Why some road safety problems are more difficult to solve than others

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ABSTRACT

Some road safety problems have persisted for a long time in nearly all motorised countries, suggesting that they are not easily solved. These problems include the high risk of accidents and injuries involving young drivers; the high risk of injury run by unprotected road users and speeding. This paper discusses factors that can make a road safety problem difficult to solve. A framework for categorising road safety problems according to their basic characteristics is provided and serves as the basis for the discussion. It is argued that if the main source of a problem is incompatibility of different groups of road users or if solutions involve overcoming social dilemmas, then problems are likely to be difficult to solve. Problems to which biological factors contribute are also likely to be difficult to solve. Problems that are likely to be difficult to solve include high risk among young drivers, high risk to unprotected road users and speeding. Unfortunately, these problems all make major contributions to road accidents, suggesting that we may be approaching a point where making further progress in improving road safety will become increasingly difficult.

Key words: road safety problem, incompatibility, unprotected road users, risk factors, solution

1 INTRODUCTION

During the period after 1970, road safety has been greatly improved in many highly motorised countries. The most impressive improvement has taken place in the Netherlands, where the number of road accident fatalities was reduced from 3264 in 1972 to 677 in 2008. This decline corresponds to a reduction of nearly 80 percent. Other countries that have succeeded in reducing the number of road accident fatalities by more than 50 percent from the peak level include France, Great Britain, and all the Nordic countries. Yet, some road safety problems persist and seem to be almost impossible to solve. Thus, even if the total number of road accident fatalities has been reduced by nearly 80 percent in the Netherlands, young drivers continue to have a considerably higher risk of accident involvement than middle-aged drivers, and the injury rate for pedestrians, cyclists and riders of mopeds or motorcycles continues to be higher than the injury rate for car occupants. A considerable proportion of drivers continue to exceed speed limits. Leonard Evans remarks that (1991, page 41): "The over-involvement of young, and male, road users is one of the largest and most consistently observed phenomena in traffic throughout the world. It is so robust and repeatable that it is almost like a law of nature".

Why are some road safety problems more difficult to solve than others? Why do some well-known problems, like the high accident rate of young drivers, the high share of traffic exceeding speed limits or the differences in accident rate between different types of traffic environment persist over time? This is the main question that is discussed in this paper.

The aim of the paper is to identify some characteristics of road safety problems that make them difficult to solve. Based on previous papers (Elvik 2004, 2006A, 2008), a taxonomy of road safety problems has been developed. This taxonomy serves a framework for identifying characteristics than can make a road safety problem more difficult to solve. Before presenting the taxonomy, a few examples will be given of road safety problems that have persisted for a long time.

2 EXAMPLES OF ROAD SAFETY PROBLEMS THAT PERSIST OVER TIME

Some important road safety problems have been known to exist for a long time. In this section, the persistence over time of the following problems will be shown:

1. The high accident rate of young drivers, in particular young male drivers, compared to the safest group of drivers,
2. The high injury rate of pedestrians, cyclists and riders of two-wheeled motor vehicles compared to car occupants,
3. The high rate at which heavy vehicles cause injuries to other road users compared to the rate of injuries to occupants of these vehicles,
4. The stability over time of differences in accident involvement rate between different types of vehicles and different types of traffic environment,
5. The high proportion of motorists who exceed speed limits.

This list is not meant as an exhaustive list of road safety problems that persist over time, but shows some of the more important problems that have been discussed for a long time.

2.1 Young driver accident rates

The very high rate of accident involvement among young drivers, in particular young male drivers, has been known for a long time. Kritz and Nilsson (1967) showed this for Sweden in 1967; little had changed when Nilsson revisited the problem more than 30 years later (Nilsson 2004). Similar stories could be told for all motorised countries. Data for Norway, referring to selected years from 1979 to 2007 are shown in Figure 1 (Vaaje 1982, Bjørnskau 1988, 1993, 2000, 2003, 2008). Figure 1 shows the relative injury accident rate for young car drivers, when the rate for the safest age group is given a value of 1.0.

Figure 1 about here

The injury rate of the youngest car drivers is seen to be about 5-10 times higher than the rate for the safest age group. There is no tendency for this difference to become smaller over time; if anything it seems to be growing. Drivers aged 20-24 years also have a higher injury rate than the safest group of driver and the difference has not diminished over time.

Young males tend to have a higher accident rate than young females. Figure 2 shows young car driver injury rates by gender for Norway from 1985 to 2007. Figure 2 is based on the same reports as Figure 1, except the report by Vaaje

(1982) which did not state driver gender. For each gender, injury rate for the safest age group was assigned the value of 1.0 and injury rates for young drivers given as relative injury rates.

Figure 2 about here

Again, the persistence over time of the high injury rates among young drivers, in particular male drivers, is striking. The differences in injury rates have not become smaller over time. Factors that may contribute to these persistent differences are discussed later.

2.2 Unprotected road user injury rates

The term unprotected road users refer to road users who are not protected by means of a surrounding bodywork of metal. Unprotected road users include pedestrians, cyclists, moped riders and motorcycle riders. Unprotected road users are known to have a higher injury rate per kilometre of travel than other groups of road users. Figure 3 shows the relative injury rates for unprotected road users in Norway from 1969 to 2005, estimated on the basis of reports by Vaaje and Bjørnskau, quoted above, and a report by Vaaje and Fosser (1976).

Figure 3 about here

Pedestrians sustain injuries about 4-5 times more often per kilometre travelled than car occupants. The relative injury rate for cyclists is higher than for pedestrians; moped riders have about the same injury rate as cyclists. Riders of motorcycles have the highest injury rate, although this rate has fluctuated greatly over time, reaching a peak in 1979 and then declining again and becoming slightly lower than the rates for cyclists and moped riders.

2.3 Incompatibility between small and large vehicles

Incompatibility denotes the differences between different types of vehicles and groups of road users in terms of the amount of kinetic energy they produce when moving around. In general the heavier the vehicle, the larger the amount of kinetic energy it produces. In accidents that involve vehicles or road users of very different mass, it will in most cases by the smaller road user who gets killed or injured. Figure 4, based on Vaaje and Fosser (1976) and Elvik (2008), shows the ratio of the number of other road users injured to own injuries for different groups of road users and vehicles in Norway in 1969-72 and 1998-2005.

