

## Tema Miljörisker – miljörisker och trafikanters beteenden

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## Förord

Detta notat är en sammanställning av resultat från projektet Tema Miljörisker. Mer specifikt handlade projektet om att undersöka hur transportrelaterade miljörisker påverkar olika trafikantgruppers beteende och hur beteendet påverkar miljön. Tema-projektet syftade till att förbereda tvärvetenskaplig forskning om miljörisker på VTI. Projektet delades in i tre delstudier. Delprojekt 1 handlade om att sammanställa litteratur om transportrelaterade miljörisker utifrån psykologiska och ekonomiska perspektiv och i delprojekt 2 planerades en betalningsviljestudie där både ekonomiska och psykologiska utgångspunkter beaktades. I dessa delprojekt medverkade Louise Eriksson, VTI, och Lena Nerhagen, VTI. Delprojekt 3 bestod av att planera för en simulatorstudie med fokus på att studera miljöeffekter av körning under kontrollerade former i körsimulatore. I delprojektet deltog Anne Bolling, Jonas Jansson, Mattias Hjort, Lena Nilsson, Mats Gustafsson, Göran Blomqvist och Bo O Karlsson, samtliga VTI. Temaprojektet genomfördes huvudsakligen under 2009.

Notatet består av två delar. I del 1 redovisas resultaten från litteratursammanställningen och förslag på betalningsviljestudie (delprojekt 1 och 2). Denna sammanställning är skriven på engelska. Del 2 innehåller en projektbeskrivning för en simulatorstudie i form av en forskningsansökan (delprojekt 3). Denna sammanställning är skriven på svenska.

## Foreword

This report compiles the results from the project Tema Environmental risks. More specifically, the project concerned how different transport related environmental risks influence different road users and how their behaviours influence the environment. The project aimed at preparing for interdisciplinary research about environmental risks at VTI. The project was divided into three parts. The first subproject aimed at compiling literature about transport related environmental risks from psychological and economic perspectives, and in the second subproject a willingness to pay study was outlined where both economic and psychological principles were considered. In these projects, Louise Eriksson and Lena Nerhagen participated. In the third subproject, a simulator study was outlined. The focus was to study environmental effects of driving under controlled circumstances in the driving simulator. The participants in this project were Anne Bolling, Jonas Jansson, Mattias Hjort, Lena Nilsson, Mats Gustafsson, Göran Blomqvist and Bo O Karlsson. The whole project was mainly carried out during the year 2009.

The report is divided into two parts. In part 1, the results from the literature review and the proposal for a willingness to pay study are described (subproject 1 and 2). This part is written in English. Part 2 contains a project outline for a simulator study in the form of an research project application (project 3). This part is written in Swedish.

Linköping Februari 2011

*Louise Eriksson*

## Kvalitetsgranskning

Intern peer review har genomförts under maj–juni 2010 av Gunnar Isacsson (del 1) och Christopher Patten (del 2). Louise Eriksson, Lena Nerhagen och Anne Bolling har genomfört justeringar av slutligt rapportmanus. Projektledarens närmaste chef Tomas Svensson, VTI, har därefter granskat och godkänt publikationen för publicering 2011-03-03.

## Quality review

Internal peer review was performed on May–June 2010 by Gunnar Isacsson (part 1) and Christopher Patten (part 2). Louise Eriksson, Lena Nerhagen and Anne Bolling have made alterations to the final manuscript of the report. The research director of the project manager Tomas Svensson, VTI, examined and approved the report for publication on 3 March 2011.

## Innehållsförteckning

Sammanfattning .....	5
Summary .....	7
DEL 1 Economic and psychological perspectives on environmental risks associated with private transportation. A literature review and suggestions for further research .....	9
1 Introduction .....	11
2 Economic theory and environmental risks .....	13
2.1 Economic theory, valuation and policy .....	13
2.2 Economic valuation of environmental risk .....	15
2.3 Concluding remarks .....	18
3 Psychological perspectives on environmental risks .....	19
3.1 Research on risk perception .....	19
3.2 Research on pro-environmental attitudes and behaviours .....	23
3.3 Concluding remarks .....	27
4 Discussion .....	28
5 Integrated research – a questionnaire example .....	30
References .....	32
Appendix .....	
DEL 2 Planering av en simulatorstudie .....	46
1 Bakgrund .....	49
2 Syfte och mål .....	50
3 Projektförslag .....	51
3.1 Implementering av modeller .....	51
3.2 Simulatorförsök .....	51
3.3 Resurser och tidplan .....	53
3.4 Seminarier och workshop .....	54
3.5 Resultat från projektet .....	54
4 Nyttan med bränsleförbruknings-, emissions- och slitagemodeller i körsimulator .....	55
5 Utveckling av forskningsområde .....	56
Referenser .....	57



## **Tema Miljörisker – miljörisker och trafikanters beteenden**

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### **Sammanfattning**

Detta notat behandlar miljörisker relaterat till transporter och är uppdelad i två delar. Del 1 (skriven på engelska) handlar om föreställningar, val och beteenden relaterade till miljörisker utifrån nationalekonomiska och psykologiska perspektiv. Del 2 (skriven på svenska) beskriver en simulatorstudie av relationen mellan förarens beteenden och miljörisker i form av en forskningsansökan.

Del 1. När transportåtgärder utformas är det viktigt att förstå hur individer uppfattar miljörisker och vad individer är villiga att göra för att minska dessa miljörisker. Två forskningsområden där man traditionellt fokuserat på risker, riskperception och beteenden är nationalekonomi och psykologi. I denna uppsats beskrivs en litteraturgenomgång av ekonomiska och psykologiska modeller av riskperception. Dessutom beskrivs planer för en enkätundersökning där psykologiska teorier används för att öka förståelsen för val i stated preferencestudier. Genomgången av ekonomisk litteratur visar att individer ibland avviker från rational choicemodellen (t.ex. en ökning av risken gör inte nödvändigtvis att viljan att betala ökar för att minska risken) och det finns invändningar gentemot möjligheterna att kunna studera vad individer verkligen skulle göra (i kontrast mot vad de bara säger att de skulle göra) (dvs. problemet med hypotetisk bias). Psykologiska teorier och forskning visar på möjliga orsaker till varför en hög riskuppfattning inte alltid realiserar i miljövänliga beteenden. Till exempel finns det stöd för att även om en individ känner till att det finns miljöproblem relaterat till bilanvändning kan han eller hon behöva planera för en minskning av bilanvändningen innan en förändring genomförs. Det finns därmed stöd för att relationen mellan riskperception och beteende kan vara indirekt. Baserat på slutsatserna av litteraturgenomgången beskrivs ett förslag på fortsatt forskning där viljan att betala för ny teknik som minskar utsläpp från bilen studeras. Syftet med den föreslagna studien är att undersöka ifall psykologiska teorier kan bidra till att avslöja graden av hypotetisk bias i denna valkontext.

Del 2. Delprojektets mål och syfte är att undersöka förutsättningarna för att genomföra miljörelaterade forskningsförsök i VTI:s körsimulatorer samt att ge förslag på ett sådant projekt. Förutsättningarna och möjligheterna att i en virtuell miljö studera miljörelaterade effekter av olika faktorer är mycket goda. Aktuella faktorer kan härröra från föraren, fordonet, vägens utformning samt situationer och förhållanden – särskilt oplanerade – längs vägen. Få sådana studier har genomförts trots de satsningar och prioriteringar som görs på miljöområdet.

Det projekt som planerats har som syfte att ta fram kunskap om och skapa förståelse för relationen mellan olika faktorer påverkan på miljön. I en sådan studie blir det möjligt att undersöka vilka åtgärder som på effektivaste sätt minskar de negativa miljöeffekterna. För en sådan känslighetsanalys krävs ett tillvägagångssätt där kombinationer av olika faktorer studeras på ett strukturerat sätt. Projektets mål är att beskriva hur val av vinterdäck (dubbade eller odubbade) påverkar körbeteendet och hur kombinationen av

däck och körbeteende påverkar energiförbrukning (bränsle), avgasutsläpp, beläggnings-  
slitage, partikelemissioner (PM<sub>10</sub>) och trafiksäkerhet. En viktig fråga att studera är hur  
körbeteendet påverkas av om föraren genomgått EcoDriving-utbildning och även  
långtidseffekten av en sådan utbildning. För att genomföra denna typ av projekt i VTI:s  
simulatorer behöver modeller för bränsleförbrukning, slitage och emissioner anpassas  
och implementeras i simulatorerna. Arbetet med att implementera bränsleförbruknings-  
modellen har påbörjats.

Intresset av att studera ett fordons miljöprestanda kopplat till förarens beteende är i dag  
mycket stort. Införandet av modeller för slitage och partikelemissioner från däck är  
unikt och skulle vara ett mycket gott komplement till VTI:s övriga verksamheter inom  
området. Kontakter är tagna med Energimyndigheten och Trafikverket och båda  
myndigheterna har visat intresse för den här typen av projekt. Inom VTI:s nätverk med  
fordonsindustrin diskuteras också förslag till utveckling av förarstöd som i bilen ger  
förarna miljörelaterad feedback med syfte att åstadkomma en varaktig förändring av  
deras körmönster.

## **Environmental risks and road user behaviour**

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### **Summary**

This report concerns environmental risks related to transportation and is divided into two parts. In part 1 (written in English), perceptions, choices, and behaviours related to environmental risks are discussed from economic and psychological perspectives. Part 2 (written in Swedish), presents a simulator study of the relation between drivers' behaviours and environmental risks in the form of a research application.

Part 1. When designing transportation policies, there is a need to understand how individuals perceive environmental risks and what individuals are willing to do in order to reduce these risks. Two areas of research that have focused on risks, perceptions, and behaviour are economics and psychology. In this paper, a literature review of economic and psychological models of risk perception is described. Moreover, preparation for a questionnaire study where psychological theories are used to improve the understanding of choices in stated preference studies is presented. The review of economic literature demonstrates that individuals sometimes deviate from the rational choice model (e.g. an increase in risks does not necessarily result in an increased willingness to pay in order to reduce that risk) and objections have been put forth regarding the possibilities of assessing what individuals would do in real life (in contrast to what they only say they would do) (i.e. the problem with hypothetical bias). Psychological theories and research point towards possible reasons as to why environmental risk perception is not always translated into pro-environmental behaviours. For example, even though environmental problems associated with using the car are recognized, the individual may need to plan for a reduction in car use before it is realized in practise. Hence, the relation between risk perception and behaviour may be indirect. Based on the findings of the literature review, a suggestion for a future study of willingness to pay for new car technology aiming to reduce emissions is described. The aim of the proposed study is to examine if psychological theories can help to detect the extent of hypothetical bias in this choice context.

Part 2. The sub-project's goal and purpose is to investigate the feasibility for environmental research trials in the VTI driving simulator and to provide suggestions for such a project. The prospects and possibilities in a virtual environment to study environmental effects of different factors are very good. Such factors may result from the driver, vehicle, road design, and situations and circumstances – particularly unplanned – on the road. Few such studies have been carried out despite the efforts and priorities given to the environmental area.

The project planned is intended to generate knowledge and understanding of the relationship between different factors' impact on the environment. In such a study it is possible to look into the measures that most effectively reduce the adverse environmental effects. Such a sensitivity analysis requires an approach where combinations of different factors are studied in a structured way. The project aims to describe how the choice of winter tires (studded or friction) influence the driving behaviour and how a

combination of tires and driving behaviour affect energy consumption (fuel), exhaust emissions, pavement wear, particulate emissions (PM10) and road safety. Important issues are how driving behaviour is affected by whether the driver has received eco-driving training but also by the long time effect of such training. In order to carry out this type of project in VTI's simulators models for fuel consumption, wear and emissions have to be adapted and implemented in the simulators. The work to implement fuel consumption model has started.

The interest in studying a vehicle's environmental performance linked to human behaviour is today very large. The introduction of models for wear and particulate emissions from the tires is unique and would be an excellent complement to VTI's other activities in the area. Contacts have been taken with the Swedish Energy Agency and the Swedish Transport Administration and both authorities have shown interest in this type of project. Within the VTI network with the automotive industry proposals are also discussed for the development of driver assistance in cars that give drivers environmental feedback in order to bring about lasting change in their driving patterns.

**DEL 1** Economic and psychological perspectives on environmental risks associated with private transportation. A literature review and suggestions for further research

Louise Eriksson

Lena Nerhagen



## 1 Introduction

The environmental consequences of transportation include effects on air quality, land quality, the climate, noise levels, and land use (see e.g. SEPA, 2002/03). In some cases these effects may result in or increase the possibility for adverse effects on living organisms or the environment. When designing transportation policies these environmental risks need to be taken into account. In order to do this, there is a need to understand how individuals' perceive these risks and what individuals are willing to do themselves, or think society should do, in order to reduce these risks. Much research in different disciplines has addressed these issues in recent years, partly inspired by the research on other risks caused by transportation such as accident risks. There are however in some cases important differences between environmental risks and other risks which make evaluation of environmental risks more challenging. One example is that effects occur some times in the future, that is, with latency, and another that there can be multiple correlations between different effects on the environment.

Two areas of research that have focused on risks, perceptions, and behaviour are economics and psychology. Traditionally, economic studies have mainly focused on individuals' actual choice behaviour and the efforts they are willing to make to achieve environmental improvements. A basic assumption in the economic models has been that choices are based on predefined and stable preferences where the alternatives are evaluated in a consistent manner, based on an objective description of the risks, and where the final choice will depend on preferences but also on various restrictions, such as income or time. Recent research has found that the underlying rationality assumption used in economics can be questioned on psychological grounds. For example, individuals rather base their choice on their subjective perceptions of a certain risk. Also, a certain change is evaluated differently depending on if it is a gain or a loss (i.e. loss aversion). There is therefore an increasing interest among economists and other research disciplines to understand the implications this might have for the design and interpretation of economic models in general. These types of issues are for example explored in a new field of research called behavioural economics.

Recently there has been an increasing awareness that individuals' behaviour is better understood if the many aspects that influence an individual's choice are accounted for. An example is a conference titled "Risk perception, valuation and Policy" that was held at the University of Florida in the US in 2004. According to Gerking and Harrison (2006, p. 267), the motivation for the theme was that "an appropriate characterization of attitudes towards risk is fundamental to properly understanding the costs and benefits of virtually all major environmental policies". That understanding attitudes is important for predicting the outcome of a choice context, in addition to aspects that are usually considered in economic models, has also been acknowledged in transportation research. One early example is a symposium on the elicitation of preferences that Daniel McFadden organized at the University of California, Berkley in 1997 which assembled a large number of researchers from different research disciplines. This initiative is of special interest since McFadden's research on random utility models has been a cornerstone for the economic research on choice behaviour in transportation<sup>1</sup>. The contribution of McFadden was an overview of the difference between psychological and economic research on preferences. According to him, psychologists focus on the process of decision making while economist are mainly interested in relating the

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<sup>1</sup> The ideas and discussions were communicated to a wider audience through a special issue in the *Journal of Risk and Uncertainty* in 1999 (Fischhoff & Manski, 1999).

outcome of a choice to the information in the choice situation. There is also a difference in the view of preferences since psychologists see them as variable while economists assume they are stable.

