THE UNITED KINGDOM TECHNICAL PRESENTATION

SECTION 2 PART 2

"FOREWORD" AND "TOWARDS SAFER ROAD VEHICLES"

RT. HON. JOHN PEYTON, *Minister for Transport Industries*

The United States Government, in initiating the experimental safety vehicle project, took an important step to make the roads safer. I was glad to be able to respond to it on behalf of the British Government. For many years we in Britain have been concerned about road safety; successive governments have consistently tried to reduce the unhappy toll of death and injury. Although the measures taken have had some success – road casualties have not risen appreciably for several years and are proportionately lower than in the United States – we are still far from satisfied. Much has to be done before the roads are as safe as they should and can be.

British road problems naturally have some specific features which are reflected in our approach to car safety. This has three aspects – accident avoidance, occupant protection, and pedestrian safety. We believe that accidents can be avoided if cars have better handling qualities, and equipment which gives drivers more information about their surroundings and what they and others are doing. We want occupants of cars which are involved in accidents to be protected against their effects as far as possible; and, since 40 percent of all fatalities on British roads are pedestrians, we must ensure that vehicles are designed to minimize injuries inflicted on those whom they strike. The British Car Safety Program takes account of all these factors. In it the emphasis is on the development of practical engineering safety systems capable of being incorporated into a wide variety of types of cars.

I am confident that this Third International Experimental Safety Vehicle Conference will show that a promising start has been made in many countries towards achieving our common aims of better and safer roads. The United Kingdom program, which forms part of this major project, is a cooperative venture between government and industry involving substantial funds to develop car safety systems. I am sure that the United Kingdom display in the exhibition will demonstrate that we in Britain are determined to make a real and valuable contribution to this essential international activity.

TOWARDS SAFER ROAD VEHICLES – A STATEMENT ON BRITISH ACTIVITIES

INTRODUCTION

Road safety covers many facets but in research a continuing effort has been devoted in the U.K. for many years to all three main aspects, namely the road environment, the road users, and the vehicle, with the maximum contribution to safety being sought from each. These activities have been supported by the acquisition of traffic and accident data on a comprehensive scale unmatched in any other country. As a result of this work the general level of road safety compares favorably with the best achieved anywhere. In the case of car occupants for example the fatality rate per mile travelled in the U.K. is just over half (55%) that of the U.S. Although this represents a position of some strength there is of course no justification for complacency. For example in the case of youngsters 15 to 20 years old, road accidents account for nearly half of the deaths from all causes. Strenuous efforts are being made to improve the education and training of road users and in particular of the young.

Equally research is proceeding on a broad front to improve the safety of the road environment but it is an inescapable fact that powered vehicles inflict almost all the road deaths and injuries and in this the passenger car is dominant because of its wide usage. It is not surprising therefore that the car occupies most of the interest but motorcycles and heavy load-carrying vehicles must not be neglected. Neither must thought be given only to vehicle occupants, since some 40 percent of road deaths are suffered by pedestrians, the majority of them as a result of being struck by cars.

VEHICLE SAFETY RESEARCH

Two main choices are available in designing a comprehensive program of vehicle safety research. One approach is to pursue the development of complete vehicles to much higher levels of safety than are achieved by their present-day counterparts. An alternative approach, which may be more fruitful when a wide range of vehicles is involved, is to direct research to establishing general performance levels and to identifying selected vehicle features which promise worthwhile improvements in safety. Within this framework research may be conveniently divided into two categories. One is accident avoidance, and the other protection of people during or following a collision, whether they are vehicle users or pedestrians.

ACCIDENT AVOIDANCE

In considering accident avoidance we must not restrict ourselves only to measures which prevent a dangerous situation developing into a collision; we must also find ways of minimizing the onset of dangerous situations. In the latter category are devices intended to help road users to take the correct decisions and to warn drivers of the dangers ahead; two current examples are the head-up displays of speed and of minimum safe following distance, and the RITA system of aural communications with drivers.