Figure 4 about here

The ratio is 0.03 for pedestrians, meaning that for each pedestrian who gets injured, there are 0.03 people belonging to other groups of road users who get injured in the same accident. This ratio is 3.46 for truck occupants in 1998-2005, meaning that about 3.5 people outside trucks are injured for each truck occupant who is injured in accidents involving trucks. The ratios are comparatively stable, but do show a small decline, which may indicate that vehicles have become a little less aggressive over time and are thus less likely to injure other road users.

2.4 Traffic environment and type of road

Different types of road and traffic environment differ in terms of the task demands they impose on road users. A motorway, at least when it is not congested, imposes relatively small task demands. The road is either straight or with very gentle curves or gradients; oncoming traffic is physically separated by means of a central reservation in which guardrails are often installed; there are no at-grade junctions with other roads; pedestrians, cyclists and slow-moving motor vehicles are not permitted; the road surface is maintained to a high standard, etc. In other words, the design of a motorway is intended to make the task of driving as simple as it can possibly be. A busy urban road, on the other hand, represents the other end of the continuum; it imposes heavy demands on the attention of road users. It is therefore no surprise that numerous studies have found that accident rates tend to be high in urban areas, lower on all-purpose rural roads and still lower on motorways.

Table 1 presents injury accident rates per 100 million vehicle kilometres of travel for urban roads, rural roads and motorways in Great Britain for 1984 (Grime 1987) and 2008 (Department for transport 2009). The upper part of the table shows actual rates per 100 million vehicle kilometres; the lower part of the table shows relative rates, estimated by setting the rate for cars on motorways to the value of 1.00 in 1984 and 1.00 in 2008.

Table 1 about here

By looking at the upper part of the table, it can be seen that travel has become safer from 1984 to 2008 for all types of vehicles in all types of traffic environment. All accident rates have been reduced, some of them considerably; not a single case of an increase in accident rate can be found. The differences in accident rates between types of vehicles and types of traffic environment are, however, remarkably stable over time. This can be seen from the lower part of table 1, which gives relative accident rates, using the rate for cars travelling on motorways as reference. While travel has become safer for everybody, it remains the case that motorcycles have the highest accident rate of all types of vehicle and it remains the case that an urban traffic environment poses the greatest risks and that motorways are the safest type of road. The stability of this pattern is truly remarkable and suggests that the improvement in safety between 1984 and 2008 cannot be attributed to safety measures that have been taken in a particular type of traffic environment or that have been targeted at certain types of vehicles. If anything, the differences in injury rates between different types of vehicles may have increased from 1984 to 2008, as suggested by the relative accident rates.

2.5 Speeding

Speeding is arguably one of the most important road safety problems in most motorised countries, and one of the problems that has been most resistant to change. Figure 5 shows the percentage of motorists exceeding speed limits in Norway at three points in time: 1971, 1980-84 (mean for these years) and 2004-06 (mean for these years).

Figure 5 about here

In 1971, around 15 % of motorists were speeding in Norway. By 2004-06, the percentage speeding had increased to about 50 %. The speed limit of 100 km/h did not exist in Norway before 2001. Elvik (2008) estimated the risk attributable to speeding in Norway in 1980-84 and 2004-06. For both periods, it was found that the number of fatalities could be reduced by nearly 25 %, the number of seriously injured road users by about 18 %, and the number of slightly injured road users by about 10 % if speeding was eliminated.

3 A TAXONOMY OF ROAD SAFETY PROBLEMS

Road safety problems can be classified in many ways. There is no right or wrong way of classifying such problems. Elvik (2004, 2006A, 2008) has developed taxonomies of road safety problems in terms of the risk factors that contribute to them and in terms of dimensions that characterise the problems. These taxonomies have been combined in this paper in order to roughly classify road safety problems in terms of how easy solving them is expected to be.

3.1 Contributing risk factors

The basic risk factors that are assumed to contribute to road safety problems, slightly modified from the list given in Elvik (2004), include speed, mass (weight), road surface friction, visibility (the possibility of seeing an object at a distance), compatibility (differences between vehicles with respect to the amount of kinetic energy they produce), complexity (the amount of information a road user must attend to per unit of time), predictability (the reliability with which the occurrence of a risk factor can be predicted; accuracy of road user expectations), road user rationality, road user vulnerability (lack of protection in case of an accident) and system forgiveness (safety margins built into the technical components of the road traffic system).

Of these basic risk factors, road user rationality in particular deserves a comment. Since it seems reasonable to assume that nobody wants to become involved in an accident, it is tempting to define road user rationality in terms of the ability to avoid accidents. Such a definition would, however, be entirely circular: whenever an accident occurred, it would be taken as evidence of a lack of rationality; whenever a trip was made safely, it would be taken as evidence of rationality.

It will be assumed that road users, although not wanting to become involved in accidents, make tradeoffs that involve accepting a certain level of risk. Road users are rational when the risk they choose to accept maximises the satisfaction of the mixture of motives that influence their behaviour and when their choices are based on an objectively correct assessment of the impacts of these choices. Failures of rationality according to this definition include (but are not limited to):

1. Choice of a driving speed that deviates from the most preferred speed, e.g. as a result of adaptation to the speed of other vehicles,
2. Driving with a lower level of alertness than ideally wanted, e.g. when fatigued, influenced by alcohol or drugs, or other sources of distraction,

3. Erroneous perceptions of the impacts of driving speed on travel time, accident risk and stopping distance,
4. Erroneous perception of driving skills, e.g. a false belief that one is able to control risk to a greater extent than is actually the case.

In general, failures of rationality are likely to increase the risk of accident. However, one should not by definition attribute every accident to a failure of rationality. As an example, it is not reasonable to regard an unsuspecting road user who strikes an animal that suddenly runs out in front of the car as acting irrationally.

3.2 Dimensions of road safety problems

The dimensions of road safety problems, as discussed by Elvik (2008) are presented in Table 2, slightly modified compared to the original list. In the original list, amenability to treatment was identified as a dimension. However, since the purpose of this paper is to discuss why some road safety problems seem to be more difficult to solve than others, amenability to treatment has been replaced by ease of observation of a problem. It is assumed that a road safety problem is more difficult to solve:

1. The greater its magnitude, since a major problem may require major investments or major changes in road user behaviour in order to be solved,
2. The more severe it is, i.e. if it contributes more to fatalities and serious injuries than to slight injuries,

3. The greater its element of externality, i.e. the greater the extent those who cause injuries are not themselves injured,
4. The greater its inequity, i.e. the greater the disproportion between the benefits of travel and the risk involved,
5. The more complex it is, i.e. the more it is made up of small contributions from a large number of risk factor that interact in non-linear or poorly understood ways,
6. The more spatially dispersed it is, since solving it may require treatment of the entire road system,
7. The more stable it is over time, since stability by itself may influence perceived urgency and stable outcomes may come to be regarded as normal,
8. When it is perceived as less urgent, i.e. when there is less support for measures that may reduce the problem,
9. When it is difficult to observe, as problems that are not readily observable may, for that reason, not be regarded as problems.