In later years, environmental policies targeting transportation have received increasing attention in Sweden, in particular due to the contribution of transportation to CO<sub>2</sub> emissions. Many proposals however are controversial since they are expected to have a large impact on the daily lives of individuals. There is therefore a need to undertake research in order to help in the design of efficient and acceptable environmental policies in the transportation area in a Swedish context. Since attempting to understand these issues from an interdisciplinary standpoint is new for VTI, a project was initiated where the aim was to explore the relationship between economic and psychological models of risk perception and behaviour and how they can be combined to better understand individuals' understanding and response towards these environmental risks. To make it more specific it was decided that a questionnaire should be designed as a part of the project. The findings from the project are reported in the present paper.

The outline of the paper is as follows. In the next chapter an overview is given on economic research regarding environmental risks, in particular valuation and transportation research on choice behaviour and on issues raised in this research. In the next chapter, a review of the different research areas that have addressed environmental risks in psychology is given. Based on the findings in the literature, we then discuss how the two fields of research may interact to obtain a better understanding of actual choice behaviour in different contexts. This issue is highly relevant in order to understand whether stated choices are likely to actually translate into behaviour or not. If not, there is a problem with hypothetical bias which means that stated preference studies are problematic to use to predict behaviour. Finally, we briefly describe the design of a questionnaire study. The idea with the questionnaire study is to explore if psychological theories can help to detect the extent of hypothetical bias in a willingness to pay study of new car technology aiming to reduce emissions.

## 2 Economic theory and environmental risks

### 2.1 Economic theory, valuation and policy

Societal decision making implies making trade-offs between different objectives. Approaching these objectives often results in direct or indirect costs to society (national or local governments) but also for single individuals. In some cases these decisions are straightforward with clearly defined costs and benefits in economic terms, but most often this is not the case. For various reasons assessing the benefit of environmental improvements can be particularly troublesome. Air pollution for example comes from various sources and has several different impacts on the natural environment and/or on human health. Moreover, the effects can occur instantly but also some time into the future. Therefore, in order not to neglect negative impacts of pollution in decision making, economic valuation methods have been developed with the purpose of “placing a price” on these impacts.

The basis for “placing a price” is the impact of pollution (measured as costs) on third parties, the term external cost is commonly used in economics. There are two main reasons for obtaining this information. One is that if we have an estimate of the cost of pollution, the external cost, a pollution tax can be placed on the production of a good. As discussed in economic theory, internalising external costs through pollution taxes will correct for the inefficiency caused by pollution<sup>2</sup>. This is because prices are a bearer of information that sends signals in a market system. Pollution taxes give actors (consumers and producers as well as policy makers) economic incentives to act and to change behaviour since they raise the cost of the polluting activity. However, for various reasons, a pollution tax is not always possible to impose on the production of a good. In such circumstances having information on the price of pollution related to a good is useful for an efficient design of other policy measure, for example standards or limit values (see for example Hanley et al., 1997 for a description of environmental economics, i.e. the theory behind the use of prices in environmental policy)<sup>3</sup>.

Hence, economist’s interest is to obtain estimates of the external costs related to environmental problems. For this purpose, economic valuation methods have been developed that try to estimate individual’s willingness to pay for a change and improvement of the environment. These methods rest on the assumption that individuals’ willingness to pay can be used as a measure of the change in an individual’s welfare that the risk reduction entails (Viscusi & Gayer, 2005). The first attempts to obtain willingness to pay estimates relied on the use of market data using so called revealed preference methods. These methods derive economic values from individuals’ choice behaviour in real markets. An early example in the case of mortality risk reductions was the hedonic wage model. In this case the estimate rests on detecting the relationship between the additional amount of income that a worker must be offered in order to

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<sup>2</sup> A basic assumption in economics is that a free market, i.e. a market in perfect competition, will result in an outcome that provides the greatest value to society. In reality however there are no truly free markets due to the existence of so called market failures, examples are monopoly, imperfect information or externalities. In the presence of market failures the market outcome is said to be inefficient since the overall value to society is not as great as it could be. Such outcomes may therefore be improved by government interventions in the market.

<sup>3</sup> The evaluation criteria used in economics is economic efficiency which is achieved if the benefit of production or consumption outweighs the cost (based on the assumption that all benefits and cost are accounted for). A central underpinning of economic theory is that there are scarce resources and that trade-offs are needed. Hence, for the sake of accomplishing other welfare enhancing actions, society has to accept a certain level of “bads” such as some impact on the environment.

motivate him to accept for example a riskier job. However, a major drawback with revealed preference methods is that there are a limited number of risk contexts that can be explored using actual choices. There are limitations since the choices are generally not representative for a larger population but also because not all risk contexts can be controlled by actions made in markets. Moreover, these methods do not capture the welfare loss due pain and suffering. Therefore, so called stated preference methods are increasingly used.

In stated preference methods information is obtained from survey data exploring individuals' choice behaviour. The analyst designs a choice context that resembles a market situation or a referendum. The earliest approach used in environmental economics was the contingent valuation method where the respondent was asked to state their willingness to pay (open-ended format) or accept or reject a certain bid (closed-ended format) for a certain improvement. Another more recent format is to ask the individuals to respond to several alternatives in a row. This is often called a choice experiment which has been developed in valuation studies in transport economics and marketing. Economists however traditionally distrusted information that was not obtained in a market and objections have therefore been raised against the use of results from stated preference studies for policy making. The methods are considered to be problematic since it is difficult to validate that answers to these questions represents actual choice behaviour, a problem often referred to as hypothetical bias.

These objections have spurred research that explore how individuals respond in these hypothetical choice situations and what the determinants of choice are (Sugden, 2005). In these studies, there have been findings of deviations from the theoretical predictions but instead of resulting in a rejection of stated preference methods they have instead contributed to an understanding that even choice behaviour in actual markets are not purely rational in an economic sense. The latter are based on rational choice theory which assumes a rational decision maker, that is, a self-interested decision maker who, based on established preferences, will make consistent choices that are based on evaluation of the consequences of each choice in order to achieve desired goals at least cost (in money or other resources such as time). Therefore there is now an increasing interest among economists in understanding systematic deviations from rational choice theory and what implications this has for policy (Shogren & Taylor, 2008). Many of the issues raised in recent years and their implications are now being more systematically addressed in new line of research within economics called behavioural economics.<sup>4</sup>

Traditionally, environmental policy has mainly been based on so called "command and control", that is, different kinds of restrictions. The reason for this has been a problem of estimating external costs and practical problems with the implementation of pollution taxes (Cornes & Sandler, 1996; Rose, 2002). However, pricing is increasingly seen and also sometimes used as an alternative to command and control<sup>5</sup>. Improvement in

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<sup>4</sup> That there is an interface between economics and psychology has been acknowledged and discussed by some researchers for a long time. The Nobel Price laureate Simon (1955) for example questioned the model of rational behaviour and introduced the concepts "bounded rationality" and "satisficing". Still, the influence of psychology and other related disciplines on mainstream economics has been limited. One explanation for the disinterest among economists for related disciplines is according to Bleaney and Stewart (1991) that: "they have enough trouble keeping up with what is going on in economics itself". Another reason, discussed for example by van Raaij (1991) is that: "economic theories do not explain or predict individual economic behaviour, but predict the "behaviour" of markets and institutions".

<sup>5</sup> Examples from the transport sector are the congestions charges in Stockholm, Sweden, and the pricing to reduce the use of studded tyres in Oslo, Norway.

technology that makes pricing possible is one reason for the increase in interest. Another is that it is acknowledged that this is a flexible regulation that allows those affected to choose their own response behaviour which in turn is more likely to result in cost-efficient solutions for society.

Still, although pricing is increasingly seen as an alternative by policy makers, actually introducing it has not been straightforward. People often resist this type of regulation. In the environmental context one reason is that these are often resources that previously have been considered to be “free”. Rose (2002, p. 242) for example writes: “The introduction of any new environmental regulatory practice generates intense political pressure; this is particularly the case for a regulatory change in which resource users have to pay for something that they previously took “for free”.” An additional important reason is that they are questioned on the grounds of fairness and equity. Therefore, how to increase the acceptance for these types of efficient environmental policies is another reason for economists’ interest in exploring individuals’ choice behaviour in this area.

Hence, economists show an increasing interest in the underlying reason for individuals’ actual choice in situations when the choice involves an economic transaction of some sort. This is for example explored by comparative studies of choice behaviour in real versus hypothetical markets. The purpose is to be able to improve the models that are used for evaluation of the outcome of government intervention in the market but also for making predictions of the outcome of proposed interventions. Since research in related areas such as psychology has revealed that many different aspects influence individuals’ choice behaviour, or put differently that preferences are not as stable and predictable at the individual level, the issue is how to account for these aspects in economic models. Regarding environmental risk, the question is how individuals perceive these risks and if they influence behaviour in any way, for example in the things individuals buy. In the next section we will give examples from economic research on this issue. We will also, based on the research we have undertaken ourselves in the area of air pollution and travel mode choice, discuss reasons for why people may not reveal a willingness to pay for environmental improvements in a transportation context.

## 2.2 Economic valuation of environmental risk

Environmental economics is a sub discipline within economics. One reason for a special treatment of these aspects is that the environment is an input to the production process that is not always paid for, especially when it is used for the deposition of waste or pollutants. Since the use of the environment may have negative effects on human health and/or the functioning of the eco-system, society engages by designing regulations regarding its use. The impact on the environment and the outcome of government regulations are both uncertain, hence the analysis of risk and uncertainty is central to the subject.

In economics, risk is commonly analysed as a lottery using expected utility theory. Regarding the environment it is assumed that people think about a combination of probabilities and consequences that define the risks to human, or other living organisms, and environmental health. There is a baseline risk that an environmental policy is expected to change. In an economic valuation context, the information that is sought is how people react to changes from this baseline due to private or collective risk reduction investments.

There is a fairly extensive literature on how well this model corresponds to actual behaviour in choices involving risk, see for example Andersson and Lundborg (2006) for an overview. In their study, they investigate how people perceive their own death risk in a road-traffic context. As in many other studies they find that the subjective risk is not equal to the objective risk and that people underestimate their overall mortality risk. Another general finding in the literature is that people in general have a problem in evaluating risk, for example concerning low probability, high consequence risks. In this context they seem to have a loss aversion, hence they deal differently with potential gains as compared to potential losses (Shogren & Taylor, 2008). The problem this raises for economic valuation is that estimates that rely on individuals' current actual or stated behaviour may under- or overestimate their willingness to pay for a change in the environment.

In previous research, we have tried to assess to what extent air pollution is likely to influence individuals' acceptance of road pricing (Nerhagen, 2007). The question is how important air pollution was for the outcome of the referendum on congestion charging in Stockholm. This was a study that summarised the current level of knowledge on this topic. The conclusion was that air pollution is likely to have a small impact on individuals' choice behaviour. The main reason is that people in Sweden do not experience air pollution to be a serious problem that imposes risks to human health or the environment. In Stockholm for example about 40 % of the population in the inner city consider the air quality to be good and an equal share thought it was bad while only a smaller group found that the air quality improved with the introduction of the congestions charges (Schmidt et al., 2006). That air pollution in Sweden is not considered to be an important problem among the general public is also confirmed in studies undertaken by the National Board of Health and Welfare that is carried out every fourth year (Socialstyrelsen, 2001; 2005). That traffic is not a cause of concern is also found in a study that specifically investigated the annoyance from traffic emissions in more densely populated areas in Sweden. Only 5% stated that traffic emissions in the winter are irritating on a daily basis and the size of the disturbance over a three month period is 2 on average, on an 11 step scale (Modig & Forsberg, 2006).

For economic valuation the problem this entails is that people may underestimate the impact of these emissions (Cropper, 2000). One reason is that these emissions are not tangible and the impact is seldom acute and in the latter case it mainly has an impact on people having a diagnosis such as asthma. It is however long term impacts that give rise to the largest cost related to air pollution (Nerhagen et al, 2005; Bickel et al., 2006). No studies have really covered how this risk is perceived but there is a study on radon which is a pollutant that has similar characteristics and impact. Radon is an odourless gas that increases the risk for cancer. Hill et al. (2006) investigated how parents perceived their children's health risk when exposed to this pollutant. They found that 21% of the respondents made an assessment that coincided with the objective risk while closer to 40% underestimated the risk and about 40% overestimated it. That people misjudge these types of risks has several explanations. The most important is probably that there are complex relationships between air pollution and human health that also scientists are uncertain of. Moreover, the information provided is scattered and often on a pollutant by pollutant basis so to make an assessment at the individual level will require both time and effort. Larson and Rosen (2002) for example state, regarding the impact of air pollution and choice behaviour, that since scientists are uncertain about the impact it cannot be expected that households understands and can incorporate them correctly into their decision making.

The possible influence that information provision on air pollution may have on sentiments and behaviour in the general public has been studied in the US. There the public can obtain information on air quality through a service called Air Quality Index (AQI) which can be accessed using Internet but that is also presented in news media. Elliot et al. (1999) investigated what people knew about this service and found that about 50% of the respondents knew this was a measure of air quality. Johnson (2003) investigated how the information provided by AQI influenced peoples' perception of air quality and their response behaviour by making an assessment of a change made in 1999 in how the information was provided. According to his result the information provided influence how people perceive the problems related to air pollution and their own health risk but some persons have a problem understanding the information. The influence on behaviour however seems to be limited and high air pollution levels will not stop people from being outdoors.

Hence, although efforts are made to provide the public with information, it is not certain that the true meaning of the message will be received. In an economic valuation context there is therefore the question if the respondents in such a study should be provided with information on the most likely probabilities and consequences of a policy proposal. Many argue that this is not correct since economist are interested in capturing the valuation and behaviour of the general public that are revealed in actual markets where no additional information is provided. Navrud (2001) for example in a study on the health impacts of air quality, did not mention the cause of the health impacts because he wanted to avoid that people in their answers also included other benefits that improvements in air quality would bring about. Others consider information provision to be part of the market.

