technology applied in speed and traffic violation monitoring and enforcement includes:

- low cost methods to measure vehicle speeds
- low cost methods to identify moving violations
- electronic vehicle identification techniques
- image processing using video pictures, etc.

Concept development and first, experimental application of speed and violation monitoring has been carried out within the DRIVE programme. Further steps in this area can not be expected from technology push, but it needs to be initiated by governments, as market for such systems can be produced only by central regulation.

2.5 LIST OF TECHNOLOGIES

The following table presents the application of the main groups of new technology in the different areas in road traffic. Some new technologies, e.g. data management systems, sensors, etc. are applied in almost every area, while others, like smart cards are bound to a few or only one area.

Table 1: Road Traffic Technologies and Applications

	VMS	RDS/ TMC	Sensors	Data management	Image processing	Beacons	Smart cards	Tolling	Car computer	GPS
Infrastructure based										
Traffic Management	+	+	+	+	+	+		+		
Traffic and Travel Information	+	+	+	+		+				
Demand Management	+	+	+	+		+	+	+		
Vehicle based										
Route guidance			+	+		+			+	+
Collision avoidance			+	+	+				+	
Vehicle control			+	+	+				+	
Vision enhancement			+						+	
Status monitoring			+						+	
Speed control	+		+	+		+			+	+
Public transport										
Passenger information	+	+		+						
Ticketing				+			+			
Enforcement										
Speed and violation			+	+	+					

3. APPLICATION OF NEW TECHNOLOGY IN AIR TRANSPORT

3.1 INTRODUCTION

Planners are predicting that air traffic could grow by 50% over the next 10 years up to 2007, and some way must be found to cope with this predicted increase. Current estimates suggest that by 2015, the number of commercial flights over the North Atlantic will reach just under half a million a year, i.e. almost 700 each way per day, or a departure roughly every two minutes. The number of flights is increasing at a rate of 3.3% per year- more than doubling the total figure for 1993 by 2015. This state of affairs clearly needs some planning to enable air traffic systems to cope.

The players in air transport have different requirements and need technology to achieve different ends. The aircraft manufacturers requirements are to do with aircraft efficiency and maintaining a competitive edge both technologically and economically—that is, offering technology packed aircraft which are fuel efficient, aerodynamic, easy to fly, and environmentally sound. The airlines have requirements for larger aircraft to carry more passengers in the most cost effective way, and technology that allows them to utilise more fuel efficient routes — i.e. higher and more direct, taking into account prevailing weather conditions and so on. The air traffic controllers on the ground need to know more accurately where aircraft are and be able to predict better and more reliably where aircraft will be at critical time windows. In order to achieve these various goals, it is often the same technology which enables success, but the applications may be different. The requirement for more accurate position information — knowing more reliably where aircraft are and where they will be in a defined period of time is one of the underlying requirements, but it is not enough to know the information, it needs to be transmitted from the air to the ground and vice versa. Accurate air position information is becoming possible due to satellite based systems and the technology to achieve information transfer is now technically achievable in the form of datalink. These technologies open up the way for better navigation systems and may allow significant changes in the way that pilots develop flight plans, for example the concept of 4D flight and ‘free flight’. These concepts will be discussed further in the following sections.

The dramatic and sustained increase in air traffic is causing significant problems for already overloaded air traffic controllers who are working with outdated technologies to cope. The limit to where modifications to the current system will alleviate the problem has been reached. Sector sizes have been reduced to reduce the number of aircraft an individual has to handle, but this has introduced more communication problems between controllers and generated more handovers from one sector to another.

There is a limit to the sector size reduction that can realistically take place, and significant changes to technology and procedures will have to be made to ensure safe transit of air traffic in the future. A number of changes are already on the way. The plan for Reduced Vertical Separation (RSVM) announced in March 1997, for example, is possible because of the increased accuracy of altimeters which will allow the maintenance of safety levels. It is estimated that the relaxing of this restriction will save airlines £20 million by the year 2015 by allowing airlines to select the most fuel efficient routes by in effect doubling capacity on all routes (for certified equipped aircraft only). This new regulation is already in force. More accurate altimeters is one element in the continuing development of aircraft systems to increase the accuracy of the aircraft position data in 4 dimensions (x, y, z and time).

The cause of accidents in the air has been attributable in whole or in part to human error in 65% – 80% of cases. Regardless of the location of the error(s) — whether due to for example, lack of training, poor ergonomics, system design, system failure, pilot error, or whatever, this attribution has remained relatively consistent. The introduction of new technologies may aid operators during ever more complex tasks, but it is important to remember that human error will never be eliminated. The design process must take this into account and make sure that the system is backed up by further support systems to ameliorate the effects of error.

3.2 DRIVERS FOR NEW TECHNOLOGIES

3.2.1 Technology drivers for the aircraft manufacturers

The primary aims for aircraft manufacturers are energy saving, achieving environmental requirements and improving aircraft efficiency (reduced fuel consumption per seat, increased range, better aerodynamics). Competition between manufacturers is significant, especially for short haul aircraft and at the very large aircraft end where profits are significantly greater. Selling price bears no relation to production cost and identification of the influence of technology on production costs is very difficult. However, to achieve the goals, manufacturers have to achieve reductions in production costs by using techniques such as CAD, and therefore building fewer expensive mock-ups. Virtual reality systems are also candidates for reducing design costs and for assessing maintenance requirements. New techniques for materials testing (especially non-destructive testing) may prove cheaper and more effective if they can maintain or improve current levels. Environmental requirements are an important driver as they are becoming more stringent — particularly with respect to noise reduction, with strong public opinion reducing the number of night time flights due to noise.

Automation of systems will only be introduced if there is a clear gain as a result. There are differences between aircraft manufacturers in their automation philosophies. One approach taken for flight deck development is to analyse accident data and pilot experiences to allow categorisation of incidents. This may identify an error prone system that would benefit from automation. The main question is ‘where can automation reduce human error?’. There will always be human error but systems must be designed to acknowledge this fact and be designed to reduce the concomitant risks of errors.

There has been a culture change and a wide range of technologies is becoming available. Airbus for example started from scratch with a new philosophy for flight deck design incorporating fly-by-wire and the glass cockpit where multi-function displays are used instead of dedicated displays for each parameter. Other companies such as Boeing /McDonnell Douglas are incorporating the same new technologies but in a evolutionary manner. The introduction of new technologies also offers new challenges for the certification process, for example: how should individual systems be assessed? how to look at integrated systems? how to assess workload and situation awareness?

3.2.2 Technology drivers for the airlines

The competition between airlines for routes and passengers is greater than it has ever been. Airlines want ATC to give them priority in already overloaded sectors. Clearly everyone cannot have priority. There are some suggestions that the higher the specification of the aircraft technology (e.g.

datalink), the more likely it is that the airline will be given priority, giving a strong driver to airlines to use well equipped aircraft. In recent trials with experimental systems, priority was a key issue. There is a risk that priority might be given to smaller unequipped craft because there is greater error in their track following and they may take longer to adopt new instructions. This mirrors the maritime adage to 'give way to sail' or to give way to the less equipped craft. This would be ineffective use of the airspace and is not what the airlines want.

Requirements for the airlines include:

- Fuel efficiency: both inherently in the aircraft and for fuel effective flight plans
- Reduced maintenance
- Ease of transfer of pilots from one aircraft to another
- Increased number of passengers per flight
- Ability to utilise the most cost effective routes
- Ability to predict arrival time to coincide with connecting flights
- Maximise time in the air and hence maximise the earning capacity of the aircraft.

3.2.3 Technology drivers for air traffic control

The main drivers for new technology in air traffic control are the increase in air traffic load and potentially unacceptable controller workload. Air traffic controllers (ATCos) are currently working near their maximum workload, and all system modifications within the current technology have been implemented. The current very old technologies need to be updated to cope with increasing traffic. Developments on the flight deck as well as the datalink technology are allowing for more, and more accurate, information. Procedures and operating methods as well as crew structure may well change. ATCos will be able to plan 20 minutes ahead of real-time, instead of just in time or very nearly as at present. New technologies will give more accurate predictions of where aircraft will be and how well they are maintaining their flight plans. Computerised tools will aid controllers to make decisions both at planning and tactical levels. There is clearly a need for harmonisation between different air traffic control systems to enable unambiguous handovers between sectors, particularly internationally.

Airspace is at a premium as it is configured today. Changes in the use of airspace and reduction in minimum separation requirements will increase capacity but will induce changes in the way that traffic is controlled. Separations between aircraft are being reduced because of better altimetry — currently vertically, but horizontal separations are also being reviewed. This is required particularly if the concept of parallel runways close together are envisaged. Reduced horizontal separations will require accurate assessment of weather conditions and even more accurate position knowledge.

Current systems work largely independently, with procedures coupling systems together. Integrated air traffic management systems may be the way forward, where the pilot and aircraft, flight management system, air traffic control system and ATC team, flight operations management for the air carriers and strategic air traffic flow management work interdependently using the same data sources.

3.2.4 Technology drivers for airports

The challenge for airports is to cope with ever increasing numbers of take-offs and landings, and to cope with ever increasing numbers of passengers and relay them to other transport networks. Airports will need to handle aircraft carrying 500 passengers and will need to load and unload people and baggage within a reasonable time. The building of further runways is fraught with public disapproval and environment issues such as noise reduction are becoming more and more important. Increasing airport capacity may be achieved by understanding the current traffic flow and by minimising the times between aircraft landing (or taking off) and by optimising the traffic cued waiting to land (take off.) One proposal to increase capacity is to have parallel runways closer together. This may become possible if separations can be reduced and shown to be safe. This would utilise the same enabling technologies which allow aircraft position to be so much more accurately controlled and monitored.

3.3 AIRCRAFT MANUFACTURING TECHNOLOGIES

In order to remain competitive, aircraft manufacturers need to embody new technology in the design and manufacturing process as well as to provide increased capability.

Predicted advances in technology in this area include:

- Advanced simulation technologies (for the design process, manufacturing process, support, and training and also Air Traffic Control simulation for workstation design and workload studies)
- Commercial electronic equipment. This is becoming increasingly reliable, with good performance and a broad operating range e.g. lap top computers, hand-held GPS receivers, flat panel displays, virtual reality glasses. There is some concern that the equipment may be designed for ground applications not airborne usage.
- Commercial off the shelf software technology systems (COTS software) and Non-development items (NDI). There are significant benefits to using these technologies, for example cost reductions and time reductions in design life cycle. There may also be negative implications with respect to integration, reliability, performance, and harmonisation with other components. There are also certification issues: to certify an item in isolation, or to certify the complete system. Retrofit technologies are especially difficult.
- Composite materials and smart structures
- Advanced sensors — for non-destructive testing (NDT) e.g. holographic or ultra sound sensors, electron beam and neutron inspection cameras etc.

Human factors issues are of concern in all but maybe the last two categories of developments.

3.4 FLIGHT DECK TECHNOLOGIES

3.4.1 Communications

Currently communication on the flight deck with Air Traffic Control uses radio telephony. Radar locates aircraft position, and secondary radar linked with transponders on the aircraft allow aircraft specific information to be added to the radar display. There are errors inherent in these technologies with possibilities of misunderstanding and potential monitoring errors. Satellite based technologies allow much more accurate position information, and allow for high bandwidth information transmission to and from the aircraft. The air traffic controller then has access to onboard flight deck systems to get timely information about flight plans — both planned and actual. However this relies on the aircraft being equipped with the appropriate technology and of course this will not happen universally unless it is made mandatory. Satellite technology offers a communication link, accurate position information and better monitoring of position.

Datalink
The manifestation of much advanced communications technology is datalink. This is the high bandwidth communication link between the pilot and the ground and vice versa. Flight plan negotiation can in future be carried out via datalink entirely via keyboard. Current R/T (radio telephony) communication by voice will be much reduced. However, R/T will still be required for aircraft not equipped with datalink technology. Many of the proposed working stations for air traffic controllers (ATCos) will be able to store messages for transmission to pilots and at the appropriate time the message is transmitted via a button-press with no verbal contact with the pilot at all.

Datalink enables 4D flying by

a) having access to enhanced and more accurate knowledge of position and
b) b) being able to share that information with ground control.

Enhanced Communication technologies are:

- CNS Communications, navigation and surveillance
  to aid in positional accuracy and
  to allow 4D flight
- Global navigation satellite system (GNSS)
- ADS Automatic dependant surveillance

The aims of these systems are to allow new navigation paradigms, to improve safety and airspace capacity and to improve air traffic management (ATM).

3.4.2 Navigation

Navigation is currently achieved by inputting waypoints within strictly controlled air corridors. Developments in communications via satellite technology mean that the aircraft pilot and air traffic controller (via datalink) will know very accurately where the aircraft is in space, and where it will be in defined time periods ahead. The aim of the new technologies is to increase data accuracy, enable new modes of flight planning and to reduce the number of incidents caused by navigation errors. Satellite communications world wide and the high bandwidth digital datalink open up the possibility for aircraft to plan flight paths in four dimensions — so-called 4D flight. Coupled with these technologies are the capability for accurate air speed assessment and better monitoring of weather effects.

The increased accuracy in position information also enables the possibility of flight plans not being constrained to the current strictly delineated air corridors, namely free flight. There are far reaching implications for all air transport stakeholders in these concepts. Potential advantages mean that most cost effective routes can be selected by airlines saving fuel and flight time, and that Air Traffic Management can be improved. The role of the air traffic control function needs careful consideration to ensure that safety is maintained, and that as airspace capacity is increased, the roles of pilots and air traffic controllers are carefully monitored.

