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THE KNOWN RISKS WE RUN: THE HIGHWAY

by

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CONTENTS

		Page
	Abstract	1
1.	Introduction	1
2.	Overall risks on the highway – perceived and actual	3
3.	Contributory factors in highway accidents	6
	3.1 The role of road, vehicle, and road user in accident risk	6
	3.2 Risk of injury	12
4.	Potential for reduction in risk of accident or injury	13
5.	Risk related to remedy	15
6.	Conclusions	16
7.	Acknowledgements	17
8.	References	17
9.	Appendix: Potential for accident and injury reduction in road accidents: revised estimates based on 1977 data	22
	9.1 Benefits A	22
	9.2 Target groups of accidents B	22

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ABSTRACT

The paper reviews known risks on the highway in perspective with the options available for reduction of risk, illustrating principles from experience in Great Britain.

Firstly, the overall risks of accident and injury on the highway are enumerated statistically in relation to the individual and to the community. The subjective view of these risks is discussed in terms of public response to different situations and monetary values ascribed.

A relatively objective assessment of risks associated with different factors has been obtained through a multi-disciplinary study of the contribution of aspects of highway design, vehicle condition, and road user behaviour to accident occurrence. Stress is laid on interactions between the road, the vehicle, and the road user. Other studies give quantification of risks for specific road engineering and environmental factors, and show how probability of injury may be related to vehicle design.

The potential for reduction in accident or injury risk is examined in the light of known benefits from well tried countermeasures, and quantified in relation to road engineering and traffic management, vehicle design and use, road user behaviour and road usage.

Finally, risk factors are contrasted with remedial potential. Future directions for application of countermeasures to reduce risk and for research to enhance quantification of risk and identify new effective countermeasures are enumerated.

1. INTRODUCTION

The desire to travel is strongly rooted in mankind. Long before the advent of powered vehicles people made many remarkable journeys on foot, by boat or with the aid of animals. They frequently suffered great hardships and in some cases lost their lives in the process. With the growth of towns journeys by road became increasingly necessary and were often made on foot. Thus travel by road became established both as a means of extending one's horizon and as a necessity of everyday life; neither class of journey could be relied upon to be comfortable, enjoyable or safe. With the growing use of horse-drawn vehicles the traveller on foot was both endangered and demeaned thus establishing the conflict between vehicle users and pedestrians. Not until relatively recently with the development of modern vehicles and highways could a typical journey be completed in comfort and without incident. Unfortunately uncertainty still remains as to whether it will be completed without accident; the 'natural hazards' of former days have been replaced by the statistical probability of conflict which stems from the sheer intensity of modern road traffic and from the disparate nature of the foot and wheeled traffic using the highway.

In considering the risks associated with travel by road it is evident that there is much historical background to the subject which influences both people's attitudes and their behaviour. In broad terms travel by road is understood by most of us to involve some risk though the level of this risk is only dimly perceived and rarely called into prominence because it has been with people almost all of their lives. Daily journeys from the home are commonplace and since, as will be seen later, road accidents are relatively rare events there is normally no reason for the question of risk to assume any great prominence. Road accidents are associated with a well-founded activity which almost everyone needs and wants to be involved in; the road accident situation is therefore very different from many other threats to personal safety which are far less well appreciated and sometimes not even recognised until irreparable damage has occurred to the persons affected.

Historically the introduction of mechanically propelled road vehicles seems to have been the signal for government to take a major hand in regulating the road scene. The highway codes and regulations which resulted were designed to instil some order into the operation of the traffic system and to impose certain requirements upon vehicles and their operators in order to protect the rights and safety of other road users and of property owners. The duties which fall upon road users, especially vehicle operators, are nowadays in Britain a complex amalgam of criminal and civil law with the law of negligence central to the question of recovery of damages following a road accident. The law of negligence as it applies to motoring is based on the principle that every road user has a legal obligation to drive carefully at all times, and to exercise proper care to all those whom he could reasonably foresee might be injured by his driving. Thus it is not surprising that until relatively recently, in most well-developed countries, road accidents and their consequences were thought of in terms of breaches of criminal law and civil lawsuits for damages through negligence; or looking to apportion blame. Though road accident casualties were treated by the medical profession in a similar way to other medical cases, road accidents were not thought of as a serious threat in public health terms. As a result the acquisition and processing of road accident data and the sponsorship of programmes to reduce road accidents have until very recently been almost exclusively the province of police and highway transport authorities supported to a small extent by educational authorities. However with the general improvement in public health the significance of road accidents is manifest; they are now the main cause of death for young people between 15 and 25 years old. The excessive consumption of alcohol, which is a serious public health problem in many countries is also a major influence in road accidents. It is to be expected therefore that the social and health aspects of road accidents which are intimately bound up with behaviour will play a much greater part in future road safety activities.

Risks encountered on the highway are of relatively certain magnitude when compared with risks in other fields and in some circumstances are relatively high compared to known risks in some other fields. Even so there is little unanimity internationally about the levels of road safety that should be sought.

This is in part because road users are exposed to a mixture of voluntary and imposed risks which are, as is well known, often regarded quite differently by the people at risk. To date the concept of 'acceptable risk' has not been applied globally to road accidents which formally and politically are regarded as unacceptable. As a result formal target setting in road safety has not been widely adopted but is often implied. In Britain guidelines exist to aid decisions about the adoption of various road safety measures and these might be considered to imply that below certain levels of risk there is no strong case for spending public funds on countermeasures. These implied risk assessments are sometimes but not always linked directly to formal cost-benefit assessments. In the road safety field considerable effort has been devoted to the application of cost-benefit and cost-effectiveness techniques in considering remedial measures but there is much scope for further work in order to make the best use of these techniques. The bulk of road safety improvements are made at the instigation of central or local government. In so doing the authorities are the proxy for the public yet there is a relatively weak link between the two perhaps because historically the welfare of the road user had not been emphasised. It is nevertheless surprising that relatively little work has been carried out to explore public attitudes to road safety or the safety expectations that people have of the highway system. Many road safety improvements confer no other benefit on the road user and some impose a definite penalty such as a limitation in freedom or of choice; this is especially true of measures which require a change in road user behaviour such as the use of seat belts or abstinence from drinking alcohol. A sound knowledge of risk perception attitudes, probable behaviour and expectations is most important to the success of some planned road safety improvements as is an understanding of the extent to which road user behaviour is likely to adapt to the changed situation and defeat the intended safety benefit. It is not unusual for other benefits such as savings in journey time to be substituted for it and thus for the planned reduction in risk to fail to materialise.

