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# The Value of Road and Railway Safety

## - an overview

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### Abstract

The level of safety investments can be argued to vary between sectors. The safety investments legally required and carried out within the railway sector indicate that there is a higher implicit value in preventing a fatality within the rail sector than within the road sector. The literature overview discusses factors possibly influencing individuals' perception of risk and their willingness to trade risk for money. The study seeks to combine results, from e.g. the field of psychological studies, with work performed by economists in order to analyse whether the value of preventing a statistical life used in the road traffic sector can be argued to differ from the value used in the railway sector. The research discussed here indicates that the use of different values may be theoretically motivated. However, empirical findings presented do not confirm that the value of a statistical life used in the railway sector is many times larger than that used in the road sector. Research indicates, furthermore, that the variation of perceived risk within the context of one traffic mode may be as large as, or even larger than, the variation between different traffic contexts. The result implies that studies estimating the value of a statistical life should focus not only on disparities between transport modes *per se* but also on disparities between accident types.

**Keywords:** value of safety, risk perception, willingness to pay

**JEL classification:** D61, D81, I10

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## 1. Introduction

In welfare economic theory a fundamental premise is that the public sector allocation process should, as far as possible, reflect the preferences and the strength of preferences of those who will be affected by the decisions concerned, Beattie, et al. (1998). Their study suggests that a measure of the strength of preferences is naturally provided by the individual's willingness to pay for desirable goods and improvements and the willingness to accept compensation for detrimental effects. Under the assumption that these values reveal individual preferences, various effects can be aggregated and recalculated into units that are more comprehensive. For instance, within the risk management area, the expected loss of life can be reduced by one. The aggregate of the affected peoples' willingness to pay for reducing the risk can then be referred to as the value of saving a statistical life or simply the value of a statistical life. This value is also referred to as the value of preventing a fatality and both expressions will be used synonymously in this study.<sup>1</sup> The value of safety is also used in relation to various degrees of injuries as well as fatalities.

Results within the so-called psychometric literature suggest that the perceived risk varies from hazard to hazard and that the variation of perceived risk in part explains our indifference to some risks and our extreme worry for others. The level of safety investments varies indeed between different sectors. For instance, the safety investments legally required and carried out within the railway sector indicate that there is a higher implicit value of preventing a fatality within the rail sector than within the road sector, Jones-Lee (2002). It is then of interest to study whether the observed variation in the applied value of safety can be theoretically motivated and empirically established within studies of individual preferences.

The aim of this literature overview is to analyse factors that may affect individuals' valuation of a marginal risk reduction. Based on the factors presented, the study discusses whether the value of a marginal risk reduction used in road project appraisals can be argued to differ from the value used in the railway sector. (The discussion here will mainly be focused on the value of a statistical life but can readily be applied to the conceptual term "the value of a marginal risk reduction".) The discussion combines results, from e.g. the field of psychological studies, with work performed by economists in order to analyse this matter. This study does not seek to give an all-embracing account of the literature but rather to point the reader to the main lines of argumentation.

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<sup>1</sup> Similar calculations can be made for various degrees of injuries.

Another aim of this literature overview is to discuss whether the value of preventing a fatality in the road and railway contexts can be argued to vary depending on the type of hazard. Studies of railway accidents suggest that the variation in perceived risk may be substantial for the same transport mode depending on accident type and circumstances of the accident. The result of the literature overview implies that studies estimating the value of a marginal risk reduction for different traffic modes should focus not only on disparities between different transport modes *per se* but also on disparities between different accident types and circumstances.

The structure of this study is as follows. Terms used within the risk management area are presented in chapter 2. In chapter 3, a short introduction is given to different techniques used to estimate the value of a marginal risk reduction. Some examples of the value of a statistical life found in the literature are also presented. The question of whether different values of safety should be used within the road and the railway sectors is then raised. In order to answer this question we first concentrate on theoretical arguments that can be found for why, or why not, there may be a difference. These arguments are discussed in chapter 4 and 5. In chapter 4, research on peoples' risk perception of different hazards is presented together with research on peoples' perception and understanding of risks. Chapter 5 focuses on research on the characteristics of risk reductions and their implication for risk valuation. In both chapters 4 and 5, the discussion is applied to hazards in general and on road and railway hazards explicitly in order to find arguments for the use of different values of a statistical life within different sectors and circumstances. In chapter 6, we turn to studies that estimate the value of a statistical life empirically for the road and railway contexts, among others, with the purpose of analysing whether the theoretical arguments previously discussed correspond with the empirical findings. Not all rail and road accidents are alike though, and in chapter 7 we discuss differences in individuals' risk perception depending on the specific hazard studied. The literature overview ends in chapter 8 with a discussion on arguments presented.

## 2. Terminology of risk

The term *hazard* will be frequently used in this study. A hazard can be defined as a potential source of danger or a situation with a potential for harm. A chance event with harmful consequences can also be defined as an *accident*.

The term *risk* is sometimes dealt with in a rather careless way in both defining the probability of an incident and the maximum negative consequence of that incident. In the literature there is, however, a fairly general consensus of the definition of risk as the combination of the probability of a certain event occurring and the effects of that event.

Many studies also make a distinction between risk and *uncertainty*. Risk refers to situations where the perceived likelihood of events of interest can be represented by probabilities, whereas uncertainty refers to situations where the information available is too imprecise to be summarised by a probability measure.

*Individual risk* is defined as the risk a specific individual is exposed to e.g. by living near a chemical industry. The purpose of using individual risk criteria is to ensure that individuals are not exposed to unacceptably large risks. *Societal risk* relates to the risk for a group of people, a region or for the society as a whole. Societal risk is often used to complement the individual risk measure in order to account for the fact that major incidents may affect many people, e.g. accidents involving transport facilities and nuclear plants. The terms individual risk and societal risk are both used in the process of analysing risks. When focusing on investments in safety, *private* and *public risk-reducing investments* are also discussed.

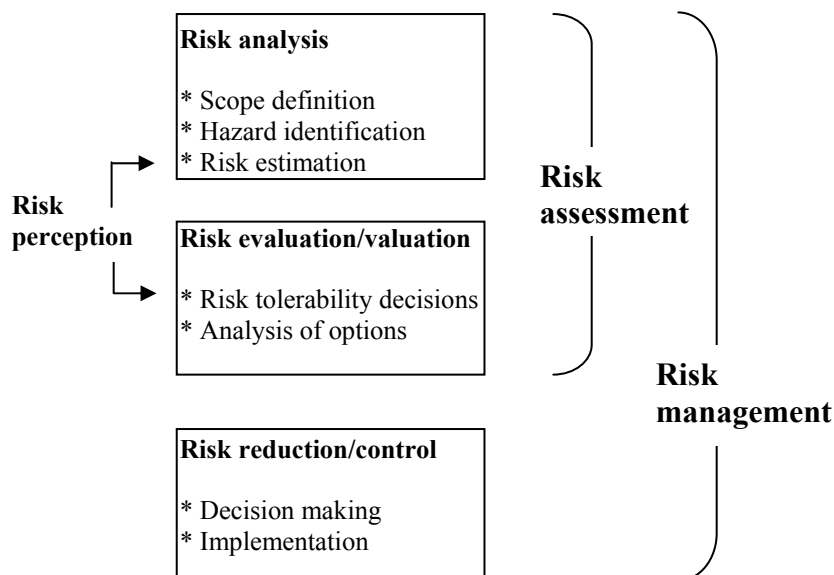
In a *public risk-reducing investment*, actions are taken to reduce the risk for a group of people or for the whole society. A public risk-reducing project may then be seen as a *public good* in that the safety arrangement, e.g. a new and safer road, is a good that is available to everyone and one person's consumption does not diminish that of others (the problem of congestion disregarded). A bicycle helmet is a typical *private risk-reducing investment*, which only reduces the risk for the person wearing the helmet. This private safety investment may then be seen as a *private good* since when consumed by one person it cannot be consumed by another.

*Objective risks* can often be estimated based on empirical material and according to statistical methods. The wording "objective" risk can, however, be questioned when dealing with low probability events since the empirical material may be very small or even non-existent. Some kind of subjective risk judgement is then required. *Subjective risks*, or

*perceived risks*, are based on individuals' own expressed risk beliefs and they are, in contrast to objective risks, affected by personal values and conceptual frameworks.

According to the Royal Society (1992), *risk management* may be described as the process of a number of elements, see figure 1. The process of *risk assessment* aims to determine the relationship between say the “dose” and the “response”. In this way, risk assessment tries to convert an uncertainty context into a risk context. According to Turner et al. (1994) the terms risk assessment and risk management tend to embrace uncertainty. That is, even if uncertainty cannot be converted into probabilistic outcomes, the same procedure of assessing e.g. doses and responses and determining acceptability and management, applies.

Figure 1. The risk management process.



The risk assessment process can be subdivided into *risk analysis* and *risk evaluation*. Risk analysis includes identification of the outcomes, the estimation of the magnitude of the associated consequences of these outcomes and the estimation of the probabilities of these outcomes. Risk evaluation/valuation on the other hand is the complex process of determining the significance or value of the identified hazards and estimated risks for those concerned with or affected by the decision. It therefore includes the concept of *risk perception* and the trade off between perceived risks and perceived benefits. Individuals' perception of risks is also likely to influence the risk analysis process when estimating probabilities of different outcomes.

Individuals' risk perception has been studied thoroughly since the 70s when a psychometric model, e.g. Fischhoff et al. (1978), was developed. Since peoples' risk perception is part of the risk assessment procedure, there have been attempts to incorporate the results of risk perception studies directly as part of the process. This is, however, difficult to do since the risk perception methodology is not an evaluative tool but an approach for identifying public concerns about technologies and activities and lacks a formal evaluative structure. In order to use information on peoples' risk perception when estimating the value of a risk reduction, additional issues have to be defined and analysed. This problem will be discussed in chapter 5.