Proposed developments in this area include:

- GNSS Navigation satellites (a generic term for global navigation by satellite)
- CNS: Communications, navigation and surveillance systems
- GPS Global positioning system (satellite based navigation system)
- Automatic dependant surveillance (ADS) for flight monitoring where radar is ineffective
- 4D flying — flying flight paths to greater accuracy in space and time

- Free flight — the pilot generating his own flight path, possibly outside current flight lanes
- Navigation using terrain databases
- Satellite navigation and flight following

3.4.3 Control automation

The direction of the application of new technology in this area is largely to extend current capability rather than to make new functions available. The greatest step was to introduce fly-by-wire where control surfaces were no longer directly linked to the control device — instead digital electronic linkages activate systems. Airbus Industrie flew a fly-by wire A320 aircraft in 1984 — the first production commercial aircraft to be equipped with digital electronic flight controls. Boeing followed with the 777 in June 1995.

Predicted extensions to current control, systems include:
- Low visibility taxiing assistance or guidance
- High precision in-trail operations in terminal areas
- Automated collision avoidance manoeuvres
- Automated wind shear avoidance manoeuvres

Automated landings may also be a possibility if minimal separations are reduced for runways — the concept of parallel runways. This is reliant on very accurate position control of aircraft.

3.4.4 Automated Flight Management

Aircraft flight management systems are currently installed in many aircraft but their level of sophistication varies, and the ease with which the pilot can interface with the system also varies. This is not therefore a new concept, but there will be continual development to enhance flight management generally. Future flight management systems (FMS) will offer a greater degree of automation selection options, or modes of operation which will be under pilot control, and these will need more intuitive interfaces. Pre-programmed options need to be provided. The pilot still chooses the degree of management of the system.

Problems with current systems include difficulties in reverting to manual control and overriding the automation in some cases, and the difficulty in changing pre-programmed flight plans. This last aspect can take valuable time to achieve, especially if the aircraft is instructed to change runway at the last moment. Systems with updated HMI are planned with cursor modification of flight plans rather than requiring the system to be completely re-programmed.

Developments in this area include:
- Improved error checking
- Error handling/management
- Enhanced error tolerance -enhanced error monitoring and trapping
- Easier more intuitive FMS interfaces
- Cursor modification of flight plans
- Improved error checking
- Direct Flight Management Centre (FMC)-ATC computer communication
- Improved electronic checklists
- Improved mental activities models for design

3.4.5 Information automation

Pilots are required to carry flight and aircraft operating manuals for each flight. This information could easily be stored on a CD ROM along with approach and en-route navigation charts to produce a so-called ‘paperless cockpit’. Electronic library systems (ELS) offer a solution to this but raise other issues that must be resolved before such a technology is adopted.

Such advances in information systems are attributable to improvements in:
- information processing theory
- telecommunications
- advanced computer hardware
- software

Other applications for information technology in air transport systems are:
- Electronic Data Access and Management Systems on the flight deck (EDAMS)
- Data warehousing — particularly for the generation of data to be used to assess safety and to identify recurring error situations which may benefit from re design/automation/changes in procedures/training and so on. An example of this is GAIN — Global Analysis and Information network. This is a method by which pilot experience can be logged, including everything from misunderstanding display information to near hit scenarios, so that problem areas can be highlighted before accidents occur.

3.4.6 Displays

The aim of advanced new technologies in this area is to present information to the pilot through the most appropriate modality. The amount of information available to the pilot will be greater than it ever has been, not only navigation and communication data but enhanced outside world views and data from smart structures giving data about the stresses of the air frame and so on, and sensors giving information about the performance and status of every aircraft system. The challenge is to allow the pilot to access information when he needs it and to remove redundant information before it creates clutter or induces confusion. Many aircraft already have the so-called glass cockpit where multi-function displays give the pilot the information he requires. Developments in this area aim to give the pilot better situation awareness by utilising additional sensor data to give a better outside world view. This in turn may allow him to proceed under weather conditions which would otherwise prevent him from landing. Other technologies such as head-up displays have been used in the military for many years to great effect, and may well have a role to play in civil aircraft flight decks especially in poor visibility and for instrumented landings.

Information handling technologies include:
- Data fusion
- Holistic spatial image processing
- Integrated information display

Display technologies proposed include:
- ‘Big picture’ integrated cockpit displays — very large screen integrated displays incorporating synthetic or enhanced views of the outside world view and including system state information.
- Enhanced head-up displays, helmet mounted displays, 3D displays, volumetric displays
- 3D audio displays
- Enhanced or synthetic vision systems

- Multi function displays — enhanced head down display technologies (e.g. AMLCD — Active Matrix Liquid Crystal Display))

3.4.7 Warning/Advisory

The aim of warning and/or advisory technology is to draw the pilot's attention to deviations from desired or planned events before those events become safety critical. There are two main areas:

a) warnings relating to aircraft systems and system errors/failures and
b) collision avoidance aids.

In order to gain system information and outside world information, sensors will be able to provide an enhanced view of the aircraft and it's environment. Intelligent Central Warning Systems (ICWS) will not only be able to warn the pilot of potential problems, but also to aid in problem solving and to provide aid for planning recovery actions. A reliable computer-human interaction environment is the goal, and this relates closely to the aims of cognitive aids discussed in the next section.

There are collision avoidance aids already fitted in aircraft but some are problematical in that they have high false alarm rates and engender ignored warnings. Current systems need refinement and development and new systems are being proposed to enhance safety.

Collision avoidance systems include:

- GPWS Ground proximity warning system
- GCAS Ground collision avoidance system
- TCAS Traffic alert and collision avoidance system. This system provides flight crew with a visual display of air traffic in the vicinity as well as aural warnings and commands.

These systems offer manoeuvre guidance, usually in urgent voice messages, for the resolution of potentially serious conflicts.

Sensor developments for enhanced vision and monitoring systems include:

- IR (infra red), millimetric radar and microwave systems for poor weather operation. The information is then presented on a HUD, HMD, or HDD.
- Advanced sensors and synthetic vision . (Most effectively presented on head-up displays)

3.4.8 Cognitive aids

Advances in cognitive modelling may allow systems to be developed which act as the pilot's 'associate'. This requires a global understanding of aircraft states and pilot intent. The aim of such systems would be to increase safety by reducing errors, to relieve unacceptable workload, or to aid in highly complex decision making situations.

The pilot's associate could act as an adaptive automation system where automation is triggered by possibly mental workload, or possibly by physiological metrics. Advanced dynamic functional allocation techniques are being developed which allow allocation of tasks between humans and machines as well as between humans in a crew. Automation is utilised when necessary and responsibility of control remains with the pilot. These techniques still require developments in the areas of physiological measurement, advanced mental workload and situation awareness metrics.

Systems already exist experimentally which log the expected flight plan and system states associated with that plan. They take a black box approach comparing expected versus actual flight parameters and matching exceptions. Warnings about the deviation from the plan are generated and flagged up to the pilot. Examples of these systems are ARCHIE and CASSIE (see references 15 and 26).

3.5 AIR TRAFFIC CONTROL TECHNOLOGIES

Current air traffic control workstations are not technology rich. ATCos operate under high workload conditions and have very little automation available to them. Sources of workload can be from routine tasks, from conflict resolution tasks or from planning and management of the sector type tasks. This is overlaid with additional workload caused by uncertainty about the accuracy of data and the fact that the ATCo is constantly assessing the reliability of information presented to him. Datalink and satellite technologies will allow ATCos to have the same accuracy of data as the pilots and the capability to plan in 20-30 minute blocks instead of the current short term planning. Information technology coupled with the source of good, timely accurate data about aircraft position, has allowed tools to be developed which aid during different phases of tasks. The ATC environment is becoming more technology driven — partly because of the developments in automation on the flight deck , and partly because the need for revision to the system is so great. As has been mentioned in the introduction, sector size modification will no longer work and ATCos need something more substantial to enable them to cope with the predicted increases in air traffic.

Air/ground datalinks will facilitate many communications tasks, particularly for negotiating trajectories or changes to agreed trajectories. The requirement is for planning at a much earlier stage and at a higher level of detail than is currently possible — to enable airspace (i.e. adequate separation) and air traffic flow to be managed safely. The aim is for more traffic to be managed safely and efficiently. However it must be remembered that uncertainties can be reduced but not eliminated. The new technologies are coupled with new procedures, issues of shared control, new navigation possibilities, and the capability for more accurate planning. There may be problems if the level of information available is different in different aircraft and in different sectors of the world. New systems will largely rely on aircraft installing technology to provide information at the groundstation so that air traffic control is dependent on aircraft capability, whether a particular aircraft is equipped to send accurate position data or not. Air traffic controllers will need to cope with mix of 3D and 4D equipped aircraft i.e. those with datalink and those without. Although the gains offered by these technologies are significant for the large airlines, charter flight companies, private pilots and other small aircraft may well not see any requirement to install expensive new technology unless it is made mandatory.

There are several major actions that have been identified to improve ATCos workstations, largely by providing tools to aid in decision making and traffic management. The strategic (planner) controller and the tactical controller have different requirements for support systems and these differences must be considered in the light of the organisation, and allocation, of tasks between the planner and tactical operators. There are major changes expected in the roles of ATCos, not only by the provision of computerised tools to aid the task, but also changes in the composition of air traffic control teams and the procedures under which they work. Moreover there are different requirements for different stages of the aircraft control process: take off, en-route, oceanic and terminal approach (TMA). Some of these issues are discussed in the following sections.

3.5.1 Information acquisition and processing aids

In order to make decisions about how to schedule aircraft routes the ATCo needs a great deal of information. This includes the filed flight plan, the aircraft call sign, the type of aircraft, that aircraft's capabilities, information about the current speed, altitude, heading of that aircraft, the weather conditions, and so on. Much of this information is stored on the paper flight strip which are added to by various team members in colour coded pens. However much of the information is currently held as knowledge by the air traffic controller — for example the aircraft capabilities and what options are available for routing aircraft.

There are several issues of interest here:

- Currently the ATCo builds a picture of the traffic in his sector so that if anything goes wrong he already knows where all the aircraft for which he is responsible are and what status they are. 'Big picture' maintenance is an important question — how important is it for the ATCo to build up a picture of the status of all the aircraft in his sector, and know what is required for each so as to maintain conflict free flight paths?
- The availability of real time information — including aircraft speed, position and so on, to enable greater certainty in the planning process
- The provision of reliable data, and data that is the same for both the pilot and the ATCo, in which the ATCo can have confidence.

The technologies that are allowing these developments are firstly the communications links enabling access to flight deck information by providing

a) more accurate information, and
b) information not accessible before.

The second technology is the much increased processing power enabling real time decision making aids.

As traffic gets denser, the time allowed to make decisions becomes shorter and all the available options may not be adequately considered. To help the controller to stay in control, various support systems are being trialled. Their main aim is to support rather than replace the operator, but they still mean that some parts of the task may be automated so that the ATCo does not have direct control of the function. In addition some mean that the planning tasks will be carried out in a different way. The way the team is configured is also being investigated in the PHARE program — looking at how the tactical and strategic planners can work together and how the work should be apportioned in peak workload conditions.

Technological developments to aid the ATCo include the following:

- Electronic data display — replacement of paper flight strips with electronic displays — not necessarily electronic flight strips but possibly labelling on a synthetic 'radar' display.
- Communication and surveillance:

  Data link functions:

  Mode 'S' secondary surveillance radar — this is an enhanced ATCRBS (Air traffic control radar beacon system) which is a surface transponder-interrogator system which obtains information from aircraft. This mode enables datalink information to be transmitted between ATC and aircraft. It also provides position and altitude data to the ground and can also communicate collision avoidance information between aircraft.

  VHF Datalink — reduced radio-telephony (R/T)

  Satellite links:

  SATCOM (Satellite communication system)

  SATNAV (Satellite navigation system)

3.5.2 Support tools for strategic tasks: planner controller

The planner controller's role is to direct the work of the personnel within the sector, and to co-ordinate all traffic entering and leaving the sector. Proposed tools that may enhance the way the planner controller carries out his tasks include:

- Trajectory prediction/ conflict probes: These use information from datalink to ensure accurate representations of aircraft position in 4D (from onboard FMS computers);
- Graphic displays for vertical and horizontal aircraft separation;
- Conformance monitor: Monitoring of progress by computer / in built warning systems;
- 'What if' displays / problem solvers: Planning tools for conflict resolution / system suggestions as to solutions; (e.g. HIPS — the highly interactive problem solver developed by the PHARE programme).
- Traffic manager: Sequencing tools for terminal in/out movements (includes aids for scheduling traffic and descent profile advice);
- Workload prediction tools: means to monitor impending workload of team to allow rescheduling of control tasks to maintain capacity;
- Electronic assistant: tool to give reminders of tasks to be completed, or advice on scheduling tasks to maintain capacity and to reduce workload. (includes capability to plan and co-ordinate traffic through 3/4 sectors prior to any tactical change to optimise airspace resources.)

3.5.3 Tools to aid in controlling traffic: tactical controller

The tactical controller's role is to maintain radar surveillance and to communicate instructions to respective pilots about what routes they should follow within the sector. Electronic flight strips may offer advantages over the current paper flight strip system, but the colour coding of information added by different personnel may be important in maintaining a picture of the overall status of each aircraft. Changes in the way the ATCo communicates with the pilot may also have implications for understanding / misunderstanding.

Tools are planned to aid in:

- Trajectory Prediction
- Conflict Detection
- Flightpath monitoring
- Clearance Advisory

The time required to operate the tools must be considered in the overall workload evaluation, as well as the cost/benefit analysis in terms of workload and number of aircraft controlled per operator.

