European Transport Safety Council

FORGIVING ROADSIDES

1.Introduction

Collisions between vehicles leaving the road and unforgiving roadside objects such as trees, poles, road signs and other street furniture are a major road safety problem internationally. Such collisions contribute to between 18 and 42 per cent of fatal accidents in several EU countries. They are typically single vehicle accidents often involving young drivers, excess or inappropriate speed, the use of alcohol or driver fatigue. A further problem with street furniture arises where accidents are caused through visibility restrictions due to poor siting of off-road objects.

Research and experience indicate that the siting and design of off-road objects can play a major role in reducing such collisions and the severe consequences that are typically associated with them. The principles for minimising the occurrence and mitigating the severity of vehicle occupant injury in collisions with street furniture have universal application but are not yet being widely applied.

This briefing provides an outline of the scale of the problem in a number of European countries. It examines the variety of effective approaches being used to improve the siting and design of street furniture with reference to the published literature and addresses policy implications at European, national and local levels. It is aimed at all with responsibilities for the siting and design of street furniture on roads in EU countries.

2. The scale of the problem of collisions with street furniture

Statistics on this problem are provided below for six different EU countries. Direct comparisons between countries are difficult to make, due to different time periods for analysis, reporting procedures, and definitions of accident types.

2.1 Finland

Between 1991 and 1995, collisions with street furniture accounted for 24 per cent of all fatal accidents in Finland(1). The most frequently struck objects were trees, followed by utility poles. More than half (54 per cent) of drivers were estimated to have been travelling at least 10km/h over the posted speed limit, and 53 per cent of the accidents involved alcohol.

2.2 France

Collisions with street furniture accounted for 31 per cent of all fatal accidents in France in 1995(2). Trees were the most frequently struck object, accounting for 56 per cent of all such collisions. Two-thirds of the collisions with trees were on roads lined with trees. Just over half (55 per cent) of the accidents occurred on bends. The majority of casualties were male (84 per cent), with half aged less than 26 years. Nearly half (46 per cent) of the accidents involved alcohol.

2.3 Germany

In 1995, accidents involving street furniture contributed to 18 per cent of personal injury accidents, 42 per cent of deaths, and 28 per cent of seriously injured casualties. More than two thirds of fatal casualties and nearly 60 per cent of serious casualties arising from collisions with street furniture take place on rural roads with trees being struck most frequently - resulting in 71 per cent of fatal accidents and 55 per cent of serious injury-producing accidents with street furniture on these roads. Trees were also the most frequently involved obstacle in urban areas accounting for 31 per cent of the fatal accidents, followed by poles (18 per cent). On motorways, where 16 per cent of all street furniture collisions happen, the guardrail was most frequently contacted, accounting for 58 per cent of these fatal accidents and 64 per cent of the serious accidents. Recent in-depth research conducted at the Medical University of Hanover indicates that high speed and alcohol are especially associated with collisions involving young drivers and street furniture[3].

2.4 Great Britain

The 589 fatalities involving collisions with street furniture represented 18 per cent of all road traffic fatalities in 1995[4]. The most frequently struck objects in single vehicle collisions with roadside objects were trees (15 per cent), being commonly struck on rural roads, followed by lamp posts (13 per cent) being more frequently struck on urban roads. A significant number of multi-vehicle accidents on high-speed roads involve collisions with off-road objects, which are not recorded as such. The true number of accidents involving roadside collisions may be around twice as many as identified through traditional single vehicle accident analyses[5]. Although many of these accidents do involve younger, male drivers, and in some cases the consumption of alcohol is a factor, there are a wide range of ages and contributory factors found in studies of this type of collision. Research [6] investigating loss of control crashes on motorways and dual carriageways in one English county found that tiredness, uncertainty about route, and vehicle faults, particularly tyre failure, were major contributory factors.

2.5 The Netherlands

Collisions with street furniture account for 22 per cent of all fatalities on Dutch roads. Around 3,000 accidents are recorded each year on motorways in The Netherlands involving collisions with items of street furniture[7].

2.6 Sweden

Around 25 per cent of car occupants killed on Swedish roads collide with a fixed object. Half of these fatalities collide with trees, 20 per cent with barriers and 20 per cent with poles and posts[8].

3. Injury causes and mechanisms

Injuries received by occupants of motor vehicles in such collisions are frequently more severe than in other types of collision. Injuries are caused by a number of factors, including the lack of stopping distance, massive deceleration forces experienced by victims of crashes, intrusion of objects into the passenger cell - in particular, narrow objects such as trees and poles, crushing of the passenger cell, unrestrained occupants being thrown around inside the vehicle, and occupants being thrown out of vehicles. The severity of injury is influenced by vehicle speed and the shape, size and stiffness of the fixed object.