Another context that has been used to assess to what extent environmental problems influence individuals choice behaviour is in their choice of travel mode. A summary of the findings in the literature is given in Hultkrantz et al. (2003). Most studies have focused on individuals' choice between car and other travel modes for a specific trip. Here it is found that environmental aspects do not seem to have a measurable influence on individuals' choice between car and other travel modes. This conclusion seems to hold also for persons that has pro-environmental attitudes. One explanation for this finding is that people has strong preferences for the flexibility that car use provides. People also seem to find excuses for themselves using the car, one being that their own car use will have a negligible influence on the total environmental impact. There is however a problem related to the use of this kind of a study to estimate the willingness to pay for environmental improvements. Individuals can express their concern for the environment in other choices they make. They can for example choose a lifestyle where they don't have to travel that much or they can decide not to own a car. Hence, obtaining information on economic values for the environment from actual market behaviour is to some extent censored information.

The conclusion from this overview is that for the more obscure or diffuse environmental threats it is likely that the benefits of environmental protection is over- or underestimated by the general population. An additional problem is that structural phenomena, such as existing norms or current property rights, may be a hindrance to individuals changing their behaviour. These findings are likely to have more far reaching implications than simply suggesting that economic valuation studies are likely to result in biased willingness to pay estimates. They also have implications on policy since they may say something about individuals' choice behaviour in a voting context. It needs to

be remembered that public elections are also an arena where people can express their attitudes and willingness to pay for improvements in the environment.

In Nerhagen (2007), the findings in the literature on the acceptance for pricing are discussed. It is found that one problem with this policy is that the basic principle for using this type of regulation is poorly understood and hence it is mostly seen as an instrument for the government to obtain more revenue (Pahaut & Sikow, 2006; Schade & Schlag, 2003). Another objection is that it is unjust, for example when a previously “free” resource suddenly has to be paid for. Hence, information needs to be provided about the benefit that will result on the part of the individual from the change in policy (Raymond, 2003; Jaensirisak et al., 2005). Finally, this type of policy is likely to be more acceptable when undertaken on a larger scale, hence nationwide rather than locally. Few economic valuation studies have been undertaken in this type of public choice context, one problem being that these measures will have a small impact on individual environmental risks so the question is what such willingness to pay estimates capture. However, this may be the choice situation that can result in larger structural changes.

### 2.3 Concluding remarks

Different disciplines in economics have increasingly investigated what influences an individual’s choice behaviour in a certain context. As discussed by Braga and Starmer (2005) there is evidence that people do not behave as proposed by standard preference theories. These “anomalies” in behaviour is for example loss aversion which implies that the value an individual places on a good depends on if he/she is already endowed with it or not. Another classical example is preference reversal resulting from the phrasing of the willingness to pay question. Many other issues have also been explored in the literature.

These findings have spurred a new line of research into what the explanations for these types of “anomalies” might be. It has also resulted in a new line of research within economics referred to as “Behavioural Economics”. According to Camerer and Loewenstein (2004) this line of research, that provides economics with more realistic psychological foundations, will increase the explanatory power of economic models. An introductory text to this research area is provided by Wilkinson (2008).

The findings about these so called “anomalies” also have implications for economic valuation. As discussed by Shogren and Taylor (2008), behavioural failures have prompted some researchers to argue that government intervention can be justified beyond the standard market failure motive since people, although they know what is good for them, still make “incorrect” choices. The problem for such solutions however is who is to judge what the welfare improving choices for an individual are. Shogren and Taylor (2008) argue that there is a need to understand under what circumstances that rational choice theory fails to capture observed behaviour, be it due to economic circumstances, institutional designs or social contexts, rather than to reject its usefulness in environmental and resource economics.

Since environmental risks have been found to be an area that is particularly troublesome to elicit willingness to pay estimates for, understanding the psychology of choice in this context is very important. Relevant aspects in this area are discussed in the following section.

### 3 Psychological perspectives on environmental risks

Psychological theory may be helpful in order to understand how individuals perceive environmental risks. Within psychology, risk perception is subjective, that is, it is the individual who defines risks and the relation to actual risk levels are less relevant. Hence, the rationality assumption applied in economic research is generally not underlying research within psychology. The main aim has been either to examine perception of risks, or the relations between risk perception and various behaviours which are intended to reduce environmental problems<sup>6</sup> (see e.g. O'Connor, Bord, & Fischer, 1999). These two research traditions have focused on different aspects and therefore have different strengths and weaknesses. A short summary of how these two research traditions provide insights into how individuals evaluate and respond to environmental risks related to transportation is presented below.

#### 3.1 Research on risk perception

##### 3.1.1 Definition of risk perception

How risk is perceived has been examined in relation to a range of different events or activities, for example smoking, accidents, sunbathing, different diseases, nuclear power, radon, and natural disasters. Hence, environmental risks constitute only one part of the research on risk perception. This section will begin with a short introduction to how risk perception has been defined and different ways to measure risk perception. Moreover, two dominant research paradigms will be described. Subsequently, environmental risk perception will be explored and a few studies examining the relation between environmental risk perception and different behavioural strategies will be highlighted.

Risk is often described as a combination of the probability of an adverse event and the magnitude of its consequences (see e.g. Rayner & Cantor, 1987 for a discussion). Since the level of risk is always estimated, the outcomes of a risk, for example the extent to which transportation has a negative effect on the climate, are always uncertain. Moreover, subjective risk perception has been defined and operationalized in a variety of different ways. For example, either cognitive aspects (i.e. mental processes helping us to make sense of the world) or affective aspects (i.e. feelings) have been emphasized. According to the consequentialist point of view, decisions concerning risk perception are made based on the consequences of a decision alternative (i.e. expected utility model) while the risk-as-feeling hypothesis stipulates that both cognitive evaluations of risks and feelings experienced when making the decision are important for how individuals respond to risks (see e.g. Loewenstein, Weber, Hsee, & Welch, 2001). Hence, both subjective calculations of risks and the feelings evoked by risks are important for how individuals perceive risks. In earlier studies of risk perception the consequentialist perspective have dominated (see e.g. Payne, Bettman, & Johnson, 1993); however, recently, studies have highlighted the affective dimension (see Finucane, Alhakami, Slovic, & Johnson, 2000) and in a few studies both cognitive and affective aspects have been assessed (Rundmo & Moen, 2006; Sundblad, Biel, & Gärling, 2007). Cognitive

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<sup>6</sup> Within psychology various behaviours which has consequences for the environment has been studied, for example transportation behaviours (e.g. choosing the public transportation instead of the car), energy behaviours (e.g. saving electricity), and consumption behaviours (e.g. buying eco labelled food, recycling). The individuals' willingness to pay in order to save the environment (within different behavioural domains) is only one type of behaviour studied in this discipline.

measures of risks include aspects, such as, the perceived probability and consequences of an event, while affective measures, have included dimensions, such as, worry. In general, perceived consequences rather than probabilities have been found to be important for demand for risk mitigation (see e.g. Rundmo & Moen, 2006; a review is provided by Sjöberg, Moen & Rundmo 2004). However, while Rundmo and Moen (2006) found that worry was also a significant predictor of demand for risk mitigation concerning accidents related to different travel modes, Sjöberg (1998) did not find that worry was an important predictor of intention to vote against localization of nuclear waste repository. Hence, it is still uncertain what aspects of risk perception that are important for different behaviours.

Environmental risks differ in many respects compared to other types of risks. According to Gattig and Hendrickx (2007), environmental risks often have uncertain and strongly delayed consequences and they occur at remote places to other people. Moreover, there are different types of environmental risks varying in source as well as impact. In a study by Walsh-Daneshmandi and MacLachlan (2000), 24 hazards were categorized into three types of environmental risks, labelled techno-human (e.g. pollution from cars), natural (e.g. earthquakes), and every day-life risks (e.g. noise).

In a review, Sjöberg (2000) highlights different factors that have been used to explain perceived risk. The first factor is real risk, or technical estimates of risk, that is, the risk is perceived as more serious when the risk estimate is higher. Although real risk may play a role particularly for risk perception of common events, certain discrepancies from this pattern occur repeatedly, for example overestimation of small risks and underestimation of large risks. A second factor is cognitive biases since individuals may use various heuristics, such as, representativeness, availability, and anchoring when estimating probability. Hence, the use of heuristics may help to explain why risk perception deviate from technical risk estimates. In studies of risk perception however, these two factors have, according to Sjöberg, been abandoned as explanations for risk perception since risk has been found to be so much more than probability assessments. According to Sjöberg et al. (2004), two of the dominant theories within the field of risk perception are instead the psychometric paradigm and cultural theory. While the psychometric paradigm has been described as mainly a cognitive approach (see Sjöberg, 1996), studies based on the cultural theory have to a larger extent considered how the social context is important for shaping our risk perception. These two approaches are described below.

### 3.1.2 The psychometric paradigm

Within the psychometric paradigm, different types of risks associated with, for example, activities, such as smoking and having surgery, technologies, such as, nuclear power and motor vehicles, and substances, such as chemical pesticides have been examined. Participants are asked to rate different types of hazards (e.g. acid rain, flooding) on different attributes (e.g. how many people that are exposed) and the mean ratings for each hazard on each scale are subsequently factor analysed. The aim is to examine what characteristics of the hazard are related to how risky the hazard is perceived to be. In these studies, dimensions, such as, dread and unknown but also exposure have been found to account for a large share of the variance in risk perception (see e.g. Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978; Slovic, Fischhoff, & Lichtenstein, 1985). Hence, higher risk ratings have generally been found for risks that are dreaded to a larger extent, risks that are less known, and risks that affect more people.

Within the psychometric paradigm, a few studies have focused on identifying important characteristics of environmental risks. In a study of ecological risk to water environments, McDaniels, Axelrod, Cavanagh, and Slovic (1997) found that four factors; ecological impact (including both impacts on species and humans), human benefits, knowledge, and controllability explained a large amount of variability in lay people's risk judgement. Moreover, ecological impact, human benefits (negative), and knowledge were important for perceived general riskiness. Four similar factors were found to be important in relation to more general ecosystem risks by Lazo, Kinnell, and Fischer (2000) and three of the identified factors (not controllability) were significant predictors of overall risk perception. In addition to the factors already identified, Willis et al. (2005) also found that aesthetic impacts were important. Ecological riskiness (excluding effects on humans) was mainly determined by ecological impacts and human impacts but also aesthetic impacts (negative) and controllability (cf. McDaniels, Axelrod, & Slovic, 1995). Overall, dimensions, such as, perceived ecological impact, human benefits, knowledge or scientific understanding, and controllability have generally been found to discriminate between different hazards.

A few studies within the psychometric tradition have examined the relation between risk perception and different behavioural responses, such as acceptability of governmental regulation. For example, McDaniels et al. (1997) found that in relation to ecological risk to water environments, ecological impact (including both impacts on species and humans), human benefits (negative), knowledge, and controllability were important for perceiving a need to regulate the actions causing the problem. In a study by Willis et al. (2005), ecological impacts (negative), human impacts (negative), and human benefits were important for a positive evaluation of governmental regulation.

### 3.1.3 Cultural theory

Cultural theory (Douglas, 1978; Douglas & Wildavsky, 1982) suggests that there are four types of worldviews important for how we act in relation to the environment: (1) egalitarians who fear events threatening inequalities amongst people, for example technologies and threats to the environment, (2) individualists who fear threats to their individual freedom, for example war and other threats to the market, (3) hierarchists who fear changes of the social order, for example threats to law and order, and (4) fatalists who are indifferent towards risks since risks are perceived to be unavoidable. The importance of cultural adherence for risk perception has been supported in a few empirical studies (see Dake, 1991).

According to cultural theory, the worldviews have different views on nature, so called myths of nature.<sup>7</sup> While individualists view nature as robust and believe in the free market and technology to deal with any environmental problems, hierarchists perceive nature as moderately vulnerable and prefer government regulation. Egalitarians perceive nature as fragile and therefore behavioural change as necessary, and in contrast, fatalists do not have a coherent view on nature and no clear preference for managing environmental problems. Studies have found that in line with expectations, individuals with an egalitarian worldview displayed higher problem awareness compared to individuals

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<sup>7</sup> The different worldviews have different labels describing their views on nature (i.e. individualists are labelled nature benign, hierarchists are labelled nature tolerant, egalitarians are labelled nature ephemeral and fatalists are labelled nature capricious). However, the overall labels for the four types of worldviews are retained throughout this paper in order to make it easier for the reader.

with other worldviews; in particular, individualists displayed lower awareness of environmental problems (Poortinga et al., 2002; Steg & Sievers, 2000).

In a few studies, relations between worldviews and pro-environmental behaviours have been identified. Moreover, in relation to the cultural theory, Steg and Sievers (2000) found that egalitarians perceived a reduction in car use as more necessary compared to the other world views. In contrast, individualists and fatalists perceived a car use reduction to be less necessary. Moreover, Poortinga, Steg and Vlek (2004) found that egalitarians evaluated different behavioural measures (e.g. using public transport, walking, or go on holiday by train) most positively, while individualists evaluated them negatively.

#### 3.1.4 Personal versus general risk perception

Research on risk perception has been criticized for not making a distinction between different risk targets, that is, whether the risk evaluation concerns the individual making the risk assessment or people in general. Since the risk target has not been specified in many studies it is likely that it is the perceived risk on a general level that has been assessed according to Sjöberg et al. (2004). However, particularly in relation to environmental risks it is important to specify for whom the risk evaluation is made. Different risk targets, such as, the individual him or herself, the family, people in general, or the environment have often evaluated differently. For example, environmental risks have been found to be more serious on a global level compared to a local and personal level (Uzzell, 2000). Moreover, Pahl, Harris, Todd, and Rutter (2005) found that people believed they were less likely to be affected by different environmental risks, such as air pollution, compared to others (so called comparative optimism). Even though there are differences in how risk targets are evaluated, studies have generally showed that perceived environmental risk and perceived personal risk are significantly correlated indicating that individuals who perceive a risk for him or herself also perceive a risk for the environment (see Schütz & Wiedemann, 1998).

In addition, studies have examined the importance of personal versus general risk perception in relation to different types of behaviours. Schütz and Wiedemann (1998) examined both personal and environmental risk perception in relation to different consumer products and found that personal risk perception, rather than environmental risk perception, was a significant predictor of recommendation of different consumer products (e.g. organic vegetable, chemical household cleaners) and Fischer, Granger Morgan, Fischhoff, Nair, and Lave (1991) found that risk-reducing actions and willingness to pay for future risk reduction were lower for threats to the environment or to people in general compared to direct personal threats (e.g. pollution versus health risks).