These assumptions guide the analysis presented below. Not all of them are equally well established by empirical research, but in the present paper they serve mainly as a framework for analysis.

3.3 Combining risk factors and dimensions of road safety problems

In Table 2, the risk factors contributing to road safety problems and the dimensions of the problems are combined, to provide a framework for assessing how difficult various road safety problems are to solve. The contribution each risk factor makes to a dimension is rated as large, medium or small (difficult, medium or easy with regard to ease of observation). Thus, speed (more specifically speeding) has been classified as making a large contribution in terms of magnitude (i.e. eliminating speeding would reduce the number of fatalities and injured road users more than eliminating many other risk factors) and a large contribution to severity, since it contributes not just to increasing the number of injuries, but also to making them more severe. Speeding has been classified as making a large contribution to stability over time, since, as shown in Figure 5, it has increased over time and has become normal behaviour. The perceived urgency of reducing speeding is low. Thus, in a Swedish survey (Ekander 2008), a representative sample of the population rated the following problems as the most important for road safety: (1) drinking and driving (93.3 %), (2) red light running (62.0 %), (3) not wearing seat belts (46.1 %), (4) tailgating (44.5 %), (5) speeding (25.8 %), (6) talking on the mobile phone (22.6 %), and (7) not wearing a cycle helmet (5.3 %). Speeding is clearly rated among the less important problems.

Table 2 about here

The other problems have been rated the same way as speeding. Three types of road safety problems emerge as difficult to solve according to the classification in Table 2:

1. Problems attributable to social dilemmas, of which speeding is a prominent case
2. Problems attributable to lack of road user rationality, of which young driver accident rates is a case
3. Problems attributable to the incompatibility between vehicles and the vulnerability of road users, exemplified by the high risk run by unprotected road users.

Is this classification reasonable? Why would one expect these problems to be more difficult to solve than other road safety problems?

4 FACTORS THAT MAKE PROBLEMS DIFFICULT TO SOLVE

4.1 Social dilemmas – the case of speeding

As noted above, speeding is a very widespread phenomenon. Very many drivers do not regard it as a road safety problem at all. There are two main reasons why speeding must be regarded as a difficult problem to solve:

1. Most drivers think they are rational in choosing speed, when in fact speed choice is partly based on misperceptions (Elvik 2009).
2. Some of the measures that are available to reduce speeding involve social dilemmas. A social dilemma is any situation in which there is a conflict between choices that are individually rational from the road user's point of view and collectively rational choices from a societal point of view.

Technology that can eliminate speeding exists in the form of systems for intelligent speed adaptation (ISA). The assessment of costs and benefits of ISA on new cars from a societal perspective and from a road user perspective are compared in table 3.

Table 3 about here

According to the societal perspective, the benefits consist of all savings in accident costs, from which the costs of additional travel time below the speed limit are subtracted. It was assumed that not all ISA-systems are perfect; hence, the mean speed of travel in a traffic stream in which all vehicles have ISA will be a little below the speed limit. This additional travel time has been included.

According to a road user perspective, the analysis is quite different. Only 60 percent of accident savings are included, as the rest of accidents are external from the road user's point of view (Elvik 1994). The full costs of reducing speed, including those attributable to the lowering of illegal speeds, have been included. While treating time saved by speeding (i.e. violating the speed limit) as a benefit is not appropriate in a cost-benefit analysis adopting a societal perspective (Elvik 2006B), it is clearly a benefit from a road user perspective; why else would drivers be speeding?

The two perspectives give dramatically different results. From the societal perspective, benefits exceed costs by a wide margin. From a road user perspective, benefits are negative. Hence, given the assumptions made, road users have no incentive to demand ISA systems and will see no net benefit in obtaining them.

4.2 Young driver accident rates

The high accident rates of young drivers are primarily attributable to a lack of rationality. This manifests itself in terms of deliberate risk taking and overestimation of skills. It would go beyond the scope of this paper to review in detail the quite extensive literature showing this. Only a few studies that give typical findings will therefore be quoted.

McKnight and McKnight (2003) examined narrative descriptions of more than 2000 accidents involving 16-19 year old drivers. They found that a high proportion of the accidents were attributable to errors in attention, visual search, speed adaptation and hazard recognition, rather than deliberate risk taking. The driving skills that are not fully developed in novice drivers are quickly learnt, contributing to a fast reduction of accident rate during the first months of driving.

It has long been the hope of educators that novice drivers can learn not just the skills needed for safe driving, but also acquire an understanding that these skills develop slowly and have not been fully learnt by the time a driver is licensed. However, teaching young people not simply to acquire certain skills, but also to correctly assess the limits of their skills is an almost impossible task. It is, so to speak, impossible to teach people that they do not know anything, or that what they know is only a very small part of what they need to know. Gregersen (1996) reported a very interesting experiment that shows this. He compared two groups of novice drivers. One group had been given skills training to make the driver as skilled as possible in braking and performing an evasive manoeuvre. The other group had been instructed that this task was very difficult and that they could not necessarily be expected to perform it successfully. The two groups then performed an evasive manoeuvre on a test track. Actually, the group that had been taught to master the skill and who erroneously believed that they did in fact master the skill, did a little worse on the task than the group who had been taught to have more modest expectations about their own performance.

Novice drivers regularly overestimate their competence. A recent study shows that 30-40 % of young drivers in Finland and the Netherlands rated their competence as better than driving licence examiners did (Mynttinen et al. 2009). Those who overestimated their competence (rated their competence higher than the rating given by the licence examiner) failed the driving test more often than those who slightly underestimated their competence. Overestimating driving skills is hazardous, as it can make the driver accept a higher level of risk than he or she would if skills were understood more correctly.