Non-Locking Brakes

A highly desirable requirement of accident avoidance is that a driver should be able to maintain complete control of the vehicle while braking and maneuvering in emergencies, even under adverse road conditions. The ability to do so is critically dependent upon preventing wheel locking and this applies to all three main categories of vehicles: motorcycles, passenger cars and goods vehicles. In the case of articulated vehicles wheel locking can lead to jack-knifing, or to trailer swing; the former is virtually uncontrollable once started, the latter too is very dangerous because the driver may be unaware that it is happening. Considerable technical progress has been made on non-locking braking systems for all three classes of vehicle but the establishment of an economically viable requirement is dependent upon the accident savings which can be achieved by non-locking braking systems, bearing in mind that various system options exist with a corresponding range of costs.

Following a large scale trial of anti-lock devices on articulated goods vehicles the U.K. is planning to carry out a trial of current production cars equipped with non-locking brakes. To obtain a reliable answer within a reasonable time the trial will need to be mounted on a large scale and will depend for success on the cooperation of many people and organizations. However, if carried through it will represent a major initiative on the part of the U.K. toward establishing a case for or against the adoption of non-locking braking systems for cars.

Handling Qualities

Another important aspect of collision avoidance is the influence on it of that rather abstract quality known as "handling." A large amount of work has been carried out on the subject mainly from the standpoint of customer acceptance but there is at present very little information relating handling features or performance levels of handling to accident involvement.

PROTECTION AGAINST INJURY

Accident reduction is of course the most desirable target because it brings with it the dual benefits of savings in both injury and property damage. But it would be indefensible to neglect measures which offer worthwhile reductions in personal injuries when a collision or loss of control occurs. This subject is not as straightforward as might appear at first sight because a gain in safety for the people within a car might accrue at the expense of increased injury to occupants of other vehicles or to pedestrians. Furthermore it by no means follows that a demand for survival at very high impact speeds will yield the best solution because most injuries and collisions occur at modest speeds. Much more is likely to be heard of these aspects as car safety programs evolve.

Human Tolerance

In pursuing greater occupant protection there are two outstanding problems neither of which is new. The first concerns the need for more data on human tolerance, i.e. the ability of the body to withstand without serious or permanent injury, unusual loads over brief periods of time; it is essential for the data to relate directly to the variety of events that occur in actual accidents. This information is crucial to vehicle design and from this standpoint one can readily appreciate the need for occupant protection to be regarded not simply as an add-on system but as an integrated vehicle design problem involving both the basic structure, the interior design and the occupant restraint system.

Test Techniques and Occupant Restraint

The second problem concerns test techniques for type approval and quality control, two of the most important being the representation of the human occupant and the associated performance levels to be applied. Both of these reinforce the need for an overall performance standard for occupant protection rather than an accumulation of piecemeal design requirements. A basic issue in forming a standard is the assumption to be made regarding the use of occupant restraints. The value in injury savings from the regular use of seat belts has been amply demonstrated but the majority of car occupants do not use them at the present time even though most cars are now equipped for the front seating positions.

To cover both situations, i.e. restrained and unrestrained occupants to the same level of protection would impose very great design problems. It is the U.K. view therefore that an occupant protection standard should be based primarily on the assumption that restraint systems will be used but it should make some provision for the unrestrained case; the survival levels for the latter however will almost inevitably be substantially below those for restrained occupants.

VEHICLE REGULATIONS

The research towards safer vehicles will be of value only when the results have been embodied in production cars. Close collaboration has existed between industry and the U.K. government for many years and many of the lessons learned have on the initiative of industry been embodied in production vehicles almost unnoticed by the general public. Nevertheless there are many instances when it is desirable and sometimes essential to reinforce the situation by official regulations.

Vehicle regulations in the U.K. are a government activity with a history nearly as long as that of the motor car itself. The first regulations were in force before the turn of the century, and since then refinements and additions have followed in a continuous stream. The primary objective has been the promotion of the safety and welfare of the citizen, as driver, passenger and as bystander. To a large extent these regulations have traditionally taken what was best, or at least what was a desirable minimum, out of current practice and technology and laid it down as a standard for all to observe.

