PROMETHEUS and DRIVE: Their Implications for Traffic Managers

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Abstract

PROMETHEUS and DRIVE are major European initiatives. They share the common objectives of applying advanced technology to the reduction of road accident risk and the improvement of traffic efficiency. The central theme of PROMETHEUS is the intelligent co-pilot; the programme is focussed on systems which aid the driver directly while DRIVE concentrates on the infrastructure of systems. Hence the programmes are complementary. This paper discusses the background to these programmes and examines their potential impact on road throughput. It concludes that the changes due to DRIVE will mainly come from the application of dynamic route guidance and information systems and are likely to be evolutionary; those due to PROMETHEUS could increase the maximum effective throughput of roads by between twenty and several hundred per cent but major problems remain to be solved.

1. Introduction

PROMETHEUS is an acronym for 'PROgraMme for European Traffic with Highest Efficiency and Unprecedented Safety'. It began in 1986 when eleven major car manufacturers agreed to work together to explore the potential of advanced electronic and computing technology for improving road safety and traffic efficiency. The European Commission (EC) was also considering a programme with similar objectives and in 1987 proposed the DRIVE (Dedicated Road Infrastructure for Vehicles in Europe) programme. It took some time to draw up the final programme of work for DRIVE and research commenced in January 1989.

Both PROMETHEUS and DRIVE are large programmes with complex objectives. This paper outlines the research programme of both projects and discusses the potential impact in one of the central areas, traffic management.

2. PROMETHEUS

2.1 PROMETHEUS PROMETHEUS is one of the largest projects within the EUREKA framework. EUREKA was established in 1985 by the ministries responsible for industrial research and development within 19 European countries, ie, it is not sponsored by the EC. The objective was to promote collaborative R and D between companies in two or more countries. There are now almost three hundred EUREKA projects, ranging from the development of high definition television to medical diagnostic kits. Financial support for EUREKA work comes, in the main, from the ministries responsible for industrial research and development within the participating countries. There is no central budget; all participants must seek their own financial support. The level of support available to participating organisations varies from country to country, but is typically between about 20 per cent and 70 per cent of the relevant costs of the industrial participants.

PROMETHEUS is led by a Steering Committee which has representatives from vehicle manufacturers from five European countries. At present they are BMW, Daimler-Benz, Porsche, Volkswagen and MAN (West Germany), Fiat (Italy), Matra, PSA and Renault (France), SAAB and Volvo (Sweden) and Jaguar and Rolls-Royce (UK).

Most EUREKA projects are aimed at developing equipment or a process which will lead directly to a new market. PROMETHEUS is different. Competition between vehicle manufacturers is always fierce and it would have been extremely difficult to promote near market research in such a diverse group. It is also aimed at exploring the potential benefits of applying a broad range of new technology to areas, such as road safety, which are of general community interest and not just restricted to vehicle manufacturers and purchasers. Hence one of the earliest, and most important, decisions taken by the PROMETHEUS Steering Committee was that the research should be pre-competitive and that contributions of research and ideas should be recruited widely from a range of Universities and Research Laboratories. At the end of 1987, towards the end of the project definition phase, other industrial partners from the vehicle equipment suppliers and component manufacturers were invited to join the programme. All of these partners will remain with the programme until its scheduled completion in 1993.

The different methods of supporting research within the countries with partners in PROMETHEUS makes it difficult to estimate the funding available for the programme. However more than three hundred scientists and engineers now participate in the work.

2.2 Research Framework PROMETHEUS is a large R and D programme spread over five countries and with about 60 participating organisations. The research straddles a whole range of technologies and there are many individual components, each with its own subset of objectives. This diversity makes it extremely difficult to manage as one large project. Over its life it has evolved into a range of sub-projects with numerous cross links to ensure that information and ideas are exchanged effectively. The whole project is managed by the Management Steering Committee, which has representation from each of the participating vehicle companies.

