THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

DRIVING IT HOME!

EXPLORING AND ENHANCING THE ADOPTION OF ECO-DRIVING

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Gothenburg, Sweden 2013

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Report no 82
ISSN 1652-9243

Published and distributed by
Department of Product and Production Development
Division Design & Human Factors
Chalmers University of Technology
SE-412 96, Gothenburg, Sweden
Telephone +46(0)31-772 1000

Cover: the illustration represents the set of eco-driving actions available to an individual. The actual action space is a subset of the full spectrum of eco-driving limited by objective constraints, while the perceived action space is what the individual perceives as possible and relevant eco-driving behaviour for their circumstances.

Printed by
Chalmers Reproservice
Gothenburg, Sweden 2013

ABSTRACT

One strategy to reduce the environmental impact of the transport sector is to increase the adoption of eco-driving among both professional and private drivers. Attempts to introduce eco-driving have though had varying success, and many questions remain to be answered. Hence, the aim of this thesis has been to increase knowledge on the mechanisms behind the adoption of eco-driving. To fulfil the aim, three themes: eco-driving in practice, understanding eco-driving, and interventions to enhance the adoption, were explored in an integrated analysis of three studies.

Multiple influences on drivers' possibility and intention to adopt eco-driving were confirmed in the analysis. Influences include driver-related factors like ability and attitudes, as well as contextual influences originating in the vehicle, the physical environment and the social context. For professional drivers, the organisational context was identified as major source of influences.

A hierarchy of eco-driving behaviours is introduced in the thesis, consisting of operational, tactical, and strategic levels of eco-driving. When investigated, participants' understanding of eco-driving appears concentrated to one level or part of one level in this hierarchy. The limited interpretations give rise to issues when the motivated participants' perceived and actual space for action does not match the eco-driving advice they know. It is hence proposed that interventions should aim to enhance the action space for eco-driving. Enabling and facilitating interventions should be put in place to widen the actual action space, and exemplifying and encouraging interventions should target the perception of it.

In conclusion, the mechanisms behind the adoption of eco-driving are complex and the influences numerous. Still, adoption can be enhanced if these influences are taken into consideration and interventions designed to increase both perceived and actual eco-driving action space.

KEYWORDS
eco-driving, pro-environmental behaviour, interventions, behaviour change, exploratory approach

ACKNOWLEDGEMENTS

The route towards this licentiate thesis has not been straightforward, and there is little trace in the thesis as it stands now of the projects that originally were supposed to make up the foundation of the work. Even if the projects did not turn out as expected, or turn out at all, I do feel fortunate to have been able to steer the work more myself and follow the lines of inquiry that caught my interest.

I would like to thank my main supervisor MariAnne Karlsson for her solid support in this process, and for always helping me find a way out of the confusion that quite often befalls me in my work. I would also like to thank my co-supervisor Oskar Rexfelt for his support and for making an effort to point out the positive.

I also wish to show my gratitude towards the people I have been fortunate enough to meet and work with during this time. This includes my collaborators at Saab, Västtrafik, Veolia, and Volvo, as well as all of the participants in the studies who have contributed their valuable time and insights to my research. Additionally, without the rest of the colleagues at Division Design & Human Factors, this period would not have been half as interesting nor as fun. I would especially like to thank my former roomie PhD Cecilia Österman for showing me the way, and the members of the Design for Sustainable Behaviour group for our interesting discussions. I could not have completed the work without you and I hope for much more collaboration in the future!

Finally, I would like show my appreciation to my family (maybe I will get a real job someday). Daniel, thank you for being patient with me during the last weeks, and for all your love and support.

LIST OF APPENDED PUBLICATIONS

PAPER A

Strömberg, H.K., Karlsson, I.C.M., 2013. Comparative effects of eco-driving initiatives aimed at urban bus drivers - Results from a field trial. *Transportation Research Part D: Transport and Environment* 22, 28-33.

Strömberg helped plan the study, gathered the data, oversaw the execution of the study by the collaborating companies, analysed the data and wrote the paper with the help of Karlsson

PAPER B

Strömberg, H.K., 2013. "But I already know how to drive" - exploring intervention strategies and systemic barriers to eco-driving in public transport, *Crafting the Future - 10th European Academy of Design Conference,* April 17-19 2013, Göteborg.

PAPER C

Strömberg, H.K., Karlsson, I.C.M., Rexfelt, O., (submitted). Eco-driving: Drivers' Understanding of the Concept and Implications for Future Interventions.

Strömberg planned the study, carried out the interviews, analysed the data and wrote most of the paper with continuous support from the two co-authors

PAPER D

Strömberg, H.K., Andersson, P., Almgren, S., Ericsson, J., Karlsson, M., Nåbo, A., 2011. Driver interfaces for electric vehicles, *Proceedings of the 3rd International Conference on Automotive User Interfaces and Interactive Vehicular Applications.* ACM, pp. 177-184.

Strömberg carried out the tests and interviews together with Almgren, analysed the data and wrote the paper.

ADDITIONAL PUBLICATIONS

Strömberg, H., Karlsson, M., Almgren, S., Andersson, P., Eriksson, J., Nåbo, A., 2011. Drivers, Electric Cars, and HMI: A Human Factors Approach, P*roceedings from the European Electric Vehicle Congress,* Brussels, 26-28 October 2011, pp. 1-9.

Wallgren, P., Strömberg, H., 2013. How will car users shape electromobility and how will electromobility shape users?, in: Sandén, B. (Ed.), *Systems perspectives on electromobility*, pp. 129-137.

Renström, S., Strömberg, H., Selvefors, A., 2013. Pathways of Sustainable Behaviours, Proceedings of the ERSCP-EMSU 2013 conference, *16th Conference of the European Roundtable on Sustainable Consumption and Production (ERSCP) & 7th Conference of the Environmental Management for Sustainable Universities (EMSU),* 4–7 June 2013, Istanbul, Turkey., pp. 1-18.

Renström, S., Selvefors, A., Strömberg, H., Karlsson, M., Rahe, U., 2013. Target the Use Phase! Design for Sustainable Behaviour, *The 6th International Conference on Life Cycle Management* in Gothenburg 2013, pp. 1-4.

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1. INTRODUCTION

1.1 BACKGROUND

As the scientific evidence grows regarding the causes and consequences of climate change, the urgency grows to reduce greenhouse gas emission from all sectors in society. One of the largest contributors to emissions is the transport sector, which was responsible for 22% of global carbon dioxide emissions in 2010 (International Energy Agency, 2012). Road transport of goods and people is the subsector with the largest impact of them all (Fuglestvedt et al., 2008). Because of this large impact, reducing the emissions from the road transport sector has received much attention from both science and policymakers, and there are a multitude of different initiatives available. The initiatives range from a new direction in infrastructure and societal development, transfer of road freight to less harmful alternatives like rail and sea, to development of more efficient vehicles.

Regarding transportation of people the major focus has been to lessen the reliance on petrol and diesel fuelled automobiles, since car use is a principal contributor to carbon dioxide emissions (Chapman, 2007). One strategy has been reduction of car use. Understanding how to affect the choice of transport mode can enable initiatives regarding modal shift from car to public transport, as well as to walking and bicycling. Therefore transport behaviour and choice of transport mode have been studied from a pro-environmental perspective (see e.g. Anable, 2005; Friman et al., 2013; Gärling et al., 2000; Graham-Rowe et al., 2011; Steg et al., 1995). However, creating this shift has been found difficult, as motorists seem reluctant to give up their cars (Chapman, 2007; Möser and Bamberg, 2008).

Another strategy has involved the development of new vehicle technology, such as electrification of vehicles and alternative fuels. The adoption of electric vehicles is another shift that has been studied extensively (see e.g. Kurani et al., 2009; Neumann et al., 2010; Pierre et al., 2011; Schuitema et al., 2013; Turrentine et al., 2011) but again, it seems difficult to bring about. Reasons include concerns about range and charging, as well as general insecurity about the new technology.

A less radical strategy, and one that has been studied to a lesser extent from a pro-environmental perspective, is eco-driving. The current fleet of petrol and diesel fuelled vehicles will continue to be in use for some time, but they can be operated more efficiently, for example by adopting a more economical way of driving. It has been suggested that eco-driving of passenger cars and heavy vehicles is one of the measures that has the highest potential for reducing carbon dioxide emissions from road transport (Johansson et al., 2010), and that a mass-scale implementation would lead to a 3 % reduction in global carbon dioxide emissions (McKinsey & Company, 2009). Hence, efforts have been made to promote eco-driving to

both professional and private drivers, predominantly thorugh means of education and implementation of in-vehicle support systems.

Educational efforts include information campaigns to the public, targeted courses and incorporating eco-driving into the driving licence curriculum. In-vehicle support systems are available in different variants, and most offer instantaneous feedback to the driver. Systems are in the form of aftermarket devices are available for trucks and buses as well as private cars, and eco-feedback is increasingly included in the instrument panel of vehicles. Field trials of the impact of both education and support systems though fail to demonstrate the large fuel savings predicted (e.g. af Wåhlberg, 2007; Boriboonsomsin et al., 2010; Zarkadoula et al., 2007). Additionally, long-term studies show that drivers regress to their old behaviour with time (af Wåhlberg, 2007; Beusen et al., 2009). It is nevertheless not clear why the predicted level of adoption is not reached and why drivers return to their old behaviour. The underlying mechanisms connected to this behavioural shift need more investigation.

Furthermore, even if most proponents of eco-driving agree that its basis lies in a fuel-efficient anticipatory driving style where the aim is to keep the vehicle rolling smoothly and steadily, the term eco-driving is not well defined. Often some maintenance practices are included like checking tyre pressure and performing scheduled services (Symmons et al., 2009). However, the term can also be used to denote a wider spectrum of pro-environmental choices such as route planning, vehicle choice and car use reduction (cf. http://www.hetnieuwerijden.nl/).

Furthermore, reduction of car use and modal shifts have been studied as examples of pro-environmental behaviour. This perspective brings with it a theoretical framework based on psychological understanding of behaviour that studies of eco-driving appear to lack. Eco-driving studies instead often focus on other perspectives such as technological development and driver-vehicle interaction. Hence, applying a pro-environmental behaviour perspective on eco-driving can lead to new explanatory insights regarding the uncertainties in the drivers' adoption of eco-driving.

1.2 AIM AND THEMES EXPLORED

The overall aim of the research presented in this thesis is to increase the knowledge on mechanisms behind the adoption or rejection of eco-driving. With a better understanding of the adoption process it should be possible to design interventions that can aid drivers and enhance the adoption of eco-driving.

One reason that little is known of these mechanisms is that few studies concern what the drivers go through when trying to practice a fuel-efficient driving style. Instead they focus on measuring the outcome. The first line of inquiry therefore explores eco-driving in practice, using a pro-environmental behaviour perspective.

Questions posed in relation to this theme include

- to what extent have different categories of drivers adopted eco-driving,
- to what extent are they able to practice eco-driving, and
- what are the influences, motivating factors, and barriers in the practice of eco-driving?

The initial focus was thus eco-driving as a fuel-efficient driving style and the execution of this driving. A second theme however emerged over time, that of the drivers' understanding of the concept of eco-driving. This theme is explored with the help of the following questions

- how do drivers understand the concept of eco-driving?
- how does the drivers' understanding influence their practice?

The nature of the abovementioned questions is exploratory and descriptive. However, in the context in which this research has been carried out, the prospective perspective is important. The third theme therefore refers to the design of interventions intended to aid a shift in behaviour and asks the question

- to what extent can different types of interventions aid the adoption process, that is enhance drivers' motivation, ability and opportunity related to eco-driving?

1.3 READING INSTRUCTIONS

The thesis is structured as follows. First, in Chapter 2, follows a description of the theory regarding pro-environmental behaviour, the underlying psychology of such behaviours and interventions to promote them. Then the case of eco-driving in research so far is presented, including a short history, overview of intervention studies carried out, and summary of proposed influences on the adoption of eco-driving.

Chapter 3 explains the methodology of the research described in the thesis. The methodology of each of the three studies on which the work is based is summarised and the approach for the integrated analysis along the three themes is reported.

The findings of the studies are reported in the three subsequent chapters. Chapter 4 describes the first part of the exploration of the first theme, eco-driving in practice. The result of the exploration of the second theme, understanding, is explained in Chapter 5. In the last of the findings chapters, Chapter 6, these two themes are combined to provide the basis for exploring the third theme: interventions.

Finally, Chapter 7 starts with a discussion on the intervention theme and makes recommendations for interventions. Implications of the findings are then discussed, along with the appropriateness of the methodology, and suggestions for further work.

2. THEORETICAL FRAMEWORK AND RELATED RESEARCH

This chapter aims to provide a theoretical context to the studies and discussion presented in this thesis. It is against this background that the results are compared, and it is also to these fields the thesis wishes to contribute.

The chapter is divided into two main sections. The first section concerns theories on pro-environmental behaviour, of which eco-driving is an example. Pro-environmental behaviours are defined as behaviours consciously performed as to minimize the negative impact on, or to benefit, the environment (Kollmuss and Agyeman, 2002; Steg and Vlek, 2009). The vast research concerning the determinants of pro-environmental behaviour and how to encourage it forms a valuable basis for understanding the mechanisms behind the adoption of eco-driving.

The second section takes a closer look at the case of eco-driving, and expands on some of the aspects mentioned in the introduction. A more detailed description of eco-driving and its history is described first. This is followed by a short review of promotional efforts and intervention studies concerning eco-driving thus far. Finally, as a background to the work presented in the thesis, and as a start for the first line of investigation, is a review of previous attempts to understand the factors influencing the adoption and implementation of eco-driving.

2.1 UNDERSTANDING AND INFLUENCING PRO-ENVIRONMENTAL BEHAVIOUR

Research into behaviour in general, and pro-environmental behaviour in particular, has been carried out over a long time in disciplines such as consumer research and psychology. Regarding pro-environmental behaviour, research has mostly been concerned with what Stern (2000) calls private-sphere environmentalism; i.e. the purchase, use and disposal of personal and household products that have an environmental impact. Personal transport and driving are examples of such behaviours. There are two main research tracks; one is investigating underlying determinants of behaviour, and the other is testing the effectiveness of intervention strategies for changing behaviour (Abrahamse et al., 2005).

2.1.1 DETERMINANTS OF PRO-ENVIRONMENTAL BEHAVIOUR

The interest in determinants stems from that behaviour change interventions can be designed to target the relevant factors, and thus be more successful, if the underlying factors are known and understood (Steg and Vlek, 2009). There are several complementary theories and models regarding the determinants of pro-environmental behaviour. Each of these has though had wavering success in accurately predicting specific pro-environmental behaviour (Jackson, 2005), as

different factors or determinants appear to be of varying importance for different types of behaviours. There have been calls for a synthesis in the field, but none of the proposed models have yet achieved this (Stern, 2000). Therefor a summary of the most commonly cited theories and concepts is presented here. The influences are organized in three groups relating to motivation, ability, and opportunity very loosely based on Ölander's and Thøgersen's MOA model (Ölander and Thøgersen, 1995).

A large number of theories and models concern the motivational factors behind a pro-environmental behaviour. Two potential motives, which received attention especially in the early development of the research field, are environmental concern and a sense of responsibility to act pro-environmentally (Tanner, 1999; Vining and Ebreo, 2002). These have however been proven weak determinants of actually performing the behaviour, and relate mostly to "good intentions" (Bamberg, 2003; Steg and Vlek, 2009). Another early line of research was investigations into the significance of values. Values are motivational constructs related to highly abstract goals, and they are general in that they transcend situations and objects (Verplanken and Holland, 2002). It has been shown that people who consider self-transcendent values more central to themselves than egocentric values are more likely to engage in pro-environmental behaviour (Steg & Vlek, 2009). Such self-transcendent values have been conceptualised differently and include prosocial values (Schwartz, 1977), environmental values (Verplanken and Holland, 2002), and biospheric and altruistic values (Stern, 2000). However, it has been argued that values are more important as underlying determinants of attitudes than as direct determinants of behaviour (Vining and Ebreo, 2002).