This paper reviews highway risks in so far as they are known and examines them in relation to the options which have been shown to reduce risk. The principles discussed are illustrated from experience in Great Britain.

2. OVERALL RISKS ON THE HIGHWAY - PERCEIVED AND ACTUAL

The overall risks of accident and injury on the highway are quantified statistically in simple terms in many countries, the most common procedure being to relate numbers of occurrences to some measure of exposure to risk. Such statistics are widely published, and used (inter alia) in attempts to compare relative performance in different countries, to identify problem areas requiring action, and to assess benefits of countermeasures. Risks are however mostly considered in relation to the community as a whole, or to groups of road users, rather than to the individual. Yet it is the risks as seen by individuals, either actual or perceived, which frequently determine the acceptability or success of countermeasures, particularly in the legislative and behavioural fields.

There are conflicts between the risks as seen by the individual and as relevant to the community as a whole, which may at times hinder progress towards improving road safety, and at other times work towards achieving it. At the basis of this dilemma is the low risk of involvement in accident and even lower risk of injury to the individual. From the reported accidents in Great Britain in 1977*[1] the risk of involvement in an injury accident is once in 57 years: in a fatal accident 1 in 2500 years; and in an accident not involving injury (estimated from insurance claims data) about 1 in 9 years. The risks of injury are lower and vary for different road users, as indicated in Table 1, but even with the most vulnerable road user (the motorcyclist) the likelihood of an injury is so infrequent that it is easy to understand why there might well be disinterest in measures to promote road safety, as is often suggested. It is interesting to compare these figures with work by Sheppard[2] which showed that about one-third of drivers in a random sample who had an opinion on likelihood of an accident thought they would be involved in a serious accident in the future.

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* NOTE: National statistics in this paper are based on reports of injury accidents made to the police in a standard format for the whole of Great Britain (England, Scotland and Wales).

TABLE 1

Casualty rates in Great Britain in 1977 for different road users

	Casualties per 100 million occupant km			Years per casualty	
	Killed	Seriously injured	All injuries	Killed or seriously injured	Injured
Motorcyclists	15.9	274	966	69	21
Pedal cyclists	6.8	107	531	not available	
Car occupants	0.7	9	42	724	166
Commercial vehicle drivers					
$\leqslant$ 1½/ton u.w.	0.5	7	31	485	115
$>$ 1½/ton u.w.	0.4	4	16		
Public service vehicles	0.1	2	21	974	105
All motor vehicle users	0.8	12	52	540	132

In contrast with the risk to the individual, the occurrences of accident or injury present a major problem to the community as a whole. In the whole world, it is now estimated that ¼ million deaths and over 10 million injuries occur as a result of road accidents each year. In Great Britain in 1977 there were 6600 deaths, 81,700 serious injuries (usually requiring detention in hospital) and 259,770 lesser injuries reported in the police statistics. It is known that injuries are underestimated by probably 30 per cent. In addition there are estimated to be at least another 1½ million non-injury accidents reported to insurance companies and an unknown number of accidents not appearing in any statistics. The cost of these accidents to the community has been fairly reliably assessed at £946 million in resource costs, damage to vehicles and property (over half the total), and costs of police and administration of accident insurance (see Table 2). Over and above these costs are the costs of pain, grief, and suffering to the involved person, to relatives and friends. These are very real costs to society but are by their nature not directly quantifiable in monetary terms. In recognition of the relevance of these losses, current practice in Britain is to include what can be regarded only as a notional minimum allowance for subjective costs, which totals £347 million, and averages £25,880 per fatal accident. However a recent appraisal of these figures[3] suggests that they are not in line with general principles of cost benefit analyses. A survey of studies where researchers have attempted to evaluate how an individual values risk has revealed figures for value of life between 2½ and 10 times this average. It is also true that UK accident values are consistently lower than those of other countries. Further work is therefore to be directed towards getting more realistic figures based on public attitudes on how much money people are willing to pay for a reduction of correctly perceived risk. One of the paradoxes of this assessment or perhaps a limitation of the method of calculation is that property damage is by far the largest element of the accident costs. Yet to most people property damage is undoubtedly secondary to loss of life and all but the most minor of injuries.

TABLE 2

Cost of road accidents in Great Britain in 1977

	Total £ million	£ per accident Fatal	Serious injury	Slight injury
RESOURCE COSTS				
Lost output	282	37,450	770	20
Police and administration	75	150	120	90
Medical and ambulance	44	300	510	30
Damage to property	545	820	690	480
Sub-total	946	38,720	2090	620
PAIN, GRIEF, AND SUFFERING	347	25,880	2650	50
TOTAL	1293	64,600	4740	670

In the environmental field, perceived risks are biassed by the drama of the accident. The relatively rare occurrence of a multiple pile-up on a motorway resulting in death (a total of 46 deaths occurred in 33 such accidents involving 3 or more vehicles in Great Britain in 1977), or a multiple fatality in a coach crash (less than 17 cases involving 34 fatalities in 1977) attracts more column-inches of press publicity than the 1940 pedestrians and 1740 other road users killed in towns in the same year. A balanced view must be maintained to ensure that the limited resources available for remedial action are applied in areas where returns are likely to be greatest. Objective risks for these situations can readily be evaluated as in Table 3. The largest numbers of casualties and the highest casualty rates occur in urban areas.