The central concept of PROMETHEUS is the intelligent co-pilot, an integrated set of systems to aid and enhance the capability of the driver. Although the development will provide some of the functions required for fully automatic driving that is not the objective; the technical problems and doubts about the fundamental need for such a system rule it out for the present. The co-pilot concept allows the development of a number of functions which can be developed and integrated into on-vehicle systems while still satisfying the requirement that the driver is in charge.

The initial industrial programme within PROMETHEUS was divided into three broad areas, PRO-CAR, PRO-NET and PRO-ROAD. Within these sub-programmes eleven 'thematic projects' were developed, each concerned with development in one area of technology. In addition the companies are developing a number of demonstrator projects; the aim with these is to provide 'technology pull' which will clarify the important developments needed within the thematic projects.

At an early stage in the development of PROMETHEUS it was realised that many of the ideas and concepts being discussed could not be realised by the available technology. There was a need for inputs of basic research. Four sub-programmes were established to satisfy this need: they are PRO-CHIP (custom integrated circuits and advanced sensors), PRO-ART (artificial intelligence and advanced signal processing) and PRO-COM (communications technology). The final group was initially known as PRO-GENERAL but this has now been abbreviated to PRO-GEN; the aim of this group is to bring existing traffic management and road safety expertise into the programme. The overall structure of PROMETHEUS and the links between sub-programmes are shown in Figure 1.

2.3 PRO-CAR The PRO-CAR programme is primarily concerned with systems which are wholly contained within the vehicle. If described in terms of the intelligent co-pilot system they are systems for enhancing the senses of the driver. Systems being examined within the PRO-CAR framework include:

Anti-collision systems; these typically use microwave or optical radar systems which will monitor the road ahead and give warnings of potential hazards. Usually the outputs from these will merely reinforce the information the driver sees in the scene ahead; however some parameters, such as closing velocities, are difficult for drivers to estimate and mechanical measurement could provide valuable additional information.

Vision enhancement systems; these would improve visibility by providing some capability of seeing using infra-red or ultra violet light with appropriate sensors and displays in the car.

Road surface sensors; these measure the coefficient of friction between the tyre and the road to determine the limits of adhesion and warn the driver if he approaches them. Ideally drivers need to know about conditions up to about 1km ahead which means that advanced systems of this type would include communications equipment to relay the information back along a traffic stream.

Driver Monitors; the PRO-CAR work includes driver monitoring, normally by analysing the pattern of steering corrections and control movements and detecting when the performance indicates his abilities are impaired, possibly due to being over-tired.

The dominant theme in these PRO-CAR systems is improving road safety, primarily for the driver of the vehicle. However they interface directly with the way that he controls the vehicle and determining whether they will produce a real reduction in accident risk is a difficult task. It demands an understanding of driver behaviour, and an appreciation of how he will use the features provided by the new system; for example a vision enhancement system might have little impact on accident rates, or even a negative impact, if drivers elected to drive more quickly when visibility is poor. The systems must be studied by assessing driver reaction, both in simulators and when driving test vehicles.

Hence a variety of thematic research projects are needed for PRO-CAR, extending well beyond the basic technical development of systems. The relevant projects are:

- Sensors and signal processing;
- Actuating Systems and Vehicle operation;
- General architecture (ie, systems architecture);
- Man-Machine Interface and;
- Vehicle safety and system dependability.

2.4 PRO-NET PRO-NET systems depend on communication links between vehicles. At the simplest level this communication link can be used merely to pass information from one vehicle to another; for example the friction information derived by the PRO-CAR sensors. However once communication links are in place it becomes attractive to use them to pass basic information about the speed of the vehicle. It is also relatively straightforward to engineer them to measure the separation and the relative bearing of adjacent vehicles. Hence within the memory of a PRO-NET processor in a vehicle it is possible to build up a model or 'plan' of the position, separation, relative bearing and relative velocity of all vehicles on the adjacent stretch of road. This is precisely the information that a driver has and uses to control his vehicle.

