Soft measures to shift modality

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Reducing the amount of car use in society is difficult. Although a necessity due to increased pressure on the environment and urban space, the many benefits of driving prevent most people from reducing it. Still, some people drive a car, not because they have to but because they are used to it and may consider changing travel behaviour if they are offered the right conditions and encouragement. This thesis examines soft transport measures that promote voluntary reductions of car use – how they motivate different segments to reduce car use and the potential of innovation for improving their effectiveness and evaluations.

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Abstract

The purpose of this thesis is to contribute knowledge on how to reduce the demand for car use by encouraging a modal shift towards walking, cycling, and public transport. Soft transport measures are the domain for this investigation. Two issues regarding soft transport measures are the focus. The first regards the lack of methodologically sound evaluations of soft measures and the potential for innovations to alleviate this and influence travel behaviour. The second issue is the need for an increased understanding of what factors motivate diverse groups of people to reduce car use, and what implications this can have for targeting soft measures. The thesis comprises five papers. Paper I investigated how information and communication technology (ICT) has been used to influence behaviour change and synthesizes key aspects into a conceptual model for creating a behaviour change support system (BCSS) for smartphone applications, based on theory. Paper II evaluated a fielded mobility service application (MSA) that was introduced in 13 Swedish organisations. Paper III explored marketing messages that promote sustainable transport and motivation to reduce private car use within different segments. Paper IV explored the preconditions affecting the motivation of people to reduce private car use. In Paper V, a randomised controlled trial with GPS data from 98 frequent drivers in Sweden was conducted to investigate the substitution effect of e-bikes. The results in Paper I suggest that customisation to the user, relevant and contextualised information and feedback, commitment, and appealing design are important aspects when influencing users to change behaviour through smartphone applications. The results in Paper II gave indications that the MSA made it easier to travel by public transport. Three factors that influence the success of a new MSA as a means to increase sustainable business trips were identified: management control and proactiveness; perceived improvement of intervention; and functions and technical sufficiency. The results in Paper III show that messages relating to the environment, personal and societal health, collective responsibility, and morality performs better than messages relating to personal health, financial benefits, convenience, and status. The results in Paper IV show that climate morality is a critical factor affecting motivation to reduce car use. Usual commute mode, car advocacy, health concerns, attitudes towards cycling, car identity and travel time also influence motivation. The results in Paper V show that the treatment group increased cycling on average with one trip and 6.5 km per day per person, which led to a 25% increase in total cycling. The whole increase was at the expense of car use, which on average decreased by one trip and 14 km per person per day, a decrease in car mileage of 37%. This thesis makes a novel contribution to the soft transport policy field by investigating innovations as a means for driving behaviour change as well as facilitating better evaluations. Another contribution to the field is the combined analyses of segmentation and motivation to reduce car use, which give insights into motivational differences and possible strategies for targeting.

Key words

Soft transport measures, Modal shift, Innovation, ICT, E-bikes, Segmentation, Motivation, Evaluation

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MADE IN SWEDEN

To my sisters, Josefine and Lovisa

Table of contents

Preface

One early morning in the spring of 2013, my girlfriend (now wife) and I waited outside the hospital in Lund, equipped with goodie bags that were to be distributed to employees who came to work by bicycle. We had recently started studying and worked extra hours for the technical administration at Lund municipality. Our mission was simple: distribute the goodie bags to as many bicycle commuters as possible.

The work required some ability to run alongside the cyclists long enough to be able to complete the handover of the bags. At the time, I did not reflect much on what effects this exercise would have on the cyclists' attitudes or future commuting behaviour (I thought more about how long we would have to chase cyclists before the bags would run out). In hindsight, I realise how complicated such an evaluation would have been. What would be measured and in what way? Should a control group be used, and if so, how to avoid contamination from the test group? How much effect can be expected and what requirements does this place on sample size? And so on.

Something that crossed my mind, however, was the different reactions we had from the cyclists. Most seemed genuinely happy with the gesture, although a few expressed that it would have been more motivating if they had received something else. 'I would rather have a sandwich', a man said when inspecting the content of the bag: bicycle lights, a saddle cover, a reflector, and a *thank you for cycling* card. In this first encounter with soft transport measures, I thus noticed that incentives motivate people in different ways.

My later experiences of soft transport measures and attempts of persuading people to change behaviour (a term I never liked[1]), both in practice and in studying them, has made me aware of the high multitude and innovativeness that exist in this field. However, these strengths may also contribute to weaknesses concerning lack of continuity and stringency. I have great respect for the challenges that planners face, administrative, practical and financial, in the implementation of soft transport measures. Hence, I hope that this research can be of scientific as well as of practical use, a dual wish that should not be overly naive in light of Kurt Lewin (1951), who wrote that 'there's nothing so practical as a good theory' (p. 169).

Alfred Söderberg

8 April 2021

[1] I was also not very happy about changing behaviour as a child. My parents (featured on the cover) can attest to this. It required a lot of persuasion on their part to convince me to swap the Bobby Car for the bike.

Summary

Traffic accumulated by cars is responsible for considerable problems in our cities. The problem is partly about the negative effects on human health due to harmful particulate emissions, noise, traffic accidents and sedentary lifestyles, partly about the space it occupies, which leads to congestion, and the fact that valuable land is taken up by road infrastructure and parking lots. In a bigger perspective, car traffic also contributes to greenhouse gas emissions that fuel climate change.

At the same time, the car is ingrained in our way of life and a necessity for many people's lives to function. Politicians are therefore generally reluctant to limit car use, and as a result, transport planners find it difficult to enforce measures that lead to a significant reduction in car traffic. Attempts are being made with soft measures that encourage people to walk, cycle and take public transport. These measures can, for instance, be to inform about alternatives to car use, marketing new cycle routes, and offering free trial periods with public transport. So far, it has proved difficult to sufficiently evaluate these measures, which has led to scepticism about their usefulness. At the same time, we need to know more about what it is that motivates modal shifts for different groups. Thus, more knowledge about soft measures is needed.

Innovations in the form of smartphones and electric bicycles (e-bikes) have opened new opportunities for soft measures, both in terms of evaluation of these and the potential to influence car use. Furthermore, previous research has shown that it is important to target soft measures and adapt information and marketing to specific target groups, also called segmentation. Against this background, this thesis (including five individual papers) has examined smartphones, e-bikes, and marketing. These three elements have been used in variation to investigate motivation to reduce car use in favour of walking, cycling and public transport, segmenting and targeting, as well as evaluation of soft measures.

Regarding the possibility of smartphone applications to influence travel behaviour, explored in the first paper, a review of previous research showed that there is potential but that too few studies have been conducted to be able to draw any general conclusions. The paper found that applications need to be customised to the user, provide relevant information and feedback about the user's behaviour, create a commitment towards its use, and have a user-friendly design. The second paper presented a process evaluation of a project where an application was developed to facilitate sustainable business travel. However, the study showed several weaknesses with the application and the difficulty in evaluating the effect of such a soft measure, which gave lessons about both study design and the development of applications and their implementation in organisations.

In the third paper, we found that marketing for sustainable travel is more motivating if it is aimed at the collective rather than the individual, and contains altruistic messages linked to the environment and health. The respondents' stated motivation to reduce car use reflected their current car use and attitude towards the environment and various means of transport. This underlines the importance of adapting marketing to the target group. The fourth paper showed that one's morality towards the climate has a significant impact on the motivation to reduce car use, but habits, travel time and attitudes towards car and bicycle use also play a role. Such factors differ between gender, age, level of education and between urban and rural areas and may be important for the segmentation used for soft measures.

The results from the fifth paper showed that e-bikes have exciting potential to replace the car and contribute to more sustainable travel behaviours. In a field experiment where the participants consisted of frequent drivers, car travel measured in distance decreased by an average of 37% as a result of the participants gaining access to their respective e-bike. The share of cycling of total travel increased by just over 20% on average. The participants measured their travel behaviour and answered survey questions using their smartphones, which contributed to high data quality. Both the effect evaluation of the use of e-bikes and the use of smartphones to measure travel behaviour make a novel and important contribution to the research field on soft transport measures, and the application of these in practice.

The thesis concludes that innovations have great potential to improve soft measures, both as a means for contributing to increased sustainable travel behaviours and as a means of making more rigorous evaluations. The thesis also contributes to the knowledge about how sustainable transport can be marketed, what creates motivation to reduce car use, as well as different perspectives on segmentation and which target groups soft measures can be aimed at.

Populärvetenskaplig sammanfattning

Bilismen orsakar en mängd problem i våra städer. Det handlar dels om negativa effekter på människors hälsa på grund av skadliga partikelutsläpp, buller, trafikolyckor och stillasittande, dels om platsen den tar i anspråk vilket leder till trängsel och att värdefull mark tas i besittning av väginfrastruktur och parkeringsplatser. I ett större perspektiv bidrar biltrafiken även till utsläpp av växthusgaser som eldar på klimatförändringen.

Samtidigt är bilen ett naturligt inslag i vårt sätt att leva och helt nödvändig för att många personers livspussel ska gå ihop. Politiker vill därför ogärna begränsa bilens framfart och transportplanerare har som följd svårt att tvinga fram ett minskat bilresande. Därför görs även försök med mjuka åtgärder som syftar till att uppmuntra fler människor att gå, cykla och åka kollektivtrafik. Det kan handla om att informera om alternativ till bil, marknadsföra nya cykelstråk och att erbjuda gratis provperioder med kollektivtrafik. Hittills har det visat sig svårt att utvärdera dessa åtgärder på ett bra sätt vilket lett till skepsis gällande dess nytta. Samtidigt behöver vi veta mer om vad som motiverar ändrade resvanor för olika målgrupper. Det behövs helt enkelt mer kunskap om mjuka åtgärder.

Ny teknik i form av exempelvis smartphones och el-cyklar har öppnat upp nya möjligheter för mjuka åtgärder, både vad gäller utvärdering av dessa och potentialen att påverka bilanvändningen. Vidare så har tidigare forskning visat att det är viktigt att rikta mjuka åtgärder och anpassa information och marknadsföring till specifika målgrupper, även kallat segmentering. Mot denna bakgrund har avhandlingen undersökt smartphones, el-cykling och marknadsföring. Dessa tre element har på olika sätt använts för att undersöka motivation att minska bilresandet till förmån för gång, cykel och kollektivtrafik, samt målgruppsanpassning och utvärdering av mjuka åtgärder.

När det gäller smartphoneapplikationers möjlighet att påverka resandet visade avhandlingens första artikel i en genomgång av tidigare forskning att det finns potential men att för få studier har genomförts för att kunna dra några generella slutsatser om hur mycket. I artikeln fastslogs att applikationer behöver anpassas till användaren, ge relevant information och feedback om ens beteende, skapa engagemang och ha en användarvänlig design. I den andra artikeln genomfördes en processutvärdering av ett projekt där en applikation utvecklades med syfte att underlätta det hållbara tjänsteresandet. Studien visade dock på flera svagheter med applikationen och svårigheten i att utvärdera effekten av en sådan mjuk åtgärd, vilket gav lärdomar om såväl studiedesign som utvecklingen av applikationer och dess implementering i organisationer.

I den tredje artikeln fann vi att marknadsföring för hållbart resande är mer motiverande om den riktar sig till kollektivet snarare än individen och innehåller altruistiska budskap

kopplat till miljö och hälsa. Respondenternas angivna motivation att minska bilanvändningen speglade deras nuvarande bilanvändning och attityd gentemot miljön och olika färdmedel. Detta understryker vikten av att anpassa marknadsföring till de målgrupper man vill vända sig till. Den fjärde artikeln visade att individers klimatmoral, det vill säga det upplevda personliga ansvaret att minska sina växthusgasutsläpp, har en betydande påverkan på motivationen att minska bilanvändningen. Även vanor, restid och attityder gentemot bil- och cykelanvändning spelar roll. Sådana faktorer skiljer sig åt beroende på kön, ålder, utbildningsnivå och mellan stad och landsbygd och kan ha betydelse för den segmentering som används för mjuka åtgärder.

Resultatet från den femte artikeln visade att el-cykeln har stor potential att ersätta bilen och bidra till ett mer hållbart resande. I en fältstudie där deltagarna utgjordes av vanebilister minskade bilresandet mätt i distans med i genomsnitt 37% till följd av att deltagarna fick tillgång till varsin el-cykel. Andelen cykling av allt resande ökade med drygt 20% i snitt. Deltagarna fick mäta sina resvanor och svara på frågor om sitt resande i sina smartphones vilket bidrog till hög datakvalité. Både effektutvärderingen av el-cykling och användningen av smartphones för att mäta resvanor ger ett nytt och viktigt bidrag till forskningen om mjuka transportåtgärder samt den praktiska tillämpningen av dessa.

Slutsatsen från denna avhandling är att ny teknik har stor potential att förbättra mjuka åtgärder, både som medel för att bidra till ett ökat hållbart resande och som medel för att göra mer gedigna utvärderingar. Avhandlingen bidrar även med kunskap om hur hållbart resande kan marknadsföras, vad som skapar motivation att minska bilresandet, samt olika perspektiv på segmentering och vilka målgrupper som mjuka åtgärder kan riktas till.

Papers included in the thesis

Paper I
Promoting sustainable travel behaviour through the use of smartphone applications: A review and development of a conceptual model
A. Andersson, L. Winslott Hiselius, E. Adell
Travel Behaviour and Society 11, 52-61 (2018)
A. Andersson: Literature review, analysis of empirical material, development of the conceptual model, manuscript writing.

Paper II
Evaluating a Mobility Service Application for Business Travel: Lessons Learnt from a Demonstration Project
A. Andersson, L. Winslott Hiselius, P. Arnfalk, J. Berg, S. Forward
Sustainability (Switzerland) 12(3), 1-18 (2020)
A. Andersson: Data management, statistical analyses, conceptual framework, the main part of manuscript writing.

Paper III
The effect of marketing messages on the motivation to reduce private car use in different segments
A. Andersson, L. Winslott Hiselius, E. Adell
Transport Policy 90, 22-30 (2020)
A. Andersson: Developing the survey, data management, statistical analyses, literature review, manuscript writing.

Paper IV
Is climate morality the answer? Preconditions affecting the motivation to decrease private car use
A. Andersson
Transportation Research Part D: Transport and Environment 78, 1-14 (2020)

Paper V
What is the substitution effect of e-bikes? A randomised controlled trial
A. Söderberg f.k.a. Andersson, E. Adell, L. Winslott Hiselius
Transportation Research Part D: Transport and Environment 90, 1-11 (2021)
A. Söderberg f.k.a. Andersson: Funding acquisition, study design, literature review, developing survey items, data management, statistical analyses, manuscript writing – original draft.

Abstracts

Paper I

The negative effects of transport in terms of pollution, congestion and climate change have driven the need for increased cleaner and more efficient modes of transport, especially in urban settings. While new technology can solve some of these issues, behaviour changes have also been identified as an important factor to achieve a modal shift from cars to walking, cycling or public transport. This study investigates how information and communication technology (ICT) has been used to influence behaviour change and synthesizes key aspects into a conceptual model for creating a behaviour change support system (BCSS) for smartphone applications. A literature review concerning behaviour change and ICT in the fields of transport, health, energy and climate was conducted to gather empirical evidence, which forms the foundation of the conceptual model. The empirical findings were verified against a theoretical framework consisting of the transtheoretical model, theory of planned behaviour, diffusion of innovations, and the concept of gamification. The results suggest that customisation to the user, relevant and contextualised information and feedback, commitment, and appealing design are important aspects when influencing users to change behaviour through smartphone applications. The conceptual model provides further knowledge of key aspects to consider when developing persuasive tools that aim to encourage more sustainable modes of transport.

Paper II

Business travel contributes to significant greenhouse gas emissions, and there is a need for measures that reduce the demand for trips made with energy-intensive means of transport. In this study, a mobility service application (MSA) introduced in 13 Swedish organisations was tested and evaluated to facilitate booking and handling of business trips, in particular public transport. A before and after study consisting of surveys and interviews with employees at the organisations was conducted. The results show that the MSA was mostly used for regional and local public transport trips, and users stated that the MSA made it easier to travel by public transport, although this particular result should be seen as tentative due to the small sample size. Three factors that influence the success of a new MSA as a means to increase sustainable business trips were identified: management control and proactiveness; perceived improvement of intervention; and functions and technical sufficiency. The results also highlight the need to establish organisational conditions that facilitate sustainable business travel, such as a coherent travel policy, accessibility to sustainable modes of transport, and a culture that encourages environmentally friendly behaviour. The study suggests improvements that can be made to similar interventions and strategies, which can be introduced to promote sustainable business travel.

