# REVIEW OF VEHICLE MEASURES FOR REDUCING ACCIDENTS AND INJURIES

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## ABSTRACT

This paper outlines possibilities for improvements to vehicle design that would reduce the occurrence of collision and the severity of injuries from accidents on the roads. It highlights vehicle safety measures which are believed to hold the greatest benefit at the current time. These proposals for the way forward relate to conditions in the United Kingdom and to a lesser extent in the European Union. The views given are those of the Parliamentary Advisory Council for Transport Safety (PACTS) rather than those of the individual members of its Vehicle Design Working Party who initiated and contributed to the study on which this paper is based. For the purposes of this paper, the various measures are only described in outline, but references to further information on specific issues are available separately on request from PACTS.

## INTRODUCTION

PACTS (the Parliamentary Advisory Council for Transport Safety) is a British organisation which forms a link between those professionally employed in transport safety and Parliamentarians and government departments. Its Vehicle Design Working Party is reviewing the vehicle factors which contribute to the occurrence of road accidents and the resulting injuries. This review has two aims: firstly to check the extent to which current accident data and analyses are adequate for these tasks and secondly to review what the existing studies suggest for the next stage in improvements to vehicle design for safety. This paper is a summary of the findings for this second aim. For each category of road vehicle, accident avoidance and injury protection are discussed separately and this is followed by overall conclusions and recommendations for action. Full discussions for each safety issue are not included because of the need for brevity, but references on which the current review is based can be obtained from PACTS (St. Thomas' Hospital, Lambeth Palace Road, London SE1 7EH, UK).

## CARS

Included with cars are recreational vehicles, people movers and two-axled four-wheel drive vehicles. Vans and light goods vehicles are intermediate between cars and heavy goods vehicles as far as appropriate safety features are concerned and it is usually obvious which type of safety feature is suitable.

### Accident Avoidance

**Braking** - Although brakes work reliably for quite long periods of time, they may suddenly fail in some respect especially if they are not properly serviced. Wet or icy weather may lead to loss of grip between the tyres and the road. The car may then slide, drift or spin and may not stop in time to avoid an accident. One extreme case occurs when roads are flooded and one or more wheels aquaplane. Another extreme circumstance is gross overloading at the rear which may lead to unexpected front wheel lock on braking and consequential loss of steering control. Anti-locking brake systems (ABS) can prevent or alleviate most of these situations. An obvious requirement is for the fitting of ABS to become compulsory. However accident evidence suggests that ABS has not been very effective in reducing accident rates. Detailed work suggests that this is not just a risk homeostasis effect, but includes drivers who do not brake hard enough to activate ABS and also ABS-fitted cars struck in the rear by other cars not so fitted. Instructions and training must be developed to match up with any requirement to fit ABS more generally. Another possibility is that powerful old cars may be put to the test by enthusiastic young drivers but the ABS may no longer be working.

**Handling** - Most recently designed cars have good safe handling up to extreme handling conditions and even then most are satisfactory. However drivers do lose control of cars in accidents which have not involved using the brakes. Accident studies show that drivers may take quite inappropriate actions when faced with emergencies, most typically by steering to avoid an obstacle just ahead but not reversing the steering a moment later in time to remain on the road. More expensive cars may be fitted with a wide range of different electro-mechanical systems from traction control to systems which cut the response to excessive steering demands or control incipient rollover and keep the car fairly level. At present these devices are expensive but costs will soon reduce. However it would be sensible to train drivers to cope better in emergencies.

**Drivers' View** - Most drivers are aware of limitations in their field of view, often when other vehicles seem to appear suddenly close by. Drivers who are short in their height of body have the greatest problems and it is suggested that seats adjustable in height are fitted to all modes of car with a poor field of view for short people. Widths of the A posts should be reconsidered, particularly close to the lower edges of highly raked windscreens. An improved field of view should help drivers avoid cyclists and pedestrians in some critical situations. Dirty, misted and frosted side windows as well as windscreens have been noted as contributors to accidents. The blind spot of most offside mirrors, which is apparent when merging into motorway traffic lanes, can be eliminated by bending or distorting one of the vertical edges of the mirror. The basic field of view problems are likely to be more important than many other problems that currently receive great attention.