In this study, the term *risk valuation* will be used rather than the term *risk evaluation* in order to point out that monetary values are used in the risk valuation process. Risk evaluation is a broader concept with a wide range of measurement units.

*Risk management* involves, besides risk assessment, the issue of how much risk is acceptable and by what means unacceptable risks should be reduced.

### **3. Risk valuation**

#### **3.1 Methods**

Under the willingness to pay approach, the value of a risk reduction (here a fatal risk) can be illustrated as follows. Suppose that 100.000 people enjoy a safety improvement that reduces the individual probability of death by 1/100 000. The expected number of deaths within that group is then reduced by one, i.e. the avoidance of a statistical death. If an affected individual is willing to pay say, 130 SEK for the 1/100 000 reduction, his/her marginal rate of substitution of wealth for risk is calculated as<sup>2</sup>:

$$\frac{130}{1/100000}=13.000.000\text{SEK}$$

The value of a statistical life is given by the mean marginal rate of substitution of wealth for risk, calculated over the affected population of individuals, Jones-Lee (1989).

There are two empirical approaches used to estimate people's willingness to pay for risk reductions. These are commonly labelled "revealed preference" and "stated preference". The revealed preference approach involves identifying situations where people do actually trade off money for risk, such as when they buy safety measures or when they take more or less

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<sup>2</sup> See Rosen (1988, p: 287) for details.

risky jobs for more or less wages. A number of wage-risk studies have been carried out and they provide useful estimates of the value of risk in the area of occupational safety. It is however, difficult to collect sufficient data to disentangle factors other than safety, which may affect behaviour. Furthermore, individuals may not have full information on the risk level. One may also argue that the data set is not representative. Through self-selection, risk-averse individuals are not likely to be found in risky jobs. There is also an issue of cognitive dissonance in these studies. The basic premise of the theory of cognitive dissonance is that people like to hold beliefs that are mutually reinforcing and are uncomfortable if their ideas are apparently contradictory. Consequently, there is a tendency to discount new information that appears to conflict with beliefs that have already been formed, or to discount the adverse potential consequences of a course of action once that course has been chosen, Akerlof and Dickens (1982). An example of the impact of cognitive dissonance is the tendency for people, who have chosen risky jobs, to discount the risk because the cognition that it was a sensible decision to choose that job sits uncomfortably with the cognition that the job is in fact dangerous.

The stated preference approach makes it possible to collect detailed data on those safety effects that are of interest. The contingent valuation method is widely used. In this method, people are asked quite directly how much they are willing to pay for a specific reduction in the risk, or willing to accept for an increase in the risk. For instance, this can be done using questionnaires by mail or telephone interviews. The approach has mainly been used on more familiar risks of death, e.g. Carthy et al. (1999) and Persson et al. (2001) for road safety and Lanoie et al. (1995) for occupational safety. People are used to making decisions about their own safety in these areas, and the risks are relatively well-defined and objective-measured since good statistical records are available.

The stated preference approach may, however, suffer from a number of problems. Research raises serious doubts about how far in practice individuals can or do process information in the way the economic model supposes, e.g. Kahneman and Tversky (1979) and Baron (1997). There has been a growing body of evidence that contingent valuation responses are vulnerable to a number of biases and inconsistencies such as starting point biases and range effects in that the respondents are influenced by whatever information the researchers choose to use. There is also the embedding effect, which suggests that the individual willingness to pay is approximately the same for a good evaluated on its own or as part of a more inclusive category. The quality of the response estimates is also dependent on the comprehension of small probabilities. With a risk reduction of the order 4 in 100,000 when



discussing fatal risks, a modest imprecision in peoples' responses can become magnified into quite substantial differences in the corresponding value of a risk reduction. Attempts have been made to develop guidelines and criteria for good practice in contingent valuation exercises, e.g. Mitchell and Carson (1989) and Carson and Mitchell (1995).

Another problem is the question of whether hypothetical choices mimic real choices. Research suggests that hypothetical contributions exceed actual contribution rates. In order to solve this issue, studies have been carried out with the purpose to identify real yes responses among hypothetical responses, e.g. Johannesson et al. (1999) and Champ and Bishop (2001). The problem of free riding may also contribute to overestimations when results are based on hypothetical responses. Provision point mechanisms have then been used in order to minimize this problem, e.g. Rose et al. (2002) and Poe et al. (2002).

Beattie et al. (1998) suggest that if stated preferences are indeed to provide a direct and reliable input into regulation and/or public expenditure policy, more intensive value elicitation methods may need to be developed. Among the approaches discussed are, for instance, choice experiments, e.g. Adamowicz et al. (1998), Louviere (2000) and Ratcliffe (2000) within the field of valuing environmental goods and health effects. Rather than asking for weights or utilities directly, respondents are asked to rank, rate or choose between holistic alternatives. Weights and utilities are then inferred, using regression analysis. Other methods discussed are Risk-risk analysis and Standard gamble; see e.g. Viscusi (1995), Carthy et al. (1999), and Trawén et al. (1999).

### **3.2 Variation in estimated values of a statistical life**

A number of studies have estimated the individual trade off between safety and money, using different approaches. In this literature overview, no attempt is made to describe the work that has been done by researchers all over the world in this matter. Instead, this section focuses on a few studies that in turn review a number of reports that estimate the value of preventing a fatality. When the economic valuations of a fatality are compiled, compared and discussed one can conclude that though a variation exists between and within approaches, the estimated values are of the same order of magnitude.

Viscusi (1992) reviews different approaches valuing fatal and nonfatal risks to life and health. 23 estimates are based on labour market studies and these estimates range from \$ 4 million to 9 million in 1999 prices. In Miller (1990), 47 estimates of the value of a statistical life are presented from different types of studies done in the US, of which 30 come from wage risk studies. An average value of \$3.7 million in 1998 prices was calculated. Partly updated

versions of the studies in Miller (1990) are to be found in Miller (2000) in addition to 21 non-US studies. The mean value of the latter is \$3.45 million in 1995 prices.

There are also studies analysing consumption choices (trade offs between safety and money) in order to estimate the value of life. These tend to be lower than the estimates from the labour market. Viscusi (1993) contains 7 studies on the trade-offs outside the labour market, the average value amounting to \$1.7 million 1998 prices. Blomquist (2001) presents 8 studies, carried out in 1990-2001 on self-protection and averting behaviour in consumption, that reveal the individual preference for safety. In this study the value of a statistical life for adults ranges from something less than \$2.6 million to 6.8 million 1998 prices.

Estimates from studies using the contingent valuation approach tend to be somewhat higher than the revealed preference estimates. Mitchell and Carson (1989) provide an overview studies using the contingent valuation approach in the field of valuing environmental goods. In Miller (2000) the value of a statistical life estimated by the contingent valuation approach ranges from \$1.1 million to 7.5 million in 1995 prices.

Since there is a variety of studies and differences have been found, there is now an increasing interest in so-called meta-analyses. These studies focus on a statistical analysis of research results attained previously in order to explain the variation among the observed estimates. In the meta-analysis of de Blaeij et al. (2000), 30 estimates from the road safety area are studied. Their result indicates that the magnitude of the value of life estimates depend on the value assessment approach (particularly stated versus revealed preferences). For studies using contingent valuation, the size of the estimate also depends on the type of payment vehicle and elicitation format.

In Elvik (1995), a meta-analysis is carried out on the value of life estimates for occupational and transport safety. The result of this study stresses the importance of high quality in the design of a study. Elvik concludes that poorly designed stated preference studies result in higher estimates than more carefully designed studies. Furthermore, estimates of studies with high validity lead to lower variation.

### **3.3 Should we apply different values of a statistical life within the road and railway sectors?**

According to Sunstein (1997) and Beattie et al. (1998), there ought to be a discussion concerning factors that might suggest the use of different values for preventing a fatality in different sectors and circumstances. This may be seen as a controversial point of view since the use of different values in different sectors conflicts with the opinion that funds should be reallocated so that the marginal cost of death prevention is equal across programs, thus maximising the number of deaths prevented for a given outlay. The logic of this argument depends upon the view that each person's life should be considered equally valuable regardless of age or other characteristics. The same goes for the issue when death occurs. It is also notable that if we decide to spend a lot more money to prevent some types of deaths than others, we will not be able to prevent as many fatalities as we could if we spent the same amount of money per fatality prevented.

It is, however, clear from a theoretical perspective that the value of a marginal risk reduction may not be a universally transferable number. Standard economic theory readily admits that people may care about a variety of factors relating, for example, to the particular nature of the hazard which could potentially cause individuals' willingness to pay for a given risk reduction to vary. Adjustments may be made depending on the context in which the risk arises and the characteristics of the risk of concern. There are for instance no a priori grounds for supposing that the value of a marginal risk reduction is the same for road users as for passengers on public transport modes such as railway traffic. Allowing for a variation in assessing risks is perfectly legitimate if individuals' preferences are to be taken into account.

According to Railtrack (2000), the company that owns and operates Britain's railway infrastructure, safety investment policies accord a significantly greater premium to activities such as rail travel, where individuals have less choice or control over the risks and which have the potential for large-scale casualties in a single event. Hence, in its appraisal of proposed railway projects Railtrack applies two distinct values of a statistical life. The first is the current road fatality figure of the Department of Transport, Local Government and the Regions, DTLR, updated for inflation and growth to £1.20 million in 2001 prices. This figure is applied in situations in which passengers or staff can be taken to have a substantial degree of control as in the case of single fatality accidents at a level crossing or on platforms. The second value of a statistical life is employed in cases in which the risk concerned applies to large numbers of people and those affected have little or no control. This figure amounts to £3.35 million in 2001 prices i.e. 2.8 times the DTLR roads-based figure.