TABLE 3

Casualty rates in Great Britain in 1977: different road types

	Number of casualties		Casualties per 100 million veh km	
	Fatal	All injuries	Fatal	All injuries
Motorways	208	6323	0.84	26
Rural roads (50–70 mile/h speed limit)				
'A' class	1957	52,717	2.9	79
Others	766	35,304	1.9	89
Urban roads (30, 40 mile/h speed limit)				
'A' class	1981	121,064	3.1	191
Others	1701	132,601	2.5	192

The consequences of different concepts of risk have been felt in various areas of legislation introduced or proposed for promoting road safety. But some evidence suggests that the risk of apprehension and its consequences are of more import than the risk of accident. Perhaps the most dramatic illustration of this lies in the effect of the British Road Safety Act of 1967[4] which introduced a legal limit of 80 mg/100 ml alcohol in the blood of drivers. Undoubtedly the public expectation of a high risk of apprehension (quite false and unrealistic in relation to police manpower available) played a large part in the impact of the legislation which overnight produced a reduction of 11 per cent in the national casualty toll. In contrast, an equally false assumption of high risk of accident involvement – the risk of being trapped, caught in fire, or overturned in a car – has been a major argument amongst some opponents of wearing of seat belts in Britain. There are of course some opponents of legislation to compel wearing of belts (but not necessarily of wearing) who regard infringement of liberty of the individual as paramount and in their case the risk of injury and road safety issues in general are irrelevant to their argument.

Overall there is a confused view of risk amongst the population of road users, which can have unpredictable effects of the acceptability or success of road safety measures. Despite this, or perhaps because of it, it is important to get a relatively objective assessment of risk associated with different aspects of highway design, vehicle condition and road user behaviour. The next section of the paper deals with this question.

3. CONTRIBUTORY FACTORS IN HIGHWAY ACCIDENTS

Most accidents on the highway have a multiplicity of causes (or contributory factors), which may be a combination of human errors and failings, poor road design or adverse conditions, and vehicle defects. Two major studies were conducted over the period 1970 to 1974 by multi-disciplinary teams in the United States (Indiana University)[5] and Britain (Transport and Road Research Laboratory)[6,7] to try to identify the main contributory factors and their interactions. The planning and execution of the studies were carried out independently, without the teams being aware of each other's activities at the time. The outcome shows remarkable similarity in the findings, which is encouraging in a field of work which is inevitably subjective in judgement to some extent. Illustration of the findings will be restricted to the British study with which the authors are more familiar.

3.1 *The role of road, vehicle, and road user in accident risk*

The study covered 2130 accidents attended by the investigation team which was on call 24 hours a day. At-the-scene evidence was supplemented by later vehicle examination and interviewing of drivers, riders, and pedestrians involved. After all the data, covering up to 400 items of information, were collated, a team discussion aimed at allotting blameworthiness and contributory factors. This was achieved in 2042 accidents.

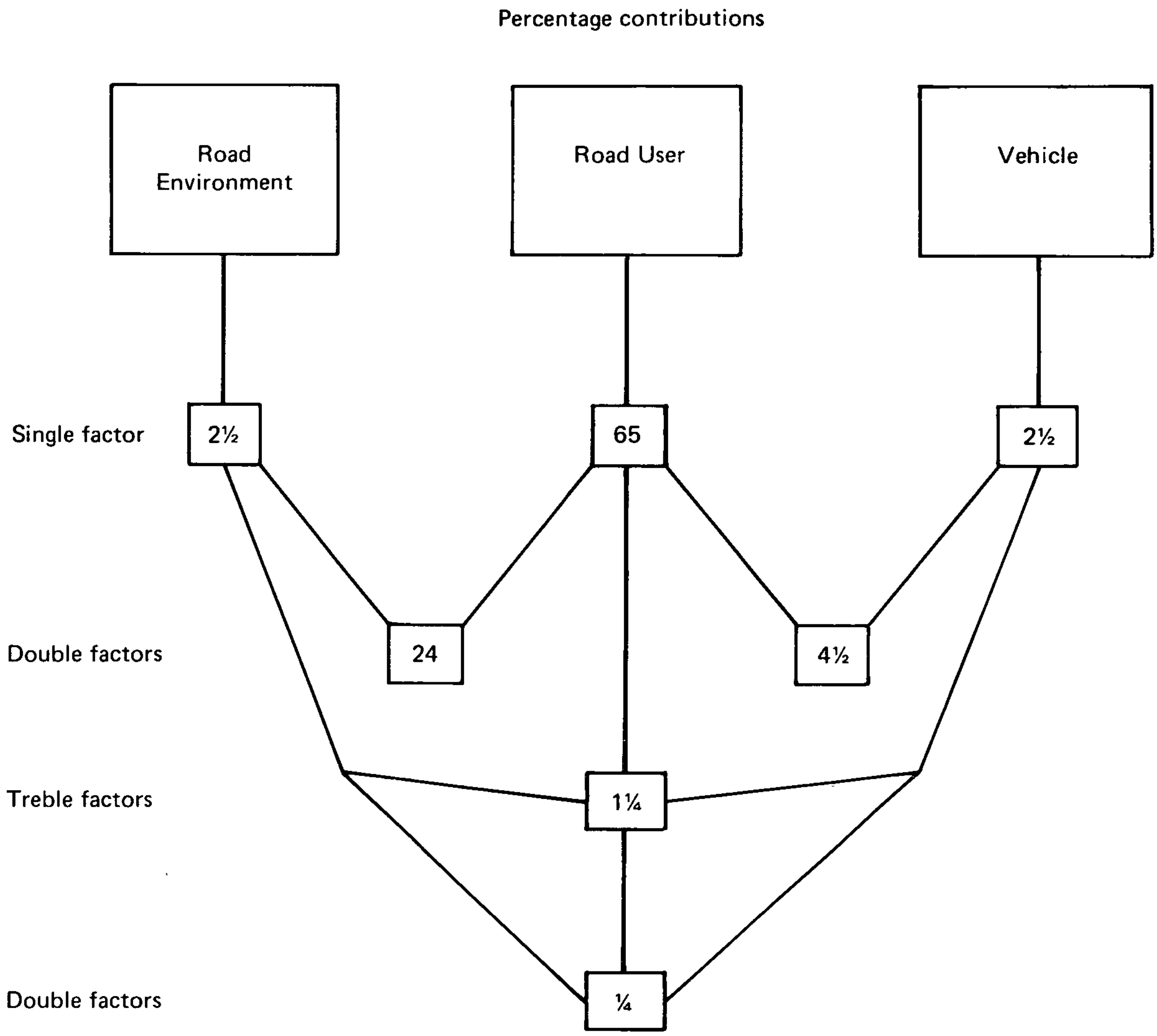
Of the 3665 drivers assessed, 41 per cent were judged to be primarily at fault, 19 per cent partially at fault, and 40 per cent victims: in contrast, blameworthiness of pedestrians was assessed as 65 per cent primarily at fault, 14 per cent partially at fault and 21 per cent victims.