**Conspicuity and Lights** - No recent data seems to be available on the influence of colour on conspicuity and consequently on accident involvement. White and very light colours may be the best, but yellow shows up well and dark colours may score by their contrast. Grey and dull colours are inconspicuous in dull and misty conditions. Lights compensate for deficiencies in conspicuity and automatic switching on of them may be sensible. Daytime running lights appear to reduce accident rates and although the evidence is still in dispute there is probably a good case for them in, for example, the northern countries of Europe. Vulnerable road users would probably gain from their use on cars because pedestrians and cyclists sometimes do not notice cars which are approaching them.

**Rear Lights** - Reconsideration of light arrays includes the separation of rear position and brake lights. The main issue is to ensure following drivers can distinguish between types of rear light and therefore take appropriate action. Motorway driving conditions illustrate these two different functions of rear lights most clearly. The use of Centre High Mounted Stop Lights is increasing and may help in this regard. A new standard is needed which alerts drivers to the need to avoid slow moving, stopped and parked vehicles in a consistent manner.

**Warning and Control Systems** - Cars have increasing numbers of electro-mechanical devices with sensors providing the inputs and actuators providing the appropriate powered output. Strictly, telematic devices include a communications link between the remote sensors and the devices. Apart from engine and environmental control measures, there are handling control modification devices which have already been discussed. There are also many possible types of driver warning systems. Those that monitor driver fitness to drive (due to drowsiness, alcohol, drugs, etc.) are potentially the most important for safety once the sensors work satisfactorily. Systems which enhance vision may have some value but trials and experience will show their potential.

External speed control linked to in-vehicle systems may prove to be valuable for improving traffic flow as well as enhancing safety. The simplest type is the maximum speed limiter as used on coaches and other vehicles. The next stage is to transmit the local speed limit to the limiting device on the car. External beacons can readily do this, but tamper proof systems are essential. The safety value might be greatest for reducing pedestrian and cyclist collisions with cars. A sophisticated system of local speed limits which further reduces the maximum speed very locally according to potential dangers of traffic, weather and other hazards ahead might have the most beneficial effect on safety, but the system would need some development. This would include pilot trails to find how drivers adapt to such a system in the longer term. It might prove to be less unacceptable to drivers than just having stricter local speed limits.

Control of cars within a traffic flow is also being developed in several different forms. Possibly the most effective, but also the most difficult, would be intersection control. Finally there is the automatic control of vehicles into streams with minimal spacing and without the need for drivers. Early systems already exist and the best initial application may be the long distance transport of goods.

**Maintenance, Repair and Inspection** - As vehicles become more complicated, the maintenance of them in safe working order will demand more sophisticated techniques. One great challenge will be the supervision of vehicles when they become old and systems in them fail much more frequently. Experience gained with ABS in service may suggest the best approach. Legal blame for accidents may prove impossible to assess. Contributions may come from the driver, the basic braking and handling, the ABS and the system modifying the handling response. The output from black boxes to record operating conditions at the time of accidents may need expert interpretation.

## Injury Protection

**Frontal Impact** - Design to meet the EuroNCAP offset frontal impact conditions is proceeding. The problem areas seem to be the collapse of footwells and neck injury. The belt improvements with pretensioners and webbing grabbers combined with airbags seem to work effectively. Permitting the car structure to compress below the passenger compartment, rather than into it, is another advance.

**Side Impacts** - Design development to meet the latest tests is continuing. Measures are needed to prevent those on the far side from the impact from being thrown sideways into the debris and consequently being injured. Releasing belt pretensioners in side impacts may prove to be effective, particularly if front seat designs can be modified to assist in retaining the occupants. The near side occupants must be able to slide towards the far side, but those on the far side must not come adrift from their belts. The avoidance of head impacts into side structures is another current problem.

**Rear Impacts** - Correct positioning and redesign of head restraints should reduce neck injuries. It may be possible to reduce the sliding of occupants under their seatbelts and this may also be assisted by releasing belt pretensioners early on in rear impacts. Rear seats need head restraints for adults.

**Seatbelts** - In the UK, current challenges include persuading rear occupants to wear the belts provided for them. In other countries wearing rates are also low in the front of cars. Design for greater convenience may still be possible, and widespread provision of three point belts in the centre rear position is required.