The use of largely differing values for preventing railway and road fatalities is questioned in Jones-Lee (2002) though. In his article, Jones-Lee discusses the European Train Control System, ETCS, which is now required by European law, as an example. When approving this investment, it is suggested that the value of preventing a rail fatality exceeds by many times the value of preventing a road fatality. According to the author, there is no empirical support for this when studying individual preferences, and an application of such a value is then “prima facie evidence of an appalling misallocation of resources”, Jones-Lee (2002, p. 7). Blomquist (2001) argues that the public trade-offs tell us little, if anything, about individuals’ preferences for safety. Mendeloff and Kaplan (1990) used a survey approach to examine whether the large variation in society’s investments in life-saving interventions reflects public opinion or not. The study showed that preferences expressed by public opinion could explain some variation in cost-effectiveness but the large variation in actual investments could not be accounted for.

In Sweden, the figure officially used as the value of preventing a road fatality is also used in the railway sector as the value of preventing a rail fatality, even though the figure is based on road accidents.<sup>3</sup> This is also the case in e.g. the US and Norway. Is this use of a single value motivated by people’s preferences or should we use different values for preventing a fatality in the road and railway sectors? In order to shed some light over this question we will now discuss factors possibly influencing individuals’ perception of risk and their willingness to trade risk for money.

#### **4. Risk perception and implications for road and railway traffic**

In order to understand and explain possible differences in the value of safety applied in the road and railway sectors, we need to understand the factors that influence our perception of risk and in turn affect our risk reduction preferences and possibly our willingness to pay for those reductions. In this chapter, we start off with an exposition of studies that seek to understand peoples’ perception of risk and risk reductions and how different characteristics of a hazard may affect peoples’ risk perception. Both hazards in general and in the road and railway context are discussed. The research presented includes inputs from e.g. psychology, sociology, decision theory, economics, and policy studies.<sup>4</sup>

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<sup>3</sup> The Swedish National Road administration uses a value of a statistical life of 16.3 million SEK in 2001 prices in their cost-benefit analyses. For a compilation of costs per fatal casualty in traffic accidents adopted by authorities in different countries, see Trawén et al. (2002).

<sup>4</sup> Reviews of the field are to found in e.g. Royal Society (1992) and Slovic (2000).

#### 4.1 Research based on the characteristics of hazards

The main argument for assessing risks differently is that characteristics of the individual or of the situation, in which the hazard is encountered, affect us differently. This effect is occasionally named “the context” of an accident. Some risks, e.g. in sports, are accepted voluntarily whereas some risks are a part of the requirements of everyday living, e.g. driving. The goal of psychological work on risk perception, so-called psychometric studies, has been to ascertain how different risks are represented psychologically; in terms of how accurately their quantity is represented with respect to some normative standard, and how qualitative dimensions of various risks cause the perceived risks to be similar or different from each other. Here, we will discuss some risk characteristics that can be argued to influence our perception of risks both in general and in the road and railway area.

##### *Dread and knowledge*

In order to analyse the factors that influence people’s perceived risk and predict the way that individuals and society respond to hazards, researchers have asked people to judge the riskiness of diverse sets of hazardous activities and technologies. People have also been asked to indicate their desire for risk reduction and regulation of these hazards. These global judgements have then been related to judgements about the hazard’s status regarding various qualitative characteristics of risk, e.g. voluntariness, dread, controllability, the benefits that the hazardous activities provide to society and the harm caused by this hazard in an average year. Since the risk characteristics judged to influence perceived risk are often highly intercorrelated, they can be reduced to 2 or 3 factors. Based on these factors a co-ordinate system, called a factor space, is created. Using the factor space, the level of perceived risk associated with a particular hazard and the attitude towards regulating this risk can be predicted quite well from knowledge of where the hazard falls in the factor space, e.g. Starr (1969), Fischhoff et al. (1978), and Slovic et al. (1980).

In Slovic et al. (1980), 90 hazardous activities were considered. The risk characteristics were in this case clustered into three factors named *dread risk*, *unknown risk* and *the number of people exposed*. The most important factor was dread risk, i.e. a risk that cannot be thought of in a calm and reasonable way. The higher a hazard score in this factor, the higher its perceived risk, the more people want to see the risk reduced and the more they want to see strict regulation employed to achieve the desired reduction in risk. According to Savage (1993), people appear to have a great dread if death is a long drawn-out event, e.g. cancer. This period of intense difficulty might impose stress on those with the illness as well as on

friends and family members. Moreover, some hazards, like pollution, often cause diseases only after many years of exposure. An unknown factor may then comprise the fact that the victims may not observe the hazard when it occurs, that they may not personally know the risk or that the probability or consequences of the hazard are not even known to scientists or experts.

These results correspond in part with those of Sjöberg (2000). In his study, a model is proposed in which attitude, risk sensitivity, and specific fears are used as explanatory variables. The model seems to explain well over 30-40% of the variance of raw data in contrast to the psychometric model where the explanatory value is only around 20% of the variance. However, Drottz-Sjöberg and Sjöberg (1991) argue that several of the dimensions used by e.g. Fischhoff et al. (1978) and Slovic et al. (1980), have not been validated. For instance, it may seem natural to ask people to rate whether they accept a risk and how much they require it to be reduced if they do not accept it, but such ratings should be validated against risk related behaviour before they can be given credibility. Furthermore, according to Drottz-Sjöberg and Sjöberg, it is well known that reactions to risk are not static but vary greatly with, e.g. the occurrence of risky events.

The results of Fischhoff et al. (1978) and Slovic et al. (1980) show that railways generally induce little dread and involve less severe consequences than other means of transportation. Factors underlying the risk perception seem to be that railways are a well-known and old technology and although they have a catastrophic potential, they compare favourably to, for example, commercial aviation. Railway traffic is associated with no dread. Motor vehicles are regarded as being a well-known, old technology with little catastrophic potential. Road traffic is also associated with little or no dread, though more dread than railroads. These results give us a better understanding of the factors people take into consideration when forming their preferences. The more dread a hazard evokes, the higher its perceived risk and consequently, the more people want to see its current risks reduced. In Fischhoff et al. (1978), motor vehicles score higher on the factor *dread* than railways. There is then an indication that people favour a risk reduction for road users. This is, however, not the case in Slovic et al. (1980). On the other hand, in Slovic et al. railways score higher on the factor *unknown risk* indicating less knowledge of railway hazards compared to roads. Consequently, based on these factors studied we can find arguments that favour risk reductions within the railway as well as the road traffic context.

### *Voluntarily and controllable*

The results of Slovic et al. (1980) and Savage (1993) also show that people's risk perception is related to whether victims are exposed to the hazard voluntarily and to the extent to which the victim can avoid death by personal skill or diligence, i.e. controllable. According to Sunstein (1997) it is, however, not clear what is meant by the suggestion that one activity is voluntary and the other is not. For instance, many people injured in automobile accidents are not at fault. Whether a risk is run voluntarily is often not a categorical one but instead a matter of degree, associated with information cost, risk reducing cost and the existence, or not, of accompanying benefits. Individuals' perception of a hazard being controllable may also be an illusion of control. Langer (1975) discovered that individuals often have a misplaced confidence in their own capacity to control events in life in that they exaggerate their perceived control of environmental events. This illusion of control refers to the belief that the outcome of random events can be influenced. An often-quoted example of illusion of control is that of an individual being more optimistic about outcomes when allowed to choose a lottery ticket rather than just being handed one.

When comparing the risk perception of road and railway traffic there are some distinct differences in the risk characteristics. One may argue that people in public transport modes such as railway traffic are unable to affect their situation and that the risk is to some degree involuntary. In road traffic, on the other hand, people think that they are in control over the situation and that the risk road users are exposed to is voluntary. These characteristics indicate that people may favour risk reductions within the railway context over reductions within the road traffic context.

### *Moral indignation and trust*

The degree of moral indignation that an accident evokes is related to the judgement over who has responsibility for safety, which in its turn may affect individual's preferences for risk reductions. According to Sjöberg (1991), moral indignation appears to be a potent factor in public response to risk and ought to be analysed more closely. Accidents inducing moral indignation in society may be argued to increase individual preferences for risk reducing investments in this area.

Accidents in the railway sector may be argued to inflict a higher degree of moral indignation in that people that are exposed to the risk have, or at least experience that they have, limited opportunity to affect the safety arrangements, e.g. Slovic et al. (1980). This result may be interpreted as, in the public opinion, accidents occur because of the railway

agencies' failure to take sufficient responsibility for safety. Road traffic accidents, on the other hand, seem to induce less moral indignation on the average in that the traffic safety is closely related to personal decisions.

Research indicates furthermore that there is a relationship between trust and risk perception. Studies by Bord and O'Conner (1992), Slovic (1997) and Siegrist (2000) show that trust in public agencies is strongly correlated with risk judgements and that social distrust increases the perceived risk. Sjöberg (2001), on the other hand, suggests that there is only a weak relationship between trust and risk perception. Instead, according to this study, people believe that there are many unknown effects of technology and such beliefs are strongly related to their perceived risk.

One may argue that social distrust, like moral indignation, has a larger impact in the railway sector compared to the road traffic sector since people may experience little or no opportunity to affect their situation. There is then an indication that people may perceive railway hazards as worse and consequently favour risk-reducing actions within this area.

### *Equity*

According to Culyer and Wagstaff (1993) and Andersson and Lyttkens (1999), people appear to have concerns regarding equity in health. The distribution of health may also relate to the distribution of safety or risk reducing actions. It is thus possible that individuals will have preferences for reducing the risk for groups that are at high risk, indicating a preference for risk reducing actions within road traffic compared to railway traffic.