#### 3.1.5 To sum up

In sum, environmental risks are only one type of risk that has been examined in research on risk perception. The two dominating approaches within risk perception, the psychometric approach and cultural theory, both have an interest for subjective views on risk but have to some extent different aims. The traditional psychometric approach focuses on differentiating between hazards and analyses are generally made on an aggregate level (see Willis et al., 2005). Hence, the focus has been on how different types of risks are perceived and the relation between the hazard's characteristics and risk perception rather than on individual differences. Cultural theory on the other hand, stipulates that worldviews, and their relation to risk perception and behavioural strategies, are central

for an understanding of risk perception. Even though a lot of research on risk perception has been carried out within these two research traditions, they have both been criticized for not being able to explain a large share of the variance in risk perception (see e.g. Sjöberg, 2000; Sjöberg et al., 2004; Oltedal, Moen, Klempe & Rundmo, 2004 for reviews). In addition, there are issues that have been given less attention in research about risk perception. For example, only a few studies have highlighted the highly relevant distinction between personal and general risk perception (see Sjöberg et al., 2004), and only a few studies have examined the relation between risk perception and behavioural strategies, such as, the need for regulation (see O’Conner et al., 1999). Even though risk perception of single environmental issues associated with transportation (e.g. air pollution from cars) has been examined, different environmental problems associated with transportation behaviours have not been examined extensively.

## 3.2 Research on pro-environmental attitudes and behaviours

### 3.2.1 Definition of pro-environmental attitudes

Parallel to studies on risk perception, research on environmental attitudes and behaviours have been examined. This field of research draws on social psychological theories in order to understand attitudes and relations between attitudes and behaviours. Frequently, the lack of correspondence between attitudes and behaviours, that is, the attitude-behaviour gap, is highlighted and attempts have been made to explain reasons for why individuals not always act in accordance with their attitudes. In this section, the concept of environmental attitudes, and related constructs, will be highlighted, and theoretical perspectives used to explain the relation between environmental attitudes and behaviours will be described. Subsequently, studies examining how environmental attitudes are related to different pro-environmental behaviours will be presented.

In this research tradition, environmental risks have often been labelled environmental problems (see e.g. Fransson & Gärling, 1999; Stern, 2000) and the focus has often been on different activities with serious consequences for the environment, for example, consumption, energy use, household waste, and travel behaviour. Certain studies measure evaluations of environmental problems in general (e.g. Rauwald & Moore, 2002; Schultz & Zelezny, 1999), while others highlight specific environmental problems, such as, climate change (Poortinga et al. 2004; Whitmarsh, 2009). Moreover, how individuals perceive environmental risks have been described using different terms, for example, environmental concern (Dunlap & Jones, 2002; Fransson & Gärling, 1999), environmental values (Nordlund & Garvill, 2002; 2003), environmental worldviews (Dunlap & Van Liere, 1978), awareness of environmental problems (Stern, Dietz, Abel, Guagnano, & Kalof, 1999), environmental beliefs (Dunlap, Van Liere, Mertig, & Jones, 2000), or environmental attitudes (Grunert & Juhl, 1995; Schultz et al., 2005). In this paper, the term environmental attitude is used when referring to individuals environmental risk perception except when different concepts are used in the respective theories.

### 3.2.2 The Value-Belief-Norm theory

One theoretical approach where the relation between environmental beliefs and pro-environmental behaviour is explained is the Value-Belief-Norm (VBN) theory (Stern et al., 1999; Stern, 2000). According to the VBN-theory, a hierarchy of values, environmental beliefs, and personal norm are important for pro-environmental

behaviour.<sup>8</sup> Altruistic and biospheric values emphasizing others' interests above one's own interests (other humans or the biosphere), general awareness of the environmental problems (i.e. the New Ecological Paradigm (NEP) scale (see Dunlap, Van Liere, Mertig, & Jones, 2000), awareness of the adverse consequences of human behaviour on the environment, and ascription of responsibility to act to oneself activate a personal norm to save the environment. In turn, the activated personal norm is expected to influence different types of pro-environmental behaviour (see Figure 1).

Numerous studies have examined the relation between environmental attitudes and pro-environmental behaviours. For example, Nilsson and Küller (2000) found that higher environmental concern was related to shorter driving distances. Hence, more environmentally concerned individuals tend to display more pro-environmental travel behaviour. Using the VBN-theory, Nordlund and Garvill (2003) found that collective values (emphasizing the collective's interests above one's own interests), ecocentric values, and problem awareness were important for a personal norm. In turn, personal norm was positively related to willingness to reduce car use. Hence, in line with the VBN-theory, awareness of the environmental problems associated with transportation is related to behaviours albeit indirectly.

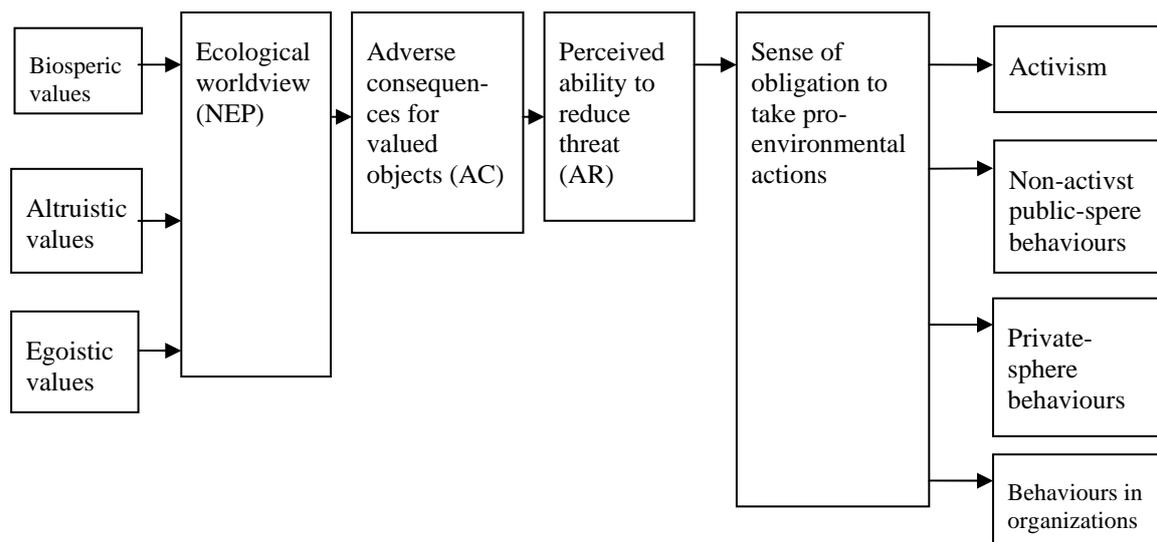


Figure 1 The value-belief-norm theory of environmentalism (Stern et al., 1999; Stern, 2000).

### 3.2.3 The theory of planned behaviour

There are other social psychological theories which may be helpful in explaining the relations between attitudes and behaviours. The theory of planned behaviour (TPB) (Ajzen, 1988, 1991) doesn't emphasize pro-environmental attitudes as an important determinant of behaviours but may nevertheless clarify how the perception of risk is related to pro-environmental behaviours. In short, the TPB stipulates that attitudes towards the behaviour (i.e. whether the behaviour is evaluated positively or negatively),

<sup>8</sup> The VBN-theory is based on the Norm activation theory (Schwartz, 1970), the theory of values (Schwartz, 1992; 1994), and the New Environmental Paradigm hypothesis (Dunlap & Van Liere, 1978; 1984).

subjective norm (i.e. the perception of whether important people think the individual should or should not perform the behaviour), and perceived behavioural control (PBC) (i.e. the perception of control over the behaviour) are important for the intention to perform a behaviour. In turn, the PBC and intention jointly predict behaviour. Figure 2 provides an overview of TPB. Other variables, such as, demographics, personality, and more general beliefs (e.g. awareness of environmental problems associated with the target behaviour) are believed to have indirect effects on behaviour.

Within the theoretical framework of the TPB, a few studies focusing on pro-environmental behaviour have included environmental attitudes. For example, Bamberg (2003) found that, in line with theoretical expectations, environmental concern had indirect effects on intention to request information about green electricity, through different beliefs, subjective norm, and perceived behavioural control. Moreover, De Groot and Steg (2007) found that environmental concern did not have a direct effect on intention to use a park and ride facility; instead environmental concern and attitude was directly related. Indirect effects were also identified in a meta-analysis about different pro-environmental behaviour (Bamberg & Möser, 2007).

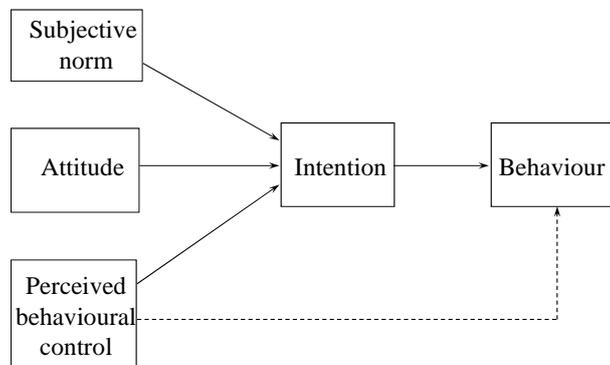


Figure 2 Theory of planned behaviour (Ajzen, 1988; 1991).

### 3.2.4 The transtheoretical model

While the VBN-theory highlights the relation between more general values and environmental beliefs on the one side, and pro-environmental behaviours on the other, the TPB focus more on behavioural specific cognitions. Both theories though describe motivational processes preceding behaviours, that is, factors important before an intention to act have been established. However, several distractions may hinder behaviours, for example, the intention may be to cycle but time pressure may cause the individual to take the car. Hence, it is also important to consider the process where attempts are made to carry out the behaviour. According to the transtheoretical model (TTM; Prochaska & DiClemente, 1983, 1984), changing behaviours is a process. The TTM stipulates that different decision stages as part of changing a behaviour. In the first stage, pre-contemplation, the individual lacks awareness that the behaviour is a problem and a behavioural change is not even considered. The second stage consists of contemplating a behavioural change. Even though individuals in this stage may perceive certain positive aspects associated with the new behaviour, negative aspects are still dominating. In the third stage, preparation, the individual has decided to carry out the behavioural change and is also testing the new behaviour. Individuals in the fourth stage, action, carry out the new behaviour, and in the fifth stage, maintenance, the new

behaviour has been carried out for a longer period of time. As discussed by Bamberg (2007), the intention to act is established after the contemplation and before the preparation phase. Moreover, in between the preparation phase and the action phase there is a need to plan how the new behaviour will be carried out. Studies have shown that forming so called implementation intentions, that is deciding where, when and how to perform a behaviour increases the likelihood that it will be carried out (Gollwitzer, 1993; see also Bamberg, 2000). As part of the action phase and the maintenance phase, the individual evaluates the outcomes of the new behaviour so that it is in line with the individual's expectations. In addition to highlighting different stages, the TTM stipulates ten processes of change as independent variables and decisional balance and self-efficacy/temptation as dependent variables. The processes of change constitute of experiential and behavioural change strategies, for example consciousness raising, stimulus control, and counter conditioning. The model further specifies that moving through the stages of change, the decisional balance changes from highlighting the cons of changing to highlighting the pros of changing. Moreover, self-efficacy increases during the later stages. An overview of the TTM is displayed in Figure 3.

Even though the TTM has mainly been used to understand changes of unhealthy behaviours, there are a few studies focusing on transportation behaviours. For example, Bamberg (2007) used the TTM to examine the change from using the car to using the public transportation. Even though it was difficult to distinguish between all five stages, the results indicate that, in line with expectations, the awareness that car use is a problem, the desire to change, and the intention to change are stronger in later stages compared to the pre-contemplation and the contemplation stages. Moreover, Gatersleben and Appleton (2007) examined the process of changing to cycling on work trips. Results demonstrated that attitudes towards cycling were more positive in later stages compared to earlier stages. In addition, it was mainly individuals in the pre-contemplation stage who perceived personal barriers, such as, perceiving cycling as uncomfortable, while structural barriers, such as perceiving cycling as unsafe, was highlighted by individuals in all stages of change. Hence, there are differences in how individuals at different stages evaluate environmental problems and the possibilities to act pro-environmentally.

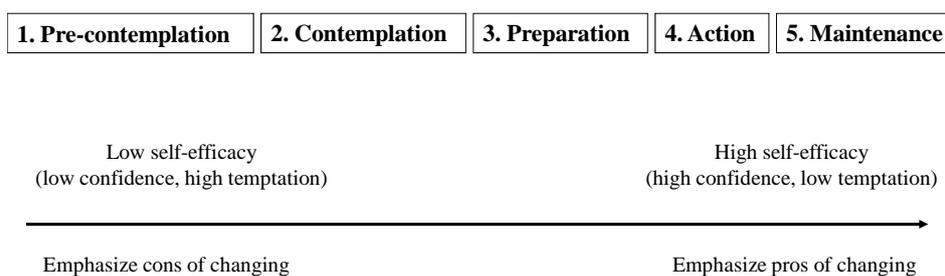


Figure 3 The transtheoretical model of change (Prochaska & DiClemente, 1983, 1984).

### 3.2.5 To sum up

Research on pro-environmental attitudes and behaviours has highlighted how these concepts are related. Different theories (e.g. the VBN-theory and the TPB) highlight various motivational factors, such as attitudes and problem awareness, important for pro-environmental behaviour. According to these theories, pro-environmental attitudes and behaviours are related, although mainly indirectly. Variables that have stronger effects on behaviours are, for example, different beliefs, personal and social norms, and/or perceived behavioural control. In addition to motivational factors, the TTM highlights volitional processes, such as, planning, as an important part of the behavioural change process. Hence, both motivational factors and volitional factors are important to consider in order to understand under what conditions pro-environmental behaviours are carried out.

Studies on pro-environmental attitudes and behaviours have examined individual differences on a disaggregate level (see e.g. Willis et al. 2005). In contrast to studies on risk perception, this approach has employed more general measures of how individuals perceive environmental problems and has often been less interested in examining different types of risks in the same study. Within this field of research, more effort has been on highlighting the connection (or lack of connection) between attitudinal factors and behaviours using social psychological theories. Quite a lot of the studies within this field of research have focused on transportation behaviour, often everyday travel behaviour including travel mode choice.

## 3.3 Concluding remarks

In psychological studies, terms such as environmental risk perception, environmental concern, problem awareness, and environmental attitudes have often been used when referring to subjective risk perception of environmental issues. Although there are a variety of different ways to assess subjective views on environmental risks, measures including the perceived consequences of environmental problems and to some extent affective dimensions, such as worry have been employed. While research on risk perception generally have included a variety of different environmental risks, research on pro-environmental attitudes and behaviour have often focused on one type of environmental risk (or activity) and instead highlighted the relation between risk perception, or environmental attitudes, and pro-environmental behaviours. A few studies have attempted to bridge the gap between the different research traditions (see Leiserowitz, 2006; Pahl et al., 2005; Slimak & Dietz, 2006; Willis & DeKay, 2007).