4. Protecting occupants in collisions with street furniture

The problem of protecting occupants in collisions with street furniture was recognised by the OECD in 1975[9]. The report set out four main principles for protection:

- Eliminating unnecessary obstacles;
- Moving obstacles further away from the roadside;

- Modifying the structure of the obstacles;
- Isolating certain obstacles by new types of safety device which are better adapted than guard-rails to the particular type and location of certain obstacles.

Subsequent in-depth research [3,10,11] suggests that the stages in any strategy for improving the siting and design of street furniture can be further developed and extended as follows:

- Designing roads without any dangerous street furniture problems;
- designing a clear zone at the side of the road;
- designing street furniture to be more forgiving;
- protecting street furniture with a barrier to absorb some of the energy of the impact;
- protecting vehicle occupants from the consequences of impacts with roadside objects through better vehicle design.

Ideally, roads should be designed without dangerous off-road objects. However, this is clearly not possible in all situations, and the option of designing in a clear zone should be considered although, as is noted later, this may not always be appropriate. Objects can be made more forgiving if struck, or protected with crash barriers where none of the other options are possible. The potential for improving crash protection through changes to the vehicle is also being recognised increasingly.

4.1 Designing roads without street furniture problems

The use of mandatory road safety audit procedures (see ETSC[12]) provides the means for removing unnecessary road side hazards within the design stages of a scheme. Best practice in safety audit involves audit by an independent team at up to five stages in the design and implementation of the scheme. The audit team is skilled in accident investigation and prevention techniques and produces recommendations for action. Experience in Britain and Denmark indicates that the benefits of systematically applied safety audit clearly outweigh the costs.

4.2 Designing a clear zone at the side of the road

This involves the design of a clear strip of verge adjacent to the road which is free of roadside hazards. Australian research by Fox [10] suggests that a clear zone of at least two, and preferably three metres back from the kerb edge will significantly reduce the consequences of vehicles leaving the carriageway. In the USA the Insurance Institute for Highway Safety (IIHS) suggest that if the ten foot (3m) clear zone, which is common practice in the USA, were increased to thirty-five feet (10.5m), collisions with street furniture would be reduced by a further 10 per cent[13]. As the following Table illustrates, the greater the size of the clear zone, the larger the accident reduction benefit.

Table showing relationship between size of clear zone and accident reduction
From Ogden[14]

Amount of increased roadside recovery distance in metres	Reduction in related accident types (per cent) Straight	Curve
1.5	13	9
2.4	21	14
3.0	25	17
3.6	29	19
5.0	35	23
6.0	44	29

On the Routes Nationales in France, one third (32 per cent) of fatal collisions with street furniture take place within two metres of the edge of carriageway, and more than two thirds (70 per cent) are within four metres[2].

On the basis of accident analysis in the Netherlands, the SWOV has estimated that the minimum width of clear zones zones for three types of roads should be [15].

- 3.5 metres for single-lane regional highways
- 7 metres for single-lane federal highways
- 10 metres for motorways.

SWOV also found that the design of slopes is very important and have made various recommendations for their design.

Most authorities in Europe have a policy of siting lighting columns on the outside of bends for optimal lighting purposes[16]. The result of this policy is that columns are placed where they are vulnerable when drivers lose control of vehicles. Lighting and crash protection needs have to be balanced here and in many situations it may be appropriate for utility poles to be placed on the inside rather than outside of bends to reduce road injuries. Swedish experience of siting lighting poles has indicated that there is value in:

- Providing fewer but longer poles with several light sources at major or complex junctions
- Replacing poles with lighting suspended from buildings in urban environments
- Replacing two poles on each side of the carriageway by one in the central reservation

It is not always practical (or desirable) to create a clear zone, particularly in urban situations. For example, clear zones may increase vehicle speeds. However, the philosophy has been adopted by some highway authorities with respect to siting lamp columns or planting trees. For example, in Birmingham in the UK, it is understood that all new lighting columns are set back a specific distance from the kerb edge as a matter of policy. Maintenance contractors replacing old columns that were sited at the kerb edge and have been struck in accidents, replace them to the rear of the footway or verge. Work in the UK suggests that up to half of the objects placed in the gore areas on motorways could be removed completely to create a clear zone, or replaced with more "forgiving" structures[5].

Trees are the most problematic roadside hazard because they are so difficult to move since their presence is desired by so many, because they can be so numerous, and because they are the most injurious of roadside objects. German accident research suggests that where ditches are present along roads, trees should be sited behind them, wherever possible and the Departement des Pyrenees Orientales in France has recently embarked on a long term policy to the year 2010 utilising this re-planting strategy. Where clearance or re-siting to less hazardous sites is not possible, the use of guard fencing discussed below may provide a solution[3].

4.3 Designing street furniture to be more forgiving

Where it is not feasible to eliminate roadside hazards, it is possible to make them less injurious by changing their design as long as this takes account of real world accident data and current vehicle design.