Frameworks concerning attitudes have been more successfully used to predict pro-environmental behaviour than environmental concern and values. Attitudes are formed by beliefs about the outcome of the behaviour and evaluation of that outcome, a form of reasoning weighing the cost and benefits of the behaviour. Thus, it is assumed that a positive attitude would to the behaviour being performed (Fishbein and Ajzen, 1975). One of the leading theories based on the influence of attitudes is the Theory of Planned Behaviour (TPB, Ajzen, 1991). In addition to attitudes, TPB incorporates subjective norms, i.e. "how I think others think I should act", and perceived behavioural control in the formation of an intention to perform the behaviour, that in turn leads to the performance of the behaviour.

Norms are yet another factor considered to motivate behaviour. Norms are shared beliefs about how we should act, reinforced by the threat of sanctions or promise of reward (Thøgersen, 2006). Norms can be divided into descriptive norms, i.e. how things are done by others, and injunctive, i.e. how others think things ought to be done (Cialdini et al., 1990). The injunctive norms can either be social or personal.

Personal norms are central to another common framework, Norm Activation Model (NAM, see Schwartz, 1977). In NAM the norm is formed by awareness of consequences and ascription of responsibility. It can thus be compared to the sense of obligation mentioned earlier (Thøgersen, 2006). The subjective norms in TPB would in this terminology be called internalised social injunctive norms. Thøgersen shows that the descriptive norms often have a higher explanatory power for pro-environmental behaviour than injunctive norms, i.e. we do what others do, not what they say.

Stern's Value-Belief-Norm combines all three of the constructs related to motivation. However, even Stern himself concludes that this combination of motivational factors cannot explain behaviour; it only forms environmentalist intent as a factor underlying a general predisposition toward pro-environmental behaviour (Stern, 2000). This predisposition is not enough, as there are so many others influences on behaviour. Also TPB hints at influences beyond motivation by including perceived behavioural control as a mediator between the intention and the behaviour. Ölander and Thøgersen (1995) affirm that motivation alone does not determine behaviour; the individual must be able to perform the behaviour as well. They consider ability twofold, as consisting of habit and task knowledge.

Habits are routine behaviours that have been performed so many times they have become guided by automated cognitive processes (Verplanken, 2006) causing them to be hard to break. When acting habitually we do not deliberate our intention to act, so it is claimed that changes in motivational factors cannot create a shift in habitual behaviour. Hence, the ability to adopt a new pro-environmental behaviour is hindered by existing habits. Habits have gained a lot of interest in pro-environmental behaviour research because much of our everyday behaviour is habitual, but many questions remain regarding habits and the debate regarding their influence goes on.

The concept of task knowledge involves knowing how to perform the pro-environmental behaviour. In Stern's (2000) view this knowledge is part of a larger concept: personal capabilities. Except for having the right knowledge and skill, the capabilities include other factors that affect the individual's ability to perform the behaviour such as having the available time and financial resources, as well as sociodemographic variables, such as age and level of education.

If the individual has formed the intention to act and has the ability to perform the action, there is one final necessary piece of the puzzle according to Ölander and Thøgersen (1995), the individual must have the opportunity to act. This opportunity is influenced by contextual and situational influences, which include a wide range of external factors e.g. available facilities, products and services involved, infrastructure, and current policies and regulations (Stern, 2000). Contextual influences directly affect behaviour by limiting behavioural choice, e.g. by

determining the available options, the needs of the individual, and the ability of the individual to benefit from performing the action. They also have an indirect effect by influencing attitudes and activating norms (Black et al., 1985). Ölander and Thøgersen (ibid.) point out that while the contextual factors offer objective preconditions, different people can perceive them differently causing them to see different opportunities.

From the available literature it seems that the opportunity to act has received the least attention out of the determinants, and the different sources do not completely agree on which aspects are part of the context or how they should be named. Contextual factors have been considered in a few cases (e.g. Frey and Foppa, 1986; Tanner, 1999) when trying to explain why behaviours do not happen as they represent objective constraints deciding whether behaviours are possible or not. It is surprising that these factors have not been studied to a higher degree because deliberate re-design of contextual factors can enable and facilitate sustainable behaviours (Steg and Vlek, 2009).

The behavioural determinants and influences described in literature are summarised in Table 1. Since it is uncertain how the factors precisely interact to form a specific behaviour, they will be considered collectively as a framework in the thesis, following the advice of Jackson (2005).

TABLE 1. SUMMARY OF BEHAVIOURAL DETERMINANTS

MOTIVATION	ABILITY	OPPORTUNITY
environmental concern responsibility to act (pro-environmental) values internalised descriptive and injunctive norms beliefs, attitudes	task knowledge and skill personal capabilities, like physical capabilities, financial resources, time, and sociodemographic variables habit	available alternatives individual needs ability to benefit structural, physical factors current policy and regulation infrastructure products and services available facilities

2.1.2 INTERVENTIONS FOR PRO-ENVIRONMENTAL BEHAVIOUR

A behaviour change intervention can be defined as a purposive change in the environmental settings or in the chain of events that is the triggering, the acting out, and the consequences of the behaviour in order to influence that behaviour (Geller et al. 1990). Implementations of intervention strategies do not only include pro-environmental behaviours, but for example safety and health related behaviours as well. This has lead to that a multitude of different behaviour change intervention strategies have been developed for different purposes e.g. public information campaigns using advertising to inform people that they should recycle,

financial rewards such as tax rebates to increase sales of environmentally friendly cars, and product designs to help the user use the product more efficiently.

Because there are so many different strategies, it is common to speak of different categories, containing strategies with similar character. A primary dichotomy is made between antecedent and consequent strategies, commonly applied when discussing strategies that aim to motivate behaviour change. Antecedent strategies aim to induce a certain type of behaviour and include forms of communication and education as well as different types of activators. Communication can be both passive, e.g. offering lectures, exemplifying behaviour through demonstrations, and writing policy documents, and active, e.g. engaging people in discussions. The information communicated features the consequences of behaviours as well as the ways behaviours can be performed with more positive consequences. Activators include many different ways of urging people to do things, including prompting them, setting goals, creating competitions, or providing incentives or disincentives. Consequent strategies come in after the behaviour has taken place and aim to change the way the behaviour is carried out next time. Common strategies here are providing feedback, giving rewards and penalties.

The categories and names of strategies used here follow Geller et al. (1990), but there are many similar categorisations using completely or partially different terms. It is noteworthy that these strategies mostly deal with motivating behaviour change (the educative strategies may be used to increase ability), but as was described in section 2.1.1, motivation is just part of behaviour change. Therefore, some categorisations include strategies that direct behaviour (cf. Lidman et al., 2011). These can be more forcing such as different forms of legal measures, or aimed at providing opportunity, e.g. the enabling strategies included in DEFRA's 4E-model (DEFRA, 2005) or the facilitation strategies described by Ölander and Thøgersen (1995).

Intervention strategies may also be incorporated into product design to encourage sustainable use of the product in question, or sustainable behaviour in the practice in which the product is used. This is commonly known as Design for Sustainable Behaviour, and translates many of the strategies already mentioned into product design.

It is argued that interventions will have varying effectiveness depending on how well the determinants that they target match the influences that cause the behaviour to be carried out (Steg and Vlek, 2009). Attempts have been made to map specific intervention strategies to determinants of behaviour to find which are most effective. Despite a number of reviews of intervention studies (see e.g. Abrahamse et al., 2005; Dwyer et al., 1993), clear connections have not been established, and research is developing slowly. It is though commonly argued that for an intervention to be successful a combination of strategies needs to be used.

2.2 A SHORT HISTORY AND DEFINITION OF ECO-DRIVING

As was explained in the introduction, there is no one clear definition of what is meant by eco-driving. According to Symmons et al. (2009) eco-driving generally refers to a smoother, more anticipatory style of driving, but it can in its widest sense include everything from maintenance practices, car purchase advice to guidelines for car manufacturers and infrastructure policy makers. The wide range and varied content is confirmed in Table 2, which summarises the advice given under the eco-driving umbrella from major actors promoting eco-driving.

The term eco-driving was originally a trademarked Finnish concept for teaching fuel-efficient driving techniques to lorry drivers in the 1990s. Advice on how to drive in a fuel efficient way had existed long before that and their popularity fluctuated with oil supply, for example peaking during the 1970's oil crisis. When the reserves of easily extracted oil began to dwindle and the impact of carbon dioxide on the climate became clear, governments (mainly European) realised the necessity of fuel saving and began promoting versions of eco-driving to the public. In Sweden, efforts have been made to educate both the public and professional drivers in eco-driving since the late 1990s (Vägverket, 2009) and the Swedish version "sparsam körning" is included in both the theoretical and practical driving licence tests for all licence types.

As shown in Table 2, the promoted eco-driving versions vary in scope. Some of the differences are related to regional differences in vehicle fleet, such as if automatic or manual transmissions dominate, and climate, such as if it is important to keep the vehicle hot or cold. Other variations are harder to explain. Even if it is well understood how driving style affects fuel consumption (see e.g. Evans, 1979; Gonder et al., 2012; Laurell, 1985; Mierlo et al., 2004), there are seldom references to a source for the advice given out under the eco-driving label, or when describing the behaviour in scientific publications (Symmons et al., 2009). Occasionally, even contradictory advice can be found as in the case of whether one should accelerate forcefully or softly. Nevertheless, Laurell (1985) found that the commonly occurring fuel saving advice is mostly accurate (see table 2 for which advice is most common).

2.3 THE CASE OF ECO-DRIVING

Both Stern (2000) and Geller (2002) stress the need for empirical analysis to understand any specific environmentally significant behaviour. However, the scientific disciplines that usually explore the determinants of, and interventions to promote, pro-environmental behaviour have given eco-driving relatively little attention compared to for example reduction of energy use in households. Instead the concept of eco-driving has been explored from other perspectives, mainly policy or technological development. These studies concerning eco-driving have focused on the driving style aspects of the concept.

TABLE 2. COMPILATION OF INTERNATIONAL ECO-DRIVING ADVICE

Advice	Sparsam körning	Het nieuwe rijden	Golden and silver rules (ecodriven)	EcoDrivingUSA	Symmons et al.
anticipate traffic flow	●	●	●		●
keep the vehicle rolling	●			●	
drive at a steady speed (at optimal rpm)	●	●	●		●
observe speed limits	●	●			●
avoid heavy or sudden acceleration and braking	●			●	●
use cruise control		●	●	●	
shift up thorugh the gears as soon as possible (shift at 2000-2500 rpm)	●	●	●		●
use the highest gear possible	●			●	●
skip gears when approriate	●				●
engine break and maximise use of vehicle's momentum	●	●	●	●	●
roll down hill, and use even acceleration up	●				
drive off immediately when starting the engine	●		●	●	●
avoid idling	●			●	●
turn off the engine at short stops >20s		●	●		
use extras wisely (ac, heat, other electrical equipment)		●	●		●
close windows (and use ac) at higher speeds >40mph			●	●	
use engine heater	●				
avoid the heat: park in the shade, use deflectors and shades, air out heat				●	
use fuel saving accessories (apps, fuel display, etc.)		●	●		
service vehicle regularly and according to manual	●	●	●	●	●
maintain vehicle and fix all problems	●	●	●	●	●
check tyre pressure often	●	●	●	●	●
use the recommended motor oil		●	●	●	
replace air filters regularly	●			●	
keep engine clean	●				
change motor oil	●				
avoid unnecessary resistance (roof box, bike rack, roof rack)	●	●	●		●
avoid unnecessary weight (empty luggage area)	●	●	●		●
use low energy tyres and use tyres without studs	●	●	●		
change tyres according to season, switch back to summer tires sooner		●			
choose low emission vehicle	●	●	●		
use vehicle with automatic transmission			●		
plan your route (avoid congestion, "bad roads")		●		●	
consolidate trips				●	
avoid short car trips		●	●		
consider alternative means of transport, walk or bicycle use more public transport			●		
rideshare			●		
carshare			●		

Sparsam körning. Advice for Swedish drivers given out by the Swedish Transport Administration and included in the driving licence curriculum (trafikverket.se).

Het neuwen ridjen. The current version of the original Dutch eco-driving concept.Began under the slogan Buy eco-nice! Drive eco-wise! (hetneuwenridjen.nl)

The golden and silver rules of eco-driving. This set of advice is the result of an EU-project (ecodriven), and the set has been used in several consequtive projects (www.ecodrive.org).

EcoDrivingUSA. Advice given out by the Alliance of Automobile Manufacturers, hoping to boost sales of efficient vehicles by making drivers aware of CO2-emissions. Believe You Can Reduce Fuel Use! (www.ecodrivingusa.com)

Symmons' and colleagues' compilation of eco-driving advice found throughout the world, prepared for the Australian government (Symmons et al., 2009)

Two types of studies are reported here, evaluative intervention studies and studies investigating the preconditions for introducing interventions. The latter have some parallels with studies investigating determinants of behaviour but lack the theoretical framework and methodological strictness. Many studies of the former type also suffer from methodological issues, why a selection of the most rigorously performed studies is presented here.

2.3.1 STUDIES OF INTERVENTIONS TO PROMOTE ECO-DRIVING

Most studies evaluating interventions have concerned some form of informing or educational intervention to promote eco-driving, targeting knowledge and intention. Different versions of courses in eco-driving have been investigated in several studies. Symmons and Rose (2009) found that heavy-vehicle drivers given a classroom-based theory session did not improve their eco-driving skill. However, when the theory session was coupled with a test drive together with an instructor, the participant did improve, as the test drive gave the participants the opportunity to consolidate their theoretical knowledge from the classroom session. In a study by Beusen et al. (2009) drivers were given course consisting of both theory and training, and were then followed up during 5 months. Beusen and colleagues found that the course gave an immediate effect but with large individual variations. It was also found to be difficult for the drivers to maintain changed behaviours, especially reducing heavy acceleration and idling. Limited long-term effects have also been reported in studies of training bus drivers in eco-driving (af Wåhlberg, 2006, 2007; Zarkadoula et al., 2007), where drivers also partially slipped back into their old behaviour over time.

An alternative to courses in eco-driving is in-vehicle support systems that provide some form of eco-driving feedback to drivers. These have the benefit of acting as a reminder in the driving situation. The feedback can range from a very simple green light that turns on when the car is driven efficiently to a system giving advanced adapted advice on how to drive in the specific situation. In the short term, van der Voort et al. (2001) report additional fuel savings of 7% when driving with support in comparison to drivers just asked to drive economically, and Boriboomsomsin et al. (2010) report average fuel savings of 6% in urban environments and 1% on highway in two-week trial of a system displaying real-time fuel economy. In the long term, the usefulness of in-vehicle feedback devices can be questioned. Larsson and Ericsson (2009) find no reduction in fuel consumption from real-world trials of an acceleration advisory tool and af Wåhlberg's (2007) long-term study with bus drivers only provides tentative positive results.

The design of the feedback is debated in terms of feedback approach and temporal granularity (van der Voort et al., 2001). Instantaneous feedback seems most promising for supporting changes in driving style (van der Voort et al., ibid.), as it allows drivers to link their current driving style, the driving conditions and the fuel consumption and change their behaviour accordingly (Boriboonsomsin et

al., 2010). In addition, a larger reduction in overall fuel consumption is reported when the feedback given is advisory rather than informative (van der Voort et al., 2001). Also, Symmons and Rose (2009) note that many questions remain to be solved regarding adaptation of the feedback to different driver groups. In a study by Stillwater & Kurani (2011) only 40% of participants changed driving behaviour in response to real time feedback.