3.5.4 Changes in aircraft navigation procedures

There will be changes in operating procedures due to the changes in flight planning in the cockpit and in the way that that flight plan is negotiated. Verbal communication between the pilot and ATCo may disappear completely, with messages being pre-planned and sent at the correct time either automatically or at the push of a button. Operating procedures will change as well as the functional tasks of tactical and planner controllers. Causes of procedural change will include:

- 4D Navigation — in space and time
- Free Flight — aircraft in control of their own trajectory
- CNS/ATM (Communications, navigation and surveillance, and Air traffic management) — data availability
- GNSS (Global navigation Satellite system) — enhanced position information

- FANS: Future Air Navigation System (ICAO co-ordinated initiative)
- ADS (Automatic Dependant Surveillance) for Oceanic airspace. This is a technique which uses on-board systems to transmit an aircraft's position automatically to ATC. Offers capability when aircraft are out of radar and VHF radio range. It is particularly relevant to oceanic areas or sparsely populated regions with minimal existing ATC infrastructure. It also updates weather information to give a better weather picture.
- NERC/AERA new en route control (UK)/ automated en route ATC (USA),. These systems are the first steps in updating air traffic control process.
- IATMS Integrated Air Traffic Management system.

3.5.5 Safety Nets

The provision of safety nets is planned to alleviate the effects of errors of judgement or system errors. These include:

- Minimum safe altitude warning (MSAW)Area proximity warning (APW)Short term conflict alert (STCA) currently available but false alarms and low severity alarms are disruptive.
- Traffic Alert and Collision avoidance system (TCAS) (available from flight deck).
- Ground proximity warning system (GPWS) (available from flight deck).

3.5.6 Interface developments

There are a number of potential developments to the ATCo working position:

- Window environments for aircraft position display and assistance tools
- High resolution displays — glass workstation analogy/multi-function displays/3D displays
- Decisions about number of controllers — planner controller/tactical controller task allocation, number of displays (if one display there is no chance of graceful degradation if the system crashes — therefore redundancy is necessary), degree of automation/assistance
- Capability for vast amount of information to be relayed from the aircraft systems to the ground
- Maintenance of the 'big picture' by the ATCos
- Voice recognition
- Handwriting recognition

3.6 TABLE OF APPLICATIONS

This section gives an idea of the interrelationship between the developing applications and the emerging technologies. It can be seen that the set of technologies is relatively small, but that many applications are made possible by harnessing the advantages of developments in one or more areas of technology. The major technological developments are computer processing power, satellite technology enabling communications as well as providing the means for accurate position data, new sensors for weather conditions, system status and other data, and the capability for this information to be provided both on the flight deck and on the ground. These developments are potentially coupled with a range of advanced interfaces including HUDs, HMDs, 3D displays, aural displays and so on. The limiting factors to developments are not technological, they are more to do with the understanding of the relationship between the human operator and the system and how increasing automation and information provision continues to enhance the task rather than disabling the operator until a critical incident requires intervention when he may or may not be able to resolve the problem.

Table 2: Flight Deck Developments

Applications	Technologies				
	IT	Satellites	Sensors	Communication links	Display technology
Communication	√	√		√	
Navigation	√	√	√	√	
Control Automation	√		√		
Automated flight management	√	√	√	√	
Information automation	√				
Displays					√
Warning /advisory systems	√		√		√
Cognitive aids	√		√		√

Table 3: Air Traffic Control Developments

Applications	Technologies				
	IT	Satellites	Sensors	Communication links	Display technology
Information acquisition/ processing aids	√	√	√	√	√
Support tools: planner controller	√			√	
Traffic control tools: tactical controller	√			√	
Navigation	√	√	√	√	
Safety nets	√		√	√	
Interface developments					√

4. APPLICATION OF NEW TECHNOLOGY IN RAIL TRANSPORT

"…perhaps the most exciting prospect for the future is the emergence of two new influencing factors that I think will substantially shape transport economy in the 90s and into the next century. These are: the current wave of technological innovation, and the emerging new socio-political pattern of life in Europe.

Current technological innovation in the transport field is mainly concentrated in the following two areas:
'Intelligent' transport vehicles and infrastructure, i.e. the 'capital goods' used for transport, and
New, more efficient and 'productive forms' of the overall operation and management of the system, i.e. the ways these 'capital goods' are used."

(George Giannopoulos, 1995, in ECMT Round Table 100)

4.1 SAFETY AND THE PECULIARITIES OF THE RAILWAY SYSTEM

In modern railways, the driver's involvement in safety issues is significantly less important than for other transportation modes. A train cannot switch path. The train paths are determined by the configuration of physical installations and the choices are implemented by the ground staff, through standard procedures ensuring full safety. In theory, a train cannot enter an unprotected conflict area. Conflict areas must be protected (generally physically) to allow trains to access them. When such an area is accessed by a train (and, as a matter of fact, even before it is accessed, as soon as it is reserved for a particular train), the conflict zone becomes unavailable to all other trains, by means of physically locked devices. In theory, a train cannot cross a red signal; the system will stop it before. Finally, in theory again, speeding is not possible, and stop points are determined. System devices do not allow the driver to go beyond the stopping point.

In practice, permanent speed monitoring is seldom generalised. In several instances, automatic emergency braking does not fully guarantee that the train will stop before the conflict zone. In main lines, a small but non negligible part of safety still lays on the driver's shoulder. In less important lines, the driver's role may be pivotal. Generally speaking, driving errors are still the origin of a significant part of rail casualties (also, because of the high reliability and low failure rate of physical protection devices).

Nevertheless, safety in railways is mainly ensured by physical devices, severely limiting the effects of a driver's bad decision, contrary to the other transportation modes. This allows for the railways to be in the first rank on safety performances, for every possible safety indicator (deaths or damages per passenger, per passenger km, per inhabitant, per year, etc.).

For the safety issue in railways, system design and procedures' elaboration are far more important than the driver's behaviour. Therefore, the direct human implications of new technologies are significantly less related to safety issues in railways than in other modes.

As railway operation has a more pronounced system aspect, implications of new technologies are more important in areas such as system performance, reliability, attractiveness and, beyond, social utility.

4.2 TRENDS IN CURRENT RESEARCH EFFORT FOR RAILWAYS

Due to evolving needs and social sensitivity, due also to technological opportunities, the main investment and research effort in railways is concentrated in the following areas:

- high speed lines
- combined transportation
- environmental issues
- separation of infrastructure and operation management

4.2.1 High speed lines change human geography

Using conventional infrastructure, a speed range of 250 to 300 km/h is currently a matter of fact in European countries. Higher speed ranges are envisioned for innovative infrastructures (500 km/h for TransRapid and SwissMetro). This allows railways already to compete against airlines in the medium range distances (300 to 1000 km), where the later are impeded also by air corridor and airport saturation.

The main human implication, already observed, is the alteration of geographical scale, due to the vastly improved accessibility between the main conurbations. TGV, for instance, made it possible what was previously unthinkable: to live in Lyons and to commute daily to Paris (at 400 km distance). There is a newly emerging social organisation, based on profoundly changing patterns of geographical distribution of activities. We are seeing only the beginning of it.

4.2.2 The hopes of combined transportation

Major efforts and investments are already dedicated to freight transportation, trying to combine road flexibility and capillarity to rail productivity and environmental friendliness. Interurban highway congestion pushes towards such solutions; environmental consciousness, too.

Combined transportation in Europe is still at its starting block. Several technologies are either under development or assessment, or under partial implementation. It is not clear for the moment which technologies will prevail. It is not even clear whether and when combined transportation will gain a fair market share in freight transportation. It is clear, however, that public investment in this sector will be heavy in the years to come.

> ***If combined transportation succeeds in obtaining a significant market share, we are going to assist to an in-depth transformation of the freight transportation sector. Nevertheless, human implications will probably remain confined into this particular sector.***

4.2.3 Environmental and sustainable growth issues

It is paradoxical to notice that environmental issues help railway rehabilitation but, at the same time, severely impede its development.

High speed alignment is as inflexible (often more) than highways' one. Railways penetrate into city core, crossing densely populated areas. It becomes therefore very hard to build new railway lines or modernise existing ones inexpensively. In addition, major investments are required to reduce noise nuisances of existing installations.

Many research and development efforts are under way to reduce noise at the source level, by designing and manufacturing less noise producing rolling stock. At the same time, significant investments are planned for noise protection structures, such as noise screening walls (the Swiss government, for instance, plans to spend an almost 2 billion ECUs amount in this area over the next 10 to 20 years).

From the HINT project point of view, though, human implications are not expected to be of significant interest (unless one counts also on human satisfaction measurement).

4.3 FOCUSING ON THE HINT PROJECT ISSUES

As far as the HINT project is concerned, a special attention must be paid to the following particular areas:

- ***intermodality***, which finally will allow for an efficient use of the transportation system as a whole, involving in the transportation chain, the most efficient modes;
- ***pricing and ticketing***, which may revolutionise the way we use the system;
- ***passenger information***, before and during the travel, which will largely improve the easiness of use of the system and its perceived reliability;
- ***automation at all levels***, which will modify the personnel qualification and training; it will also modify the way people interact with the system; among these issues, automatic (driverless) train operation is paramount;
- ***train safety and control system***, concentrating probably the largest research effort in the last years; this topic is directly related to the automation issues, too;
- ***security issues*** will become more acute, especially in urbanised areas, aggravated by the reduction of onboard and ground personnel, due to the increased automation of tasks.

The survey conducted by ITEP among highly qualified railway experts, confirms a very consistent convergence on these areas, generally thought as the areas where research and development will shape the future of railways.

4.3.1 The passenger side

The issues of ***intermodality***, ***pricing and ticketing***, and ***passenger information*** are strongly interrelated.

Intermodality is clearly a chief objective in European policies, at the national, regional, urban, and European levels. Motivation is not always the same: some people are mainly concerned with the saturation of existing infrastructures (airports, highways, urban networks) and their loss of efficiency; while other people are more concerned with environmental issues, such as energy consumption, air and noise pollution. Whichever the motivation is, a better intermodality brings a beginning of solution to these problems.

To increase intermodality, in a framework of free market, where freedom of choice must be preserved, we need to meet several minimum technical and commercial conditions. Physical infrastructures allowing mode shift must exist and be practical. Their usability requires not only efficient design for the terminals, but also very strong simplification of administrative burden (now one usually has to pay a parking fee, then to buy a ticket, then, sometimes, a second ticket later, and so on). Here the **ticketing** issue comes into play: we are soon going to see implementation of many *pay-once-for-all* schemes; major transportation authorities are already experimenting with such schemes. The ***underlying technological issues*** are: prepaid or credit cards, contactless reading and counting, with several particular technologies involved for each topic.

Besides practicality, intermodality requires also that the total cost of a journey stays competitive against the most preferred current mode (which may be the car for some trips, the plane plus rented car for other). The **pricing** issue raises several organisational questions, because from a market perspective we are dealing with a single product (the intermodal trip) but with multiple producers (transportation companies, public road managers) who are not necessarily willing to agree.

Pricing may also be involved to make system use more efficient. In urban areas flat pricing schemes are usually applied. With an urban pass, fares are insensitive to the utilisation rate or time. With an underground ticket (such as in London or Paris), fares are insensitive to the utilisation time or to the trip length. This is interesting for long trips during peak hours, but modal share for these trips is already favourable for public transportation. Thus, current pricing practices are anti-economical, and work against intermodality.

However, more intelligent pricing schemes require more intelligent and more flexible ticketing. *Pay-as-you-travel* methods are only possible with innovative ticketing, involving smart card use. These methods may induce a side effect: privacy protection concerns may rise, because the ticketing system may potentially trace the whole travel pattern of an individual.

> ***More flexible pricing with modern ticketing may revolutionise the way people use the transportation system; the issues are: contactless and smart cards, pay-as-you travel methods, fare modulation in order to shift demand off the peak periods, and many other topics; at the end, we are going to see a more dynamic interaction between the passenger and the system. This evolution may raise privacy protection concerns.***

Finally, for **intermodality** to succeed, we need enhanced **passenger information**, before the trip and during the trip. Providing the technical and economical conditions for intermodality is not sufficient if the passenger is not aware of the supplied possibilities. Then, for urban trips, partial modal shifts may be made, if the user has real time information on network performances (road jams, parking availability, public transportation running times). During the trip, information in road transportation already allows drivers to change routes in real time: in the future, it may also allow real time modal shift. During the trip information is especially important for the user in a public transportation vehicle: because he/she does not drive it, he/she feels more dependable of the system than a driver; keeping him/her informed on travel progression, alleviates this dependence feeling.

To ensure passenger information, operators need to get real time vehicle location data. They also need access to efficient diffusion channels to reach the user. This issue is covered by two areas of intensive technological research and development: vehicle location and communications. The ***technologies involved*** in the first area are GPS, radio links, different flavours of transponder identification, etc. The ***technologies involved*** in the second area are RDS/TMC, the Internet and other flavours of home computing (Minitel), speech synthesis and recognition, etc.

Passenger information before and during the travel will be vastly improved in the years to come. It is a requirement not only for a more efficient mode use, but also for intermodality. It involves important technological developments on the passenger's and, mainly, on the operators' side. Telematics is the keyword for many of them: information by itself is a flow.

4.3.2 The operator side

Here again, the main issues are strongly interrelated: ***automation***, ***train operation and safety***, ***train control***, and ***security***. Here also, communications are the common glue.

Driverless operation has been a main challenge for railways since at least two decades. The context for it is quite different for underground metropolitan networks, for so-called *Automatic People Movers* (APM), or for conventional railways.