As far as deliberate risk taking is concerned, Evans (2006) proposes the hypothesis that it can be caused by hormonal factors, in particular the high level of testosterone in young males. While introducing biological explanations of social phenomena is controversial and not always taken seriously, the data presented by Evans at the very least indicate that his hypothesis is plausible, although these data do not confirm it. Support for the hypothesis that testosterone levels influence risk taking comes from a study of financial risk taking and career choice, although in that study the largest effect of testosterone was found among women (Sapienza, Zingales and Maestripieri 2009; both sexes produce both male and female sexual hormones, but in different mixtures).

In a similar vein, recent brain research has found that the human brain is not fully developed until the age of about 25 (Pasnin et al. 2009). Areas that are involved in higher order cognitive functions, such as risk assessment, are among those that develop most slowly.

In short, the high risk of young drivers is probably attributable to a powerful mixture of biological factors (hormones and brain development), overoptimistic self-assessments and being in a phase of life in which becoming independent, testing limits and rebelling against adult values is important. It is difficult to see how the enduring effects on risk of these factors can be substantially reduced.

4.3 Incompatibility and lack of protection

The incompatibility of vehicles and groups of road users is probably growing. Heavy vehicles get heavier, as economies of scale favour the use of ever larger vehicles. Passenger cars are becoming more heterogeneous. While sports utility vehicles are heavy, there is a growing number of hybrid cars or electric cars that tend to be small. Both incompatibility and lack of protection are very important for the outcome of accidents.

In Norway, during 1998-2005, in crashes involving truck-trailers combinations and single trucks, occupants of the single truck were injured 2.5 times as often as occupants of the truck-trailer combination. This ratio increases as the difference in mass increases. Thus, car occupants are injured 18.6 times as often as occupants of truck-trailer combinations in accidents involving these vehicles. Unprotected road users are injured 56.7 times as often as truck-trailer occupants in accidents involving both groups of road users.

Case fatality rates, i.e. the percentage of all those involved in injury accidents who are killed, varies hugely depending on the types of vehicles and groups of road users involved in accidents. For Norway during 1998-2005, the following case fatality rates were found:

1. Car occupants in accidents involving cars of equal mass only: 1.27 %
2. Car occupants in the large car in accidents involving cars of different mass: 0.43 %
3. Car occupants in the small car in accidents involving cars of different mass: 9.81 %
4. Unprotected road users struck by large cars (trucks, buses): 23.52 %
5. Unprotected road users struck by small cars (car, van): 8.20 %
6. Unprotected road users involved in accidents with other unprotected road users: 2.49 %

It is difficult to imagine that these huge differences can be eliminated. Kinetic energy can always be reduced by reducing speed, but in accidents involving unprotected road users and large vehicles, it is often the sheer dimensions and design of the vehicles that cause fatalities; accidents need not happen at high impact speed to become fatal.

5 DISCUSSION

In many motorised countries, the number of traffic fatalities, as well as the number of seriously injured road users, has declined considerably from the peak levels that were reached around 1970. At the same time, traffic volume has grown substantially; in many countries to more than double the level in 1970. There is therefore no doubt that travel has become safer in the past 40 years. Progress has been made in many countries in promoting safer behaviour, such as the wearing of seat belts and crash helmets and the abstention from drinking and driving. Despite this progress, some road safety problems persist and continue to contribute as much to fatalities and injuries as they did some 30-40 years ago. This paper has shown examples of such problems.

Why are some road safety problems more difficult to solve than others? In principle, there are many answers to this question. In the first place, it could be the case that a road safety problem persists simply because no attempt is made to solve it. This in turn may be because the problem is regarded as very difficult to solve, or it may be because the problem is tolerated and not regarded as a serious problem.

This explanation is likely to be partly correct for one of the problems discussed in this paper: speeding. Speeding is widespread in all motorised countries. This has been the case for a long time, so it is fair to say that speeding is widely tolerated. When asked about important road safety problems, speeding is hardly the first problem mentioned by road users. The risks involved in speeding tend to be underestimated and few drivers see any reasons to change their speed behaviour.

Today, technical solutions to the problem of speeding are available. There is, however, no strong pressure to introduce these solutions. On the contrary, it can be argued that Intelligent Speed Adaptation is unwanted by most drivers, as they see no net benefits of such a system, whereas there are net benefits from a societal point of view.

This leads to the second possible reason why some road safety problems remain difficult to solve, which is that their solution involves overcoming social dilemmas. A social dilemma exists whenever the costs and benefits of a measure as seen from a road user perspective differ from the costs and benefits as seen from a societal perspective. There are many cases of social dilemmas in road safety: the setting of speed limits, speed enforcement, the use of studded tyres, road pricing and insurance pricing. In all these cases, the existence of social dilemmas leads to a sub-optimal use of the measures from a societal perspective.

A third possible reason for lack of success in solving a road safety problem is that the problem may be caused, at least in part, by biological factors that are very difficult to influence. It is likely that the high accident involvement of young drivers is to some extent the result of factors related to biology and human development, such as brain development and emotional maturity. It is certainly not correct to say that no attempt has been made to reduce the high accident rate of young drivers. Extensive research and experimentation on driver training has been performed, but so far with limited success.

The fourth reason why a road safety problem may be difficult to solve that has been touched upon in this paper, is that the outcome of accidents may be closely linked to the physical dimensions of vehicles and the kinetic energy they produce. The physics of kinetic energy can be modified either by reducing speed or by reducing the mass of vehicles, but it is not clear that any of these options would help much in reducing the problems caused by incompatibility between vehicles and lack of protection in case of an accident. Heavy goods vehicles are large and heavy for reasons of transport economy: transport becomes cheaper the larger the vehicle is. Economic forces are very strong: every business is looking for the cheapest possible transport; nobody wants it to be more expensive than it has to be. Moreover, it is not obvious that, say, reducing large goods vehicles from a mass of 50 tons to a mass of 25 tons would help much. Incompatibility would still be very large, and you would need twice as many vehicles to haul the same amount of goods.

6 CONCLUSIONS

The main conclusions of the research presented in this paper can be summarised as follows:

1. The number of road accident fatalities has been greatly reduced in many highly motorised countries the past 40 years. Despite this, some of the

problems that were regarded as important then continue to be regarded as important road safety problems today.