### *Size of the accident*

The perception of risk also seems to be dependent on the size of the accident, i.e. whether it is catastrophic. This effect is also frequently named "the scale" of an accident. The public appears to react more strongly to infrequent large losses of life than to frequent small losses, so-called disaster aversion.<sup>5</sup> Some researchers propose a weighting factor that accommodates the greater impact of N lives lost at one time relative to the impact of one life lost in each of N separate incidents. The precise nature of the fatality-weighting factor has been the subject of some speculation and square and cubic functions have been proposed. On the other hand, in Melinek et al. (1973) in which people's attitude towards risks of fires is analysed, no disaster aversion can be detected. In the study, a question is designed to analyse whether the public, on

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<sup>5</sup> Zeckhauser (1996) provides an extensive discussion on the mechanism to prevent or ameliorate catastrophes. In his study liability, insurance and government regulations are considered.



learning of certain number of deaths in a disaster, would be more concerned than if they learned of a similar number in small incidents, the average number annually being the same in each case. The result indicates that people are equally concerned by a single fire causing a large number of deaths and a large number of fires with a single fatality in each incident. Slovic et al. (1984) also conducted an experimental test of catastrophe avoidance and found that subjects chose to minimise average lives lost rather than reduce the risk of a catastrophic accident.

Keeny (1980) argues, however, that people simultaneously hold several conflicting attitudes about the fatality-weighting function. They believe that the function relating the social impact to N lives lost should be 1) convex because large losses of life have important higher order consequences and may even threaten the resilience of a community or society, 2) linear because each unidentified life is equally important and 3) concave because they recognise that the same additional number of lives lost seems more important in a small accident than in one large accident. Keeny argues that in spite of their individual appeal, the three value judgements are mutually incompatible so that a decision-maker that subscribes to one must reject the other two.

Railway accidents happen rarely, but when they do they tend to result in quite severe accidents in terms of the number of people killed or injured. Road accidents, on the other hand, occur on a daily basis with generally a limited number of people involved. Based on the research that indicates that the size of an accident affects our perception of risk, we can thus find preferences for increased risk reductions in the railway area compared to the road traffic area. As was shown, these arguments are not unchallenged though.

### *Socio-economic variables*

Socio-economic variables are not much discussed by the early psychological literature in that the study-design is relatively insensitive to the analysis of group differences. There might be a correlation between risk evaluations and measures of general attitudes, experience of accidents and socio-economic variables such as age, education, and gender. For instance, Greenberg and Schneider (1995) indicate that women are more concerned about environmental risks than men are. Beattie et al. (1998) review studies that analyse whether socio-economic variables influence evaluation of risk. There are results indicating that gender, age, occupational affiliation, and ethnic group membership influence the evaluation of risk. However, there are also studies, e.g. Gardner and Gould (1989) that report very little relationship between socio-economic variables and risk perception. Sjöberg (2001) concludes

that while significant differences can sometimes be found between e.g. gender and risk appraisal, correlations are usually very weak and therefore explain only a very small amount of the variation in perceived risk scores. If any differences can be detected between the groups of people using railway transport compared to road transport, this can, according to the literature, be an indication that risks are perceived differently between the two transport modes.

To sum up, we can find quite a few characteristics of railway hazards, e.g. that they are involuntary and uncontrollable, that they induce high degrees of social distrust and moral indignation and that the accidents are large-sized. These characteristics indicate a preference for reducing risks in the railway sector compared to the road traffic sector. We will now turn to researchers that do not focus on the characteristics of the hazard. Instead, they try to explain how we perceive risks more generally.

## **4.2 Research based on peoples' perception and understanding of risks**

### *Heuristics and over/under assessments*

In Tversky and Kahneman (1974), a number of heuristics (mental short cuts or rules of thumb) which people use in simplifying the task of estimating probabilities are presented. Two heuristics are discussed here, availability and representativeness. The *availability* heuristic has special relevance for risk perception. People who use this heuristic judge an event as likely or frequent if instances of it are easy to imagine or recall. In addition, Fischhoff et al. (1978) found that vivid, imaginable causes of death receive similar estimates to non-vivid ones, which occur with much higher frequency. According to the *representativeness* heuristic people neglect general information and are too impressed by the concrete details of a case at hand. The use of these two heuristics may lead to systematic bias in risk estimation and are thus of special interest.

Furthermore, the standard result in the literature, e.g. in Lichtenstein et al. (1978) and Slovic et al. (1980), has been that people over-assess low probability events and under-assess larger risks, leading to the well-established size-related bias in risk perceptions. Since experimental evidence suggests that a subjectively given probability often differs from the statistical one, i.e. the probability calculated as the number of a certain outcome divided by the number of trials, one might argue that subjective risk perceptions ought to be corrected. There are, however, studies arguing that a perfect risk perception is not identical to the actual risk level but rather reflects the rational use of incomplete information sets. The typical starting point for an analysis of risk perception biases is simply to link perceived population death risks with

actual death risks and to note any systematic difference in this relationship. Instead, Benjamin and Dougal (1997) and Benjamin et al. (2001) make the assumption that it is the set of age-cohort risks that is the principal source of risk information.<sup>6</sup> In their model, it is the rationality with which respondents perceive death risks, based on information on their own age cohort, that is the test of accuracy of risk perceptions. They suggest that risk beliefs may not be erroneous at all. The expressed risk beliefs may rather be the rational expectations of the actual values given the age-specific accident rates facing the respondents' group. People are well informed about the risks they themselves face, but relatively uninformed about aggregated, population-wide fatality rates. Their basic point is that information about accident rates, especially those currently faced by an individual's own age-cohort, is likely to be both more available and more relevant to that individual than population wide averages. Population death frequencies, on the other hand, are unlikely to be known to most people because they are costly to obtain and essentially worthless to know. When viewed from this perspective the relation between perceived risk and true age-specific risk is not significantly different from the statistical correlation between actual population risks and the age-specific risk level.

Hakes and Viscusi (1997) argue furthermore that people form their risk beliefs using two other sources besides the age-specific accident rate. They reanalyse the data of Lichtenstein et al. (1978) using a Bayesian learning approach. According to their study, people also use information on the actual population mean death risk level and the discounted lost life expectancy when founding their risk beliefs. Their conclusion coincides with the result of Benjamin and Dougan in that the appropriate criterion for judging the validity of risk perceptions is not the perfect information case, but rather whether people form their risk beliefs in a rational manner given a world of costly and limited risk information. The authors also suggest that the difficulties people have in making judgements about low probability events stem in part from the limited guidance that the usual sources of information provide to them in their thinking about the level of rare accidents. In a world of costly information, there will be stronger incentives to learn about large risks than small ones.

Since railway accidents are low-probability events with catastrophic potential, people are likely to attach great importance to these events. Railway accidents may then be judged as being more likely than they are. However, people probably do not over assess railway accidents in such a way that these events are judged as being as likely as road accidents. Road

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<sup>6</sup> The study by Benjamin and Dougal (1997) is based on a reanalysis of the data in Lichtenstein et al. (1978), and in Benjamin et al. (2001) new data are collected and analysed.

accidents that happen frequently may, on the other hand, be under assessed. Peoples' tendency to over and under-assess risks, may accordingly lead to smaller differences in the perceived risk of road and railway accidents.

### *Risk aversion and uncertainty aversion*

An important ingredient in the analysis of risk is that of the individual's attitude to risk. Risk loving individuals may prefer to take risks, while risk averts, may prefer to avoid or minimise risk taking. According to the psychometric literature, dread seems to have an important impact on peoples' risk perception. If dread is related to (as described in the psychometric analysis) risk aversion as well, the perception of risk is also related to the degree of risk aversion. Thus, as the amount of dread that a hazard evokes seems to vary depending on the hazard studied, it is likely that peoples' risk attitude varies as well.

Risk aversion is a subject very much discussed in the economic literature within the area of decision under risk, i.e. the expected utility theory.<sup>7</sup> However, over the years, experimental tests of the expected utility theory have shown a violation of the assumptions that the expected utility theory builds upon. One test that has some interesting interpretations is the Allais paradox and the fanning-out hypothesis, Allais (1979). The implication of this hypothesis is that people act as if they become more risk averse when they choose among gambles with increasing probability weights and more-preferred consequences. There is then a systematic relationship between the attitude towards risk and the degree of uncertainty. The hypothesis can also be interpreted as a tendency to exaggerate the probability of extreme outcomes. Applied to our discussion in this chapter on issues influencing peoples' perception of risk and possibly the value of a risk reduction, the fanning out hypothesis suggests that we need to have a better understanding of the nature of peoples' risk aversion. If an individual's perception of risk is correlated with his/her risk aversion, then the risk perception is also correlated with the degree of uncertainty of the outcomes.

For some hazards, the information available is too imprecise to be summarised by a probability measure. As mentioned in chapter 2 this situation is rather described as an uncertainty than a risk. The economic theory describing decisions under uncertainty is called the subjective expected utility theory, e.g. Anscombe and Aumann (1963). Criticism of the subjective expected theory has been concentrated to tests of its axioms. One violation of the subjective expected utility theory is that individuals behave as if they have uncertainty aversion, i.e. they prefer facing risks (or objective probabilities) as opposed to uncertainty,

Ellsberg (1961). Ellsberg showed that people are less willing to bet on the basis of ambiguous probabilities than on point estimates of the same mean value. Hence, the individual would rather draw a ball from the urn with a known proportion of red and black balls, than draw a ball from an urn in which the proportion of red and black balls was unknown. If individuals have uncertainty aversion, they prefer risks to uncertainties. Hazards with unknown probabilistic properties are consequently perceived as worse than hazards with known probabilities. This may in part explain individuals' indifference to some hazards and the extreme worry for others. The aversion may be interpreted as a preference for risk reducing investments in areas with unknown probabilistic properties. Under the assumption that the value of a marginal risk reduction can be calculated for a hazard characterised by uncertainty, the aversion towards uncertainties is likely to be mirrored in the value of risk.<sup>8</sup>

Accidents within the railway sector occur infrequently. One may argue that railway accidents are characterised both by uncertainty regarding the consequences of an accident and by unknown probabilistic properties (i.e. genuine uncertainty) for an accident to happen. Road accidents on the other hand occur on a daily basis and we have good knowledge of both the probability and the outcome of this type of accident. Based on the theory of risk aversion and uncertainty aversion, one may then argue that individuals prefer risk-reducing investments in the railway sector to investments in the road traffic sector.