The first step in PRO-NET development is to produce the system which will permit this 'plan' to be computed and maintained in real time as vehicles drive; the next is to examine how it can be used to aid the driver in ways to reduce accident risk and improve traffic flow. At first the objective is to develop computing systems which process this 'plan' to derive information which can be presented to the driver but beyond that it may be possible to interface it directly with the vehicle controls.

The thematic projects which are mainly concerned with PRO-NET systems are:

- PRO-NET system engineering;
- Communication for PRO-NET and PRO-ROAD and;
- Emergency warning systems.

2.5 PRO-NET Safety Systems In principle PRO-NET systems could have an impact on road safety. If the 'plan' processor in the vehicle detects that adjacent vehicles are moving with a velocity and trajectory that means that a collision is likely it can warn the driver or even assume limited control of the vehicle to avoid the accident.

Assessing the potential impact of PRO-NET systems is difficult. Typically over 90 per cent of accidents can be ascribed to a temporary failing in drivers and are potential savings for PRO-NET systems. In reality the system to prevent many of those would demand a system of higher capability and reliability than the driver; it returns to the problem that it is impossible within the foreseeable future to develop a system with the capabilities of a human being.

A methodology for guiding the development of this type of safety system and assessing the potential benefits is being developed within PRO-GEN. In the past several European countries have conducted in-depth on the spot analysis of road accidents. Typically these were based on having an expert team on standby which was called out when a serious accident was reported to the police. In France and West Germany researchers are examining the records from these in-depth analyses and asking the question "What type of PROMETHEUS system function would have been needed to avoid or minimise the impact of this type of accident?". In some cases it is clear that nothing could have been done; in others there are clear indications that some of the possible functions of PRO-NET might have helped. Sometimes detailed research work is needed on computer simulations. Eventually the intention is to build up a detailed picture of the incidents that might have been prevented by a workable PRO-NET system; the numbers of these can then be scaled up using national accident statistics to predict the expected benefit. The ideal would be to identify a set of system functions which would be useful in minimising a range of incident types.

There are problems which need to be addressed in the research associated with PRO-NET. One is the practicability of developing an introduction strategy; will the system be effective if only a few vehicles on the road are equipped or is it vital that all vehicles have working equipment? The second is the problem of bringing vulnerable road users, such as pedestrians and cyclists, into the system so that its benefit is not restricted to high speed special roads. One possibility is to issue them with a simple lightweight transponder but the practicability of this approach is open to question. Finally there is the question of how drivers would use the system; if they drove with less care after its installation the benefits could be negated.

The other major area where extensive research would be needed is that being assessed within the Vehicle Safety and System Dependability thematic project. A practical PRO-NET system might eventually interface with primary controls of vehicles, such as the accelerator, brake and possibly even steering. Any failure would have major consequences and the probability of causing an accident would be high. A failure might occur in the hardware, the software or in the overall system structure; reducing the joint probability of all failure modes to an acceptable level is a major task.

It is instructive to examine the failure rate of the existing driving process. The UK has a vehicle population of 22 million and there are 5,000 road deaths each year. The average journey distances and speeds indicate an average vehicle usage of about 350 hours each year. Hence the MTBF (mean time between failure) of the present driver vehicle system can be evaluated as 1.5 million hours for fatal accidents. This is an extremely high figure in comparison with most conventional engineering systems. Those that achieve it, such as jet aircraft or nuclear power plants, have extensive fault monitoring and repair by expert teams. If PRO-NET were to be successful the acceptable increase in risk of a fatal accident due to system failures might need to be ten times this figure, ie, a MTBF of 15 million hours. It remains to be seen whether figures of this order are possible.

2.6 PRO-NET and Road Capacity Road capacity is limited by the way that drivers judge separation from the vehicle in front and adjust the gap in line with road conditions. Capacity could be improved if these behavioural constraints were modified.