2. Road safety problems that have persisted over time include: (a) the high risk of accident involvement among young drivers; (b) the high risk of injury to unprotected road users; (c) the high risks to other road users caused by heavy vehicles; (d) the high risk of injury in urban areas; (e) the risks attributable to speeding.
3. Possible reasons why these problems have persisted over time are discussed, and the following main reasons are proposed to explain why certain road safety problems remain unsolved: (a) the problem is widely tolerated, and not regarded as a problem; (b) solving the problem involves overcoming social dilemmas, which means overcoming opposition to effective but unpopular measures; (c) the problem is to a certain extent caused by biological factors or factors related to human development that are difficult to influence; (d) the physics of kinetic energy involved in accidents are such that they make the problem difficult to solve.

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LIST OF FIGURES AND TABLES

Table 3:

Costs and benefits of Intelligent Speed Adaptation seen from a societal perspective and a driver perspective

Figure 1:

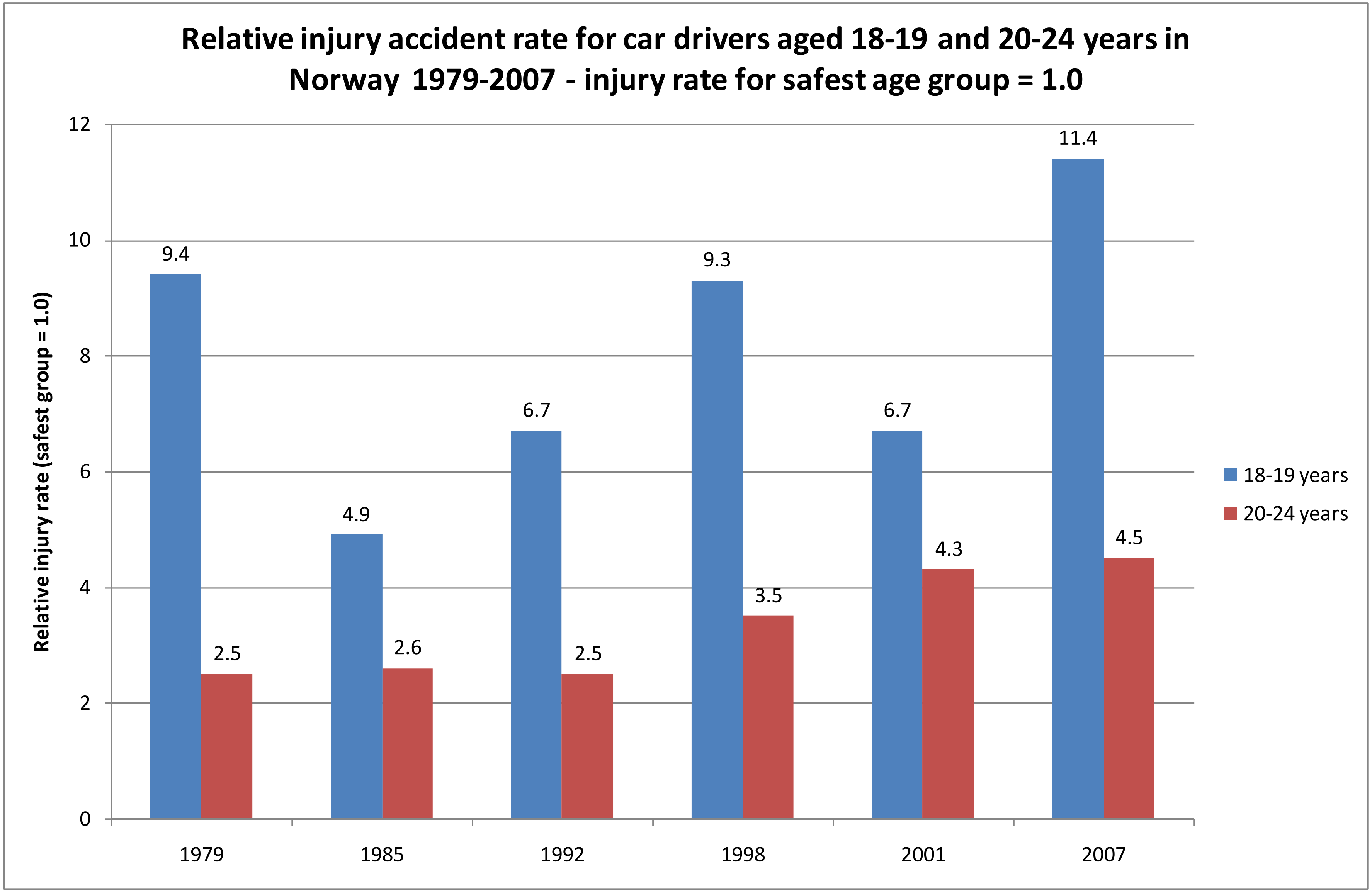

Relative injury accident rate for car drivers aged 18-19 and 20-24 years in Norway 1979-2007 - injury rate for safest age group = 1.0
Relative injury rate (safest group = 1.0)
12
10
8
6
4
2
0
9.4
2.5
4.9
2.6
6.7
2.5
9.3
3.5
6.7
4.3
11.4
4.5
1979
1985
1992
1998
2001
2007
18-19 years
20-24 years

Figure 2:

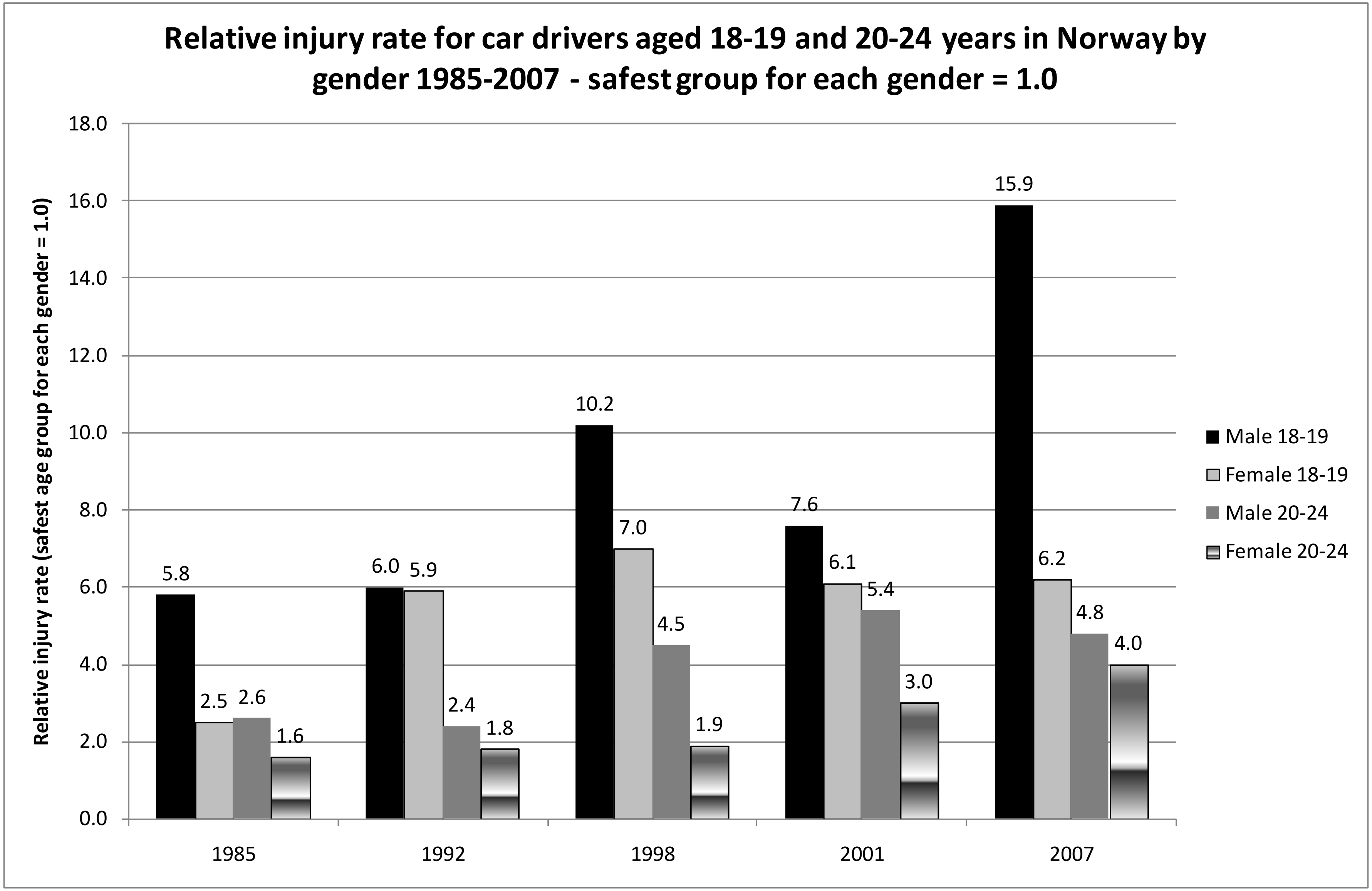

Relative injury rate for car drivers aged 18-19 and 20-24 years in Norway by gender 1985-2007 - safest group for each gender = 1.0
Relative injury rate (safest age group for each gender = 1.0)
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
5.8
2.5
2.6
1.6
6.0
5.9
2.4
1.8
10.2
7.0
4.5
1.9
7.6
6.1
5.4
3.0
15.9
6.2
4.8
4.0
1985
1992
1998
2001
2007
Male 18-19
Female 18-19
Male 20-24
Female 20-24

Figure 3:

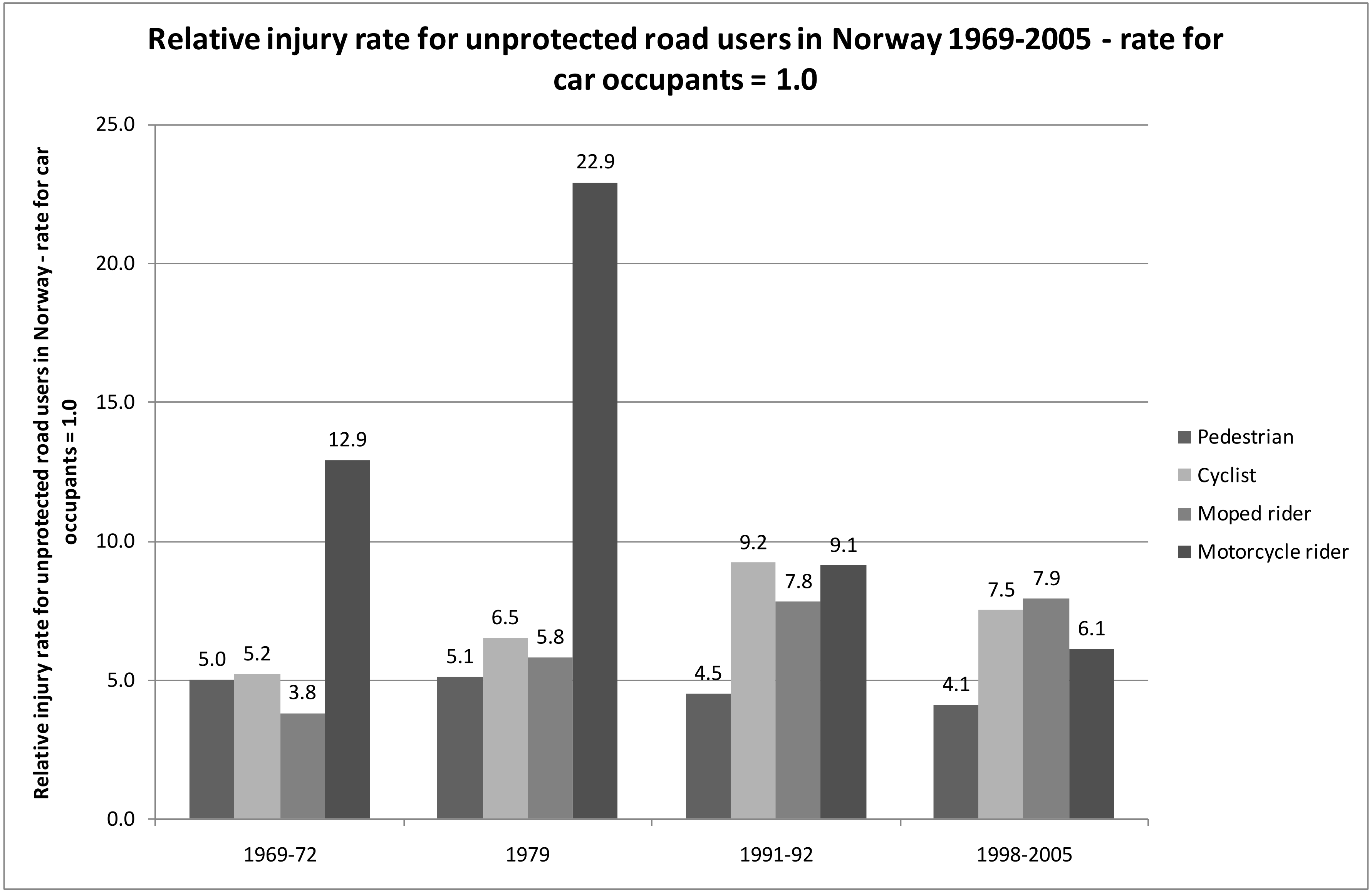
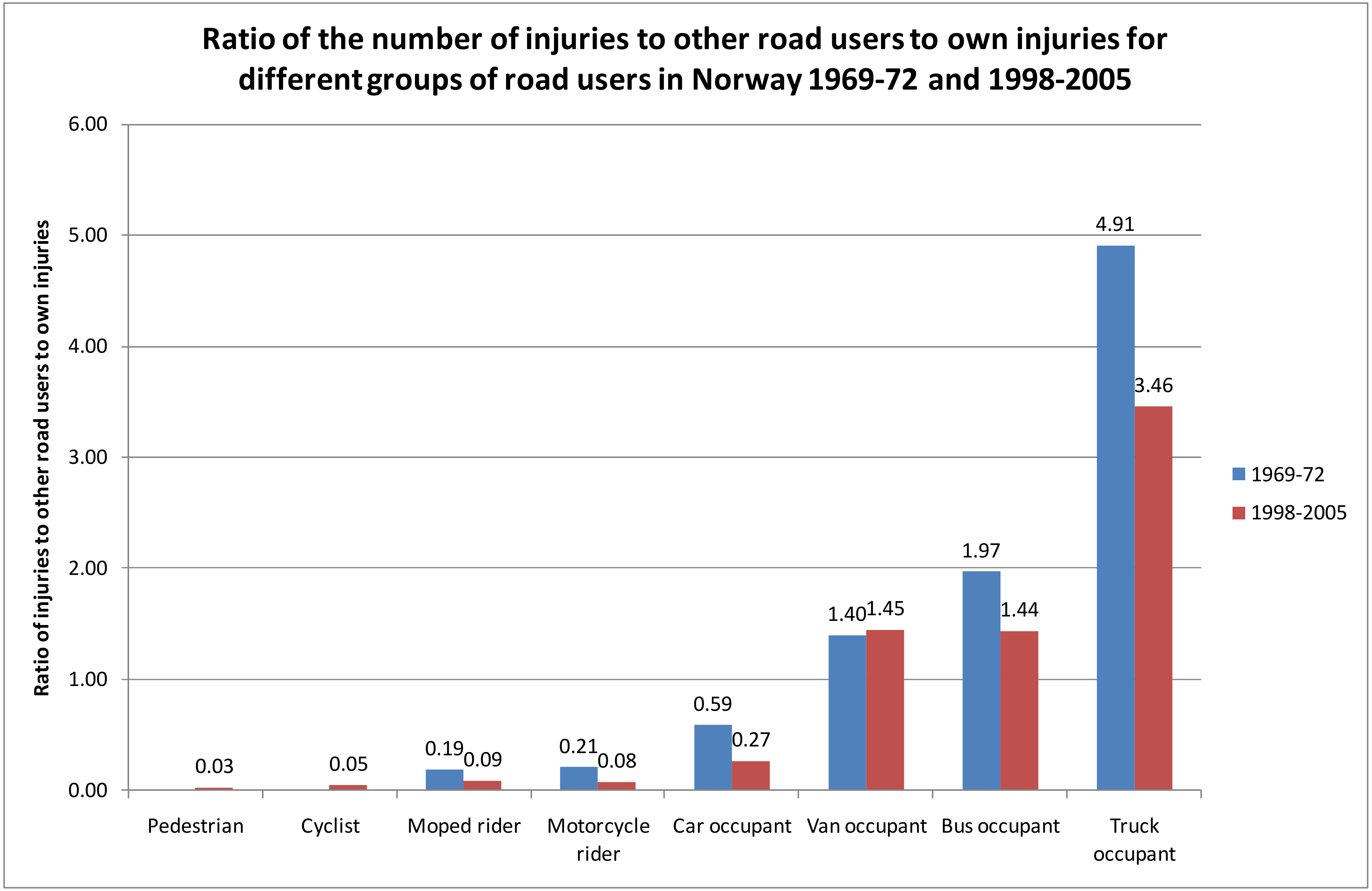

Relative injury rate for unprotected road users in Norway 1969-2005 - rate for car occupants = 1.0
Relative injury rate for unprotected road users in Norway - rate for car occupants = 1.0
25.0
20.0
15.0
10.0
5.0
0.0
5.0
5.2
3.8
12.9
5.1
6.5
5.8
22.9
4.5
9.2
7.8
9.1
4.1
7.5
7.9
6.1
1969-72
1979
1991-92
1998-2005
Pedestrian
Cyclist
Moped rider
Motorcycle rider

Figure 4:



Ratio of the number of injuries to other road users to own injuries for different groups of road users in Norway 1969-72 and 1998-2005
Ratio of injuries to other road users to own injuries
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.03
0.05
0.19
0.09
0.21
0.08
0.59
0.27
1.40
1.45
1.97
1.44
4.91
3.46
Pedestrian
Cyclist
Moped rider
Motorcycle rider
Car occupant
Van occupant
Bus occupant
Truck occupant
1969-72
1998-2005

Figure 5:

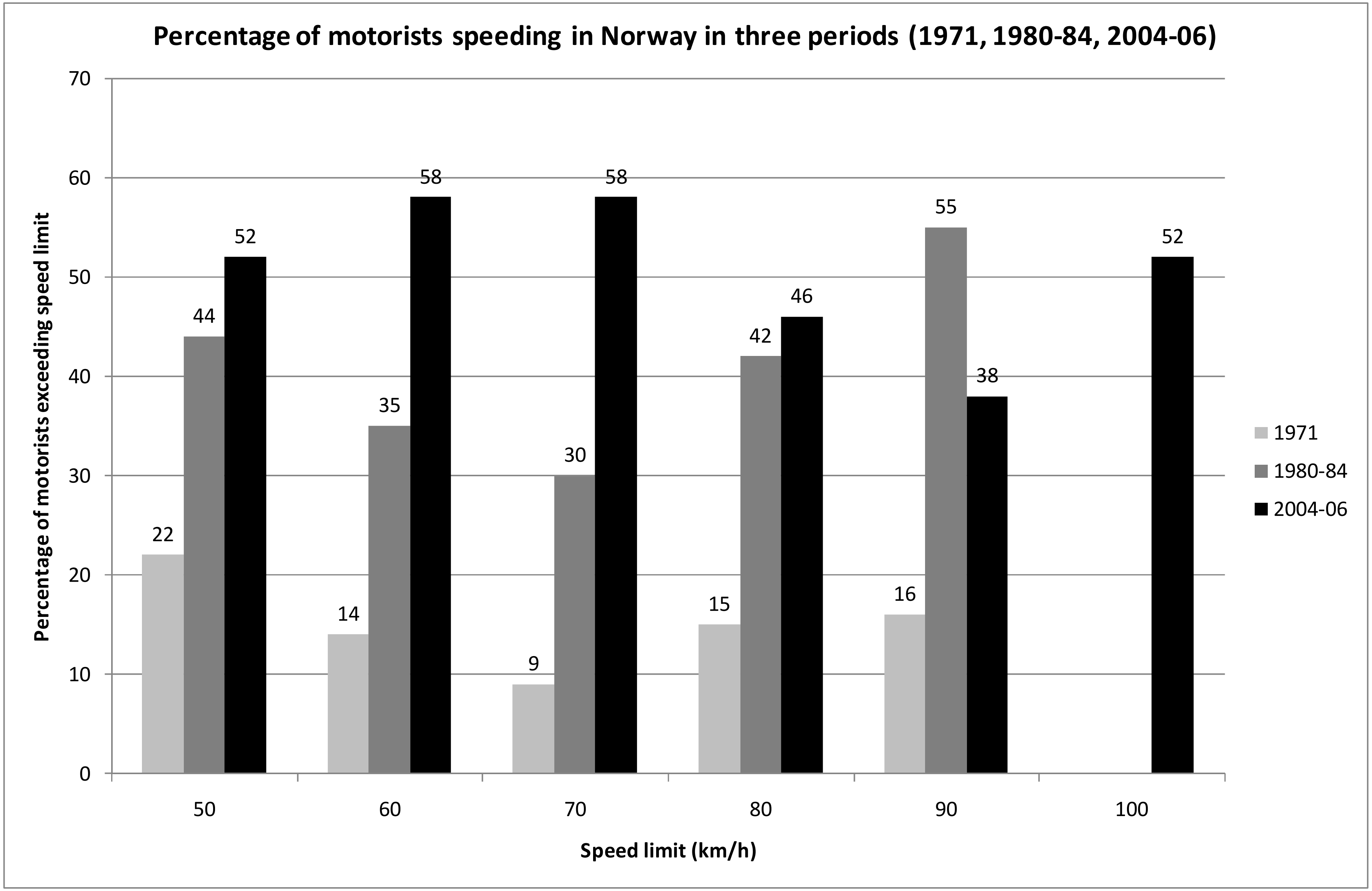

Percentage of motorists speeding in Norway in three periods (1971, 1980-84, 2004-06)
Percentage of motorists exceeding speed limit
70
60
50
40
30
20
10
0
22
44
52
14
35
58
9
30
58
15
42
46
16
55
38
52
50
60
70
80
90
100
Speed limit (km/h)
1971
1980-84
2004-06

Table 1:

	Injury accidents per 100 million vehicle kilometres and relative injury accident rates, using cars on motorways as reference (reference = 1.0)					
	Urban roads		**Rural roads**		**Motorways**	
Type of vehicle	**1984**	**2008**	**1984**	**2008**	**1984**	**2008**
	Absolute injury accident rates (per 100 million vehicle kilometres)					
Cycle	737	383	306	241		
Motorcycle	1334	554	594	340	193	75
Car	201	71	60	30	25	9
Bus	604	228	109	63	34	15
Light goods vehicle	142	29	55	15	23	8
Heavy goods vehicle	124	65	63	31	22	14
	Relative injury accident rates, using cars on motorways as reference (reference value = 1.0)					
Cycle	29.5	42.6	12.2	34.0		
Motorcycle	53.4	61.6	23.8	66.0	7.7	8.3
Car	8.0	7.9	2.4	6.7	1.0	1.0
Bus	24.2	25.3	4.4	12.1	1.4	1.7
Light goods vehicle	5.7	3.2	2.2	6.1	0.9	0.9
Heavy goods vehicle	5.0	7.2	2.5	7.0	0.9	1.6

Table 2:

Contributing risk factors	Dimensions of road safety problems								
	Magnitude	**Severity**	**Externality**	**Inequity**	**Complexity**	**Spatial dispersion**	**Stability over time**	**Perceived urgency**	**Ease of observation**
Speed	Large	Large	Medium	Medium	Medium	Medium	Large	Small	Easy
Mass	Medium	Medium	Large	Medium	Medium	Small	Large	Small	Easy
Friction	Small	Small	Small	Small	Small	Large	Medium	Medium	Medium
Visibility	Medium	Medium	Medium	Small	Medium	Small	Large	Small	Easy
Compatibility	Medium	Large	Large	Large	Small	Small	Large	Medium	Easy
Complexity	Large	Small	Large	Medium	Large	Small	Large	Medium	Easy
Predictability	Medium	Small	Small	Small	Large	Small	Small	Small	Difficult
Road user rationality	Large	Medium	Medium	Small	Large	Small	Large	Small	Difficult
Road user vulnerability	Large	Large	Large	Large	Medium	Small	Large	Medium	Easy
System forgiveness	Medium	Medium	Small	Small	Small	Small	Small	High	Medium

Table 3:

	Amounts in million NOK (1 NOK = 0.12 Euro in May 2009) if all cars have Intelligent Speed Adaptation. Negative amounts are added costs		
Item of benefits or costs	**Societal perspective**	**Driver perspective**	**Comments**
Accident savings	28,997	17,398	About 40 % of accident costs are external and not counted as a benefit by drivers
Extra travel time	−6,402	−38,410	Only reduction in legal speeds included according to societal perspective
Vehicle operating costs	720	720	Car drivers will include all savings in vehicle operating costs
Environmental benefits	2,350	0	Environmental benefits are external from drivers' point of view
Total benefits	25,665	−20,292	
Installation costs	9,181	9,181	Costs are paid in full by drivers
Annual running costs	2,333	2,333	Costs are paid in full by drivers
Total costs	11,514	11,514	
Benefit cost ratio	2.23	−1.76	Dramatic difference in results depending in perspective adopted