Overall, the review demonstrates a need to consider individuals' values, beliefs, and attitudes in order to understand environmental risk perception and behaviours with negative impacts on the environment. Moreover, we believe that economic choices, such as the willingness to pay in order to achieve a risk reduction can be discussed in relation to this frame of reference.

## 4 Discussion

An understanding of how individuals perceive environmental risks associated with transportation is important in order to formulate effective and acceptable policies. From an economic point of view, an improved understanding of factors underlying individuals' risk perception and pro-environmental behaviours or choices can contribute to an understanding of the "anomalies" discovered in economic research. McFadden (1999) have provided a good description of the "anomalies" discovered when comparing real decision with the economic model of rationality, examples are context effects, reference point effects, and process effects. Much research in recent years has been devoted to the analysis of how they influence choice and how they can be included in economic models relating to the environment. In addition to the previously mentioned texts on Behavioural Economics, there have for example been special issues in Environmental and Resource Economics that have focused upon issues related to stated preference studies and on the valuation of risk (ERE 2005 No. 32; 2006 No. 33 and 34). One example of how this has influenced economic choice studies is that they in addition to socio-economic variables such as sex and income can include measurements of the attitudes held by the individual. Since the study of attitudes has a long tradition within psychology, it is obviously beneficial to more thoroughly take psychological theories into account when examining choices in relation to environmental risks in economics.

Covering all these aspects and discussing what the benefits could be from combining psychological and economic findings is a daunting task that is not possible within the limits of this project. Hence, we will focus on what seems to be important issues in relation to individuals' choice behaviour and the interaction between transportation and the environment. As discussed by McFadden (1999), we believe that the interesting things to explore are the preferences underlying a decision and the process leading towards making a choice. More specifically, the question is how well psychological and economic models reflect the actual inputs used in a decision making process. There is also an interest in understanding how these inputs vary depending on the circumstances of choice. Can we for example expect that attitudes expressed regarding the importance of protection of the environment will actually materialize into action of some sort, be it changing travel mode, buying a more environmental friendly car or vote for a green party in government elections? This issue is often referred to as the attitude-behaviour gap in attitude research.

At the individual level it may be various aspects that are important for the outcome of a choice that could change environmental risk. As psychological research have shown (see e.g. Nordlund & Garvill, 2003), how a person experience a risk, whether he/she believes it is important for his/her wellbeing and/or others wellbeing is important for pro-environmental choices in combination with perceiving a personal responsibility to act. However, having a motivation to act may not be sufficient. In addition there is often a need to implement volitional strategies, such as planning, in order to counteract distracters that may otherwise hinder pro-environmental behaviour (see e.g. Bamberg, 2000). Hence, psychological studies show that there are many reasons as to why pro-environmental attitudes are never realized into pro-environmental action.

For economists there are also other aspects that are important in a choice context. First and foremost, economists believe that every choice implies a cost of some sort. It need not always be a monetary cost. If there are two travel modes to a destination that cost the same but where one is faster, then the slower implies a cost since less time can be spent at the destination. Or, travelling by bus to work offers less flexibility than going

by car since there is less room for changing plans (for example going to the movies after work is ruled out if there is no bus scheduled in the evenings). Since these factors may act as barriers against making pro-environmental choices they need to be accounted for when analyzing a choice situation.

Although there are important differences between traditional economic and psychological research on environmental risks, as this literature review has show, we believe they can complement one another. Overall, psychological theories can help explain why certain of the “anomalies” occur and point towards possible ways to study these issues in future research. Obtaining more information about pro-environmental choices and reasons underlying these choices will be helpful in designing environmental policies that are efficient while at the same time being acceptable to the general public. As in all other choices, designing policies involve a trade-off between different goals. A closer cooperation and understanding between psychology, economics and other related sciences is probably needed in order to better understand the problems of changing behaviour and by that achieving environmental change.

## 5 Integrated research – a questionnaire example

Based on the literature review and the previous discussion, we have designed a questionnaire where a choice involving an economic decision can be analyzed using psychological theories to help explain the outcome of the choice situation. The research issue we are interested in is if we can separate out individuals that are likely to make the choice if real from those who might have rather expressed an attitude. More specifically, the aim of the research would be to study the individuals' willingness to reduce the emissions from his/her own car use.

The hypothetical choice context is that car users would be able to change to a more environmentally friendly technology, converting a petrol engine to a hybrid, for a pre-specified sum of money. By varying the amount of money (e.g. 25,000 SEK versus 50,000 SEK) we would be able to study the willingness to pay (WTP) for reducing emissions. Moreover, we draw on psychological research to understand underlying reasons for making different choices. Hence, in addition to including questions about the individual's personal characteristics, his/her current car use, and WTP, we have added various questions concerning beliefs, attitudes, and norms (e.g. risk perception, perceived personal responsibility to act, and in which stage of change the individual is according to the TTM). We believe this would provide us with more information on how individuals reason when it comes to environmentally relevant economic choices. An example of the questionnaire is included in the Appendix. In a preliminary test, a small group of students answered the questionnaire by e-mail. The few responses we received indicated that the students understood the questions. Hence, the suggested questions may be valid in future studies of this topic.

The issue of identifying those that would actually make pro-environmental choices in real life is an important issue in relation to the use of so called stated choice studies, commonly referred to as hypothetical bias. Harrison (2006) discusses this issue and argues that hypothetical bias may manifest itself in the "buy something" versus the "buy nothing" stage in decision making. Perhaps it is possible to draw parallels to the different decision stages according to the TTM. A person in the preparation phase (i.e. in stage 3) may say they would do something although a lot of planning is still needed in order for the new behaviour to be carried out.

One explanation for a preference for the current situation, or statement of a zero willingness to pay, could be objections to the question as such, so called protest bids. Answers in a hypothetical setting may for example reflect individual's sentiment towards public authorities and also whether or not they consider the problem at hand to be something for the authorities to care about. Example of such behaviour is for example found in a contingent valuation study by Heberlein et al., (2005) where the estimated value to obtain control over fishing access was probably downward biased because the payment would be used to compensate a single group in society. Heberlein et al. (2005) however also found the same type of behaviour also for less emotionally sensitive goods and they therefore suggested that surveys preferably should include a deeper investigation of the reasons for the response behaviour, irrespective of if the scope test, that is if the willingness to pay increases as expected when more of a good/utility is offered, is passed or failed. Such an analysis has for example been performed by Viscusi et al. (2008) and in the type of study we suggest it would be possible to further explore these issues.

There is however also the possibility that people accept bids without considering the cost. One reason for this could for example be explained by what Thompson and

Gonzalez (1997) call sacred goods. These are goods that a decision maker deems unavailable for compromise or trade. It could also be that warm glow that is, paying for a good cause, is driving the responses. In these cases the stated values in valuation surveys may rather represent the contribution that people are willing to make to a good cause, hence payments due to moral satisfaction, rather than an actual purchase that people would make that would depend on the quantity of a good on offer (Ritov & Kahneman, 1997). In our survey we have tried to avoid asking questions about a good that could stir these types of sentiments. We have therefore chosen a situation that is closer to something that could be experienced in a real market.

The proposed questionnaire study is an initial attempt to integrate economical and psychological perspectives on environmental risks. Future research will show whether it is fruitful to use these psychological theories when examining hypothetical bias in economic valuation studies.

## References

- Ajzen, I. (1988). *Attitudes, personality, and behaviour*. Chicago: Dorsey Press.
- Ajzen, I. (1991). The theory of planned behaviour. *Organizational Behaviour and Human Decision Processes*, 50, 179–211.
- Andersson, H. & Lundborg, P. (2006). *Perceptions of own death risks. An analysis of road-traffic and overall mortality risks*. VTI-notat 12A-2006. [www.vti.se/publications](http://www.vti.se/publications)
- Bamberg, S. (2000). The promotion of new behaviour by forming an implementation intention: Results of a field experiment in the domain of travel mode choice. *Journal of Applied Social Psychology*, 30, 1903–1922.
- Bamberg, S. (2007). Is a stage model a useful approach to explain car drivers' willingness to use public transportation? *Journal of Applied Social Psychology*, 37, 1757–1783.
- Bamberg, S. & Möser, G. (2007). Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour. *Journal of Environmental Psychology*, 27, 14–25.
- Bamberg, S. & Schmidt, P. (2003). Incentives, morality, or habit? Predicting students' car use for university routes with the models of Ajzen, Schwartz, and Triandis. *Environment and Behaviour*, 35, 264–285.
- Bickel, P., Friedrich, R., Link, H., Stewart, L. & Nash, C. (2006). Introducing Environmental Externalities into Transport Pricing: Measurement and Implications. *Transport Reviews*, 26, 389–415.
- Bleaney M. & Stewart I. (1991). Economics and Related Disciplines. In D. Greenaway, M. Bleaney & I.M.T. Stewart (Eds). *Companion to Contemporary Economic Thought*. Routledge.
- Braga J. & Starmer C. (2005). Preference Anomalies, Preference Elicitation and the Discovered Preference Hypothesis. *Environmental and Resource Economics*, 32, 55–89.
- Camerer C.F. & Loewenstein G. (2004). Behavioural Economics: Past, Present and Future. In CF. Camerer, G. Loewenstein & M. Rabin (Eds). *Advances in Behavioural Economics*. Princeton: Princeton University Press.
- Cornes, R. & Sandler, T. (1996). *The Theory of Externalities, Public Goods and Club Goods*. Cambridge: University Press.
- Cropper, M.L. (2000). Has economic research answered the needs of environmental policy? *Journal of Environmental Economics and Management*, 39, 328–350.
- Dake, K. (1991). Orienting dispositions in the perception of risk: An analysis of contemporary worldviews and cultural biases. *Journal of Cross Cultural Psychology*, 22, 61–82.
- De Groot, J. I. M. & Steg, L. (2007). Value orientations and environmental beliefs in five countries. Validity of an instrument to measure egoistic, altruistic and biospheric value orientations. *Journal of Cross-Cultural Psychology*, 38, 318–332.
- Douglas, M. (1978). *Cultural bias*. Occasional Paper no 35, Royal Anthropological Institute of Great Britain and Ireland.
- Douglas, M. & Wildavsky, A. (1982). *Risk and culture*. Berkely, CA: University of California Press.

- Dunlap, R. E. & Jones, R. E. (2002). Environmental concern: Conceptual and measurement issues. In R. E. Dunlap & W. Michelson (Eds.), *Handbook of environmental sociology* (pp. 482–524). Westport Conn.: Greenwood Press.
- Dunlap, R. E. & Van Liere, K. D. (1978). The 'New Environmental Paradigm'. *Journal of Environmental Education*, 9, 10–19.
- Dunlap, R. E., Van Liere, K. D., Mertig, A. G., & Jones, R. E. (2000). Measuring endorsement of the New Ecological Paradigm: A revised NEP Scale. *Journal of Social Issues*, 56, 425–442.
- Elliott, S.J., Cole, D.C., Krueger, P., Voorberg, N. & Wakefield, S. (1999). The Power of Perception: Health Risk Attributed to Air Pollution in an Urban Industrial Neighbourhood. *Risk Analysis*, 19, 621–634.
- Finucane, M. L., Alhakami, A., Slovic, P. & Johnson, S. M. (2000). The affect heuristic in judgement of risks and benefits. *Journal of Behavioural Decision Making*, 13, 1–17.
- Fischer, G. W., Granger Morgan, M., Fischhoff, B., Nair, I. & Lave, L. B. (1991). What risks are people concerned about. *Risk Analysis*, 11, 303–314.
- Fischhoff, B., Slovic, P., Lichtenstein, S., Read, S. & Combs, B. (1978). How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. *Policy Sciences*, 8, 127–152.
- Fischhoff B. & Manski C.F. (1999). Editors' Introduction: Elicitation of Preferences. *Journal of Risk and Uncertainty*, 19, 5–6.
- Fransson, N. & Gärling, T. (1999). Environmental concern: Conceptual definitions, measurement methods, and research findings. *Journal of Environmental Psychology*, 19, 369–382.
- Gatersleben, B. & Appleton, K. M. (2007). Contemplating cycling to work: Attitudes and perceptions in different stages of change. *Transportation Research Part A*, 41, 302–312.
- Gattig, A. & Hendrickx, L. (2007). Judgemental discounting and environmental risk perception: Dimensional similarities, domain differences, and implications for sustainability. *Journal of Social Issues*, 63, 21–39.
- Gerking S. and Harrison G. W. (2006). Risk perception, Valuation and Policy. Introduction *Environmental and Resource Economics*, 33, 267–271.
- Gollwitzer, P. M. (1993). Goal achievement: The role of intentions. In W. Stroebe & M. Hewstone (Eds.), *European Review of Social Psychology* (Vol. 4, pp. 141–185). Chichester, England: Wiley.
- Grunert, S. C. & Juhl, H. J. (1995). Values, environmental attitudes, and buying of organic foods. *Journal of Economic Psychology*, 16, 39–62.
- Hanley N., Shogren J.F. & White B. (1997). *Environmental economics in Theory and Practice*. Macmillan Press Ltd.
- Harrison G. W. (2006). Experimental evidence on alternative environmental valuation methods. *Environmental and Resource Economics*, 34, 125–162.
- Heberlein T.A., Wilson M.A., Bishop R.C. & Schaeffer N C. (2005). Rethinking the scope test as a criterion for the validity of contingent valuation. *Journal of Environmental Economics and Management*, 50, 1–22.