Driver and pedestrian error, and impairment were main contributory factors* in 1942 accidents (95 per cent); road and environmental factors were contributory in 569 accidents (28 per cent); vehicle features were contributory in 173 accidents (8½ per cent). There were many interesting factors, which can be briefly summarised in Table 4.

* NOTE: In this context a main contributory factor means something without which the accident would have been less likely to happen or at least would have been less serious.

TABLE 4

Contribution to road accidents



Total percentage contributions for each factor

28	94¾	8½

The road user was the sole contributor in 65 per cent of accidents; road and vehicle factors were usually linked with a road user factor.

The detailed analyses identified the kinds of error or deficiency most prevalent in accident occurrences. Categories of human error were chosen to some extent arbitrarily, but on the basis of past experience to cover all likely situations. The boundaries between some classifications could not always be clearly defined and in many cases it was necessary to use several factors to describe different aspects of behaviour. In the original analysis one classification used was 'lack of care' but this is so general a description that it has now been deleted in favour of more specific aspects. The individual errors can be grouped into areas (Table 5). One important general finding is that the majority of driver errors constitute poor behaviour related to some deficiency in the driver's action rather than deliberate aggressiveness or irresponsibility.

TABLE 5

Road user factors contributing to accidents

Factors	Drivers	Pedestrians
PERCEPTUAL ERRORS		
– looked but failed to see – distraction or lack of attention – misjudgement of speed or distance	1090	53
LACK OF SKILL		
– inexperience – lack of judgement – wrong action or decision	462	–
MANNER OF EXECUTION		
a) Deficiency in actions: too fast, improper overtaking, failed to look, following too closely, wrong path	1153	107
b) Deficiency in behaviour: irresponsible or reckless, frustrated, aggressive	94	–
IMPAIRMENT		
– alcohol – fatigue – drugs – illness – emotional distress	632	7
TOTAL FACTORS	3431	167

Total accidents in which a road user factor was a main contributor – 1942

Total accidents assessed – 2042

As road environment deficiencies were usually associated with driver error, features can conveniently be grouped which show similarity in the difficulties they present to the driver (Table 6). Once again there are links between the different factors, which are not mutually exclusive.

TABLE 6

Road environment factors contributing to accidents

ADVERSE ROAD DESIGN	316
– unsuitable layout, junction design	
– poor visibility due to layout	
ADVERSE ENVIRONMENT	281
– slippery road, flooded surface	
– lack of maintenance	
– weather conditions, dazzle	
INADEQUATE FURNITURE OR MARKINGS	157
– road signs, markings	
– street lighting	
OBSTRUCTIONS	129
– road works	
– parked vehicle, other objects	
TOTAL FACTORS	883

Total accidents in which a road environment factor was a main contributor	– 569
Total accidents assessed	– 2042

The features of 'adverse road design' are derived mainly from accidents prior to which a driver did not appreciate a misleading visual situation. 'Adverse environment' features are those which contributed to accidents by increasing the difficulty of manoeuvring a vehicle safely. Features of 'inadequate furniture or markings' represent insufficient and unclear information being presented to the driver who is pre-occupied with manoeuvring his vehicle. 'Obstacles' are unexpected hazards. Although human factors play the largest part in contributing to accidents they are difficult to identify and costly to remedy. In the accident situations described here, remedial measures of an engineering nature, which are easier to identify and often readily and cheaply effected, can be applied to counter human failings.

Vehicle defects making a major contribution to accidents were mainly of the kind which can develop in a relatively short space of time due to lack of regular maintenance by the user of the vehicle (Table 7). Defective tyres and brakes featured most frequently, making up one-third each of all the main contributory defects.

TABLE 7

Vehicle factors contributing to accidents

Factors – defects	Number
Tyres	67
Brakes	65
Steering	7
Lights	10
Mechanical failure	22
Electrical failure	4
Defective load	10
Windscreen	4
Poor visibility	4
Overall poor condition	5
Unsuitable design	9
TOTAL FACTORS	207

Total accidents in which a vehicle factor was a main contributor	– 173
Total accidents assessed	– 2042

Such multi-disciplinary studies as these give measures of risk of accident occurrence related to specific features. In relation to application of countermeasures they indicate the areas needing remedial action, though not necessarily capable of remedy. More importantly they indicate interactions which may suggest alternative remedies more likely to be effective. When considering remedial measures, as opposed to blame or risk, the most effective remedy is not necessarily related directly to the main cause of the accident and may even lie in a different area, ie of road environment, vehicle, or road user. This is particularly true of accidents in which the road user fails to cope with the road environment. Further, even in circumstances in which human error or impairment has been judged to be the sole contributor, it may be possible to influence human behaviour more readily by engineering means than by education, training, or enforcement of legislation.

Before discussing this aspect further, it would be an omission not to recognise many other accident investigations, particularly in the road engineering field, which have quantified risk of accident occurrence. The subject of identification of hazardous road locations, safety principles related to road design – in terms of geometry, surfaces, markings, signs and furniture, and traffic management – and countermeasures applicable has been discussed in detail by an OECD Road Research Study Group, whose report[8] references much of the relevant work worldwide. Table 8 summarises some of the more important aspects quantified.