### *Certainty effects*

Another demonstration of risk aversion is the certainty effect, Kahneman and Tversky (1979). This effect suggests that individuals prefer a given outcome to a gamble even if the expected outcome is the same. The certainty effect can be interpreted as a higher willingness to pay for a complete elimination of risk compared to a reduction of the same magnitude where the resulting risk is not zero. Viscusi et al. (1987) have explored this effect empirically and found indeed a premium for a total reduction in risk.

Large sums are invested in order to increase safety in both the road and railway sectors. Even if the Swedish National Road Administration has launched a long-term vision of a road traffic system in which nobody is killed or sustains lasting impairment, Tingvall (1997), we are far from experiencing a complete elimination of risks in this sector. Furthermore, even though railway transports can be considered safe, zero risk is most unlikely to be achieved.

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<sup>7</sup> An overview of the expected utility theory and its pros and cons are to be found in Machina (1987).

<sup>8</sup> There are obvious and severe methodological problems estimating the value of a risk reduction for an uncertainty since the probabilities by definition cannot be calculated.

According to the research presented in this section, we can again find arguments why people may assess risks within the road and railway areas differently. Heuristics and our tendency to prefer risks to uncertainties seem to be interesting factors of explanation.

### **4.3 Conclusion**

The research suggests that a whole range of social and psychological factors may play a far more significant role in people's perception of risks and their preferences for reductions in those risks than economists have initially assumed. The research helps us identify factors that tend to affect our preferences for risk reductions systematically in one direction or the other. We should, for instance, expect a general trend of higher preferences for safety in those cases where the hazard evokes a particular uncertainty, unease or dread.<sup>9</sup>

Research based on peoples' perception of risk as well as characteristics of hazards seems to indicate that people's preferences for risk reductions vary between road and railway traffic. The question to be asked at this stage is whether individuals' risk perception also reflects the values that should influence public expenditure and/or regulation. As a basis for guiding the allocation of safety resources, the factor space has important limitations according to Beattie et al. (1998). They state that it may be tempting to superimpose some form of expenditure contour map on the Dread/Unknown diagram in such a way that the value of a marginal risk reduction gets progressively higher as one moves from bottom left to top right. There are, however, a number of reasons for doubting whether such an approach would be valid and/or reliable. This view coincides with the work of Gregory and Mendelsohn (1993) and Gregory and Lichtenstein (1994). They state that the risk perception methodology is not an evaluative tool but an approach for identifying public concerns about technologies and lacks a formal evaluative structure. The insights of risk perception have no obvious translations to quantifiable evaluative measures and give little guidance regarding how public concerns should be weighted against other sources of cost and benefits. Consequently, additional factors have to be taken into consideration before we get the overall picture.

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<sup>9</sup> This is shown in e.g. MacDaniels et al. (1992) and Savage (1993). Gregory and Lichtenstein (1994) report higher values of safety when a general description of uncertain, unknown, long-term consequences is added to two otherwise familiar risk scenarios (new bicycle brakes and plastic material in motor vehicles).

## 5. Risk valuation and implications for road and railway traffic

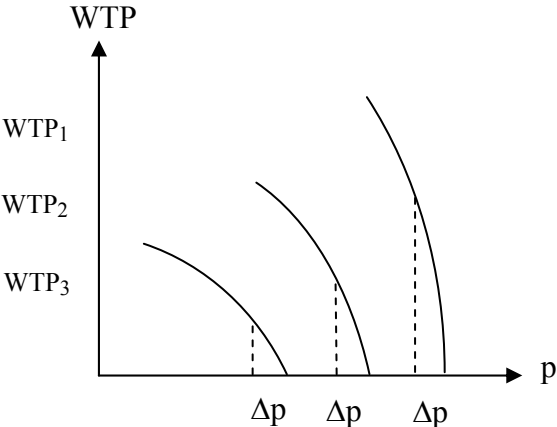
In the previous chapter, we considered factors that affect our perception of risk disregarding the actual risk reduction in order to find arguments why the value of safety may vary between different contexts in general and between the road and railway sectors. We will continue with a discussion on the characteristics of a risk reduction and in what way they possibly affect our preferences and preference-based values of risk reductions.<sup>10</sup> Since we are now discussing risk reductions, we will focus on effects on peoples’ willingness to pay for the risk reduction rather than the effects on peoples’ perception of the risk of concern.<sup>11</sup> We will discuss both hazards in general and in the road and railway context explicitly.

### 5.1 Research based on characteristics of the risk reduction

#### Baseline risk/ratio

The level of baseline risk in the exposed population has also been found to influence people’s valuation of a risk reduction. The typical model of individual’s attitudes towards risk to life suggests that an individual’s willingness to pay (WTP) for a reduction in mortality risk increases with the baseline risk, Hammerton et al. (1982), Jones-Lee (1989). This is illustrated in figure 4. In the figure, the willingness to pay for a risk reduction at a high baseline risk,  $WTP_1$ , is larger than the willingness to pay for a risk reduction at a low baseline risk,  $WTP_3$ , though the size of the risk reduction ( $\Delta p$ ) is the same.

Figure 4. The relationship between individual willingness to pay (WTP) for a risk reduction and the baseline risk (p).



<sup>10</sup> We are here excluding a discussion concerning increases of risk since the value of preventing a fatality is mostly connected to risk reducing activities. It is, however, worth noting that theoretical studies, e.g. Kahneman and Tversky (1979), suggest that there is a difference between peoples’ stated willingness to accept increases in risk and willingness to pay. This has also been shown in empirical studies, reviewed in e.g. Horowitz and McConnell (2002).

A number of empirical studies analysed this subject with mixed results. Smith and Desvousges (1987) studied the value of a reduction in the risk of premature death due to hazardous waste exposures and they could reject the conventional hypothesis that people prefer reductions in risk where baseline risk is higher. Instead, their findings suggest that the estimated marginal valuation of a risk change decreases with increases in the level of risk. Weinstein et al. (1980), on the other hand, show that the marginal valuation of risk changes increases with the baseline level. This study offers an intuitive reason why changes in risk are valued more at higher levels of probability: because marginal assets are valued more highly in life than in death.

Also in Covey (2001), the program targeted at the higher baseline number of deaths was evaluated as more beneficial than the program that offered the larger proportional reduction. The study discusses the possibility that the factor influencing peoples' evaluations of risk reduction efforts is not the baseline risk *per se*. Favouring the program with high baseline risk, respondents seemed to perceive that they would benefit more from a safety program that targeted a higher baseline risk, than from a program that addressed an area with lower baseline risk. The situation occurred even though the nominal risk reduction was the same. A higher number of deaths was then seen as an indicator that more lives would be saved, and/or more people were at risk, and/or more people would benefit. Covey concludes that the number of deaths matters, although not always for reasons strictly consistent with the conventional hypothesis.

This is also the result obtained by Horowitz and Carson (1993). Their study presents a situation where subjects do prefer to reduce environmental risks for which the baseline is higher, though for altruistic reasons. The authors argue that there is a baseline effect since the subjects believe that more people can be saved by risk reduction efforts when risks are higher. In Van Houtven (1997), individuals were asked to state their preference for equally costly life-saving programs that would only affect others' level of risk. Controlling for the number of lives saved, the individuals preferred programs that affected smaller populations facing higher levels of baseline risk. According to this study, increases in baseline risk of one order of magnitude doubled the value of death avoided.

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<sup>11</sup> Problems connected with the elicitation methods as such will not be considered.



According to Jenni and Loewenstein (1997) people value a reduction from a higher baseline risk more, but on the other hand evaluate effectiveness by whichever intervention offers the bigger ratio reduction in risk. There are consequently some indications, e.g. in Gyrd-Hansen et al. (2002), that people prefer interventions in which a bigger ratio of the lives at risk can be saved even though the number of lives saved may be the same. This means that they are willing to pay more to save 900 lives from a disease causing 1,000 deaths per year than to save the same number of lives from a disease causing 10,000 deaths per year. This diminished sensitivity to valuing life-saving interventions against a background of an increasing number of lives at risk is coined “psychophysical numbing” by Fetherstonhaugh et al. (1997). In their study an intervention saving a fixed number of lives was judged significantly more beneficial when fewer lives were at risk overall. The authors suggest that the human cognitive and perceptual system is sensitised to small changes in our environment, possibly at the expense of making us less able to detect and respond to large changes. This argument is also in line with the certainty effect discussed in chapter 5.2 indicating that we have preferences for eliminating risks.<sup>12</sup>

Even though the results are mixed, a majority of studies suggest that an individual’s valuation of a risk reduction increases with the baseline level of risk, indicating that the value of a risk reduction estimated for a low risk level is not necessarily the same as the value estimated for a high risk-level. Consequently, when studying the value of a risk reduction for road and railway traffic, the value may differ due to differences in the baseline risk. To what extent can the risk level for different contexts be considered to vary and still be alike? For instance, Mattson (2000) argues that the risk of dying or being injured in road traffic, aviation and in major parts of the labour market is in general very small and almost alike. The same value of a marginal risk reduction should therefore be used in the appraisal of investment projects in these areas.

Risk perception data show that train travel is generally perceived as safer than road traffic.<sup>13</sup> In Fischhoff et al. (1978) respondents were asked to rank 30 different hazards with respect to perceived risk and benefit. Road traffic was ranked as the second most risky activity and railway traffic was ranked as 24. Alhakami and Slovic (1994) show that among

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<sup>12</sup> Another way of describing this tendency is that we have preferences for “topping up the bucket” rather than “filling the bottom”.