**Seats** - Development is needed as already indicated. The rears of front seat backs need padding to help rear occupants, and in particular to prevent knees being thrust into the backs of belted front occupants.

**Padding of Internal Structures** - The measures suggested above may reduce head impacts into the roof, headers and cant rails. However, improvements in roof design should provide what is effectively padding for head impacts which cannot be provided in other ways.

**Steering wheels** - Those cars without driver airbags must incorporate energy absorbing components in their steering wheels. Some padding is needed for those steering wheels incorporating airbags for head impacts at just below the minimum speed set for firing the airbags in crash impacts.

**Child Restraints** - ISOFIX locations for child restraints in rear and front passenger seat positions should be fitted as soon as standardisation discussions permit. Design groups may be able to show that upper tethers which provide a further point of attachment are not essential.

**Airbags** - Accident evidence on the performance of European airbags is needed before detailed improvements can be considered. There may be a case for modifying the bags to reduce injuries to small people, those positioned close by the bag and young children in rear facing child restraints. The performance of airbags is much reduced when the impact is sufficiently angled for the occupant to be flung along the edge of the bag.

**Door Latches** - Tighter requirements for door latches up to the standards reached by most, but not all, models of car may be needed.

**Compatibility** - Much research is in progress and so it may be timely to restate the basic ideas. Compatibility of structures of different vehicles at the point where they impact each other should be matched in terms of stiffness of crush. They should be arranged so that they crush each other and do not slide past (except where intended) and do not penetrate each other without absorbing the intended amounts of energy as they crush. The basic crush stiffness of compatible front structures should closely match the first 700mm or so of the fronts of small cars whether fitted to goods vehicles, coaches or cars of any size. The sides and rears of all large vehicles should match up with the proposed extended fronts, whether they be side guards, rear underrun bumpers or the panelled structures of public service vehicles. The basic intention of using compatible structures is that small cars should be given the benefit of the maximum possible depth of crush in a frontal impact so that there is a reduced level of intrusion and a softened deceleration pulse. In other words the larger vehicle provides part of the increased depth of crush that the small car can use.

It may be possible to design the compatible nose section so that when it impacts a car in the side of the passenger compartment it does so sufficiently low down for the side impact performance of the car to be greatly improved.

**Pedestrian and cyclist protection** - The three component tests for pedestrian protection being addressed within the EU and by EuroNCAP are designed to provide basic protection for pedestrians struck by cars at the front bumper, front structure and bonnet areas. The latest studies suggest that this protection can be provided for a typical new design of car at a total cost which is well below five times the monetary value of injury savings to pedestrians. These costs are an acceptable price to pay. Accident studies show that the heads of adult pedestrians are likely to strike the A posts, header rails and windscreens of cars. Design developments are now needed to provide some level of protection in this area of car fronts as well as lower down. Cyclists should also experience some protection from these advances in design.

### Conclusions and Recommendations

Although ABS has considerable potential, it so far has not been shown to reduce accident rates. Improved driver behaviour and training in the use of ABS may be helpful. However, in view of its characteristics and cost it may be sensible not to require it for cars with low power to weight ratios. Similar considerations apply to the various aids to safe handling.

A review of driver fields of view to somewhat tighten requirements would be appropriate. In particular A posts should be reconsidered. Daytime running lights may have benefit particularly for the countries of northern Europe. Alternatively a simple system to switch on running and position lights automatically in conditions of poor visibility might be more acceptable. A rethink of how to meet all the different requirements for rear light arrays in a logical manner is overdue. A simple electronic system to switch on suitable rear lights when a vehicle is approaching from the rear on a potential collision course may be helpful.

Telematics and electro-mechanical systems which might most greatly benefit safety are those that monitor driver condition, warnings of hazards, speed limiters linked to roadside sensors, intersection crossing aids and systems to eliminate the need for drivers on segregated tracks or lanes. The safety contribution of all telematic devices for cars must be carefully checked by pilot scale trials and experience in service.

The review of injury protection measures suggests that detailed redesign of seats, head restraints and footwells is needed to address situations causing injury. This may include pretensioning seatbelts in side and rear impacts. ISOFIX mountings for child restraints and more convenient rear belts are both needed improvements.