Paper III

This study explores marketing messages promoting sustainable transport and reported motivation to reduce private car use within different segments. A stated preference survey targeting a sample of 1,300 residents in Sweden was conducted, and exploratory factor analysis was used to identify underlying dimensions of a set of 19 marketing messages. Self-efficacy and collective efficacy were defined as latent factors, and the latter was found to be a better motivator for all segments. For the most car-advocating segment, however, the factors (both self and collective efficacy) were unsuccessful in inducing any reported motivation to reduce private car use. Assimilation bias seems to influence the respondents' interpretation of marketing messages.

Paper IV

Persuasive messages are commonly used in campaigns promoting sustainable transport to motivate people to reduce private car use. This paper explores the preconditions affecting the motivation of people to reduce private car use when exposed to such messages. A sample of 1,300 Swedish residents was analysed for the effect of variables related to accessibility, usual commute mode, and attitudes. Significant variables were used to create a precondition index, which was cross-tabulated with demographic variables and stages drawn from the transtheoretical model. The results show that there are differences in the preconditions regarding motivation to reduce private car use between segments of the population. Results indicate that climate morality is a critical factor affecting motivation, specifically the motivation of persistent drivers. Usual commute mode, car advocacy, health concerns, attitudes towards cycling, car identity and travel time also influence motivation. Males, the middle-aged, people with low educational attainment, and rural residents have the least favourable preconditions concerning motivation to reduce private car use.

Paper V

As sales of e-bikes increase, so does the need for reliable evaluations of which means of transport the e-bike replaces, the substitution effect. A randomised controlled trial with GPS data from 98 frequent drivers in Sweden was conducted to investigate the effect of the e-bike on modal choice, the number of trips and distance, as well as perceptions of the e-bike as a substitute for the car. The results demonstrate that the treatment group increased cycling on average with one trip and 6.5 km per day per person, which led to a 25% increase in total cycling. The whole increase was at the expense of car use, which on average decreased by one trip and 14 km per person per day, a decrease in car mileage of 37%.

1 Introduction

The purpose of this thesis is to contribute knowledge on how to reduce the demand for car use by encouraging a modal shift towards walking, cycling, and public transport. In the big picture, car use is a critical issue that affects the balance between all three dimensions of the concept of sustainability: socially, environmentally, and economically (van Wee, 2014), as well as the intergenerational definition that 'the current generation should not fulfil its needs in such a way that it jeopardizes the needs of future generations' (WCED, 1987). On a smaller scale, the issue of car use affects individuals to a high degree, as it accounts for a large proportion of all travel (most notably in the western world) and is perceived as a major asset by most households (Lucas and Jones, 2009). There is undeniably a duality of car use. When designing measures that force a reduction in car travel, improvements are generated in certain respects and for some people, while also leading to deteriorations in other respects, for some people (Levinson, 2002). However, when people choose to voluntarily alter their car use instead of being forced, benefits are mutual (Taylor and Ampt, 2003).

1.1 Car use. Two sides of the same coin

Car use makes a significant contribution to general welfare in societies and for individuals. In economic terms, the speed and flexibility of the car, combined with infrastructure and policies that pave its way, help people and businesses to connect. As a result, positive agglomeration and productivity effects can be realised (Börjesson et al., 2019; Graham, 2007), which in turn can facilitate functioning labour markets and increased employment (Norman et al., 2017). Moreover, the car provides people with convenience and freedom to travel independently from a to b while constituting a personalised space for socialising with family and friends. For many people, travel by car is related not only to instrumental benefits but also affective and symbolic benefits (Steg, 2005) and may be desired for its own sake (Mokhtarian et al., 2001). For those with access to a car, it provides accessibility to live and work in areas that are unreachable by public transport or active travel modes such as walking and cycling.

In most industrialised countries, the car is deeply entrenched in the way of living and despite recent expectations of 'peak car' in conjunction with the 2008 economic

recession (Bastian et al., 2016; Stapleton et al., 2017), car use per capita, at least in Sweden, seems fixed. There is no doubt that car use provides enormous benefits to society and individuals (Banister, 2011).

Flipping the coin reveals the downside of car use, also referred to as negative transport externalities, which harm people, society, and the environment. Traffic is responsible for (severe) injuries and fatalities (Elvik et al., 2009), congestion (Stopher, 2004), local air pollution and noise (Holgate, 2017), degradation of urban space and landscapes (Gössling, 2020, 2016), as well as the release of carbon dioxide, which exacerbates climate change (Banister, 2005). The latter has been at the forefront of car-related issues addressed in the last decades due to the large portion of CO_2 emissions stemming from the transport sector. In Sweden, this portion accounts for a third of domestic emissions, of which 93% originates from road transport, and 67% of this from passenger transport (Swedish Transport Administration, 2020). As such, there is no doubt that car use also causes tremendous damage to people and the planet, at least in its current shape.

1.2 The benefits of soft transport measures

In both research and practice, the way to limit the release of carbon emissions caused by transport is often divided into three mitigation measures: (i) switching to low-carbon fuels; (ii) improving vehicle efficiency; and (iii) reducing vehicle travel (Axsen et al., 2020). For fuels, the goal is to replace diesel and gasoline with electricity, biofuels, and hydrogen (each from low-carbon sources), while vehicle efficiency is principally enforced by requiring car manufacturers to comply with vehicle emission standards. In terms of reducing vehicle travel, this is referred to in transport research as travel demand management (TDM) (Gärling et al., 2002). TDM measures are in turn divided into 'hard' and 'soft' measures. The former typically includes physical measures such as changes in infrastructure, as well as legal, and financial policies, while the latter includes measures such as information, incentives, and administrative changes. Hard measures are often more coercive than soft measures, which aim to empower individuals to voluntarily reduce their car use (Bamberg et al., 2011).

The three overarching measures (fuel-switching, vehicle efficiency, and TDM) will need to be integrated into strong policy mixes to fulfil the climate targets for the transport sector (Banister, 2019; Brand et al., 2020; Milovanoff et al., 2020). Some argue that it is unlikely that TDM measures will contribute significantly in this sense, although they can 'provide important complementary co-benefits and mitigation of rebound effects from other efficiency policies' (Nieuwenhuijsen, 2020).

Regardless of the extent to which soft measures lead to reduced carbon dioxide emissions from the transport sector, there are many benefits from increasing the share

of walking, cycling, and public transport. Successful soft measures lead to improved public health through reduced pollution and higher levels of physical activity (Shaw et al., 2014), less congestion, as well as less need for road expansions and parking infrastructure, while improving equality and road safety (Anable and Goodwin, 2019). These benefits cannot be achieved by just focussing on low-carbon fuels or vehicle efficiency. Realising a shift from cars to active transport (principally walking and cycling) is associated with large societal benefits (Rabl and de Nazelle, 2012). The societal cost of a kilometre driven by car in urban areas has been estimated to be more than six times higher than the cost of a kilometre cycled (Gössling and Choi, 2015). Due to its relatively low cost and potential societal benefits, the value for money of soft measures has been estimated to provide a benefit-cost ratio of more than 10:1 (Cairns et al., 2008).

There is an increasing understanding of the problems associated with high volumes of car traffic in urban areas (Hrelja, 2019). As city officials become more interested in reducing car use to create more attractive and liveable urban areas, increased attention has been directed towards soft measures to facilitate more walking, cycling, and use of public transport (Hino et al., 2019; Kuang et al., 2019). This justifies more research on the current issues affecting the development of soft measures, as there are still unanswered questions regarding soft measures in terms of their feasibility and optimal use in practice.

1.3 Key issues addressed

Two issues are the focus of this thesis. The first regards the lack of methodologically sound evaluations of soft transport measures, and the potential for innovations to alleviate this and influence travel behaviour. Research about innovation in soft measures has been scarce and may represent untapped potential. The second issue regards the need for an increased understanding of what factors motivate diverse groups of people to reduce car use, and what implications this can have for targeting soft measures. We will now look at these two issues in brief.

As stated by Bamberg and Rees (2017), many are still sceptic about the effectiveness of soft transport measures. Even though numerous research studies (including a few meta-analyses) have shown that soft measures bring real, tangible effects on car use and benefits to society (Richter et al., 2009), there is still a consensus that these findings are threatened by a lack of internal and external validity, partly due to a lack of controlled evaluations and insufficient data quality (Chatterjee and Carey, 2018). This has led researchers to continuously call for more rigorous evaluations of interventions aimed at reducing car use (Arnott et al., 2014; Bonsall, 2009; Chatterjee, 2009; Graham-Rowe et al., 2011; Petrunoff et al., 2016; Rosenfield et al., 2020; Semenescu et al., 2020;

Shaw et al., 2014; Yang et al., 2010). At the same time, rapid technological development is currently experienced in the transport domain. This includes 'new mobility' innovations such as ride-hailing and shared vehicle systems, electrification, and automation (Sperling, 2018). Users of these new services, as well as of traditional public transport, are becoming increasingly dependent on internet and communication technology (ICT), in particular smartphone applications, to access travel information, planning tools, and to make payments (Gössling, 2018). Another innovation is the electric bicycle (e-bike), which has gained serious interest in recent years due to its potential to substitute car trips (Cairns et al., 2017), making it a promising and potentially critical component of the necessary shift toward more sustainable transportation systems (Plazier et al., 2018).

Surprisingly few studies seem to have analysed how these innovations can be used to improve soft measures. For e-bikes, Moser et al. (2018) found that a year after an e-bike trial, the participant's habitual association with car use had weakened significantly. Similarly, a recent study found that a significant modal shift from cars to e-bikes found in a trial setting was replicated for actual e-bike customers (Fyhri and Sundfør, 2020). Two examples of studies of ICT and soft measures are Sottile et al. (2020), who incorporated soft measures in the form of personal travel plans within a smartphone application (IPET), and Matyas and Kamargianni (2019), who evaluated whether a bundle of transport services (referred to as mobility as a service, or MaaS (Karlsson et al., 2019)) could be used as a tool for promoting shared transport. Still, the lack of studies examining potential synergies between these innovations and soft measures can lead to missed opportunities to facilitate modal shifts.

Previous research has made considerable contributions to our understanding of the motivational determinants that can influence modal shift (Bamberg, 2014; Fujii and Taniguchi, 2006; Hoffmann et al., 2017; Javaid et al., 2020). However, motivational determinants may differ between groups, which is why segmentation has been increasingly called for to understand how different target groups respond to soft measures such as information and marketing messages (Pangbourne and Masthoff, 2016; Richter et al., 2011; Semanjski and Gautama, 2016; Thøgersen, 2018). Moreover, there is a need for more studies that take a theory-driven approach to soft measures (Arnott et al., 2014). According to Chatterjee and Carey (2018), there seems to be some inconsistency in how theory is applied in soft measures and as a basis for evaluation. The application of theory in interventions is important for understanding why an intervention did or did not work and can advance our understanding of how to design effective soft measures (Bamberg et al., 2011).

This research contributes to filling these gaps by exploring two innovations of relevance for soft measures. The first is ICT, with a particular emphasis on smartphone applications, while the second innovation is the e-bike. Additionally, marketing messages that promote walking, cycling, and public transport are explored. These three

cases form the basis for analysing segmentation of potential populations, motivation to decrease car use, and evaluation of soft transport measures. The thesis attempts to base analyses on theories of behavioural intention, behaviour change, and technology adoption. Two aims have guided this endeavour.

1.4 Aims and objectives

The first aim is to explore two transport innovations, smartphone applications and e-bikes, in terms of their potential to improve evaluations of soft transport measures and influence travel behaviour.

The second aim is to investigate what influences motivation to decrease private car use for different segments, and how this can be used to improve soft transport measures.

The aims will be realised by achieving the following objectives:

1. To conduct a literature review on smartphone applications and behaviour change techniques, and contrast the findings against theories of behavioural intention, behaviour change, and technology adoption.
2. To assess the effect of a smartphone application on travel behaviour and perceptions towards using public transport within a field experiment. A theory of acceptance and use of technology will be used to analyse the findings.
3. To conduct a survey measuring motivation to reduce car use in diverse attitude-based segments and a stage-based theory of change.
4. To assess the effect of an e-bike trial on travel behaviour and perceptions towards the e-bike as a substitute for the car, in a field experiment utilising smartphone data.

1.5 Main contribution

This thesis makes a novel contribution to the soft transport policy field by investigating innovations as a means for driving behaviour change as well as facilitating better evaluations. Another contribution to the field is the combined analyses of segmentation and motivation to reduce car use, which give insights into motivational differences and possible strategies for targeting.

The empirical contribution consists of field evaluations of a smartphone application, as well as an e-bike trial. The findings from the analyses of motivation to reduce car use

within different demographic groups, as well as in behaviour change stages, are of use for both research and practice. The results regarding the marketing messages could be of use, for instance, by regional public transport authorities in their marketing efforts.

The study design of the e-bike trial offers some methodological elements of interest for both research and practice regarding smartphones for data collection, and the option to offer treatment to the control group for mitigating dropouts in behavioural interventions.

The theoretical contribution consists of a conceptual model for developing behaviour change support systems, which was created in the first paper, the evaluation of a smartphone application in light of theory on user acceptance and use of technology, as well as the application of attitude-based segmentation and behaviour change stages to explore motivation to reduce car use in different groups.

1.6 Structure of the thesis

This thesis consists of this summary and the five papers which are found in the appendix. After this opening chapter, an introduction to soft transport measures is given in Chapter 2. Chapter 3 presents the framework containing the central concepts and theories that have guided the interpretation of the empirical material. Chapter 4 provides an overview of the methods and datasets, while the results from each paper are presented in Chapter 5. In Chapter 6, the results are discussed in relation to previous research and ends with the thesis' conclusions, limitations, and suggestions for further research.

2 The little brother in transport policy

This chapter addresses the origins, definition, and effectiveness of soft measures as reported by previous literature and then delves into the transport planning context of such measures in Sweden.

2.1 Born in the USA

The need for urban transportation policy to manage the travel demand arose in conjunction with the oil supply disruptions in the early 1970s in the United States. Attempts were made from the public domain to reduce the use of single-occupant vehicles, for instance by promoting carpooling (Ferguson, 1997); see Figure 1. The following decade saw a rapid growth in traffic volumes, which began to outpace the supply of new road infrastructure. A broad welfare-increase occurred in combination with sprawled land-use planning, and between 1982 and 1996, car use as measured by vehicle miles travelled increased annually by 3.2% while the population was growing at an annual rate of 1% (Winters, 1998). Traffic congestion increased and in addition, other negative externalities from traffic, especially environmental impacts, were receiving more attention from federal and state legislators (Meyer, 1999). One response to these challenges was the introduction of a concept referred to as Transport (or Travel) Demand Management (TDM), which eventually spread to Europe as well.

Figure 1. A sign encouraging carpooling during the gas shortage resulting from the 1973 oil crisis. Source: David Falconer, U.S. National Archives and Records Administration.

2.2 Managing travel demand through 'hard' and 'soft' measures

TDM includes a variety of strategies that attempt to change travel behaviour in order to increase transportation system efficiency, also labelled mobility management by some scholars (Litman, 2010). A wide array of measures exists for that purpose, ranging from *physical alterations* of land use, *legal policies* such as prohibiting cars in city centres, *fiscal policies* like congestion charging, *information* such as marketing campaigns for new cycling routes, *incentives* such as temporarily reduced fares on public transport, and *administrative instruments* in the form of travel policies and organisational carpooling schemes (Fujii et al., 2009; Gärling et al., 2002).

These measures are commonly divided into 'hard' and 'soft' measures (Bamberg et al., 2011). Hard measures are designed to push individuals towards the desired behaviour, for instance through physical changes like closing roads, or increasing taxation of car ownership, fuel costs, or prohibition of car use under certain conditions. Fiscal interventions typically require substantial resources to implement, while coercing people through modifications of the physical environment or legal policies may involve political costs, as such measures can be met with opposition from the public (Ockwell et al., 2009; Semenescu et al., 2020).

In contrast, soft measures attempt to pull people out of their cars by providing information, offering incentives, and lowering barriers for reducing car use. They attempt to influence car users to voluntarily switch to sustainable travel modes, sometimes referred to as 'voluntary travel behaviour change' (VTBC) (Bamberg et al., 2011) and are defined by Steg (2003, p. 109) as 'strategies aimed at influencing people's perceptions, beliefs, attitudes, values, and norms'. One upside of using soft measures is that there is rarely any public opposition to it. Another advantage is the flexibility with which it can be implemented, thus making it easier to customise according to prevailing contexts compared to hard measures. Soft measures have, on the other hand, been difficult to assess in terms of effectiveness, making their usefulness uncertain (Bonsall, 2009).

There is an assumption of a synergetic relationship between hard and soft measures in which they could strengthen one another. With the implementation of hard measures that change the relative attractiveness of travel options, the possibility increases that soft measures would be effective in motivating and empowering car users to decrease car use (Bamberg et al., 2011). Likewise, if soft measures succeed in reducing car use in conditions of congestion, induced traffic effects must be handled with hard measures in order to 'lock in' the net car use reduction, for example by reallocating road capacity and restraining parking (Cairns et al., 2004).