<sup>13</sup> According to Blomquist (2001), studies estimating the value of a risk reduction should be based on the risk level perceived by the affected individuals. In comparison with objective data the railway risk is somewhat underestimated, e.g. in Slovic et al. (1980). The average risk in road traffic is, on the other hand, often more or less correctly estimated when people are asked. However, when asked about their own personal risk the majority

40 technologies, motor vehicles were ranked as fifteenth most risky and railways as number 32. In Slovic et al. (1980) railways were ranked 61 of 90 activities studied. Motor vehicles were perceived as more risky, ranked as number 17. Also based on objective data from the Swedish National Rail Administration (2000), railway traffic may be regarded as being safer than road traffic. The average number of persons being killed per year in the railway sector is 15 whereas 600 persons on average are killed per year in the road sector. There is also a difference in risk when calculated per number of fatalities per kilometres travelled. The average risk level for railway passengers is 0.17 fatalities per billion kilometres travelled compared with 4.5 fatalities per billion kilometres travelled for a road user.

As was illustrated in figure 4 economic theory suggests that an individual's willingness to pay for a reduction in mortality risk increases with the baseline risk, Hammerton et al. (1982), Jones-Lee (1989). The value of a marginal risk reduction based on individual preferences in the railway area may therefore be lower than the value of risk used for road investments. This difference in the value of safety is, however, based on the assumption that the same magnitude of the absolute reduction in risk is studied. Since there are differences in the baseline risks of railway and road traffic, we are not likely to find safety projects that reduce the risk to the same magnitude. Furthermore, although the relative risk reduction is the same (e.g. 20 % risk reduction), the absolute reduction in risk, i.e. the actual number of deaths and injuries avoided, may differ since the baseline risk in the railway sector is lower than in the road sector.

#### *Size of the risk reduction*

Standard economic theory predicts that there is a diminishing utility of a reduction in risk, Hammerton et al. (1982), Jones-Lee (1989). Although the willingness to pay increases for increased risk reduction, the marginal willingness to pay per unit of risk decreases,  $\frac{WTP_2}{\Delta p_2} < \frac{WTP_1}{\Delta p_1}$  in figure 5. Empirical studies do suggest such a relationship, e.g. Viscusi et al. (1987) and Persson et al. (2001).

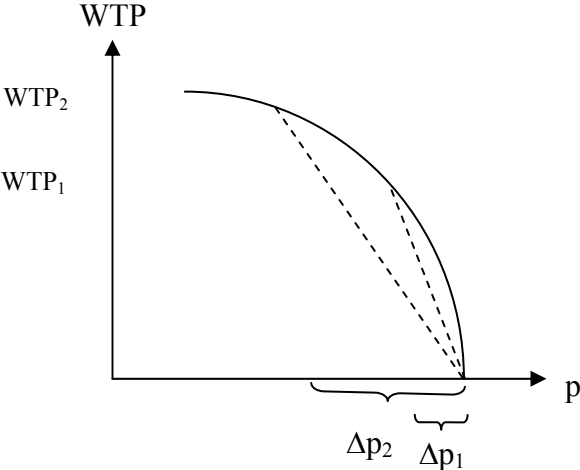
This indicates that the size of a risk reduction resulting from a road or railway investment is of interest. Since the baseline risk is many times smaller for a person travelling by train than by car, the traffic safety investment is likely to have a larger risk reducing effect in the road traffic area than in the railway area. This situation consequently indicates a higher willingness

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state that their risk is lower than the average. Thus, the personal risk is underestimated; see e.g. Svensson (1981) and Sjöberg (1991).

to pay per risk reduction in the railway area due to the diminishing utility of a reduction in risk.

Figure 5. The relationship between individual willingness to pay (WTP) and marginal changes in risk ( $\Delta p$ ).



*Private or public safety actions*

The psychometric literature pays relatively little attention to the distinction between risks affecting one’s own person and risks affecting other people as well, a distinction that is fundamental according to Sjöberg (1991). Sjöberg concludes that just asking people to rate a risk without specifying to whom the risk pertains is an unfortunate practice since risks are perceived in a different manner depending on to whom they pertain. For instance, Gyrd-Hansen et al. (2002) studied whether the effect of the baseline risk is different when respondents are faced with own risk profiles as opposed to general risk profiles for groups of the public. The study indeed found a difference in that people preferred a risk reduction in the area with lower baseline risk when the risk was expressed as an individual risk, and that they preferred a risk reduction in the area with higher baseline risk when the risk was expressed as a general risk.

Discussing the value of a marginal reduction in risk, there may be an important difference between a risk reduction achieved by an investment in private safety arrangements and a risk reduction achieved by a public safety project. At the beginning of chapter 3 we defined the value of a statistical life as the population mean of the marginal rate of substitution of wealth for probability of death over the affected population of individuals, Jones-Lee (1989). The definition is based on the assumption that people are concerned solely for their own safety. Beattie et al. (1998), however, states that an individual’s willingness to pay for a public safety project may not only reflect the value of the personal reduction in the

risk of death, but also the value they may place upon other considerations such as the reductions in the risk to other people (altruism) and the equality of the distribution of those reductions. Altruism has its origin in the fact that besides an individual's willingness to pay for his/her own safety, many people may also be concerned, and therefore presumably willing to pay, for improvements in the safety of others. It has therefore been argued that the value of a statistical life should be augmented by a sum reflecting this additional willingness to pay. However, Bergstrom (1982) and Jones-Lee (1992) showed that inclusion of such a component is appropriate if and only if altruism is exclusively safety-focused and other dimensions of welfare are ignored. This means that safety is the only aspect of a person's well being that is of concern for another individual. On the other hand, if people's concern for others' well being relates to any aspects of quality of life, i.e. a pure form of altruism, it is not appropriate to include additional willingness to pay for others' safety when estimating values of safety. The intuition behind this result is that the pure altruist values both benefits and costs that accrue to others. At the margin, a person's concern for other people's safety will be precisely balanced by his concern for the reduction in their consumption that will be required to finance the extra safety by public funds. Adding values of others' safety to peoples' willingness to pay for their own safety would result in an overvaluation of safety relative to other determinates of their utility. Jones-Lee (1989) concludes that in the end it appears that the legitimacy of augmenting the value of a statistical life to reflect concern for other people's well being depends on the precise form that this concern takes. Studies estimating the value of a statistical life have reported a willingness to pay for a public safety project that exceeds the willingness to pay for a private safety device, e.g. Jones-Lee et al. (1985), Viscusi et al. (1988) and Strand (2002). Strand consequently states that the elicitation of the value of a marginal risk reduction as a purely private good may then be misleading in public policy contexts where mortality risk reduction is usually of the public good kind. In Johannesson et al. (1996), however, the estimate of the willingness to pay for a private safety device is higher than the willingness to pay for a public safety program.

In both the road and railway areas, investments are made in public safety projects and, in this respect, there are no differences between the traffic modes. However, when studying private safety arrangements there are several within the road sector, for instance airbags and different types of tyres and vehicles whereas within the railway sector there are no personal safety arrangements at all. Hence, if there is a difference between the individual willingness to pay for private and public safety arrangements, it is important to consider the type of safety investment of concern.

## **5.2 Conclusion**

Research suggest that the individual willingness to pay for a risk reduction may vary depending on baseline risk, size of the risk reduction and whether we are discussing private or public safety investments. The characteristics discussed indicate no clear-cut evidence of whether risk reductions in the railway area are preferred to reductions in the road traffic area. The summed result of the research presented may go either way. Differences in the baseline risk favour risk reductions in road traffic. (Here we are assuming the same magnitude of risk reduction in different transport areas, which can be questioned though.) Different sizes of the risk reduction favour risk reductions in the railway area and, if we are only discussing public safety arrangements in both transport areas, no differences can be found.

According to the previous chapter, there are indications that people prefer risk-reducing investments in the railway sector to investments in the road sector and in the view of chapter 4 and 5, altogether, there seems to be more indications suggesting that the value of safety is higher for railway traffic than for road traffic than vice versa.

## **5.3 Adjusting preferences?**

When applying preference elicitation methods an implicit assumption is made that peoples' decisions are a true reflection of their preferences. The individuals are also assumed to have access to well-formed preferences and that they are able to form such preferences based on information they either have or is given out to them. However, research into risk perception raises the question of whether people can make accurate judgements about risks or whether there are systematic biases in their evaluation.

What if the theory is not supported by empirical results and what if preferences do not accord with rational behavior? According to the studies reviewed here there may be substantial inconsistencies in the way people view risks due to the presence of heuristics, psychological numbing, preferences for eliminating risks, risk aversion, etc. One finding suggests that preferences for relative risk reductions rule over preferences for absolute risk reductions. This result indicates that people go after the small problems, not optimizing life expectancy. In Slovic et al. (1980), the risk judgements of non-professionals were only moderately related to annual death rates. Accordingly, public fears appear to be driven by perceptions of the worst possible outcome rather than by any assessment of the expected number of deaths. Is this acceptable? If not, can we draw a line between acceptable and unacceptable preferences?

Beattie et al. (1998) argue that if people rank the importance of the risks of various activities in a different order from their ranking of the frequencies of fatalities, this cannot be attributed to a lack of information or awareness concerning those relative frequencies. This in turn suggests that the notion of risk means something more to people than just expected fatalities. Furthermore, Beattie et al. state that public perceptions matter. Public judgments should, however, not be the only input to decisions regarding valuation and regulation of health and safety. According to the authors there are clearly cases when the public is likely to be error prone or biased. Psychological theory can then be used to predict such cases. Beattie et al. also suggest that, e.g. group discussions, varying elicitation techniques and decision structuring may serve as tools for debiasing the judgments.