Modifying behaviour to improve capacity could have an impact under a variety of road operating conditions, including:

(i) Flow breakdown as a high speed road nears saturation flow. On most parts of the network the capacity is determined by junction capacity. However the capacity on high speed roads, usually with grade separated junctions, can be determined by the capacity of the link itself. As the traffic flow increases to around 2000 pcu (passenger car units) per hour per lane on unobstructed roads speeds drop and vehicle concentrations increase until the drivers have to use brakes as well as accelerator to maintain his separation from the vehicle in front. The appropriate region in the speed flow relationship, circled in Figure 2, is characterised by unstable flow; speeds often fall to low levels and there is stop-start driving, particularly in regions downstream from junctions. In a PRO-NET system where vehicles are aware of the positions and velocities of adjacent vehicles there are a number of possibilities for improving capacity.

The first approach would be to assume limited control of the vehicle accelerator. If vehicle speeds were maintained as traffic flows increased up to and beyond 2,000 pcu per hour per lane the inter vehicle gap would not reduce to the same extent and the onset of breakdown could be held off. For example the typical speed flow relationship shown in Figure 2 is based on measurements on the M6 motorway; it indicates that speeds drop from 105 km/h at low flows to about 75 km/h at mean flows of 1900 vehicles per hour just before the onset of flow breakdown. If breakdown is assumed to be solely determined by the gap to the vehicle in front maintaining the speed at the low flow value would increase the breakdown threshold flow from 1,900 to 2,650 vehicles per hour per lane, an increase of 40 per cent.

This system resembles an intelligent cruise control. At the onset of flow breakdown drivers would be travelling at significantly higher speeds and would have to brake even more sharply than would normally have been the case; the breakdown will be even more abrupt than usual. This could be overcome in part by also linking the PRO-NET processor to the brakes of the vehicle. Typically driver reaction times before braking are in the 0.3 to 1 second time interval (1), and towards the top end of that figure if he is basing his judgement on a difficult parameter, such as the closing speed and distance to a vehicle in front. The PRO-NET controller could eliminate this reaction time and produce a smoother transition from the free flowing traffic conditions to breakdown.

Other control strategies are possible. Instead of holding speeds at the low flow level the system could interact with the driver to allow lower inter-vehicle gaps before his reactions cause breakdown at lower speeds. The mean inter-vehicle gap at breakdown is approximately 31m in the example shown in Figure 2; if the operation of PRO-NET allowed vehicles to operate with an inter-vehicle gap of 20m at speeds of 60 km/h the breakdown capacity figure would move to 2,400 vehicles per hour per lane, a 26 per cent increase in maximum throughput.

Hence PRO-NET could, in principle, increase capacity of a high speed road by up to 40 per cent. Much research needs to be done to determine whether such systems are really feasible. This includes research into the control algorithms embedded in the processor and into the MMI aspects. The latter are particularly critical since for part of the time, at least the equipment would be operating the controls in a manner counter to the drivers instincts. The transition from automatic to manual control would be particularly difficult as would the problem of ensuring he was confident that he could always over ride the system. The system reliability constraints outlined in Section 2.5 would also apply.

(ii) Pulling away from a stop line. Typically this occurs at signalled intersections but the case where drivers leave the front of a slow moving queue on passing a traffic incident is similar. Once again the capacity is limited, typically to about 1800 vehicles per hour per lane, by a combination of the drivers reaction time and his wish to increase the gap between his vehicle and that in front as the traffic stream speeds up. A reduction in headway of 0.5 second for all vehicles in the stream would increase capacity by about 25 per cent, to about 2250 vehicles per hour per lane. This headway reduction is of the same order as the drivers reaction time; if the reaction time of the system were negligible this benefit need not be accompanied by an increase in accident risk.

These examples illustrate that PRO-NET systems could provide a major increase in road capacity at the expense of the introduction of systems of considerable complexity into the driving process. There are many practical problems to be solved before such systems could be considered a realistic option.

2.7 Longitudinal Control Longitudinal control can be viewed as a simplified version of PRO-NET. Vehicles are fitted with sensors to measure the separation from the vehicle in front. The outputs from these sensors are processed and the outputs are linked to the vehicle brake and accelerator controls so that as drivers move towards the vehicle in front the controls are overridden to allow it to operate with a separation of a few cm. Systems of this type have been demonstrated by PROMETHEUS partners, in particular by Volkswagen.