To deal with the problems of drivers returning to their old behaviour combinations of interventions have been suggested. Providing incentives such as monetary rewards for fuel saved have been suggested (e.g. by Barkenbus, 2010). Combining training and in-vehicle feedback has also been proposed as an effective arrangement for introducing eco-driving. It would ensure a basic theoretical understanding of eco-driving and, additionally would provide the repetition necessary to maintain the changed behaviour. Claims have been made that the effects of eco-driving training can be doubled if it is coupled with in-vehicle feedback (Barkenbus, 2010), but no empirical studies verifying this claim have been found.

2.3.2 STUDIES OF INFLUENCES ON THE ADOPTION OF ECO-DRIVING

At least three previous studies attempting to summarise the influences on the adoption of eco-driving have been made: Smokers et al. (2006), Barbé and Boy (2008), and Gonder et al. (2011 & 2012). All three have done so with the aim to introduce some form of in-vehicle feedback*. Table 3 compiles their work.

The driver related factors correspond quite well with the internal determinants described in section 2.1, even if the wording and the categorisations differ between the three studies. For example, while Smokers and colleagues combine the internal influence of the driver with the influence of fellow road users and passengers, Gonder and colleagues put more emphasis on the influence of other people, as well as the societal influence, by highlighting different types of norms. Fellow road users convey of informal social norms regarding what is acceptable driving behaviour in the specific situation. For example, drivers generally adapt their speed to the speed kept by other motorists on the road, a speed that often exceeds the speed limit (Gonder et al., 2011).

Barbé and Boy only see other road users as a part of traffic, i.e. part of the contextual influences in the environment. Such contextual influences appear to have received more attention in eco-driving studies compared to investigations into other pro-environmental behaviours. They are divided into the vehicle and equipment with which the driver interacts directly, and the environment with which the combined driver-vehicle system interacts. The factors in both these groups influence the driver's behaviour, but integrated among them are also factors that

* It is not clear what type of driver that these investiagtions had in mind, whether it is drivers in general or private drivers.

TABLE 3. SUMMARY OF INFLUENCING FACTORS ON ECO-DRIVING

BARBÉ & BOY (2008)

DRIVER	VEHICLE & ON-BOARD SYSTEMS	ENVIRONMENT	TASK/ACTIVITY
personal factors (e.g. age, sex, driving experience, social attitudes, cognitive capabilities) situational factors (e.g. fatigue, motivation, stress, vigilance, emotions)	type on-board systems characteristics (e.g. weight, engine)	traffic climatic conditions road infrastructure	primary driving task secondary tasks (e.g. radio, phone)

SMOKERS ET AL. (2006)

HUMAN BEHAVIOUR	EQUIPMENT (VEHICLE)	DRIVING CONDITIONS/CIRCUMSTANCES
eco-driving training & trainer experience motivation habits passengers other road users	eco-driving systems (assisting, informational, advising, forcing) driveability power noise/vibrations engine type/power train future technology	traffic conditions road type traffic situation weather road condition speed control other road users

GONDER ET AL. (2011, 2012)

(NO CATEGORISATION)		
legal or regulatory norms social norms/social comparison surrounding vehicle behaviour anxiety over trying to get somewhere quickly driving enjoyment	available power from vehicle (accurate pressure on pedal difficult)	traffic (light good for mild driver, heavy good for aggressive) outcome varies according to temperature and road conditions

can affect fuel consumption but are not coupled to changing driving behaviour. af Wåhlberg (2007) lists these factors and includes changes in the servicing of vehicles, in the vehicle fleet, in the weather (temperature, rain, ice, etc.), in the traffic situation (new roads, etc.), and in the loaded weight of the vehicle (number of passengers etc.).

2.3.3 COMPILATION OF PROPOSED INFLUENCES

It is here proposed that together, the influences mentioned in all four studies can be classified into three different categories of influencing factors. The first category contains the factors that determine the driver's possibility to practise eco-driving. These possibilities are decided by the driver's ability in combination with the driver's opportunity constrained by the contextual influences. The physical environment, the vehicle and the regulations set the boundaries for which actions can be taken; for instance, the advice to change gear early is not applicable

if driving with automatic transmission. The second category includes factors that determine the driver's intention to practise eco-driving such as attitudes, norms and stress. Finally, the third category includes the factors that affect the outcome of the driving behaviour, i.e. the fuel consumed, without affecting the driving behaviour itself, for instance weather factors such as strong winds.

Arranging the identified factors into these three categories, while retaining a revised version of the groupings in Table 3, produces a matrix that describes the factors that influence the adoption and implementation of eco-driving (see Table 4). Adding a column of societal and social factors highlights their influence, and clarifies that they contribute to both the intention and opportunity to eco-drive.

This categorisation of the influential factors clarifies the complexity of the driver's situation, and indicates the relative potential influence of contextual factors for the adoption of eco-driving. However, the division of factors is not as clear-cut as it may appear in Table 4 and each factor has been included in the category where it is judged to have the largest influence. For example, type of vehicle sits in the outcome category, even if it may affect the driver's intention to eco-drive as well. A powerful sports car has higher fuel consumption than a smaller, slower car because of its configuration, but as Gonder et al. (2012) describe, by sitting in one the driver may be triggered to drive faster and more aggressively because the car has the capability to handle it and because it is enjoyable.

TABLE 4. FACTORS INFLUENCING THE ADOPTION AND IMPLEMENTATION OF ECO-DRIVING

	DRIVER	VEHICLE	ENVIRONMENT	SOCIAL
INFLUENCES ON POSSIBILITY	knowledge and skill physical and cognitive capabilities habits	vehicle characteristics and driveability assistive systems	climatic conditions road infrastructure traffic situation	traffic rules speed control
INFLUENCES ON INTENTION	attitudes responsibility to act stress			fellow road users passengers
INFLUENCES ON OUTCOME		weight type of vehicle engine type, drivetrain	weather road conditions	

3. METHODOLOGY

The results presented in the thesis are based on three studies performed within three different projects. Each of the studies has in its own way contributed to the knowledge needed to explore the three themes described in section 1.2. The following three sections describe how each of the studies was conducted. Thereafter, follows a description of the integrated analysis of the studies.

3.1 STUDY ONE: FIELD TRIAL AND INTERVIEWS WITH BUS DRIVERS

The study was performed within the project European Bus System of the Future, which aimed to develop a new generation of urban bus systems that would increase the attractiveness and standing of the bus system. Study One consists of two parts, here called A and B, both carried out in Göteborg and in collaboration with Västtrafik and Veolia transport. Drivers from the same group partook in both parts. Study One is described in both Paper A and B. Figure 1 depicts the process and relation between the two parts.

3.1.1 PART A: BUS DRIVER INTERVIEWS

Part A consisted of an interview study in two rounds in connection with the development of a prototype bus. Eco-driving was included in these interviews partly because it is an important part of driving in the best way possible, and partly because the already planned interviews provided the opportunity to interview an otherwise difficult to reach driver group.

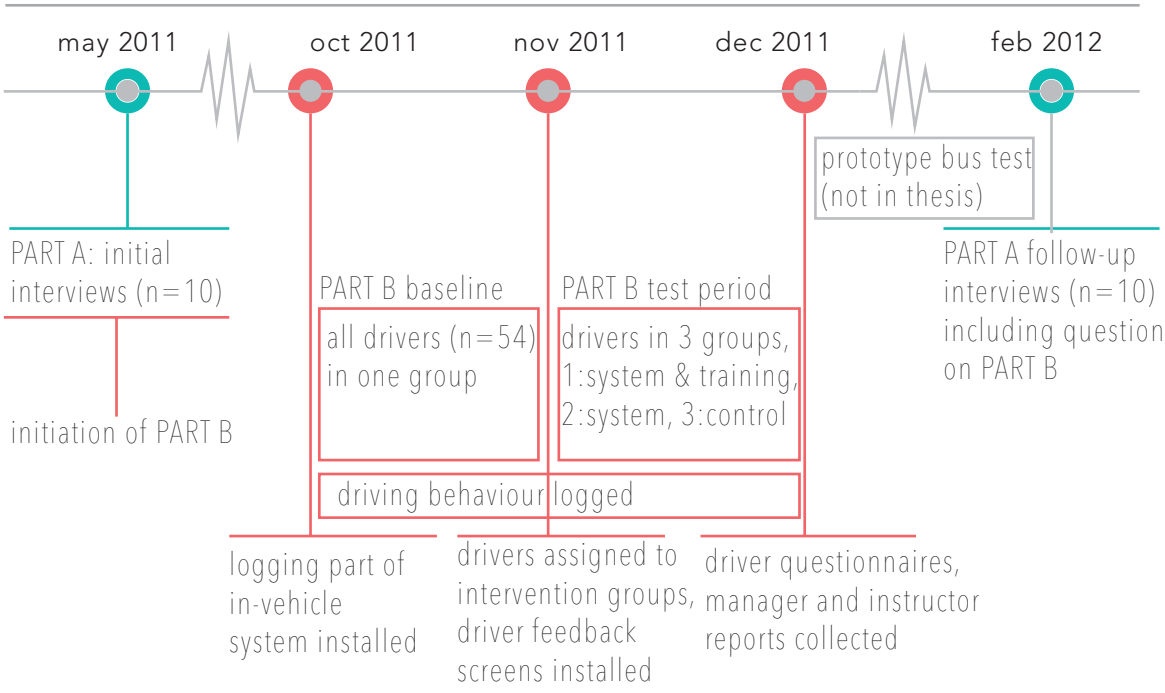

FIGURE 1. PROCESS OF STUDY ONE

Ten drivers were interviewed in each round of interviews. The participants in the first round were selected by the bus company to participate in the interviews on the basis that they worked on the line on which the new bus would be introduced, and that their schedule fit with the interview times. The drivers in the second round were those ten drivers selected to drive the prototype bus.

Both rounds of interviews followed the same design which was divided into two parts: one structured part with questions regarding education, work environment, and technical aids, and one semi-structured part focusing on eco-driving. It is this second part that is of most interest to the thesis. The questions in this part concerned attitude towards eco-driving, both the driver's own and that of company and colleagues, prevalence and quality of eco-driving education and technical aids. Finally the drivers were asked to rate how much a number of factors disturbed or helped them when trying to eco-drive. Part A's second round of interviews was carried out after Part B and therefore was used partly to evaluate the result of part B. Therefore questions about the drivers' experience of Part B were added to the eco-driving part of the interview in the second round.

3.1.2 PART B: ECO-DRIVING FIELD TRIAL

Part B was initiated partially based on the results of Part A, which indicated that there was an interest among the drivers to learn more about eco-driving in a bus context. The field trial aimed to investigate the effects of different eco-driving interventions for urban bus drivers. Two types interventions were compared, one consisted of an in-vehicle eco-driving support system offering feedback on driving style, and the other was a combination intervention consisting of the feedback system plus two individual coaching sessions. During the trial the two interventions were introduced on one selected bus line in Gothenburg. Hence, all 54 drivers working on the line participated in the study as a part of their everyday work.

A between-subject design was used for the study, and included both a baseline and a control group (Figure 1). The participating drivers were thus divided into three groups;

- one group that received an introduction to the support system and were asked to use it;
- a second group that received the same introduction accompanied by individual training on two occasions; and
- a third group, the control group, that were informed that there was a test going on.

The drivers were assigned into groups by managers at the company who tried to ensure groups with as equal distribution as possible in terms of age, sex, driving experience and driving style. The study was carried out in late autumn 2011; the baseline covered 3 weeks in October/November and the test 3 weeks in November/December.

During both baseline and test periods, the drivers' behaviour was logged using the same system that produced the driver feedback. The specific parameters measured are described in Paper A. When analysing the data afterwards the logging system offered the possibility to obtain data sorted by bus or, if the driver had logged into the system, sorted by driver. The logged driving data was supplemented by driver questionnaires and instructors' reports. The questionnaires were administered after the test period, and used to provide a fuller picture of the drivers' perception of interventions and what they gained from them, as well as the entire eco-driving effort.

The instructors' reports were also collected after the project, and contained written accounts of the project from the instructors responsible for the individual training and the project manager responsible for the eco-driving project at the company where the drivers were employed. They were asked to document their activities during the project and also to give their views on the drivers' advancement and receptivity to the eco-driving efforts, and their views on the project's progress.

3.1.3 ANALYSIS

Statistical analyses were performed on the logged data from the field trial to find whether the intervention introduction had been successful. Analysis was done across baseline and test period and comparing the two intervention types (detailed description in paper A). To further explore the effects of the interventions, the answers from the questionnaires (response rate 20 out of 54) were reviewed to find how drivers had perceived their progress and the contribution of the interventions. In addition, the interviews from part A were compared before and after the introduction of the interventions to see if the drivers' perception had changed because of the interventions and if the effects of the interventions were still present (subjectively) over two months after the field trial had ended. Together, this offered a fuller picture of the effects.

To gain further knowledge on how the intervention study was perceived, data related to this was extracted from the questionnaires. Adding to the questionnaire data was the documentation data from the instructors' and project manager's reports, which were also compared to each other to find common themes in their experiences of the project. The perception aspect was then further explored using the interview material from part A as these offered the opportunity to find out more about how the drivers' had perceived the intervention project, and the interview data was compared to those statements made in the instructors' reports to find if all actors involved had concordant views on the project.

3.2 STUDY TWO: ECO-DRIVING INTERVIEWS WITH PRIVATE DRIVERS

The aim of the second study was to explore the dissemination of eco-driving among Swedish car drivers. The primary goal was to establish a wide as possible picture of how eco-driving is understood and carried out in relation to driving in general. A secondary goal was to investigate whether the inclusion of eco-driv-

ing in the driving licence requirements has had any effect regarding these topics. Hence, the choice was made to interview drivers from two groups: drivers with new licences, i.e. less than 5 years (after December 2007) and experienced drivers who had a driver's licence for more than 30 years. In total 18 drivers participated in the study, 9 experienced (4 male/4 female) and 9 new drivers (3 male/5 female). All currently lived in the Göteborg area. Study Two is reported in Paper C.

3.2.1 PROCEDURE

Interviews were semi-structured to allow for exploration of the participant's answers, whilst not loosing sight of the main topic. Each interview lasted between 1 and 1,5 hours, and included a small test drive, about 15 minutes. During the drive the participants were asked to explain their driving behaviour whilst performing it. The motive behind the test drive was twofold. Partly, it was to probe participants to become conscious of their behaviour as driving is so habitual it can be hard to explain otherwise, and partly it was to see if they did indeed eco-drive. The test drive route included a wide range of traffic situations, such as domestic areas, larger road with heavy traffic, and complicated intersections.

The questions concerned the following topics: the state of knowledge regarding eco-driving among the drivers, what they see as eco-driving, how much their current driving practice reflects their perception of eco-driving, which factors determine if they can eco-drive (hinders/helps), if they have aspirations to improve their eco-driving, and if so, which tools would help them.

Interviewees were not informed that the interview focused on environmental aspects, but instead were invited to talk about driving in a wide sense, and explain their view of it and their thoughts on how to drive. This choice was made in order to gauge the participants' true feelings on the environmental responsibility of car drivers, instead of feeling obligated to express environmentally friendly views. If the participants did not bring up the environmental issues of driving themselves, they were asked about it quite late in the interview.

