JPRS-EST-91-018
5 SEPTEMBER 1991

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JPRS Report

Science & Technology

Europe

TWENTY-FOURTH ISATA INTERNATIONAL SYMPOSIUM
ON AUTOMOTIVE TECHNOLOGY AND AUTOMATION

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5 SEPTEMBER 1991

SCIENCE & TECHNOLOGY

EUROPE

TWENTY-FOURTH ISATA INTERNATIONAL SYMPOSIUM ON AUTOMOTIVE TECHNOLOGY AND AUTOMATION

91WS0503A Florence AUTOMOTIVE TECHNOLOGY AND AUTOMATION in English 1991 pp 261-296

[Selections from the Twenty-Fourth International Symposium on Automotive Technology and Automation held in Florence, 20-24 May 1991, sponsored by the Italian National Committee for the Research and Development of Nuclear and Alternative Energies (ENEA), the Province of Florence, Autostrade (Italy) and Sumitomo Electric Industries (Japan). 2 Vols. Vol. I: "Road Transport Informatics (RTI) and Intelligent Vehicle Highway Systems (IVHS)"]

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ADVANCED ROAD TRANSPORT TELEMATICS IN EUROPE - A FOLLOW UP TO DRIVE

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910196

Foreword

The DRIVE programme of Community research and development in the Road Transport Informatics domain has been taking place as a part of the 2nd Community Framework programme in R&D - 1988-1991. During the latter part of this period experts from Europe have been making preparations for follow up actions planned to take the developments in Europe forward towards implementation. This paper reports the summation of those preparations which are ready for inclusion in any future Community programme. At the time of writing of this paper (February 1991) no formal final decision had been taken to establish such a programme. The contents of the paper should be taken as indicative of the contents, and give a framework to the possible actions, and describe the preparations and parallel activities that have been undertaken by European interests.

The DRIVE Programme

1. A programme of Advanced Road Transport Telematics is being planned as a successor programme to the 1988 - 1991 Community research and development programme in transport, DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe). The current DRIVE programme is seeking to achieve the high level objectives of improving road safety, maximising road transport efficiency and contributing to environmental improvement through 71 projects. Each project is engaged in a specific pre-competitive, pre-normative field of research and development and is partially funded up to 50% under the Community's 2nd Framework Programme of Research and Technological Development.

2. DRIVE looks forward to a common European road transport environment in which drivers are better informed and where so-called "intelligent" vehicles interact with the infrastructure systems. The projects involve consortia whose partners are from the research and development sector (both private and governmental), from industry and are service providers in about equal proportions. On average there are 5 to 6 partners in each consortium. There has been a wide and comprehensive dialogue established and some long lasting pan-European working relationships have been established.

3. The output of DRIVE has added to the high profile being established for effective technological aids for road transport. Integrated information and control systems have been developed. In some domains physical and system prototypes are available and these now need real world verification. In other cases common functional specifications have been drawn up. These can be expected to be taken forward in the next phase of DRIVE and lead to widespread conformity in usage in Europe. DRIVE projects have bought forward developments in guidance and control of traffic in cities and on inter-regional highways; in the field of incident and congestion detection there has been a significant advance through the DRIVE project INVAID whereby computer-aided video cameras can watch traffic and report the occurrence of an incident without human involvement until traffic control operator intervention is required; smart card payment systems are ready for testing; comprehensive information systems capable of supporting use in more than one transport mode have been developed. The recent allocation of Common European Frequencies for DRIVE projects, initially in the 5.8 GHz band will facilitate coordinated future development. The pre-standard for traffic messages (Protocol ALERT C) developed in the RDS-ALERT DRIVE project by broadcasters, industry and the ECMT will assist in the verifications required in this area. A crucial aspect of payment for motorway use, Auto-debiting, now has a common functional specification as a result of the DRIVE project VITA. In the freight area preparations for standards for Container and Vehicle Identification was the result of CENELEC analysis by a team chaired by a member of the DRIVE Office. Driver safety techniques have been advanced and particularly in this area there has been a dialogue with the related programmes in EUREKA, in particular PROMETHEUS.

The Need for new activities

4. DRIVE and the other programmes have taken the research and development so far, but now is the time for prototypes and systems to be tried out in the real world. The question whether the development will actually provide the public and private benefit that is expected must be answered. More importantly, perhaps the individual prototypes and systems need to be combined into more comprehensive and integrated systems to gain the utility of using the same data sources efficiently and providing coordinated and not conflicting advice, guidance and information.

5. An Advanced Road Transport Telematics programme would have a part to play in taking this step forward, and since it will be a programme of the European Community it expects to establish a framework which can be applied throughout Europe.

6. The finding of preparatory actions which led to the suggested ATT programme are summarised in the following paragraphs.

Advanced Transport Telematics - a follow up programme to DRIVE

The objectives of such a programme

7. The positive outcome of the DRIVE programme and other achievements in the field of telematics in the transport domain enables the general objectives of improvements in efficiency; in safety; and connected with the environment to be continued and augmented by more specific objectives in an Advanced Road Telematics programme. The programme would seek to establish:

- a framework which will validate and improve results achieved so far in DRIVE I and the EUREKA programme (PROMETHEUS CARMINAT), to assist decision makers - administrations and industry - in their future actions on implementation;

- common functional specifications and promote standards which meet user needs and provide basis for innovation and competition, concentrating on those which need European co-ordination and contribute to the completion of the single market.

8. The new programme expects to:

- promote confidence in Advanced Road Transport Telematics services amongst service providers, regulators and users, having particular regard to all aspects of safety;

- advance Road Transport Telematics technologies in selected areas where these hold promise of success, complementary to the achievements so far, and which require further development and validation during the new programme cycle;

- encourage the development of administrative, legal and financial procedures and advice to enable the adoption of ATT systems which are compatible internationally;

And to promote:

- assurance of the necessary interoperability of equipment and comprehensibility of services;

- development of the interfaces with the other modes of transport, via appropriate information systems, in an architecture which will allow the integration of services by all modes of transport;

- provision for applicability and transfer of results to lesser developed regions of the Community.

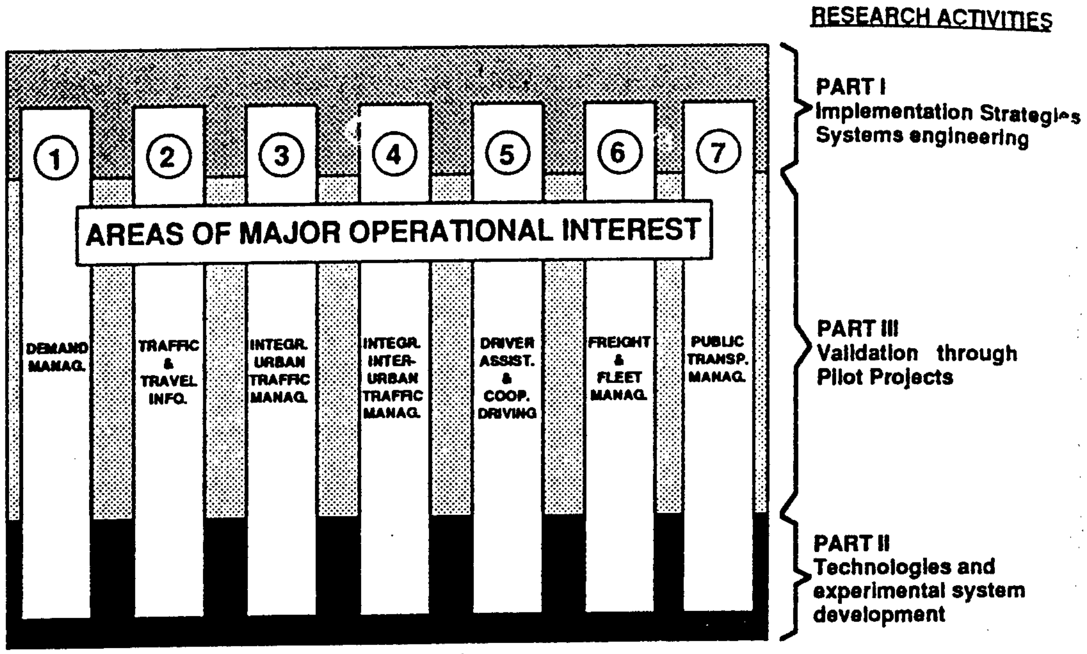

Fig. 1 : Relationship between areas and research activities

The related actions

9. In the Advanced Road Transport Telematics programme, as it has been defined following the extensive consultations of all sector actors and the Management Committee of DRIVE, three distinct, but strongly related actions are put forward. These are planned to take place in seven areas of major operational interest. The three related actions are in:

- Systems Engineering & Implementation Strategies
- Advanced Road Transport Systems and Techniques
- Validation through Pilot Projects

The Areas of Major Operational Interest for the programme are:

- Demand Management
- Traffic and Travel Information
- Integrated Urban Traffic Management
- Integrated Interurban Traffic Management
- Driver Assistance & Cooperative Driving
- Freight & Fleet Management
- Public Transport

RESEARCH ACTIVITIES (Chapters of Workplan)	Demand Management	Travel & Traffic Information	Integrated Urban Traffic Management	Integrated Interurban Traffic Management	Driver Assistance & Cooperative Driving	Freight & Fleet Transport	Public Transport
I. Systems Engineering and Implementation Strategies							
I.1 Functional Specifications and Systems Definition	#	#	#	#	#	#	#
I.2 Implementation Aspects	#	#	#	#	#	#	#
I.3 User Demand Evaluation and Modelling	#	#	#	#	#	#	#
II. Advanced Road Transport Telematics Systems and Technologies							
II.1 Information Management, Communication Architectures and Technologies	#	#	#	#	#	#	#
II.2 Development of Transport Management and Traffic Control techniques and systems	#	#	#	#			
II.3 Advanced Systems for Road Safety			#	#	#		
II.4 Freight Transport		#				#	
II.5 Public Transport		#					#
III. Validation through Pilot Projects							
III.1 Demand Management Systems	#		#				
III.2 Travel and Traffic Information Systems	#	#	#	#	#	#	#
III.3 Urban Traffic Management Systems	#	#	#				
III.4 Interurban Traffic Management Systems		#		#			
III.5 Driver Assistance and Cooperative Driving Systems				#	#	#	
III.6 Freight & Fleet Management Systems						#	
III.7 Public Transport Systems	#	#	#				#

Fig. 2 : Research activities related to areas of major operation interest

10. There is a complex relationship between the three actions of the programme and the Areas of Major Operational Interest, but the relationship is seen more clearly when the sub-actions which can be described as research activities are considered. The output from several of the research activities is an essential ingredient for the full consideration of the work of a project in any of the Areas of Major Operational Interest. This can be seen more clearly through figure 2 which indicates the specific research and development needed as elements of robust projects in each of the Areas of Major Operational Interest.