Peoples' limited ability to make accurate judgements about risks is a problem irrespective of elicitation method, i.e. the stated preference or the revealed preference approach. If there is a disparity in the level of risk assessed by the affected individuals and the objective risk level, the estimate of the value of a statistical life can be adjusted. If the individual risk estimate is known to be 20% lower than the expert judgement of risk, the value of a marginal risk reduction can then be recalculated based on the lower risk. For instance, Miller (1990) scaled the estimates with the ratio of perceived to actual risk levels based on the work of Slovic et al. (1980), obtaining the values of a statistical life implied by the perceived risk.<sup>14</sup>

Is this the way to go? One point of view may be yes, if people are given obviously biased information and/or have no ability to assess the information correctly, leading to inconsistencies and anomalies, and no, if individuals' risk assessment is based on fairly objective information, have reasonably stable and well-defined preferences and consider other attributes than probability and size of loss. This point of view is perhaps easy to put but less easy to decide upon. Even if we could adjust the estimated values, we have no assurance that expert judgements are immune to biases, and in many cases effective risk management requires the co-operation of a large body of non-experts. One problem lies in how people deal with very small probabilities. For high frequency cases where the outcome is well defined, the accuracy of individuals' judgements can be explored by relating the subjective probability for an event predicted by the individual to the actual outcome frequency. However, in many cases objective measures of the risks of technologies, against which the accuracy and rationality of public perceptions can be judged, do not exist. Especially for novel technologies, true risks

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<sup>14</sup> However, Miller (1990) was criticised due to the relatively limited study that it relied on in order to estimate the risk misperception ratios. In Miller (2000), unadjusted values were presented.

must be predicted not with historical statistics but by using complex analytic techniques such as fault-tree analyses, which usually require subjective or intuitive judgements on the part of the experts performing them. This means that all risk perceptions are subjective, since even expert estimates involve some amount of judgement, Sjöberg (1991).

Blomquist (2001) suggests that future projects should be encouraged to combine analysis of the risk perception associated with the activity of concern with the basic study estimating the value of a statistical life. Yet, Blomquist stresses that the risk level of interest is the one the individuals base their behaviour and trade-offs upon. If the objective is to estimate people's willingness to pay for a risk reduction, it is then the value of a statistical life implied by the perceived risk that should be estimated

A short remark may be that we should be careful in what we conclude from preference elicitation methods and choice behavior. Further effort should be made in order to give a better understanding of underlying motivations to ensure that we are indeed eliciting individual preferences for risk reductions.

## **6. Values of safety empirically estimated for road and railway traffic**

### **6.1 Values of safety empirically estimated for road traffic relative to other contexts**

A number of studies estimate the relative value of a risk reduction, the majority including road traffic but excluding railway traffic. There is nevertheless an interest in discussing these studies since they give an *indication* of whether the value of a risk reduction is likely to vary between road and railway traffic.

Mendeloff and Kaplan (1990) found up to approximately twice a difference in the relative valuation of the benefits of preventing a given number of deaths in different contexts. 8 prevention programs were studied, each addressed to a different hazard, e.g. bicycle and automobile accidents and fatal crib-slat accidents to young children. The authors argue that although research does not support very large differences in spending per death prevented, it also indicates that not all deaths are valued equally.

MacDaniels et al. (1992) studied both familiar and well-defined hazards, such as automobile and aviation accidents and less familiar and more poorly understood hazards, such as nuclear power and electromagnetic fields. Comparing the mean value of the willingness to pay for a reduction in the numbers of deaths in automobile accidents, the willingness to pay for a reduction in the risk of death in commercial aviation was 7 times lower and for hazardous chemical waste 5 times lower. In turn, Savage (1993) found differences in the

mean willingness to pay to reduce risks of road and aviation accidents, domestic fires and stomach cancer. The willingness to pay was significantly affected by various psychological factors including perceptions of death and unknown attributes of the hazard concerned. The study concludes that people are willing to pay significantly more to contribute to lowering the risks of cancer than they are willing to contribute to lowering the risks posed by automobile accidents, home fires and aviation. The indication is that the implied underlying valuations of life vary across the hazards. The estimated value of life for automobile accidents was 5% higher than that for aviation accidents and 3% higher than that for fires in the home.

The issue in Subramanian and Cropper (2000) is whether observed disparities in cost-per-life saved reflect public preferences for environmental and public health programs. Environmental regulations often have much higher costs than other health and safety programs, which implies that the marginal social utility of saving a life via an environmental program may be higher than the marginal social utility of saving a life through other health and safety programs. The study analyses the public choices between life saving programs. Respondents were confronted with pairs of saving programs that differed in number of lives saved and asked which program in each pair they would choose to implement. Each pair consisted of one public health program and one environmental health program. The latter included programs for reducing air pollution from automobiles and factories, drinking water treatment, regulations to limit pesticide residues in food and workplace smoking. The public health programs included colon cancer screening, smoking education and pneumonia vaccinations as well as regulations requiring passenger side airbags and radon tests in homes. Subramanian and Cropper suggest that the great majority of people do not favour rates of trade-off between preventing deaths from different hazards that are dramatically different from 1:1. The study concludes that while people's priorities are indeed sensitive to the combined influence of the number of deaths, the psychological characteristics of hazards and social amplification effects following a major accident in practice, it is the number of deaths that appears to dominate the quantitative judgements people give.

The findings suggest that there is no significant disparity in the value of a statistical life based on individuals' risk reducing preferences for a variety of hazards, which indicates that we are not likely to find differences within one and the same area, e.g. the transport area.



## **6.2 Values of safety empirically estimated for railway traffic relative to road traffic**

Due to the comparatively low baseline risk in the railway context, a direct estimation of the value of a marginal risk reduction is problematic and prone to error, Jones-Lee and Loomes (1995). As preference-based values of a statistical life are estimated by dividing the reported willingness to pay for a given risk reduction by the risk reduction itself, even small errors in the responses will escalate to unacceptable error bands if the risk reduction of concern is minuscule. This is inevitably the case if the baseline risk is very small, as in the case of the railway sector. Therefore, a relative valuation method is often used. Based on this “relative method” a premium is estimated for a railway fatality relative to a road fatality. The value of preventing a railway fatality can then be calculated by applying the premia to the value of preventing a road fatality.

Jones-Lee and Loomes (1995) studied the value of a statistical life for the Underground in London compared to the value of a statistical life for road traffic. Their study showed a clear context premium in relation to road safety. There was, however, no evidence in favour of a significant positive scale premium. The premium appeared to derive entirely from considerations of control, voluntariness, and responsibility and owed nothing to the possibility of large-scale catastrophic accidents on modes such as the Underground. The arithmetic mean scale and context premium that emerged from the study pointed towards a willingness to pay based value of statistical life for Underground safety risks that was some 50 % larger than its road counterpart was. This figure was thereafter revised to about 18 % due to new methods for aggregating the results, Jones-Lee (2001).

Chilton et al. (2002) present the results of two studies carried out in the UK that analyse the relative valuation of safety in railway transports and fire safety (domestic and in public places) compared to the value of road traffic safety. The first of the two studies was carried out in autumn 1998. The second study was carried out in early 2000 in the aftermath of a major rail accident at Ladbroke Grove near London’s Paddington station in which 29 passengers and 2 train-drivers died. In the first relativities study the responses were such as to entail discounts for the value of a statistical life relative to the figure for roads in all the studied contexts. Consequently, railway safety was given a lower priority than road safety. The figure estimated for railways was 80% of the value for roads. One explanation is that the sample did not contain a representative proportion of rail users. In the second relativities study, called a follow-up study, the proportion of regular rail users was increased and a major rail accident had recently occurred. The result also indicated, as one might expect, a rise in the concern for railway safety. However, the safety preferences did not change dramatically.

Instead, the relative value of railway safety was fairly close to one for the sample as a whole, and a premium of about 16 % for preventing a rail fatality relative to the road figure for those who were regular rail users. According to the authors, this result contradicts the current safety investment policy in the UK and elsewhere which often accords a significantly greater premium to activities such as rail travel. However, one problem discussed in the article is that the contexts studied can be regarded as being spread over a rather limited area of the psychological characteristic space. It may be that risks with rather different features show larger trade-off differentials.

Bäckman (2002) builds upon the two studies presented in Chilton et al. (2002). However, in this case the study is carried out for Swedish conditions. Three hazard contexts were studied, railway risks, underground risks and risks from fires. The reference point in the comparisons was road risks. On the average for the whole sample, only a small premium of 2-3 % favouring rail and underground relative to road could be detected. Safety measures aiming at preventing small-scale accidents received a higher value than safety measures aiming at preventing large-scale accidents. When studying the values of the individuals using public transports frequently, a premium of around 10-15 % was found for railway and underground safety. Bäckman consequently concluded that “there is no support in the public’s preferences for valuing railway, metro or fire safety at two, three or four times the value of road safety, as is currently the practice”, (p. 142).

The result of the studies estimating the relative value of a marginal risk reduction within the railway context compared to the road traffic context coincide with the result of the empirical reports previously presented in that there is only a limited difference. The findings do not correspond to the use of a value of a statistical life in the railway sector many times larger than in the road sector.