3.2.2 ANALYSIS

The interviews were transcribed in full. For each interview participant a summary sheet was produced where the statements of that person relating to the topics of interest were collected. These topics included among others environmental interest in connection to driving, perception and attitude towards eco-driving and to other forms of adapting driving and travelling according to environmental impact, as well as barriers and facilitators to driving and travelling as wanted especially out of environmental concern. This material was then analysed to find the major themes for each person. As a next step, all participants were compared to find themes across participants and how they related to each other. With these new themes as a framework, the full interviews were reread to see if the themes were supported in the larger context.

To contribute to the exploration of the concept of eco-driving and its contents, all of the behaviours or choices that the participants stated as an answer to the questions "what do you think of when you hear the word eco-driving?" and "how do you eco-drive?" as well as all statements where they made a comment to eco-driving or fuel-efficient driving were gathered and grouped together. The groups were compiled based on similarity of behaviour, target of behaviour and time perspective of behaviour.

3.3 STUDY THREE: ELECTRIC VEHICLE SIMULATOR AND INTERVIEWS

The main objective of the study was to compare two different designs of the instrument cluster in an electric vehicle, regarding their usability and their aptness in communicating the key aspects of operating an electric vehicle. A secondary goal was to explore the potential for an EV to act as an intervention to induce a more efficient driving behaviour. To fulfil the secondary goal special attention was paid to the ecometer component of the instrument cluster, and interviews were conducted to probe the participants on their perception regarding the connection between electric vehicles, the environment, and eco-driving. Paper D describes the study in full.

The studies included altogether 20 individuals. The participants were divided into two groups of 10 individuals each with equal distribution of age and gender. They were recruited internally at Saab*, using their simulator study participant database. The participants had none or very little experience of driving electric or hybrid vehicles.

3.3.1 PROCEDURE

The study included two consecutive user tests of the two different user interface designs, and the tests were performed in a driving simulator according to a between-subject procedure. During the test drivers were asked to test the interface whilst stationary and while driving. They were also given the task to accelerate and brake hard a couple of times to experience the function of the Ecometer. After the driving participants filled out a questionnaire and an interview was conducted to gather their opinions about the design of the HMI. A complementary interview was conducted to elicit additional information about their opinions and understanding of the eco-related aspects of the interface, and to explore their views of electric vehicles and eco-driving more in-depth. Each test took approximately 60 minutes, with about a third of that time spent driving.

Both objective and subjective data were collected during the tests. Throughout the procedure during both test and interview, notes were taken of actions and statements made by the participants, and audio recorded for later analysis. All of the participants' interactions with the simulator were logged.

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* Study Three was part of a larger research project carried out in collaboration with Saab. This project unfortunately was cancelled due to the bankruptcy of Saab.

3.3.2 ANALYSIS

The interviews were transcribed in full and the participants' answers compared. In a similar way to the analysis in Study Two, the answers to the questions "what is eco-driving?" and "how do you eco-drive?" were collected and compared. Special attention was paid to how the participants reasoned regarding the relation between electric vehicles and eco-driving as well.

3.4 INTEGRATED ANALYSIS

The general approach in the integrated analysis of all three studies was explorative in nature, but with the ambition to draw tentative prospective conclusions in the end. The methods used within the three studies have been a mix of methods aimed at collecting quantitative data, such as driving data logging during the field trial and logging of the interaction patterns in the simulator study, and methods aimed at collecting qualitative data such as interviews, which have been used in all three studies. The intent has been to capture complementary perspectives of the events unfolding during the studies. In the integrated analysis the results of these methods were evaluated together and compared as this was considered to provide a more multifaceted picture of the mechanisms underlying the adoption of eco-driving.

As was described in the introduction, three themes are the focus of this thesis; eco-driving in practice, understanding eco-driving, and intervention. The relationships between the studies and the themes, as well as the analysis surrounding each theme are described below.

Theme: practice

The first step of the integrated analysis of the studies was based on the results of Study One showing some unexpected tendencies. These tendencies clarified the need for further investigation factors beyond the commonly studied behavioural determinants attitudes and knowledge. This was the starting point for the exploration of theme practice. In the analysis, the determinants of eco-driving behaviour in practice were sought in all of the data collected from Study One, and compared to the influential factors found in literature (section 2.3.2-3) to confirm the role of the factors described in literature, explore the extent of their impact, and establish if there are factors missing. The outcome of this first part is described in Chapter 4.

Based on findings that emerged in the exploration of theme understanding, theme practice was continued with an analysis of the influences described by the participants Studies Two and Three. In this analysis an expanded concept of eco-driving was used. The influences relating to this expanded concept were compiled and compared to influences found in literature, as well as to the influences previously identified within the theme. Chapter 6 reports the findings.

Theme: understanding

The second theme explores the concept of eco-driving and how it can be viewed from different perspectives. A comparison of all the different participants' interpretations of eco-driving revealed a large variation; from the bus drivers' narrow but concordant view, to the participants' in Study Three rather uninterested view to Study Two's very varied but engaged understanding. To be able to discuss the interpretations in a meaningful way, all of the mentioned eco-driving behaviours from Studies Two and Three were collected and compared to find groupings and common characteristics. This allowed the large spectrum to be categorised, and the variations of the understandings to be explored in relation to the categorisation. The resulting categorisation is described in Chapter 5.

Theme: interventions

When the threads of the two themes above are woven together, as described in Chapter 6, the resulting weave of influencing factors and categories of eco-driving provided the basis for making recommendations on how eco-driving interventions should be designed, as it identified the factors that can be the key to success or failure for an intervention. The recommendations were then created with the help of the theory on interventions described in section 2.1.2. They can be found in the first part of the discussion.

4. ECO-DRIVING IN PRACTICE AND INFLUENCING FACTORS

This chapter is based on Study One, and revolves around the bus drivers' experiences of practicing eco-driving in their everyday job. Hence, it forms the first part of the exploration of the practice theme. Study One built upon previous studies described in literature, and therefore used the same eco-driving concept, i.e. eco-driving as a fuel-efficient driving style based on anticipatory behaviour with the aim to keep the vehicle rolling at a steady speed, using the engine's power as economically as possible.

In the initial interviews the participating drivers were positive towards eco-driving as well as motivated to eco-drive, but felt incapable to, why interventions to increase their ability were introduced in the field trial. In theory, the combination intervention with both personal training and in-vehicle feedback should have provided the better opportunity for drivers to improve their skills (see section 2.3.1). However, the results of the field trial show that both interventions were equally effective in creating changes in driving behaviour among the bus drivers. In both cases, decreases in instances of harsh deceleration (reduced by 66%), speeding (reduced by 42 %), and idling (reduced by 10%) led to an average reduction in fuel consumption of 6,8% compared to baseline. The results of the logged data analysis from the field trial are described in more detail in paper A.

The participating drivers reported a small increase in eco-driving knowledge but they still felt hindered from really driving accordingly. Further, they expressed discontentment with the eco-driving project and they discontinued their use of the feedback system over time. The benefit of using the system did not exceed the effort of using it.

Comparing the fuel reduction results of the study to calculated potential, which has been estimated to 20-25% (Vangi and Virga, 2003), indicate a discrepancy between the empirical real-world results and the predicted potential, similar to the results in other comparable studies. It is possible that this gap would be smaller if the drivers had felt able to fully put their knowledge into practice. As the drivers felt hindered, the sources of this were explored in the analysis. Information regarding behavioural barriers was sought in all of Study One's data and compiled, and those empirically determined barriers and a few facilitators were juxtaposed with the influential factors in Table 4. This was done to confirm the influence of those factors already described and to investigate whether further factors existed. The following sections report the analysis results per column in the matrix.

The last row of the matrix concerning outcome has been intentionally left out, as these factors do not influence the adoption of eco-driving behaviour, only the measurable effects of the behaviour.

4.1 FACTOR EXPLORATION: DRIVER RELATED INFLUENCES

POSSIBILITY	knowledge and skill, physical and cognitive capabilities, habits
INTENTION	attitudes, responsibility to act, stress

The first factors under investigation are those that were targeted by both interventions: the driver's knowledge and skill regarding eco-driving. It is not possible to say from the empirical data that changes in knowledge and skill were the cause behind the changes in behaviour. The drivers' ratings of their knowledge level and skill before and after the interventions show a small increase in theoretical knowledge but almost none in practical skill (Paper A). It should be noted that all participating drivers had been educated in the theoretical eco-driving before the study, and that their level of knowledge was quite high to start with. However, both before and during the study, they did report difficulties in translating their knowledge into practical skill. The interventions aimed to alleviate this problem by providing real time feedback and advice on how to act in specific situations, but this seems not to have been enough for the drivers to be able to put their knowledge into practice. They expressed frustration at not being able to drive in the planned calm way they wanted to and knew they should. In summary, lack of knowledge did not seem to be a barrier for these drivers.

Regarding the other internal factors that affect possibility, the drivers briefly mentioned their cognitive capabilities in connection to aspects that impacted their ability to think and concentrate on their driving style, e.g. the climate in the bus and the level of stress. Habits were not mentioned, but could be one of the underlying reasons for not being able to translate eco-driving knowledge into skill, even though the drivers insisted that they tried their hardest to practice what the trainer and feedback system told them.

The bus drivers' positive attitudes towards eco-driving should have played a big part in creating a changed driving behaviour as attitudes are considered important determinants of the intention to adopt a behaviour (Ajzen, 1991). The drivers were indeed positive; both in the interviews and in the questionnaires eco-driving was described as important and with several benefits in addition to reducing strain on the environment (see Paper B for more detail).

But the attitudes towards eco-driving are not the only ones that need consideration when introducing interventions, the attitude towards the interventions themselves are also important. Some drivers had strong negative opinions about

the necessity of promoting eco-driving and the way it was carried out. One of the reasons given was that the drivers thought that they did not need to be educated since they already knew how to drive, just given the opportunity to do their job properly. The interventions were seen as just adding insult to injury as the feedback system and training required even more tasks to be done in an already stressful job.

Stress and being pressed for time were recurring themes in the interviews with the drivers. Many of them spoke about often being stressed when driving and the negative consequences this had for how well they drove. Stress was said to decrease concentration levels and hence, detrimental to the intention as well as the ability to eco-drive. The analysis revealed that many of the sources of stress relate to the other categories described below, among others the state of the vehicle, the urban traffic environment, and the passengers.

4.2 FACTOR EXPLORATION: VEHICLE RELATED INFLUENCES

POSSIBILITY vehicle characteristics and driveability, assistive systems

INTENTION

The participating drivers confirmed the importance of vehicle qualities for being able to drive well, claiming that some buses in the company fleet made them appear as if they could not drive. In contrast, the type of bus used in Study One was perceived as having excellent driveability. One driver stated, "it flows down the street like a snake", and many drivers expressed great affection for the bus. Yet, because of lack of maintenance, the buses were in poor condition and often broke down, which was cited as a major cause of stress and made calm driving difficult. It also led to added consequences like a poor physical working environment and angry passengers (see Paper B). When malfunctioning, the buses did not only limit the possibility to eco-drive, but they also led to a decrease in the intention to do so.

4.3 FACTOR EXPLORATION: PHYSICAL ENVIRONMENT INFLUENCES

POSSIBILITY climatic conditions, road infrastructure, traffic situation

INTENTION

The listed environmental factors were confirmed to have both negative and positive impact. Drivers mentioned examples in all groups of factors (the most prominent are described in Paper B). The Gothenburg climate was said to be a negative influence on the possibility to eco-drive with reduced sight due to heavy rain and fog as well as slippery streets during winter.

The combined influence of public transport infrastructure and planning was seen as a major negative factor as both failed to accommodate for the amount of traffic out there. This caused a lot of start-stop driving, e.g. when queuing up at bus stops, which is not compatible with eco-driving. Heavy traffic in itself was also considered a very negative influence on the possibility to eco-drive. Dedicated bus lanes on the other hand were considered a positive influence, which shows that intentionally designed environmental features can facilitate the adoption of eco-driving.

4.4 FACTOR EXPLORATION: SOCIAL INFLUENCES AND NORMS

POSSIBILITY	traffic rules, speed control
INTENTION	fellow road users, passengers

Drivers did not talk about their possibility to eco-drive being affected by social environment, but they spoke about the influence of other road users and of passengers on the intention to eco-drive. Taxis, pedestrians, and bicyclists exerted a negative influence by aggressive driving and carelessness in traffic, causing stress among the bus drivers. The role of passengers is both negative and positive. Because of the bus drivers' strong dedication to passenger safety and comfort the intention to eco-drive becomes stronger because of the passengers. This is especially true if there are elderly passengers on board or many standing passengers (see Paper B). However, passengers who are misbehaving, are loud, or are themselves stressed raise the bus drivers' stress level and decrease their ability to concentrate. The drivers were less inclined to provide comfortable rides if passengers were harassing them, even if they understood that the passengers' frustration stemmed from malfunctioning, late, and overcrowded buses.

4.5 MISSING CATEGORY: ORGANISATIONAL AND JOB-RELATED

Based on the analysis, the factors at which the interventions were aimed appear to only make up a small part of what determines the adoption of eco-driving. The numerous contextual factors in Table 4 were confirmed and exemplified, and partly explain why drivers are limited when turning their pre-existing, and newfound, eco-driving knowledge into practice. However, the matrix is missing several factors mentioned by the drivers as exerting large influence on the way they drive, all related to the occupation and employment of the drivers. Based on the drivers' and the instructors' comments it is here argued that these organisational factors form the basis of many of the previously mentioned negative influences, and that they affect both drivers' opportunity to eco-drive as well as their intention to.

Performing the tasks of a bus driver entails driving in a way that is not optimal for eco-driving. For example, it is hard to maintain a smooth driving style with

uniform speed when having to stop often to pick up passengers at bus stops. Bus driving also includes driving according to a timetable, which puts the driver under constant time pressure. The stress this causes is detrimental to the ability to eco-drive. Corresponding conclusions were drawn by Dogan et al. (2011) who show that fuel-saving performance diminishes for drivers who have to manage fuel-saving and timesaving together, from 10% reduction to 2%. Time pressure was very salient to the drivers in Study One because of the tight schedule and because they were continuously reminded of the importance of bus punctuality, by the management and by a feedback system fitted in the instrument panel. The results of Dogan et al (2011) indicate that this time pressure needs to be lessened to give drivers better conditions for eco-driving.

The company's behaviour was the underlying cause of many of the stressors that reduced bus drivers' intention to eco-drive, e.g. the condition of the buses and the suspicion they felt towards the effort. The drivers, the trainers, and the project manager all mention the negative influence of company culture and the lack of communication, commitment and willingness to change. Because of lack of support in the organisation, the project manager felt unable to engage the driver managers, and concluded that without their support the drivers developed a negative attitude towards the entire effort and were not as informed as they needed to be. For the instructors, the lack of preparation and information in the company were an even bigger issue and led to that training session needed to be cancelled when drivers did not show up, or there was no bus to train in. Moreover, the drivers failed to realise the importance of logging into the system in order to receive the tailored feedback and allow data to be gathered, a complication for which the company was unprepared. Symmons et al. (2011) found similar issues with identification and reporting in a corporate fleet eco-driving study, even though the participating companies were confident that their reporting routines were of high standard. Companies aiming to implement eco-driving should therefore be aware of these issues and prepare for proper commitment to the cause.

The participating drivers also expressed concern about the priorities of the company, which they felt were too fixated on making a profit instead of providing a good service. They felt the company cut corners and pressured them into performing without being rewarded for it. Whilst the company spoke well about environmental efforts and that calm driving was important, the drivers perceived mixed messages as they were evaluated solely on their performance in keeping with the timetable.

It is here argued that the identified additional factors further constrain the drivers' action space in which to practice eco-driving and can be added to the matrix in the same format as the other categories. To summarise; the driver's possibility to eco-drive is affected by work tasks such as picking up passengers, as well as the performance requirement that he/she should do so according to a timetable.