11. The first group of Research Activities - Systems Engineering & Implementation Strategies - relate to the full range of Areas of Major Operational Interests; they are essential "top-down" issues addressed to strategic planning, investment decisions and policy choices. The background strategies, systems, models and techniques for evaluation and implementation can be expected to be used as a guiding framework in the use of techniques in the Pilot Projects, and also for the continuing development of technologies. The integration of these elements of the programme especially the specification of technical requirements; development of a consensus on functional specifications and draft standards; and the implementation aspects can

be expected to be important to its success. To assist in this process of integration a "core project" would be required to coordinate and oversee:

- the economic and social evaluation of projects alongside the technical evaluation
- the monitoring of performance of Pilot Projects
- the assessment of potential for the services and technologies.

12. The second group of Research Activities - Advanced Road Transport Systems and Techniques are the essential tools of the next generation in management and control of road transport. Hardware and software developments still in a pre-competitive stage and technologies and systems not sufficiently mature for direct use in the Pilot Projects will be further developed. Thus research and development of this nature may be considered as being covered in two levels:

- basic development/laboratory experiment (level A1 of figure 3)
- controlled environment experiment (level A2)

13. The developments undergoing the limited verification at levels A1 and A2 will, providing those trials are successful, ultimately require the real world testing envisaged in the third research and development group - Validation through Pilot Projects (level B). This will be the core of a new programme where past and ongoing research and development is verified (or validated) through comprehensive Pilot Projects, all in real world environments. By carrying out such tests in real environments, verification of the benefit of the overall traffic performance in order to win public and individual acceptance can be made.

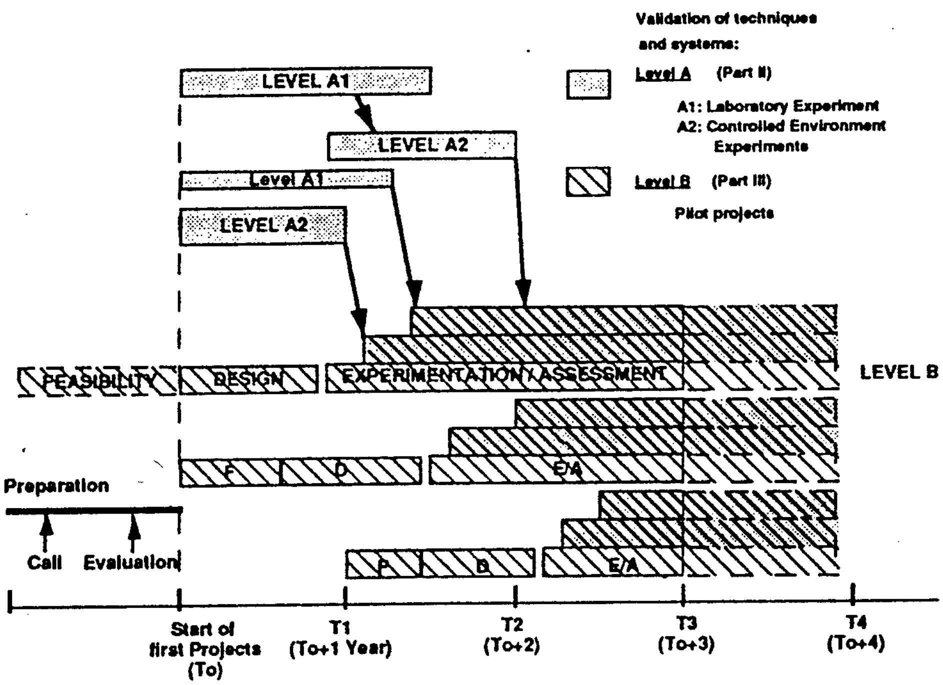

Fig. 3 : Levels of validation and overall planning of actions

Pilot Projects

14. The Pilot Projects will seek to verify, evaluate and demonstrate

- feasibility and user behaviour
- effectiveness of the ATT measure(s) and system
- organisational, technical, social, and financial issues and problems arising from system introduction
- the European Dimension - that is the wide application of measures resulting from successful Pilot Projects.

15. In effect, Pilot Projects are the first direct exposure of new developments to the final users in a real environment. Many of the final users will play no direct part and will often be unaware that ATT is in use. Never-the-less the effect on them in terms of safety, convenience, environmental impacts or the effects on their businesses or employment will be crucial to the success of the measure on trial. Each project will need a sound technical framework, both in its execution and assessment. This will need to be established during the preceeding phases of project, design and feasibility. This progressive method of working which allows subsequent stages to take place only when justified can be expected to ensure that projects reach recommendations for implementation of suitable local and European solutions.

16. Feasibility stages might last for up to six months and can be expected to provide output which:

- describes the transport problem
- sets out key statistics
- gives a technical framework
- details logistics, such as equipment, staffing liaison with others etc.
- estimates approximate cost and financial feasibility
- gives a commitment on behalf of the project to proceed towards implementation
- makes a proposal for the design and execution/assessment stage

17. The Design stage (up to 15 months in duration) sets out the means of conducting the pilot itself - the execution/assessment stage. Its output would detail:

- system configuration
- the requirement for any permanent infrastructure
- necessary equipment, operating methodology and staffing
- performance indicators
- draft contracts between partners, and also with external suppliers.
- costs and timing
- the proposals for execution and assessment stage of the Pilot Projects, and indicate how subject to a successful outcome, the system might be adopted as a permanent operation.

18. The Execution/Assessment stage (lasting 2 to 3 years) is the main stage of the Pilot Projects. This stage would:

- undertake the verification and assessment as set out in the Design stage
- make recommendations for common functional specifications
- make recommendations for further trials or for direct implementation
- make recommendations for new or continued research and development

19. The European Dimension, which is a high ambition of the Community for the outcome of the proposed action, particularly in the Pilot Projects looks to provide:

- intercommunication/interoperability
- a transfer of technology
- sharing of experience
- integrated European networks

Initiatives for European Collaboration Networks

20. In a programme which involves verification of research and development it is the owners and operators of the infrastructues who are the key actors. Two initiatives, one concentrating on those interested in urban experimentation sites and the other on inter-regional main traffic corridors are working to bring the various parties together in advance of a successor programme to DRIVE.

The network of cooperation POLIS*

21. POLIS is a network of European cities which have decided to cooperate in investigating the new telematic technologies to help to solve their traffic problems and their consequences, in particular in terms of road safety, impact on the environment, quality of life and fuel energy consumption.

Initiated under the administrative aegis of the secretariat of technical cooperation of the Eurocities, the POLIS organization which was set up step by step in 1990, is currently receiving a financial support from the EC Commission's DG XVI (regional policy) through the Council of Communes and Regions of Europe (CCRE).

The financial contribution from the Community structural fund (Art. 10) is not intended to finance the feasibility studies of the pilot projects envisaged by the cities, but the so-called "networking process" only. So far the cities themselves have financed their studies.

22. The POLIS network is an "open Club" administered by the cities themselves. It is not a "programme" (the top-down approach); on the contrary, it is a bottom-up action of the "client organizations" who want to put on the real operating situation, the R & D results of the Community and Eureka programmes (Prometheus, Carminat) in order to validate the results before moving forward towards large-scale implementation of the proven technological solutions.

* POLIS - Promoting Operational Links with Integrated Services through road traffic informatics between European cities.

During the first year of common work, the cities have identified four levels for a suitable structure of their organisation as a network:

- The political supervison level: the assembly of cities at the POLIS conferences
- The coordination level: ensured by the POLIS technical secretary
- The task force level in charge of the so-called "convergence process"
- The information and liaison level to be fulfilled by a non-profit association to be established in Lyon (France): the CEDIL (Centre for Exchange and Diffusion of Information and Liaison).

23. The European cities can be involved in the POLIS network in either of two modes :

The participant "site" mode for cities in which they express their commitment to set up and fund the larger share of a R&D pilot project.

"The follower" mode for cities in which they express their interest to follow closely the designs and field trials of other cities without wanting to take the lead themselves in the setting up of an R&D pilot project.

In February 1991, POLIS cities were classified as follows (cf map of location - Figure 4):

Participant "site" mode : Amsterdam, Athens, Barcelona, Birmingham, Bologna, Brussels, Dublin, Cologne, Glasgow, Gothenburg, Lyon, Marseille. Munich, Paris, Pireus, Stuttgart, Southampton, Turin, Toulouse, Trondheim

"Follower" mode : Antwerp, Bristol, Cork, The Hague, Madrid, Norwich, Seville , Valencia

Pending confirmation : Berlin, Edinburgh, Copenhagen, Lisbon, Porto, Rennes, Rome , Region Umbria.

24. The "convergence process" is being carried out by the task force on four main types of lead applications":

- automatic debiting and fare integration,
- dynamic route guidance and driver information,
- public transport + park and ride information systems,
- traffic control.

However the inherent difficulty of the convergence process lies in the complex combination of applications which is of paramount importance for the majority of cities.

In February 1991, the cities were discussing with one another according to "political" preference for their grouping on the basis of the convergence process performed by the Task Force. The Task Force identified the most appropriate grouping based on technical criteria. The most adequate federated structure to tackle the pilot projects in the proposed new Advanced Telematic programme for Road Transport of the EC is still to be found.

CORRIDOR

25. The initiative was launched by the DRIVE Infrastructure Group (DRIG) in autumn 1990. CORRIDOR is an acronym for Cooperation On Regional Road Informatics Demonstrations On Real Sites. The DRIG is an advisory group to the Commission's DRIVE Programme and consists of delegates from national road administrations and service providers from all Member States and some EFTA countries (S, A, CH).