Further research and development into compatible front bumper structures for all vehicles should continue, keeping the various different aims in mind.

The three component tests for pedestrian protection on car fronts must be made into EC Directives. Further research is needed to extend protection at A posts, headers and side rails to reduce head injuries to adult pedestrians and cyclists.

## COACHES, BUSES AND MINIBUSES

Coaches and buses are noteworthy for their low rates of occupant casualties, especially fatal casualties. If it were not for their being public service vehicles, it might have been possible to rate safety improvements for them at a low level of priority compared with that needed for other vehicles. However certain improvements, suggested by accident investigations, do seem to be possible and hence to be appropriate. Most noteworthy is the need for protective features for pedestrians, and to some degree cyclists, who are struck by them mainly on urban roads.

Minibuses come between buses and coaches on the one hand and cars and people movers (cars with up to eight passengers) on the other. Minibuses have traditionally been derived from vans, but are now becoming more satisfactory from an injury protection point of view. Their standard of interior design and trim for safety is also improving towards that typical of cars and coaches.

### Accident Avoidance

**Braking** - Coaches and minibuses can have large variations in fore and aft positions of centre of mass and so the maintenance of stability when braking is not certainly achieved without electronic control of their brakes and the contribution of ABS. This is less important for buses because they are effectively restricted to relatively low speeds, mostly on urban roads.

**Stability and Handling** - Stability and handling when not braking seem to be minor problems. This partly stems from the high standards of resistance to rollover resulting from the tilt test requirements in the UK. However rollovers do occur and cause fatal and serious injuries which could be readily prevented by the wearing of seatbelts.

**View from Driving Seat** - As for large trucks, some pedestrian and cyclist accidents occur when a bus or coach driver does not see these road users immediately ahead and moves off from rest. Good all round vision is needed for all sizes of driver.

**Speed limiters** - The limitation of maximum speeds has proved to be technically feasible in coaches, although accidents are so few that detailed evidence of the safety consequence is lacking. There may be a special case for limiting the maximum speed of minibuses if their handling and braking performance is inadequate at higher speeds. The universal limitation of bus speeds down to a suitable maximum speed for urban use may be worth consideration.

**Conspicuity** - All vehicles larger than cars might usefully have high level lights to supplement those already required.

## Injury Protection

**Pedestrian Protection** - It is surprising that some degree of protection for pedestrians struck by the fronts of these vehicles has not been developed. This is an urgent task because buses and coaches on urban roads cause a significant number of pedestrian casualties and a half of the road users killed by these vehicles are pedestrians. Currently frontal designs are much too rigid where pedestrians are likely to be struck and the indications are that these fatalities often occur at low speeds. Minibuses and people mover cars may require similar protective features much more like those needed for buses and goods vehicles than for cars.

**Compatibility** - Frontal structural designs to match those of cars and all other vehicles that may be struck by coaches and buses are needed in the slightly longer term. Apart from helping to reduce car occupant casualties, the low front bumper structures would help to reduce intrusion into the driving position of coaches. Being relatively small, minibuses need the extra protection that compatible front structures would provide.

**Seat and Interior Design** - There is a good case for going somewhat beyond the three current EC Directives 96/36, 96/37 and 96/38, which will require that retractable lap belts be fitted in all new coaches from 1999. Seats should be designed to be more protective when struck by passengers and also they should withstand loadings from both their own belts as well as from unrestrained passengers thrown into them from behind. Minibus seating is not always of a satisfactory level of design for safety. It should incorporate lap and diagonal belts which are retractable and this will be required in new minibuses from 2001. Bus seats should have suitable shape, cant and coverings so that passengers should not slide off them during emergency braking. Bus interiors need all the other components to be less injurious for standing passengers who fall as well as for seated ones who come adrift during emergency braking. Bus interior layouts are now being designed to meet standards which reduce risks to passengers boarding and alighting as well as when they are moving around the bus.