In recent years most people have become increasingly aware of a second strand in vehicle regulations. Safety considerations have inspired many countries to develop systems of regulation comparable to our own – comparable but not identical. The development of a vast international trade in motor vehicles has made it abundantly clear that compliance with the multifarious requirements of the many export markets is a major headache to the manufacturer. The demands of safety cannot be disregarded but in many instances the differences do not represent different degrees of safety. They exist simply because administrators have approached the same problem in isolation from each other and have tackled it in their own way, with the frequent result of provisions of similar effect but annoyingly divergent in detail.

From this situation spring the efforts, particularly through the agency of the Economic Commission for Europe, to develop internationally agreed regulations. Valuable work has been done although progress is admittedly not as fast as either the industry or the Department would like. An impetus to this search for harmonization has been given by the efforts of the Common Market. As a part of the Community's program of work to eliminate barriers to trade between member states a system of standards is being developed and embodied in directives within the framework of the EEC type approval system. When this system is complete any vehicle which conforms to all the standards must be accepted throughout the Market area. British membership will enable us to benefit from this system.

Another comparatively recent development in the field of vehicle safety is the tendency for governments to go beyond the traditional role of merely consolidating existing good practice. The increasing toll of road accidents and the mounting concern in all quarters – public opinion, press, parliament and government – to explore all possible means of curbing it have inevitably focussed attention on a number of areas in which a more positive approach might appear to pay dividends. Amongst these naturally figures the setting of new requirements for the design and construction of vehicles intended to achieve new levels of safety for road users.

In the future this more active role of government seems likely to develop. Although the industry continues to devote spontaneously much effort to the improvement of vehicle safety, and although what the industry can technically achieve sets a limit to what can be required by regulation at any given time, it is nevertheless true that government initiatives may promote the concentration of resources in such a way that desirable improvements are achieved more quickly than would otherwise be the case.

One method of setting about this would be to link regulations not to what is now technically possible but to what is hoped to be possible in the future – to set a kind of legal target which the industry must achieve by a stated date. This is not however the U.K. approach, where it is considered preferable to foster the necessary research and development in order to demonstrate the practicality of a new requirement and also to show that its introduction could be expected to produce benefits in terms of accident or injury reduction commensurate with the cost it would impose on the public.

It is important too that standards should not be drafted in such a way as to inhibit further development and innovation by the industry. For this reason the U.K. will be looking increasingly towards performance-based standards rather than design-based standards. By this is meant that a standard should ideally tell the manufacturer how the vehicle should behave in certain prescribed conditions, rather than prescribe the constructional features which must be incorporated to make it behave in such and such a way. The manufacturer then retains the freedom to develop and modify design in such a way as to achieve the required performance standard more efficiently.

A particular field in which we are interested in developing such an approach is that of occupant protection. Regulatory action in that field recognizes that accidents will continue to happen, whatever other improvements are made in vehicle design, in road layout and in driver behavior, and sets out to mitigate the consequences of this inevitable residue of accidents to the driver and passengers. The U.K. believes that the principle is good, and is interested in investigating, in co-operation with the industry and with other governments, the way in which it might usefully be applied to the typical European car. It may well turn out that this will be the most satisfactory way of implementing the lessons which will be learned from our research program as to the feasibility of new levels of vehicle safety.

DRIVING AIDS

MR. H. A. J. PRENTICE, *Head of Driver Aids and Abilities Division*

Transport and Road Research Laboratory

INTRODUCTION

Over the last 25 years the average speed of vehicles has considerably increased, the traffic density has greatly increased, as has the number of regulations, signs and signals which must be obeyed or interpreted. In addition development in road layout design has not solved all the problems facing the driver in reaching his decisions. The physical and mental abilities of people who must operate in this environment have not changed. The problem then is to ensure that people drive within their physical limitations and yet drive to a higher standard of safety than at present. Here we are not dealing with a specialist body like air-line pilots but with an entire cross-section of the population. It is therefore necessary to either provide drivers with instruments to make up their deficiencies or to take the decision-making out of their hands. This can be done either by altering the structure of the environment or by providing suitable electro-mechanical equipment. Automatic systems now available are far superior to man in the speed with which they can make decisions and can thus be used to supplement the driver in critical driving situations.

The limitations of human performance are under continuous study at the Transport and Road Research Laboratory, so that the appropriate equipment may be developed.