    The DRIVE Infrastructure Group has developed an implementation plan of an Integrated Road Safety Information and Navigation System (IRIS) to be installed all over Europe. This system would on the one hand comprise the simple, already developed RTI systems and on the other hand it would put into practice and operation all the results developed under the running R&D programmes. The plan aims at the implementation of these systems along main European traffic corridors and European cities.

26. In order to accelerate the process for the testing and validation of the developed systems resulting from DRIVE, EUREKA and national R&D programmes, the DRIG identified the need for an initiative, which should be concerned with the interurban transport telematics experiments. Therefore the so-called CORRIDOR initiative was originated, which could be considered in many respects as a natural counterpart to the POLIS initiative. However both initiatives (POLIS and CORRIDOR) should be seen as complementary actions and will be linked, in particular if common applications considered in an urban testbed, form in parallel a part of larger geographically connected interurban testbed.

27. In brief, the CORRIDOR initiative is aiming at the creation of a collaboration network of all actors (national and regional road administrations, motorway companies, IT&T industry, service providers and operator) involved in the process towards the implementation of new ATT services on European motorways. The infrastructure owners, in most cases national or regional road administrations, will play a crucial role. The importance of this role is given by the fact that these authorities are responsible for the investments of the road-side infrastructure.

    The initiative provides a framework for the exchange of experience in the process of planning and conducting interurban pilot projects, containing preferably either a cross border traffic flow and/or a cross border traffic information flow. Therefore, the initiative is contributing to the social cohesion of European regions and the unification of the Single European Market, 1993.

28. The wide range of applications of interest are covering for example information systems based on standardized radio data transmission protocols (RDS/TMC), cellular radio system (GSM) and variable message signs (VMS), incident detection systems based on closed circuit television (CCTV), speed and network control systems, weather detection and pollution monitoring systems as well as freight and fleet related applications.

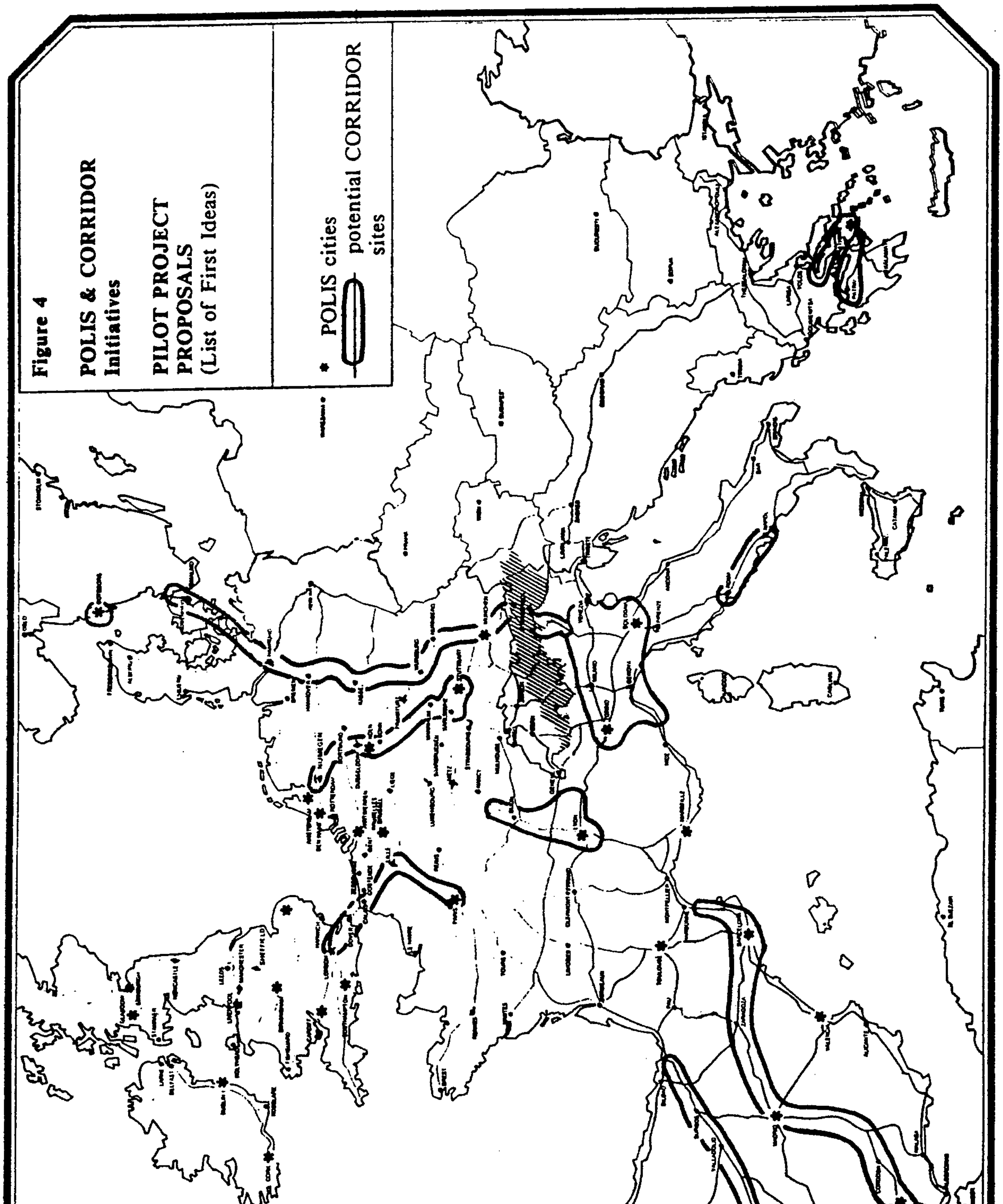

Figure 4

POLIS & CORRIDOR Initiatives

PILOT PROJECT PROPOSALS
(List of First Ideas)

The applications can be grouped into three main areas of interest :

- Interurban/inter-regional Traffic Management
- Travel & Traffic Information
- Freight and Fleet Management.

As these three areas are equivalent with the corresponding areas of major operational interest of the proposed ATT Programme, it becomes evident that the projects considered in the CORRIDOR Initiative will form major parts of the proposed DRIVE follow-up programme.

29. The DRIVE Infrastructure Group started last year to assemble and promote ideas for potential test areas for pilot projects in main European traffic corridors. The location of these test-sites are shown in Figure 4. In the meantime, some of the ideas have been taken up by the infrastructure owners, who are currently preparing proposals for feasibility studies and starting the merging of nationally oriented proposals towards proposals containing the European dimension.

As examples of project plans already containing the cross-border aspect the following test-sites could be listed :

- London - Lille - Paris (UK, F)
- Rhone - Rhine - Stuttgart (F, D)
- Rotterdam - Rhine (NL, D)
- Munich - Brenner - Modena (D, A, I).

30. The creation of the inter-regional collaboration framework is financially supported by Directorate General XVI (Regional Policy). This contribution enables firstly a CORRIDOR support group to give advice and assistance to the infrastructure owners and research community for the preparation of meaningful projects and secondly to start the creation for an inter-regional collaboration network. The CORRIDOR support group is supervised by DRIG and assisted by the DRIVE Central Office, Directorate General XIII of the Commission.

Summary

31. The DRIVE programme and the other parallel EUREKA and national programmes have taken recent research and development to the stage where real world tests are needed. The successor programme is planned to provide the framework for these tests, in particular it seeks to to prepare systems and applications using techniques that are capable of widespread use thoughout Europe. The POLIS network of cities is expected to open a new area of technical cooperation between local authorities in the field of road transport in urban areas. It is another example of the strengthening of Europe. The inter-urban CORRIDOR initiative has similar objectives for those actors involved in the pilot projects in inter-regional traffic corridors.

SCENARIOS FOR INTEGRATED RTI/IVHS APPLICATIONS

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INTRODUCTION

The DRIVE project TARDIS (Traffic And Roads - DRIVE Integrated Systems) has as its main objective the specification of functional requirements of an Integrated Road Transport Environment (IRTE), in order to provide a common framework for technical developments in which the different system operating philosophies in different countries can still be embodied.

A framework has been developed for assessing various system architectures into which the following RTI/IVHS applications can be integrated:

- dynamic route guidance
- advanced traffic control
- parking management and information
- public transport management and information
- fleet management
- tourist information
- automatic debiting.

Within this framework a simulation model, "TARSIM", has been developed which allows the analysis of the communications infrastructure necessary to support a particular scenario for integration.

The broadly-based TARDIS consortium, which includes national highway authorities, Government research organisations, automotive manufacturers, electronics industry and consultancies, has developed a number of integration scenarios for analysis, taking into account the administrative, commercial, practical and technical viability of their implementation.

The scenarios have been developed in liaison with work within the POLIS initiative on the pilot projects expected to form the basis of the successor programme to DRIVE, and the results of the scenario analysis are anticipated to form an important input to the development of the pilot projects.

The paper describes the simulation techniques developed within TARDIS and presents the scenarios currently being analysed.

SIMULATION OF SYSTEM ARCHITECTURE

TARSIM is a tool for simulating data flows in an hierarchical system. Within TARDIS it is used for designing and evaluating system architectures for the IRTE (Integrated Road Transport Environment for Europe). It enables the analyst to test proposed system designs and evaluate impacts on existing systems; it is particularly applied within TARDIS to the analysis of the effects - and potential benefits from shared communications requirements - of integrating RTI applications into a single system.

TARSIM is designed around a logical modelling framework in which the simulation problem is segmented into a "model" (general system architecture) and an "experiment" (scenario).

The model describes the elements of the system such as sensors, control centres, etc., and their interrelationships (transmission paths). The general system architecture used in TARSIM is shown in figure 1.

The experiment specifies the experimental conditions under which the model is to be exercised. These include such input parameters as
- specific system architecture (e.g. number of sensors, control centres and other processing units),
- data records (e.g. their origin, size, update rates, etc),
- transmission data (capacity of transmission paths) and
- traffic data (e.g. number of vehicles per hour).

Since the experimental conditions are specified externally to the model description, they may be easily changed without affecting the basic model definition. Many different "what-if" questions can be answered merely by changing some of the input parameters.