Already today, major cities' underground lines are very often under automatic train operation. The driver's function is to give the departure order, and to operate the train on emergency or degraded situations. Still, driverless operation was only introduced in a main underground only a few years back, in theLyons D line (Maggaly project). There are two main reasons for such a delay. The first is economical: there are few circumstances where the presence of the driver is still mandatory and the marginal automation cost to cover those situations is so high (or at least, it was thought to be so high) that automation seems not to be cost effective in many cases. The second reason is human: it has to do with union reactions, and with a perceived unwillingness of the passenger to be underground in a train set without an official agent in control.

These factors were not the same for APMs. Therefore, many APM lines have been under operation for more than 20 years now (even for a longer time, if one counts lifts among them). Because they were designed as completely new systems, infrastructure (mainly stations) was designed from the beginning with an agentless operation in mind. Thus, the high marginal cost problem was not relevant for these systems, and neither was the union problem.

Driverless operation is a more formidable challenge for conventional railways, because open lines are still largely unprotected (except for high speed ones), and less densely operated than metros. Therefore, the investment cost for fully automatic operation is higher, and potential savings (in terms of number of drivers) lower. Unless we find especially inexpensive technologies, or special cases (no risk of human casualties, non-critical missions, where operation may be interrupted as a last fail-safe measure, etc.), main railway lines will remain human operated in the medium range.

In recent years, a tremendous effort, spurred by European incentives, has been spent on the conception of new ***safety systems***, providing ***train operation and control***, through major advances in ***telematics***. Even if the ERTMS project sounds too ambitious, its spin-offs provide useful and concrete insight of what the tomorrow's railway could (should) be. There are very numerous technologies involved, allowing the design of many alternatives, and tracing a path towards partial automation first, full automation later. All these alternatives are based on a more intelligent vehicle, and a more intelligent infrastructure. Vehicles started already to locate or help locate themselves; infrastructure, in many cases, identifies trains and controls that they respect the limits associated to their category and acts on train operation if necessary.

None of the above mentioned developments is possible without fast and reliable ground-train communication links. The research on this topic is generic; new communication technologies will help to design new safety systems, new train operation, new train control, new passenger information, etc.

Increased automation will have several impacts on the way we use railways:

- tasks done today by the personnel will be automated, eliminating a series of specialised professions in the railways;
- new tasks will require staff with new qualification and training, in order to manage and to maintain the automatic components;
- this will result in deep modifications of the company structure and organisation, and of its social substance;
- from the level of service point of view, automation will allow for types of services unthinkable under manual operation; for the customer, this will change the supply, and the image of railways as well.

Automation follows multiple goals: reliability, safety, and personnel size (costs) reduction. This last point, for the operator and for the society, raises two questions:

- unions will not be easy to convince;
- security will become even more important, as ground personnel will be less visible.

Security is already a major concern for many urban and suburban networks. There are discussions, still inconclusive, about whether the need for increased public security offsets the savings of the personnel reduction provided by automation. From this point of view automation, if not carefully thought through, may become self-defeating.

> ***We may expect significant progress of automation in all fields during the next two decades. This will change the shape of the companies and their organisation. This will also change the human involvement at every level of the company. Automation will also help to provide additional services, which were impossible under manual operation. In some areas, automation may aggravate security problems, producing really negative human impacts.***

4.4 LIST OF TECHNOLOGIES

It is important to distinguish technologies and systems. When dealing with complex systems, involving several subsystems, components and functions, major human impacts will be due to the introduction of new subsystems combining several technologies, new and old ones, and not to a single technology. It is necessary to keep this in mind, while going through the list of new technologies.

This list was based on an analysis of the ongoing railway research, mainly in European countries. It is probable that many other technologies, not included in the list, combined with some among the included ones, will help to produce subsystems with significant human or organisational impacts. This is the reason why, in the previous sections, the analysis focused more on functions and subsystems, and less on single technologies. A complete list of references is included in the appendix.

The following list includes technologies and some possible applications:

Radio [Data] Link

GPS (Global Positioning System)
Radio Balises
Ground - Train Communication

Magnetic Induction
  Transponders Powered by Induction
Local Data Bus
  Onboard Data Transmission
Radar Frequencies
  Speed Measurement
Fault Tolerant Informatics
  Fail-safe Computerised Equipment
Public Data Networks
  Internet
  Booking and Billing Services
  Freight Tracking
Local and Wide Area Computer Networks
Simulators (Software and Hardware)
  Personnel Training
Speech Recognition and Synthesis
  Automatic Information System
Image Analysis
  Real Time Processing of Data
Smart Cards
  Contactless Technology
  Real Time Processing of Data
Composite Materials
  Lightweight Materials
  Impact Absorbent Materials

Finally, Table 4 summarises the links between the technologies and the main issues referred to in the previous section:

Table 4: Technologies and Applications in Rail

	Intermod-ality	Pricing Ticketing	Passenger Information	Automation	Safety Train Control	Security
Radio [Data] Link						
GPS (Global Positioning System)	✓		✓	✓	✓	
Radio Balises			✓	✓	✓	
Ground - Train Communication			✓	✓	✓	✓
Magnetic Induction						
Transponders Powered by Induction				✓	✓	
Local Data Bus						
Onboard Data Transmission		✓		✓	✓	
Radar Frequencies						
Speed Measurement				✓	✓	
Fault Tolerant Informatics						
Fail-safe Computerised Equipment		✓		✓	✓	
Public Data Networks						
Internet	✓	✓	✓			
Booking and Billing Services	✓	✓				
Freight Tracking	✓	✓				
Local and Wide Area Computer Networks		✓	✓	✓	✓	
Simulators (Software and Hardware)						
Personnel Training					✓	✓
Speech Recognition and Synthesis						
Automatic Information System			✓	✓		
Image Analysis						
Real Time Processing of Data			✓	✓	✓	
Smart Cards						
Contactless Technology	✓	✓				✓
Real Time Processing of Data	✓	✓				✓

5. APPLICATION OF NEW TECHNOLOGY IN MARITIME TRANSPORT

5.1 INTRODUCTION

In order to understand what motivates the application of certain technological developments in the maritime industry it appears wise to give a short description of the industry as we find it today.

We are, first of all, dealing with an environment of professionals in which there is, nevertheless, concern over the maintenance of sufficient professional skills overall. This is because not in all countries of the world are standards of training up to the level that is required for present-day or future seamanship. Also, even in countries that maintain these high standards there is awareness of the fact that increasing traffic intensities, resulting from a global economy in high gear, will put ever increasing demands on personnel that have to be met in some way. It is hoped that new means of supporting the mariners' task will take away at least some of this pressure on personal levels of skills.

The second significant factor underlying much of what is going on in the sector is intense global competition, forcing ship owners to look for maximal cost-effectiveness — personnel reduction in particular — to which new technology might contribute.

The third factor to be mentioned is concern over negative effects, with particular reference to safety and pollution. So many disasters at sea have happened in recent years, leading to either considerable loss of life or to extensive pollution of waters and shores, that there is now a general attitude among the public as well as among administrators that nothing of the kind should be allowed to happen again. Technology should at least provide part of the solution in this respect.

Finally, there are the external technological developments that appear to be applicable to maritime operations. By this we mean technology that, though not specifically developed for maritime applications, proves to be 'naturally' useful there as well.

The overall picture of the industry thus is that it is very much on the look-out for solutions that reduce (labour) costs on the one hand, while on the other hand trying to comply to the demand for safer operations. The present contribution identifies and describes some of the ways in which the industry is resorting to technological developments in order to reach such solutions.

5.2 NAVIGATION SUPPORT

Traditionally, navigation — bringing a vessel to its destination by checking at a chain of consecutive intermediate locations, or waypoints — was an autonomous activity executed aboard ship. The information required to answer the question: "Where am I?" was collected by own observation, and then referred to a paper map in order to check whether this was indeed the location at which one intended to be. There was then sufficient assurance that the next leg of the voyage could be undertaken. Preparations for the next part of the journey, i.e. determining how to proceed to the next waypoint, were then started.

This picture has changed considerably, and will continue to change in the foreseeable future, because of the availability of technology permitting more assured operation in all stages of the navigation process.

5.2.1 GPS

Satellite-derived positioning has replaced the traditional astronomical or dead-reckoning means of determining the present location of the ship. Within this domain there is another important development taking place at this moment. While in the earlier days of GPS the accuracy of the location fix was not sufficient to manoeuvre in confined waters (e.g. harbour and archipelago navigation, berthing) or under unfavourable weather conditions, this is increasingly becoming possible because of the availability of differential GPS (DGPS). Accuracy has already improved from about 100 to about 15–25m, and is expected to increase one step further (down to a few metres) when the military precise positioning system (PPS) of the GPS satellites will be released for civilian use. The navigation process per se is thus seen to gradually move into, and touch upon, the areas of manoeuvring and collision avoidance.

It is evident that the increased accuracy of GPS-based location systems, as compared to traditional means, warrants certain positive expectations with respect to its effects on safety. On the other hand it may also be the case that mariners change their behaviour exactly *because* of the availability of improved navigation aids in ways that are not always beneficial to safety. For example, cases have already been reported of so-called GPS-assisted groundings of ships, occurring because the availability of very accurate GPS information induced a shortcut in route choice leading into terrain that, despite the support, still proved too difficult to navigate (Nijjer, 1993). This is a reminder that users of whatever means of support offered may choose to trade a potential gain in safety for what they rightly see as a potential gain in the efficiency of the primary operation.

In a similar vein it has been observed (Pfeiffer, 1993) that it is paradoxical but true that the greater precision of position determination is in itself one of the main causes of the enormous increase in traffic density and thus of the potential risk of collision. Whereas, in the past, shipping traffic spread itself out over a wider area simply because position determination was less precise, nowadays traffic becomes concentrated on an extremely narrow lane. This not only makes overtaking difficult but also reduces the room for manoeuvring available for an avoiding action in case of another ship approaching.

5.2.2 Electronic charts

While paper maps are legally still the primary means of supporting navigation in waters with which one is unfamiliar, electronic chart displays are on the rise. IMO (the International Maritime Organisation) is presently discussing four different types of equipment in this area (Beattie, 1995). These are the video plotter, the electronic chart system (ECS), the electronic chart display and information system (ECDIS), and the rasterscan chart display system (RCDS).

Video plotters were originally used for fishing, and were later introduced for pleasure craft. They do probably not really form part of the discussion for merchant ships.

The acronym ECS describes a wide range of equipment varying in complexity. The element they have in common is that IMO has defined an ECS as not equivalent to the paper chart. In their most advanced form, known as ECDIS (Electronic Chart Display & Information System) these will not just be passive displays, but they will actively issue warnings for real and potential dangers that they ‘know’. The most significant of these is to provide an alarm when the vessel approaches a depth of water that equals the draft of the vessel. Apart from this it will permit at least the following functions to be executed:

- automatic planning of the route to be followed to the next waypoint after clicking on the desired position on the map;
- automatic and continuous display of the ship's position;
- making deviations from the desired course apparent upon request;
- deriving estimates of time/distance to go.

The electronic information in the device will be frequently, and automatically, updated by INMARSAT satellite. The costs of this will be much lower than the (annual) correction and renewal costs for the paper sea chart. The Rasterscan Chart Display System (RCDS) is one particular developing technology that will permit this to be done easily.

It is to be expected that ECDIS-like systems will become the primary navigation support within the next decade or so (despite some are arguing that navigation, particularly in confined waters, should be based on numerical rather than cartographic information: e.g. Weeks, 1993). It is probably best to see them as permitting entirely new forms of support rather than as simple replacements of the paper map. Moreover, the system is flexible enough to be applied to fields other than navigation, including the monitoring of marine resources, offshore surveillance, and the management of maritime traffic and shipping movements. Given that this is the case it becomes then extremely important to be able to predict how users will employ these supports before they are actually implemented.

Superimposition of radar information (see section 5.3) will presumably result in even more capabilities added to electronic charts that are relevant to safety and efficiency.

5.2.3 Intelligent autopilots

Autopilots are widely used aboard modern ships as a means of keeping ships on a pre-set course. Originally, they contained a simple algorithm that exerted a force on the rudder that was proportional to the ship's momentary deviation from an ideal course. However, more sophisticated control algorithms are presently being developed, and they can be expected to become implemented within the next decade. These come under the heading of 'adaptive', 'self-tuning', 'fuzzy-logic' and 'self-organising' control, which makes them capable of encompassing ship dynamics and sea state disturbances on a moment-to-moment basis (Sutton et al., 1996; Witt et al., 1994). Much as in the process industry, therefore, we will see more reliance on automation, at the expense of traditional skills.

5.3 MANOEUVRING AND COLLISION AVOIDANCE SUPPORT

As may be apparent from the previous paragraphs, the line that exists between navigation in open waters and manoeuvring in confined waters is gradually being extinguished because of the availability of very accurate position providers. However, there is still the issue of manoeuvring with respect to other traffic, in particular, of avoiding collisions with such traffic.

5.3.1 Advanced ARPA

An Automatic Radar Plotting Aid presents a display on which the position of the own ship is indicated relative to position of other ships. This representation is in vector form. ARPA is a standard provision aboard modern ships. However, technological improvements are envisaged that entrust it with even more power than it has presently. These improvements / additions are discussed below.

Superimposition

In the past attempts have been made to integrate typical sea chart information into the radar image. The opposite is being attempted now. The superimposition of radar information on ECDIS-displays produces a complete picture of the geographical surroundings as well as of the surrounding traffic. The positions of all objects detected by the radar are thus displayed relative to the own ship's position in a 'natural' way. There now exists a possibility of direct comparison for all objects which appear on both the sea chart and the radar.