The TRRL in looking at these problems has concentrated on a limited number of items, details of which are available in this paper, or in the exhibition at Dulles. In the area of helping the driver by giving him the right information in the right place the Head Up Display speedometer has been demonstrated to be a very valuable aid and can now be produced at an economical cost. Using the same principle a station keeping indicator is being developed that will advise drivers on the minimum safe following distance from the car in front. The whole concept of aural communication is being looked at and plans are being developed for systems specific to individual drivers. The night driving problem is under continuous study and recent work on vehicles has been on a "dim-dip" or running lights system. Finally the "dual-mode" vehicle has been considered as the ultimate form of personal transport; working on this project has yielded a technological spin-off in the sense that we can now see safe ways of remotely controlling speed and braking of vehicles. As part of this project an automatic following system giving close, high speed following in safety is being developed; the broad outline of this work together with proposed ways in which the various steps in reaching full automation might be implemented are given later.

VEHICLE BORNE DISPLAYS

Station Keeping Indicator

A safe time interval between vehicles may be regarded as being one within which the driver of the following vehicle is able to react to the stopping maneuver of the preceding vehicle and initiate his own stopping action, in other words his brake reaction time. Therefore, if a driver travels behind another at such a distance that he is able to react before his vehicle passes the place on the road at which the preceding driver reacted and his vehicle does not have an inferior braking system, he should always be able to stop safely when only braking is involved. Under the most favorable conditions, that is, in a simulated emergency, brake reaction times of less than half a second are not unusual. However, in a true emergency situation with an alert but unexpected driver a reaction time of less than one second is unlikely. On one fully instrumented section of urban motorway in the United Kingdom time intervals between succeeding vehicles of less than one second are regularly recorded. There is no reason to suppose that this finding is other than typical of all heavily trafficked fast urban roads.

The problem is that it is virtually impossible for a driver to be able to choose unaided correct following distances for particular speeds so as to always allow for a one second minimum reaction time.

As an aid to achieving greater safety in car following situations a device has been developed at TRRL which may be used to indicate to the driver the minimum following distance at which he should travel to allow himself one second in which to react.

This device comprises a pair of vertical lines against which the vehicle being followed is viewed by the driver. The gap between the lines is varied by the speedometer mechanism so that the faster the vehicle travels the closer the lines move together. It is essential that the driver sees the lines at the same time as he views the vehicle ahead. When the vehicle ahead is bracketed by the lines he is then at a safe following distance. This is achieved by the use of a head up display system similar to that used in combat aircraft or, in a modified form, to display speedometer readings in motor vehicles, as exhibited at Dulles.

The optical components used are quite simple. A cheap plastic moulded lens of aspherical form is used as a collimator. This lens is used to produce images of the lines which are seen by the driver as reflections in his windscreen. The reflection actually comes from a small flattened area of the windscreen. The production of such a flattened area is not as difficult as it would at first seem to be since on modern cars the portion of the windscreen normally viewed through when looking straight ahead is very nearly flat. The lines themselves are generated by means of a single strip filament lamp which is moved by means of a drive taken from the speedometer mechanism. Two lines are obtained by using a view of the lamp directly together with its real image formed by means of a small concave mirror.

In practice the device has been so calibrated that it may be used when following most passenger cars on British roads with an error of approximately ±10% taking the widest and narrowest vehicles. It may also be used with trucks, etc., since they are required to have rear end markings of certain sizes which could be used in lieu of the overall vehicle width. These marking sizes are not yet tightly controlled but the appropriate legislation exists to do this if necessary.

Brake Lights

To be more certain of safe stopping even though he has been able to react within one second a driver needs to know as quickly as possible that the vehicle ahead has initiated emergency braking. At present there is no way of knowing how severely the driver ahead intends to stop. A system which will indicate the severity of braking as well as its onset is being developed. It takes the form of a multi-level brake light display. Simply, the greater the vehicle deceleration the more brake lights are illuminated. At present three separate levels of deceleration are used and up to seven lights are used illuminated in the sequence one, three and seven lights as the deceleration severity increases giving an impression of suddenly increased vehicle width.