2.3 Evaluation and effectiveness of soft measures

For the last two decades, much of what has been discussed in the research literature regarding the effectiveness of soft measures has to do with whether mainstream evaluations of soft measures can be trusted, and in what ways they need to improve.

A few large-scale programs have implemented and evaluated the effectiveness of soft measures, for example in Australia (Rose and Ampt, 2001), the UK (Cairns et al., 2004; Parker et al., 2007), Germany (Brög et al., 2009), and Sweden (Friman et al., 2013). Rose and Ampt (2001) reported an approximate 10% reduction in car driver kilometres and a slightly higher percentage reduction in car driver trips. Cairns et al. (2004) projected a decrease in traffic levels by 4-5% nationally in a low-intensity scenario, in which soft measures are applied inconsistently, and a 10-15% decrease in a high-intensity scenario, in which soft measures are consistently utilised and supplemented by hard measures. Brög et al. (2009) reported reductions in car use of 5-15%; however, these estimates were for car trips only and not related to car distance. Friman et al. (2013) analysed 32 programs but concluded that the evaluations were of insufficient quality to be assessed for effectiveness in reducing car use.

Indeed, compilations of the kind reported above have received much criticism for evaluating studies with weak research designs, and for combining the results of these studies narratively. Instead, Möser and Bamberg (2008) introduced a meta-analytic approach to synthesising the results from 141 intervention evaluations, a more reliable method and one that can be used to determine causal effects (Bamberg and Möser, 2007). They found that soft measures generally led to an increase of 7% in the proportion of trips not conducted by car, but that the ability to draw strong conclusions was limited by the fact that all the 141 evaluation studies used weak quasi-experimental designs. As noted by Bonsall (2009), if there is a systematic bias in the reporting of effects in individual studies, this problem will not be alleviated simply by conducting meta-analyses based on published results.

Four meta-analyses including randomised controlled trials and strong quasi-experimental studies have been conducted since then. Fujii et al., (2009), including 15 studies, found that the average number of weekly car trips reduced by 11-17%. Arnott et al. (2014), including four studies, found no evidence for behavioural interventions to reduce car use frequency. Bamberg and Rees (2017), including 11 studies, found an average reduction in car modal share of about 5%. The latest meta-analysis by Semenescu et al. (2020), including 30 studies, found an overall reduction in car modal split of 7%.

Although these meta-evaluations provide more reliable estimations than previous narrative compilations, the studies on which they are based are still limited by internal validity issues due to data collection practices being based on self-reports. A related issue

is the lack of studies measuring travel distance, which is important in order to assess intervention effects, for instance on energy, emissions, and health. Further, more individual studies need to employ controlled evaluations, preferably randomised experimental designs, to control for confounding factors that might impede on results (Bamberg and Rees, 2017).

2.4 Soft measures in the context of Swedish transport planning

In Sweden, decisions on investment projects that are estimated to cost more than SEK 100 million are to be preceded by an action selection study (ÅVS) that reviews potential measures by application of a four-step principle. The first step of this principle investigates whether it is possible to address the deficiency, need, or problem by reducing or changing demand. The second step identifies more efficient ways of using existing transport infrastructure. As the third and fourth steps, reconstruction and new construction measures are considered (Swedish Transport Administration, 2018). The idea is that the fourth and most costly step should only be proposed if measures in the first steps are insufficient to meet the needs (Swedish Transport Administration, 2014).

Table 1
Different approaches to Travel Demand Management and its relationship to the Swedish four-step principle.

The Swedish four-step principle	Travel Demand Management					
	Hard measures			Soft measures		
	Physical changes	Legal policies	Economic policies	Information & feedback	Incentivised schemes	Administrative change
1. Reducing or changing transport demand	Land use planning Localisation (e.g. industry, shops, residential areas)	Decreasing speed limits Parking control	Parking charges Increased fuel prices	Marketing of new services Travel information to households	Temporarily reduced fare for PT Free e-bike trial	Travel policy at schools or workplaces Flexible working hours and teleworking
2. Use existing infrastructure more efficiently	Redistribution of street space Increased PT frequency	Prohibiting cars in city centres	Congestion charging Peak hour road tolls	Digital travel planner	Reward for driving off-peak hours	Organisational carpooling Car cooperatives
3. Make limited renovations	Relative capacity adjustments that disfavour car use					
4. New investments or major renovations	New relative capacity investments that disfavour car use					

One can easily identify the first two steps in the four-step principle as typical domains for TDM measures, in which soft measures are most common in step 1. Fujii et al.

(2009) divided hard measures into physical, legal, and economic policies. A parallel division of soft measures is made here, which includes information and feedback, incentivised schemes, and administrative changes. In Table 1, examples of hard and soft TDM measures divided into these categories are presented in relation to the four-step principle.

Even though soft measures are included in the national planning toolbox, the utilisation of step 1 measures is low compared to step 2-4. In an evaluation of the application of the four-step principle in practice, the Swedish National Audit Office (2018) found that step 1 measures were only considered in half of the 170 action selection studies that were reviewed (compared to 89% for step 2, 88% for step 3, and 71% for step 4), and just 35% of the studies proposed an actual implementation of step 1 measures. The reasons for the low utilisation of step 1 measures are, according to the evaluation, that they are not regarded as useful in many cases and because the Swedish Transport Administration lacks the mandate to implement and finance step 1 measures, resulting in most of them being conducted on the municipal or regional level. There is also a lack of knowledge about the effects of soft measures which contributes to their insignificance in the action selection studies (Swedish National Audit Office, 2018). This situation is not unique for Sweden. When interviewing officials at the local level in the UK, Cairns et al. (2004) found that planners often feel that working with soft measures is not recognised as being of central importance in transport strategy, which is affecting resources, political support, career expectations, and profile. There was also a perception that the relevant professional skills were not widely available or given sufficient importance.

Indeed, the implementation of soft measures in Sweden is mostly conducted at the local level in municipalities or within regional public transport authorities. Coordination on the national level is missing, although some are facilitated on a regional scale.

Given that soft measures are still in their formative years, are smaller in scale compared to conventional measures, and are relatively insignificant in the national planning practice, makes them something of a little brother within the transport policy family. It also highlights the need for more research about the design and effectiveness of soft measures. The next chapter presents the framework that has formed the basis for such an examination in this thesis.

3 Framework of the thesis

Soft measures is a particularly dynamic field of transport policy, in which many new schemes and initiatives are being developed on an ongoing basis (Cairns et al., 2008). Nevertheless, from an implementation perspective, this thesis has focused on three concepts that are essential parts of conducting soft measures. The concepts are segmentation, motivation, and evaluation, the assumption being that implementing soft measures includes the questions of how to segment and target populations, how to enhance motivation for participants to change travel behaviour, and how to evaluate the effect of interventions. These three concepts have been used to structure and analyse the combined material of the papers.

Segmentation, motivation, and evaluation can be positioned within current guidelines for conducting soft measures as proposed by several actors within the field (Steg and Vlek, 2009; Sussman et al., 2020; The Behavioural Insights Team and Alta Planning + Design, 2017; Whillans et al., 2020). These guidelines follow a general approach that includes: (1) defining the behaviour to be changed and population to target; (2) determining what factors affect the target behaviour; (3) designing and implementing a suitable intervention; and (4) evaluating the effect of that intervention and taking advantage of lessons learned. Figure 2 exemplifies this stepwise approach and how the concepts (segmentation, motivation, and evaluation) are positioned within this process.

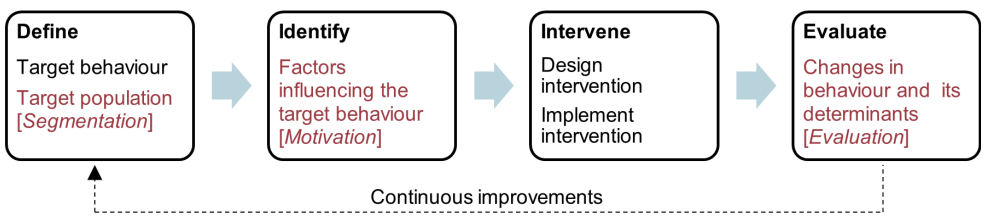

Figure 2. A stepwise process for conducting soft measures. Adapted from Steg and Vlek (2009) and Sussman et al. (2020).

Based on a study of soft transport measures implemented in Sweden (Friman et al., 2013), it is clear that there is some discrepancy between these general guidelines and how soft measures are conducted in practice. A principal concern is the lack of rigorous study designs, which makes it difficult to evaluate the effect of the interventions. Few

soft measures are theoretically grounded, or measure changes in behavioural determinants such as motivation to change travel mode. Further, the majority of such programs usually recruit as many participants as possible in an uncontrolled manner and provide general rather than personalised information (Friman et al., 2013), indicating a lack of targeting. Consequently, the main difficulties with facilitating soft measures seem to be related to segmentation, motivational triggers to pursue in order to influence behaviour, and how to evaluate the effect of soft measures. Thus, increasing the understanding of these principles and how they can be applied in practice can help overcome some of the barriers to implementing successful soft measures. Table 2 shows which papers have examined which of the concepts. How the concepts have been operationalised within this thesis will be explained next.

Table 2
The concepts under study in each paper.

Paper	Segmentation	Motivation	Evaluation
I		X	
II		X	X
III	X	X	
IV	X	X	
V	X		X

3.1 Segmentation

Previous research has established that segmentation is a useful tool for making campaigns more effective. In practice, however, it is still common to implement soft measures to maximise the reach of campaigns (Stopher et al., 2009). This carries the risk of the campaign being irrelevant or even disturbing to a large section of the audience. Many people are highly reluctant to reduce their car use and will not pay attention to soft measures (Innocenti et al., 2013; Lattarulo et al., 2018; Tertoolen et al., 1998).

Because soft measures are limited to voluntary behaviour change and often smaller in scale than other transport policy measures (not least financially speaking), spreading a campaign across the whole population according to the 'shotgun approach' is likely to result in a low return on investment ratio. Instead, interventions need to be targeted at suitable segments that are susceptible to changing behaviour and thus more likely to respond in the desired way. Designing interventions to target appropriate 'high yield segments' ensures resources are placed where they are most likely to have a positive effect on travel behaviour (Parker et al., 2007).

Market segmentation was first proposed by Smith (1956, p. 6), who defined segmentation as 'viewing a heterogeneous market (one characterised by divergent

demand) as several smaller homogeneous markets'. The idea is to match the genuine needs and desires of consumers with the offers of suppliers particularly suited to satisfy those needs and desires (Dolnicar et al., 2018). Segmentation is often part of a larger approach to strategic marketing, together with targeting and positioning, referred to as the STP approach. The process starts with market segmentation (the extraction, profiling and description of segments), followed by targeting (the assessment of segments and selection of a target segment), and finally positioning (adjustment of the product so it is perceived as different from competing products and in line with segment needs) (Dolnicar et al., 2018).

Segmentation has been used to a varying degree of sophistication within transport research and typically departs from variables related to demographics, travel behaviour, spatial distribution, and attitudes (Haustein and Hunecke, 2013). For instance, MaxSEM[2] uses six 'stage diagnostic' statements, inspired by the transtheoretical model of change (TTM) and Self-regulation theory (Bamberg et al., 2011; Prochaska and Diclemente, 1986), and segments people according to their readiness to decrease car use (Van Acker et al., 2013). Another example is the travel behaviour and attitude-based segmentation by Anable (2002, 2005), who used an expansion of the theory of planned behaviour (TPB) to identify segments. These were further developed within the EU project 'SEGMENT' to a market segmentation technique for promoting more energy-efficient forms of transport (Anable and Wright, 2013).

Segmentation has been used in this thesis to increase the understanding of how motivation to decrease car use in favour of alternative modes differs between subgroups in the population, and how targeting can be used to increase the efficiency of campaigns. The TTM and the SEGMENT model have been utilised for this purpose and are explained next.

The transtheoretical model

The TTM (Prochaska and Diclemente, 1986; Prochaska and DiClemente, 1982) is a behaviour change model that integrates key constructs from other theories into a comprehensive model of change. It has been applied to a variety of behaviours, mostly related to health, particularly smoking cessation. The TTM assumes behaviour change to be a dynamic process rather than an isolated event and consists of five stages as described in Table 3. The stages of change are just one core construct of the model, which also includes 10 main processes of change, decisional balance, and self-efficacy. According to the theory, an optimal scenario would be where processes of change within interventions are matched with the most suitable stage of change. However, the processes of change have received less empirical support than the stages of change

[2] MaxSEM was developed as part of the wider MAX project (2006-2009), which was the largest research project on Mobility Management within the EU's sixth framework program (European Commision, 2009).

(Prochaska et al., 2008), which could be the reason that the stages of change are the part of the model that have been applied the most by researchers (Spencer et al., 2002). The TTM has received unprecedented research attention, yet it has simultaneously attracted much criticism, partly related to the number and classifications of stages, and to the fact that stages might differ between contexts (Brug et al., 2005). Some point to the stages themselves as being insufficient to the task of explaining behaviour change since behaviour change is a continuous process (West, 2005). Even today no definitive conclusions can be made regarding the effectiveness of stage-matched interventions to promote behaviour change (Vela and Ortega, 2020).

Table 3
Stages of change within the TTM.

Precontemplation	No intention to take action within the next six months
Contemplation	Intends to take action within the next six months
Preparation	Intends to take action within the next 30 days and has taken some steps in this direction
Action	Changed overt behaviour for less than six months
Maintenance	Changed overt behaviour for more than six months

There is an ongoing strand of research that attempts to increase the understanding of the processes underlying the stages of change in travel behaviour (Bamberg, 2007; Forward, 2019; Friman et al., 2019; Olsson et al., 2018). In a review of the usage of the TTM in the transport domain, Friman et al. (2017) conclude that studies generally lack proper designs and outcome measures in relation to the processes and stages of change, making it difficult to conclude their effectiveness. Still, there is some evidence to suggest that it may be useful to conduct segmentation based on stages of change (Armitage, 2009; Thigpen et al., 2019). For instance, in a modified version of the TTM including four stages, Bamberg (2013) confirmed distinctive stages of change and showed that a stage-based intervention significantly reduced private car use. Thus, in this thesis, the use of the TTM has been delimited to the stages of change, which is a common approach for utilising the model (Gatersleben and Appleton, 2007; Thigpen et al., 2015; Waygood and Avineri, 2016).

The SEGMENT model

Attitude-based segmentation has been shown to effectively predict travel mode choice and offer a potential avenue for targeting soft measures more effectively (Hunecke et al., 2010). In this thesis, the SEGMENT model was chosen to study because its development is well documented (Anable, 2005; Anable and Wright, 2013), its segments can be detected in crowdsourced mobility data (Semanjski and Gautama, 2016), and the model has been applied in practice with promising results (Ladbury, 2013).

The SEGMENT model consists of eight segments, five with high accessibility to a car and three with low accessibility. By answering a set of 18 questions on a five-point

Likert scale (the survey items are presented in the appendix), respondents are assigned to one of the segments. The developers behind the SEGMENT identified the questions through discriminant analysis (Anable and Wright, 2013). The allocation of respondents to segments is made by multiplying their answers on each question by a weighting coefficient, which differ depending on the segment. Then, the products for each question are summed, generating a total score for each respondent for each segment. After subtracting the constant, which is a sum of the weighting coefficient from each segment, the respondents are allocated to the segment which they score highest (Anable and Wright, 2013). A description of each segment is provided in Table 4.

Table 4
Description of segments. Source: Andersson et al., (2020a).

	Segment	Description
High-car accessibility	Devoted drivers	Do not intend to reduce car use and think successful people drive. They do not use public transportation, nor cycling, and think walking is too slow. They are not motivated by fitness and have a very low moral obligation to the environment.
	Image improvers	Like to drive, see the car as a way of self-expression and do not want to cut down car use. They do not use public transportation but see cycling as a way of expressing themselves and a good way to keep fit. They have neutral or moderate environmental attitudes.
	Malcontent motorists	They do not like to drive and find it stressful. They have a moderately strong intention to reduce car use but are not motivated to increase the use of public transport, although they prefer it more than cycling. They walk but do not see any advantage to walking, except for fitness. They have a small level of environmental consciousness.
	Active aspirers	Have a high moral obligation to the environment and are highly motivated to use active transport modes, predominantly cycling, as they believe that it is quick and provides freedom and fitness. They are not public transport users and see problems with using it.
	Practical travellers	They use a car only when necessary as they think that it reduces the quality of life. They prefer cycling to the use of public transportation and would walk when it seems more practical. They are not motivated by climate change and see local pollution and congestion as issues. They are highly educated and above-average part-time working.
Low-car accessibility	Car contemplators	They do not use a car, are the highest proportion of non-driving licence owners, but would like to as they see cars as status symbols. They see many problems with public transportation use and find it, the same as cycling, stressful. They believe walking is healthy and have a neutral or moderate attitude towards the environment.
	Public transport dependents	They think people should be allowed to use cars and would like to see less congestion (they consider more roads as an appropriate solution). They use public transport, although they perceive it to be slow. They do not cycle but would like to walk more for fitness. They are not motivated by the environment and are the least likely to start driving.
	Car-free choosers	They think that cars lead to unhealthy lifestyles and do not like to drive. They prefer cycling as they feel a high moral obligation to the environment. Alternatively, they will choose public transport, which they do not consider stressful nor problematic, and walking. They are more likely to be women.