### Conclusions and Recommendations

The overall safety record of buses and coaches is relatively very good with the exception of accidents involving pedestrians. It is most important that detailed studies are put in hand to find out how to provide some protection for pedestrians struck by buses and to a lesser extent coaches. This should lead to the development of component test procedures to check the suitability of frontal designs. This work will also be applicable to the front faces of goods vehicles and flat fronted people mover types of car. The coming of low front bumper compatible structures on public service vehicles will mean that studies should include procedures to suit this modification of frontal designs.

Coaches should be fitted with electronic braking systems including ABS. The overall safety of minibuses is not known with any precision but improvements are needed to seats, detailed interior design and most of the features proposed for cars.

## TRUCKS AND HEAVY GOODS VEHICLES

These comments apply to all goods vehicles which are larger than cars. Heavy goods vehicles usually cause many more casualties in other vehicles, and to pedestrians and cyclists, rather than to their own occupants when there are collisions between them. Consequently many of the injury protection items relate to those for other road users.

### Accident Avoidance

**Braking** - The main current emphases are on the various electronic control systems such as ABS, electronic systems to balance the braking and the timing of the braking between the various axles and wheels, and related systems such as for traction control and for the maintenance of stability and control when control is being lost. For these categories of vehicles, ABS and brake balance systems are the most important and regulations to require them are appropriate once they are proved to be operationally satisfactory with suitable maintenance and diagnostic support.

**View from the Driving Seat** - A current study in the UK is reviewing the problem of drivers not seeing pedestrians immediately in front of them and cyclists not being seen when at the front nearside corners of large vehicles. These are largely urban traffic problems which arise when the vehicles are starting to move away after having stopped. Alarms are already in use to alert those positioned just behind large vehicles when they are ready to be reversed. The driver's view along the nearside may be poor although mirror systems are usually adequate and in any case the consequences are less serious now that adequate sideguards on larger vehicles are required in the UK.

**Conspicuity** - Although road layout improvements at junctions have decreased the incidence of large goods vehicles not being seen, especially when they are turning at junctions, there is still a case for better marker lights along the sides of vehicles. Of greater importance is the need to reduce impacts into the rears of large vehicles by faster moving cars. A higher standard of rear lighting is needed which includes a proper differentiation between the use of lights which indicate a vehicle is braking, stopping or stationary from those which indicate its position when it is moving and can safely be followed.

**Driver Warning Systems** - Further research and development are still needed for systems which warn drivers of their reduced state of alertness and indeed of sleepiness when on long monotonous journeys. Warnings of hazards ahead such as traffic which has slowed down just ahead are also needed. Sophisticated speed limiting systems which slow a vehicle when its speed is over the local limit or because of the hazards in front of it are the ultimate development.

**Rollover** - High mounted loads on goods vehicles, and especially those which hang and can swing laterally, do sometimes tip the balance and roll over goods vehicles. The effect is similar to the lateral surge of partially emptied tanker vehicles. Accident evidence shows that there is almost no margin between the speeds and lateral accelerations at which these vehicles roll from those at which they are normally driven around sharp bends. Good suspension design improves the situation, but warning systems will probably not be successful. These concerns are important for the carriage of dangerous fluids such as fuel.

## Injury protection

**Compatibility at impact** - Currently this is the most important safety development needed for goods vehicles, and has different implications for design at the fronts, rears and along the sides. Because of the high mass, rigidity of structure where it strikes other vehicles and unsuitability of shape at these points, there is a great need for improvement in structural design and layout if many fatalities and other casualties are to be avoided. Rear underrun guards, side guards and front underrun guards have made great contributions where they have been introduced and when their specifications are adequate. More recently far reaching compatibility proposals have suggested that all four wheeled and multi-axled vehicles have matching structures at the points of impact. These structures would be designed to correspond to the frontal stiffnesses and depths of crush typical of the fronts of small cars. The implication for trucks is that a matching low frontal bumper structure would be provided low down at the front and project forwards by from say 700cm to a metre.

Rear underrun bumpers have been shown to be valuable in the UK but maximum protection is not provided when the full permitted ground clearance is used in the design. Many car front structures can underrun the rear bumper guard.

Side guards of the low panel type in the UK appear to provide adequate protection for pedal cyclists and some protection for motorcyclists and cars striking them. Some details of the requirements need revision.