TABLE 8

Road engineering measures quantified in specific studies

GEOMETRIC DESIGN Junctions: layout, alignment, sight distances, channelisation, access control Horizontal and vertical alignment: curvature, superelevation Cross sections: number of lanes, shoulder design, medians
SURFACES Micro- and macro-texture: wet road performance – skidding resistance and speed – visibility by day and night Evenness and profile
MARKINGS AND DELINEATION Indicators of prohibitions or appropriate manoeuvres Channelisation Guidance
ROAD SIGNS AND FURNITURE Lighting Traffic islands Anti-dazzle screens Safety fences and guard rails Warning signs
TRAFFIC MANAGEMENT Speed control and limits Junction control One-way systems Parking

All the foregoing risks enumerated are relatively objective measures. A recent study[9], prompted by the multi-disciplinary at-the-scene investigation, has aimed at relating the objective and subjective measures by examining aspects of road layout that affect drivers' perception and risk taking. A total of 45 road locations were investigated by requiring 60 volunteer drivers to make assessment of risk on a 16 mile route, which covered a wide range of road types and hazards, including rural divided carriageways, narrow suburban roads, steep hill crests and level crossings. There was found to be a significant agreement between drivers in ranking the subjective risk at the different locations. The locations were ordered on these subjective evaluations (on a scale of 0 to 10) and compared with the ranking on objective risk, which was obtained from accident and traffic flow data. Although there was a significant rank correlation (Spearman rho 0.37) between subjective and objective risk, at some locations there were wide discrepancies. The five most over- and under-rated location types are described in Table 9.

TABLE 9

Under- and over-rated hazards

Description of hazard	Difference in rank
UNDER-RATED	
Suburban dual carriageway near a pedestrian bridge	– 26.0
A rural crest on a single carriageway	– 25.5
A left turn off a rural road	– 25.0
A rural dual carriageway near a picnic area	– 24.5
Rural cross-roads controlled by traffic lights	– 21.0
OVER-RATED	
Hump bridge on rural road	+ 35.0
Level crossing on rural road	+ 32.0
Suburban shopping centre	+ 31.0
Right turn onto rural dual carriageway	+ 24.5
Right bend at the end of rural dual carriageway	+ 22.0

At 16 of the locations where vehicles were generally freely moving it was also possible to calculate a safety margin based on the difference between the forward visibility distance and the total stopping distance estimated from recorded speeds. The average safety margin correlated well with average subjective risk ratings. As expected, the margins were found to be smallest at vertical and horizontal curves. There was also variation in performance between different drivers, some having negative safety margins at some locations. At one location however, a left-hand bend, the average safety margin adopted was negative. The results suggest some possible countermeasures, for example, increasing sight-line distances on bends. Further work of this kind could greatly aid the understanding of the interaction between the road user and his environment and identify more effective engineering measures in particular circumstances.

3.2 *Risk of injury*

Consideration of objective measure of risk should also include assessment of risk of injury once the collision has occurred. The most relevant issues here are vehicle occupant protection, protection of the vulnerable road user (pedestrian and cyclist), and protection against impact (rigidity of roadside obstacles). A few examples of risk of injury may be cited.

In relation to occupant protection, the simplest concept of risk of injury has been indicated in studies of the effectiveness of wearing seat belts. It is widely accepted and stated that, overall, risk of death or injury in an accident is halved when a seat belt is worn. Such statements related to this or other vehicle safety features tend to imply that there is a clear-cut threshold below which no one will be injured and above which all will be injured, ie an absolute measure of safety. This is not so, as is recognised by some of the current research into vehicle secondary safety which is directed towards quantifying probability of injury in relation to impact forces and accelerations experienced by human bodies in accidents. Wall, Lowne and Harris[10] have outlined a procedure for estimating how the likelihood of being injured in accidents may be related to different injury tolerance levels, so that with a knowledge of the severity distribution of accident impacts, the overall effect of changes in the tolerance level can be predicted to compare the extra cost of providing cars to this new level with the benefits from injury reduction. Figures 1 and 2 illustrate the principle by two examples:

(1) the incidence of chest injury as a function of shoulder belt tension,

and

(2) the incidence of hip dislocation as a function of impact forces on the knee.

In the first example a reduction in the tolerance level from 7 kN to 5 kN predicts a reduction in 40 per cent of the population suffering injury. In the second example a reduction in tolerable impact force to 4 kN predicts a reduction in 80 per cent of hip injuries.

4. POTENTIAL FOR REDUCTION IN RISK OF ACCIDENT OR INJURY

As has already been suggested, identifying the risk of accident or injury may not be directly indicative of the potential for reduction in risk. Although studies of accident 'causation' indicate that the greatest potential for accident reduction lies in influencing human behaviour, it would be impossible at present to predict future trends on the basis of causes of errors alone: in many cases there is no known effective remedy. In a recent assessment[11] of the potential for accident and injury savings in Great Britain, the approach made therefore was to consider proven remedies, or measures for which there was strong evidence of potential benefits, regardless of blame. The principle applied was: firstly, to quantify savings from individual measures; secondly, to identify the target group of accident or casualty types amenable to change; thirdly, to apply the estimated savings to the target group; fourthly, to relate these savings to the total accident or casualty situation. Thus, if a particular measure suggests a return of A per cent in accidents or injuries, and is applicable to B per cent of the total accidents or injuries, the potential saving is A x B per cent. The various options for countermeasures were identified under the broad headings of road environment, vehicle, and road user. The options are not mutually exclusive and the benefits are not cumulative: some of the interactions were considered.

Over the four years since the assessment was made there have been some changes in the factors A as new research findings have established more reliable assessments of benefits. Factors B (originally based on the year 1973) have also changed in some respects, largely as a result of changes in vehicle usage associated with the environmental changes consequent on the fluctuating fuel supplies. The opportunity has therefore been taken to update forecasts of potential savings based on 1977 (the latest year for which full accident data are available in Great Britain), and to present them here.