Figure 1 shows how this is to be imagined (from Pfeiffer, 1993).

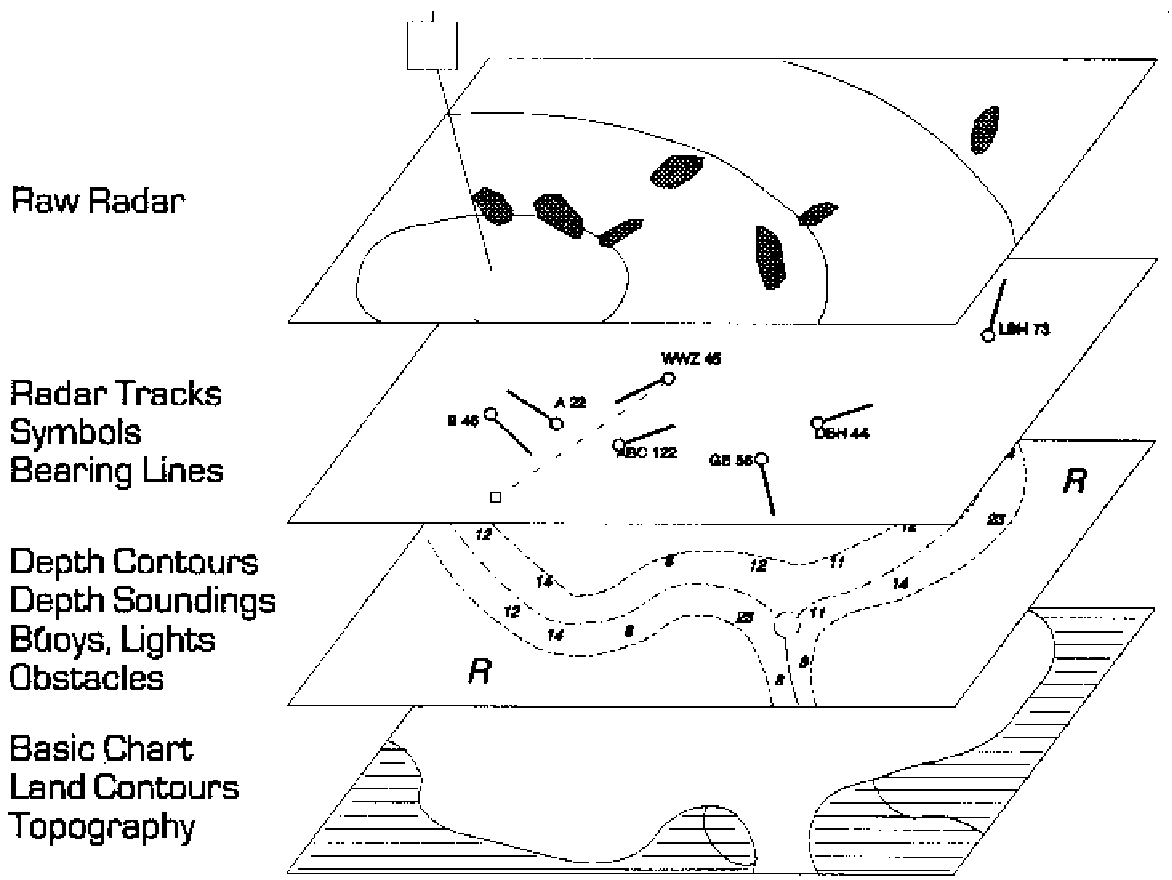

Figure 1: Multifunction display: Electronic Chart (ECDIS) multi layer structure with superimposed radar and track data signal (from Pfeiffer, 1993).

Of importance to the user, the officer of the watch, is that, when the superimposition would be in order, he would never have to leave his surveillance station for work involving the (sea) chart. Two of the essential elements of navigation, namely position-monitoring and collision avoidance, are now combined in a single display.

Sophisticated path prediction tools

These are more or less the mirror image of the advanced tools for intelligent autopilot control that were mentioned in the previous paragraph.

How an advanced navigator display might look is shown in Figure 2 (from Heikkilae, 1996). The display format is basically a ship's outline presented continuously on a digital chart on the correct scale with information on the history of the motion and a display of a prediction of the ship's future sweep. The paths of the extreme points of the vessel both to starboard and to port from the present position to the predicted position are also displayed. The prediction also shows the turning motion, which has never been done in current displays.

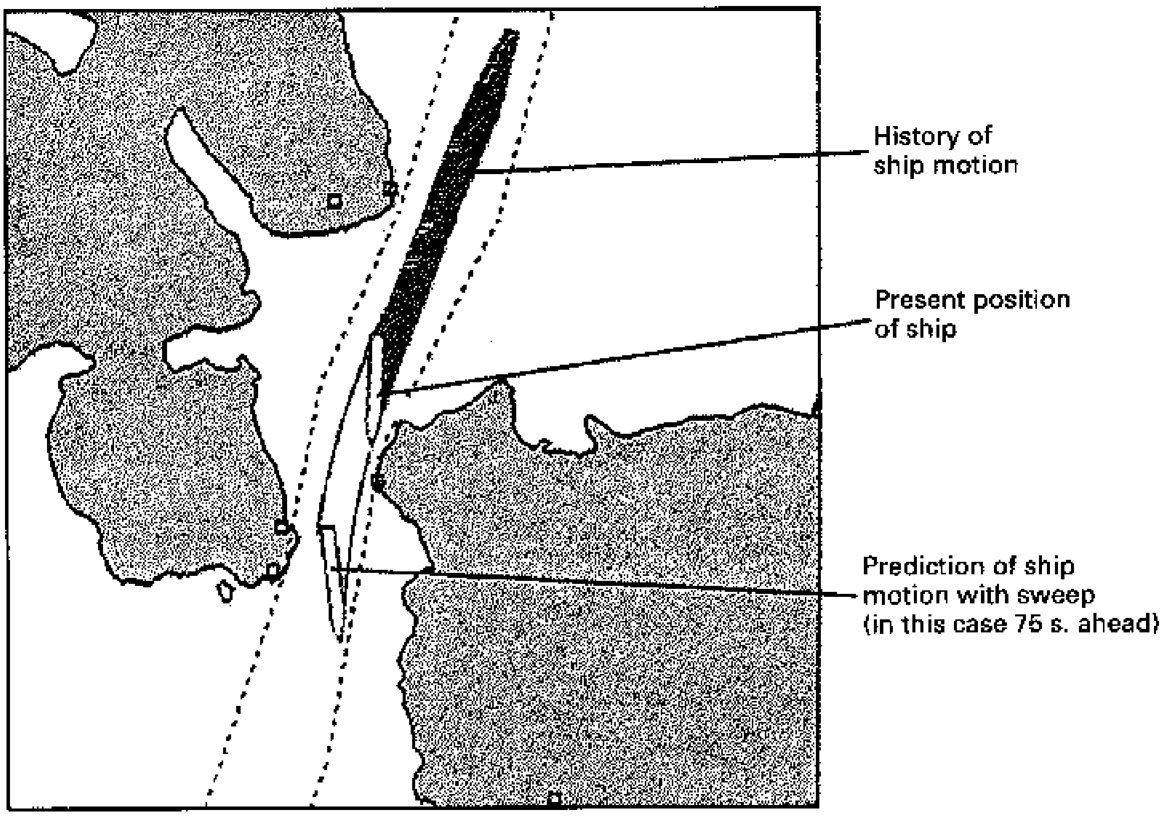

Figure 2: Ship path prediction (from Heikkilae, 1996).

It has been shown (van Breda and Schuffel, 1988) that this type of tool has very favourable effects on performance, in terms of accurately tracking an intended course, compared to conventional procedures (parallel indexing, ground speed vector indication).

It is the reliance on radar that may impose a natural limit on what can be accomplished by (advanced) ARPA. Because every individual ship has to find out about every other individual ship by this means the question naturally arises as to whether it is conceivable that a supervisory intelligence can be designed that takes care of all individuals, for the benefit of the whole: this leads to the developments discussed in section 5.5.

5.4 INTEGRATED BRIDGE SYSTEMS

Although it is not so much a new technology as a new concept that makes use of existing, or possibly redesigned, technology IBS (Integrated Bridge Systems) should be mentioned here. The aim here is to present all displays and controls on the bridge in such a manner that OMW (One-Man Watch) can be performed, at least under normal circumstances. Several of the developments that have been described previously will actually form part of an integrated bridge. In one prototype implementation (INA, 1996) the integrated bridge consists of no more than four workstations:

- The navigation workstation, containing ECDIS as well as ARPA radar, and an adaptive autopilot.
- The navigation planning station, which can work both online and offline from the main ECDIS.
- The communication station.
- The manoeuvring station.

The design of integrated bridges will require human factors knowledge in the broadest sense.

5.5 TRAFFIC MANAGEMENT SYSTEMS

Instead of letting each ship decide for itself when and where it goes attempts could be undertaken to exert some external influence on this decision. This could range from just presenting relevant information to providing information when asked to explicitly prescribing the ship what to do. New technology permits almost a free choice from this range of alternatives.

5.5.1 VTS, VTIS, VTMS, MTC

Vessel Traffic Services, Vessel Traffic Information Services, Vessel Traffic Management Systems, and Marine Traffic Control are different existing or prototype systems that provide the 'supervisory' function over individual ships that was mentioned earlier. Their development is seen as one of the major activities included in the European transport network (Tytgat, 1995). Naturally, they will most often be found in extremely busy or confined waters, and along inland waterways. Although their primary aim has been to guard safety they are now also seen as potentially contributing to efficient flow (minimal travel times). They will then resemble the control centres as we know them in road traffic.

Most VTS in the world until now have been radar-based, but in the future DGPS-based VTS will be set up. Such systems rely of GPS for positioning and a communication link to transmit the information to a control centre.

The central question with regard to information and/or control centres is whether they should actually be allowed to exert control over ship movements, or whether their role should be more of an informative one. Although this is most often treated as a legal matter it appears to be of the utmost importance to assess this question from a human factors viewpoint, that is, by analysing whose tasks will ultimately be alleviated in what ways.

5.5.2 Transponders

Transponder technology will be the core around which maritime traffic control centres, whichever form they may have, will be developed. Two types of transponders have been tested (Heikkilae, 1996). These are the DSC VHF transponder and the Ship-Shore Ship-Ship (4S) transponder. The DSC transponder, when interrogated, provides basic ship identification, position, course and speed data to receiving stations on shore and to other ships. The 4S transponder, developed in Sweden, is able to automatically broadcast full ship-reporting data and short messages, in addition to basic ship identification, position, course and speed, at high data and repetition rates. It has the potential to provide much more information about a ship, and to perform other functions.

It is a matter of further investigation what information these transponders should contain, and what part of this should be subject to active interrogation only. This is not a purely technical matter, because it should be remembered there is an operator in the traffic centre who should be capable of managing the information that is simultaneously obtained from a number of transponders (cf. ATC operators). Operator constraints would pose a limit to what use traffic control centres can make of information broadcast by transponders.

The availability of transponders may, alternatively, result not in more power to traffic control centres, but in a renewed independence of ships to arrange their own affairs. That is, if each and every ship continuously makes its particularities known to all who are in the surroundings this may create new possibilities for traffic to regulate itself. There is even the view that information from transponders may be used to be applied within a new system of collision avoidance rules tuned to these new conditions, replacing the existing COLREGS (Crichton and Redfern, 1996).

It is interesting to note that transponders are also virtual ‘black boxes’. The information that they send, if properly recorded, presents an impartial picture that can, for example, be used for accident analysis purposes. The fact that it is virtual is an advantage compared to ‘real’ black boxes, which may never be recovered in case of an accident.

5.6 SUMMARY

Revolutionary developments are underway that will change the maritime industry in ways that it has never experienced before. It is too early to say to what degree the expected benefits of these developments on safety and efficiency will indeed materialise. One reason for this, apart from those already mentioned, is that some of these developments proceed independently from each other, although it is clear that they will have to interact at some point. For example, while there is still technology being developed that strengthens the position of the ship as an individual decision-taking entity there are simultaneous developments towards taking this power away. Much of these contradictory activities will have to be resolved by analysis and research leading to insights into what is best for the system, rather than by a priori or legalistic reasoning.

6. APPLICATION OF NEW TECHNOLOGY IN PUBLIC TRANSPORT

6.1 INTRODUCTION

An effective integration of individual transport modes and public transport operations is essential for the future development of transport services. The main elements of this integration — taking into account expected technical possibilities in a 10-20 years perspective — is the construction of interconnecting transport infrastructure, and bringing together all the public transport modes into a common operating environment. The European Commission Green Paper defines as the three most important parts of an integrated system: coordinated timetables, through-ticketing and multi-modal terminals.

The Transport Telematics Programme (1992-94) of the European Commission gave high priority to developments and deployment within the public transport area. The main focus of the work has been:

- database development for systems integration and planning, under the general area of 'information management,'
- vehicle scheduling and control systems,
- vehicle priority systems,
- passenger information systems and
- demand responsive ticketing systems.

This chapter follows the structure of the work in the Transport Telematics Programme, putting the emphasis on two main aspects of new technology application, namely passenger information and ticketing, that approach the question from the needs of the potential user of public transport.

6.2 INFORMATION MANAGEMENT

The efficient management of information is essential for a better integrated and more attractive public transport system. Correct, real time information on the functioning of the multimodal system is a necessary background support.

New technology applied in information management:

- computer modelling
- traffic simulation
- means of real time traffic information collection
- means of communication with the drivers and passengers of public transport vehicles

Projects like EUROBUS, PHOEBUS, GAUDI has developed and tested data management models in the Third Framework Programme, and further development and harmonisation of the program outputs can be expected.