TARSIM simulates the data flows within the architecture specified in a particular scenario, based on the input data defining the nature and structure of data for each application.

Outputs from the model include queues of data records waiting to be processed in the processing unit; queues of data records waiting to be transmitted to the next system component; activity levels showing the load of the system components (processing units, transmission paths) during the simulation; and response times in the system.

INTEGRATION SCENARIOS

The idea of a scenario is to specify the set of RTI applications which could co-exist in a single integrated system. The process of defining a realistic scenario for modelling using TARSIM is itself a useful analytical process, and the detailed definition of scenarios is already providing useful information about the viability of specific scenarios.

The five POLIS convergence groups

The framework for scenarios developed within TARDIS is based on the approach taken within the POLIS initiative.

There are seven application areas expected to be covered by Advanced Transport Telematics (ATT) within DRIVE 2; the POLIS panel grouped these into four major areas:

automatic debiting
route guidance
public transport and
traffic control

and a number of secondary areas:

parking
fleet management
tourist information
hazard warning

All the major areas are potentially of great importance to the POLIS cities. In particular, public transport and traffic control are topics of specific interest because they are existing systems which directly affect the quality of the overall transport provision within any city.

Automatic debiting systems (ADS) and dynamic route guidance (DRG) however are different. In general there are no such systems available today. But the potential from these types of system for making a major contribution to improving urban transport during the next decade is very significant.

From a technological point of view, these two applications are also significant - each of them requires some form of communications infrastructure which provides two-way communication between a control centre and equipment installed in individual vehicles. In addition, it seems likely that in the right political environment either application could provide the economic and financial conditions which would justify the investment necessary to set up the two-way communications infrastructure.

The identification of the four major application areas offered a natural structure for grouping cities according to common interests, or "convergence groups."

Although not necessarily the most important in terms of effects or in terms of overall transport policy, the technological aspects of ADS and DRG are significant because the provision of a new communications infrastructure will have a major potential effect on all RTI applications, including those in which individual authorities may have the greatest interest, such as traffic control or public transport.

ADS and DRG were therefore chosen as the basis for the first two convergence groups, with public transport and traffic control the focus of groups three and four respectively: but in any of the groups it was clear that any DRIVE 2 activity should involve aspects of integration of applications.

The fifth convergence group emerged because of the technological consideration of the nature of the two-way communications infrastructure. ADS and DRG have different requirements of the communication link between vehicles and roadside or other equipment: for DRG what is required is information exchange, in two directions but not necessarily in the form of a dialogue. For ADS hoever, in which the communication link represents financial data, the link must provide a true dialogue in which a transaction takes place.

One of the most important aspects of integration is the equipment on the vehicle. Two separate types of communication system might require unnecessary duplication of equipment, so the POLIS Task Force recognised that there would be special progress in combining the two types of communication requirement - information exchange and transaction.

Therefore the concept of the fifth convergence group emerged, based mainly on the technological requirement for developing a communication link suitable for all types of RTI application. Because ADS and DRG are the main applications using each type of link, the key to a project in CG5 would be the linking of these two applications into an integrated system.

The POLIS convergence report [1] uses the five convergence groups to classify the fifteen founder POLIS cities according to their stated interests.

THE PROPOSED SCENARIOS

Functional requirements of each application area have been analysed in collaboration with other projects dealing directly with individual applications. The analysis has been carried out using an approach developed jointly by TARDIS and the DRIVE project SECFO [2].

The analysis has produced block diagrams of possible system architectures together with detailed definitions of information flows between system components. The TARSIM generalised system architecture is used as the basis of each individual application architecture.

The detailed functional analysis of application areas led to the expansion of three application areas so that there are 12 specific applications.

For most of the applications there are many possible technical sub-systems which would fulfil the requirements; a total of 22 technical sub-system definitions have been produced (or are currently being finalised) within the TARDIS functional requirements workpackage.

An integrated scenario consists of the combination of two or more technical sub-systems using as far as possible a common system architecture. The formalised analysis of individual applications allows the integrated scenario to be analysed for common sub-functions, and allows the information flows in a combined system to be studied. The TARSIM simulation model provides a further tool for analysing the consequences for the design of an integrated system architecture.

Using the 22 technical sub-systems there are about one billion possible integrated scenarios which could be studied. The framework for integrated scenarios is intended to produce a small number (less than 10) scenarios to be studied in depth using the TARDIS functional analysis techniques.

8 draft scenarios were proposed for discussion, based on input from the following sources: known work on integration of applications within DRIVE; the convergence process within POLIS; the PRO-GEN scenario approach within PROMETHEUS [3]; work on functional requirements within TARDIS, including the VITA specifications for automatic debiting systems [4, 5]; and existing and planned field trials.

The draft scenarios were presented and discussed at a workshop during a DRIVE concertation meeting; they were modified slightly in order to reflect the interests and opinions of other relevant DRIVE projects.

Figure 2 shows the relationships between the 7 TARDIS application areas, the 12 applications, the 22 technical sub-systems, and the definition of the current set of 8 scenarios.

Brief descriptions of the 8 scenarios are as follows:

1 This is based on the concept of the POLIS convergence group 1; the introduction of automatic debiting for urban road pricing is linked to other automatic charging applications such as reservation and payment for parking spaces. This scenario could be relevant to the POLIS proposal from Barcelona.

2 This scenario is derived from the work of the CAR-GOES DRIVE project (V1011) which is investigating the linking of dynamic route guidance, based on the Siemens ALI-SCOUT technology, with urban traffic control (UTC). This is the basic combination of applications considered within the POLIS CG2.

3 This is an expansion of scenario 2 to include other applications: Variable Message Signs (VMS) on inter-urban roads; in-vehicle information on parking, park & ride and public transport; commercial fleet management; and tourist information. This scenario is close to that proposed by Munich within POLIS [6].

4 Scenario 4 encompasses the same applications as scenario 3 but using a different technological approach: cellular radio, as developed within the SOCRATES DRIVE project (V1007) [7]. Input from the Transport and Road Research Laboratory, partners in the TARDIS consortium, allows the detailed analysis of UTC based on SCOOT to be included.

5 This represents the integration of applications proposed in the POLIS convergence group 5, in which the two types of communications requirement (information exchange and transactions) are combined. Scenario 5 is essentially an urban scenario, including road pricing and parking reservation and payment as in scenario 1 as well as most of the features of scenario 3.

6 This is also based on CG5, but with an inter-urban emphasis suitable for the ultimate objectives of projects within the CORRIDOR initiative; the SOCRATES concept is used for communication, with automatic toll collection the application for automatic debiting.

7 Scenario 7 is based on the approach being proposed in the Turin "5T" project; this includes the "MIZAR concept" for de-centralised route guidance using intelligent beacons, and the Utòpia system of urban traffic control already operational in Turin.

8 Scenario 8 represents the TARDIS "reference scenario" in which all RTI applications based in vehicle-to-control-centre communication are assumed to be widely available. This scenario includes the integration of the two main approaches for communications, beacons and cellular radio.

CONCLUSIONS

The process of defining the 8 scenarios for analysis has itself been a useful one, and has included a great deal of liaison with potential pilot projects and with developments within and outside the current DRIVE and PROMETHEUS programmes. The application of the TARSIM simulation tool is allowing a detailed analysis of information flows within specific communication system architectures to be carried out.

It is anticipated that the techniques developed within TARDIS will become useful tools in the next stage of development towards the European Integrated Road Transport Environment, allowing pilot projects to investigate the full poptential for integrating RTI applications.

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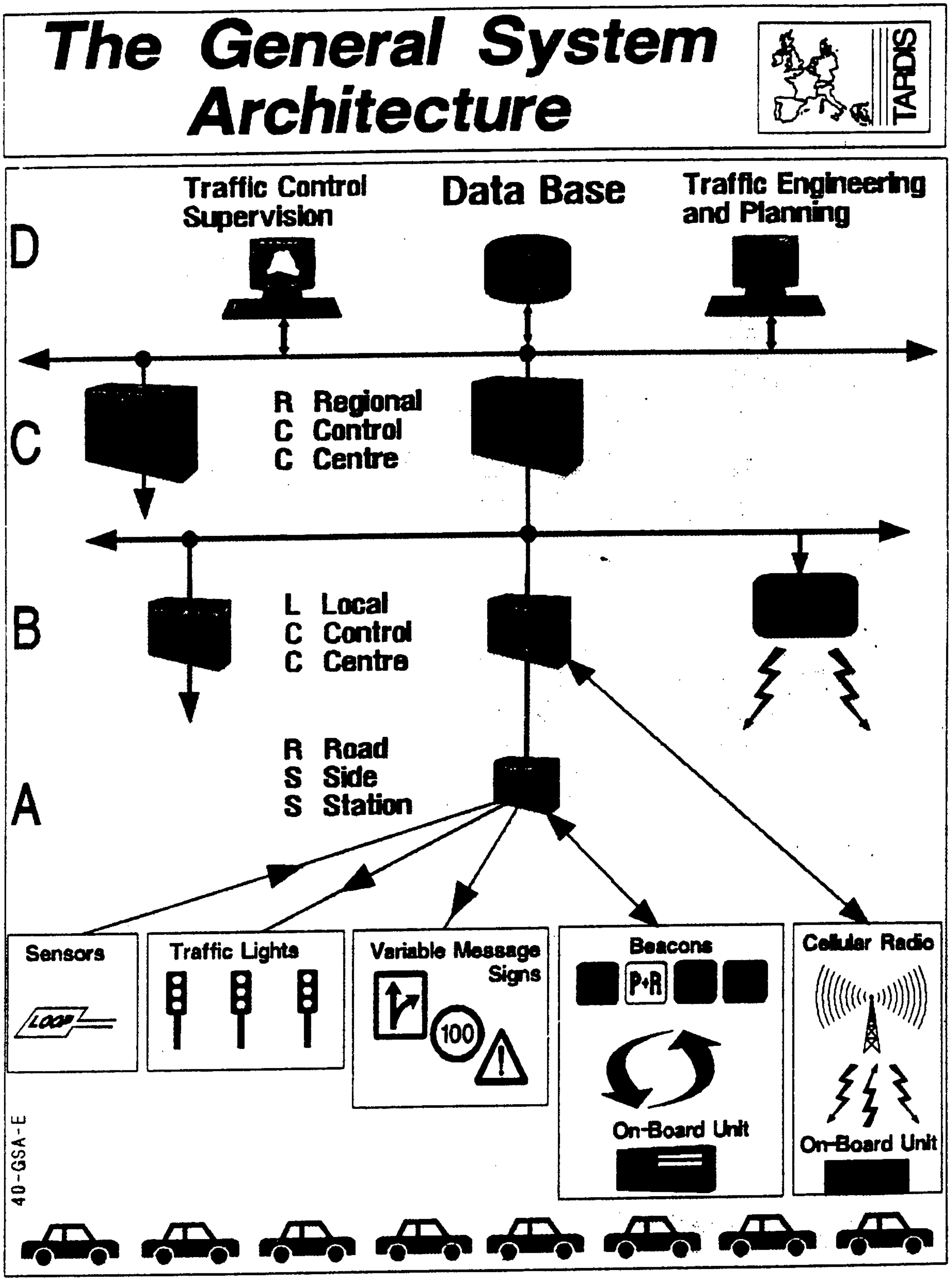