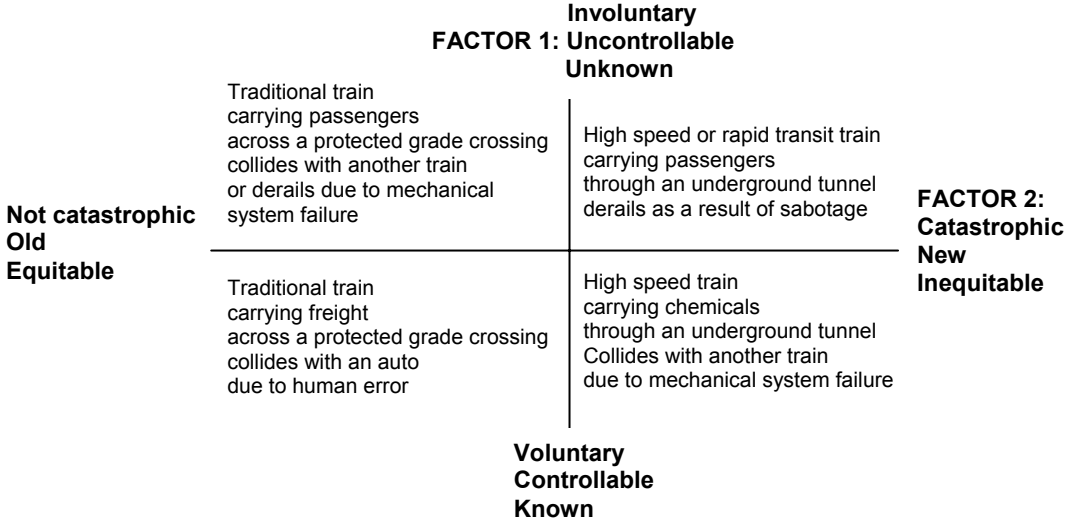
## 7. Diversity of road and railway accidents

This overview has so far concentrated on differences in the value of preventing a fatality in the railway context compared to the road context. Having discussed possible differences between different traffic modes, one may also discuss whether different hazards can be perceived differently when focusing solely on one transport mode. Research indicates that the variation within the context of one traffic mode may be as large as, or even larger than, the variation between transport contexts.

In some psychometric studies, e.g. in Fischhoff et al. (1978) and Slovic et al. (1980), comparisons are made of large hazard sets containing items as diverse as bicycles and nuclear power plants. The activities/technologies studied in the factor space concern some kind of an average hazard, which means that important implications may be left out. There may be considerable differences in aspects and characteristics of a hazard depending on e.g. location, type of accident, and time of day. Consequently, there may be differences in individuals' risk perception depending on the specific hazard studied. In Fischhoff et al. (1978) and Slovic et al. (1980), railways and motor vehicles were also studied disregarding the fact that not all road and railway accidents are alike. They may for instance differ with respect to type of train or vehicle involved, the potential type and cause of the accident, the nature of the consequences in the event of a mishap and so on.

Kraus and Slovic (1988) argue that railway accidents are really quite diverse, with some approaching nuclear reactors in their perceived seriousness. In their study, 49 railway accident scenarios are constructed. Each scenario is made up of the following components: type of train involved (traditional train, high speed train or urban rapid-transit system); type of cargo (passengers, benign freight or explosive chemicals); location of the train at the time of the accident (underground tunnel, underwater tunnel, on a bridge, in a city, in the mountains, on a protected grade crossing or on an unprotected grade crossing); type of accident (two-train crash, train-car crash, derailment or fire); and the cause of the accident (sabotage, mechanical failure, human error, earthquake or rock slide). The railway space is well represented by two factors in which knowledge and catastrophic potential play a defining role. The higher an accident score in catastrophic potential (the further to the right it appears in the space) the higher its perceived risk and the more people want to see the risk reduced. Figure 2 is derived from Kraus and Slovic and shows a "representative" railroad accident from each quadrant.

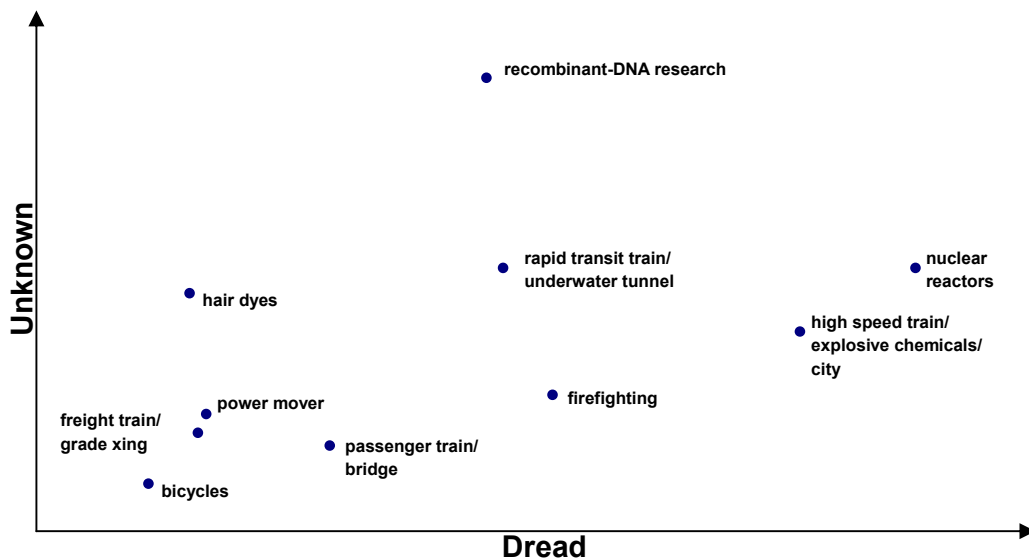
Figure 2. Two-dimensional factor space with representative railway accidents, Kraus and Slovic (1988, p. 451). Reprinted with permission from the Society for Risk Analysis.



In e.g. Slovic et al. (1980), the dread component was categorised as the most important factor in the factor space. In Kraus and Slovic, however, the dread component had little impact on determining the structure of the data. Furthermore, newness replaced involuntary and vice versa. As a result, catastrophic potential and newness were loaded on the same factor. The accidents perceived as both new and potentially catastrophic all involved trains with explosive chemicals as their cargo. Control too loaded differently in this study, relating more to the knowledge dimension than to the risk-size dimension. Again, this relationship may be a function of the specific set of accidents being considered. Uncontrollability and lack of knowledge characterise quite appropriately the nature of threats from hazards involving sabotage and earthquakes.

In Kraus and Slovic the respondents were also asked to rate the risks of several railroad accidents embedded in a diverse set of non-railroad accidents. This was done to calibrate different types of railroad hazards in relation to other hazards. Four railway scenarios were analysed. 1) A high-speed train carrying explosive chemicals in a city. 2) A rapid-transit train carrying passengers through an underwater tunnel. 3) A traditional train carrying freight over a protected grade crossing. 4) A traditional train carrying passengers over a bridge. The other accidents were nuclear reactors, fire fighting, power lawn mower, hair dyers, bicycles and recombinant-DNA research. Figure 3 is derived from Kraus and Slovic (1988) and shows the relationship between railway accidents and non-railway accidents.

Figure 3. Railway accidents and other non-railway accidents. Figure redrawn from Kraus and Slovic (1988, p. 453). Reprinted with permission from the Society for Risk Analysis.



According to Kraus and Slovic, accidents involving a traditional train carrying freight over a protected grade crossing or a traditional train carrying passengers over a bridge are much like the general railway point in Slovic et al. (1980). In contrast, an accident involving a high-speed train carrying explosive chemicals near a city is perceived to be much more like accidents associated with nuclear reactors than other railway accidents. The results of this study indicate that even though there is no larger variation in the risk preferences of the public when general accidents of different transport modes are studied, there might be substantial variation in the perception of risk when studying a single traffic mode depending on the attributes and circumstances of the hazard. An interesting conclusion drawn from Kraus and Slovic is that the railway accidents are spread over the factor space in much the same manner as in Slovic et al. (1980) when 90 different technologies were studied.

The discussion concerning the diversity of hazards connected with one transport mode focuses on railway accidents simply because no other research has been found. It is likely though that a similar discussion can be applied to other areas, e.g. the road traffic context.

The above stresses the importance of taking the characteristics and circumstances of the hazard of concern into consideration. Based on the assumption that peoples' risk perception affects their willingness to pay for safety, one universal value of preventing a fatality is unlikely to be found. Kraus and Slovic, suggests that even if only small differences can be found in the estimated values of safety for different contexts, there are indications that the value of safety may vary for different hazards *within* the same context.

## 8. Concluding remarks

This study concentrated on possible differences in the value of railway and road safety. The discussion has mainly been carried out by economists but there is now an increasing understanding that other disciplines have to be considered in order to understand what individuals respond to, how risk beliefs are formed etc. The literature includes inputs from e.g. psychology, sociology, decision theory, economics, and policy studies.

Legislated safety standards within the railway sector imply that the value of prevention of a rail fatality greatly exceeds its road counterpart. This disparity is also supported by the literature on people's risk perception. Psychologists have provided extensive evidence indicating that the public's perceptions of, and attitudes to, risk may vary substantially over different hazards. This indicates that some risks are perceived as being more dreadful than others. Besides the psychometric literature, a number of other issues are discussed that suggest the use of difference values of a marginal risk reduction for different circumstances. Consequently, an individual's preferences for safety investments may differ from one transport mode to another. Based on the research presented we can find arguments for the use of a higher value of preventing a fatality within the railway sector than in the road traffic sector.

When preference-based values of marginal risk reductions have been estimated empirically within the railway and road context, some disparities have indeed been shown. The size of the calculated disparity is, however, not in the same range as the disparity that can be observed when studying safety levels. This can be interpreted in two ways. If we believe that the elicitation method used is correct and the estimated values of preventing a rail fatality are unbiased and consistent, this in its turn suggests that the value of preventing a rail fatality, implied by e.g. legislated safety levels, is grossly overestimated. The use of such a value will furthermore lead to a misallocation of resources that in the end may lead to premature deaths that otherwise would have been avoided. An important task is then to call attention to this problem and to support an alteration of the safety policy, see Jones-Lee (2002). If we, on the other hand, believe that the values implied by safety standards etc, do reflect individual preferences, we then have a methodological problem of trying to find better methods to estimate preference-based values of safety. Different approaches are discussed in for instance Beattie et al. (1998). The crucial point is whether we believe in estimated values of a marginal risk reduction or not. More empirical studies have to be carried out in order to constitute data for decision-making, and further research is needed.

Furthermore, the findings indicate that, for each transport context, there ought to be an interest in studying different accidents types since there may be a substantial variation in the value of a marginal risk reduction between a general accident and, for instance, an accident involving hazardous goods. This type of study has not yet been conducted and the subject deserves a further exploration in the future.

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