IMPROVEMENTS IN VEHICLE LIGHTING SYSTEMS

Driving at night poses its own particular problems and the present systems of vehicle lighting in general use throughout the world are the result of an evolutionary process that has gradually been taking place since it was found that the primitive lighting carried by the first mechanically propelled vehicles was not good enough to fulfil the functions of enabling a driver to see where he was going, and to warn other road users of his presence and intentions. In particular, the headlamp in its present form is a searchlight that will enable a driver to see as far ahead as possible without causing intolerable glare to drivers of vehicles approaching from the opposite direction. Thus the headlamp must be a compromise and like most compromises the end product is not entirely satisfactory. Visibility given by the upper beam is adequate in most cases but this is not the case with lower beams, which also still give undesirably high glare illuminances in the direction of oncoming drivers, in spite of modifications in the distribution of the light emitted by the lower beam. It is felt that the present headlamp systems have now been developed as far as they can go and that any improvement will only be achieved by the use of entirely novel systems. The idea of polarized light headlamp systems has been with us for a long time and there is much current activity both in Europe and the U.S., where the results of proposed tests are awaited with interest. Looking further ahead we can imagine the general use of "opposing driver sensitive" headlamp beams that will automatically avoid emitting any light in the direction of an oncoming driver's eyes.

For the immediate future, however, we shall have to exist with the present system of upper and lower headlamp beams and the main task, from the point of view of the safety vehicle, is to ensure that the lower beam is used as safely and effectively as possible.

The full benefit of the present design of headlamp beam is only obtained when it is correctly aimed and it is obviously desirable that this correct aim should be maintained at all times. Headlamp aim is normally carried out with the vehicle unloaded except for the driver. Unfortunately many modern vehicles tilt to a significant extent when loaded and measurements in Britain have shown that the tilt is more likely to result in a 'nose up' attitude rather than the reverse. A change of only 1 degree upwards in vehicle attitude can result in severe glare to an oncoming driver, even with headlamps that have been correctly aimed. In seeking a low cost solution one approach to this problem has been tackled in Europe. It has been to pivot the headlamps in their mountings then making them automatically tilt to compensate for vehicle body movements. This has been achieved by means of either hydraulic or mechanical systems, the latter being the cheaper. Both systems use the relative movement of wheel axles and car body to produce the necessary correction signals. The front and rear suspension movements are detected and are combined to transmit a vertical angle correction system to the pivoting headlamps. Both the hydraulic and mechanical systems have been tested statically and dynamically. A load of 500 lb in the rear of the cars tested caused a 'nose-up' attitude of approximately 1.25 degrees but the compensated lamps in both systems moved by less than 0.1 degrees from the horizontal.

The lower headlamp beam is designed to allow drivers to see ahead as well as possible in the face of oncoming traffic. On unlit and poorly lit roads it is imperative that the lower beam should emit as much light as possible, as long as the light emitted in the direction of an oncoming driver's eyes is kept within reasonable limits. However, more and more roads are nowadays being equipped with street lighting of a much higher standard than in the past, and the need for lower beams to emit light at their full intensity no longer exists, although there must be some form of vehicle lighting to permit pedestrians and other road users to differentiate between parked and moving vehicles. Although some countries adopt the practice of using normal lower headlamp beams at all times, whatever the standard of the street lighting, in others, such as France, lower headlamp beams are not normally used in areas where the street lighting is good. In Britain practice varies between one town and another, but the use of standard lower beams in well-lit streets has been shown to be a disbenefit in terms of accidents.

It would be desirable to have some form of intermediate front vehicle lighting lying between the normal parking lights and the normal lower headlamp beam and such a system has been developed. This system automatically reduces the intensity of the lower headlamp beam when a vehicle is in a well-lit area until the brightness of the headlamp is about 20 per cent of its normal value. This is bright enough to enable the light to be differentiated from a parking light.

The automatic headlamp brightness control has to meet a number of different requirements for satisfactory operation. Firstly, it must be sensitive to light from the street lighting luminaires but not to light from the headlamps of opposing vehicles. This is achieved by taking advantage of the fact that as headlamps are normally run from a direct current supply they give a steady output whereas the light from the discharge sources normally associated with high quality street lighting installations fluctuate at a frequency that is twice that of the electricity supply (i.e. at 100 Hz in most of Europe and at 120 Hz in the USA). Although fluctuations at these frequencies cannot be detected by the human eye they can be easily detected and amplified electronically. This is what the control device does.