Figure 1: The General System Architecture

TARDIS Scenario Framework

APPLICATION AREA :	Application	Technical sub-system (concept)	1 POLIS , CG 1	2 CAR-GOES	3 POLIS , CG 2	4 SOCRATES	5 CG 5 , URBAN	6 CG 5 , INT-URB	7 5 T (Torino)	8 reference
Dynamic Route Guidance	D R G	-EURO-SCOUT		●	●		●		●	●
		-Dual-Mode								●
		-SOCRATES				●		●		●
		-Canminat								●
		-MIZAR concept							●	
Traffic Control	Urban T C	-SCOOT				●				●
		-MOVA								
		-Siemens		●	●		●			●
		-PRODYN								
		-Utopia							●	
		-Motion								
	Inter-urban T C	-ramp control						●		●
		-VMS (net/line oriented)			●	●	●	●		●
Parking	Information and Park + Ride				●	●	●	●	●	●
	Reservation and Payment		●				●		●	●
Public Transport	Public Transport				●	●	●		●	●
Fleet Management	Commercial Fleet Management, Emergency Fleet Management				●	●		●	●	●
Automatic Debit.	Road pricing	-VITA/Reken. Rijden	●				●			●
	Automatic Toll Coll.	-VITA						●		●
	Congestion Pricing	-PAMELA								
Tourist Informat.	Tourist Information				●	●		●	●	●

49—FRAME

Figure 2: TARDIS Scenario Framework

THE DACAR PROJECTS; ASSESSMENT SCHEME FOR RTI TRANSMISSION SYSTEMS

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Abstract

The general objective of DRIVE is to solve problems associated with traffic and transport, by means of modern information and telecommunications technologies. DACAR is a major DRIVE project aiming at RTI technology.
In the view of DACAR there are two sides to the project: the technical means to realize the new ways to cope with a new organization of traffic and transport and the identification of criteria for the assessment of their suitability for RTI applications.
The technical solution are actively being worked upon by car manufacturers, in cooperation with the electronic, telecommunication and information technology industry.
Before such systems can come into operation it is clear that several steps have to be taken. This article firstly outlines the projects in progress in the framework of DACAR and then shows more deeply the main aspects related to the assessment activity.

1 - Introduction

In the industrialized nations road traffic makes up for over 80% of passenger transport and for more than 50% of freight transport, and it is predicted that the number of road vehicles is still increasing. In most of the countries, especially in Europe, it will not be possible to enlarge the road network to such an extent, that it can cope sufficiently with the increasing number of road vehicles that are expected in the future, unless other means of traffic improvement will be introduced. For this reason research programmes have been started in Europe and in the United States within the last years: PROMETHEUS and DRIVE in Europe, IVHS in the United States. The DRIVE program consists of over 50 projects undertaking pre-competitive and prenormative R&D. One of these projects is the DACAR - project: Data Acquisition and Communication techniques and their Assessment for Road transport. It deals with the development and demonstration of basic RTI-technologies, especially transmission techniques, and with the evaluation and assessment of the basic technologies.
Five technologies were reviewed and analyzed during the first half of 1989: sensor, radio, cable systems (inductive loops and leaky feeders), microwave and infrared. During the second half of 1989 and during 1990 work has been concentrated on three of them, which seemed particularly worthwhile for further investigation: cable systems, infrared systems and microwave systems.
In parallel, within DACAR a specific group is investigating on the criteria to be used for the assessment and selection of proper transmission techniques, required for a suitable and effective implementation of RTI applications. These assessment criteria have been sought for a more general use, outside DACAR, in the DRIVE programme.

2 - The technological sub-projects in the DACAR framework.

The research activity in the DACAR project has been channellized into five technology-oriented subprojects and into one assessment subproject. This approach can shortly be described as the parallel and continuous work on the top-down analysis of RTI-applications and bottom up synthesis of RTI-technologies (in this case: proposed RTI-systems) with the iterative assessment making use of lab-tests, prototype tests and, not provided within DACAR, field tests in order to link theory with realization. (Such large scale field tests (pilots) are being looked for in DRIVE II). It is important to realize, that the assessments is an iterative process, that has to be performed continuously depending on the state of development of RTI-systems and the state of analysis of known RTI-applications.
As mentioned in the introduction, following a first analysis nainly based on omnidirectional oriented criteria only three out of the five subprojects have been funded for further activity. In what follows a quick review of their fields of interest is provided.

Infrared waves are subject to free space loss, absorption, reflection, interference etc. and to limitations like the optical horizon. Absorption has been kept at a feasible order of magnitude by the choice of the wavelength at 830 nm. This choice of wavelength is also determined by the technological possibility to construct transmitters and receivers for this wavelength. Transmission and reception gains can be obtained by optical focusing devices like lenses. Infrared waves can be modulated by all known modulation techniques and thus can carry information. As the wavelength mentioned (830 nm.) represents an extremely high frequency (in comparison to radiowaves and microwaves) the bandwidth available for information transfer is also large. The free-space loss and absorption are cause of a limitation in distance. At the same time the multiple path effect is minimal. No significant provision for fading needs to be made.
However infrared waves suffer from any kind of obstruction a the propagation path and are not suitable for long range communications. The applications proposed within the DACAR project use a "vertical" geometry, based on a beacon mounted on gantries or lamp posts, exploiting the high bit rates offered by an infrared bearer in order to achieve relevant information exchange even in short time windows.

3.- Assessment activity

As already mentioned, within DACAR a specific group is investigating the aspects concerning the selection of proper transmission techniques, suitable for an effective implementation of RTI applications. This group is formed by Bakkenist Management Consultants, Fondazione Ugo Bordoni and Volkswagen AG supported by consultants from the University of Bologna and the University of Braunschweig.
The first step has obviously been the identification of the applications leading to the desired Integrated Road Transport Environment; based on a functional analysis three main functional areas, including specific applications, have been identified:

- driving support systems: facilitating short term tasks of the driver; these include both autonomous driving support and cooperative driving systems;
- traffic control systems: dealing with traffic flow management, performing an overall control aimed at increasing the efficiency of road transport;
- special services: keeping the driver in contact with the outer world; this area includes commercial and public fleet management and automatic debiting systems.

A proper assessment has to take into account the importance of each application with reference to the main DRIVE objectives; it is then clear that some decisions have to be taken in a smart way by weighing each application, and hence techniques fulfilling them, through some factors giving a ranking of priorities (for example driving confort is less essential than traffic safety).
Furthermore a technically feasible system might not be implemented due to social or legal or economic reasons: no mathematical formula can rigourously express this kind of constraints.
For these reasons, beyond a technical analysis affording an evaluation of performance and feasibility of a given technique, some smart considerations have to take part in the assessment procedure. The broad lines of a complete assessment procedure have been elsewhere [SAE] outlined; the main activity has been focused on technical issues. To this end, a simplified sub-alghoritm concerning the technical assessment of transmission techniques with respect only to relevant RTI applications has been identified, fig.1.
A transmission system can be designed by means of different technologies.
The assessment methodology is based on an analytical approach describing the transmission system through a detailed analysis of the main "sub-systems" which form the whole transmission system; this methodology allows the choice and the evaluation of the actual values of all parameters necessary for "circuital design" of the afore-mentioned system.
An obvious, but somewhere understated, distinction has to be made between system performance parameters and system characteristics. It should born in mind that performance must be specified for each RTI application according to specific requirements and does not depend on the technique which will be chosen to realise that particular application; whereas system characteristic parameters have to be chosen in relation to the stated performances, leading to a proper subsystem design matching all performance requirements.

A detailed description of all technical subjects related to the characterization of telecommunication systems can be found in reference [DEL1.2]. Here it is worthwhile reminding that the keypoints are related to the following:

- messages to be transmitted (message characteristics);
- the definition of the main parameters describing system performance and system characteristics (physical layer and data link layer).
- the definition of problems and functions connected with selective communication networks (medium access and network layer)

2.1 - Microwave communications.

Marconi Command and Control Systems Limited and Standard Elektrik Lorenz AG are currently collaborating for the development of a millimetre wave communications link suitable for a large number of applications envisaged for the Road Transport Informatics.

The progress of technology is leading to cost effective devices at ever increasing frequencies; therefore new frequency bands are going to be made available. Furthermore the higher the frequency the smaller the size of the devices, so the problems of integration of the device in the car structure can be accordingly reduced.

It should also be noted that the use of frequency band which are not yet allocated eases down the problems related to pre-existing users sharing the same spectrum resources.

For these reasons the link is being sought to operate at a transmission frequency of 60 GHz. Moreover the choice of this frequency band allows to take advantage from the peak exhibited by atmospheric oxygen attenuation at this frequency: this evidence results in a lower mutual interference among adjacent roadside unit which are allowed to use the same operating channel and therefore can be equipped with the same operating frequency.

The vehicle mounted transceiver is expected to be pretty small so easing the problems for its insertion in the body of the car. Typical locations for the link assemblies are more carefully depicted in reference [1].