The driver's intention to eco-drive is in turn affected by the company's priorities, whether they conflict with eco-driving or are fully behind it, as well as the company's willingness to change. Finally, organisational factors affect the available outcome of the driving behaviour as well, through e.g. the state of the vehicles the company provides, and by the combined weight of the passengers aboard.

The updated matrix (Table 5) now provides a more comprehensive picture of factors that influence the adoption and implementation eco-driving for professional drivers. In light of the multiple factors listed here, the gap between the projected fuel saving potential and the actually achieved fuel saving is more explainable. The drivers' resistance towards the interventions is also more understandable as the interventions did not in fact help them tackle these factors, and instead added to the negative influence of some.

TABLE 5. FACTORS INFLUENCING THE ADOPTION OF ECO-DRIVING AMONG BUS DRIVERS

	DRIVER	VEHICLE	ENVIRONMENT	SOCIAL	ORGANISATIONAL
POSSIBILITY	knowledge and skill physical and cognitive capabilities habits	vehicle characteristics and driveability assistive systems	climatic conditions road infrastructure traffic situation	traffic rules speed control	work tasks performance requirements
INTENTION	attitudes responsibility to act stress			fellow road users passengers	company's priorities company's readiness for change and commitment
OUTCOME		weight type of vehicle engine type, drivetrain	weather road conditions		assigned vehicle and route loaded weight

5. UNDERSTANDING ECO-DRIVING: LEVELS AND LIMITATIONS

This chapter concerns the questions asked within the understanding theme. The interpretation of eco-driving among different drivers is explored, along with the level of understanding, and the consequences the understanding can have for practicing eco-driving. It represents a shift from the strictly delimited version as driving style that has so far been considered in the thesis, to considering more of the advice that can be fitted into the eco-driving spectrum.

For the bus drivers in Study One, it was clear that eco-driving denoted the anticipatory driving style that they had been taught to strive for. Both their bus driving licence education and the mandatory refresher courses organised by the company promoted this understanding of eco-driving. Any of the other advice given under the eco-driving umbrella, such as checking tyre pressure, avoiding congested routes or choosing a fuel-efficient vehicle, were not applicable to them as these aspects were out of their control, decided on by their job and the company employing them.

For the participant in Studies Two and Three, the situation was slightly different. Their understanding of the concept of eco-driving was more diverse and varied among the different participants. The extent of both their knowledge and which aspects they included in the concept differed (see paper C). Considered all together, these various understandings represent a very large and inclusive concept of eco-driving. To fully comprehend the different ways in which eco-driving was perceived by these participants and to facilitate discussing these differences, it becomes necessary to structure the contents of the concept. To accomplish such a structure, all of the techniques, decisions, and behaviours related to eco-driving mentioned by the participants were compiled and analysed. The resulting systematisation from this analysis comprises three levels of eco-driving, here denominated operational, tactical and strategic (cf Sivak & Schoettle, 2013). The three levels differ on two accounts: the time span for which the decisions on each level have consequences and which type of aspect that the decisions regard. Each of the levels is described and exemplified below.

5.1 OPERATIONAL ECO-DRIVING WHILST DRIVING

This first level of eco-driving relates to the basic driving behaviours. The behaviours at this operational level presuppose that the individual performing them is engaged in driving at the moment and the behaviours take place in the interaction between driver and vehicle. The time span is short as executing an action has immediate consequences as to how much fuel is used by the car. For example, the choice to brake by down-shifting instead of pressing the pedal is made for each and every stop, weighing the general guideline to do so against the consequences

it will have in terms of safety and braking distance. All of the behaviours aim to curtail the amount of fuel used directly by operating the vehicle, and especially the engine, efficiently. All operational eco-driving behaviours mentioned by the participants in Studies Two and Three are listed in Table 6.

All of the participants in Study Two that admitted to knowing anything about eco-driving included behaviours on this level in their interpretation of eco-driving. In Study Three, all except one participant identified the behaviours on this level as eco-driving. Among all participants the most commonly mentioned behaviour is engine braking, which seems intimately connected to eco-driving in Sweden, and driving at slow steady speeds. Among the new drivers in Study Two skipping gears was a very commonly mentioned behaviour.

The impact of practicing operational eco-driving was perceived as small by the new drivers in Study Two, but larger by the more experienced drivers (this is discussed in more detail in Paper C). In reality, the effect of each individual action leads to small changes in fuel consumption, but together these behaviours can lead to an average reduction in fuel consumption of about 10% (Barkenbus, 2010; Smokers et al., 2006), or more depending on how the initial driving style (Gonder et al., 2011).

5.2 TACTICAL ECO-DRIVING CONCERNING THE TRIP

The next level in eco-driving still presupposes the use of a car, but concerns the tactical decisions made in preparation for each trip, either by planning the route and timing of the trip or by preparing the vehicle for the trip. The decisions made here has consequences for the fuel spent during the trip, but not in the same direct way that operational eco-driving has, which gives it a midrange time span.

The behaviours on this level appear to be mostly unconnected to eco-driving for the new drivers in Study Two, and the participants in Study Three mentioned none of them. However, the more experienced drivers in Study Two spoke about many different behaviours belonging to this category, see Table 6 for complete list of tactical eco-driving behaviours.

Some of the participants focused on the behaviours related to preparing the vehicle such as removing racks from the roof when they were not needed in order to reduce wind resistance and keeping unnecessary baggage away from the trunk to reduce the weight of the vehicle. Other participants instead focused on trip planning like avoiding heavy traffic by choosing to drive at a different point in time or taking a different route. The most frequently mentioned tactic to reduce environmental impact of car trips was ridesharing*, especially on work-related trips.

* Ridesharing, also known as carpooling, and is when several people share car for a specific trip, for example commute to work together. It should not be confused with carsharing where several people share a car, but use it for indvidual trips.

TABLE 6. THE THREE PROPOSED LEVELS OF ECO-DRIVING

 STRATEGIC ECO-DRIVING *concerns decisions that have consequences in the long-term, either by guiding future behaviour, or by creating preconditions*	*minimize car use* do not drive drive less use more public transport walk and bicycle more use alternative transport - for long distances (train) - for short distances (walk, bicycle) - in the city (public transport) use multimodal transport *maintain vehicle* perform all scheduled services service the car often change filters change oil change sparkplugs switch tyres according to season keep tyres in good condition	occasionally drive long distance to clear the system park in heated garage *vehicle choice* do not own a car join car sharing service only own one car (per family) buy a more environmentally friendly car - alternative fuel (electric, gas, hybrid, biofuel) - more fuel-efficient vehicle - smaller car - newer car - automatic transmission* - with more gears invest in good tyres no studded tyres
 TACTICAL ECO-DRIVING *concerns choices about the context of the trip made in preparation for each trip. Presupposes that car has been chosen as transport mode*	*plan trip* rideshare/carpool avoid driving at rush hour choose routes with less traffic	*prepare vehicle* avoid starting with a cold engine use engine heater park in heated garage correctly load vehicle remove roof racks park so you can drive out instead of backing out
 OPERATIONAL ECO-DRIVING *concerns the interaction between vehicle and driver while driving, consists of fuel-efficient driving techniques*	skip gears when possible up-shift as soon as possible use correct gear maintain revolutions low maintain top gear shift to top gear shift smoothly only use first gear to start put car in gear before starting drive softer drive slow drive carefully accelerate to the correct speed quickly do not accelerate forcefully observe speed limit	drive slower than speed limit on the motorway maintain steady speed do not drive aggressively do not brake harshly plan driving keep vigilant keep car rolling coast/motorbromsa brake in time brake softly slow down in time before red lights do not start car before driving off avoid idling do not overtake unnecessarily use cruise control* shut off AC

The experienced drivers seem to have acquired their insights into tactical level eco-driving mostly from experience of using a car for a long time and in different situations, which may help explain why the new drivers were less aware about tactical eco-driving.

To give an estimation of the effect of performing tactical eco-driving, it can be said that choosing a less congested route can affect fuel consumption by 20-40%, and choosing a less hilly route by 15-20%, whilst carrying extra 50kg has less than 2% effect.

5.3 STRATEGIC ECO-DRIVING INCLUDING TRANSPORT MODE AND VEHICLE CHOICE

In the final third level of eco-driving the car is no longer given; it concerns long-term decisions about how to transport oneself (see Table 6). The most basic advice given on this level is not to drive at all, something that most of the new drivers in Study Two and one in Study Three found to be the most valid eco-driving advice that could be given. However, there are numerous other actions that can have a great impact if not driving is not an option. From the examples given by the participants in Study Two these include reducing car use by switching to public transport when available for the whole or part of the trip, maintaining and servicing the car so that it can perform at its optimum, and investing in an efficient vehicle. Such behaviours impact the fuel use in the long-term perspective by determining the base consumption or acting as guidelines for future behaviour.

The experienced participants in Study Two and the participants in Study Three quite often connected vehicle choice to eco-driving, and many spoke about the importance of the car being environmentally friendly for their next purchase. The impact of keeping the vehicle in good shape was less mentioned and only those who were very interested in cars or had experiences of lowered fuel consumption after getting a problem fixed mentioned aspects in related to strategic maintenance. The new drivers in Study Two did not speak of maintenance, and very little of vehicle choice in connection to eco-driving; those that mentioned behaviours on the strategic level were mostly focused on reducing car use.

The behaviours on the strategic level were perceived as having a large effect, which they indeed have. Carefully choosing the type of vehicle can for example have a great impact on fuel consumption, as it is estimated that the worst vehicle on the market consumes nine times more fuel than best one (Sivak & Schoettle, 2013). Choosing a fully electric vehicle instead would bring fuel consumption to zero. Fixing an out of tune engine can improve fuel economy by up to 40%, whilst rolling resistance, tyre inflation and proper engine oil have impacts in 1-5% range (Sivak & Schoettle, ibid.).

5.4 THE CONSEQUENCES OF A LIMITED UNDERSTANDING

By dividing the full range of eco-driving** activities as perceived by the participants in this way, and comparing each participant's understanding of eco-driving to it, the limitations of the individual participants' understanding becomes clearer. For most participants, their belief about what comprises eco-driving is confined one level, or even part of one level. For example, many newly educated drivers only spoke of operational eco-driving behaviours, while a few experienced drivers only spoke about car choice. This limited understanding in turn limits the actions that they perceive as possible to perform in order to reduce the environmental impact of their driving.

In some cases this limited understanding gave rise to a negative attitude towards eco-driving. For example, the new drivers only knew of operational eco-driving, but perceived the outcome of it as so small in comparison to not driving at all, that they considered it futile even trying on the rare occasions when they were forced to drive. The participants in Study Three echoed some of these concerns, saying that for them to care more about eco-driving they would need to learn something with a larger impact than just braking, shifting and keeping a steady speed.

The participants in Study Two whose interpretation of eco-driving related mostly to the tactical and strategic level behaviours were more positive towards eco-driving as these behaviours were believed by the participants to have a large impact. However, when speaking about performing these behaviours, participants in Study Two mentioned various reasons for why they were not applicable to them. Influences such as lack of financial resources, poor physical health, or available infrastructure hindered them from performing them. For example, one participant wanted to avoid using the car when moving in the city, but did not have access to good public transport communication and did not feel strong and safe enough to cycle so she had to rely on driving anyway. Because these participants were

** A note on terminology. Each of the promoted versions of eco-driving has its own unique design with regards to the advice included, but they are all centred on the operational driving behaviours. Based on the studies, most drivers appear to connect the term eco-driving to these behaviours as well. Thus, when eco-driving is used to include of the behaviours on the tactical and strategic levels in the way it is here, confusion may arise. Especially since the strategic behaviours are not often mentioned in connection with the eco-driving advice, but mentioned in other contexts.

The question arises whether to use a different terminology to avoid confusion. Using "driving" to denote all of the levels can be seen as somewhat strange when one advice is not to drive. The strategic level behaviours touch upon other concepts such as sustainable transport and eco-mobility from which terminology could be borrowed, but they often come with other connotations, so for the purpose of this thesis, eco-driving will continue to be used for all three levels.

concerned for the environment, they felt frustration and resignation when unable to perform those behaviours they knew of. In a sense, all of the participants in Study Two experience lock-in effects based on their limited view of eco-driving, i.e. they believe they know what eco-driving is, but cannot apply it and do not realise that there is more to know. The new drivers have been locked in by their one-sided education, and thus rejected the whole concept. The more experienced were locked by not having access to information that can widen their view and help them find suitable alternatives to fit their circumstances. These lock-in effects are a major constraint to the participants' eco-driving action spaces, i.e. the set of activities that they fell they can carry out as eco-driving.

The influences mentioned briefly in the text above confirm that some of the factors in Table 4 affect adoption of operational eco-driving among drivers of passenger cars as well, but hint at there may be different factors influencing the adoption of operational, tactical and strategic eco-driving. These various influences will be explored in the following chapter.

6. INFLUENCES ON ALL LEVELS

In the conclusion from chapter 4 multiple factors influencing the bus drivers' ability, motivation, and opportunity to practice operational eco-driving were described. With the conclusions from chapter 5, a more inclusive view of eco-driving was adopted than the delimited view used in the bus driving study and in the eco-driving studies found in literature. Thus, the factors in Table 4 are only confirmed to describe the influence of level one eco-driving, and additionally, only for professional drivers. Using the data collected in Studies Two and Three, influences on the two additional levels are explored and confirmation is sought to influences found on the operational level in a private driver perspective.

6.1 FACTORS INFLUENCING THE OPERATIONAL LEVEL

Theories regarding the factors influencing adoption of operational eco-driving have been described and discussed throughout this thesis. The results of the included studies show that the factors found in literature give together a relatively informed picture of the influential factors. Even though Table 4 was shown to be missing an important component for professional drivers in Study One, the results of Studies Two and Three indicated no other such large group of factors missing from Table 4 for driving in a private context.

The participants mentioned many of the factors when discussing operational eco-driving behaviours, and their experiences from trying to implement level one eco-driving adds details and exemplifies some of them. They discussed among other things different qualities of the vehicle design that either helped or hindered them from adapting a calm and anticipatory driving style. Having a vehicle with a powerful engine makes it more fun to drive fast and more aggressively, but the participants underscored that they would get over that quickly, and drive normally when commuting. Having a comfortable and quiet interior was considered calming, but deceptive as the lack of natural feedback in the vehicle meant it was easy to drive fast without noticing. The participants did not agree on whether they would like cars to be more autonomous or if they would like to retain control. Some thought the car would do a better job and that it would be more comfortable, whilst others did not trust the car and thought that it would take all of the fun out of driving.

Being in full control of the car and the situation ties in with being able to anticipate what will happen. Anticipation is key to being able to carry out many of the level one eco-driving behaviours. Because Göteborg was perceived as an unpredictable city to drive in because of its layout, knowing your way around the city was seen as a very important factor in being able to carry out eco-driving. This highlights the influence of two factors, a road infrastructure that is logically laid out and easy to follow, and good local knowledge to find alternative routes.

Another influential factor connected to anticipation is the level of cooperation between motorists. This type of social interaction between drivers facilitates eco-driving when everybody works together, but hinders it when somebody behaves in a non-cooperative manner (cf. Wilde, 1976). Other motorists driving aggressively contribute to cooperation problems, but also simply inattentive motorists and other types of fellow road users not following the rules can cause issues, as well as complicated traffic situations, where the complexity and number of different coexisting transport modes cause stress. The participants also reported occasional conflicts when trying to both use eco-driving techniques and follow traffic rhythm, as it would annoy other motorists when they were going slower or anticipating stops. This was a problem noted also by Gonder et al (2012).