The second important requirement is that the device should not be sensitive to isolated light sources but should wait until light of the required intensity has been continuously experienced for a long enough period (typically 25 seconds) to ensure that the vehicle is in fact in a well-lit area of some extent. Thirdly, it is imperative that the headlamp beam should revert to its full brightness on leaving a well-lit area for one without street lighting, or with street lighting of a lower standard. Both these requirements are satisfied electronically.

AURAL COMMUNICATION

Both from the point of view of road safety and traffic control it is recognized generally that the communication link with the driver must be improved. At present the driver uses his visual senses to control the path of his vehicle and simultaneously to seek relevant traffic and safety information from visual road signs. In spite of improvements in visual signing and visibility from vehicles the driver's visual senses are heavily loaded in many driving situations and this position will deteriorate further as vehicle densities increase. It is also a fact that visual signs are frequently obscured for a variety of reasons (e.g. other traffic, difficult siting problems, heavy rain, fog, snow etc.). Serious consideration has been given therefore to the communication of information to drivers by means of the aural sense.

Two kinds of information are required by drivers – one is strategic and the other is tactical. Strategic information is used by drivers to plan their journeys, ideally before starting out on the road system; this is best provided by the present traffic information services radiated by local radio stations or national broadcasting networks. Such information is regionally based and gives a general picture of the situation in the road network. The second kind of information required is tactical i.e. that required for detailed traffic control and emergencies on individual roads within the network and it is this kind of information with which the TRRL RITA (Road Information Transmitted Aurally) project is concerned. The tactical information is under the immediate control of Area Traffic Control authorities and provides the communication channel for traffic control measures.

It is necessary for operational reasons, apart from driver convenience, that information be confined to a particular carriageway i.e. so that drivers will only receive messages relevant to their carriageway and direction of travel, as in present visual methods of traffic control. This requirement limits the choice of techniques available for a RITA system.

A range of standard messages appropriate to the particular location would be pre-recorded and stored in a message bank; the messages would contain information relating to traffic control measures (diversion, tidal working, lane closures, speed) and emergency situations (accidents, weather conditions). The message bank can be located at the roadside transmitting point or in a central control room from which the traffic controller can select the appropriate message for the location and traffic situation.

When the roadside transmitter is not required for its traffic control or safety function the messages radiated can provide route and amenity information. Since drivers familiar with the area would not require this information they could switch off their message receiver. However, when traffic control or emergency messages are transmitted all receivers would be switched on automatically by suitable coding tones on the roadside transmitter.

With such a communication channel available in the vehicle it could be used for other situations such as directions to car parks, transit areas, advice on all-night restaurants and garages, thus providing a very valuable amenity service. In addition to the permanent roadside installation portable equipment would allow temporary traffic control for large public events and police requirements.

Research at TRRL has been concerned with three main aspects; the question of driver acceptance, the division of attention between aural and visual inputs to the brain, and the evaluation of possible technical systems.

Driver acceptance of a simulated installation has been found to be very favorable in trials in Central London both by day and night. Experiments on the division of attention show no drop in driver performance, and on the whole drivers were more relaxed and gave more attention to their driving.

In technical systems considerable experience has been gained with buried loop techniques. Problems have been encountered at bridges and on reinforced concrete structures; in general however, the system is satisfactory. The frequencies are confined to below 500 kHz. and there is the problem of the disturbance to traffic during installation.

The use of point source radio transmitters with a triggering system is very attractive but in the United Kingdom there is the very difficult question of frequency allocation in an already overloaded spectrum.

Investigation is going ahead into the newer near-field systems such as a leaky coaxial cable, and a short buried loop employing "fast in – slow out" methods using digital techniques would enable a lengthy message to be passed to the vehicle in milli-seconds, and then played back slowly aurally to the driver. This method has the advantage that the information could be held in store for repeating if necessary.

Full scale road trials are planned for the RITA system and pilot installations are being evaluated.