3.2 Motivation

The ultimate aim of soft measures is to change people's behaviour. This is done either directly through, for example, incentives and trials, or indirectly by influencing people's beliefs and attitudes.

In this context, it is often said in everyday speech that people need to be 'motivated' to 'do' or 'change' a behaviour. Indeed, enhanced motivation increases the likelihood of behaviour change, which is why it is desirable to strengthen the motivation of individuals in interventions to modify their behaviour (Sarafino, 2012). Motivated behaviour is goal-directed and purposeful and it is difficult to think of any behaviour that is not motivated in this sense (Gross, 2010). According to the Oxford English Dictionary, *to motivate* means 'to provide with a motive', and *motive* means 'a reason for doing something'. The following definition by Miller (1962) captures this essence of motivation:

> The study of motivation is the study of all those pushes and prods – biological, social and psychological – that defeat our laziness and move us, either eagerly or reluctantly, to action.

Thus, motivation can emerge for several reasons connected to biological, social, and psychological forces. These are commonly divided by psychologists into two parts: *drives*, which are mainly biologically based, such as hunger and thirst, and *motives*, which are at least partly learned and psychologically or socially based (Sarafino, 2012), such as the desire to drive a car. This thesis focuses exclusively on the latter of the two.

Motives are in turn influenced by *external* conditions (e.g. institutional, economic, social), such as the accessibility to transport modes, generalised costs for travelling, and social norms, and *internal* cognitive processes, such as attitudes towards driving a car or riding a bike, personal norms, and perceived behavioural control (Jakobsson, 2004). Several internal motivational determinants have been identified that influence car use, for instance, problem awareness (Steg et al., 2001a), personal norm (Abrahamse et al., 2009; Bamberg et al., 2007; Klöckner, 2013; Nordlund and Garvill, 2003), attitudes, social norms, and perceived behavioural control (Ajzen, 1991; Chen and Chao, 2011; Lois et al., 2015), habit (Bamberg, 2006; Eriksson et al., 2008; Gärling and Axhausen, 2003), as well as symbolic and affective motives (Steg, 2005). Hoffmann et al. (2017) found, in a systematic review and meta-analysis, that the strongest cognitive correlates of using alternatives to the car were intentions, perceived behavioural control, and attitudes. The same factors were the strongest in predicting car use, with the addition of habit. In a recent review of reviews, Javaid et al. (2020) investigated both external and internal factors and stated that psychological and sociological factors, as well as the built environment, influence car use. Perceived behavioural control, attitudes, personal

norms, social norms, habits, infrastructure factors, and time and price elasticities were the key factors.

Although soft transport measures are defined by scholars as 'strategies aimed at influencing people's perceptions, beliefs, attitudes, values, and norms' (Steg, 2003), which would suggest an exclusive orientation towards internal motives, many soft interventions modify external conditions as well, for example, by providing participants with a free public transport ticket for a limited time (Bamberg, 2006; Friman et al., 2019; Fujii and Kitamura, 2003; Thøgersen, 2009). Further, it is important to stress that even if soft interventions intend to address beliefs, norms, and attitudes through, for example, information and feedback, they always do so in an environment of external conditions that influence the degree to which internal processes can explain behaviour (Bandura, 2000; Guagnano et al., 1995), resulting in people not always doing what they say they will do, also referred to as the attitude-behaviour gap (Geng et al., 2016; Milfont and Duckitt, 2010).

Earlier research on behaviour change interventions in transport highlights the need for more theory-based approaches in the implementation and evaluation of soft transport policy measures (Chatterjee and Carey, 2018). The following theories and concepts have been employed in this thesis to better understand the motivation to decrease car use in favour of alternative modes.

The theory of planned behaviour

One exceptionally influential theory is the theory of planned behaviour (TPB) (Ajzen, 1991). It is a theory of how intentions to perform behaviours are formed and postulates that a choice is made among alternative behaviours based on the relative strengths of the intentions. Intentions are in turn formed by the attitude towards the behaviour, the perceived social pressure from significant others (subjective norm), and perceived behavioural control. The TPB is an extension of the theory of reasoned action (Ajzen and Fishbein, 1980; Fishbein and Ajzen, 1975), which is a rational choice model that presumes that people form intentions based on logic and reasoning. The difference between TPB and the reasoned action theory is the additional variable, perceived behavioural control, which is intended to account for behaviours that are not under complete volitional control (Ajzen, 1991). Several meta-analyses have found empirical support for the TPB and that the theory is capable of explaining around 20% of the variance in observed behaviour (Armitage and Conner, 2001). Likewise, many studies have found support for TPB in explaining transport-related behaviours (Forward, 2019; Lanzini and Khan, 2017).

The transtheoretical model

Described in the preceding section.

Diffusion of innovations

Diffusion of innovations (Rogers, 1995) is a theory about the spread of innovations in society. Innovations could be a behaviour, technology, service, system, object, or idea that are considered by society to be new. Diffusion is the process where innovations are communicated via different channels over time among members of a social system. The theory is particularly valuable in gaining insights into what qualities make innovations spread, the importance of social networks that spread the word about innovations, as well as identifying segments and their needs (innovators, early adopters, early majority, late majority, laggards). The theory has been used to categorise consumers according to their attitudes and adoption of innovations such as electric cars (Noppers et al., 2015).

Gamification

Gamification is the use of game elements/game mechanisms in activities that are traditionally unrelated to gaming to enhance the user experience of a particular activity (Deterding et al., 2011). In recent years, the concept has been applied in many areas to influence behaviours and increase the motivational power of the user, but without much consensus on how the concept should be formulated and what the actual benefits are (Seaborn and Fels, 2015). This is also true in the transport domain, where there are a number of examples of scientific studies where attempts have been made to change travel habits using gamification (Castellanos, 2016).

The unified theory of acceptance and use of technology

UTAUT, defined by Venkatesh et al. (2003), aims to explain user intentions to use an information system and subsequent usage behaviour. The UTAUT states that perceived usefulness (performance expectancy), perceived ease of use (effort expectancy), and norms (social influence) affect technology adoption intention via behavioural intention, which in turn leads to behaviour, whereas facilitating conditions directly antecede behaviour. The UTAUT model has for instance been used to explain the adoption of e-bikes by early adopters (Wolf and Seebauer, 2014).

3.3 Evaluation

An essential but often marginalised element when carrying out soft measures is evaluation (Davies, 2012; Friman et al., 2013). Successful evaluations of intervention studies are critical because they reveal the effectiveness of an intervention in achieving improvements to society. Parker et al. (2007) provide three reasons why evaluations should be of substantial interest, the first being to inform decision-makers of whether interventions are a good choice for the spending of resources, compared to other options. Second, to understand how and why effects were achieved, to support adaptive

learning and improve future interventions, and third, to enable the possibility to inform participants about the outcome of the intervention in which they took part.

However, conducting good quality evaluations of soft measures is not an easy task, a fact for which Stopher et al. (2009) list several reasons. First, it usually requires both before and after surveys, spaced sufficiently far apart to detect stable changes in travel behaviour. Second, it requires data of the average daily numbers of trips, distances, and times travelled for each mode of transport to enable an assessment of the change taking place. The common use of self-report surveys suffers from measurement errors and low resolution, making it inappropriate for measuring soft measures, which often results in small changes of 5-10%. Third, small changes in travel behaviours often require large sample sizes to be detected. Fourth, methods for evaluating the wider benefits of soft measures are often overlooked, such as potential spillover effects caused by interactions between the treatment group and their family or friends. Fifth, the evaluation should not be conducted by the agency undertaking the intervention, in order to minimise bias. Sixth, it requires a control group. A control group is a group from the same population, while a comparison group is a population group that is similar to the target group but not from the same population (Stopher et al., 2009).

The critique from reviews of behavioural transport interventions reflects these difficulties (Graham-Rowe et al., 2011). Research from a public health perspective especially expresses concern that intervention studies lack internal validity and objective outcome measures, and instead advocate evaluation studies that employ rigorous research designs in the form of randomised controlled trials (RCTs), which are referred to as the 'gold standard' in evaluation research (Arnott et al., 2014; Ogilvie et al., 2007; Yang et al., 2010). Reviews from the transport domain on the other hand highlight issues related to insufficient sample sizes, short data collection periods, and response/social desirability bias, thus advocating longitudinal studies and evaluations with aggregated travel data to supplement survey-based material (Chatterjee, 2009; Möser and Bamberg, 2008).

The discussion of what constitutes good evaluation practice in research about soft measures was nuanced by Bamberg and Rees (2017). They advocate the use of randomised experimental designs for future evaluations seeking to establish whether an effect and the size of such an effect is existent or not, while also acknowledging that understanding processes involved in behaviour change could require different study designs. This line of reasoning is shared by Chatterjee and Carey (2018), who declare that 'the priority for research [on behavioural transport interventions] should not only be to assess whether expected outcomes occur, but also to understand how targeted groups respond to interventions and what processes of change take place'. This thesis has attempted to include both these dimensions of evaluation, that is, assessing the effect of soft measures as well as analysing the underlying process of change.

4 Methods and data

4.1 Progression of the thesis

The scope of this thesis has developed over the course of the project. At the outset, ICT and smartphone technology was the main focus of the thesis. Due to uncertainty whether the project assessing the smartphone application in Paper II would be completed in time for it to form part of the thesis, the scope was extended to soft measures in a more general sense. Two strands of research needs were identified in Paper I for further investigation.

The first strand was connected to innovations for soft transport measures. A lack of field evaluations of smartphone applications in transport research was identified, as well as the potential to utilise smartphones for measuring and collecting travel behaviour data. A field evaluation of a mobility service application (MSA) was conducted in Paper II. In Paper II, it was evident that more rigorous study designs needed to be facilitated to enable adequate evaluations of soft measures. This need was found to be echoed in the literature concerning soft measures. This knowledge fed into Paper V, where a considerable emphasis was placed on study design in an attempt to assess the substitution effect of e-bikes. One such effort was to utilise smartphones for collecting data of the participant's perceptions and travel behaviour.

The second strand was that of motivation to reduce car use, and segmentation to enable more effective interventions, which led to the research on marketing messages for different segments in Paper III. This generated new questions regarding people's preconditions for motivation to decrease car use in favour of alternative modes of transport, which was investigated in Paper IV. The results in Paper IV, in turn, led to the targeting strategy in Paper V, where individuals with high car use were invited to participate in the e-bike trial.

The iterative emergence of the papers meant that gaps and observations identified in one study could be investigated in the next, thus producing a cumulative understanding of the research theme. A schematic representation of how the papers relate is presented in Figure 3.

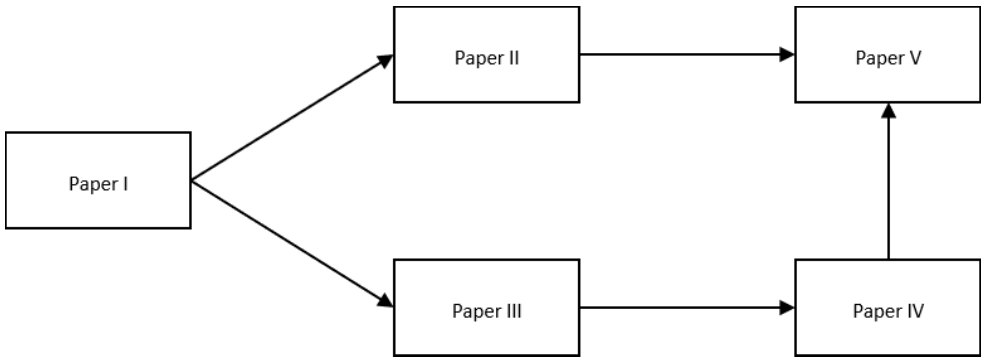

Figure 3. The linkages between the papers concerning how findings have been incorporated into the research questions or design of upcoming studies.

4.2 Method rationale

The methods employed in this thesis have been mainly quantitative, the exception being Paper II in which a mixed-method approach was employed including both surveys and qualitative interviews.

Carrying out the objectives has demanded an explorative (inductive) as well as hypothesis-driven (deductive) research approach. The inductive approach was suitable in Papers I, III, and IV because these studies aimed to explore new themes and develop hypotheses. Papers II and V were deductive in the sense that we attempted to establish cause and effect from the MSA intervention and the e-bike trial. Surveys and experimental research are the methods that have been mainly used in this thesis.

The theoretical stance of the thesis is post-positivist in the sense that it maintains the idea of an objective truth while recognising that prevailing knowledge and values of the researcher influence the research process, as well as the interpretation of results (Crotty, 1998). As such, bias is undesired but inevitable, and as a researcher one can only try to detect and correct misinterpretations. This quality has been refined during the research project; however, some of the methods employed in this thesis demand a layer of subjectivity, for instance in the interpretation of factors in the factor analysis, which certainly influence subsequent analyses and conclusions. From a post-positivist point of view, this is natural and part of the notion that reality can only be known imperfectly. Similarly, principles and hypotheses are not intended to be proven as true but, rather, tested for falsification and should therefore be presented as clearly as possible to be open for refutation. As Karl Popper put it (1959, p. 280) 'every scientific statement must remain *tentative forever*'.

4.3 Datasets

Four unique datasets were collected within the thesis, see Table 5. In the following sections, the data collection procedure and details for these datasets will be presented.

Table 5
Overview of datasets.

Dataset	Method	Databases and tools	Date of collection
Literature data	Literature review	Scopus, Web of science, Google scholar	Feb and Sep 2017
Business travel data	Surveys, interviews, and field experiment	Netigate survey tool	Before study: March 2017 and Feb-June 2018 After study: April 2019 Interviews: March 2019
National survey data	Survey	Kantar Sifo online panel	Feb 2018
E-bike trial data	Surveys and field experiment	TravelVu smartphone application	March-June 2020

4.3.1 Literature data

The empirical data used for the literature review in Paper I was based on peer-reviewed articles between 2008 and 2017. The keywords used to find relevant articles consisted of combinations of the terms 'travel/transportation/mobility behaviour', 'behaviour change', 'smartphone/application', 'mobile device', and 'persuasive technology'. After fulfilling the search, a snowball review was conducted, where references from the articles in the literature search were screened for additional eligible papers.

Criteria for inclusion

The criteria used for assessing articles for inclusion demanded that papers had been peer-reviewed and that they investigated behaviour change related to some form of smartphone applications or other types of ICT. The decision about which articles to include in the review followed the four steps of the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Moher et al., 2009): identification, screening, eligibility, and inclusion.

Empirical content

In total, 32 articles were included in the empirical material. Two were in the field of energy, 12 in the fields of health and fitness, two were concerned with climate mitigation and pro-environmental behaviours in general, and 15 articles were related to transport and mobility.

4.3.2 Business travel data

This dataset was collected over two years in collaboration with Samtrafiken, a company that connects all public and private transport operators, coordinates public transport data, and develops and manages ticketing and payment standards in Sweden. The dataset entailed both surveys and interviews. The emphasis was on business trips and the evaluation of a support system specifically developed to simplify the handling of business trips.

The mobility service application (MSA)

Between 2017 and 2019, Samtrafiken provided a service consisting of a mobile web application where, among other things, employees of recruited companies, authorities and organisations could manage their business trips by public transport and car. The MSA provided timetable information as well as the purchase of tickets for local and regional buses, commuter, regional and national train services, registration of car trips, and reporting of travel expenses. Through the MSA, trips by public transport were paid by monthly invoice, including a financial statement from Samtrafiken to the recruited organisations. The research team was not participating in developing the MSA or recruiting the participants.

Surveys

The survey included questions about the participants' business trips, attitudes toward transport modes, and the perceived possibility to use these modes for business trips. The after study also contained questions regarding the use of the MSA. A record of the questionnaire items is presented in Paper II.