The one factor that the data indicate is missing from the matrix is fun in driving. Study Two participants mentioned it in relation to vehicle features, but the participants in Study Three spoke of it directly in relation to adoption of operational eco-driving. Four of the participants claimed to know very well how to eco-drive, but did not do it because it was more fun to drive in a less efficient manner, they were impatient or they just did not feel it was worth the fuel saving unless it was winter. It may be compared to the driving enjoyment mentioned briefly by Gonder et al (2012).

6.2 FACTORS INFLUENCING THE TACTICAL LEVEL

The choices on the tactical level concern preparatory behaviours of two kinds: planning the trip and preparing the vehicle. The choices available on this level were the least cited by the participants in Study Two, and cited by none in Study Three, indicating that the behaviours are not well known or not connected to environmental concern.

The empirical data from Study Two provides some suggestions regarding influences on adoption of tactical eco-driving. One of the more frequently mentioned behaviours was choosing to the timing or the routing of the trip with the intent of avoiding congestion. For the participants who were pensioners or had flexible hours it was possible to make this choice without making too many adjustments, but it was perceived as much harder by the participants with fixed working hours. Participants in Study Two were more likely to consider the environmental impact of their trip route and timing when making longer trips, since these trips often are made in connection to leisure and hence not governed by strict timing. A comparable difference in relevant factors between leisure and commuting trips has been found elsewhere, but then concerning transport mode choice (see Anable and Gatersleben, 2005).

Very few studies have looked at route and time choice from an eco-perspective. Delhomme et al. (2013) mention it, but only state that the studied drivers found changing their itineraries to avoid congestion one of the most difficult eco-driving

advice to follow. More studies are available for comparison from a traffic efficiency perspective, e.g. Chorus et al. (2006) review the factors that determine the decision to search for information about alternative routes, times, and modes. They conclude that the purpose of the trip and its context has an influence, especially when these include uncertainty. Longer trips are such a source of uncertainty.

Many of the participants in Study Two spoke about the important influence of being familiar with the alternatives in order to be able to make the better choice. This influence is also confirmed by Chorus et al. (ibid.). Study Two participants were more likely to search for alternatives when travelling to new destinations and making longer trips. Many commented on the usefulness of tools for planning routes, both in-car devices such as GPS and web-based map tools for getting directions. For shorter trips and trips made often, the participants had a route that they like to follow. This could be the result of habit, i.e. drivers use the route they usually drive, or it could be connected to aspects beyond travel efficiency such as how attractive the route is to drive (Anable and Gatersleben, 2005; Gärling, 1998). Getting drivers forego such favourite routes has been pointed out as a major challenge when trying to reduce kilometres unnecessarily travelled (Waters and Laker, 1980)

The second of the popular tactical eco-driving behaviours among Study Two's participants was ridesharing. Again trips covering longer distances increased the likelihood that the participants considered the behaviour, especially when they knew that acquaintances were travelling to the same destination, such as business trips and trips with friends. A few of the participants mentioned discussing ridesharing in their workplace, and agreeing to make a conscious effort to use one vehicle when travelling to the same destination. This indicates that the influence of the image of ridesharing in the social setting is large, but also that there are obstacles, such as itineraries need to match. Similar influences have been found to affect the specific action of ridesharing to work, but the main explanatory variable in that case was how ridesharing was perceived in terms of convenience, comfort and time saving (Horowitz and Sheth, 1976).

Very few participants in Study Two mentioned behaviour related to preparing the vehicle before a trip. It appears that knowledge about the impact of these behaviours may be the most influential factor. A further influence indicated by the participants is having access to facilities such as garages or good parking spaces in order to be able to e.g. plug in a heater. Another facet of access to facilities was that participants had things in their car that they had yet leave at their intended destination because these places were too inconvenient to get to, e.g. participants had household waste in the car because they had not got around to drive to the recycling station. The design of the vehicle and equipment can also play a role as e.g. roof racks hard to detach. Additionally, weather has an impact, but mostly as it determines which actions may be necessary. This is made visible as the partici-

pants in Study Two only mentioned behaviour related to the cold climate in Sweden, whilst the compilation of advice in Table 2 includes references to keeping the vehicle cool in hot climates. It has not been possible to find any studies regarding the vehicle preparation behaviours in literature.

One common influence on both trip planning behaviours and vehicle preparation behaviours is that many of them are enforced as they fulfil other goals apart from being environmentally responsible, such as convenience. For instance, if you rideshare you can have company on long trips and you do not have to drive the whole way. Avoiding congestion means you do not have to sit in a queue. Some actions have multiple benefits, e.g. parking your car in a heated garage reduces the impact of the elements on the car so that it lasts longer, keeps the engine warmer reducing emissions when starting it, as well as eliminates the job of scraping ice off the windows in the winter.

The influences identifed concerning the tactical level are summarised in Table 7, and categorised following the same model as previous summaries of influences.

TABLE 7. FACTORS INFLUENCING THE ADOPTION OF TACTICAL ECO-DRIVING

	DRIVER	VEHICLE	ENVIRONMENT	SOCIAL	UNCLASSIFIED
POSSIBILITY	knowledge of alternatives knowledge of impact flexibility of itinerary habit	in-vehicle planning tools (e.g. GPS) design of vehicle and accessories (ease of use)	available alternatives (routes) accessibility to facilities weather	social connections with matching itineraries	
INTENTION	convenience and added benefits		route attractiveness	social status of action	trip purpose trip length

6.3 FACTORS INFLUENCING THE STRATEGIC LEVEL

The strategic level of eco-driving contains behaviours related to reduction of car use, as well as choice and long-term maintenance of vehicle. Reducing car use was quite a common topic among Study Two participants. Mostly they brought up shifting their travel mode from car to other more sustainable modes of transport such as train, public transport, bicycle or walking. One major barrier mentioned by several of the participants was physical capabilities. Two participants talked about not feeling fit or safe enough use their bicycle to work, and another driver with some disabilities was unable to travel in any other way than by car. But increasing one's physical capabilities was also a motivating factor in reducing car use as making short trips by walking was seen as a nice way to squeeze in some exercise into daily life.

Some participants viewed public transport as an excellent means of transportation for trips in the inner city, but not as an option for travelling longer distances or commuting. Some of the problems cited were low frequency of buses, limited operating hours, and many stops and changes en route. Several reported nevertheless carrying out work- and shopping related trips by public transport once in the city. This is interpreted as a real ambition to use public transport when it was more available. Some participants mentioned conflicts within the family with regards to mode choice, when one part wanted to do the "environmentally responsible thing" and use public transport or train, and the other wanted to use the more comfortable and convenient travel option.

A few participants in Study Two discussed moving to a place where they would be closer to stores and other amenities when they became pensioners so that they would not need to own a car, and maybe join a carsharing service instead. The rise of carsharing services in Göteborg was seen as something very positive, but with the lifestyle and place of residence the participants had now, needing a car for everyday errands was an inhibiting factor for taking full advantage of such services. Both retirement and moving to a more urban area have been connected to a decreased share of travel conducted by driving and increased use of non-motorised transport (Scheiner and Holz-Rau, 2013). There are many such changes in life situation that can affect the choice of transport mode, as it leads new needs and purposes for making trips.

Regarding influences on the strategic maintenance behaviours very little was mentioned in the interviews. Similarly to the case with the tactical preparation of the vehicle it appears as if knowledge is a large influence. Once informed of the behaviour, Delhomme et al. (2013) state that drivers found it quite easy to adopt the habit of checking tyre pressure at every second visit to the petrol station, at least in comparison to adopting other eco-driving behaviours. Those participants in Study Two that did talk about maintenance behaviours also displayed a higher interest in cars in relation to the other participants, indicating that interest may be an important influence. This can be compared to a study of repairs of small household appliances, where those who fixed broken products to a higher rate were people who like to understand how things work and get personal satisfaction from mending the products. Barriers to repairing included not understanding what was wrong, insufficient information from the manufacturer and either too simplified or too complex service manuals (Lilley et al., 2013). Some of these factors may influence maintenance of cars as well.

With relation to vehicle choice, the participants' perception of what they use a car for affects the choice they believe they have among more environmentally friendly cars. A common explanation for why smaller and less powerful cars were out of the question was that a car should have greater power to be safe so that you could drive away from dangerous situations and overtake properly on the motorway.

Other reasons for needing a larger engine was that the pulling power was needed to pull a caravan during vacation or a horse carriage for competitions. A larger car was needed so that it could be used to haul building material and tools when renovating. Even if these activities where not everyday activities they still set the demands for what the car should be able to do. A similar line of reasoning was applied to (not) buying an electric vehicle in Study Three; the range would be perfectly fine for everyday use but it could not cope for example with the biannual trip to the mountains. Participants were not able to imagine choosing other alternatives at those special occasions. Even if the stated reasons are true for the participants, they could also be examples of the participants rationalising their choices in hindsight. Research into the role of the car, which has found that the car often is seen as something more than a mode of transport, may offer some explanations to why the car is a primary choice for many. The car can be seen as a source of freedom and a means to be in control (Mann and Abraham, 2006). For leisure journeys, which are connected to freedom of choice, relaxation and enjoyment, the car is seen as the best option for providing this freedom (Anable and Gatersleben, 2005).

Another aspect that affected if they were willing to invest in an environmental car was whether they perceived the car as really sustainable. Participants in both Study Two and Study Three mentioned that they believed that electric vehicles were not as sustainable as they were made out to be because of the battery technology. The social sustainability of the fuel was also a consideration for some who thought that ethanol powered vehicles were horrible as the ethanol production used up land that should be used for food production.

Other reasons behind the choice of vehicle given by the participants in Study Two were financial. Environmentally friendly vehicles, especially those run on alternative fuels, were perceived as costly. On the other hand, another alternative for lessening the impact was to choose a smaller vehicle, which was perceived less costly with the added benefit of being fun to drive. However, the above-mentioned reasons for not buying a small car often dominated.

As mentioned already in the introduction chapter, there exists a large body of literature regarding the behaviours included on the strategic level of eco-driving. The studies concern mainly reduction of car use including modal shift, and adoption of new vehicle technology. There are a few comprehensive reviews of previous work in this area (see e.g. Anable et al., 2006; Fujii and Taniguchi, 2006; Graham-Rowe et al., 2011; Lane and Potter, 2007; Möser and Bamberg, 2008) and a recently published special issue of Transportation Research Part A, Psychology of Sustainable Travel Behaviour (vol. 48, 2013), presents the latest research. The conclusions drawn in the analysis described here (see Table 8 for a summary) largely reflect influences found in the more comprehensive descriptions of motivating and hindering factors resulting from these studies, even if they describe

many more factors. The studies although predominantly focus on internal factors, and reviews of the impact of contextual factors have not been found. Thus, the complexity of determinants of travel behaviour, including the links between psychological, social and contextual factors, is not fully understood (cf. Gehlert et al., 2013). Furthermore, studies regarding the adoption of maintenance related behaviours appear to be missing in literature.

TABLE 8. FACTORS INFLUENCING THE ADOPTION OF STRATEGIC ECO-DRIVING

	INDIVIDUAL	TRANSPORT MODE	ENVIRONMENT	SOCIAL	UNCLASSIFIED
POSSIBILITY	physical capabilities financial resources life situation and itinerary knowledge of alternatives knowledge of impact	available vehicle alternatives available transport alternatives	accessibility to facilities (e.g. for maintenance) distance to amenities	family disagreements	perceived and actual needs
INTENTION	attitudes towards cars, safety beliefs about sustainability interest in cars	quality and convenience of transport alternatives			trip purpose trip length

7. DISCUSSION AND IMPLICATIONS

The discussion starts with an attempt to tie together the three themes of the thesis and discuss the possibility for interventions to impact the adoption of eco-driving. The discussion on interventions is followed by an examination of the connections within the hierarchy of eco-driving. After that, the methodological approach, the contribution of the thesis and further work are deliberated.

7.1 THEME: INTERVENTIONS

Up to this point, the thesis has primarily dealt with the two themes practicing and understanding, and the connections in between the two. The conclusions regarding understanding and practicing eco-driving form a platform upon which the discussion regarding the third theme, interventions, can emerge.

7.1.1 THE PREREQUISITES FOR INTERVENING

Very briefly summarised, the extent to which an individual can adopt eco-driving depends on two aspects; how they understand eco-driving and how well that understanding can be turned into practice given the individual's travel needs, available alternatives, and the situation when driving. The extent of the latter, the driver's possibility and intention to practice eco-driving, is governed by a multitude of factors. These were compiled for all three levels of eco-driving in (see tables in chapter 4 and 6) and include internal factors such as task knowledge and attitude combined with numerous contextual factors in the physical, social, and organisational environment.

The extent to which eco-driving is known and how it is understood varies. Among participants in the different studies their understanding was found to be confined to a small subsection of the different behaviours that can be included under the eco-driving umbrella. This means that individuals can become locked in to an understanding that only concerns one small part of the eco-driving spectrum, which may or may not fit their needs, alternatives, or situation.

Together, the limited interpretation and the influences on practice establish the boundaries for the set of possible actions available to the individual. In other words, individuals have a limited action space for eco-driving. It is this action space that can be enhanced via targeted interventions.

7.1.2 THE OUTCOMES OF THE INTERVENTIONS TESTED

Based on the two interventions examined in the studies, a few points can be made about the successfulness of interventions to enhance drivers' action spaces. From the empirical data in Study One, it can be said that both training and feedback systems can help bus drivers gain more theoretical knowledge of eco-driving, but has less effect on helping them practice it. For the newly educated drivers in Study

Two, the obligatory eco-driving education appears to have been quite effective in increasing the knowledge of the version of eco-driving that is taught. However, as the new drivers perceived the effects of operational eco-driving as very limited, some participants reported being unmotivated to execute eco-driving techniques when driving. Some even saw it as slightly irresponsible to teach it as it can promote the idea that driving can be seen as something environmentally friendly. Thus, their perceived set of actions did not increase as a result of further knowledge.

In this case, the interventions did not reach their predicted potential because they promoted knowledge about operational eco-driving to already knowledgeable bus drivers on the one hand, and to individuals who consider driving environmentally irresponsible on the other. This is indicative of a larger problem behind the failure of eco-driving interventions; they do neither sufficiently consider the context in which the intervention is introduced, nor the previous knowledge, values, or commitment of the individuals it is introduced to. As concluded in section 2.1.2, interventions will have varying effectiveness depending on how well the determinants that they target match the determinants causing the behaviour to not be carried out in the first place. Nevertheless, offering knowledge about operational eco-driving to drivers who are unfamiliar with it can be an important first step to widening the action space of those individuals, but it is not enough.

With an expanded eco-driving concept, which includes more than just operating the vehicle in a fuel-efficient manner, and the influences on its adoption charted, the range of possible targets for interventions is much larger. This wider spectrum allows for design of interventions that are better adapted to the target group's characteristics and the context, hopefully leading to interventions that are more effective in widening the action space and more accepted by the individuals exposed to the intervention.

7.1.3 DESIGNING INTERVENTIONS THAT ENHANCE ACTION SPACE

Given that the studies show that environmental concern is high among the participants, and they were motivated to act, it is here argued that the focus of interventions should not be to convince people of the necessity of action, but to enhance their space for taking such action. For the sake of the continued discussion a more detailed explanation of what is meant by action space in this context is in order. It is proposed that action space can be seen as consisting of two parts, the actual action space and the perceived action space. The actual action space describes the individual's possibility to perform behavioural alternatives limited by objective constraints. Such constraints can be both internal, such as skill level and physical capabilities, and external, such as available transport mode alternatives and road infrastructure. The perceived action space is the individual's perception of his or her own possibilities. Here, the constraints relate to whether they realise that they can act, if they have the knowledge, or consider that type of action relevant to themselves, which includes such aspects as attitudes, values and perceived

needs. Figure 2 aims to illustrate the two aspects of action space in relation to the full spectrum of eco-driving.