TABLE 10

Potential for accident and injury reduction in road accidents (based on 1977 data)

Options		Potential – per cent savings
ROAD ENVIRONMENT (low cost remedies)		
	– geometrical design, especially junction design and control	10½ (11½)
	– road surfaces in relation to inclement weather and poor visibility	5½
	– road lighting	3 (1½)
	– changes in land use, road design, and traffic management in urban areas	5–10 (7½–16½)
	OVERALL	ONE-FIFTH of accidents
VEHICLE SAFETY MEASURES		
Primary	– vehicle maintenance, especially tyres and brakes	2
	– anti-lock brakes and safety tyres	7 (6)
	– conspicuity of motorcycles	3½ (3)
Secondary	– seat belt wearing	7 (10)
	– other vehicle occupant protection measures	5–10
	OVERALL	ONE-QUARTER of casualties
ROAD USER AND ROAD USAGE		
	– restrictions on drinking and driving	10
	– more appropriate use of speed limits	5
	– propaganda and information	up to 5
	– enforcement and police presence	up to 5
	– education and training	up to 5
	– other legislation (eg restrictions on parking)	up to 5
	OVERALL	ONE-THIRD of accidents

Figures in brackets indicate earlier values based on 1973 data – where different from latest estimates.

The revised benefits from individual road engineering and vehicle safety measures and the reasons behind the revisions are detailed in the Appendix. Overall there is no change in the estimates. A summary of the options and their potential savings is given in Table 10. For the road traffic situation obtaining in Britain potential savings in terms of injury accidents from remedies applied in the three main areas are of the order of:

road environment	–	one-fifth	(E)
vehicle (primary and secondary safety)	–	one-quarter	(V)
road user and road usage	–	one-third	(U)

These are the ultimate which could be achieved at some future date (when all known options in each area were implemented) in relation to the predicted base level accidents at that date. No interactions between benefits have been considered in these estimates, so the total potential is less than the sum of these fractions.

One method of estimating the combined effect is to assume that the fractional reductions E, V, U result from three different and mutually exclusive methods. Then the resultant reduction will be $(1 - E)(1 - V)(1 - U)$ of its former value. The outcome of this simple calculation is to indicate a potential overall saving of THREE-FIFTHS – a substantial impact on the road accident toll.

5. RISK RELATED TO REMEDY

From studies of countermeasures to the known risks on the highway it has become increasingly clear in recent years that the priorities for action are not determined by levels of risk alone. Apart from the obvious need to know what remedy suits what risk, attitudes to risk play a vital part in the success of any proposed countermeasure. In the former area there is still considerable research to be done to seek remedies to identified problems, despite much effort already applied. However in comparison with this, the understanding of attitudes to risk is in its infancy.

In this context it is interesting to compare the contribution to accident causation with potential savings as described in the previous two sections of this paper.

Contribution to accident causation		Potential savings in injury accidents
28%	road environment	1/5
8½%	vehicle	1/4
95%	road user	1/3

The potential has been based on remedies proven by past experience, but it has to be assumed that these remedies will be equally effective in the future. There may be some doubt about this unless attitudes to risk and understanding of perceived risk are adequately taken into account.

The most clear illustration of this lies in the manner of dealing with the drink/driving problem. The impact and decline of the 1967 British legislation[12], already mentioned, has had to be carefully analysed to enable recommendations for new legislation to be put forward which will have a chance of making the same level of impact. In particular, since the myth of high perceived risk of apprehension has been exploded, future proposals must lead to the *actual* risk being seen to be increased. This must be backed by a reversion of attitudes to recognise drinking and driving as a social stigma.

The exploitation of the biorhythm theory gives an interesting illustration of the positive benefit of perceived risk. Examples of reduction in accident involvement have been cited by some workers[13], consequent on warning drivers to take care on days in the biorhythm cycles which are designated critical and said to present a high risk situation. However a recent objective study[14] of a sample of over 110,000 accident involvements in Britain has shown that there is no convincing evidence that the biorhythm theory has any basis for accident involvement. It remains to be seen whether disclosure of this negative result might affect the success of campaigns based on the biorhythm theory.

The success of speed limits in reducing speeds depends critically on attitudes, as has been shown by many studies[15]. Indeed, since the discrepancy between the contribution of road user factors in accidents and the potential for savings hinges on the paucity of proven remedies to change human behaviour, it may well be that a better understanding of attitudes to risk is critical to enhancement of remedial action in this area.

The application of vehicle safety factors and road engineering factors are not immune from the consequences of public attitudes to risk. As already seen, the wearing of seat belts is a critical issue in this respect and illustrates yet another difficulty associated with attitudes to risk; experience in different countries[16] highlights how attitudes depend so strongly on national characteristics and on the value attached to freedom of the individual in relation to the perceived seriousness of the prevailing road accident situation. In general terms vehicle safety features aimed at improving secondary safety are less likely to be influenced by attitudes than are measures related to primary safety. As regards road engineering, public participation in road schemes is assuming greater importance in Britain. The need to explain not only the risk but also the remedy, and to identify associated side-effects, whether beneficial or otherwise, is now recognised as a major factor in many safety schemes.

6. CONCLUSIONS

For the future, it will be necessary to pay much more attention to what is likely to be publicly acceptable in terms of countermeasures to risk, and at what cost. One of the difficulties here is that in dealing with accidents on the highway there can be no absolute measure of risk nor overall level of safety which is tolerable. 'How safe is safe enough?' is a very real question in this situation. Road safety measures already cost about £1000 million pa in Great Britain – a sum comparable in scale to the costs of accidents themselves. To achieve further advances it is necessary to balance resource costs, attitudes to risk, and potential benefits, but how this can be done to set targets if indeed targets are desirable is not yet resolved. It is the intermediate factor of attitudes to risk, which is so subjective and unpredictable, that can sway the balance in decision taking one way or the other.

In terms of application of countermeasures, future decisions for road engineers in Britain have to some extent already been defined. Under the Road Safety Act of 1974, a specific responsibility for road safety was placed on local authorities. Effort is now being concentrated on low cost remedial measures, and targets are being set on the basis of potential benefits enumerated in this paper. To encourage and enhance work further a set of guidelines for accident reduction and prevention is being drawn up[17]. The resources required are low compared with the potential benefits or with general road building costs, and road engineering for safety is generally considered acceptable, so the prospects for realisation of the full potential of one-fifth savings in accidents are high.

Future directions for vehicle safety measures and influencing road user behaviour are much more uncertain. Vehicle engineering costs are much higher, in that any safety measure has to be applied to a large population of vehicles. There may also be conflicting requirements for other reasons, particularly to promote energy savings, to improve environmental conditions, and to prevent barriers to trade. Not least of the difficulties is the attitude to protective devices. In the human engineering field attitudes are paramount: influencing the road user is the most difficult safety measure to effect, but when it can be achieved it can also be the most dramatic. A major priority here is the revision of the drink/driving legislation, and the scene will be set for action by a consultative document based on the recommendations of the Blennerhassett Committee of Inquiry[18] which is being published in the Autumn of 1979.