Sample

The survey was dispatched to a sample of 525 individuals working in one of the 13 organisations that took part in the study, via the marketing research company Netigate. The online questionnaire was accessed through an e-mail, and 250 people completed the first round (48% response rate), 193 of whom were carrying out any business trips. In the second round (the after study), 77 participants responded, 35 of whom had used the MSA for conducting business trips. Thus, in the analyses, we had 35 users of the MSA constituting a test group and 42 non-users who formed the control group. Additionally, in the second round, 40 individuals agreed to participate in an interview, 20 of whom had used the MSA.

Interviews

Nine focus groups and 10 individual interviews were conducted, of which seven were over the phone and the rest at the informant's workplace. The purpose of the interviews, which were semi-structured to provide the respondents with an opportunity

to discuss without restraint, while ensuring that several themes were covered (Flick, 2002), was to gain an understanding of how the participants perceived their business trips and to get their views of the advantages and disadvantages of the MSA.

Study area

A total of 13 organisations distributed throughout five of Sweden's 21 counties participated in the project. The counties were Halland, Kronoberg, Östergötland, Uppsala, and Stockholm.

4.3.3 National survey data

This dataset consisted of answers from a cross-sectional stated preference survey that was distributed across Sweden. The survey included questions regarding demographics, accessibility, travel behaviour, attitudes, and motivation to decrease car use for commuting trips when exposed to different marketing messages.

Pros and cons of stated preferences

Stated preference (SP) methods are widely used in travel behaviour research to identify behavioural responses that cannot be observable in the market (Hensher, 1994). The main limitation of the SP approach is that it can result in low internal validity due to a discrepancy between self-reported behaviour and actual behaviour (see, for example, Rosenfield et al., 2020). Social desirability bias is a common cause for flawed answers, meaning that some respondents tend to underreport socially undesirable activities and overreport socially desirable ones (Krumpal, 2013). In the national survey conducted in this thesis, the intention was to examine the relationships between attitudes (and subsequent segmentation profile) and motivation imposed by a set of different marketing messages. This kind of data material would be hard to ascertain by examining revealed preferences, and while stated preferences carry the risk of social desirability bias, it has been shown to provide a reasonably accurate description of true preferences and market behaviour (Lambooij et al., 2015; Loureiro et al., 2003).

Due to the length of the survey, we chose not to include a social desirability scale such as the Marlowe–Crowne Social Desirability Scale (Crowne and Marlowe, 1960). Still, to mitigate biased answers, the participants were informed that the survey was anonymised and that there are no 'right' or 'wrong' answers. The purpose of the survey was stated to be purely scientific with no reference to sustainable transport to prevent respondents from giving responses they perceive to be more socially acceptable. Further, statistical techniques were utilised to detect false responses. This will be discussed in the next section.

The use of an online panel to recruit respondents

The survey was distributed through an online panel owned by Kantar Sifo, one of Sweden's major marketing research companies. It consists of approximately 100,000 Swedish citizens 16-79 years of age. The panel members are randomly recruited through nationally representative telephone surveys, and the panel is continuously replaced with new members to prevent them from becoming too accustomed to the survey methodology. Those who agree to participate in surveys receive compensation in the form of bonus points that can be redeemed for movie tickets or gift cards.

Although the use of online panels for collecting survey responses has been criticised by some scholars for resulting in low data quality, essentially related to low external validity and measurement error, the examination of these issues has indicated that the validity of responses from online panels generally falls within the credibility intervals of results from conventionally sourced data (Walter et al., 2019). In fact, the use of online panels can be of significant use because they are more diverse and provide access to underrepresented populations (Landers and Behrend, 2015). However, it has been suggested that researchers who use online panels for data collection consider the risk of mischievous respondents (MRs), and employ suitable statistical techniques to omit cases if necessary (Hays et al., 2015). In Papers III and IV, this was performed by applying Hyman and Sierra's (2012) MR algorithm. The MR algorithm begins with an intra-case assessment of each respondent's answers and assumes that MRs, in trying to sabotage studies yet remain undetected, will answer in ways that produce high or low means or variances relative to other survey participants. Then, like outlier analyses, the algorithm identifies potential cases for removal based on a threshold criterion. The respondents were considered mischievous if the variance of their responses was below 0.25. This resulted in 16% of the sample being removed for the sample in Paper III (191 cases) and 13% of the sample in Paper IV (127 cases).

Questionnaire content

A detailed account of the questionnaire items is presented in Papers III and IV and in the appendix. The marketing messages that were assessed in the survey were inspired by real mobility management campaigns in Sweden, and carried out by regional public transport authorities, municipalities, train operators, and pro-bicycling organisations. However, they were adapted to fit the common marketing 'frames' used to promote pro-environmental behaviours as identified by previous research (Avineri and Waygood, 2013; Bolderdijk et al., 2013; Griskevicius et al., 2010; Loureiro and Veloso, 2017; Nisbet and Gick, 2008; Winslott Hiselius and Smidfelt Rosqvist, 2015). These were related to either economic, environmental, health, or status-frames. The messages are presented in Table 6.

Table 6
Marketing messages with means and standard deviations. Theme abbreviations: $=economy, E=environment, H=health, S=status.

	Marketing message	Theme	Mean	SD
1.	We all must help to reduce our climate footprint. The result will be a sound environment that future generations also need!	E	3.73	1.10
2.	Those who mostly walk, cycle or ride transit are doing something good for the environment.	E	3.64	1.09
3.	Research shows that public transport users are walking on average four times more per day than car drivers, therefore reducing the risk of acquiring severe non-communicable diseases.	H	3.60	1.08
4.	Those who cycle and go by public transport not only improve their health but also contribute positively to other people's health.	H	3.57	1.08
5.	Did you know that cyclists have a 52% lower risk of dying of heart disease and a 40% lower risk of dying from cancer?	H	3.53	1.13
6.	You save about 350 euro per month if you live without a car and instead go by public transport and even more if you cycle or walk.	$	3.37	1.24
7.	Bicycles run on fat and save you money. Cars run on money and make you fat!	H, $	3.37	1.27
8.	If Sweden is to achieve its climate targets, then generally every third car trip must be replaced with more environmentally friendly alternatives.	E	3.36	1.19
9.	By cycling instead of taking the car to work, you save money and contribute to society at the same time! Try it!	$	3.28	1.16
10.	The car traffic in Sweden induces a socio-economic loss above 10 billion euros in adverse health effects.	H	3.21	1.17
11.	In the government budget, support for investments in cycling infrastructure increased by 50 million euros in 2018.	$	3.17	1.18
12.	If you want to improve your health, you should ride a bicycle instead of driving a car. If the distance is a problem, then an electric bike can be an option.	H	3.14	1.19
13.	Many Swedes use public transport to get to school or work every day. Thanks!	S	3.13	1.18
14.	It may seem inconvenient, but studies show that over 60% of those who test an electric bike continue to use it!	-	3.08	1.08
15.	The environmental impact per bus passenger is only 65% of the private car user in rural areas and 40% in urban areas.	E	3.04	1.09
16.	Beginning in 2018, you can get 25% of the cost subsidised by the government when purchasing a new electric bicycle.	$	3.02	1.28
17.	The car used to be a status symbol, but today other values are more important, such as taking care of oneself and the environment. Such values are usually related to cycling or public transport.	S	2.95	1.18
18.	Few things today can be considered more modern and prestigious than commuting by bicycle.	S	2.62	1.14
19.	Swedish Olympic champion Björn Ferry has decided to be fossil-free by 2025. If he can do it you can!	S	2.59	1.18

The level of motivation was measured on a five-point Likert scale from 'very unmotivated to decrease my car use' to 'very motivated to decrease my car use', in line with the scale used by Waygood and Avineri (2018). Respondents who already had low or no car use had a slightly adjusted scale: 'very unmotivated to keep my low level of car use', and 'very motivated to keep my low level of car use'. The order of the messages was randomised in the survey to prevent an accumulated message exposure that could affect the relative outcome of the messages.

One could question whether measuring motivation according to this scale would capture 'real' motivation to decrease car use or merely the extent to which respondents liked the messages. However, marketing research has demonstrated that attitudes toward advertisements influence attitudes toward what is advertised (for a meta-analysis, see Brown and Stayman, 1992), and some suggest that the liking of an ad may be the best indicator of advertisement effectiveness (Haley and Baldinger, 2000). Still, it is important to underline that it is the stated motivation to decrease car use *as a result of being exposed to the marketing messages* that forms the basis for the analyses in Papers III and IV.

Sample

The survey was distributed in February 2018 and answers were collected from 1,500 individuals, 1,300 of whom stated that they were regularly commuting to school or work. Commuting trips were focal because the survey items measuring motivation were contextualised around commuting trips. The sample was stratified to match the national conditions regarding gender and age, and analytical weights were used to compensate for the overrepresentation of respondents with higher educational attainment (10% difference from the average).

Study area

The geographical scope for the survey was limited to seven out of the nine municipality groups in Sweden according to the classification made by the Swedish Association of Local Authorities and Regions (2016). The two excluded municipality groups are classified as rural, with a population of fewer than 15,000 inhabitants in the largest urban area or with a commuting rate for work outside of the municipality of less than 30%. They were excluded since their modal options, in general, are much more limited than for the rest of the population. The included municipality groups include 95% of the Swedish population.

4.3.4 E-bike trial data

This dataset encompassed three data collection rounds from a randomised controlled e-bike trial conducted in the spring of 2020.

Study area

The project was a joint venture between the authors of the papers and the mobility management team at the Västra Götaland Region (VGR). VGR is one of Sweden's 21 counties. VGR had previously carried out a study of cycling within the county, which comprises 49 municipalities. Skövde municipality was identified for having particularly low levels of cycling, despite decent preconditions. Skövde has just over 50,000

inhabitants and is characterised by large companies within the heavy industry and professional services.

VGR established contact with one large employer in Skövde and acquired 50 e-bikes of the 'pedelec' sort which were lent to participating employees for five weeks.

TravelVu logging and surveys

The data collection was facilitated through TravelVu, a GPS-tracker smartphone application that registers the duration, distance, route, time, and travel mode of each trip. An advantage of this method is that it provides travel data independent of self-reports from the participant and more details regarding each trip compared to conventional travel surveys. The application was also used for distributing the surveys, which included questions about age, gender, education, access to travel modes, and attitudes towards e-bikes and cycling. Since the first data collection period began in March 2020 when the outbreak of COVID-19 occurred, additional survey questions were incorporated in the second survey round to capture the effect of the pandemic on the trial.

Trial procedure

Measurements (travel logging and survey) were conducted for one week at baseline (M1) and four weeks into the trial for both the treatment and control group (M2 and M3). Table 7 provides a timeline for the intervention and the data collection. A second e-bike trial period was conducted for the control group only. After the first trial was finished, the control group got access to the e-bikes and had their trial period. The second trial period was conducted to prevent dropouts from the control group by keeping them motivated to participate and to validate the results from the treatment group. All participants were informed that they would get access to an e-bike that could be used as much as they liked. The VGR team informed the participants about the appropriate use of the TravelVu app and was available for support during the trials.

Table 7
Timeline for the e-bike intervention and the data collection. Adapted from Söderberg f.k.a. Andersson et al. (2021).

	M1		M2		M3
Group	Treatment and control	Treatment	Treatment and control	Control	Control
Activity	*Baseline measurement and survey*	*E-bike trial*	*Follow up measurement and survey*	*E-bike trial*	*Follow up measurement and survey*
Date	March 9-15	April 2-May 7	April 27-May 3	May 8-June 15	June 1-June 7
Duration	1 week	5 weeks	1 week	5 weeks	1 week

Sample

Participants who were chosen for taking part in the trials (typical individuals with high car use and a distance of 5-12 km between their home and workplace) were randomly assigned to a treatment or control group.

The aim was to recruit 100 participants. In total, around 3,200 employees were contacted, 317 of whom stated that they would like to participate. At the start of the trials, the sample consisted of 98 individuals. In the end, the analytical sample consisted of 65 participants, 40 of whom belonged to the treatment group and 25 to the control group.

4.4 Representativeness of datasets

It is important to emphasise the limits of the datasets in terms of the possibility to generalise the results to other contexts. The choice of data to be collected, sample size, and study design all depend on the purpose of the study.

For the literature review in Paper I, the search criteria was limited in terms of language (English) and to the fields of energy, transport/mobility, health and fitness, and pro-environment/climate. Thus, the review is not representative of publications in other languages and cannot generalise beyond these fields. However, the scope of the study was principally the role of ICT for transport, and most studies included in the review were in the transport/mobility domain, the field in which we were most interested to generalise.

The business travel data used in Paper II was collected from participants who were recruited through convenience sampling from the participating organisations, a process in which the research team was not part. Analysing the travel behaviour of the participants revealed a considerably higher share of public transport for business trips (about 45% of all business trips) than the national average as informed by the national travel survey (10%). Further, women were overrepresented. Consequently, the sample is not representative of the general population. However, the aim was to demonstrate the strengths and weaknesses of the implemented MSA, with potential effects on business trips rather than to generalise the effects on travel behaviour to the general population.

The national survey data utilised in Papers III and IV were stratified to match the national conditions regarding age and gender. The sampling was conducted in seven out of the nine Swedish municipality groups, excluding only the most rural parts of the country (inhabited by 5% of the population). As such, the sample can be used to get a rough estimation of the national conditions, although, there is a tendency of online panels to consist of people with higher education than the national average. Analytical

weights were used to compensate for the overrepresentation of respondents with higher education (the sample had 10% more highly educated participants than the Swedish average) and the underrepresentation of older respondents. However, differences in attitudes between panellists and non-panellists cannot be controlled and it is wise to interpret the results and generalise in light of these limitations.

The target group in the e-bike sample used for Paper V was deliberately chosen due to its high car use, which was believed to offer the highest potential for substitution and reduction of car use. In the case of external validity, it limits the degree of substitution that can be expected to occur for the average individual because the general amount of driving is considerably lower. However, soft measures are often targeted to this kind of groups, that is, segments with high car use who are willing to try a new mode of transport. This is the primary group to which the e-bike data can be generalised.

4.5 Analyses

This section gives an overview of the analyses that have been employed to evaluate the datasets in relation to the research questions. The research questions for each paper are presented in Table 8. It does not cover the work conducted for preparing the data for the analyses. Such initial data processing has included (but is not limited to) data screening, descriptive analyses, the transformation of (and creation of new) variables, and reliability analyses for constructing composite variables. IBM SPSS statistics 25 was the software used for most processing and analyses of the data.

Table 8
Research questions of each paper.

Paper	Research questions
I	How can smartphone applications be used to promote pro-environmental travel behaviours? What are the key aspects to consider in developing a behaviour change support system for ICT?
II	How does a mobility service application (MSA) affect travel behaviour and perceptions towards using public transport for business trips? What factors enable an MSA to facilitate more sustainable business trips?
III	How do marketing messages influence different segment's motivation to reduce car use? What underlying dimensions affect the interpretation of such messages?
IV	What influence do attitudes, accessibility to travel modes, travel time, and usual commute mode have on the motivation to reduce car use? How does the motivation to reduce car use differ between the segments?
V	To what extent do e-bikes increase cycling for frequent drivers and what modes, if any, are substituted and to what degree? How does an e-bike trial affect perceptions towards e-bikes?

Note: The research questions have been adapted from the aims as expressed in each paper

The relationship between the papers, the datasets, the approach, the method of analysis, and the analysis types are presented in Table 9.

Table 9
The relationship between the papers, datasets, method, approach, and analysis type.

Paper	Dataset	Approach	Method of analysis	Analysis type
I	Literature-based data	Inductive	Review	Content analysis and inductive category development
II	Business travel data	Inductive and deductive	Mixed	Independent/paired samples t-tests and content analysis
III	National survey data	Inductive	Quantitative	Exploratory factor analysis, analysis of variance (ANOVA), and paired samples t-test
IV	National survey data	Inductive	Quantitative	Multiple regression modelling and analysis of variance (ANOVA)
V	E-bike data	Deductive	Quantitative	Paired-samples t-tests and content analysis

4.5.1 Analytical samples and dependent variables

For each study, an analytical sample was defined to ensure that all analyses were based on the same individuals. The size of these samples, gender distribution, mean age, and share of trips undertaken by car pre-intervention, is presented in Table 10.

In the cases where a certain type of trip has been examined, these have been either business trips or commuting trips. Commuting trips to work and school combined with business trips constitute about half of all trips in Sweden (Transport Analysis, 2020) and are important to study as they are fixed in time and place for most people, thereby contributing disproportionally to traffic congestion and environmental pollution (Heinen et al., 2010).

Table 10
Analytical samples used in the analyses for each paper.

Paper	Analytical sample	Share of women	Mean age	Share of car trips
I	32 articles	-	-	-
II	77 participants	65%	46	22% (business trips)
III	994 respondents	48%	45	46% (commuting trips)
IV	850 respondents	49%	42	51% (commuting trips)
V	65 participants	12%	48	90% (commuting trips)

In Paper I, the focal interest was key aspects for promoting behaviour change through ICT, which was examined through a narrative synthesis of previous research. Since no statistical analyses were conducted, no dependent variable (DV) was specified.