FIGURE 2. PERCEIVED AND ACTUAL ACTION SPACE

In order to be effective and accepted, interventions must consider both of these action spaces. Removing an objective constraint without removing the perception of it will most likely not lead to change. Reducing a perceived constraint without considering if there are objective constraints hindering the action may lead to frustration and disbelief, like the case with the bus drivers in Study One. However, the two action spaces will probably need to be targeted with different types of interventions.

For the actual action space, interventions need to provide opportunity, that is, they should enable and facilitate eco-driving actions to be taken. Enabling can be done in many different ways, and can target almost all of the factors in the matrices, by removing physical and mental barriers, spreading information, providing facilities, providing viable alternatives, as well as educating and providing skills. The

range of possible interventions is large, from very costly long-term city rebuilds to small changes in road signs. There are plenty of examples of enabling and facilitating interventions already implemented that can provide an overview of potential targets and strategies. A few examples are described below.

A large contributing factor for enabling eco-driving on all three levels is rebuilding cities and their infrastructure. The need for cars can for example be reduced by densification of cities ensuring that inhabitants have needed amenities in walking distance, a process that is going on in many cities at the moment. Creating safe and pleasant walkways and bicycle lanes can also increase the attractiveness of using non-motorised transport, or letting bicycles set the pace of traffic in the street. The flow of traffic can be improved by reconstructing the infrastructure of the cities and facilitate operational eco-driving as well as making the environment more attractive for other forms of transport. A quite substantial rebuild was for instance done in the case is Poynton village in the UK where a 'shared space' replaced a busy intersection in the middle of town. By removing traffic lights, traffic signs, painted lines in the roadway, and curbs the design aimed to increase calmness, respect among road users, and attention, and has managed to successfully reduce both congestion and accidents (Goodyear, 2013). Less radical is adding more bus lanes, which has the double benefit of removing hindering traffic for bus drivers and increasing the quality of public transport through shorter journeys with better punctuality. Increasing the availability and attractiveness of public transport is one major strategy to reduce car use.

Another means for intervention is redesigning vehicles so that they provide the right conditions for eco-driving. Lack of natural feedback in new quiet cars was a problem for participants in Study Two, so designing a car that better communicates its power outtake and speed to drivers could be one strategy to facilitate operational eco-driving. Incorporating eco-driving feedback systems in instrument panels is one way, but they may be a little too easy to ignore. In order to facilitate maintenance and preparation a lot can be done through design of vehicles, as well as products like roof racks and roof boxes. These should be easy to remove, and as aerodynamic as possible. Vehicles could communicate their function better to encourage regular maintenance for car owners that are not that interested. As the price of service is perceived as high, more things could also be done to offer facilities and help car owners so that they can perform maintenance on their own.

Regarding the choice of vehicle, environmentally friendly vehicles need to be available for purchase. This was mentioned as a problem in relation to electric vehicles in both Study Two and Study Three. Another issue with electric vehicles is the limited range, which could be extended through development work. In the meantime, package deals have been tried out where the purchase of an electric vehicle comes with easy access to a rental car with longer range when needed, or in combination with a train pass, like the Belgian Plug and Ride project (Denys, 2011).

Not only physical interventions can increase the objective action space, there are policy options too. For example, tax rebates for environmentally friendly vehicles put them in the price range of more people. There is also the possibility to rethink how some services are carried out. Based on Study One, bus drivers could be enabled to eco-drive by removing the timetables, in order to make them less stressed. If bus frequency is high enough, this will not impact on the quality of the service. Buses can be sent off at regular intervals from the depot, and riders can use the real time information already available online and at bus stops.

In addition, there are numerous examples of interventions in the form of online services to facilitate eco-driving behaviours. Ridesharing applications for smart phones, such as Zimride (zimride.com) and Liftshare (liftshare.com), have been created where members can offer a passenger seat to other members when going for a drive, or search for members to hitch a ride with. Similar applications exist for carsharing, such as Zipcar (zipcar.com) and RelayRides (relayrides.com), where car owners can offer their car for hire when not using it. There are also sites, like trafiken.nu, that offer live streaming videos of commonly congested places so that drivers can make an informed decision about which route to take.

To target the constraints of the perceived action space more exemplifying and encouraging interventions should are proposed. Since the perception of the actions available is steered by knowledge of which actions are available, a first strategy is simply informing people that these behaviours are indeed available. This is done in many forms already, the inclusion of operational eco-driving in driver's education is one example, providing this type of information on websites another. Such informative interventions have their role to play in order to spread knowledge to people and widen the scope of their eco-driving understanding. Nevertheless, they should probably clearly communicate the effects of the behaviours as well, as disbelief in the outcome was concluded as a factor in Study Two contributing to not accepting the behaviour.

Different forms of exemplification can be used to make people reflect on their behaviour and challenge their beliefs on whether a certain eco-driving behaviour is applicable for them. Hemtjänsten (in-home care and assistance for the elderly) and the postal service in Sweden for example proudly display on the side of their vehicles that they are electric vehicles, which can motivate others to consider if electric vehicles are right for them. There are also more unusual and more fun strategies, like the mimes used in Bogota, Colombia, to poke fun at reckless drivers and exemplify good behaviour in traffic (Caballero, 2004).

Encouraging interventions should target beliefs about how easy actions are to perform and how convenient they are. One strategy is to provide incentives to try new behaviours. Being offered a bus pass by the employer was one example mentioned in Study Two, and Västtrafik, the public transport provider in Göte-

borg, has offered free two-week bus passes to car drivers to encourage them to try public transport instead of driving. Other forms of prompting can be used as well. There are already signs along the approaches to the Göteborg city informing passers-by of the time to different destinations via different routes, they could display carbon dioxide spent as well to highlight the environmental aspect. Another example is the signs along the motorway where there are commuter train stations for when the next train leaves, combined with a parking lot.

From the many examples described here it can be concluded that progress is made towards enabling people to take action. Most of these examples however only consider either the objective constraints or the perceived constraints, but do not consider how they relate to each other. It is here argued that there is a need to use combinations of strategies in the intervention approach to reach the full effect on both the actual and perceived action space. A further aspect is to be consistent across the levels, and across actors. Mixed messages confuse and since the environmental issues sometimes conflict with other aspect of driving, like safety, it is important to be clear in these instances.

7.2 CONNECTIONS BETWEEN THE LEVELS

The choices made at the different levels of eco-driving, i.e. operational, tactical and strategic, are interconnected. They are hierarchically ordered, which means that decisions on a higher level will affect the available choice in the lower levels. Choosing to walk to work means that there is no need to consider operational eco-driving.

Table 4, the original matrix of influences on the adoption of eco-driving, included an outcome row, which served as a first indicator of the effects of this hierarchy*. In the field trial in Study One the effects on fuel consumption of vehicle load and weather were clearly demonstrated. From the results of Studies Two and Three it can be seen that the choices at the tactical and strategic levels also appear to affect the intention to eco-drive. For example, the participants in Study Three discussed whether it was more important and easier to drive economically in an electric vehicle, and participants in Study Two mentioned that it was easy to get carried away in a car with sporty looks and powerful engine. Both of these examples demonstrate the effects of vehicle choice on operational eco-driving. Another aspect of vehicle choice is that buying an environmentally friendly car can increase the will to eco-drive, either by increasing the driver's self-image as "green" or through design elements included to fit that target group. The tactical decisions also have a facilitating effect on operational eco-driving as choosing route and timing the trip mean that congestion can be avoided, providing the right conditions for keeping the car rolling.

* In Study One the effects of the influences included here, e.g. vehicle, route, load and weather were confirmed (see figure 3 in paper A)

These are examples of top down effects, i.e. decisions at higher levels set constraints for lower level decisions, but there may be bottom up effects as well. This would mean that a decision taken at a lower level causes a higher level decision to be taken. An example from Study Two is that some of those drivers that could not avoid rush hour because of their working hours, had begun using public transport or at least considered it, to avoid sitting in queues and spewing out exhausts. They had thus been unable to carry out a tactical decision leading them to change their strategy. A connection between practicing operational eco-driving and purchase of a more efficient vehicle have been seen elsewhere (Harvey et al., 2013), possibly because drivers become aware of how much fuel they really consume.

However, the full extent of these connections between the levels is not known. Research tends to focus on one type of action, for example shifting from car driving to public transport, and the effects it has on other behaviours are not studied. Performed investigations into the connections between behaviours have mainly focused on rebound effects, i.e. where a reduction in one behaviour's environmental impact leads to increasing the frequency of that behaviour or another behaviour. One such example is that people who purchase an electric vehicle drive more, and replace trips using non-motorised transport with electric vehicle driving. The existence of rebound effects further strengthens the need to actually study a range of behaviours. Additionally, the approach of endorsing one, "correct", behaviour may not always be appropriate, as in the case of the promotion of car use reduction for those that have no other choice than to drive. If the promoted behaviour does not fit with the individual's actual action space, not being able to perform it may lead to frustration and guilt, and it is unlikely that the individual will realise the next best options if only one behaviour is promoted.

This interconnectedness is not only important to consider when making research studies or governmental educational interventions. It also needs to be considered by the other actors that have an influence on the performance of eco-driving behaviours, including vehicle manufacturers, city planners, and public transport companies. It is easy to create inadvertent effects on other behaviours if the whole system around the intervention is not considered, like the effects created when not considering the context of the intervention or the characteristics of the target group. There is also a positive side to the interconnectedness, since thoughtfully created interventions can maybe make pro-environmental behaviour easier not only on lower levels in the eco-driving hierarchy, but on the higher levels as well. In the best-case scenario they can even spread to other areas than travel behaviour.

7.3 APPROPRIATENESS OF METHODOLOGICAL APPROACH

An exploratory, mixed methods approach was used in order to fulfil the aim of increasing knowledge of the mechanisms behind the adoption of eco-driving and identifying motivators and barriers in the adoption process. Taking this approach and letting the empirical material steer the investigation resulted in some unex-

pected turns, like the insight that the understanding of eco-driving expands beyond a driving technique, and that being able to eco-drive is constrained by much more than knowing how to. But is it the most appropriate approach and could it have been possible to fulfil the aim using a different approach?

Applying a mixed method approach in Study One instead of taking the more traditional route of introducing the in-vehicle device and measuring only the effect on fuel consumption, meant that it was possible to go beyond results along the lines of positive potential so frequent in previous studies. The interviews enabled the mechanisms underlying the adoption process among the bus drivers to be identified and explained. Study Three addressed another level of eco-driving, but the same exploratory approach played an important role here as well. Through this it was not only possible to shed light on some of the barriers in the process of adopting new technology for environmental reasons, but also put the result of the HMI evaluation into an adoption context. It was possible to elucidate that the uncertainties in the process affected the evaluation of the usability of HMI, and that it in turn affected the adoption process, thus exposing aspects that could not be found through more classic questionnaire studies.

Study Two did not go as deep into the mechanisms behind transforming knowledge of an action into practice as did the other studies, but instead explored a wider context. This allows the adoption of eco-driving to be related to a societal and systems perspective, which has revealed more information about the connections between the adoption of different behaviours, as well as the wealth of determinants. It has also showed that taking a too narrow perspective when trying to promote more sustainable travel behaviour can have unintended and even adverse effects.

In all three cases the exploratory dimension was very important for reaching the end result, and a different approach would most probably have resulted in a different result. The mixed methods led to a better understanding of the complex connections and influences present in the adoption process. Without the approach used, comprehending the mechanisms to the extent they have been would have been much more difficult.

7.4 CONTRIBUTION OF THE THESIS

In the prelude to the theoretical framework it was stated that the thesis wished to contribute to the fields described, i.e. the theory on pro-environmental behaviour and the theory on adoption of eco-driving. This section aims to clarify this contribution.

With regards to the pro-environmental behaviour framework the hope is that this thesis can serve as an example of the explanatory rewards of working with contextual factors. The nuanced picture produced in this case of eco-driving highlights

the importance of these factors in relation to psychological factors. It has been demonstrated that studying the contextual influences may be very important as they exert a large influence by setting the boundaries for which pro-environmental behaviours are available to an individual. They also affect how pro-environmental behaviours are perceived in terms of how convenient they are or if they fit into an individual's circumstances. As was shown in Study One, they may be the factor hindering an otherwise successful intervention.

The contributions to the theoretical context of adoption of eco-driving are multiple. One contribution to eco-driving theory is the categorisation of eco-driving behaviours into strategic, tactical and operational, which hopefully allows for a more informed discussion of behaviours. By using a clearer distinction of what is meant when one says eco-driving, it should make it easier to talk about different behaviors, and discuss how they fit together and what their respective effects are. The proposed categorisation should hopefully facilitate both discussions within an educational context and in a research context when evaluating eco-driving interventions.

A second contribution is the mapping of the influences on the adoption of eco-driving. The thesis has highlighted the special case for professional drivers by adding the additional determinants originating in the organisational context. A tentative mapping of influences for all three levels of eco-driving in a private context has been provided as well. The matrices describing these influences should be useful when choosing how to design an intervention and when trying to predict or evaluate the success of an intervention.

This latter contribution relates to the overall aim; to increase the knowledge on mechanisms behind the adoption or rejection of eco-driving. It can be concluded that the large number of influences contribute to that these mechanisms are complex. Summarised, it can be said that adoption is partly dependent on how eco-driving is interpreted; a limited understanding of the concept creates a narrow set of actions to adopt. It is also dependent on the objective range of actions that the individual can practice, the actual action space. When these two do not match, adoption is hard to bring about. The challenge of designing interventions lies in creating an overlap between the two, either by increasing the actions known and perceived as eco-driving by the individual, or by removing objective constraints and enabling more actions to be carried out. In short, interventions should enhance both the actual and perceived action space.

Finally, it can be concluded that there are plenty of options available for creating effective and accepted interventions to increase the adoption of eco-driving. However, they need to be carefully designed not to create inadvertent lock-in effects, both in the minds of target group and of the researchers studying them. The complexity of influences means that it is vital to look at all parts to see the interconnectedness and find the influences of one choice on another.

7.5 FURTHER RESEARCH

The descriptions of the influences on the strategic and tactical levels in Chapter 6 are only tentative. Further studies are needed to validate the influential factors already identified and to investigate whether there are more. A good place to start such an investigation would be a literature review of the available material regarding car use reduction, modal shift, and adoption of new vehicle technology.

As the work in the thesis has shown, there is a considerable need for empirical studies with an explicit focus on contextual factors. Such studies would provide an opportunity to examine whether the recommendations for interventions argued here succeed in a real-world context. Applying a systems perspective should be a fruitful approach as it allows for the interconnectivity of the eco-driving levels, as well as the influences, to be explored. Thus, both rebound effects and positive spill over could be studied and with any luck more deeply understood.

The mechanisms behind which part of the eco-driving spectrum that an individual has recognised as eco-driving cannot be fully explained on the basis of this thesis. It is another aspect that needs further work. However some inkling to causes can be found in the material. Whether the driver drives in a professional context or not affects how much of the eco-driving spectrum can be applied. Hence, the professional drivers perceive only level one as eco-driving, because it is what they have control over in their work. In addition, they have also been educated in bus eco-driving, which focuses solely on level one. All of the private drivers, however, can to a larger extent choose how, when, and why to transport themselves, so more of the available eco-driving advice can be applicable to them depending on their situation. Nonetheless, the new drivers (with licences after 2007) consider only operational or not driving at all as eco-driving because they have, like the bus drivers, been educated that this is eco-driving. The more experienced private drivers (Studies Two and Three) have not been automatically exposed to information about eco-driving and if they have heard of it, the amount of information they have attained varies along with the content of that information. How their understanding is formed is not known.