6.3 PUBLIC TRANSPORT VEHICLE SCHEDULING AND CONTROL

Vehicle scheduling and control systems attempt to optimise the operation by switching vehicles between routes, integrating schedules for a group of routes, and incorporating special journeys. They are used to provide operational support to public transport operations by providing continuos real time location of the vehicles within the system. New development in information technology provide more efficient ways to carry out this function and the operational effectiveness of vehicle scheduling and control systems can be improved further through the addition of artificial intelligence and knowledge-based techniques.

New technology applied in vehicle scheduling and control:

- GPS
- transponders
- vehicle identification techniques
- computer models

Experiments with public transport vehicle scheduling and control systems have been carried out in Bologna (GAUDI), Hasselt and Brussels (PHOEBUS) and in some other European cities. Wider, inter-modal applications are needed in the future.

6.4 PUBLIC TRANSPORT VEHICLE PRIORITY

Priority for public transport vehicles, especially in an urban environment, can improve the efficiency and attractiveness of public transport. Projects within the Transport Telematics Programme implemented public transport priority schemes in London, Turin, Gothenburg and other cities, using bus transponders, inductive loops or radio communication.

New technology applied in public transport vehicle priority:

- radio communication
- transponders
- GPS

The technology and strategies for public transport priority are now tested and ready for implementation on a basic level. Priority strategies for more complex situations need to be developed and implemented in the future.

6.5 PASSENGER INFORMATION

The objective of passenger information is to provide public transport users and potential users with necessary information in order to improve the attractiveness and convenience of public transport as an alternative to the private car, and provide travellers with a “seamless journey”. New data processing and transfer technology makes data exchange between different travel modes possible, and information can be disseminated via many channels, according to user needs and preferences.

Information on public transport schedules, travel time, network, fares, interchanges, etc. can be given in different public and individual means. New technology makes it possible that information is real time, correct and fits the individual demand.

New technology applied in passenger information:

- data exchange between different travel modes,
- multi-modal trip planning systems,
- public information terminals
- information dissemination via radio, teletext, internet, etc.

Systems have been developed and implemented in several areas of Europe within different DRIVE projects (EUROBUS, PHOEBUS, QUARTET, PROMISE, etc.). Passenger information systems of different level of sophistication function in many towns of different countries in Europe.

According to the UK 'Informed Traveller' forecast the following can be expected:

1. In 5 years perspective: information published through electronic signs at stops and stations, teletext, radio broadcasts. Enquiries via on-line information services, mobile phones. All modes covered, but not all with real-time information.
2. In 10 years: On-line access in most homes. Real-time information for nearly all services on all modes.
3. In 20 years: Intelligent exception reporting services (alerts relevant to your specific journey) available as well as general enquiries. Frequent traveller discounts, ticket prices vary daily according to demand. Most people subscribe to travel and traffic information services.

6.6 SMART-CARD TICKETING

The objective of smart-card ticketing systems is to make fare collection simpler and more comfortable for passengers, and allow more flexibility in public transport fare policy according to requirements of demand management in the overall network. Additional information on customer trips and their preferences for payment may also open the way to offering customer loyalty schemes and a better understanding of the customers needs.

Electronic fare collection by smart cards is set to replace traditional paper tickets for public transport. Credit-card sized and a powerful micro-processor, smart cards can be an electronic purse, allowing rapid, non-stop payment in public transport. Operators benefit, too, from quicker transactions.

Integrated payment becomes possible by smart card technology, i.e. secure open electronic payment or the sharing of a common payment mechanism between different operators in order to offer the passengers convenient way to pay for journeys which may involve travel on the vehicles of more than one operating company, or even more than one travel mode (bus, train, boat, metro, airline, etc.).

New technology applied in fare collection:

- smart cards with contacts
- hands free card wallet
- smart card with transponder
- contactless smart cards

Several EU projects develop and test smart cards. Cities, like London, Tampere, Turku and Helsinki have embarked on projects to introduce smart-card ticketing throughout their public transport network. An experiment in Paris and its region has been started in 1997, covering regional railway, subway, tram, automated light rail and bus systems. Contactless pass has been developed in a cooperation of Paris, Lisbon, Venice and Constance in the framework of the European ICARE project. Wide implementation can be expected in the near future.

According to a UK forecast the following can be expected:

1. In 5 years perspective: Smart card for travel services used by a minority of regular travellers across a single mode.
2. In 10 years: Travel smart cards used by the majority of regular travellers covering most of the modes.
3. In 20 years: Everyone either pre-pays for trips, pays during the trip via cashless transactions, or pays post-trip by monthly account.

7. CONCLUSIONS

Expected applications of new technology in the road- air-, rail and maritime transport have been reviewed in the previous chapters. Although there is some development in the area of new materials, especially new energy sources for transport, the main area of expected development is based on new possibilities of information acquisition, -processing and dissemination. There are several parallel developments in the road-, rail-, air and maritime sectors of transport, and the importance of integrated, intermodal transport of passengers and goods will bring the different transport modes closer in the future.

The present report approaches new developments in transport in two different ways. First, from the point of view of expected new functions/applications. This is the main approach of the previous chapters. Second, from the point of view of new technologies. A list of new technologies that are predicted for implementation in some or many transport areas is presented here, indicating which transport areas are going to use them in the near future. Most of the technologies in the list cover many related technological possibilities, not only one specific technology.

Technologies	**Transport area(s) of implementation**			
new sensor technology	road,	air,	rail,	maritime
image processing	road,	air,		
speech recognition and synthesis	road,	air,	rail,	maritime
Global Positioning System	road,	air,	rail,	maritime
new visual information systems	road,	air,	rail,	maritime
new radio information systems	road,	air,	rail,	maritime
new transponder technology	road,	air,	rail,	maritime
smart card technology	road		rail	
computers in vehicles	road,	air,	rail,	maritime
new displays in vehicles	road,	air,	rail,	maritime
new communication links	road,	air,	rail,	maritime
public information centres	road,	air,	rail,	maritime
internet as information source	road,	air,	rail,	maritime
simulators as training tools	road,	air,	rail,	maritime
real time data collection	road,	air,	rail,	maritime
real time data processing	road,	air,	rail,	maritime
real time data dissemination	road,	air,	rail,	maritime
electronic charts	road,	air,		maritime
radar technology	road,	air,	rail,	maritime
laser technology	road,	air,	rail,	maritime
computer hardware developments	road,	air,	rail,	maritime
computer software developments	road,	air,	rail,	maritime
automation	road,	air,	rail,	maritime

8. APPENDICES

8.1 THE PRESENT SITUATION IN SOME CENTRAL AND EASTERN EUROPEAN COUNTRIES

8.1.1 Hungary

Hungary has an ambitious programme for constructing new motorways and highways in the 1990s and into the 21st century. In 1994, the Ministry of Transport, Communications, and Water Management completed formulating its ‘Hungarian Concept of Transportation Policy’, whose strategic elements are to: (1) promote integration with the European Union; (2) promote balanced regional development and more efficient transport in Hungary; (3) protect life and the environment; and (4) regulate traffic efficiently.

The document on the transportation policy of the Hungarian Government is underlining the necessity of adapting telematic applications as well as of joining the European R&D activities in this field. Significant efforts have been made to apply state-of-the-art techniques in road management. There are numerous ongoing projects, as well as local initiatives (new technologies being applied by the different county road administrations), such as MARABU (Management of Road Traffic around Budapest), weigh-in-motion, ice control devices in the town Zalaegerszeg, meteorological and signal control systems in the county of Nógrád etc.

The intention of road authorities is to involve the police, ambulance and weather forecast staffs. The most important aim is to provide as quick information as possible. There should be an indirect link between those collecting and processing the information and the users of information.

A new system called IKIR (traffic management and information system) is being developed in the framework of US federal financing. The project began in March 1997, with the aim to co-ordinate the different techniques already in use. IKIR will be based on real-time information for congestion control, route guidance, travel time estimation, etc. A GPS system will be used for automatic vehicle identification. Roadside information (through radio: RDS-TMC) and variable message signs are parts of the system. Loop detectors + TV will be used along the M0 and M7 motorways; standards will be set up by the Ministry of Transport.

Another proposal has also been made to create a real time traffic monitoring system (IATMS/AHOF). Its goal is the development of an on-line, real time traffic monitoring system for decision makers, based on actual traffic data. A preliminary congestion warning system was put into service in August 1988, on the M7 motorway between Budapest and Lake Balaton on a critical upgraded section of the M7. Congestion decreased there, and traffic became homogeneous and calm. Traffic safety improved and noise was reduced. The system aimed to adjust traffic flow to unusual circumstances, appeal to all drivers, and provide information and recommendations for drivers outside their vehicles. This pilot system is now outdated and should be updated and extended. The new control system will provide adequate congestion warnings and gradual speed regulation, with the aim of keeping traffic flow stable for as long as possible. The automatic traffic management system for the M0 aims to: (1) ensure optimal flow of traffic bypassing Budapest; (2) improve the capacity utilisation of the road network connecting with the M0; (3) optimise the distribution of traffic to different parts of Budapest.

8.1.2 Romania

According to a study-programme made by the National Union of Road Hauliers from Romania, it is necessary to show a permanent concern for the modernisation of the present transport technologies and for the use of the new transport technologies and of goods manipulation (combined traffic, RO-LA, RO-RO, logistics, etc.);to increase the efficiency of the transport activity, by the use of telecommunications, informatics and the increase of the quality of services; to train the managing staff, through management programmes, with the help of the international organisations, using forms and methods of training at the level of the requirements of the year 2000.

8.1.3 Slovenia

Special attention is devoted to improvement of the control of traffic lights which should reduce congestion at busy intersections and within the city transport network in general. Dynamic control system are used, based on real time adaptations to the actual density of traffic. The level of dynamic operation is controlled by various parameters. The development and research work in the field of automated traffic control relies on computer models for the optimisation and simulation of traffic (HCS, HCM CINEA, TRAFNETSIM).

The Traffic Technical Institute at the University of Ljubljana was one of the first developers of integrated systems for traffic engineering. These models are based on the connection of existing traffic models with geographical information systems. A complex integrated system called UTCS-GIS has been developed, which is employed to collect, edit and process data about the traffic volume and the elements of the road network and intersections, and also to plan the traffic, improve the system of traffic lights, simulate traffic, improve safety on the roads and graphically present the results.

A system for automated toll payment (ABC) is being developed, which is based on a microwave read/write connection between equipment installed along the road and inside vehicles. Once European standards are introduced, the system will be upgradable so that it can operate with free traffic flow.

In the PROVAGIS project the technology of geographical information system (GIS) served as the basis for the computer system used for assistance in the decision making process related to measures undertaken to improve safety on the roads. The research work connected with the Geographic Information Systems concentrates on the possibilities of using these systems for the modelling of traffic and their integration with existing transport models.

8.1.4 Poland

Radical economic reforms in Poland since 1990 have had important impacts on transport. Increased political and economic freedom, access to Western consumer markets, reductions in government subsidies, increases in public transport fares and service cutbacks have led to a striking modal shift away from public transport to the automobile. Increased auto use and the deterioration of public transport are causing serious social and environmental problems such as air pollution, noise, congestion, traffic accidents, and reduced mobility for the poor. Although minimal government involvement may be appropriate in other economic sectors, the government must intervene in urban transport to correct for many important external effects. Simply leaving transport to the private market seems certain to end in excessive auto use and such deteriorated public transport systems that irreversible damage would be done to Polish cities.

Poland is an important transit area for traffic between several other European countries, including Germany and Russia. Thus the Polish road system, and especially the Polish sections of international roads, are very important for the development of transport in Europe. There are over 365,000 km of roads in Poland, including 45,600 km of national roads and 52,200 km of roads in urban areas. The highest traffic volume has been observed on three international roads and especially across the border with Germany. Traffic growth is also high around large urban areas. Special methods have been adopted to maintain an acceptable standard of roads. National investment and modernisation programmes have recently been developed and implemented, aiming to upgrade the Polish road network to meet the continually increasing demands of European economic integration. The Polish road network development programme is based on extensive studies of a model of the future road network.

Transformation of the Polish economic and political system has caused changes in the organisation of the road administration system, which resulted in decreased employment and introduction of the free market. To overcome the decline of the road maintenance budget which also affects winter maintenance, road administration in Poland has begun to improve and develop the winter road management system. Activities include the following: wide-range implementation of computers on all levels of road administration; development of computer programs to assist winter road management and modernisation of the road weather service system. In addition, preparations for implementation of new technologies in de-icing, not used in Poland yet, have been started.

8.1.5 The Former Soviet Union

Today, there are six republics (in order of area size): Russia, Ukraine, Belarus, Lithuania, Latvia and Estonia. The total area is about 3.1 million square km and population over 140 million. Vehicle ownership levels vary from 25 to 170 cars per 1000 population. The highest values are found in the Baltic Republics. The transport system was earlier mainly based on railways. Waterways played an important role, as well. It is estimated that there will take place a drastic change in transportation systems with a rapid growth of car fleet and new modal split. Market economy and new tariff systems will renew the whole field of transportation. The economical problems have reduced the number of air passengers. The change in freight transport work will mean a drop of the transport work of railways. Road transport will be more important both in passenger and freight sectors.

8.2 SOURCES OF INFORMATION

8.2.1 Road transport

Relevant projects

ASSIST/ROADSTER (Anti-collision Autonomous Support and Safety Intervention System)
APPLICATION: Driver assistance (Collision avoidance by warning and emergency intervention)
EC financed project (DG XIII) within the 4th Framework Programme.