**Pedestrian and Cyclist Protection** - Pedestrians and cyclists suffer fatal and other injuries when struck by trucks and large vehicles and until now little has been done to provide protection for them. Most pedestrians are struck by the flat fronts of these vehicles and most obviously head injuries result, mainly because the structures that the heads of adults and children strike are relatively rigid. These and other frontal features could readily be improved in design, especially if in the longer term the fronts of trucks are designed to be compatible with small car fronts.

**Interaction with Roadside Crash Barriers** - These barriers are designed to fend off cars and so it is not surprising that smaller trucks tend to roll over them and heavier ones to flatten them. The basic dynamics of these situations suggest that such outcomes are almost inevitable. Heavier and taller barriers are much more costly and protection for cars and their occupants inferior. Research might show that existing barriers might deflect heavy vehicles striking them almost parallel to their paths of travel if the bumper ahead of the front wheel of the truck could interact with the barrier and not leave the wheel to roll over it.

**Driver protection** - Ejection is the greatest hazard and seatbelts prevent this, but currently it is not compulsory to fit seatbelts in HGVs, and many drivers do not use them even when fitted. Passive seatbelts which fasten themselves around the driver may improve wearing rates. Structural intrusion is the other main problem for heavy goods vehicles and this results from striking trees, heavy vehicles and structures such as bridge piers, from falling into ditches and from miscellaneous penetrations by posts and other objects. Structural strengthening cannot readily take all these situations into account, but weak cab structures should be avoided and local strengthening around the driver might also help on some occasions.

### Conclusions and Recommendations

Goods vehicles make stringent demands on brake systems because of the large differences between laden and unladen conditions. It is recommended that ABS systems be generally required, with electronic control of brake systems especially for multi-axle vehicles.

Driver view forwards and low down so that pedestrians and cyclists can always be seen when they are close by, is a much needed improvement. The provision of pedestrian and cyclist protection at the front of all these vehicles is also important, although some research and development is needed initially.

The current UK requirements for front underrun guards, rear bumpers and side guards should be reviewed to tighten the specifications in one or two respects mainly with regard to reducing maximum permitted ground clearance. In the longer term fully compatible structures should be required on the fronts of all trucks, heavy goods vehicles and indeed on all vehicles.

One of the greatest hazards while driving is the onset of sleepiness and priority is needed for the development and introduction of systems to combat this.

Driver protection could be greatly advanced by persuading drivers to use their seatbelts. This might be helped by providing passive self-fastening belts for goods vehicle drivers. Some strengthening of cabs locally around the drivers and the use of protruding front bumper systems as recommended for full compatibility may be the most practical improvements.

## MOTORCYCLES

### Accident Avoidance

Motorcyclist casualties have declined greatly in some countries. This may be linked to more arduous training and test requirements and because the cost of driving an old car may be less than riding a motorcycle.

**Braking** - The introduction of ABS has been a major improvement in motorcycle design. The next stage is to work towards requiring them to be fitted to all motorcycles, except the smallest, and mopeds.

**Conspicuity** - Motorcycles are not easily noticed in many traffic and lighting situations both by night and by day, though bright and reflective clothing and helmets contribute to making the motorcyclist more conspicuous especially in heavy traffic. In terms of collision reduction or prevention, daytime running lights appear to be the most effective, although the effect might diminish if all vehicles had to be fitted with such lights. Small motorcycles would need enhanced lighting systems so that their daytime running lights would be as effective as those on larger machines.

### Injury Protection

**Leg Protectors and Trajectory Control** - It has been shown in several projects that leg protection can be built into motorcycle designs. The high rate of serious leg injury shows the need for it. There is the possibility that the trajectory of riders thrown forwards in collisions may be adversely affected by restraints at the knees. Further studies should show how any extra risk of head injury can be avoided. The tendency of the machine to pitch can be reduced if the height of impact can be raised a little. It may be possible to decelerate the upper body and head before the rider is thrown over the motorcycle. Studies are showing how airbags may contribute to this.

**Helmets** - Several investigations have shown the effectiveness of crash helmets, but further design improvements in materials and in the distribution of the padding within them may be possible.

**Clothing** - Studies of both motorcyclist and pedal cyclist injuries show the value of tough clothing which resists abrasion. Some padding over vulnerable areas may also be worthwhile.