In general, the situation for different types of drivers is something that needs further work. The eco-driving conditions for a bus driver differs from the situation for a taxi driver or a truck driver, even if all are professional drivers. The implications of these differences could be another line of inquiry.

From a wider perspective, it would be interesting to compare and draw parallels to other areas where a shift to pro-environmental behaviour is needed and studied, including household energy use and food. Could the theories regarding different types of action space be informative when applied in that context?

REFERENCES

Abrahamse, W., Steg, L., Vlek, C., Rothengatter, T., 2005. A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology* 25(3), 273-291.

af Wåhlberg, A.E., 2006. Short-term effects of training in economical driving: Passenger comfort and driver acceleration behavior. I*nternational Journal of Industrial Ergonomics* 36(2), 151-163.

af Wåhlberg, A.E., 2007. Long-term effects of training in economical driving: Fuel consumption, accidents, driver acceleration behavior and technical feedback. *International Journal of Industrial Ergonomics* 37(4), 333-343.

Ajzen, I., 1991. The theory of planned behavior. *Organizational Behavior and Human Decision Processes* 50(2), 179-211.

Anable, J., 2005. "Complacent Car Addicts" or "Aspiring Environmentalists"? Identifying travel behaviour segments using attitude theory. *Transport Policy* 12(1), 65-78.

Anable, J., Gatersleben, B., 2005. All work and no play? The role of instrumental and affective factors in work and leisure journeys by different travel modes. *Transportation Research Part A: Policy and Practice* 39(2–3), 163-181.

Anable, J., Lane, B., Kelay, T., 2006. *An evidence base review of public attitudes to climate change and transport behaviour.* London, Department for Transport.

Bamberg, S., 2003. How does environmental concern influence specific environmentally related behaviors? A new answer to an old question. *Journal of Environmental Psychology* 23(1), 21-32.

Barbé, J., Boy, G., 2008. Analysis and modelling methods for the design and evaluation of an eco-driving system, *European Conference on Human Centred Design for Intelligent Transport Systems*, Lyon, France, pp. 183-192.

Barkenbus, J.N., 2010. Eco-driving: An overlooked climate change initiative. *Energy Policy* 38(2), 762-769.

Beusen, B., Broekx, S., Denys, T., Beckx, C., Degraeuwe, B., Gijsbers, M., Scheepers, K., Govaerts, L., Torfs, R., Panis, L.I., 2009. Using on-board logging devices to study the longer-term impact of an eco-driving course. *Transportation Research Part D: Transport and Environment* 14(7), 514-520.

Black, J.S., Stern, P.C., Elworth, J.T., 1985. Personal and Contextual Influences on Household Energy Adaptations. *Journal of Applied Psychology* 70(1), 3-21.

Boriboonsomsin, K., Vu, A., Barth, M., 2010. *Eco-Driving: Pilot Evaluation of Driving Behavior Changes Among U.S. Drivers.* UC Berkeley: University of California Transportation Center.

Caballero, M.C., 2004. Academic turns city into a social experiment - Mayor Mockus of Bogotá and his spectacularly applied theory. *Harvard Gazette.* March 11

Chapman, L., 2007. Transport and climate change: a review. *Journal of Transport*

Geography 15(5), 354-367.

Chorus, C.G., Molin, E.J., Van Wee, B., 2006. Use and effects of Advanced Traveller Information Services (ATIS): a review of the literature. *Transport Reviews* 26, 127-149.

Cialdini, R.B., Reno, R.R., Kallgren, C.A., 1990. A Focus Theory of Normative Conduct: Recycling the concept of norms to reduce littering in public places. *Journal of Personality and Social Psychology* 58, 1015-1026.

DEFRA, 2005. *Securing the future - delivering UK sustainable development strategy.* UK Department of Environment, Food & Rural Affairs.

Delhomme, P., Cristea, M., Paran, F.ß., 2013. Self-reported frequency and perceived difficulty of adopting eco-friendly driving behavior according to gender, age, and environmental concern. *Transportation Research Part D: Transport and Environment* 20, 55-58.

Denys, T., 2011. EV's In a Belgian Multimodal Demonstration Project, In: Vergels, F. (Ed.), *European Electric Vehicle Congress,* Brussels, Belgium.

Dogan, E., Steg, L., Delhomme, P., 2011. The influence of multiple goals on driving behavior: The case of safety, time saving, and fuel saving. *Accident Analysis & Prevention* 43(5), 1635-1643.

Dwyer, W.O., Leeming, F.C., Cobern, M.K., Porter, B.E., Jackson, J.M., 1993. Critical Review of Behavioral Interventions to Preserve the Environment. *Environment and Behavior* 25(5), 275-321.

Evans, L., 1979. Driver Behavior Effects on Fuel Consumption in Urban Driving. *Human Factors: The Journal of the Human Factors and Ergonomics Society* 21(4), 389-398.

Fishbein, M., Ajzen, I., 1975. *Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research*. Addison-Wesley, Reading, MA.

Frey, B.S., Foppa, K., 1986. Human behavior: possibilities explain action. *Journal of Economic Psychology* 7(2), 137-160.

Friman, M., Larhult, L., Gärling, T., 2013. An analysis of soft transport policy measures implemented in Sweden to reduce private car use. *Transportation* 40(1), 109-129.

Fuglestvedt, J., Berntsen, T., Myhre, G., Rypdal, K., Skeie, R.B., 2008. Climate forcing from the transport sectors. *Proceedings of the National Academy of Sciences* 105(2), 454-458.

Fujii, S., Taniguchi, A., 2006. Determinants of the effectiveness of travel feedback programs—a review of communicative mobility management measures for changing travel behaviour in Japan. *Transport Policy* 13(5), 339-348.

Gehlert, T., Dziekan, K., Gärling, T., 2013. Psychology of sustainable travel behavior. *Transportation Research Part A: Policy and Practice* 48(0), 19-24.

Geller, E.S., Berry, T.D., Ludwig, T.D., Evans, R.E., Gilmore, M.R., Clarke, S.W., 1990. A conceptual framework for developing and evaluating behavior change

interventions for injury control. *Health Education Research* 5(2), 125-137.

Geller, E.S., 2002. The challenge of increasing proenvironment behavior, in: Bechtel, R.B., Churchman, A. (Eds.), *Handbook of environmental psychology.* John Wiley & Sons, Inc., New York, pp. 525-540.

Gonder, J., Earleywine, M., Sparks, W., 2011. *Final Report on the Fuel Saving Effectiveness of Various Driver Feedback Approaches*. NREL

Gonder, J., Earleywine, M., Sparks, W., 2012. Analyzing Vehicle Fuel Saving Opportunities through Intelligent Driver Feedback, *Presented at the 2012 SAE World Congress and Exhibition*, Detroit, Michigan.

Goodyear, S., 2013. Lots of Cars and Trucks, No Traffic Signs or Lights: Chaos or Calm? *The Atlantic Cities*. April 2nd

Graham-Rowe, E., Skippon, S., Gardner, B., Abraham, C., 2011. Can we reduce car use and, if so, how? A review of available evidence. *Transportation Research Part A: Policy and Practice* 45(5), 401-418.

Gärling, T., 1998. Behavioural assumptions overlooked in travel-choice modelling, in: Ortuzar, J., Hensher, D., Jara-Diaz, S. (Eds.), *Travel behaviour research : updating the state of play.* Elsevier, Oxford.

Gärling, T., Gärling, A., Johansson, A., 2000. Household choices of car-use reduction measures. *Transportation Research Part A: Policy and Practice* 34(5), 309-320.

Harvey, J., Thorpe, N., Fairchild, R., 2013. Attitudes towards and perceptions of eco-driving and the role of feedback systems. *Ergonomics,* 1-15.

Horowitz, A.D., Sheth, J.N., 1976. *Ridesharing to work: a psychosocial analysis. University of Illinois at Urbana-Champaign*. College of Commerce and Business Administration.

International Energy Agency, 2012. *CO2 Emissions from Fuel Combustion Highlights* (2012 Edition).

Jackson, T., 2005. Motivating sustainable consumption. *A review of evidence on consumer behaviour and behavioural change*. A report to the Sustainable Development Research Network, Surrey: Centre for Environmental Strategies.

Johansson, H.k., Eklöf, H., Karlsson, L., 2010. *Trafikslagsövergripande planeringsunderlag för begränsad klimatpåverkan*. Enhet Miljö och hälsa, Trafikverket

Kollmuss, A., Agyeman, J., 2002. Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? E*nvironmental Education Research* 8(3), 239-260.

Kurani, K.S., Axsen, J., Caperello, N., Davies-Shawhyde, J., Stillwater, T., 2009. *Learning from Consumers: Plug-In Hybrid Electric Vehicle (PHEV) Demonstration and Consumer Education, Outreach, and Market Research Program. Institute of Transportation Studies*, University of California, Davis

Lane, B., Potter, S., 2007. The adoption of cleaner vehicles in the UK: exploring the consumer attitude–action gap. *Journal of Cleaner Production* 15(11–12), 1085-1092.

Larsson, H., Ericsson, E., 2009. The effects of an acceleration advisory tool in ve-

hicles for reduced fuel consumption and emissions. *Transportation Research Part D: Transport and Environment* 14(2), 141-146.

Laurell, H., 1985. *Körsättets betydelse för bränsleförbrukningen*. Statens väg- och trafikinstitut (VTI).

Lidman, K., Renström, S., Karlsson, M., 2011. The Green User. Design for Sustainable Behaviour, *Proceedings from the IASDR Conference 2011, Diversity and unity,* Oct 31-Nov 1, 2011, Delft, s. 1-12.

Lilley, D., Bailey, V., Charnley, F., 2013. Design for sustainable behaviour: a quick fix for slower consumption?, *16th Conference of the European Roundtable on Sustainable Consumption and Production (ERSCP) & 7th Conference of the Environmental Management for Sustainable Universities (EMSU) (ERSCP-EMSU 2013),* Istanbul, Turkey.

Mann, E., Abraham, C., 2006. The role of affect in UK commuters' travel mode choices: An interpretative phenomenological analysis. *British Journal of Psychology* 97(2), 155-176.

McKinsey & Company, 2009. *Roads toward a low-carbon future: Reducing CO2 emissions from passenger vehicles in the global road transportation system*, New York.

Mierlo, J.V., Maggetto, G., van de Burgwal, E., Gense, R., 2004. Driving style and traffic measures-influence on vehicle emissions and fuel consumption. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering* 218(1), 43-50.

Möser, G., Bamberg, S., 2008. The effectiveness of soft transport policy measures: A critical assessment and meta-analysis of empirical evidence. *Journal of Environmental Psychology* 28(1), 10-26.

Neumann, I., Cocron, P., Franke, T., Krems, J.F., 2010. Electric vehicles as a solution for green driving in the future? A field study examining the user acceptance of electric vehicles, In: Krems, J.F., Petzoldt, T., Henning, M. (Eds.), *European Conference on Human Interface Design for Intelligent Transport Systems.* Humanist Publications, Berlin, Germany, pp. 445-453.

Pierre, M., Jemelin, C., Louvet, N., 2011. Driving an electric vehicle. A sociological analysis on pioneer users. *Energy Efficiency,* 1-12.

Scheiner, J., Holz-Rau, C., 2013. A comprehensive study of life course, cohort, and period effects on changes in travel mode use. Transportation Research Part A: Policy and Practice 47(0), 167-181.

Schuitema, G., Anable, J., Skippon, S., Kinnear, N., 2013. The role of instrumental, hedonic and symbolic attributes in the intention to adopt electric vehicles. *Transportation Research Part A: Policy and Practice* 48(0), 39-49.

Schwartz, S.H., 1977. Normative Influences on Altruism. *Advances in Experimental Social Psychology* 10, 222-279.

Sivak, M., Schoettle, B., 2012. Eco-driving: Strategic, tactical, and operational decisions of the driver that influence vehicle fuel economy. *Transport Policy* 22, 96-99.

Smokers, R., Vermeulen, R., Mieghem, R.v., Gense, R., Skinner, I., Fergusson, M., MacKay, E., Brink, P.t., Fontaras, G., Samaras, Z., 2006. *Review and analysis of the reduction potential and costs of technological and other measures to reduce CO2-emissions from passenger cars.* TNO Science and Industry, p. 303.

Steg, L., Vlek, C., 2009. Encouraging pro-environmental behaviour: An integrative review and research agenda. *Journal of Environmental Psychology* 29(3), 309-317.

Steg, L., Vlek, C., Rooijers, T., 1995. Private car mobility. Problem awareness, willingness to change, and policy evaluation: A national interview study among Dutch car users, *Studies in Environmental Science*. Elsevier, pp. 1173-1176.

Stern, P.C., 2000. Toward a Coherent Theory of Environmentally Significant Behavior. *Journal of Social Issues* Vol. 56(No. 3), pp. 407–424.

Stillwater, T., Kurani, K., 2011. Field Test of Energy Information Feedback: Driver Responses and Behavioral Theory. T*ransportation Research Record: Journal of the Transportation Research Board* 2252, 7-15

Symmons, M.A., Rose, G., 2009. Ecodrive training delivers substantial fuel savings for heavy vehicle drivers, *Proceedings of the 5th International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design,* Big Sky, Montana.

Symmons, M.A., Rose, G., Rorke, J., Watkins, C., 2011. Eco-driving: Insight from a real world fleet-based trial, *Australasian Transport Research Forum* 2011 Proceedings, Adelaide, Australia.

Symmons, M.A., Rose, G., Van Doorn, G., 2009. *Ecodrive as a road safety tool for Australian conditions*, Road Safety Grant Report 2009-004. Australian Government: Department of Infrastructure, Transport, Regional Development and Local Government.

Tanner, C., 1999. Constraints on Environmental Behaviour. *Journal of Environmental Psychology* 19(2), 145-157.

Thøgersen, J., 2006. Norms for environmentally responsible behaviour: An extended taxonomy. *Journal of Environmental Psychology* 26(4), 247-261.

Turrentine, T., Garas, D., Lentz, A., Woodjack, J., 2011. *The UC Davis MINI E Consumer Study, UC Davis Institute of Transportation Studies Research Report*. Institute of Transportation Studies University of California, Davis.

van der Voort, M., Dougherty, M.S., van Maarseveen, M., 2001. A prototype fuel-efficiency support tool. *Transportation Research Part C: Emerging Technologies* 9(4), 279-296.

Vangi, D., Virga, A., 2003. Evaluation of energy-saving driving styles for bus drivers. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering* 217(4), 299-305.

Verplanken, B., 2006. Beyond frequency: Habit as mental construct. *British Journal of Social Psychology* 45(3), 639-656.

Verplanken, B., Holland, R.W., 2002. Motivated decision-making: Effects of activation and self-centrality of values on choices and behavior. *Journal of Personality and Social Psychology* 82(3), 434-447.

Vining, J., Ebreo, A., 2002. The challenge of increasing proenvironment behavior, In: Bechtel, R.B., Churchman, A. (Eds.), *Handbook of environmental psychology*. John Wiley & Sons, Inc., New York, pp. 541-558.

Vägverket, 2009. *Sparsam körning i världen - en internationell utblick*. Vägverket.

Waters, M.H.L., Laker, I.B., 1980. *Research on fuel conservation for cars,* TRRL Laboratory Report 921, p. 34.

Wilde, G.J.S., 1976. Social interaction patterns in driver behavior: an introductory review. *Human Factors* 18(5), 477-492.

Zarkadoula, M., Zoidis, G., Tritopoulou, E., 2007. Training urban bus drivers to promote smart driving: A note on a Greek eco-driving pilot program. *Transportation Research Part D: Transport and Environment* 12(6), 449-451.

Ölander, F., Thøgersen, J., 1995. Understanding of consumer behaviour as a prerequisite for environmental protection. *Journal of Consumer Policy* 18(4), 345-385.