ADEPT II (Automatic Debiting and Electronic Payment for Transport II)
APPLICATION: Public Transport (Electronic Ticketing Systems)
EC financed project (DG XIII) within the 4th Framework Programme.

AUSIAS (ATT in Urban Sites with Integration and Standardisation)
APPLICATION: Inter-urban (Regional Traffic Control Centres**).**
EC financed project (DG XIII) within the 4th Framework Programme.

CAPITALS (Capitals' Project for Integrated Telematics Application on Large Scale)
APPLICATION: Urban Traffic Management and Control, Urban demand management and Inter-urban (Regional Traffic Control Centres).
EC financed project (DG XIII) within the 4th Framework Programme.

CHAUFFEUR
APPLICATION: Inter-urban (Electronically linked trucks on motorways)
EC financed project (DG XIII) within the 4th Framework Programme.

CLEOPATRA (City Laboratories Enabling of Particularly Advanced Telematics Research Assessment)
APPLICATION: Urban (Route guidance, parking guidance, incident effect prediction, etc.)
EC financed project (DG XIII) within the 4th Framework Programme.

CONCERT (Cooperation for Novel City Electronic Regulating Tools)
APPLICATION: Urban (Urban Traffic Management and Control, and Urban demand management); Public Transport (Electronic ticketing systems)
EC financed project (DG XIII) within the 4th Framework Programme.

COSMOS (Congestion Management Strategies and Methods in Urban Sites)
APPLICATION: Urban (Urban Traffic Management and Control)
EC financed project (DG XIII) within the 4th Framework Programme.

DACCORD (Development and Application of Co-ordinated Control of Corridors)
APPLICATION: Inter-urban (Dynamic traffic management system for inter-urban motorway corridors)
EC financed project (DG XIII) within the 4th Framework Programme.

ENTERPRICE (Enhanced Network for Traffic Services and Information Provided By Regional Information Centres in Europe)
APPLICATION: Urban (Urban Traffic Management and Control);

Inter-urban (Regional Traffic Control Centres);
Driver assistance (Collision warning avoidance);
Public Transport Priority.
EC financed project (DG XIII) within the 4th Framework Programme.

EUROSCOPE (Efficient Urban Transport Operation Services Cooperation of Port Cities in Europe)
APPLICATION: Urban (route guidance, network management) and Public transport (multi-modal trip planning terminals)
EC financed project (DG XIII) within the 4th Framework Programme.

FORCE/1 (Enhanced Field Projects for Large Scale Introduction and Validation of RDS/TMC Services in Europe)
APPLICATION: Demonstration of RDS/TMC service in Europe.
EC financed project (DG XIII) within the 4th Framework Programme.

HANNIBAL (High Altitude Network for the Needs of Integrated Border-Crossing Applications and Links)
APPLICATION: Inter-urban (Traffic management by data exchange, user information, automatic tolling, demand control and automatic incident detection)
EC financed project (DG XIII) within the 4th Framework Programme.

INFOTEN (Multimodal Information and Traffic Management Systems on Trans-European Networks)
APPLICATION: Inter-urban (Multimodal communication between different countries and regions, roadside and in-car information systems).
EC financed project (DG XIII) within the 4th Framework Programme.

MASTER (Managing Speeds of Traffic on European Roads)
APPLICATION: Urban and Inter-urban (Demonstration of speed management methods and tools in different traffic environments)
EC financed project (DG VII) within the 4th Framework Programme.

PROMISE (Personal Mobile Traveller and Traffic Information Service)
APPLICATION: Public transport (Mobile multimodal travel and traffic information services)
EC financed project (DG XIII) within the 4th Framework Programme.

QUARTET PLUS (Validation of a European Urban and Regional IRTE based on Open System Architectures)
APPLICATION: Urban (Demonstration on integrated road transport informatics)
EC financed project (DG XIII) within the 4th Framework Programme.

SAVE (System for Effective Assessment of Driver State and Vehicle Control in Emergency Situation)
APPLICATION: Driver assistance (Detection of driver stateand emergency action if needed)
EC financed project (DG XIII) within the 4th Framework Programme.

SAMPO (System for Advanced Management of Public Transport Operations)
APPLICATION: Public transport (ATT for integrated multi-modal passenger transport services: booking, reservation, information, smart cards, etc.)
EC financed project (DG XIII) within the 4th Framework Programme.

TABASCO (Telematics Applications in Bavaria, Scotland and Others)
APPLICATION: Urban (Urban Traffic Management and Control, and Urban demand management); Public Transport (Electronic Information Systems)
EC financed project (DG XIII) within the 4th Framework Programme.

TROPIC (Traffic Optimisation by the Integration of information and Control)
APPLICATION: Driver assistance (Navigation/route guidance systems; Lane keeping support and Driver and vehicle status monitoring); Inter-urban (Variable Message Signs).
EC financed project (DG VII). The project is in a starting phase.

UDC (Urban Driver Control System Specification and Evaluation)
APPLICATION: Urban (Speed recommendations and autonomous longitudinal control in urban environment)
EC financed project (DG XIII) within the 4th Framework Programme.

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8.2.2 Air transport

Relevant projects

SWIFT: Specification for controller working positions in future air traffic control. (EURET project, completed 1996)

AEGIS: ATM European group for improvement of scenarios (includes GIANTS - Generic integrated ATM and networks scenario) (EURET project, completed 1996)

PHARE: Programme for harmonised ATM Research in Eurocontrol. Planning for 2015. (EUROCONTROL project 1989 - 1998, but EURET projects SWIFT, AEGIS and EURATN results have fed into PHARE)

CINCAT: Capacity increase through controller assistance tools. (Telematics Applications Programme 1994 - 1998. DGXIII)

ADORA: Analysis and definition of operational requirements for ATM (Air Traffic Management) User requirements... (DGVII Transport RTD programme, 1996 - 97)

FACTOR: Development of functional concepts from the EATMS Operational requirements (assessment criteria and methodology) (DGVII Transport RTD programme, 1996 - 97)

SECAM: Safety Efficiency and Capacity of ATM systems (methodologies for assessment that could then be used to assess to impact of new systems) .

RHEA: Role of the human in the evolution of ATM systems. Automation strategies, safety, efficiency, satisfying jobs for air traffic controllers, automation assistance tools, intervention levels... (DGVII Transport RTD programme, 1996 - 97)

CASCADE: Contribution for assessment of common ATM development in Europe. Including a survey of validation tools. (DGVII Transport RTD programme, 1996)

ECOTTRIS: European Collaboration on transition training for improved safety. Automation impact on airline crews, training implications. (DGVII Transport RTD programme, 1996 - 98)

GORAC: GCAS Operational requirements and certification. Ground collision avoidance system-new MMI. (DGVII Transport RTD programme, 1996 - 97)

FANSTIC II: Future ATM, new systems and technologies integration in cockpit. (IMT - Industry Materials Technologies project 1996)

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8.2.3 Rail transport

Relevant projects

ERTMS (European rail traffic management system
The European system for the management of rail traffic constitutes an integrated project, which includes many tasks concerning the system of command control of rail traffic.

EUROSIG (Development of the complete ERTMS concept)
The main objectives are the demonstration of the technical feasibility of the ERTMS System concept, including main critical subsystems, and the establishment of a common approach for the assessment of system safety

Users specification of the complete ERTMS
The project addresses the full range of preparations activities leading to full scale trial tests of the European Rail Traffic Management System (ERTMS) in a number of pilot sites to be located in France, Germany and Italy.

EMSET (Functional eurocab component validation on the Madrid Sevilla line)
The objective of the EMSET project is to perform the preparatory activities conducive to a full-scale functional validation of the on-board European Rail Traffic Management System (ERTMS) sub-system.

ACRUDA (Assessment and certification rules for digital architecture)
The project aims to the definition of the assessment framework and criteria for safety architectures used in the guided public transport industry; and to the development of a certification scheme for safety architectures.

MORANE (Mobile radio for railway networks in Europe)
Based on existing systems, the project will support standard European rail management applications and be extended to multimedia services for passengers.

ETCS-VB (Customisation and Tests on Site for the ERTMS/ETCS Level 1 Pilot Installation Vienna-Budapest)
The project ETCSVB has the main objective to set in place a pilot installation of the ERTMS, Level 1, on the Vienna-Budapest line.

REMAIN (Modular system for Reliability and Maintainability Management in European rail transport)
The REMAIN project aims to conceive practical and realistic methods for evaluation as RAM (Reliability, Availability and Maintainability) in railway system.

ROSIN (Railway open system interconnection network**)**
The ROSIN project seeks to develop interconnection between equipment located inside a single railway vehicle or in different train vehicles, by means of a standard digital communication network.

TWIN (Technologies for Wireless Interconnection of Mobile Networks)
The TWIN project concentrates on the wireless segment, specifically on the radio transmission link, and will investigate the interconnection of mobile sub-networks (mobile platforms carrying users of data, voice and possibly video services communicating with the outside world through access points that are concentrated onto a single radio mobile interface node) to fixed networks (immobile communication network with multiple access points) through this transmission medium.

ICARE (Integration of contactless technologies into public transport environment)
ICARE will implement a comprehensive telematics-based public transport ticket system for areas covered by several kinds of service with more than a single operator.

MARCO (Multilevel advanced railways conflict resolution & operation control)
Traffic conflict detection and resolution on EU railway and metro networks is the focus of MARCO. The project will develop tools, algorithms and technologies for this purpose at top high traffic and mainline supervisory level, the medium level of high traffic areas with complex junctions or stations, as well as local lines, and the end line situation on underground services.

TRIO (Transportation railways innovative optimisation)
The TRIO project is a part of EuROPE: EUropean Railways Optimisation Planning Environment, a project which aims to develop a telematics and software system that provides the Railways with an integrated architecture, made of new development and demonstrator tools to help in easing the massive resource planning problems they face in continuation.

TRIS (Telematic railways information system)
TRIS aims to develop a telematics and software system to support expanding national and trans-European traffic planning needs, focusing on long-term tactical timetabling as well as daily or weekly contingency planning.

WELCOM (West-East logistics corridor for multimodal transport:)
WELCOM is a design study for demonstration of telematics applications on a transport corridor linking Ireland, the Netherlands and Germany towards Poland. It will examine current freight transport user requirements there, as well as telematics needs for freight transport and resource management

VADE MECUM (Vehicle ATT demonstrations, evaluation and monitoring on a European corridor uniting member states)
VADE MECUM is a design study focusing on a regional corridor linking towns, cities, ports and regions across Ireland, the UK and The Netherlands. The study will confront technical, institutional and socio-economic problems in the area arising from commonly encountered user needs in travel and freight operations.

INTER (Integration of networking technologies for harmonising the European railways)
INTER is a feasibility study to develop the principles of an integrated multi-service, multimedia, multi-rate, multi-vendor harmonised European railways communications network. It is intended to combine state-of-the art and more conventional technologies for wide area and local area networks.

IMPULSE (Interoperable Modular Pilot plants Underlying Logistic System in Europe)
The project focus on determining, introducing and recommending focused technical and logistics developments which will result in the increased economic-, management- and technical efficiency of intermodal transport to deliver trans-European freight at lower cost, within a quality framework, while meeting the customers' needs.

FREIA (Towards the networking of European Freight Villages)
The FREIA project aims at facilitating the access of SME's to intermodal transport, and focuses hereby on the establishment of commercially viable relations with freight villages, their services, procedures and infrastructure.

IQ (Intermodal Quality)
IQ stands for intermodal quality, it is aimed at analysing the quality aspects influencing intermodal transport, both of terminals and of network. It will work on the improvement of the interoperability among terminals, the interconnectivity and accessibility in intermodal transport.

AUSIAS (ATT in urban sites with integration and standardisation)
AUSIAS will integrate different urban control and information systems already in existence, in accordance with EU standardisation proposals. At the same time, it will adapt and demonstrate new technologies, also partly developed from earlier EU research.

CAPITALS (Capitals' project for integrated telematics applications on large scale)
In CAPITALS, four EU capital cities will co-operate in the search for telematics-based solutions to their common traffic management and control problems.

CONCERT (Cooperation for novel city electronic regulating tools)
In CONCERT, telematics will be mobilised to test the effectiveness of different ways of boosting public transport in preference to private cars, including price incentives, road-use management, and traveller information.

CROMATICA (Crowd management with telematic imaging and communication assistance)
CROMATICA is concerned with improving safety and efficiency of rail travel. The project objective is to increase passenger capacity and security by using telematics to monitor, detect and implement strategies to improve the management of passengers and railway stations

MOSTRAIN (MOSTRAIN mobile services for high speed trains)
MOSTRAIN aims to ensure that new technologies are able to deliver the services required by passengers, public and railway operators, and other transport and professional radio users in general.

ENTERPRICE (Enhanced network for traffic services and information provided by regional information centres in Europe **)**
ENTERPRICE will focus on developing and setting up of Mobility and Traffic Information Centres with the capability to generate, integrate and provide intermodal traffic information.

EUROSCOPE (Efficient urban transport operation services co-operation of port cities in Europe)
EUROSCOPE aims to develop and demonstrate advanced transport telematics systems across Europe for the benefit of travellers and passengers, transport systems operators and freight carriers. The work will focus on many aspects of smoother transport operations, among them planning, information on timetabling, route guidance and incident management.

GNSS (Global navigation satellite systems support)
GNSS will study the operational requirements for current and future satellite navigation systems in the road, rail, maritime, aviation and survey sectors.

MAGNET-A (Multimodal approach for GNSS 1 in European transport a)
The MAGNET-A project seeks to develop and assess user segment prototypes for prospective users of the Global Navigation Satellite System (GNSS).