- Hill, W.G., Butterfield, P. & Larsson, L.S. (2006). Rural partents' perceptions of risks associated with their children's exposure to radon. *Public Health Nursing*, 23, 392–399.
- Hultkrantz L., Li, C-Z. & Nerhagen L. (2003). *Fart eller miljö: Är avvägningarna rimliga?* Rapport 5271, Naturvårdsverket.
- Jaensirisak, S., Wardman, M. and Day, A.D. (2005). Explaining Variations in Public Acceptability of Road Pricing Schemes. *Journal of Transport Economics and Policy*, 39, 127–153.
- Johnson, B.B. (2003). Communicating air quality information: Experimental evaluation of alternative formats. *Risk Analysis*, 23, 91–103.
- Lazo, J. K., Kinnell, J. C. & Fischer, A. (2000). Expert and layperson perceptions of ecosystem risk. *Risk Analysis*, 20, 179–193.
- Leiserowitz, A. (2006). Climate change risk perception and policy preferences: The role of affect, imagery, and values. *Climate Change*, 77, 45–72.
- Loewenstein, G. F., Weber, E. U., Hsee, C. K. & Welch, N. (2001). Risk as feelings. *Psychological Bulletin*, 127, 267–286.
- Larson, B. A. & Rosen, S. (2002). Understanding household demand for indoor air pollution control in developing countries. *Social Science and Medicine*, 55, 571–584.
- McDaniels, T. L., Axelrod, L. J., Cavanagh, N. S. & Slovic, P. (1997). Perception of ecological risk to water environments. *Risk Analysis*, 17, 341–352.
- McDaniels, T. L., Axelrod, L. J. & Slovic, P. (1995). Characterizing perception of ecological risk. *Risk Analysis*, 15, 575–588.
- McFadden D. (1999) Rationality for Economists? *Journal of Risk and Uncertainty*, 19, 73–105.
- Modig, L. & Forsberg, B. (2006). *Besväröfrekomst i relation till luftföroreningshalten i tre svenska städer. En studie inom den hälsorelaterade miljöövervakningen 2005.* Slutrapport för del 1 inom projekt NR 215 0401. Institutionen för folkhälsa och klinisk medicin. Umeå Universitet.
- Navrud, S. (2001). Valuing health impacts from air pollution in Europe. *Environmental and Resource Economics*, 20, 305-329.
- Nerhagen, L., Forsberg, B., Johansson, C. & Lövenheim, B. (2005). *Luftföroreningarnas externa kostnader. Förslag på beräkningsmetod för trafiken utifrån granskning av ExternE-beräkningar för Stockholm och Sverige.* VTI-rapport 517. [www.vti.se/publications](http://www.vti.se/publications).
- Nerhagen, L. (2007). *Hälsoeffekter, påverkar de acceptansen för prissättning av vägtrafik?* VTI-rapport 582. [www.vti.se/publikationer](http://www.vti.se/publikationer)
- Nilsson, M., & Küller, R. (2000). Travel behaviour and environmental concern. *Transportation Research Part D*, 5, 211–234.
- Nordlund, A. M. & Garvill, J. (2002). Value structures behind proenvironmental behaviour. *Environment and Behaviour*, 34, 740–756.
- Nordlund, A. M. & Garvill, J. (2003). Effects of values, problem awareness, and personal norm on willingness to reduce personal car use. *Journal of Environmental Psychology*, 23, 339–347.

- O'Connor, R. E., Bord, R. J., & Fischer, A. (1999). Risk perceptions, general environmental beliefs, and willingness to address climate change. *Risk Analysis*, *19*, 461–471.
- Oltedal, S., Moen, B-E, Klempe, H. & Rundmo, T. (2004). *Explaining risk perception. An evaluation of cultural theory*. Trondheim: Rotunde Publikasjoner.
- Pahl, S., Harris, P. R., Todd, H. A. & Rutter, D. R. (2005). Comparative optimism for environmental risks. *Journal of Environmental Psychology*, *25*, 1–11.
- Payne, J. W., Bettman, J. R., Johnson, E. J. (1993). *The adaptive decision maker*. New York: Cambridge University Press.
- Pahaut, S. & Sikow, C. (2006). History of thought and prospect of road pricing. *Transport policy*, *13*, 173–176.
- Poortinga, W., Steg, L. & Vlek, C. (2002). Environmental risk concern and preferences for energy-saving measures. *Environment and Behaviour*, *34*, 455–478.
- Poortinga, W., Steg, L. & Vlek, C. (2004). Values, environmental concern, and environmental behaviour: A study into household energy use. *Environment and Behaviour*, *36*, 70–93.
- Prochaska, J. O. & DiClemente, C. C. (1983). Stages and processes of self-change in smoking: Toward an integrative model of change. *Journal of Consulting and Clinical Psychology*, *51*, 390–395.
- Prochaska, J. O. & DiClemente, C. C. (1984). *The transtheoretical approach: Crossing the traditional boundaries of change*. Homewood, IL: Irwin.
- Rauwald, K. & Moore, C. F. (2002). Environmental attitudes as predictors of policy support across three countries. *Environment and Behaviour*, *34*, 709–739.
- Raymond, L. (2003). *Private Rights in Public Resources. Equity and property allocation in market-based environmental policy*. RFF Press.
- Rayner, S., & Cantor, R. (1987). How fair is safe enough? The cultural approach to societal technology choice. *Risk Analysis*, *7*, 3–9.
- Ritov I. & Kahneman D. (1997). How people value the environment. In Tenbrunsel A.E., Wade-Benzoni K.A., Messick D.M. & Bazerman M.H. (Eds). *Environment, Ethics and Behaviour – The Psychology of Environmental Valuation and Degradation*. San Francisco: The New Lexington Press.
- Rose, C.M. (2002). Common Property, regulatory property, and environmental protection: comparing community-based management to tradable environmental allowances. In Ostrom E., Dietz T., Dolsak N., Stern P., Stonich S & Weber E.U. (Eds). *The Drama of the Commons*. National Academy Press.
- Rundmo, T. & Moen, B-E. (2006). Risk perception and demand for risk mitigation in transport: A comparison of lay people, politicians and experts. *Journal of Risk Research*, *9*, 623–640.
- Schade, J. & Schlag, B. (2003). Acceptability of urban transport pricing strategies. *Transportation Research Part F*, *6*, 45–61.
- Schmidt, L., Köhler, J., Persson, S., Hultin, K. & Tegnér, G. (2006). *Invånarnas upplevelser av stadsmiljön före och under Stockholmsförsöket 2005–2006*. Transek rapport nr. 2006:23.

- Schultz, P. W., Gouveia, V. V., Cameron, L. D., Tankha, G., Schmuck, P. & Franek, M. (2005). Values and their relationship to environmental concern and conservation behaviour. *Journal of Cross-Cultural Psychology*, 36, 457–475.
- Schultz, P. W. & Zelezny, L. (1999). Values as predictors of environmental attitudes: Evidence for consistency across 14 countries. *Journal of Environmental Psychology*, 19, 255–265.
- Schütz, H., & Wiedemann, P. M. (1998). Judgements of personal and environmental risks of consumer products – Do they differ? *Risk Analysis*, 18, 119–129.
- SEPA (Swedish Environmental Protection Agency). (2002/03). *Environmental impact from different modes of transport. – Method of comparison*. Report 5183. Stockholm: SEPA.
- Shogren J.F. & Taylor L.O. (2008). On Behavioural-Environmental Economics. *Review of Environmental Economics and Policy*, 2, 26–44.
- Simon H.A. (1955). A behavioural model of rational choice. *Quarterly Journal of Economics*, 69, 99–118.
- Sjöberg, L. (1996). A discussion of the limitations of the psychometric and cultural theory approaches to risk perception. *Radiation Protection Dosimetry*, 68, 219–225.
- Sjöberg, L. (1998). Worry and risk perception. *Risk Analysis*, 18, 85–93.
- Sjöberg, L. (2000). Factors in risk perception. *Risk Analysis*, 20, 1–11.
- Sjöberg, L., Moen, B-E. & Rundmo, T. (2004). *Explaining risk perception. An evaluation of the psychometric paradigm in risk perception research*. Trondheim: Rotunde Publikasjoner.
- Slimak, M. W., & Dietz, T. (2006). Personal values, beliefs, and ecological risk perception. *Risk Analysis*, 26, 1689–1705.
- Slovic, P., Fischhoff, B. & Lichtenstein, S. (1985). Characterizing perceived risk. In R. W. Kates, C. Hohenemser & J. X. Kaspersen (Eds.). *Perilous Progress: Managing the hazards of technology* (pp. 91–125). Boulder, CO: Westview Press.
- Socialstyrelsen (2001). *Folkhälsorapport 2001*. Artikelnr. 2001-111-2.
- Socialstyrelsen (2005). *Folkhälsorapport 2005*. Artikelnr. 2005-111-2.
- Sugden R. (2005) Anomalies and Stated Preference Techniques: A Framework for a Discussion of Coping Strategies. *Environmental and Resource Economics*, 32, 1–12.
- Sundblad, E-L., Biel, A. & Gärling, T. (2007). Cognitive and affective risk judgements related to climate change. *Journal of Environmental Psychology*, 27, 97–106.
- Steg, L. & Sievers, I. (2000). Cultural theory and individual perceptions of environmental risks. *Environment and Behaviour*, 32, 250–269.
- Stern, P. C. (2000). Toward a coherent theory of environmentally significant behaviour. *Journal of Social Issues*, 56, 407–424.
- Stern, P. C., Dietz, T., Abel, T., Guagnano, G. A. & Kalof, L. (1999). A value-belief-norm theory of support for social movements: The case of environmentalism. *Human Ecology Review*, 6, 81–97.

- Thompson L.L. & Gonzalez R. (1997). Environmental disputes – Competition for Scarce Resources and Clashing of Values. In A.E. Tenbrunsel, K.A. Wade-Benzoni, D.M. Messick & M. H. Bazerman (Eds). *Environment, Ethics and Behaviour – The Psychology of Environmental Valuation and Degradation*. San Francisco: The New Lexington Press.
- Uzzell, D. L. (2000). The psycho-spatial dimension of global environmental problems. *Journal of Environmental Psychology*, 20, 307–318.
- Walsh-Daneshmandi, A. & MacLachlan, M. (2000). Environmental risk to the self: Factor analysis and development of subscales for the environmental appraisal inventory (EAI) with an Irish sample. *Journal of Environmental Psychology*, 20, 141–149.
- Van Raaij W.F. (1991). Economics and Psychology. In D. Greenaway, M. Bleaney & I.M.T. Stewart (Eds). *Companion to Contemporary Economic Thought*. Routledge.
- Viscusi K. & Gayer (2005) Quantifying and valuing environmental health risks. In K-G. Mäler & J.R. Vincent (Eds). *Handbook of Environmental Economics, Volume 2*. Elsevier B.V.
- Viscusi W.K., Huber J. & Bell J. (2008) The economic value of water quality. *Environmental Resource Economics*, 41, 169–187.
- Whitmarsh, L. (2009). Behavioural responses to climate change: Asymmetry of intentions and impacts. *Journal of Environmental Psychology*, 29, 13–23.
- Wilkinson N. (2008). *An Introduction to Behavioural Economics*. Palgrave Mcmillan.
- Willis, H. H., & DeKay, M. L. (2007). The roles of group membership, beliefs, and norms in ecological risk perception. *Risk Analysis*, 27, 1365–1380.
- Willis, H. H., DeKay, M. L., Fischhoff, B., & Morgan, G. (2005). Aggregate, disaggregate, and hybrid analyses of ecological risk perceptions. *Risk Analysis*, 25, 405–428.



## Appendix

### EN STUDIE OM BILEN, RESANDE OCH MILJÖRISKER

Vid Statens väg och transportforskningsinstitut (VTI) pågår just nu ett forskningsprojekt om hur trafikanter upplever olika miljörisker. Vi är intresserade av vad Du anser om dessa frågor och det finns inga svar som är rätt eller fel. Resultaten kommer endast att redovisas i statistisk bearbetad form och alla deltagare är anonyma. Din medverkan är frivillig men vi är givetvis tacksamma ifall Du har möjlighet att fylla i formuläret. Om Du har frågor går det bra att kontakta oss på nedanstående e-post adresser. Frågeformuläret *ska endast* besvaras av personer som har körkort och tillgång till bil.

Det ifyllda formuläret skickas till: [louise.eriksson@vti.se](mailto:louise.eriksson@vti.se)

Louise Eriksson  
VTI Linköping  
[louise.eriksson@vti.se](mailto:louise.eriksson@vti.se)

Lena Nerhagen  
VTI Borlänge  
[lana.nerhagen@vti.se](mailto:lana.nerhagen@vti.se)

#### FRÅGOR OM DITT RESANDE

**1. Hur ofta använder Du nedan angivna färdssätt för resor till arbete, för inköp och för övriga resor? (Kryssa för det svarsalternativ som bäst svarar mot Din uppfattning för varje typ av resa)**

	Mindre än 1 ggr/mån	1-3 ggr/ mån	1-2 ggr/ vecka	3-4 ggr/ vecka	5 ggr/vecka eller mer
<b>Bil</b>					
till arbete/studier	<input type="checkbox"/>				
för inköpsresor	<input type="checkbox"/>				
för övriga resor (t ex. resor på fritiden, hämta/lämna någon)	<input type="checkbox"/>				
<b>Kollektiva färdmedel ex. buss, tåg</b>					
till arbete/studier	<input type="checkbox"/>				
för inköpsresor	<input type="checkbox"/>				
för övriga resor (t ex. resor på fritiden, hämta/lämna någon)	<input type="checkbox"/>				
<b>Cykel/gång</b>					
till arbete/studier	<input type="checkbox"/>				
för inköpsresor	<input type="checkbox"/>				
för övriga resor (t ex. resor på fritiden, hämta/lämna någon)	<input type="checkbox"/>				

2. Vilket av följande påståenden beskriver bäst Din användning av cykel, gång och kollektiva färdmedel (ex. buss) på RESOR KORTARE ÄN 1 MIL? (Kryssa endast i en av rutorna som bäst stämmer överrens med Din uppfattning)

- Jag använder inte cykel, gång eller kollektiva färdmedel regelbundet och jag planerar inte att göra det inom de närmaste 6 månaderna.
- Jag använder inte cykel, gång eller kollektiva färdmedel regelbundet men jag funderar på att börja göra det inom de närmaste 6 månaderna.
- De senaste sex månaderna har jag sporadiskt prövat att använda cykel, gång eller kollektiva färdmedel.
- Jag använder cykel, gång eller kollektiva färdmedel regelbundet och har gjort det de senaste 6 månaderna.
- Jag använder cykel, gång eller kollektiva färdmedel regelbundet och har regelbundet gjort det i minst 6 månader.
- Tills helt nyligen använde jag cykel, gång eller kollektiva färdmedel men har slutat göra det.

3. Vilket av följande påståenden beskriver bäst Din användning av kollektiva färdmedel (ex. buss, tåg) på RESOR MELLAN 1 och 10 MIL? (Kryssa endast i en av rutorna som bäst stämmer överrens med Din uppfattning)

- Jag använder inte kollektiva färdmedel regelbundet och jag planerar inte att göra det inom de närmaste 6 månaderna.
- Jag använder inte kollektiva färdmedel regelbundet men jag funderar på att börja göra det inom de närmaste 6 månaderna.
- De senaste sex månaderna har jag sporadiskt prövat att använda kollektiva färdmedel.
- Jag använder kollektiva färdmedel regelbundet och har gjort det de senaste 6 månaderna.
- Jag använder kollektiva färdmedel regelbundet och har regelbundet gjort det i minst 6 månader.
- Tills helt nyligen använde jag kollektiva färdmedel men har slutat göra det.