The needs for research to enhance quantification of risk on the highway are still quite extensive, and they are inextricably linked with the identification of more effective countermeasures. The major areas include:

- risks related to features of road design and traffic flow;
- demonstration of application of low cost remedial measures;
- probability of injury related to vehicle design;
- alcohol countermeasures and medical factors;
- aspects that affect drivers' perception and risk taking;
- attitudes to risk;
- evaluation of engineering and behavioural changes.

In the short term the lowering of risks can best be achieved by application of low cost road engineering measures and some legislation. In the long term it must rely on behavioural changes brought about by education and dissemination of information in the broadest sense.

7. ACKNOWLEDGEMENTS

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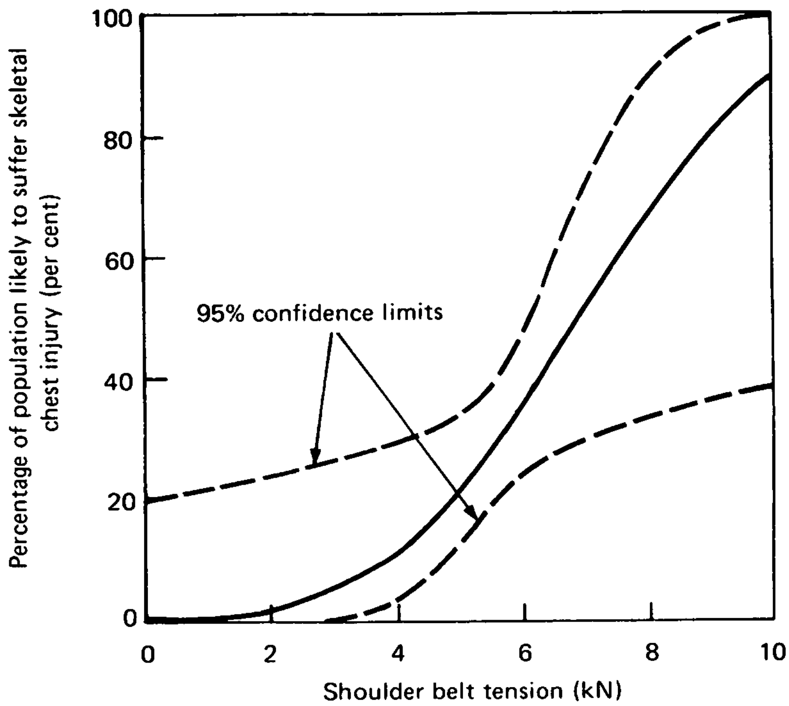
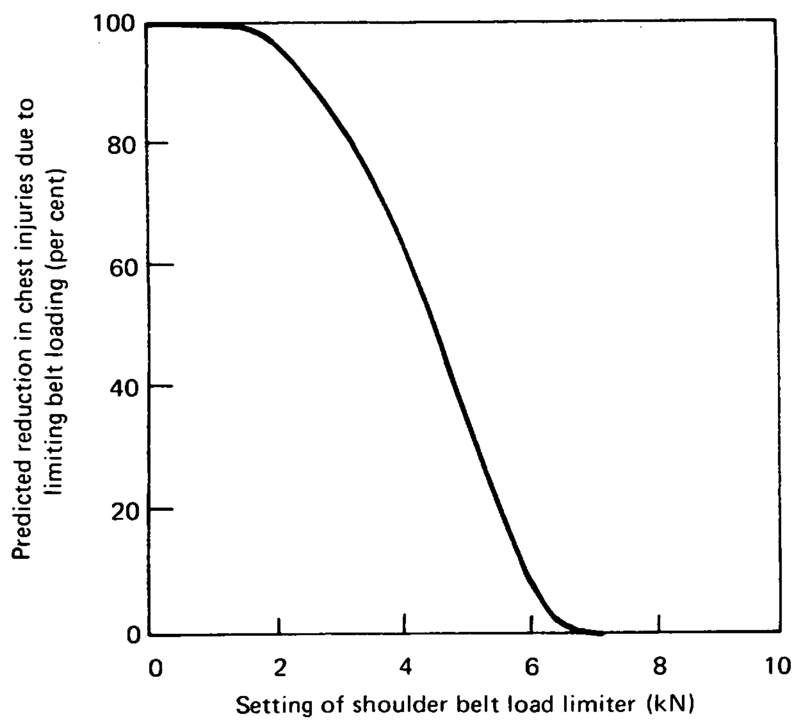
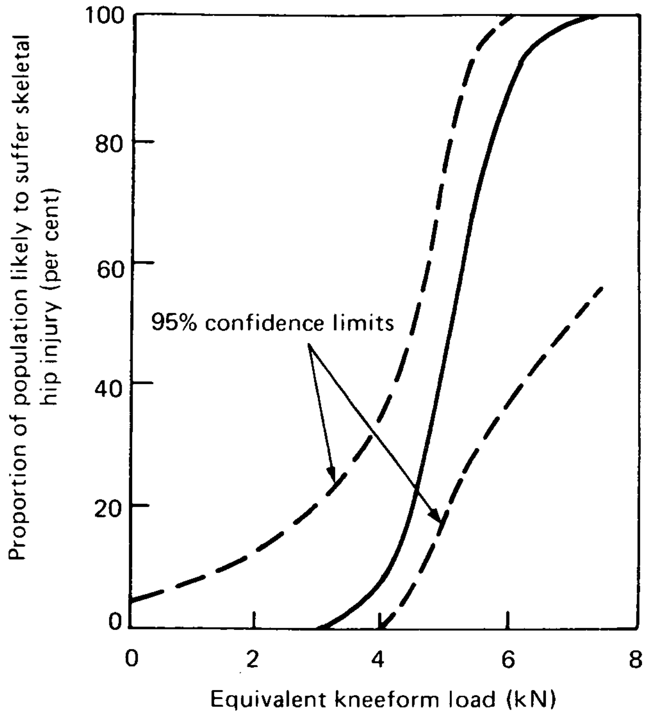