Dependent variables in Paper II

In Paper II, the DVs were related to reported travel behaviour on the one hand, and perceptions about the MSA as a tool for increasing public transport trips on the other.

The travel behaviour DVs were based on survey answers about the number of business trips undertaken by car, public transport, bicycle, foot, and aeroplane, before and after the use of the MSA.

Three pairs of DVs (before and after the use of the MSA) were constructed to assess the effect on perceptions towards public transport. These determinants were: performance expectancy, effort expectancy, and social influence, which are parts of the UTAUT theory. The first question was stated as 'How possible is it for you to travel by bus/train for business trips?' (performance expectancy). The second was a statement saying, 'You think that using the bus/train is difficult' (effort expectancy). The third question was 'Your closest colleagues, who also make business trips, how often do you think they travel by bus/train?' (social influence). Each question was asked once for bus trips and once for train trips, and the scale was from 1 to 7, where 1 was impossible/totally agree/very seldom and 7 was very possible/totally disagree/very often. The mean score was then computed from the bus/train questions to get an average public transport score for each determinant.

Dependent variables in Paper III

In Paper III, the DVs consisted of the factors identified from the exploratory factor analysis, which was based on the stated motivation to decrease private car use from the 19 marketing messages.

The first factor (and subsequent DV) consisted of the mean value from 11 messages, while the second factor (DV) consisted of the mean value from eight messages. A third DV consisted of the mean response from all the messages as a representation of the general motivation to reduce private car use. The scale of the three DVs was 1 to 5 ('very unmotivated to decrease my car use' to 'very motivated to decrease my car use').

Dependent variables in Paper IV

In Paper IV, the marketing messages were used as the DV in the regression modelling to represent motivation to decrease private car use. However, since it was believed that the five messages related to status were of lower validity due to stronger reactance towards these kinds of messages, they were omitted from the DV. The aggregated values from the remaining 14 marketing messages were used to compute a continuous variable that formed the DV. The scale of this variable was 14-70. Using the responses to the marketing messages as a proxy for general motivation to decrease car use was chosen because the responses were strongly associated with the behaviours and attitudes of the segments that were investigated in Paper III.

A second DV was computed from the significant predictors in the regression to form a 'precondition index'. This was used to explore the trends in how the preconditions for motivation to reduce private car use are distributed demographically, and in the

behaviour change stages of the TTM. The following procedure was undertaken to compute the index:

First, a new variable was created for each of the significant predictors, and each significant category was loaded with the estimated coefficients retrieved from the regression. The non-significant categories (and reference categories) were given the value zero. Second, all the new variables were summed into a continuous variable in which each respondent had a value positioned on the index scale. Different methods are available for aggregating indicators to form a composite index, and the most common are the 'additive methods that range from summing up unit ranking in each indicator to aggregating weighted transformations of the original indicators' (Matteo Mazziotta, 2013). The latter method was used to compute the precondition index: the significant predictor coefficients were used as weights and aggregated to form an index. Third, the variable was transformed into a categorical variable for further analyses. The range produced by the respondents was equally divided into four categories, with the lower range indicating unfavourable preconditions, the higher range indicating favourable preconditions, and zero representing neither favourable nor unfavourable preconditions.

Dependent variables in Paper V

The majority of DVs were constructed from travel behaviour data retrieved from the participants' smartphones. Several DVs were created based on the week of measurement, mode of travel, and treatment/control group for the number of trips, distance, and modal share.

A set of DVs was also constructed of perceived obstacles preventing participants to commute by bike to work, comparing between a conventional bicycle and an e-bike. The obstacles that constituted a DV were practical (pick-up/drop-off, transporting goods), time-consuming, physically demanding, too much of a distance, bad cycling infrastructure, traffic safety, incentives for car commuting, lack of secure parking.

4.5.2 Type of analyses

Content analysis

Content analysis was employed to a varying degree for extracting key findings from previous literature (Paper I), interviews (Paper II), and qualitative survey answers (Paper V). There are three approaches to content analysis: conventional, directed, and summative (Hsieh and Shannon, 2005). The differences between these approaches have to do with how content is categorised, where the conventional content analysis derive categories directly from the text data, the directional approach begins with a theory or a priori understanding that guides the development of categories, and the summative approach involves counting and comparisons of content, followed by

interpreting the underlying context. Papers I and II used both the conventional and directive approaches because the coding of the literature and the interviews were derived inductively from the data (conventional approach) but interpreted in light of existing theories (directed approach). In Paper V, a summative content analysis of the free-text answers was conducted in which the occurrence of stated advantages and disadvantages were counted and ranked for comparison.

t-test

In experimental work, the *t*-test can be used to establish whether two means differ significantly at a predetermined probability level.

Several of the papers set out to examine the difference between means representing either different treatments (for example, different marketing messages and their influence on motivation to decrease car use) or different points in time (such as distance cycled before and after the e-bike intervention). Both of these examples, drawn from Papers III and V, assessed the potential difference between two means that came from the same sample, also referred to as repeated measures design. As such, the *paired* samples *t*-test was used for making these comparisons because it assumes that the means come from the same entities.

In contrast, *independent* samples *t*-test assumes that two means are drawn from different samples, a test that was used in Paper II to compare means for different characteristics between the treatment and the control group. However, assessing the effect of the MSA was a repeated measures design conducted within the treatment and the control group respectively, and consequently, the paired samples *t*-test was used for this analysis.

Analysis of variance (ANOVA)

In Papers III and IV, there were more than two means from independent samples to be compared. Therefore, the one-way analysis of variance (ANOVA) was used for investigating whether motivation differed between eight segments (Paper III) and whether preconditions for motivation differed between the five stages of change in the TTM model (Paper IV). The ANOVA test cannot reveal which specific group means are significantly different from each other; it only demonstrates if at least two groups are different. To determine the relationships between all combinations of group means, a post-hoc test needed to be conducted for each ANOVA analysis. Different post-hoc tests exist depending on the assumptions that apply to the sample, particularly if equal variance of the populations can be assumed. For Paper III, this assumption was violated and therefore a stricter post-hoc test was applied (Tamhane's T2). In Paper IV, equal variances were met and so the Tukey post-hoc test was used instead, which gives better power to the test than its stricter colleagues (Field, 2018).

Exploratory factor analysis (EFA)

In Paper III, a relatively large set of marketing messages (19 to be precise) were shown to the respondents, who were asked to state the level of motivation they felt to decrease their personal car use when exposed to each argument. Every message had been predeterminably framed around typical themes (economy, environment, health, status). However, there was an interest in understanding what, if any, underlying dimensions unite the messages and, if so, what do these stand for? Factor analysis attempts to achieve parsimony by explaining the maximum amount of common variance in a correlation matrix using the smallest number of explanatory constructs (Field, 2018). These 'latent variables' represent several variables, in this case marketing messages, that correlate highly with each other. As such, EFA is useful for reducing large sets of information into fewer manageable factors.

Two tests are indicative of the suitability for factor analysis. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) is a statistic that suggests the share of variance in the variables that could be caused by underlying factors. High values close to 1.0 indicate that EFA may be useful for the data. Values less than 0.50 suggest that EFA would not be very useful. The other test, Bartlett's test of sphericity, tests the hypothesis that the correlation matrix is an identity matrix, which would indicate that the variables are unrelated and therefore unsuitable for structure detection. A significance level of $p < 0.05$ indicate that factor analysis may be useful. Both these tests indicated that factor analysis would be suitable for the data (KMO = 0.95, Bartlett's test of sphericity ($p < 0.001$).

Principal axis factoring was chosen for extraction with oblique rotation (Promax) because this carries the assumption that the factors are correlated, which is not accounted for in the commonly used orthogonal rotation, which assumes factors to be independent (Pituch and Stevens, 2016). Deciding on the number of factors to retrieve from the factor solution is often done iteratively and, in the next stage, interpreting the meaning of the factors is a subjective task. However, there are a few common thresholds that can guide the factor extraction process. In the case of Paper III, factors with eigenvalues larger than one in combination with a visual inspection of the scree plot served as guidance for the extraction procedure, which resulted in a two-factor solution. Messages clustering to the factors were considered meaningful if their loadings were above 0.35 (Jung and Lee, 2011).

Multiple linear regression

In Paper IV, linear regression models were estimated to establish the feasibility of variables related to attitudes, usual mode choice for commuting, commuting time, accessibility to travel modes, and driving license in predicting motivation to decrease car use. The rationale for estimating the linear models were threefold: (1) to assess the correlational strength between each predictor and the dependent variable (motivation

to decrease private car use); (2) to establish the predictive power of the models (by inspection of explained variance via the adjusted R^2 value); and (3) to create an index of significant predictor coefficients to be used for exploring how preconditions for motivation to reduce car use are distributed demographically and in the TTM stages.

Preliminary analyses were conducted to ensure the non-violation of the assumptions of normality, linearity, and homoscedasticity by visualising the data in histograms, scatterplots, and normal P-P plots of standardised residuals. Two outliers were excluded based on standardised scores (> 3) and casewise diagnostics. Cook's distances were checked for influential cases, and variance inflation factor values (VIF) were inspected for assessing the level of multicollinearity between predictor variables. Combined, these tests suggested that the variables were suitable for being included in the regression.

The attitudinal survey questions were measured on a five-point Likert scale (strongly disagree, disagree, neither/nor, agree and strongly agree). Some of these variables were non-linear. Therefore, dummy variables were created for each category within each attitudinal predictor, and neither/nor served as the reference category. This enabled to account for potential thresholds in the data and presenting a nuanced picture of how the predictors influence the dependent variable (see Páez and Whalen (2010) for a similar approach).

5 Results

This chapter presents a summary of the aims and results from each paper (for a more detailed account of these, see the respective papers in the appendix). The analyses and tools used are presented in the tables, along with key findings, and model summary when applicable.

5.1 Paper I

The purpose of this study was to investigate how behavioural change techniques can be implemented in smartphone applications to encourage sustainable travel behaviours. This was investigated by conducting a literature review from which key aspects of combining behaviour change techniques with ICT/smartphones were compiled. Such systems are referred to as behaviour change support systems (BCSS) (Oinas-kukkonen, 2010). The empirical findings were evaluated against a theoretical framework consisting of the TPB, the TTM, diffusion of innovations, and gamification.

An initial observation from the review was that many empirical studies (about half of the studies included in the review) lack theoretical grounding, which suggests that there is a need for more research on this topic that embeds empirical findings in theory. Further, in the literature review, 26 findings were identified which concern different aspects of BCSSs. Through an inductive category development, four distinctive categories were defined, namely (1) customisation to the user, (2) information and feedback, (3) commitment, and (4) appealing design.

Based on the empirical findings and in light of the theoretical framework, a conceptual model was developed that highlighted these aspects for creating a BCSS (see Figure 4). First of all, customisation to the user appeared to be crucial to contextualise information, feedback, goal setting, stimuli, motivational mechanisms and other content within the BCSS. Segmentation and targeting were identified as enablers for better customisation. Due to its importance, *customisation to the user* is the starting point in the model, which influences *information and feedback* and *commitment*, since both of these parts should be grounded in the user's needs as well. The rationale is that these three parts in combination will contribute to an *appealing design*, which in itself also needs to be simple and user friendly. The arrow design is a reminder that the

development of a BCSS is a process that benefits from continuous evaluation and improvement, preferably with input from the users themselves.

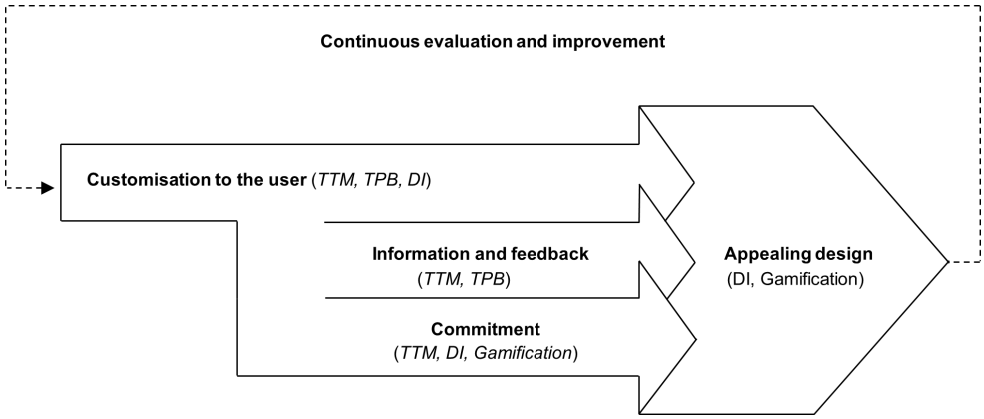

Figure 4. A conceptual model for combining behavioural change techniques with ICT to create a behaviour change support system (BCSS). Source: Andersson et al. (2018).

A suggestion for further research was to evaluate the effect of BCSSs to change behaviours, preferably with larger datasets to allow generalisations and with support in theory. Further, a potential research strand identified was more studies that explore transport-related segmentation and that evaluate the effect of tailored messages for changing travel behaviour. Finally, future research was recommended to continue exploring the possibility of measuring actual travel behaviour change with the use of smartphone technology.

Table 11
Summary of results from Paper I.

Analysis	Tool	Key findings
General observations regarding previous research on ICT and behaviour change support systems	Qualitative content analysis	Lack of studies grounding behaviour change techniques in behaviour theory. Segmentation would allow better customisation to the user.
Key aspects for influencing behaviour through ICT in the fields of energy, health and fitness, climate and environment, transport and mobility	Inductive category development	26 findings sorted into four categories: customisation to the user, information and feedback, commitment, appealing design

5.2 Paper II

The aim was to evaluate the implementation of a new smartphone application, developed by Samtrafiken to facilitate more business trips to be carried out by public transport. The application was referred to in the study as a mobility service application (MSA). Both surveys and interviews were conducted to evaluate the MSA. The quantitative part focused on analysing changes in travel behaviour and changes in determinants based on UTAUT regarding perceptions of public transport. The qualitative interviews focused on how the participants believe that their organisations manage business trips, and their view of the MSA as a support to facilitate more sustainable business trips.

Of the three UTAUT determinants (performance expectancy, effort expectancy, and social influence) only effort expectancy was significantly different comparing between before and after the implementation of the MSA. This indicates that the treatment group (MSA users) thought it was easier to use public transport after they had experienced the application. No difference was found for the control group.

In Paper II, the performance expectancy variable was omitted from the analysis due to violation of normality (although several attempts to overcome this were made by transforming the variable). In retrospect, performing the analysis with bootstrapping would have solved the issue because it does not assume normality (Field, 2018). Since the sample size was small (n = 77), this would also have added rigour to the analysis by estimating more robust confidence intervals. Therefore, post-publication, the paired samples *t*-tests were re-estimated for all three determinants for both the treatment and the control group.[3] Based on 2,000 random resamples and 95% confidence intervals it was found that performance expectancy (the skewed variable) and social influence were not statistically different (p = 0.597 and 0.119, respectively) while effort expectancy was (p = 0.026). Thus, the conclusions made in Paper II are valid even with robust estimations, with the additional result that the perceived possibility to travel by public transport (performance expectancy) did not change as a result of using the MSA.

Due to a high dropout rate, missing data from the sample, and low use of the MSA, it was not possible to assess potential differences in travel behaviour as a result of using the application. The trips made using the MSA consisted mainly of regional trips by train and bus. Only 35 out of 193 individuals used the MSA for the full period and this group already travelled more by public transport than the rest of the sample. This is an example of the importance of collecting data from larger samples, especially when the intervention is expected to yield a small effect. Since the research team was not participating in the recruitment procedure, it was difficult to limit attrition and self-

[3] Not part of Paper II.

selection bias, which is a general problem in studies attempting to evaluate these kinds of interventions in field experiments (Cellina et al., 2019).

From the interviews, three factors were identified that could affect the success of a new MSA as a means of increasing sustainable business trips: management control and proactiveness, perceived improvement due to the intervention, and functions and technical sufficiency of the MSA tool.