## FRÅGOR OM BILEN OCH MILJÖRISKER

4. I vilken utsträckning anser Du att bilanvändning leder till följande miljörisker? (Markera den siffra som bäst svarar mot Din uppfattning)

	Inte alls							I mycket stor utsträckning
	1	2	3	4	5	6	7	
Luftföroreningar	1	2	3	4	5	6	7	
Klimatförändringar	1	2	3	4	5	6	7	
Buller	1	2	3	4	5	6	7	

**5. Hur troligt anser Du att det är att luftföroreningar från bilanvändning leder till att:** (Markera den siffra som bäst svarar mot Din uppfattning)

	Inte alls troligt						Mycket troligt
din hälsa försämras?	1	2	3	4	5	6	7
andra människors hälsa försämras?	1	2	3	4	5	6	7
miljön i Din närhet försämras?	1	2	3	4	5	6	7
den globala miljön försämras?	1	2	3	4	5	6	7

**6. I vilken utsträckning är Du orolig för att luftföroreningar orsakade av bilanvändning leder till att:** (Markera den siffra som bäst svarar mot Din uppfattning)

	Inte alls orolig						Mycket orolig
din hälsa försämras?	1	2	3	4	5	6	7
andra människors hälsa försämras?	1	2	3	4	5	6	7
miljön i Din närhet försämras?	1	2	3	4	5	6	7
den globala miljön försämras?	1	2	3	4	5	6	7

**7. Hur troligt anser Du att det är att klimatförändringar orsakade av bilanvändning leder till att:** (Markera den siffra som bäst svarar mot Din uppfattning)

	Inte alls troligt						Mycket troligt
din hälsa försämras?	1	2	3	4	5	6	7
andra människors hälsa försämras?	1	2	3	4	5	6	7
miljön i Din närhet försämras?	1	2	3	4	5	6	7
den globala miljön försämras?	1	2	3	4	5	6	7

**8. I vilken utsträckning är Du orolig för att klimatförändringar orsakade av bilanvändning leder till att:** (Markera den siffra som bäst svarar mot Din uppfattning)

	Inte alls orolig						Mycket orolig
din hälsa försämras?	1	2	3	4	5	6	7
andra människors hälsa försämras?	1	2	3	4	5	6	7
miljön i Din närhet försämras?	1	2	3	4	5	6	7
den globala miljön försämras?	1	2	3	4	5	6	7

**9. Hur troligt anser Du att det är att buller orsakade av bilanvändning leder till att:** (Markera den siffra som bäst svarar mot Din uppfattning)

	Inte alls troligt						Mycket troligt
din hälsa försämras?	1	2	3	4	5	6	7
andra människors hälsa försämras?	1	2	3	4	5	6	7
miljön i Din närhet försämras?	1	2	3	4	5	6	7
den globala miljön försämras?	1	2	3	4	5	6	7

**10. I vilken utsträckning är Du orolig för att buller orsakade av bilanvändning leder till att:** (Markera den siffra som bäst svarar mot Din uppfattning)

	Inte alls orolig						Mycket orolig
din hälsa försämras?	1	2	3	4	5	6	7
andra människors hälsa försämras?	1	2	3	4	5	6	7
miljön i Din närhet försämras?	1	2	3	4	5	6	7
den globala miljön försämras?	1	2	3	4	5	6	7

**11. Nedan följer ett antal påstående om vad Du anser om resor med bil samt olika miljörisiker. Ange i vilken utsträckning Du instämmer i eller tar avstånd från vart och ett av påståendena:** (Markera den siffra som bäst svarar mot Din uppfattning)

	Tar helt avstånd ifrån						Instämmer helt
Alla bilanvändare har ett ansvar för att minska luftföroreningar från bilanvändningen.	1	2	3	4	5	6	7
Alla bilanvändare har ett ansvar för att minska klimatförändringar orsakade av bilanvändningen.	1	2	3	4	5	6	7
Alla bilanvändare har ett ansvar för att minska buller orsakade av bilanvändningen.	1	2	3	4	5	6	7
Jag upplever ett personligt ansvar för att minska luftföroreningar från bilanvändningen.	1	2	3	4	5	6	7
Jag upplever ett personligt ansvar för att minska klimatförändringar orsakade av bilanvändningen.	1	2	3	4	5	6	7
Jag upplever ett personligt ansvar för att minska buller från bilanvändningen.	1	2	3	4	5	6	7
Jag upplever en moralisk skyldighet att minska luftföroreningar orsakade av bilanvändningen.	1	2	3	4	5	6	7
Jag upplever en moralisk skyldighet att minska klimatförändringar orsakade av bilanvändningen.	1	2	3	4	5	6	7
Jag upplever en moralisk skyldighet att minska buller orsakade av bilanvändningen.	1	2	3	4	5	6	7

## FRÅGOR OM DIG

12. Jag är  Kvinna  Man

13. Jag är \_\_\_\_\_ år

14. Min högsta genomförda utbildning är:

- Grundskola/folkskola  
 Gymnasieskola/folkhögskola  
 Universitet/högskola  
 Annat: \_\_\_\_\_

15. Ungefär hur hög är Ditt hushålls sammanlagda inkomst per månad före skatt (inkludera alla slags inkomster, t ex sjukpenning, föräldrapenning, studiemedel, arbetslöshetsersättning etc.).

- 10000 kronor eller mindre  40001-50000 kronor  80001-90000 kronor  
 10001-20000 kronor  50001-60000 kronor  90001-100000 kronor  
 20001-30000 kronor  60001-70000 kronor  Mer än 100000 kronor  
 30001-40000 kronor  70001-80000 kronor

16. Hur långt är det mellan Din bostad och följande platser i kilometer:

	Avstånd	Vet ej
Närmaste hållplats för kollektiva färdmedel t ex buss	_____ km	<input type="checkbox"/>
Närmaste cykelbana	_____ km	<input type="checkbox"/>
Affären där Du/Ni huvudsakligen gör inköp av livsmedel	_____ km	<input type="checkbox"/>
Barnens skola/förskola	_____ km	<input type="checkbox"/> Har inga barn <input type="checkbox"/>
Mitt arbete eller skola där jag studerar	_____ km	<input type="checkbox"/>

17. Hur många bilar finns det i hushållet?

- 0 bilar  
 1 bil  
 2 bilar  
 3 bilar eller fler  
(Om Du inte har någon bil i hushållet gå vidare till Fråga 23.)

18. Vilken bil kör Du vanligtvis?

Märke: \_\_\_\_\_ Årsmodell: \_\_\_\_\_

19. Hur många mil kör Du ungefär per år? \_\_\_\_\_ mil

20. Ungefär hur mycket bränsle förbrukar den bil Du vanligtvis kör per kilometer?

\_\_\_\_\_ per kilometer

21. Vilket bränsle använder Du i bilen Du vanligtvis kör? \_\_\_\_\_

(Om Du endast använder fossila bränslen såsom bensin eller diesel gå vidare till Fråga 23).

22. Om Du vanligtvis kör en bil som kan köras på alternativa bränslen (t ex etanol, biogas, el) är den bilen dyrare eller billigare än en vanlig bil med liknande utförande och prestanda:

- Nej
- Ja, inköpskostnaden ökade/minskade med ..... kronor
- Ja, driftskostnaden ökade/minskade med ..... kr/mil
- Annat: \_\_\_\_\_

23. Funderar Du på att köpa en ny bil inom 6 månader?

- Nej
- Ja, en bensinbil
- Ja, en dieselbil
- Ja, en etanolbil, biogasbil eller hybridbil

## FRÅGOR OM DITT FRAMTIDA RESANDE OCH MILJÖN

24. Nedan följer ett antal påståenden om vad Du och andra skulle kunna göra för att minska bilens påverkan på miljön. Ange i vilken utsträckning Du instämmer i eller tar avstånd från vart och ett av påståendena: (Markera den siffra som bäst svarar mot Din uppfattning)

	Tar helt avstånd ifrån					Instämmer helt	
Minskad bilanvändning reducerar privata transporters negativa effekter på miljön.	1	2	3	4	5	6	7
Ökad användning av buss, tåg, cykel och gång minskar privata transporters negativa effekter på miljön.	1	2	3	4	5	6	7
Ökad användning av bilar som drivs av alternativa drivmedel (t ex etanol, biogas, el) minskar privata transporters negativa effekter på miljön.	1	2	3	4	5	6	7
Högre skatt på fossila drivmedel minskar privata transporters negativa effekter på miljön.	1	2	3	4	5	6	7
Högre skatt som används för att förbättra möjligheterna att gå, cykla eller åka kollektivt minskar privata transporters negativa effekter på miljön.	1	2	3	4	5	6	7

25. Nedan följer ett antal påståenden om vad Du skulle kunna göra för att minska bilens påverkan på miljön. Ange i vilken utsträckning Du instämmer i eller tar avstånd från vart och ett av påståendena: (Markera den siffra som bäst svarar mot Din uppfattning)

	Tar helt avstånd ifrån					Instämmer helt	
Jag är villig att minska min bilanvändning för att reducera privattransporters negativa effekter på miljön.	1	2	3	4	5	6	7
Jag är villig att välja färdmedel såsom buss, tåg, cykel och gång för att reducera privattransporters negativa effekter på miljön.	1	2	3	4	5	6	7
Jag är villig att köpa en bil som drivs av alternativa drivmedel (t ex etanol, biogas, el) för att reducera privattransporters negativa effekter på miljön.	1	2	3	4	5	6	7
Jag är villig att betala en högre skatt på fossila drivmedel för att reducera privattransporters negativa effekter på miljön.	1	2	3	4	5	6	7
Jag är villig att betala en högre skatt för att förbättra möjligheterna att gå, cykla eller åka kollektivt.	1	2	3	4	5	6	7

26. Hur lätt eller svårt skulle det vara för Dig att utföra de alternativ som uppgavs i fråga 25? (Markera den siffra som bäst svarar mot Din uppfattning)

	Mycket lätt		Varken lätt eller svårt			Mycket svårt	
Minska Din bilanvändning	1	2	3	4	5	6	7
Välja alternativa färdmedel såsom buss, tåg, cykel och gång	1	2	3	4	5	6	7
Köpa en bil som drivs av alternativa drivmedel (t. ex. etanol, biogas eller el)	1	2	3	4	5	6	7
Betala en högre skatt på fossila drivmedel	1	2	3	4	5	6	7
Betala en högre skatt för att förbättra möjligheterna att gå, cykla eller åka kollektivt	1	2	3	4	5	6	7

27. I vilken utsträckning upplever Du blandade känslor (dvs. både positiva och negativa känslor) gentemot att använda bilen för Dina vardagliga resor? (Markera den siffra som bäst svarar mot Din uppfattning)

Inte alls						I mycket stor utsträckning
1	2	3	4	5	6	7

**Läs följande innan Du svarar på den sista frågan!**

Forskningen kring nya bilar som orsakar mindre utsläpp pågår. En teknik som redan finns är hybridbilen, en bil som kan köras både på bensin men också med elmotor eller på batteri. De senare kan användas vid stadskörning vilket innebär mindre utsläpp av luftföroreningar och buller i tätbefolkade områden. Hybridbilar innebär också en minskning av bränsleförbrukningen per km jämfört med vanliga bensinbilar vilket medför mindre utsläpp av klimatpåverkande gaser. En genomsnittlig svensk bil förbrukar ungefär 0,82 liter per mil medan förbrukningen för en hybridbil är ungefär 0,42 liter per mil. En minskad förbrukning med 0,40 liter per mil innebär att bensinkostnaden minskar med 4,80 kronor per mil om bensinen kostar 12 kronor. För en person som kör 1 500 mil per år innebär det att bensinkostnaden minskar med 7200 kr/år.

28. Antag att teknik utvecklas som gör det möjligt att enkelt omvandla en vanlig bil (bensin eller diesel) till en hybridbil. Genom att installera denna teknik i Din bil skulle Du kunna minska Din påverkan på miljön. Det kostar 25 000 kronor att installera tekniken och den innebär att Din nuvarande bränsleförbrukning halveras. Skulle Du välja att installera denna teknik om den fanns tillgänglig idag?

- Nej eftersom \_\_\_\_\_  
\_\_\_\_\_
- Ja, kanske
- Ja det skulle jag vilja göra
- Vet ej

Övriga kommentarer till enkäten:

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**TACK FÖR DIN MEDVERKAN!**

## **DEL 2** Planering av en simulatorstudie

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Rapporten innehåller ett projektförslag som nu ligger till grund för en ansökan om medel för finansiering av studiens genomförande.



## 1 Bakgrund

Larsson (2009) inleder sin licentiatuppsats med en diskussion om att det inte räcker med bara teknikutveckling för att minska trafikens miljöpåverkan. Hon skriver t.ex.

"Förutom att anpassa trafikmiljön och förbättra fordonsegenskaperna för att minska bränsleförbrukningen och emissionerna handlar det också om att påverka hur och var föraren kör." Att körbeteendet påverkar vår miljö kan vi vara säkra på men hur det påverkar och relationen mellan olika faktorer påverkan är av intresse att studera.

En genomgång av litteratur kring effekter på emissioner av EcoDriving finns i Smokers et al. (2006). Av de studier som refereras är de flesta fältstudier och någon datorsimulering. En sammanställning ger att korttidseffekt av EcoDrivingutbildning, alltså direkt efter utbildning, ger en minskning av emissioner på 10 % och att långtidseffekt, 1 år efter utbildning, ligger minskningen runt 3 %.

En fältstudie (Dahlstedt, 2002) som undersöker effekten av olika körförlopp har genomförts på gator i Linköping och Norrköping. Resultaten visar på att bränsleförbrukningen påverkas av både vilken förargrupp (utbildning och vana) och vilken instruktion (normal, bråttom eller snålkörning) som ges.

I en fältstudie varierar omgivande trafikmiljö för varje försöksperson medan en stor fördel med att genomföra en studie i simulator är möjligheten att styra den omgivande miljön så att det blir lika för alla försökspersoner. Förutsättningarna och möjligheterna att i en virtuell miljö studera miljörelaterade effekter av olika faktorer är därför mycket goda. Aktuella faktorer kan härröra från föraren (variation i körbeteende på grund av t.ex. kunskap, erfarenhet, och attityd rörande miljökonsekvenser), fordonet (t.ex. skillnader mellan personbil och lastbil eller beroende på olikheter rörande däck och annan utrustning), vägens utformning (t.ex. kurvatur, beläggning och hastighetsgräns), situationer och förhållanden – särskilt oplanerade – längs vägen (t.ex. väglag, annan trafik, skyltning och signaler). Få sådana studier har genomförts trots de satsningar och prioriteringar som görs på miljöområdet.