(a) INCIDENCE OF SKELETAL CHEST INJURY AS A FUNCTION OF SHOULDER BELT TENSION

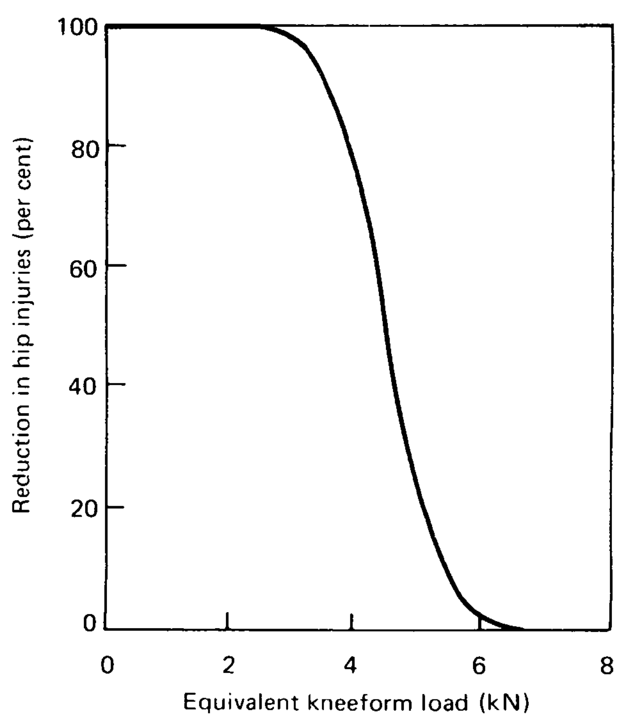


(b) EFFECT OF VARIOUS SETTINGS OF SHOULDER BELT LOAD LIMITER ON THE INCIDENCE OF CHEST INJURIES ATTRIBUTED TO SEAT BELT LOADINGS

FIGURE 1



(a) INCIDENCE OF SKELETAL HIP INJURY AS A FUNCTION OF EQUIVALENT KNEEFORM LOAD



(b) PREDICTED REDUCTION OF HIP INJURY AS FUNCTION OF MAXIMUM PERMITTED KNEEFORM LOAD

FIGURE 2

9. APPENDIX

Potential for accident and injury reduction in road accidents: revised estimates based on 1977 data

Tables 11 and 12 give the estimates of potential savings from road environment and vehicle safety measures, evaluated on the same principles as in reference 11 but using more up-to-date knowledge of benefits where available and basing target numbers of accidents on 1977 accident data.

9.1 *Benefits A*

Recent studies have provided an estimate of benefits to be obtained from improving quality of lighting on lit roads[19] and more realistic estimates for urban areas[20] and use of seat belts[21].

9.2 *Target groups of accidents B*

The main differences which are important in the sizes of the target groups between 1973 and 1977 are:

- 6000 fewer accidents at uncontrolled junctions in urban areas
- 27,000 more accidents involving motorcycles.

TABLE 11

Potential accident savings from improvements in road environment by low cost remedial measures

Feature	Improvement	Target group of accidents B	Benefit A	Potential savings A x B (at 1977 levels) No. of accidents	Per cent of total
Geometrical design: junctions	Control and design: mini-roundabouts, traffic islands, speed control, visibility	Uncontrolled junction accidents on class A and B roads in urban areas: 63,000	40%	25,000	10½%
		Rural junctions on class A and B roads, 15,100	20%	3,000	
Surface	Rougher texture	Excess of accidents due to wet weather:			
		slippery roads – 13,000	75%	10,000	5½%
		impaired visibility in the dark – 5,000;	40%	2,000	
		splash and spray – 7,000	33%	2,000	
Lighting	Installation of new lighting and guard rails	A proportion of dark accidents on unlit roads:			
		urban – 1,600	30%	500	3%
		rural – 8,000	50%	4,000	
	Improvements on lit roads	Half of accidents on lit roads – 25,000	20%	5,000	
Urban areas: arterial roads and residential roads	Area application of low cost measures	Accidents on arterial roads and residential areas: two-thirds of total in urban areas – 138,000	10–20%	14,000–28,000	5–10%

TABLE 12

Potential savings from improvements in vehicle safety

Feature	Improvement	Target group of accidents or casualties B	Benefit A	Potential savings A x B (at 1977 levels) No. of accidents casualties	Per cent of total
PRIMARY SAFETY – ACCIDENTS					
Defects	Tyre and brake maintenance	All accidents: 266,000	2%	5,000	2%
Handling	Antilock brakes	Car accidents: 202,500	4%	8,000	6%
		Motorcycle accidents: 72,000	10%	7,500	
	Elimination of worn tyres	Wet road accidents: 89,000	3%	2,500	1%
Conspicuity	Wearing of conspicuous clothing, etc	Vehicle/vehicle accidents at junctions: 98,500	10%	10,000	3½%
SECONDARY SAFETY – CASUALTIES					
Occupant restraint	Use of seat belts	Front seat occupants of cars not wearing belts: fatal and serious – 21,000 slight – 61,000	60% fatal and 45% serious 15% slight injury	10,000 9,000	7%
		Rear seat occupants: 21,000	25%	5,000	
Other protective measures					5–10%

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Firstly, the overall risks of accident and injury on the highway are enumerated statistically in relation to the individual and to the community. The subjective view of these risks is discussed in terms of public response to different situations and monetary values ascribed.

A relatively objective assessment of risks associated with different factors has been obtained through a multi-disciplinary study of the contribution of aspects of highway design, vehicle condition, and road user behaviour to accident occurrence. Stress is laid on interactions between the road, the vehicle, and the road user. Other studies give quantification of risks for specific road engineering and environmental factors, and show how probability of injury may be related to vehicle design.

The potential for reduction in accident or injury risk is examined in the light of known benefits from well tried countermeasures, and quantified in relation to road engineering and traffic management, vehicle design and use, road user behaviour and road usage.

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