DUAL MODE VEHICLES

So far the work described has been research into how drivers carry out their task of controlling vehicles, and into methods of helping them in this task. However, there are distinct limitations to a human being's performance as a controller, particularly with the present day, regular increases in traffic speeds and densities. Therefore a more radical solution is now being worked on which replaces rather than merely aids the human driver. This will be achieved by converting normal road vehicles to dual mode operation by fitting them with electronic "auto-drivers" similar in concept to aircraft autopilots. The idea is that people will drive as usual on minor roads, but will switch to the automatic mode on main roads and motorways.

The first question arising from this concept of highway automation is "why," and the only satisfactory answer to it, as with any proposed technological advance, must be because the economic and social benefits from highway automation will exceed its costs. The main quantifiable benefits expected are

1. reduced number of accidents, because of the much higher reliabilities obtainable from machines than from human beings, and

2. increased road capacities, due to more accurate steering, quicker reactions, i.e. more vehicles per unit length and better control at junctions.

It should be remembered that if main road automation were complete, manual driving (and the accidents arising from it) would be confined to minor roads where slow speeds could be enforced. The need for expensive safety devices required to protect occupants in high speed accidents will then disappear and the cost of these can be offset against the autopilot costs. A simple cost/benefit analysis has suggested that these benefits would justify an equipment cost of up to £5000/lane mile and £75 - £100 per vehicle. Automation would appear to be justifiable provided its cost is of this order and present effort is concentrated on finding out if reliable systems can be produced in this price range.

The present position at TRRL is that there are two cars (a Mini, the smallest British car and a Cortina, a medium-sized saloon) able to steer themselves automatically using a single leader cable system, and able to respond to speed, stopping and starting commands received by inductive links from the road. These vehicles use simple and cheap control actuators – electric motors for steering and electro-vacuum systems for throttle and brake. Work has just started to convert a bus to automatic control; this will carry a general purpose analog computer for control system tests and mathematical modelling work.

The main technical problem which workers in this field are trying to solve is that of automatic longitudinal control, to allow both close following of other cars and stopping at obstacles in the road. Two approaches seem promising here;

1. a self-contained or "non-co-operative" headway measuring system such as primary radar

2. a "co-operative" system using electronic equipment in the vehicle to be followed as well as in the following vehicle.

At present it appears that a non-co-operative system will only allow safe following at headways down to 1-2 seconds, i.e. rather longer than those used by human drivers. This would not increase road capacity, and to achieve much shorter headways than used by human drivers a co-operative system would appear to be essential, either secondary radar or a system indicating position measurement with respect to inert road markers and a microwave link to following vehicles.

Investigation of possible techniques during the past two years has indicated that such a system is technically possible. The need for co-operation however increases the difficulties of introducing automation onto a country's main road network. Since this introduction problem is important it is discussed in detail below.

It is felt that the chances of introducing a program of vehicle automation in most countries will be very small if it involves either legislation forcing drivers to fit equipment to all vehicles, or building special new roads for automatic vehicles. A gradual introduction program is favored at present with the aim that each stage must be economically viable and socially attractive in itself while leading both technology and public opinion towards the next stage and eventual full automation. It should be noted that automatic vehicles are already in use, such as driverless factory tractors, vehicles in mines and tunnels, farm tractors, vehicles for tire and automotive component testing. Such a phased program could be as follows:

1. Automation of buses operating on reserved tracks, such as the bus way already in use at the New Town of Runcorn. This should reduce labor costs and allow a much improved late-night service, and should also allow the buses to be run more economically. This could be regarded as a "horizontal elevator," a great advantage being that since the vehicles are normally driveable, they could be used off the reserved track, which considerably improves their economic use.

2. The use of road-to-car communication links; e.g. in-car displays of road signs passed, route guidance, control of speed and braking.

3. The introduction of a co-operative headway control system giving very close following at high speeds. This would require reservation of the offside (or right hand) lanes of motorways for equipped vehicles. Initially steering would be carried out by the driver, while the automatic system handled only longitudinal control, followed by reserving the nearside (or left hand) lanes for commercial vehicles.

4. Conversion of these reserved motorway lanes to full automation, including steering.

5. Extension of reserved lanes to all main roads.

Technically the problems involved are soluble, and the governing factors in implementation will be politico/economic rather than technological.