### Conclusions and Recommendations

The fitting of ABS braking systems on all but the smallest motorcycles is probably the first priority. The universal provision of leg protection remains a high priority, provided that it does not adversely affect the incidence of head injuries to a significant extent. Daytime running lights may be desirable for all motorcycles as long as the smaller machines have enhanced lighting systems to give the same light as on larger machines. Developments in clothing, both for protection and conspicuity, should match efforts for actively discouraging unsuitable clothing.

## PEDAL CYCLES

Any restriction or reduction in the use of cars in the UK as a result of an integrated transport policy would be likely to increase the use of pedal cycles and this would almost certainly lead to an increase in road casualties, unless there are remedial measures taken to improve the design and layout of the road system and improved cyclist training. The following are some of the possible safety features for pedal cycles suggested by accident studies.

### Accident Avoidance

**Brakes** - Wet braking has been improved during the last decade in the UK and the standard now reached might usefully be adopted more generally in the EU.

**Stability** - Many injuries result from falling off pedal cycles in incidents both on and off the road. Uneven and rough surfaces contribute to these cases. Road edges, much used by cyclists, are sometimes hazardous due to debris thrown there by vehicle tyres and because of projections and sunken gratings in the gutters. Large wheeled bicycles are usually more stable than those with small wheels. Slow cycling trials indicate the degree of stability and some improvements can probably be made.

**Conspicuity of Cycle and Rider** - Drivers failing to notice cyclists is the most frequently noted contributory factor in daylight as well as in darkness. Tests show that white and brightly coloured clothing improves the conspicuity of cyclists. Fluorescent and reflective stripes, patches, helmets and clothes are all valuable aids. Half metre spacer arms projecting to the offside lead to some increases in the gaps between cyclists and overtaking vehicles and these seem likely to reduce some impacts to near misses.

**Reflectors and Lights** - Forward and rearward facing reflectors, when correctly aligned, are valuable for conspicuity in conditions of poor daylight and during the hours of darkness. Pedal reflectors are most effective, but side facing reflectors have more limited value. A high standard of cycle lighting is very desirable so rechargeable and dynamo systems should be encouraged. Intermittent electronic cycle lights are a useful extra for conspicuity. Powerful cycle lights are also invaluable for helping riders avoid obstacles and for seeing bends on poorly lit roads. Finger tip control for the most powerful bulbs may be a way of conserving battery power.

**Rider View to Sides and Rear** - The ability to glance to the sides and rear is needed and the cycle should not wobble as a result. Rear view mirrors may be an additional help, but the mirror should not disturb the handlebars if it is struck by an overtaking vehicle.

### Injury Protection

Although possibly a half of injuries occur when cyclists fall off their machines, the severity of injuries in these cases is usually low compared with those from impacts with road vehicles. Taking both circumstances together, severe injuries are mostly to the head with some to the neck and thorax. However upper limb injuries are very numerous and lower limb injuries only slightly fewer, but neither are fatal. This means that head protection is essential and either a padded hard helmet or the 'hairnet' type (fairly popular in Australia) is effective in preventing most of the more serious injuries. Study of helmets damaged in accidents shows that impacts to the front are by far the most numerous, with some impacts occurring at the sides. This suggests that preferential protection could be provided at the front. The design limitations include the need to maintain an all round field of view and also to provide adequate ventilation, especially for cycling in hot weather.

It seems unlikely that pedal cycles could be altered to provide protection for the upper limbs. However abrasions and infections through open wounds are common and there is a good case for cyclists wearing tough clothing on the arms and trousers which protect the knees.

### Conclusions and Recommendations

Gross underreporting of accidents and injuries involving cyclists is still widespread, although statistics of fatalities may be almost complete in some countries. This factor must always be allowed for when using cyclist accident data for policy planning purposes.

The design standards for lights should be upgraded as indicated. Much greater attention should be paid to the use and condition of lights and reflectors in service. The condition of brakes in service is often not satisfactory.

Large gains in conspicuity and in protection could be made by advances in the design of clothing, which cyclists find acceptable.

Helmets can probably be further improved with regard to protection and comfort in use. The voluntary use of helmets should be strongly encouraged to raise wearing levels, with a view to compulsion in the longer term, especially for children.