Antennae, which should be located externally in order to reduce propagation losses, can be placed behind light clusters or front and rear number plates or inside plastic wing mirror housing or at top of windscreen and rear window.

Some prototype are being constructed using waveguide components and in order to avoid new development of interfaces a waveguide horn radiator is going to be used. Operational units will be based on microstrip components in a cheaper and more integrated assembly. Great care will be required by the window protecting the antenna, whose dielectric characteristics must negligibly alterate the expected performances.

The vehicle mounted units will consist of a millimetre wave/intermediate frequency subsystem which is connected to a processing unit devoted to the elaboration of the baseband signal.

Particular attention should be paid to minimizing power consumption, especially when the vehicle is stationary.

2.2 - Cable systems.

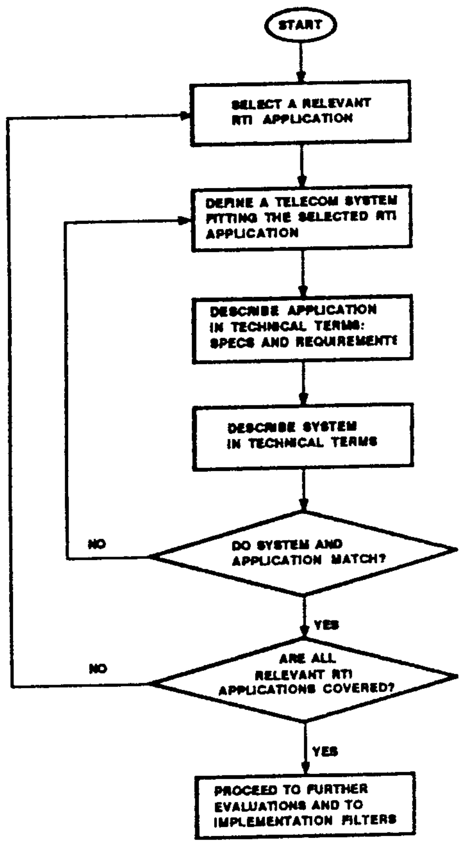
The subproject related to cable systems is dealing with two different technical applications of cables. The first one is carried out by the ANT and refers to the fixed infrastructure which will form the backbone of the Integrated Road Transport Environment (IRTE).

All RTI elements, e.g. beacons, inductive loops, variable traffic signs etc., need to be connected to this cable system. Via the cable system the RTI elements can communicate with management stations which remotely control the traffic. The implementation of this infrastructure is based on already existing coaxial cables, which have been proven to be already quite extensively installed along European main roads, and on newly laid optical fibres providing much higher transmission capacity and bit rates. Alternative infrastructures could be based on the GSM system (the next Pan-European mobile radio system) or on the Radio Data System or even on satellites, however the authors of this research activity state that access time and transmission capacity make the cable system the only suitable solution. GSM, RDS or satellites can support or substitute the cable solution in those rural areas where cable installation does not seem to be economically convenient.

As a communication link between vehicles and road-side, radiating cables, buried in the road have been proposed and studied by Gotting KG. These cables, referred to as a continuous cable system, will allow vehicles to be guided along a given track following the cables installed in the lane of the road. Communication between vehicles via the cable will also be possible, with the support of a road-side computer.
The information exchange is based on the inductive coupling between the buried cable and vehicle-born antennas. The magnetic field is poorly affected by environmental conditions and the magnetic field can be easily controlled and confined to the desired area (very close to the cable).
It is also possible to easily compute the relative position of the car with respect to the cable; so it is possible to accomplish guiding and location functionalities.

2.3 - Infrared systems.
The subproject on infrared communications have been carried out by VALEO, France.
The interest in infrared technology is well justified by the low cost and the availability of infrared components. Moreover other advantages are seen: the directivity of the transmission allows a wide range of applications with low mutual interferences; easiness of mounting and maintenance of equipment; small size of components.

SIMPLIFIED FLOW CHART FOR RELEVANT RTI APPLICATIONS



All the involved key parameters have then been grouped in two tables: the first one listed system characteristics, the second one listed system performance.
The partners engaged in the above described technological subprojects filled out these tables in order to provide a common ground for all subsequent assessment exercises.
These tables, fulfilled for different techniques, see tables from 1 to 3 [DEL 1.2], ease the comparison among different ways of implementing the data transmission system. It is important to stress that these tables give just a first evaluation allowing to verify whether and how performance level is met and, by means of system characteristcs, not reported here for sake of conciseness, to check their actual feasibility.
According to the operational flow chart in fig. 1, once the transmission systems are technically described, it is necessary to translate each RTI application in technical terms in order to check the actual fitness of the proposed telecommunication systems in the IRTE. As a matter of fact, each application is characterized by its own message structure, by a given number of potential users, by a minimum transmission range, by a fixed performance level (maximum bit error rate and maximum outage) and so on.

TABLE 1 - MICROWAVES

MAIN PARAMETERS DESCRIBING SYSTEM PERFORMANCE FOR DATA COMMUNICATION		
I. PERFORMANCE DESCRIPTION AT MESSAGE LEVEL		
IA.	MAXIMUM INFORMATION BIT RATE (DURING A PACKET TIME)	274 Kbits / sec
IB.	MAXIMUM PACKET REPETITION TIME	0.1 sec
II. PERFORMANCE DESCRIPTION AT TRANSMISSION LEVEL		
IIA.	MAXIMUM RANGE OF TRANSMISSION LINK	300 m.
IIB.	MAXIMUM VEHICLE SPEED	200 Km/h
IIC.	MAXIMUM BIT ERROR PROBABILITY PE0	$5.\cdot10^{-3}$ (without coding)
IID.	OUTAGE PROBABILITY	$= < 4 \cdot 10^{-3}$
III. PERFORMANCE DESCRIPTION AT "NETWORK LEVEL"		
IIIA.	MAXIMUM NUMBER OF USERS IN THE NETWORK	30
IIIB.	MAXIMUM END-TO-END TRANSMISSION PACKET DELAY	0.1 (n-1) sec.

TABLE 2 - CABLE SYSTEM

MAIN PARAMETERS DESCRIBING SYSTEM PERFORMANCE FOR DATA COMMUNICATION		
I. PERFORMANCE DESCRIPTION AT MESSAGE LEVEL		
IA.	MAXIMUM INFORMATION BIT RATE (DURING A PACKET TIME)	4.8 Kbits / sec.
IB.	MAXIMUM PACKET REPETITION TIME	1 / 2 sec.
II. PERFORMANCE DESCRIPTION AT TRANSMISSION LEVEL		
IIA.	MAXIMUM RANGE OF TRANSMISSION LINK	0.6 m
IIB.	MAXIMUM VEHICLE SPEED	no restr.
IIC.	MAXIMUM BIT ERROR PROBABILITY PE0	0.01
IID.	OUTAGE PROBABILITY	
III. PERFORMANCE DESCRIPTION AT "NETWORK LEVEL"		
IIIA.	MAXIMUM NUMBER OF USERS IN THE NETWORK	50
IIIB.	MAXIMUM END-TO-END TRANSMISSION PACKET DELAY.	

TABLE 3 - INFRARED

MAIN PARAMETERS DESCRIBING SYSTEM PERFORMANCE FOR DATA COMMUNICATION		
I. PERFORMANCE DESCRIPTION AT MESSAGE LEVEL		
IA.	MAXIMUM INFORMATION BIT RATE (DURING A PACKET TIME)	493 Kbits / sec
IB.	MAXIMUM PACKET REPETITION TIME	continuous
II. PERFORMANCE DESCRIPTION AT TRANSMISSION LEVEL		
IIA.	MAXIMUM RANGE OF TRANSMISSION LINK	6 meters +
IIB.	MAXIMUM VEHICLE SPEED	120 Km/h
IIC.	MAXIMUM BIT ERROR PROBABILITY PE0	0.01 (in 4 message)
IID.	OUTAGE PROBABILITY	
III. PERFORMANCE DESCRIPTION AT "NETWORK LEVEL"		
IIIA.	MAXIMUM NUMBER OF USERS IN THE NETWORK	
IIIB.	MAXIMUM END-TO-END TRANSMISSION PACKET DELAY.	

Once all the above is stated, i.e. when the application has been properly translated, it is possible to check systems versus application. This forms the necessary step for the prosecution of the assessment activity.Obviously system description through these tables has to be suitably re-defined according to the unavoidable corrections suggested by the experimental campaigns.
In any case, the authors believe that , in order to have some reliable tools which can be useful for any further system development, it is highly important to yield some more consolidated theory, giving some application-oriented models (channel characterization, interference analysis and so on), which can avoid a time consuming experimental work for every RTI application.

4 - Technical description of applications: an example.

In order to test the suitability of the proposed assessment procedure, in what follows a specific RTI application will be considered. The selection of the application to be examine is based on simple considerations of practical nature: since a complete trustworthy technical description is needed, it is available to consider a well known case, even if its technical content is not very innovative. Therefore the case of an automatic debiting system, and more precisely a tool motorway, has been selected: application requirements derived in the following implicitly refer to a beacon-to-vehicle communication.

Once mre it seems useful to stress that this example is not aimed at describing the application, but at illustrating the way the previously described approach can be used; therefore some inaccuracies or omissions describing the application will not compromise the general reliability of the approach.

The automatic debiting system will allow the driver when equipped with a proper unit, to carry out all transactions without stopping at the barrier

Our interest is restricted to the transmission aspects of the air segment, without considering the fixed network which is devoted to collection of transaction data by the motorway operator.

At this stage we leave out of consideration the system architecture, since it is up to the system designer. We focus on some requirements that an independent of the final technical solution. In doing that we will fill out the table on application requirements.

Maximum information bit rate

The information to be exchanged refers to a number of issues including vehicle identification and classification, and so on. Let us assume that the total amount is equal to 5000 bits. In order to evaluate the maximum information bit rate, we have to know how much time can be used for a transaction; this time interval depends on practical constraints rising from the minimum separation distance between two consecutive vehicles and from the maximum vehicle speed. Its computation will be possible after the selection of maximum vehicle speed and transmission range. It will then be considered in the following.

Maximum packet repetition time

This parameter is meaningless in applications where the information to be transmitted does not change with time and therefore no re-transmission is required.