MAGNET-B (Multimodal approach for GNSS 1 in European transport b)
Global Navigation Satellite System (GNSS) user segments, along with local area ground augmentations, will be developed and tested for applications which have the most demanding requirements in terms of accuracy and integrity.

INFOPOLIS (Advanced passenger information in European cities)
INFOPOLIS is to enhance the availability and use of telematics-based information on public transport. There will be due regard for its presentation as well as its content including timetables, suggested routes and stop-off points.

PROMISE (Personal mobile traveller and traffic information service)
PROMISE aims to give EU citizens easy access to a mobile multi-modal travel and traffic information service throughout their journey.

VALIDATION OF A EUROPEAN URBAN AND REGIONAL IRTE BASED ON OPEN SYSTEM ARCHITECTURES (QUARTET PLUS)
QUARTET PLUS is pursuing demonstration activities on integrated transport environments (IRTEs) in urban areas.

EUROBUS (European Reference Data Model for Public Transport (Transmodel) and Polis Passenger Information Services (Popins))
The EuroBus Project had the following objectives:
to define a European reference data model for public transport (Transmodel);
to design computer-aided tools for passenger information services (Popins).

TITAN/1 (Transmodel based integration of transport applications and normalisation /1)
TITAN concerns the field of information and communication systems management for Public Transport. It aims at the validation and further development of the European Reference data model for Public Transport operators (Transmodel), designed during previous Research and Development Programmes.

TITAN/2 (Transmodel based integration of transport applications and normalisation /2)
TITAN/2 is an accompanying measure of the TITAN/1 project. It aims at the standardisation through certification procedures geared to adoption by the European Committee for Standardisation.

TRACAR (Traffic & cargo supervision system)
TRACAR is aimed at a common telematics system and standard for the identification, positioning, and management of freight, goods or their accompanying documents when carried by more than one form of transport.

MULTITRACK (Tracking, tracing and monitoring of goods in an intermodal and open environment)

The goal of Multitrack project is to provide a mechanism that allows the end-user monitor the location and status of a cargo throughout the whole logistic chain in an intermodal transport system comprising sea, rail and road transportation means.

INFOTEN (Multi-modal information and traffic management systems on trans-European-networks)
The goal of INFOTEN is validation and demonstration of a multi-modal communication backbone for private and public traffic and transport information service in regions of the southern and eastern area of Europe and a public network of interoperable traffic information centres in the central and northern area of Europe to enhance the results of previous research.

EUROECRAN (European programme for elaboration of competitive railways noise barriers)
The primary objective of the research programme is to develop methodologies as well as design and evaluation tools for railway noise barriers made for this type of infrastructure.

EUROBALT (European research project for optimised ballasted tracks)
The research programme established an experimental designation of the ballasted track and of its interactions with trains and subgrade and to build on this base, using even unconventional analysis methods, a model of the track-ballast-subgrade system, describing its static and dynamic behaviour and its long-term evolution.

Reliability of Advanced High Power Semiconductor Devices for Railway Traction Applications
Power modules in IGBT (insulated gate bipolar transistor) technology are now at the threshold of their introduction to railway traction applications. Owing to the very rigorous operating conditions involved, very high demands are made on the reliability of these power devices: thus they must operate for 35 years without failures. The core of the activities planned for the project consists of the elaboration of accelerated reliability tests, whose scientific basis consists of the failure mechanisms and the corresponding models.

Mise au Point d'un Procédé et d'un Logiciel de Simulation d'un Incendie en Ouvrage Soutérrain
This RDT program aims at setting up a new reliable tool, for the design and optimisation of ventilation in Subways and Railway Tunnels, taking into account the various nocive effects of an underground fire. This tool should help to increase safety and reduce the direct and indirect costs of ventilation.

Transient Aerodynamics for Railway System Optimisation
Objectives of this project are the following:
- develop and validate common scientific databases and methods to study these phenomena and to design optimised solutions;
- prepare guidelines for interoperability based on these data and methods;
design and validate some solutions of wind barriers and tunnel design.

Sound Attenuation by Optimised Tread Brake
The objective of this project is to develop suitable brake block materials, which prevent the build-up of periodic roughness on the wheel running surface. This should be readily applicable to existing freight rolling stock and locomotives without significant extra costs. The aim is to achieve reductions in rolling noise of 5-12 dB compared to traditional cast-iron block brake stock.

Hybrid Composite Structures for Crash Worthy Bodyshells, Containers and Safe Transportation Structures
There is a demand from the railway industry and other transportation sectors for lightweight yet impact absorbent materials to replace metals. This project is needed to provide the enabling technologies to produce safe hybrid composite sandwich panels, modular sections, bodyshells, containers, vessels, and transportation structures with crash worthiness and a predictable failure mechanism. The project will also produce a standard procedure for full-size property prediction using scale models.

Integrated Study of Rolling Contact Fatigue
The project objectives are to develop and validate theoretical models for the prediction of wheel rail contact conditions and rolling contact fatigue under realistic operating conditions. These will enable rail rolling contact fatigue damage to be minimised through the optimisation of wheel rail profiles, rail metallurgy, maintenance strategies and friction conditions between the rail and the wheel.

TRAINOX (Fatigue behaviour of stainless steels for railway carriages in corrosive environments)
The main objective of this project is to determine the fatigue behaviour of several stainless steels that are subjected to corrosive attack.

Guided urban innovative discerned electric system
The aim of the project is to demonstrate that the implementation of a new, efficient and attractive GLT (Guided Light Transport) will also lead to the reduction of traffic in the City Centre through a model shift from the private car to public transport.

EMC measurements in railways
Accurate quantification of electromagnetic interference (EMI) between electric railway traction power supply, drives and signalling systems is necessary to ensure satisfactory systems integration and to prevent interference causing safety and reliability problems. The objective of this project is to provide a set of measurement and testing methodologies for railway rolling stock and its components based on anechoic chamber and vehicle test room.

ARISE (Automatic railway information systems for Europe**)**
ARISE will develop systems that use speech technology to handle automatically relatively simple telephone-based inquiries for rail travel schedule information.

Development of New Technologies for low Noise Freight Wagons
The objectives of the project are the following: develop a number of innovative technical solutions to be applied to existing freight rolling stock, and also to future wagons, allowing to reach, together with a combined action on track, a global reduction of noise emitted by the train/track system by about 10 dB(A).

Flexible Intermodal Horizontal Transshipment Techniques
The project directs to investigate various alternatives and to confirm the validity of the horizontal transshipment for combined intermodal freight traffic; to introduce innovations for the load units improving transport cycle automation; to study the characteristics of exchange points in terms of the best lay-out; to reduce cost break-even for the combined techniques below 200 Km. (today 400-500 Km.) , to give more opportunities to the market in terms of flexible and low cost techniques.

Development of New Technologies for Low Noise Railways Infrastructure
The objectives of the project are to develop a number of innovative technical solutions to be applied to existing tracks, and also to new infrastructure, allowing to reach, together with a combined action on vehicles, a global reduction of noise emitted by the train/track system by about 10 dB(A).

COMBICOM (Combined Transport Communication Systems)
The aims of the project COMBICOM are to develop and to install a Road/Rail Transport Informatics (RTI) system which can be used to communicate all relevant operational information, e.g. the status of Combined Traffic(CT), at particular points of their journey, to all relevant systems participants, including shippers, highway operators, hauliers, freight forwarders, customs, and receivers of goods.

ADEPT (Automatic Debiting and Electronic Payment for Transport)
The objectives of the ADEPT Consortium are to use the results of the DRIVE I programme in order to take further the concept of using an intelligent transponder and smart-card for a multitude of automatic debiting (ADS), electronic payment and other complementary RTI applications.

MITHOS (Monitoring intermodal transport of hazardous goods)
The objective of this project is to develop the specifications and propose the most suitable architecture for an information system for the monitoring of hazardous goods shipments in an intermodal transport environment. This system should provide services to all parties involved in the transport process, control and administrative aspects.

MASK (Multimodal Multimedia Automated Service Kiosk)
The rigidity of touch-screen based, menu-driven user interfaces for public systems prevents users from transacting tasks as fluently as when communicating with another person. The objective of the MASK project is to pave the way for more advanced public service applications by employing multimodal and multimedia input-output.

MULTITRACK (Tracking, tracing and monitoring of goods in an intermodal and open environment.)
MULTITRACK pioneers a telematics system enabling carriers and other users to monitor the location and condition of goods or freight over an entire journey comprising sea, rail and road transport.

HAGIS (Hazardous goods information system)
HAGIS is developing an information service to improve security in the handling and transport of dangerous goods. The project aims to demonstrate the feasibility of a user-friendly telematics-based information service on regulations governing this activity, irrespective of EU language and the means of transport adopted.

INTER (Integration of networking technologies for harmonising the European railways)
INTER is a feasibility study to develop the principles of an integrated multi-service, multimedia, multi-rate, multi-vendor harmonised European railways communications network. It is intended to combine state-of-the art and more conventional technologies for wide area and local area networks.

8.2.4 Maritime transport

Relevant projects

ATOMOS I/II/III
Improving the future ship bridge, in terms of efficiency and safety, on the basis of user requirements (‘integrated bridge’).

CASMET
Develops a common methodology for the investigation of maritime accidents and the reporting of hazardous incidents, on the basis of a more thorough understanding of the human element.

COMFORT
This is a super-consortium created to coordinate activities going on in the INCARNATION, COMFORTABLE, and MASSTER projects.

COMFORTABLE
Develops tools and supports for VTS operators for the recognition and assessment of traffic situations.

DISC
Aimed towards the standardisation in the field of marine electronics, with particular reference to Human Machine Interfaces. In it relevant activities from the COMFORT, MiTS, MBB/MBBII, and ATOMOS III consortia are coordinated.

INCARNATION
Develops efficient inland navigation information systems, on the basis of policy requirements and technological developments.

MARCOM
The research in this project deals with the fundamentals of maritime socio-linguistic communications, both ship-ship and ship-shore.

MASIS II
This project aims to improving the human element on board ships, with special attention to emergency situations. It does this by providing practical tools and solutions which can be readily implemented.

MASSTER
Aims toward standardising maritime simulator training exercises**,** on the basis of a task categorisation and a set of scenarios derived from that. The project will also provide performance assessment tools.

MBB/MBBI
Development of a maritime black box system.

MiTS
Develops a control system integration protocol for high level integration of different manufactures’ sub-systems.

MOVIT
The objective of this project is to achieve a mobile vessel traffic management and information system that may be transported to any on-site evaluation of traffic conditions.

RINAC
Develops a control centre on board of an inland navigation vessel that integrates a multitude of different sources.

SAFECO
This project attempts to contribute to the safety of shipping in European coastal waters by analysing the underlying factors that contribute to accidents. This will be done by a detailed evaluation of safety-critical functions, from which a risk evaluation methodology will be derived.

VASME
This project has at its objective to design and develop a real-time, voice-operated, automatic, on-demand information system for ships.

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8.2.5 Public transport

Relevant projects

ADEPT I-II. (Automatic Debiting and Electronic Payment for Transport)
Application: Field trials in different European sites with smart cards.
EC financed projects (DG XIII) within the 3rd and 4th Framework Programmes.

CONCERT-P (Co-operation for Novel City Electronic Regulating Tools)
Application: The project combines smart card and information technologies and facilitates access and payment in a multi-modal multi-service system, integrating payment and operational service data.
EC financed project (DG XIII/DG VII) within the 4th Framework Programme.

EUROBUS (European Reference Data Model for Public Transport and Polis Passenger Information Services)
Application: Development of a complete data model (Transmodel) for European public transport companies, and experiments with computer aids for passenger information in the area of public transport.
EC financed project (DG XIII) within the 3rd Framework Programme.

GAUDI (Generalised and Advanced Urban Debiting Innovations)
Application: Barcelona, Bologna, Dublin, Marseille and Trondheim co-operate on the future integration of electronic payment linked to use of passenger transport systems (bus, metro, parking, road toll, etc.) with a reliable compensation system sharing revenues between service providers.

PHOEBUS (Project for Harmonising Operations of the European Bus)
Application: Development of a demand responsive system with automatic reservation and a real time passenger information system.
EC financed project (DG XIII) within the 3rd Framework Programme.

PRIMAVERA (Priority Management for Vehicle Efficiency, Environment and Road Safety on Arterials).
Application: the project focuses on integrated traffic control on urban arterial corridors, integrating queue management techniques, public transport priority techniques, and traffic calming techniques.
EC financed project (DG XIII) within the 3rd Framework Programme.

PROMISE (Mobile and Portable Information Systems in Europe).
Application: Development of a multi-modal traveller information system.
EC financed project (DG XIII) within the 3rd Framework Programme.

PROMPT (Priority and Informatics in Public Transport)
Application: The project focuses on the problem of achieving active priority of public transport within systems of dynamic urban traffic control.
EC financed project (DG XIII) within the 3rd Framework Programme.

QUARTET (Quadrilateral Advanced Research on Telematics for Environment and Transport)
Application: Public transport management and information system in Birmingham.
EC financed project (DG XIII) within the 3rd Framework Programme.
EC financed project (DG XIII) within the 3rd Framework Programme.

SAMPO (Systems for Advanced Management of Public Transport Operations)
Application of integrated Demand Responsive Transport Services as a tool to support the use of multi-modal passenger transport services.
EC financed project (DG XIII) within the 4th Framework Programme.

TRANSPRICE (Transmodal Integrated Urban Transport Pricing for Optimum Modal Split.)
Application: pricing/payment measures for demand management and
for changing modal split.
EC financed project (DGVII) within the 4th Framework Programme.

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