Collapsible lighting columns were introduced in the United States around twenty years ago and in Sweden in the early 1980s [16]. These are either mounted on shear bolts, or constructed of a deformable, yielding material. Slip-base poles break away at the base when struck by a vehicle and include special provisions to ensure electrical safety. Research conducted in the USA indicates that breakaway columns can result in injury reductions of around 30 per cent [14]. Research by SWOV has demonstrated that aluminium poles can bring about the same order of reductions[15].

In Australia, some telegraph poles have holes drilled in them to provide a more forgiving structure in a loss of control collision. In the state of Massachusetts, breakaway timber utility poles have been field tested at locations where a hazard is posed but removal or relocation is not possible [17].

Solutions for road signs have also been considered in Sweden, including slip bases and multi-post signs. Unless protected by safety barriers (discussed below), all road signs in hazardous locations should have a collapsible post.

4.4 Effective safety barriers and the protection of street furniture with energy absorbing rails or barriers

If it is not possible to move the object, or make it breakable, the highway authority may need to protect it with an effective safety fence, guard, or barrier.

Safety barriers are also used to separate traffic or to prevent it from leaving the road. They have the function of deflecting or containing the striking vehicle while ensuring that the forces involved do not result in serious injury to vehicle occupants, but experience shows that they are often less than effective. Research carried out by SWOV in the Netherlands shows that around 20 per cent of fatal accidents on motorways are the result of collision with a safety barrier [15]. This highlights the need for effective interaction between vehicle protection standards and safety-barrier standards, taking into account different types of vehicles from small cars to heavy lorries.

- ***Guard fences, rails***

The range and effectiveness of guardrails has been reviewed fairly recently by Ogden[14]. Guard-rails comprise either rigid (concrete), semi-rigid (steel beam or box beam barriers) or are flexible (cable or wire). They are situated at the edge of the carriageway, to deflect or contain errant vehicles, or in the central reserve with the aim of reducing crossover accidents.

- Rigid concrete barriers
These are very rigid systems which are used mainly as a central dividing barrier on the road with the aim of directing the errant vehicle away from oncoming traffic and to minimise damage during low angle impacts. It has been noted that small and large vehicles with a high centre of gravity are more likely to roll over in a collision with a barrier. Their rigidity also proves to be hazardous for vehicle occupants in severe impacts. Experience with metal and concrete median barriers on French motorways indicates that the risk of injury for vehicle occupants is higher for concrete than for metal barriers[18].

- Semi rigid guard rails
Experience has shown that the effectiveness of steel guard railing is highly dependent on being installed correctly. Often railing is installed which is insufficiently well anchored, too low allowing vehicles to roll over the rail, or too high resulting in the vehicle passing underneath or being entrapped. The configuration and sharp edges of certain types of guardrail have been reported as posing increased injury risks to motorcyclists[19].

- Cable barriers
Steel cable barriers are less commonly installed than the other types but have been in use in Denmark, Sweden, Switzerland, and the UK, for some time and have proved to be highly cost-effective. Central cable rails are being installed to an increasing degree in Sweden as part of the Vision Zero policy.

Whilst safety fences and barriers may form part of the solution in offering increased protection, an additional hazard may be created by the end terminal of the barrier itself. It has been noted in Sweden that striking a barrier terminal involves a very high risk of fatality[8]. It has been estimated in the UK that each safety fence terminal in gore areas is struck in an injury accident once every five to ten years. One way of protecting occupants in collisions of this type is to use a crash cushion or an energy-absorbing terminal[5]. The common practice in The Netherlands of anchoring the end of guard rail underground has proven cost-effective[15].

- ***Crash cushions***

Crash cushions, also called impact attenuators, are passive restraint systems, and are not designed to prevent an accident from happening. The crash cushion is designed to reduce the consequences of an accident by slowly decelerating an out-of-control vehicle before it strikes a rigid roadside hazard.

Types of crash cushion include sand-filled plastic barrels, water-filled tubes, foam-filled cartridges, aluminium tubes, and steel drums. Cushions are available in most European countries: for example in Germany they are manufactured for a variety of applications[20].

In Birmingham, UK, an evaluation of six crash cushion installations has been carried out [6]. The study found that the number of recorded injury accidents was reduced by 40 per cent, and that the proportion of fatal and serious accidents was reduced from 67 to 14 per cent following installation.

Crash cushions designed to absorb the energy of the impact by the crumpling of aluminium tubes were developed and introduced in The Netherlands in the early 1980s [7]. They have been applied in gore areas, on verges, at guardrail end points and to protect isolated obstacles. Between 1982 and 1992 a total of 235 crash cushions of this type were installed, and 185 collisions were recorded from field observations and maintenance records. Each crash cushion was struck on average once every five years. Looking just at those sites where accidents were noted, each cushion was struck once every year. The worst case involved a cushion struck 3.7 times per year.