Maximum range of transmission link

The transaction associated with each operation of automatic debiting can be performed in different ways, but it can be assumed that it will be always carried out in the vicinity of the toll station on a car-by-car basis. Therefore, even though other topologies might be possible (according to operating principles of particular techniques), we consider that the procedure takes place when the car passes through the barrier. In this case the maximum range of transmission link would ensure that just one car per lane is present in the communication zone associated with a single toll beacon. The maximum range will then be equal to the minimum separation distance between two consecutive vehicles. Let us assume a distance of 20 meters.

Maximum vehicle speed

At the time being the selection of this parameter is just an arbitrary estimation. This value, however, is a key point for the dimensioning of many other parameters: therefore, in order to carry on this example, a maximum speed equal to 150 km/h will be considered.

According to the assumption that the transaction should be completed before the following car enters the zone illuminated by the toll beacon, a time interval of 480 milliseconds represents the upper limit for the overall procedure to be completed. The information bit rate will be then equal to 5000 bits / 480 ms, that is about 10.4 kbit/s.

In order to better explain the meaning of the proposed table, it is to be noted that, depending on the transmission technique, the area illuminated by the toll beacon can be much smaller than the separation distance between consecutive vehicles. In such a case the exploitable time interval will be accordingly smaller and hence a higher information bit rate should be taken into account. On the contrary, whichever the technique would be, a larger time interval cannot be achieved: it is then clear that the 480 msec interval, and the previously computed information bit rate, is inherent to the application itself and cannot be modified. This is value to be inserted in the table.

Maximum bit error rate probability

The goal of the system operator is usually expressed as a percentage of successful transactions rather than as a bit error rate probability. It is then necessary to translate the practical goal of the operator in technical terms. To this end, let us assume the above mentioned percentage equal to 0.1% (i.e. a failure will occur for one of thousand vehicles). This percentage will result in an error rate for information bits (5000 per transaction) equal to 2×10^{-7}.
It is useful to underline that this value is referred to information bits after the decoding process, whereas the error rate of the transmitted bits could be greater.
Maximum number of users in the network
The problem of the multiple access in this application has to be referred to the presence of a multi-lane architecture resulting in a number of vehicles which perform simultaneously the payment operation. On a single lane transactions occur on a car-by-car basis and hence interference from the same lane can be ignored; on the contrary interferences can arise from other users accessing adjacent toll beacons. As a matter of fact even with directive beacons some multipath effect can impair the operation reliability.
The maximum number of simultaneous users, i.e. the number of lanes affecting each other, is set to 5. This choice is also justified by considering that in practical situations it is generally sufficient to reject interference coming from the nearest lanes, since the directivity of the beacon prevents from interferences originated more than two line.
Maximum end-to-end transmission delay
This parameter applies when the multiple access scheme can produce some collisions, and its value depends on the margins the designer introduces on previous parameters. In other terms if the information bit rate is very close to its minimum value there is no room for possible collisions, because any retransmission would result in an unacceptable information loss.
Once the above parameters have been examined it is possible to fill out the table on application requirements as shown in table 4.

Table 4 - AUTOMATIC TOLL MOTORWAY COLLECTION

MAIN PARAMETERS DESCRIBING APPLICATION REQUIREMENTS		
I.	PERFORMANCE DESCRIPTION AT MESSAGE LEVEL	
IA.	MINIMUM INFORMATION BIT RATE	10.4 kbit/sec
IB.	MAXIMUM PACKET REPETITION TIME	—
II.	PERFORMANCE DESCRIPTION AT TRANSMISSION LEVEL	
IIA.	MINIMUM RANGE OF TRANSMISSION LINK	3 m
IIB.	MAXIMUM VEHICLE SPEED	150 km/h
IIC.	MAXIMUM BIT ERROR PROBABILITY	2×10^{-7}
IID.	OUTAGE PROBABILITY	not computed
III.	PERFORMANCE DESCRIPTION AT "NETWORK LEVEL"	
IIIA.	MAXIMUM NUMBER OF USERS IN THE NETWORK	5
IIIB.	MAXIMUM END-TO-END TRANSMISSION PACKET DELAY	dependent on item IA.

Any proposed system to be used for automatic debiting must fulfil the stated requirements, no matter which technical solution is used.
It is now of paramount importance to warn the reader that a direct comparison between table 4 and tables from 1 to 3 can be misleading, since the above technical projects were not oriented to our particular application. Evidently, due to some flexibility in any technology so far considered, suitable rearrangement of system design can be easily obtained, in order to properly meet the particular application considered. In other words, some of the already proposed systems are not suitable for automatic debiting, nevertheless the same technological approach can be adapted to the stated requirements .

5 - Conclusions

The DACAR Project, since the start of its activity, has been dealing with the assessment of transmission techniques for Road Transport Informatics. The task of assessment had to analyse both the potentiality of different technologies, evaluating their inherent limits, and the performance of the proposed systems oriented to specific RTI applications.

A proper assessment of transmission techniques must take into account a number of aspects, not only related to telecommunication issues, but also to boundary conditions of political, economical and social nature. This paper has presented a procedure more related to technical matters.

To this end a simplified sub-algorithm has been extracted from the overall assessment procedure, and an example of its application has been proposed.

Finally, it is worth noting that a continuous comparison process between applications and systems should play a more relevant role in DRIVE II where a greater attention should be paid to practical implementations.

Acknowledgements

This activity is carried out with partial funding by the Commission of the European Communities accorded to the DACAR Project, within the DACAR Programme.

The work by Fondazione Ugo Bordoni falls within the framework of the agreement between the Italian P.T. Administration and the Fondazione itself.

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SOCRATES: SYSTEM OF CELLULAR RADIO FOR TRAFFIC EFFICIENCY AND SAFETY

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1. INTRODUCTION

The introduction of communications and information technology to the problems of road transport is a major area for development, known as Road Transport Informatics (RTI) or Advanced Transport Telematics (ATT) in Europe and Intelligent Vehicle/Highway Systems (IVHS) in the USA.

SOCRATES is a multinational research project investigating the use of cellular radio for a complete system of RTI, including dynamic route guidance and many other applications. The project is the largest (V1007) in the European Communities' research programme DRIVE - "Dedicated Road Infrastructure for Vehicle safety in Europe."

DRIVE seeks to apply advances in information and communications technologies to road transport, which together are known as RTI, in order to achieve an "Integrated Road Transport Environment" (IRTE) in which there will be significant benefits of traffic efficiency, road safety and reduced environmental pollution. The current DRIVE programme runs for three years, from 1989 to the end of 1991, and consists of some 72 projects, investigating various aspects of the IRTE.

SOCRATES is developing techniques for using cellular radio as the basic communication medium of the IRTE. Many RTI applications will depend upon the widespread availability of two-way communication between vehicles and a control centres; cellular radio offers a potential pan-European infrastructure which should provide an economically efficient basis for the IRTE.

2. APPLICATIONS

A basic hypothesis of the IRTE is that a common communications infrastructure should provide for all the RTI applications within it. The main applications considered within DRIVE and hence within SOCRATES are listed below:

dynamic route guidance: this is the major RTI application, which will give in-vehicle routeing recommendations to drivers based not only on detailed knowledge of the road network but also of the current and forecast traffic conditions. Estimates (Jeffery et al, 1987) by the Transport and Road Research Laboratory of the benefits of dynamic route guidance show that savings of time and vehicle operating costs will be substantial - for example savings of at least £100 million per annum are expected to follow from a dynamic route guidance system installed in London;

advanced traffic control: the improved traffic monitoring which will follow from the IRTE, together with the ability to influence overall traffic routeing patterns, will allow traffic managers and automatic traffic control systems to control traffic flows in order to optimise the efficiency of operation of the road network;

parking management and information systems: linking information from parking facilities will improve parking management, allowing drivers to locate the most convenient car park spaces at the end of their journeys and ultimately to reserve and even pay for their spaces in advance;

fleet management: the IRTE will provide the facilities for fleet operators to monitor their vehicles and to carry out efficient scheduling and control;

public transport management & information systems: dynamic vehicle scheduling, passenger information servies and public transport fleet management will be included in the IRTE;

hazard warning: on-board communications will provide for drivers to be warned of hazards such as accidents, fog, ice, etc;

emergency call: the SOCRATES system will provide an emergency call facility, activated either by the driver in an emergency or by automatic crash sensors;

emergency paging: allowing individuals to be paged over the communications infrastructure for emergency purposes;

automatic debiting: the ability to charge drivers, for toll collection, for road pricing or for the provision of services, will be an important part of the IRTE;

driver information: the link to the vehicle will provide for general information to be given to the driver on traffic conditions, specific problem spots, and on the availability of specific services such as hotels, fuel stations, etc.

tourist information: information of specific interest to tourists will be provided, perhaps including options such as choosing scenic routes as well as details of special events, etc;

data for traffic management and traffic planning: the improved traffic monitoring of the IRTE will provide an important source of traffic data, producing significant savings in conventional traffic surveys;

trip planning: the linking of dynamic route guidance with public transport information will allow pre-trip planning services to be offered, so that a traveller can plan not only the time but also the modes of his journey.

Within DRIVE there are two projects in particular which take an overall view of the full list of applications potential within the IRTE. These are SECFO (Mauro et al, 1990) and TARDIS (Bell and Catling, 1990). SOCRATES maintains close liaison with both these projects, and with other DRIVE projects as required, in order to maintain progress towards an integrated traffic environment.

The key development which is likely to provide the technological environment to enable the implementation of the IRTE is the widespread availability of two-way communication between vehicles and a network of traffic information and control centres. Most of the applications listed above will realise much greater benefits when able to make use of such a communications infrastructure. However, for most applications this communications link need not be the one-to-one contact familiar for normal telephone calls.

The concept of SOCRATES will support all of the applications listed above. During the current development stage, work is focusing in particular on the most important application, dynamic route guidance.

3. THE SOCRATES CONCEPT

At the centre of the RTI applications considered in the IRTE is the concept of a traffic information and control centre.. The SOCRATES control centre will be more sophisticated than the traffic control centre of today, because it will use the communication facilities of the IRTE to monitor traffic flows and speeds in real time to an accuracy which is not possible with current systems.