The potential increase in road capacity by close following allowed by these longitudinal control systems is large. For example if cars operated within a 6m slot in a uniform stream of traffic at 100 km/hour the theoretical capacity is over 16,000 vehicles per hour per lane. However the technical problems are formidable. Drivers might be uneasy travelling at high speeds with minimal separation from the vehicle in front and there would still be considerable problems in developing an introduction strategy, particularly if reserved lanes were necessary, as seems likely.

These types of system pose major psychological, environmental and technical problems. Nevertheless the benefits of the approach may justify significant effort to overcome them. It might be impossible to achieve the full 16,000 vehicles per hour per lane capacity but a practical system could perhaps manage 6,000 by using platoons of about 100 vehicles, with significant gaps between them to allow for vehicles joining a platoon from the rear or for a platoon splitting to allow vehicles to exit at a junction. It would be difficult to operate these platoons in normal mixed traffic; one possibility is a lightweight road with dual single lane carriageways for cars only. This could be built at the side of or elevated above existing road and rail links. Such a lightweight road might offer the capacity of a three lane motorway at a fraction of the cost and would free the conventional network for heavy traffic. Accident rates might be lower for normal roads. These roads could be built in rural or urban areas. The technical problems are difficult, but the potential gains are enormous.

This high capacity road system could only be adopted if technology made the necessary high reliability systems available. The reserved lane option is attractive because these roads could operate apart from the normal traffic congestion. The enhanced level of service available on these roads would allow the option of operating platoons at moderate speeds, possibly in the 100 to 120 km/hour range, while still achieving acceptable journey times. This might be desirable to minimise energy consumption in future decades.

2.8 PRO-ROAD PRO-ROAD is the third part of the industrial research programme and is concerned with systems which depend on communication between the vehicle and roadside equipment. Typically these are information systems and dynamic route guidance systems. Three of the thematic projects are primarily concerned with this area. They are:

- Information Processing and DATA acquisition (including digital mapping);
- PRO-ROAD System Engineering and Standardisation and;
- On-board elements.

Inevitably some aspects of these thematic projects overlap into the areas covered by PRO-CAR and PRO-NET. For example the last of these projects is concerned with the integration of the systems and equipment needed for the full range of PROMETHEUS functions. It includes work on the architecture and structure of the system needed to provide dynamic route guidance. However some of the information systems being developed within PRO-CAR would need to interface with this system.

PRO-ROAD was unusual within PROMETHEUS in that when it began there was already an active programme in progress elsewhere in Europe. The ALI-SCOUT infrared route guidance system was being developed within West Germany (2) and plans were being advanced for a major demonstration in Berlin. At the same time the prospects for providing a dynamic route guidance system, known as AUTOGUIDE, were being assessed in the UK (3). Both of these systems had considerable implication for vehicle manufacturers and it was natural to include these systems, and related developments such as the CARMINAT system being developed in France, within PROMETHEUS. Research into the traffic impacts of these systems was established within PRO-GEN and other topics, such as digital mapping, MMI work and the processing requirements was appropriate for the thematic projects.

This division of responsibilities was complicated by the emergence of DRIVE, as discussed in the next section. This programme is primarily concerned with traffic management infrastructures; analysis of the traffic effects of dynamic route guidance and development of the control infrastructure has more relevance to DRIVE than PROMETHEUS. When this became clear in 1988 PRO-GEN offered assistance to aid DRIVE set up its research programme. Moreover almost all of the organisations participating within PRO-GEN were successful in bidding for work within DRIVE. However PROMETHEUS retained a programme of work which deals with the aspects of guidance system which are primarily of interest to the vehicle companies. These include MMI, the acceptability of systems to drivers and the safety implications of systems. One large block of work, digital mapping has been hived as a separate EC sponsored benchmark project.

Hence the interaction between DRIVE and PRO-ROAD is complex. Many people have interests in both. It is a mark of success that both of these major programmes have managed to reach a consensus on how the responsibilities should be divided. Inevitably there is some overlap but it is relatively small.