The importance of facilitating organisational conditions that favour sustainable business travel was highlighted, expressed as the factor *management control and proactiveness*. For this to happen, the interviewees expressed that management needs to take responsibility for implementing and promoting a travel policy, making sustainable transport more accessible for employees, and creating an organisational culture that encourages pro-environmental behaviour. The management also need to lead by example. Regarding the *perceived improvement due to the intervention*, the respondents who used the MSA were generally positive about it as a means of managing business travel and many emphasised that the MSA had the potential to make a significant contribution, although not in its current form. The fact that the MSA automatically handled travel expenses was especially appreciated, but there were also shortcomings (technical and functional) that prevented participants from using the MSA. Much criticism was related to *functions and technical sufficiency*. The participants wanted a greater range of transport services to be included in the MSA. In addition to the purely technical aspects, the MSA was expected to offer more ticket options and be easier to use. An important reason for not using the MSA was that existing business travel booking systems were either procured and thus employees had to use that service, or that existing booking systems were more flexible and offered more personalised service. The results also show that the MSA would need to be integrated with existing systems and guidelines to avoid conflicts that might otherwise occur to the user.

A methodological lesson from this study was the need to carefully design intervention studies to avoid significant differences in representativeness between the treatment and the control groups, as well as consider what type of information and incentives could increase participation in field experiments.

Table 12
Summary of results from Paper II.

Analysis	Tool	Key findings
The difference in attitudes before and after the MSA trial, comparing test- and control group	Paired samples *t*-test	Increase in effort expectancy (easier to use PT) for the test group ($p < 0.05$) while no change was observed for the control group
Aspects that affect the success of a new MSA as a means of increasing sustainable business trips in organisations	Qualitative content analysis	Management control and proactiveness; perceived improvement due to intervention, functions and technical sufficiency. Establishing an organisational culture that favours sustainable business trips.

Methodological weaknesses	Reflections on the method	Challenging to retain interest from participants over time in app-based interventions. Future studies should carefully consider what type of information and incentives could increase participation.

5.3 Paper III

The aim was to evaluate how common marketing messages to promote sustainable transport influence different segments' motivation to reduce car use, and to identify underlying meanings that affect the interpretation of such messages to understand how sustainable transport can be promoted more effectively.

The respondents (n = 1,300) were asked to assess their level of motivation to decrease their private car use when exposed to each of the 19 marketing messages. Information about mode choice for commuting as well as attitudes were used for segmentation according to SEGMENT (for details about the items, see appendix).

Descriptive statistics showed that divided into the predetermined frames (environment, health, economy, status), messages induced more motivation if related to environmental or health issues, which had mean values of 3.51 and 3.44, respectively, compared to economic (3.27) and status (2.76) messages.

Running the messages within a factor analysis suggested a two-factor solution based on eigenvalues over Kaiser's criterion of 1, which explained 50% of the variance in combination. The messages clustering to the first factor seemed to represent personal health, financial benefits, convenience, and status. Overall, these items point toward the individual gaining utility from using sustainable transportation, and that one should act pro-environmentally due to self-interest. On the contrary, the messages related to the second factor seemed to be related to concerns of the environment, health (both personal and societal), collective responsibility, and morality. This suggested that a more altruistic dimension was uniting the messages in the second factor. Based on this line of reasoning, one could argue that the factors represent egoism on the one hand (first factor) and altruism on the other (second factor). This labelling was used in the first drafts of Paper III.

Another interpretation could be to judge the messages within the factors according to whether they communicate individual or collective efficacy, since the first factor included more individualistic messages and the second more collective messages.[4] In the end, the choice was made to label the factors accordingly, that is, the first factor was to represent *self-efficacy* and the second *collective efficacy*. Self-efficacy focuses explicitly

[4] A suggestion put forward by one of the anonymous reviewers.

on the efficacy expressed by an individual and is defined as 'the belief in one's capabilities to organise and execute the courses of action required to manage prospective situations' (Bandura, 1995, p. 2), while the definition of collective efficacy is 'a group's shared belief in its conjoint capabilities to organise and execute the courses of action required to produce given levels of attainments' (Bandura, 1997, p. 477).

However, it is important to emphasise that self-efficacy and collective efficacy are not interchangeable with egoism and altruism. Self-efficacy has been demonstrated to be important for individuals in performing all kinds of behaviours, including pro-environmental behaviours (Klöckner, 2013; Skarin et al., 2019). In general, individuals are more inclined to perform behaviours they believe to be achievable, and people with high self-efficacy set higher goals for themselves, put more effort into changing behaviour, and persevere when facing obstacles (Bandura, 1997). Collective efficacy has on the other hand been increasingly associated with pro-environmental behaviours (Barth et al., 2016; Doran et al., 2015; Reese and Junge, 2017) and it seems reasonable to assume that motivation to act in response to collective problems requires a sense of collective efficacy. This could, for instance, turn perceived individual powerlessness in the face of climate change into personal action since a strong sense of collective efficacy has been shown to increase perceived self-efficacy (Jugert et al., 2016).

Still, it is important to stress that labelling the factors is a subjective task and other labels might be more suitable for capturing their essence: that the first factor relates to personal health, financial benefits, convenience, and status, while the second factor relates to concerns of the environment, personal and societal health, collective responsibility, and morality.

The analysis of the difference in reported motivation for the two factors showed that the second factor was significantly more motivating for all segments, although there were also significant differences between the segments' general level of motivation. The results indicated that the segments were more motivated by messages that confirmed their current attitudes and travel behaviour. For instance, cycling messages appealed more to regular cyclists. However, this expectation, that attitude-based segments would differ significantly in motivation depending on the kinds of messages, was not so clear. Rather, the difference between segments was expressed in the general motivation to decrease car use based on existing preconditions. The difference in general motivation seemed to depend on prevailing attitudes and behaviours, demonstrating the effect of assimilation bias, which occurs when perceptions of new evidence are interpreted in such a way as to be assimilated into prevailing beliefs (Lord et al., 1979). Consequently, the way to influence preconditions for motivation to decrease private car use was the subject under study in Paper IV.

Table 13
Summary of results from Paper III.

Analysis	Tool	Key findings	Model summary
Mean values for pre-defined message themes	Descriptive analysis	Environmental (3.51), health (3.44), economic (3.27), status (2.76). Scale 1-5 (very unmotivated to very motivated)	-
Latent dimensions in 19 marketing messages	Exploratory factor analysis	Two-factor solution interpreted as 'self-efficacy' (11 items, α=.87) and 'collective efficacy' (8 items α=.88).	KMO = 0.95. Bartlett's test of sphericity: Approx. Chi-square = 8590.68, df = 171 ($p < 0.001$). % of variance = 50.49.
Difference between latent variables for each segment	Paired samples *t*-test	Devoted Drivers ($p < 0.001$) Image Improvers ($p < 0.001$) Malcontent Motorists ($p < 0.001$) Active Aspirers ($p < 0.001$) Practical Travellers ($p < 0.001$) Car Contemplators ($p < 0.01$) PT Dependents ($p < 0.001$) Car-free Choosers ($p < 0.001$)	-
Analysis of variance between segments	One-way between-subjects ANOVA Post Hoc analysis (Tamhane's T2)	Segments differed in motivation. Segments motivation to reduce car use based on the marketing messages seemed to be influenced by assimilation bias	All messages: $F(7) = 40.027$, $p < 0.001$ Self-efficacy messages: $F(7) = 33.504$, $p < 0.001$ Collective efficacy messages: $F(7) = 36.514$, $p < 0.001$

5.4 Paper IV

The aim was to explore what motivates people to reduce their car use and how such preconditions for motivation are distributed in the population demographically and the behaviour change stages of the TTM. Further, the study attempted to analyse motivational preconditions for persistent drivers in isolation.

A multiple linear regression model was estimated to understand which variables correlate with the motivation to decrease private car use. Driving license, accessibility (to a car, public transport, and/or bicycle), the usual modal choice for commuting, and commuting time were used to predict motivation to decrease private car use together with attitudinal variables towards the climate, car use, cycling, and public transport. The model explained about half of the variance in motivation.

It was found that climate morality was the most critical factor associated with motivation to decrease private car use. Those strongly disagreeing with feeling a moral obligation to reduce one's carbon emissions were significantly less motivated to decrease their car use. On the contrary, agreeing with this statement was associated with higher motivation compared to being indifferent (neither/nor).

Other influential factors were the usual commute mode, where those usually travelling with public transport, walking, or cycling, were more motivated to decrease car use

than those commuting by car. For car advocacy, that is, the level of 'attachment' one feels towards the car, less attachment was associated with higher motivation. Health concern, that is, being less aware of the positive health gains associated with cycling, was correlated with a lower level of motivation. Having a positive attitude towards cycling increased motivation compared to those being indifferent to cycling. Further, having a weak car identity (disagreeing with identifying oneself as a car user) had a positive association with motivation. Travel time for commuting was not a significant factor on motivation to decrease car use until it reached long commuting times of more than 60 minutes, which significantly dampened the motivation compared to those with travel times of 10 minutes or less.

In the next analysis, the precondition index (constituting the significant predictors from the regression) was cross-tabulated with demographic variables to see how motivational preconditions differ between groups. Significant differences were found for gender, age, educational attainment, and residence, while relationship status and whether one has children living at home were non-significant. Males, the middle-aged, people with low educational attainment, and rural residents had the least favourable preconditions concerning motivation to reduce car use.

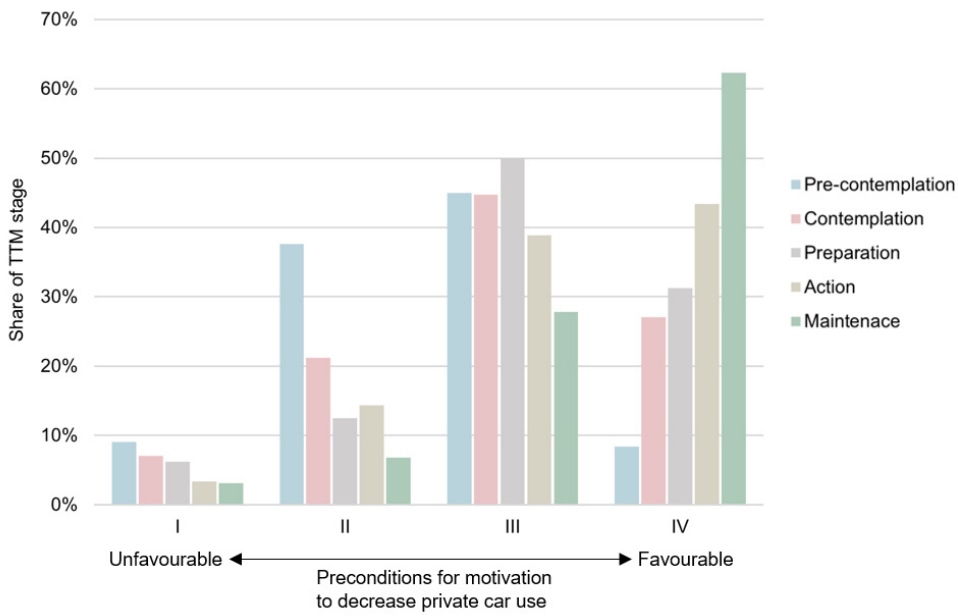

Figure 5. Cross-tabulation between the precondition index and the TTM stages. Source: Andersson (2020).

An additional cross-tabulation was made between the precondition index and the TTM stages (see Figure 5), which revealed that preconditions are increasingly more favourable

moving from pre-contemplation (the first step in the TTM) to maintenance (last step). A separate correlation analysis[5] (Pearson's *r*) revealed a moderate but significant correlation of 0.46 ($p < 0.01$). This means that behaviour change stages could be a useful tool for determining suitable segments to target within an intervention since preconditions for motivation do correlate with the TTM stages. Further, it was observed that the highest precondition threshold between stages was between pre-contemplation and contemplation, suggesting that the transition from pre-contemplation is the hardest step. The strategy of targeting the 'ambivalent' segments, for instance, the contemplation and preparation stages (Forward, 2014), could therefore be much more fruitful than trying to convince pre-contemplators to shift behaviour.

As can be seen in Figure 5, pre-contemplators had less favourable preconditions than the other segments (pre-contemplators differed significantly from all the other stages). A separate regression analysis was therefore conducted to see if the associations with motivation differed for this segment. The same variables were used as in the first model but this time only the pre-contemplation segment was included.

The results were similar to the first regression model, with a few exceptions. Climate morality was even more influential for pre-contemplators. Strongly disagreeing was associated with a near ten-fold lower motivation to decrease car use compared to neither/nor, while strongly agreeing increased motivation five-fold. Being a car advocate and neglecting the positive effects of cycling correlated with motivation negatively, while enjoying cycling and disagreeing to identify as a car user had a positive association. Unlike the first model, usual commute mode and travel time were not significant, which may be due to the overall higher commute by car habit in the pre-contemplation segment and the smaller sample size (n = 299).

Table 14
Summary of results from Paper IV.

Analysis	Tool	Key findings	Model summary
Motivational associations	Multiple regression. DV: motivation to reduce private car use	Usual commute mode (ref: car) (*B* 3.25, CI 1.81-4.68, $p < 0.001$) Travel time > 60 min (ref: 10 min) (*B* -3.31, CI -5.73--.89, $p < 0.01$) *Attitudes (ref: neither/nor)* Climate morality strongly (st.) disagree (*B* -7.21, CI -9.28--5.14, $p < 0.001$) Climate morality agree (*B* 2.18, CI 0.65-3.71, $p < 0.01$) Climate morality st. agree (*B* 4.69, CI 3.10-6.27, $p < 0.001$) Advocate private car use st. disagree (*B* 2.24, CI .42-4.06, $p < 0.05$) Advocate private car use disagree (*B* 2.41, CI .80-4.02, $p < 0.01$)	Adjusted R-square: 0.47

[5] Not part of Paper IV.

		Advocate private car use agree (*B* -2.81, CI -4.51--1.06, p < 0.01) Advocate private car use st. agree (*B* -3.89, CI -5.57--2.20, p < 0.001) Like cycling agree (*B* 3.37, CI 1.75-4.98, p < 0.001) Like cycling st. agree (*B* 3.69, CI 1.95-5.43, p < 0.001) Concerned about health st. disagree (*B* -2.23, CI -3.98--.47, p < 0.05) Perceive cycling as fast st. disagree (*B* -2.66, CI -4.49--.82, p < 0.01) Perceive cycling as fast disagree (*B* -1.97, CI -3.92--0.02, p < 0.05) Identify as a driver st. disagree (*B* 1.79, CI .07-3.50, p < 0.05)	
Pre-conditions for motivation in the sample	Analysis of frequencies	Four categories of pre-conditions ranging from unfavourable to favourable: 1st category (6%), 2nd category (22%), 3rd category (40%), 4th category (32%)	-
Pre-conditions within demo-graphic factors	Cross-tabulation analysis	Significant differences (more favourable): gender (women), age (younger cohorts), education (higher), occupation (students), residence (urban) No differences: relationship status, children living at home	-
Distribution of sample based on TTM-stages	Analysis of frequencies	Pre-contemplation (36%), contemplation (10%), preparation (4%), action (31%), maintenance (19%)	-
Pre-conditions within TTM-stages	Cross-tabulation analysis and one-way between-subjects ANOVA (post hoc test Tukey's HSD)	*Preconditions in category 1, 2, 3, and 4 for each TTM-stage. Items in superscript indicate significant differences* a. Pre-contemplation[b, c, d, f]: (9%, 37%, 45%, 8%) b. Contemplation[a, d, e]: (7%, 21%, 45%, 27%) c. Preparation[a, e]: (6%, 12%, 50%, 31%) d. Action[a, b, e]: (3%, 14%, 39%, 43%) e. Maintenance[a, b, c, d]: (2%, 7%, 28%, 62%)	*F*(4) = 53.211, p < 0.001
Motivational associations in the pre-contemplat-ion segment	Multiple linear regression	*Attitudes (ref: neither/nor)* Climate morality st. disagree (*B* -9.95, CI -13.57--6.32, p < 0.001) Climate morality st. agree (*B* 4.97, CI 1.77-8.17, p < 0.01) Advocate private car use agree (*B* -4.55, CI -7.37--1.73, p < 0.01) Advocate private car use st. agree (*B* -5.74, CI -8.51--2.97, p < 0.001) Like cycling agree (*B 4*.79, CI 1.95-7.64, p < 0.01) Like cycling st. agree (*B 4*.88, CI 1.68-8.08, p < 0.01) Concerned about health st. disagree (*B* -4.69, CI -8.21--1.16, p < 0.01) Perceive cycling as fast disagree (*B* -3.42, CI -6.55--.29, p < 0.05) Identify as a driver st. disagree (*B 3*.35, CI .53-6.17, p < 0.05)	Adjusted R-square: 0.51

5.5 Paper V

This paper aimed to assess the substitution effect of e-bikes in a randomised controlled e-bike trial and the influence of the trial on the participants' perceptions towards e-bike use.

Earlier research in this field has employed either a cross-sectional or quasi-experimental study design that suffers potential bias from confounding factors or a lack of internal validity. Further, most studies rely on self-reported survey answers which could result in over or underestimation of effects due to memory biases and social desirability bias. To the best of the knowledge of the author, this was the first study to assess the substitution effect of e-bikes using an RCT design with objective travel behaviour data from smartphones.