In Sweden the use of crash cushions has been recommended in situations where objects could not be moved or made breakable. For example, bridge piers, barrier terminals, lighting posts, and sign supports, particularly in gore areas[21].

A Norwegian study found that both safety fences and crash cushions reduce accident rates and accident severity[22]. Six countries were represented in a comprehensive study of thirty-two previously published pieces of work. Median barriers were found to increase accident rates by 30 per cent but to reduce accident severity. Safety fences at the edge of carriageways were found to reduce both accident rate and severity by 50 per cent. Crash cushions were found to reduce accident rate and severity, but the results for this part of the study were based on only a small sample of cases.

4.5 Protect vehicle occupants by building in crash protection into vehicle design

In-depth accident research in Germany indicates that the most frequent type of collision between cars and roadside obstacles in rural areas is frontal impact in the middle of the car, followed in frequency by a right-angled impact to the centre of the side of the car.

Collisions with cars and trees or poles are characterised by their high injury severity. Current legislation only requires the use of crash tests with barriers representing car-to-car impacts and it may now be time to supplement these with front and side car-to-pole tests. German accident research suggests that the test barrier representing a pole should be round with a diameter of approximately 40 cm and be of greater height than a passenger car. Car structures should be improved in side impact by modifications to the door, the door sills, and the roof. It is widely acknowledged that better interface is required in the design of cars and of safety barriers.

5. Summary - Implications for policy makers

In contributing to between 18 and 42 per cent of all road accident fatalities, collisions between vehicles and street furniture or roadside obstacles are clearly an important problem, which needs to be addressed by highway authorities. Various options have been discussed and while there is increasing emphasis on this area the scope for implementing known solutions which can often yield large ratios of benefit to cost is very large. ETSC believes that possible actions by policy makers at European, national and local levels are as follows:

5.1 European policy

In 1990 the European Committee for Standardisation (CEN) initiated a working group on Road Restraint Systems. The following Standards have so far been produced by the group:

Approved standards:

- 1317-1: Terminology and general criteria for test methods;
- 1317 -2: Safety barriers-performance classes, impact test acceptance criteria and test methods;

Preliminary standards:

- 1317-3: Crash cushions-performance classes, impact test acceptance criteria and test methods (preliminary);
- 1317-4: Barrier interfaces: terminals and transitions;
- 1317-5: Durability and attestation of conformity;
- 1317-6: Pedestrian restraint systems;
- 12767: Passive safety of support structures for road equipment.

Although most of the standards have not yet become finally accepted and approved, aspects of some of them are observed to be working. Tests carried out according to the proposed standards are performed at several laboratories in Europe, and national requirements are being adjusted to cover products approved to these standards.

The EU-funded international project SAFESTAR is due to report in late 1998 and is likely to provide further valuable input into the understanding of how to design forgiving roadsides.

ETSC welcomes the fact that action both on forgiving road design and safety audit is foreseen in the EU Road Safety Programme for 1997-2001(23). The development of EU guidelines for both is envisaged and ETSC recommends their adoption on all EU-funded infrastructure together with the development of EU standards giving the highest level of protection in forgiving roadside furniture. In addition the EU should invite the European Experimental Vehicles Committee to devise car to pole crash test procedures for incorporation into EU Whole Vehicle Type Approval legislation.

5.2 National authorities

From the short overview of evidence about collisions with roadside obstacles in different Member States, it is clear that further information could be collected nationally to identify other obstacles (such as wooden fences) that are being struck in collisions but which are currently excluded from data collection forms. Research should be carried out to determine the full extent of the problem, including multi-vehicle collisions that involve street furniture.

National action to increase awareness amongst road authorities about the problem of roadside obstacles is needed. A requirement to introduce safety audit procedures is also recommended. Problems in the literature point to the need for improvements in safety fence standards. In particular, short gaps in sections of fence between adjacent protected features, and ramped end treatments to safety fences may be causing accident problems that need urgent treatment. Improvements to national standards should be carried out in conjunction with the adoption of high level European standards.

Action on seat belt wearing, speed control, drink/drugs and driving and fatigue are likely to be beneficial in reducing the incidence of loss of control accidents in the long term.

5.3 Local highway authorities

In practice local road authorities have the main opportunities for create forgiving roadsides and to make the choices needed to suit local conditions. To achieve this, systems are required for identifying sites and routes where there is a high risk of collisions with off-road objects so that the use of remedial resources can be prioritised. This system should already form a key part of local road safety engineering programmes.

Local authorities should develop policies for appropriate re-siting of street furniture that has to be replaced after being struck in accidents, and for siting of new objects. These policies should take the accident risks into consideration. Road safety audit procedures also need to be developed so that all road schemes are checked for potential safety problems that include the risk of vehicles colliding with street furniture.

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