2.9 Demonstrator Projects One of the objectives of PROMETHEUS is ultimately to produce workable hardware. As described previously this led to the introduction of demonstrator projects to provide 'technology pull' to help focus the research programme. The intention of these projects is that they should demonstrate:

(i) Technical feasibility and
(ii) Relevance to a future integrated system

In the early years of the programme the aim is to equip vehicles to demonstrate specific features, such as vision enhancers, communication systems, and sensors. Eventually functions and systems will be integrated to produce a system which could be installed on a single vehicle without intimidating or overloading the driver.

Some demonstrator vehicles have already been produced. These include:

- Friction Monitoring System;
- Longitudinal Control System;
- Electronic Architecture (essentially a pc integrated into a car);
- An MMI Test bed;
- Headway advice and control system;
- HIGH-NET. This demonstrates the bottom level of the PRO-ROAD system, ie, the ability of an in-vehicle computer to maintain a model of the position of adjacent vehicles;
- Vehicle to Vehicle data links;
- ARTHUR - a system for automatically advising the emergency services when there has been an accident; the vehicle's position is reported to the control centre automatically;
- Mobile information systems, demonstrating the application of RDS (Radio Data System), cellular radio data systems and other mobile links;
- Satellite Communication Systems, using the MARECS 82 geostationary satellite;
- CARMINAT, based on the CARIN autonomous navigation system which uses a map stored on compact disk and;
- AUTOGUIDE and LISB, the dynamic route guidance systems being tested in London and Berlin respectively.

3. DRIVE

DRIVE (Dedicated Road Infrastructure for Vehicles in Europe) is a programme developed by the Commission of the European Community. The primary objectives are the same as those of PROMETHEUS, namely:

- to improve road safety
- to improve traffic and transport efficiency, and
- to reduce environmental pollution.

Within DRIVE these objectives will be achieved by the application of road transport infomatics (RTI) to the roadside infrastructure and to vehicles. The programme will run for three years and commenced on 1 January 1989. A total of about ECU 55 million has been allocated by the EC for the work but the programme cost is approximately twice that figure because most partners are only funded at 50 per cent of their costs.

Although the objectives of DRIVE and PROMETHEUS appear similar the programmes are substantially different; PROMETHEUS is focussed on the driver and assisting him in his task while DRIVE concentrates on the roadside infrastructure. As discussed in Section 2.8 there is considerable potential overlap, in particular in the areas which originally fell within the remit of PRO-ROAD and PRO-GENERAL. However responsibilities have been adjusted so the programmes complement each other; there is still an overlap, but often the same people are involved in the work for both programmes and wasteful duplication of research is avoided.

DRIVE consists of 60 separate projects, each with up to a dozen partners drawn from industry, research laboratories and Universities. The list of projects and participants has been published (4). They fall into five main groups with the following headings:

- Evaluation and Modelling
- Behavioural aspects and traffic safety
- Traffic control
- Public transport and freight management and;
- Telecommunications.

3.1 Safety Impacts of DRIVE Thirteen of the DRIVE projects are concerned with behaviour and safety, covering the following topics; accident analysis, vulnerable road users, man-machine interface, collision avoidance, evaluation of driver behaviour, data recording and impact and implementation issues. The data recording project, DRACO, is concerned with developing a solid state recorder, with sensors, which can be fitted to a large test fleet to record vehicle movements and accelerations immediately before an accident.

It is difficult at this stage to predict the impact that the DRIVE safety work will have. Much of it is concerned with collecting data and improving the understanding of the road accident problem; much of the initiative research on safety will probably be left for DRIVE 2, which may be approved by the EC to commence in 1991 or 1992.

3.2 Traffic Management Impact of DRIVE It is difficult to identify the potential impact of individual projects which may have an impact on traffic control; they are inter dependant and ultimately it will depend on the take up of ideas. However if the programme is successful it will result in the following systems:

- Dynamic route guidance, integrated with UTC systems where they exist;

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