## 2 Syfte och mål

Med syfte att ta fram kunskap om och skapa förståelse för relationen mellan olika faktorer påverkan på miljön (via bränsleförbrukning och utsläpp) har en simulatorstudie planerats. I en sådan studie blir det möjligt att undersöka vilka åtgärder som på effektivaste sätt minskar de negativa miljöeffekterna. För en sådan känslighetsanalys krävs ett tillvägagångssätt där kombinationer av olika faktorer studeras på ett strukturerat sätt. Kanske är effekten av någon faktor försumbar jämfört med effekterna av de övriga, eller kanske effekterna av vissa faktorer tar ut varandra.

Projektets mål är att beskriva hur val av vinterdäck (dubbade eller odubbade) påverkar körbeteendet och hur kombinationen av däck och körbeteende påverkar energiförbrukning (bränsle), avgasutsläpp, beläggningsslitage, partikelemissioner (PM<sub>10</sub>) och trafiksäkerhet. Studien begränsas till personbilar och på vinterväg med halka. En viktig fråga att studera är hur körbeteendet påverkas av om föraren genomgått EcoDrivingutbildning och även långtidseffekten av en sådan utbildning. Skillnaden i körbeteende mellan förare som vanligen använder dubbade vinterdäck och förare som använder odubbade däck ska också studeras. Det är alltså inte endast effekten av däckvalet i sig, utan även hur förarens körbeteende tillsammans med däcktyp påverkar energiförbrukning, avgasutsläpp, beläggningsslitage, partikelemissioner och trafiksäkerhet, som ska klarläggas.

### 3 Projektförslag

Det föreslagna projektet innehåller delarna:

**Implementering av Modeller,  
Simulatorförsök  
Seminarier och workshop.**

#### 3.1 Implementering av modeller

För att genomföra denna typ av projekt i VTI:s simulatorer behöver modeller för bränsleförbrukning, slitage och emissioner anpassas och implementeras i simulatorerna.

Arbetet med att implementera bränsleförbrukningsmodellen har påbörjats under hösten 2009. Slitagemodellen kommer att kompletteras med en partikelemissionsmodul under 2010 inom ramen för ett Road Technologyprojekt (RT10-044). Slitage- och partikelemissionsmodellerna behöver dock anpassas för att kunna implementeras i simulatorerna.

Dubbdäckparametrar behöver också mätas in för att kunna användas som indata i de däckmodeller som finns implementerade i simulatorerna.

#### 3.2 Simulatorförsök

##### Frågeställningar

Projektet förväntas ge svar på följande frågeställningar:

1. Hur körbeteendet påverkas av att man kör med dubbade eller odubbade vinterdäck.
2. Hur körbeteendet påverkas av om man är van att köra med dubbade eller odubbade vinterdäck.
3. Hur körbeteendet påverkas av att man genomgått EcoDriving-utbildning.
4. Hur effekter av EcoDriving-utbildning kvarstår efter några år.
5. Hur **energiförbrukningen** (bränsle) påverkas av ändrat körbeteende.
6. Hur **avgasutsläppen** påverkas av ändrat körbeteende.
7. Hur emissionen av **partiklar** till omgivningen påverkas av ändrat körbeteende.
8. Hur risken för en **olycka** påverkas av ändrat körbeteende.

##### Försöksdesign

En mixed design kommer att väljas som i detta sammanhang innebär att alla försökspersoner kör båda betingelserna (inomindividsdesign), dubbade och odubbade däck. Försökspersonerna kommer att rekryteras utifrån vana vid körning med olika däcktyper och EcoDriving-utbildning nyligen genomgången och genomgången för några år sedan (mellangrupsdesign) för att möta de aktuella frågeställningarna.

För att få en bra uppfattning om betydelsen av körbeteendet kommer försökspersonerna få köra i två olika scenario, ett stressat under tidspress och ett lugnt utan tidspress. I båda scenarierna kommer försökspersonerna att köra en körning med dubbdäck och en med odubbade vinterdäck.

Försöket körs i halt väglag. Graden av halka och händelsernas skärpa trimmas in i pilotkörningar före det ”skarpa” försöket. Varje körning startar med en sträcka utan halka den sträckan används sedan som referenssträcka.

Fördelning av olika grupper av försökspersoner och körordning med de olika däcken: 60 försökspersoner (FP).

Körning 1 Körning 2 Körning 3 Körning 4

EcoDriving utbildning 20 FP	Kör dubbat 10 FP	Dubbat 5 FP	Odubbat 5 FP	Dubbat 5 FP	Odubbat 5 FP
		Odubbat 5 FP	Dubbat 5 FP	Odubbat 5 FP	Dubbat 5 FP
	Kör odubbat 10 FP	Dubbat 5 FP	Odubbat 5 FP	Dubbat 5 FP	Odubbat 5 FP
		Odubbat 5 FP	Dubbat 5 FP	Odubbat 5 FP	Dubbat 5 FP
Ej EcoDriving utbildning 20 FP	Kör dubbat 10 FP	Dubbat 5 FP	Odubbat 5 FP	Dubbat 5 FP	Odubbat 5 FP
		Odubbat 5 FP	Dubbat 5 FP	Odubbat 5 FP	Dubbat 5 FP
	Kör odubbat 10 FP	Dubbat 5 FP	Odubbat 5 FP	Dubbat 5 FP	Odubbat 5 FP
		Odubbat 5 FP	Dubbat 5 FP	Odubbat 5 FP	Dubbat 5 FP
Äldre EcoDriving utbildning 20 FP	Kör dubbat 10 FP	Dubbat 5 FP	Odubbat 5 FP	Dubbat 5 FP	Odubbat 5 FP
		Odubbat 5 FP	Dubbat 5 FP	Odubbat 5 FP	Dubbat 5 FP
	Kör odubbat 10 FP	Dubbat 5 FP	Odubbat 5 FP	Dubbat 5 FP	Odubbat 5 FP
		Odubbat 5 FP	Dubbat 5 FP	Odubbat 5 FP	Dubbat 5 FP

Varannan försöksperson startar med det lugna scenariot körning 1 och 2 och varannan startar med det stressade. Därefter byts scenario för körning 3 och 4 till det stressade respektive det lugna.

### Genomförande av försöket

Varje försöksperson får börja sin körning i simulatormen med en träningssträcka som tar ca 5 minuter att köra. Under träningssträckan får försökspersonen köra delar av den

vägmiljö som ingår i försöket. Försöksledaren har kontakt med försökspersonen under hela träningen.

Efter träningen startar försöket med att försökspersonen får läsa igenom en scenario-beskrivning. Försökspersonerna kör sedan en teststräcka som innehåller både tätortsmiljö och landsbygdsmiljö. De kör hela teststräckan två gånger, en gång med dubbdäck och en gång med odubbade däck. Vid båda körningarna av försöksrutten kommer ett antal händelser att inträffa där det krävs en aktiv handling från försökspersonen. Händelserna kan vara ändrad tillåten hastighet, ett trafikljus som växlar till rött (tätort), upphinnande av långsamt fordon (landsväg) eller att en buss kör ut från en hållplats (tätort). Händelserna inträffar under båda körningarna men platsen för händelser varierar mellan körning 1 och 2.

När de två körningarna är klara får försökspersonen läsa en ny scenariobeskrivning och därefter upprepa de två körningarna med det nya scenariot (körning 3 och 4).

Under körningarna har försöksledaren normalt inte kontakt med försökspersonen, men skulle något onormalt inträffa kan kontakt tas.

Total tidsåtgång för träning och körning av teststräckan fyra gånger är ca 45 minuter. Försöket beräknas ta 10 dagar att köra och till det kommer ytterligare 3 pilotdagar i simulator för intrimning av försöket.

Energiförbrukning, avgasutsläpp, partikelutsläpp och slitage kommer att mätas kontinuerligt under hela försöket. Detta gäller även för hastighet och sidoläge. Vid händelserna kommer även andra effekter att mätas såsom tidlucka till framförvarande, tid till kollision(TTC), reaktionstid och stoppsträcka. Eventuella oönskade händelser såsom avåkning/sladd eller beteendeförändringar (bromsa/styra) kommer också att studeras. Till dessa mått kommer också subjektiva mått där försökspersonerna får besvara frågor om sina upplevelser av körningarna och skatta hur belastande de olika körningarna var.

### 3.3 Resurser och tidplan

Anpassning och implementering av modeller för beräkning av partiklar och slitage samt  
inmätning av däcksparmetrar 300 000 kr

Simulatorstudie 1 690 000 kr

Planering, grafik och programmering 600 000 kr

Försöksledare 150 000 kr

Simulatorhyra 13 dagar 390 000 kr

Arvoden till försökspersoner 50 000 kr

Analys och rapportering 400 000 kr

Vetenskaplig artikel 100 000 kr

Seminarier och workshop 200 000 kr

Demo för att åskådliggöra och presentera miljöeffekter i simulatorn 150 000 kr

**Totalt 2 340 000 kr**

Projektet föreslås genomföras under 2011 och 2012 med deltagare från enheterna FTS, MFT och MTA på VTI. Projektledare Anne Bolling, FTS, VTI.

### 3.4 Seminarier och workshop

Att använda körsimulator för att studera miljörelaterade effekter av såväl förarbeteende som olika fordons- och infrastrukturlösningar är ett forskningsområde som bör utvecklas på VTI.

För att bidra till kompetensutvecklingen på VTI kommer ett antal interna seminarier att ingå i projektet. Dessutom kommer en workshop att genomföras med deltagande av externa experter från EcoDriving-utbildning samt andra intressenter.

### 3.5 Resultat från projektet

Simulatorstudien kommer att redovisas i en VTI rapport och som en vetenskaplig artikel. Ytterligare resultat av projektet kommer att vara de seminarier och den workshop som ingår i projektet. Förutom detta kommer som resultat av detta projekt miljörelaterade modeller att anpassas och implementeras i simulator vilket gör det möjligt att i simulator genomföra studier med fokus på miljö. Ett demonstrationsprogram som åskådliggöra och presentera miljöeffekter i simulatorm ska också tas fram.

#### 4 Nyttan med bränsleförbruknings-, emissions- och slitagemodeller i körsimulator

Införandet av modeller för att studera miljöaspekter i körsimulator drivs av flera faktorer. Den grundläggande fördelen med simulatorförsök är att de erbjuder exakt repeterbarhet (trafik, väder m.m.). För frågor rörande energieffektivitet och emissioner möjliggörs jämförelser på en mer detaljerad nivå (ända ned till specifika händelser). Genom implementationen av denna typ av modeller öppnas möjligheten för en ny typ av forskningsstudier, med fokus mot miljö, i VTI:s simulatorer. Intresset av att studera ett fordon miljöprestanda kopplat till förarens beteende är i dag mycket stort t.ex. rörande nya stödsystem för miljövänlig körning, nya typer av drivlinor, EcoDriving-utbildning m.m. Införandet av slitage- och partikelemissioner från däck är unikt och skulle vara ett mycket gott komplement till VTI:s övriga verksamheter inom området.

Genom att logga miljöparametrar i studier som ej fokuserar på miljöfrågor kan man bygga en databas över hur olika betingelser påverkar körstil med avseende på emissioner. Detta skulle ytterligare stärka VTI:s position inom miljöområdet.

Även kurser och demonstrationer har stor nytta av den exakta repeterbarheten i körscenarion vilket gör prestationer i simulatorerna mer jämförbara än körning på väg. Att genomföra körningar i simulator istället för på väg erbjuder i sig också en miljövinst.

## 5 Utveckling av forskningsområde

I och med att modeller som beräknar miljöeffekter implementeras i VTI:s simulatorer kommer det att vara möjligt att söka projekt inom miljöområdet som inte förut varit möjligt. Detta kan intressera uppdragsgivare som inte förut använt fordonssimulatorer för sina studier. Det föreslagna projektet kan ses som en plattform för vidare arbete inom miljöområdet där andra effekter kan beräknas och modellerna kan förfinas.

Kontakter är tagna med Energimyndigheten och Trafikverket och båda myndigheterna har visat intresse för den här typen av projekt. Särskilt Energimyndigheten har uttryckt att kunskapen är bristfällig om förarbeteendets del i trafikens miljörelaterade effekter, och att mera forskning inom området behövs. En ansökan till Energimyndigheten rörande inverkan av utbildning i EcoDriving på beteendet i olika situationer, t.ex. varaktigheten av för miljön positiva förändringar, är under planering. Inom våra nätverk med fordonsindustrin diskuteras också förslag till utveckling av förarstöd som i bilen ger förarna miljörelaterad feedback med syfte att åstadkomma en varaktig förändring av deras körnönster. Utvecklingen i det föreslagna projektet (ansökta fortsättningen av temat) av såväl kompetens som körsimulatorernas tekniska plattform ökar möjligheterna till VTI-deltagande i sådana framtida samarbeten och uppdrag.

## Referenser

Dahlstedt (2002). **Individuella körstilar vid sparsam körning och andra körsätt – effekter på trafiksäkerhet och bränsleförbrukning.** VTI Notat 37-2002.

Larsson (2009). **Review and analysis of the reduction potential and costs of technological and other measures to reduce CO<sub>2</sub>-emissions from passenger cars.** Bulletin – Lunds Universitet Tekniska högskolan Lund. ISSN 1653-1930.

Smokers et al. (2006). **Review and analysis of the reduction potential and costs of technological and other measures to reduce CO<sub>2</sub>-emissions from passenger cars.** TNO-report 06.OR.PT.040.2/RSM





VTI är ett oberoende och internationellt framstående forskningsinstitut som arbetar med forskning och utveckling inom transportsektorn. Vi arbetar med samtliga trafikslag och kärnkompetensen finns inom områdena säkerhet, ekonomi, miljö, trafik- och transportanalys, beteende och samspel mellan människa-fordon-transportsystem samt inom vägkonstruktion, drift och underhåll. VTI är världsledande inom ett flertal områden, till exempel simulatorteknik. VTI har tjänster som sträcker sig från förstudier, oberoende kvalificerade utredningar och expertutlåtanden till projektledning samt forskning och utveckling. Vår tekniska utrustning består bland annat av körsimulatorer för väg- och järnvägstrafik, väglaboratorium, däckprovingsanläggning, krockbanor och mycket mer. Vi kan även erbjuda ett brett utbud av kurser och seminarier inom transportområdet.

VTI is an independent, internationally outstanding research institute which is engaged on research and development in the transport sector. Our work covers all modes, and our core competence is in the fields of safety, economy, environment, traffic and transport analysis, behaviour and the man-vehicle-transport system interaction, and in road design, operation and maintenance. VTI is a world leader in several areas, for instance in simulator technology. VTI provides services ranging from preliminary studies, highlevel independent investigations and expert statements to project management, research and development. Our technical equipment includes driving simulators for road and rail traffic, a road laboratory, a tyre testing facility, crash tracks and a lot more. We can also offer a broad selection of courses and seminars in the field of transport.