It will use this information for example to generate information for traffic managers, but it will also carry out short-term traffic forecasting using predictive models. The results of the models will be used for generating route guidance information.

SOCRATES will make use of a cellular radio infrastructure in order to achieve two-way communication between vehicles and control centres, but with an important difference from conventional telephony. Telephone calls are made on a one-to-one, or point-to-point, basis. SOCRATES will use only one channel for each cell, by broadcasting information to all equipped vehicles in the cell, and by receiving data from the vehicles on a single channel using a multiple access protocol.

Cells in a cellular radio system are typically between 2 km and 35 km across. The SOCRATES control centres will generate messages to be transmitted from each base station in the relevant region, and will receive data transmitted by vehicles to each base station in the region.

4. PROJECT OUTLINE

The consortium consists of the following members:

Ian Catling Consultancy (ICC), acting jointly with
Tate Associates, UK - prime contractor
British Telecom, UK
Philips Research Laboratories, UK
Philips Project Centre, the Netherlands
SEMA Group, France
Swedish National Road Administration, Sweden
Robert Bosch, Germany
Volvo, Sweden
Saab-Scania, Sweden
Universitat Politecnica de Catalunya, Spain

In addition, it is expected that Ford of Europe and Daimler Benz will join the project during 1991.

The project has the following objectives, to:

* demonstrate the feasibility of dynamic route guidance systems based on cellular radio;
* show how the proposed communication link can also support other applications such as hazard warning, emergency calls, automatic vehicle location, road pricing, hotel/parking status, etc;
* quantify the capacity of the system in terms of numbers of users;
* show how the technology developed for cellular radio can be used in simplified equipment for DRIVE users;
* provide computer simulations of the data processing, information flows to and from the vehicles, and the navigation system;
* equip a test site and use lab models and prototypes to verify and validate the theoretical predictions;
* make preliminary recommendations for a coherent system with route guidance and other applications supported by cellular radio.

The project began on 1st January 1989 and the current phase will be completed at the end of 1991 with a functioning demonstration site in Gothenburg, forming a substantial part of the West Sweden RTI field trial co-ordinated by the Swedish National Road Administration (SNRA).

The project is organised into five tasks, or groups of work packages, outlined below:

4.1 Traffic modelling and traffic management

This task is developing models which will run in the control centre in order to build the traffic messages to be transmitted to equipped vehicles. These messages will contain current and predicted link travel times, or impedences. An important element of the work in this task is the development of equilibrium assignment techniques capable of running in near-real-time in order to update current and predicted link flows and travel times.

The task includes the investigation of the different objectives of the traffic management authorities and those of the individual driver.

One aspect under investigation is the potential for weighting link impedences to modify slightly the otherwise individual optima, in order to move closer towards the community optimum.

Figure 1 shows the structure of the data collection and processing within the SOCRATES control centre. Data is collected from a number of sources - conventional as well as the new source of the floating car data - and processed through the modelling procedures to produce the data transmitted to vehicles.

4.2 Communications

This task includes the development of protocols suitable for transmitting traffic messages via SOCRATES, both for the common downlink and the multiple-access uplink. It involves close liaison with the GSM committees in order to feed the requirements of SOCRATES to the process of fully specifying the GSM system. Links are also maintained with the RACE Mobile Telecommunications Project (R1043) which is looking further ahead than GSM, to the next pan-European cellular radio system, UMTS.

Included in this task is the development of short-range beacons able to provide accurate positioning data to vehicles and to transmit local information.

4.3 System design

This task is concerned with the overall design of the SOCRATES system, whose specification is the main objective of the current SOCRATES project. It includes the consideration of all the RTI applications discussed in section 2, some of which are represented in figure 2.

This task has included the development of an initial demonstration site at Philips Project Centre in Geldrop, which includes the transmission of data and messages to a vehicle equipped with a CARIN unit, as well as a short-range beacon.

4.4 In-vehicle equipment

This task includes the development of existing or new on-board systems able to make use of the data transmitted via SOCRATES. An initial workpackage investigated the requirements of the driver.

Work is now continuing on the definition of on-board data structures and the development of equipment able to combine the existing autonomous systems with real-time data from SOCRATES.

4.5 Test site

A main objective of the project is to be able to demonstrate the concepts in a major test site. The city of Gothenburg was chosen during 1989, and the concept of the West Sweden Field Trial has emerged from this decision.

An initial demonstration was operating before the end of 1990, but the main implementation will not be complete until the last six months of the project, during the second half of 1991.

5. ROUTE GUIDANCE

Dynamic route guidance is the primary application considered within SOCRATES and within the IRTE as a whole. Leading members of the SOCRATES consortium are Philips and Bosch, the manufacturers of the two European autonomous navigation systems CARIN (Thoone, 1987) and TRAVELPILOT (Neukirchner and Zechnall, 1986). Also represented in the consortium are ICC, the consultants responsible for the London Autoguide demonstration scheme (Catling and Belcher, 1989).

Autonomous systems are able to give navigation advice to the driver based on a knowledge of the vehicle's position and of the road network. Both TRAVELPILOT and CARIN rely on a combination of dead reckoning and map-matching in order to maintain the vehicle's position; both systems use compact disc to store the digital map representation of the road network on board the vehicle. Philips and Bosch have joined forces in DEMETER and in other DRIVE projects to produce a common European standard for the digital map base on which both systems depend.

Given a suitable up-to-date map, CARIN is able to give routeing advice based on shortest distance paths through the stored network; the current TRAVELPILOT does not produce routes, but Bosch expect to introduce a new version which will include route recommendations.

However, without access to up-to-the-minute traffic information, a fully autonomous system can not give the driver the best route at the time it is required under the traffic conditions being experienced. The work at TRRL and elsewhere estimated that the benefits of a route guidance system would double by changing from a purely autonomous, or static, route calculation to one which fully took account of existing and predicted traffic conditions - a dynamic route guidance system.

A system based on two-way communication provides not only the means of giving the driver information but also a new high-quality method of collecting traffic data, both real-time and historic. Messages can be transmitted from equiped vehicles totally anonymously to provide the equivalent of a large number of simultaneous, continuous, "floating car" surveys - these are the costly conventional methods by which highway authorities collect data on network travel times.

By using cellular radio, SOCRATES is investigating the use of a communications infrastructure which will be installed for the whole of Europe - the pan-European GSM (Group Speciale Mobile) cellular radio system is already undergoing tests and is planned to become widely installed during the early 1990s.

The fact that only a single channel per cell is required for the SOCRATES system means that SOCRATES will require less than 1 per cent of the capacity of the GSM system, and will provide unlimited access to the traffic information from the SOCRATES control centres.

6. CONCLUSIONS

Results in SOCRATES so far have been encouraging. As well as successful technical development, significant progress is being made with the various committees responsible for the development of the GSM specifications and with the PTTs which would implement SOCRATES systems. Potentially, the system will offer fully dynamic traffic information over the whole of Europe.

Demonstration sites have already been implemented in Geldrop and Gothenburg, and the system has been successfully demonstrated at major international exhibitions.

It is confidently expected that the viability of SOCRATES as the basis of the IRTE will be demonstrated successfully there before the end of the current project at the end of 1991.

It is also anticipated that the investigation of compatibility with beacon-based systems will lead to the development of integration scenarios which will allow the combination of the two systems to provide greater geographic coverage, more functionality and increased flexibility for both drivers and traffic managers.

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SOCRATES

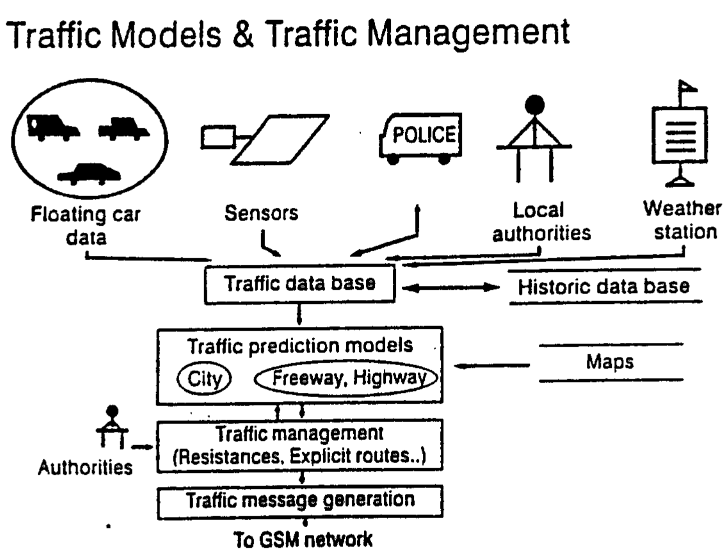

Fig 1 - Data collection and processing in the SOCRATES system

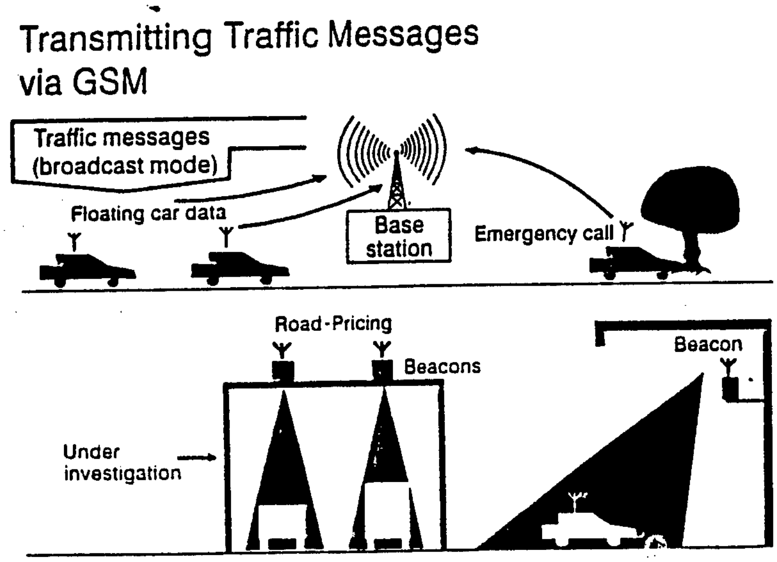

Fig 2 - SOCRATES and RTI applications

- END -

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