About 100 participants were targeted for the trial. Car use in the sample was extremely high; nearly all participants usually drove to work and around 70% had two or more cars within the household.

Three measurements were undertaken during spring 2020. Due to the COVID-19 outbreak, it was fortunate that we included a control group that could help isolate the effect of the trial, despite the circumstances.

The e-bike use increased by an average of one trip and 6.5 km per person per day, which led to a 25% increase in total cycling. The whole increase was at the expense of car use, which on average decreased by one trip and 14 km per person per day, a decrease in car mileage of 37%. The modal share of the car decreased by 21%, expressed both as the number of trips and distance. The effect size was medium for the decrease in car trips and distance (d = 0.4-0.6), and large for the increase in cycling (d = 0.88-6.31).

An unexpected effect was that the total distance travelled decreased by approximately 20% during the trial, which contributed to half the reduction in car mileage, with the increase in cycling accounting for the other half. The travel behaviours in the control group remained unchanged during the treatment group's trial period but the same pattern was observed when the control group had their trial period. This could be due to changes in travel patterns resulting from choosing more proximal destinations when having access to the e-bike. However, the cause remains to be further investigated.

Most participants considered work and other single purpose trips to be the errands best suited for e-cycling. E-cycling was perceived as less time-consuming and physically demanding compared to conventional cycling, and long distances were perceived to be 'shorter' due to the ease of use associated with e-cycling. On the other hand, lacking a secure parking spot was a significantly larger issue when using the e-bike, because of the increased risk of theft.

In the qualitative assessment of the e-bike, stated advantages outweighed stated disadvantages. Bad weather was the largest disadvantage of e-cycling according to the participants. The other disadvantages were practical issues like performing errands that included transporting goods or passengers, the heavy battery and the risk of theft. Some reported that it was time-consuming to e-cycle compared to driving, that it had technical weaknesses such as low speed and bad geometry, and that it was heavy and too expensive to purchase.

The most positive aspect of the e-bike according to participants was the ease and convenience of use. Some of the other benefits were related to altruistic and hedonic aspects; e-biking was considered good for the environment and positive in the sense that it made one more alert and provided more opportunities for exercise. The participants also appreciated getting fresh air during their morning commute, and some wrote that it was fun to use and contributed to increased wellbeing. About one in five participants stated that the benefits of the e-bike were also related to time savings, avoidance of congestion, not having to find a parking space, and cost savings.

Table 15
Summary of results from Paper V.

Analysis	Tool	Key findings	Model summary
Effect of the e-bike trial on the number of trips by mode of transport per person per day (modal share in paratheses)	Paired samples *t*-test with 2,000 bootstrap samples	*Test group* Car -1 (-21%) ($p < 0.05$), e-bike +0.6 (+17%) ($p < 0.01$), total bike +0.9 (+25%) ($p < 0.01$) *Control group* No differences *Control group with an e-bike* Car -1.1 (-31%) ($p < 0.05$), e-bike +1 (+19%) ($p < 0.05$), bike +0.5 (10%) ($p < 0.05$), total bike +1.5 (+29%) ($p < 0.01$)	Cohen's *d* Car 0.50-0.58 E-bike 5.25 Bike 1.96 Total bike 1.92-5.52
Effect of the e-bike trial on distance travelled by mode of transport per person per day (modal share in paratheses)	Paired samples *t*-test with 2,000 bootstrap samples	*Test group* Car -13.7 km (-21%) ($p < 0.05$), e-bike +5.1 km (+16%) ($p < 0.05$), total bike +6.5 km (+21%) ($p < 0.01$) *Control group* No differences *Control group with an e-bike* Car -12.5 km (26%) (n.s.), e-bike +7.1 (+22%) ($p < 0.01$), total bike +8.2 (+23%) ($p < 0.01$)	Cohen's *d* Car 0.60 E-bike 1.96 Total bike 1.96-6.31
Comparing obstacles for cycling with bicycle and e-bike	Paired samples *t*-test	Less time-consuming and physically demanding to e-cycle and long distances are a smaller issue ($p < 0.001$). Lack of secure parking a larger issue for e-bikes ($p < 0.01$)	-
Advantages and disadvantages of the e-bike (% of respondents mentioning the issue in question)	Qualitative content analysis, inductive category development, and analysis of frequencies	*Positive* Easy, convenient (41-60%), exercise/health, environmentally friendly, fresh air, pleasant/fun, fast/save time (21-40%) no congestion, increased wellbeing, save money (1-20%) *Negative* Bad weather, errands with goods, heavy battery (21-40%), risk of theft, time-	-

	consuming comp. to a car, technical issues with e-bike, heavy bike, expensive to buy (1-20%)

6 Discussion

As laid out in the introduction of this thesis, the purpose of this research is to contribute with knowledge on how to reduce the demand for car use by encouraging a modal shift towards walking, cycling, and public transport. Soft measures have been in focus to achieve this. It is now time to put the results from this work into context and discuss them in relation to the research aims.

6.1 Recapitulation of aims

The first aim was to explore two transport innovations, smartphone applications and e-bikes, in terms of their potential to improve evaluations of soft transport measures and influence travel behaviour.

The second aim was to investigate what influences motivation to decrease private car use for different segments and how this can be used to improve soft transport measures.

6.2 First aim: Potential of innovations for soft transport measures

Soft transport policy is perhaps not the field most commonly related to 'innovation' in the sense that new technological solutions appear that significantly change the preconditions for what can be achieved. However, one could argue that the emergence of (at least) two innovations within the last decade have done precisely that and could potentially contribute to enhance the conduct of soft measures in two important ways. Firstly, through the e-bike as a new competitive alternative to the car. Secondly, by the utilisation of the GPS-tracker smartphone application as a data collection tool for evaluating soft measures.

A new star in the soft measure's toolbox?

As found in Paper V, a large substitution effect was realised from car to e-bike in the e-bike trial. Cycling increased and car use decreased significantly (both in terms of the number of trips and distance travelled). The effect sizes for the decrease in car use were medium at Cohen's *d* 0.44-0.60, which is substantially more than the average range of soft measures (0.11-0.17) as reported by previous meta-analyses (Bamberg and Rees, 2017; Fujii et al., 2009; Semenescu et al., 2020). Indeed, the decrease was so large that the participants' average car use at the end of the trial, expressed as daily kilometres driven, was in the range of what has been estimated to be at the sustainable level per capita (21.8 km) for reaching the climate goals for the Swedish transport sector (Winslott Hiselius and Smidfelt Rosqvist, 2018). Thus, the potential for e-bikes to contribute to a more sustainable transport system is large.

However, only about half the decrease in car kilometres could be explained by the e-bike substitution, raising the question of what could be causing the rest of the decrease? Moreover, would the effect hold over time, say a year after the intervention? Although a follow-up survey was conducted four to five months after the intervention by the partner organisation VGR (Västra Götalandsregionen), in which 44% of participants stated that they cycled more to everyday activities than before the e-bike trial and 16-26% that they bought an e-bike, more robust and longitudinal evaluations are needed. Results from earlier research are promising; participants have been found to have weaker car habits a year after trialling an e-bike (Moser et al., 2018) and the substitution effect for consumers of e-bikes are similar to the effects found in trial settings (Fyhri and Sundfør, 2020). From the perspective of implementing soft measures, e-bike trials seem promising as well. Since we carried out the campaign in Skövde, the same arrangement has been implemented in another six municipalities with a total of over 200 participants. It is now a continuous measure used by the mobility management team in VGR to encourage more sustainable travel behaviours (Ryberg, 2021).

The potential with e-bikes has been recognised in the UK as well. Philips et al. (2020) found that e-bikes, if used to replace car travel, can cut car carbon dioxide emissions in England by up to 50%. The authors emphasise that the greatest potential lies in the rural and sub-urban settings and advocate the implementation of a strategic national cycle network linking villages to towns and towns to cities.

Perhaps one of the most intriguing aspects of the e-bike is that it appeals to a wider array of segments than conventional bicycles and public transport do. E-bikes provide people who would otherwise not be able to bike, due to old age, physical limitations, or proximity to locations, the ability to overcome these challenges (MacArthur et al., 2014). Further, studies from Western countries have found that more men than women use e-bikes (Haustein and Møller, 2016), which is positive from the point of view that men, generally, use cars more compared to women while also being less motivated to reduce that use (Polk, 2004, 2003; Waygood and Avineri, 2016). Indeed, 80% of the

participants in the e-bike sample were men and, judging by the qualitative survey answers, they seemed to appreciate using the e-bike primarily for its convenience, for giving health benefits and increased wellbeing, and for being an environmentally good option.

Unclear to what extent smartphones can 'nudge' travel behaviour

From the perspective of influencing modal choice, a smartphone innovation was evaluated in Paper II in the form of a mobility service application (MSA). Unfortunately, the data material was insufficient for an effect-evaluation to be carried out and as a result, the potential for smartphones to influence travel behaviours could not be assessed, although there was an indication that the MSA had made it easier to travel by public transport.

The qualitative process evaluation revealed that several weaknesses with the MSA, as well as organisational barriers, discouraged participants from using the MSA to a large extent. The weaknesses of the MSA can be interpreted in light of the conceptual model developed in Paper I. It was stated that the MSA failed to align with the current, and often procured, business travel agency, which made it difficult for some participants to use the MSA even if they wanted to. Some stated that the app had too few ticket options and was lacking the personalised service that users were accustomed to from their travel agency. According to the model, this level of customisation to the user would be insufficient. Further, there were no real incentives to use the MSA, and the users received no feedback regarding their behaviour or use of the app. In some organisations, the MSA was hardly advertised at all. It thus seems that the importance of personalised information and feedback, as well as commitment towards using the app as stated in the model, were neglected in the design of the MSA. A particular limitation of the MSA related to technical weaknesses such as a slow login procedure and non-user-friendly interface, which made many of the participants think that the app was not fully developed. Clearly, the MSA lacked an appealing and user-friendly design which is an essential part of the model. Hence, when contrasting the MSA against the conceptual model it is unsurprising that the MSA was not more successful.

Despite these issues, many participants thought that the MSA had the potential to improve how sustainable business trips can be handled (an example was the automatic handling of travel expenses). However, the diversity of apps and their increased technical development means that conclusions about smartphone applications' general ability to influence travel behaviour can hardly be drawn from this particular case. Many factors determine the effectiveness of an intervention, not just the design of the app but also the design of the study. Lately, several research studies have demonstrated a significant behavioural effect by utilising some of the features stated in the conceptual model within smartphone apps to encourage cycling (Weber et al., 2018), walking (Nakashima et al., 2017), and more sustainable and healthy modes of transport in general (Cellina et al., 2019; Ek et al., 2020). Thus, there seems to be some potential

in these apps that could benefit soft measures, although more research is needed in this emerging field before any conclusions can be drawn about their general effectiveness.

A game-changer for evaluation practice

'Are we there yet?' This question is posed by Harding and colleagues (2020, p. 1) upon assessing a range of smartphone applications as tools for collecting travel-data. After assessing 17 different travel apps in 2016, they conclude that while accuracy in terms of trip detection is high in most cases, performances are more varied for mode inference.

The pursuit for more sophisticated GPS-based solutions for measuring the effect of soft transport measures has been around for some time now. The conventional method of using travel diaries is not as reliable as we would like (Bonsall, 2009; Rosenfield et al., 2020). Already within the TravelSmart program in Australia, GPS measurements were piloted as an alternative to travel diaries (Stopher et al., 2006). Before the prevalence of smartphones, GPS devices were used to measure time and distance travelled, and the data was then coupled with the road network, public transport routes, and survey answers from the participants to establish mode choices (Stopher et al., 2009). With smartphones, high-quality data can be collected from individuals over several days while minimising the burden on the owner. Individuals do not need to remember and manually report details about their trips. Instead, the app can log travel activities in the background and provide a user interface so that the respondents can validate the information at the end of the day. Even now though, this technology is as of yet untapped in evaluating soft measures, something that is highlighted in the latest meta-analysis by Semenescu et al. (2020, p. 14):

> A significant limitation to current data collection practices based primarily on self-reported information is the possibility of bias, both from the intervention evaluator as well as from the intervention recipient. These biases could be eliminated by the process of collecting data with the use of smartphones or GPS devices. Such changes should be adopted not only by progressive researchers but should become standard practice for intervention providers, especially if financing organisations demand higher quality evaluations as an important part of the intervention program.

The e-bike intervention carried out within this thesis came with the opportunity to collect data with the TravelVu smartphone application. Three measurement periods of one week each were undertaken that resulted in a detailed dataset in which it was also possible to detect smaller changes in travel behaviour as a result of the intervention. Moreover, the survey responses were collected from the app as well, making it easier for the respondents since they did all the reporting in the same tool. Some participants had problems with the app, although these were few and could most often be alleviated with support from the project team.

Compared to the data collection procedure in Paper II, which was conducted with a web survey, the dropout rate was much lower in the e-bike sample (34% drop-out in the e-bike sample and 60% dropout in the business travel sample). Further, the data collected from smartphones provided considerably more details about the travel behaviours of the participants.

So, are we there yet? Perhaps it is too early to say that smartphone applications are ready to replace conventional methods used in large-scale national travel surveys, one reason being that the response rate could be lower and more skewed, thus increasing the risk of attaining a biased sample. However, as a tool used for assessing behavioural interventions such as soft transport measures, it seems to be increasingly indispensable, and my own view is that it should be preferred whenever possible, as long as an in-depth examination is warranted for the study in question.

To control, or not control, that is not a question

The problem of weak study designs in evaluations of soft measures often has to do with the absence of a control group. This is a significant issue because it prevents the production of reliable and politically useful evaluation results (Arnott et al., 2014). On the other hand, including controls in real interventions could be met with reluctance from practitioners who do not want to 'waste' participants who would otherwise have gone into the treatment group (Lieberoth et al., 2018). The usual goal of the actor that fund soft measures is to engage as many of the population of an area as possible in the campaign (Stopher et al., 2009). Moreover, if a control group is incorporated it might result in larger dropouts since the control group is usually less incentivised to participate in the study than the individuals assigned to the treatment group.

In a systematic review in the field of medicine on exercise oncology trials, Bisschop et al. (2015) found that control groups receiving an intervention have lower contamination and dropout rates compared to control groups receiving no intervention. To the best of my knowledge, similar studies have not been conducted in the transport field, despite the obvious advantages of minimising attrition in transportation intervention studies. From experiencing high dropout rates in Paper II, preventing this from happening again in the e-bike trial became a priority. The attempt with an additional trial phase was therefore made in which the control group received the e-bike treatment as well. This had likely a positive effect on participation since the trial lasted for a relatively long period (two months excluding the last trial phase). Moreover, the participants volunteered to take part in the study with hopes of trialling an e-bike. Without treatment, those randomly assigned to the control group could have been disappointed and dropped out of the study, especially since they would have had to record their travel behaviour and answer questionnaires without getting anything in return.

Apart from mitigating attrition, offering the intervention to the control group after the test group deals with the concern of 'wasting participants', since all participants get treatment. An additional bonus is more trial data that can be used to validate the effect of the original test group. This approach will help to satisfy both the practitioner aiming to maximise the reach of the intervention and the researcher whose main priority is scientific rigour. Hence, in cases where an effect evaluation is warranted, the reasons for not including a control group seem increasingly invalid. In fact, disseminating this method could lead to increased use of control groups in practice, thus realising better evaluations which, in turn, would facilitate a cumulative understanding of the effects of soft measures.

6.3 Second aim: Motivation to decrease car use and the use of segmentation for improving soft measures

Climate morality can only get us so far

One of the key questions that confront research and practice regarding soft transport measures is what motivates pro-environmental travel behaviour. In this thesis, climate morality was particularly important for the motivation to reduce car use and for travelling with more sustainable means of transport. Attitudes towards cycling and car use, past behaviour, and travel time were also significant predictors. This is in line with previous research that has found people to be more likely to reduce car use if they like cycling and have experience of it (Fernández-Heredia et al., 2014; Gatersleben and Uzzell, 2007; Handy and Xing, 2011; Rondinella et al., 2012). People with higher affection for cars are less likely to reduce their use of them (Steg, 2005; Steg et al., 2001b), and long distances tend to discourage commuters from using sustainable transportation (Heinen et al., 2013).

Climate morality was the most influential factor. This picture was reinforced by the fact that marketing messages for sustainable travel did induce more motivation to reduce private car use if the messages were more altruistic, that is, emphasised the need to care for the environment, personal and societal health benefits of more sustainable travel behaviour, collective responsibility and morality. This is in line with Franssens et al. (2021), who found that public transport operators can increase public transport use by incorporating messages that positively label passengers as sustainable travellers in their communication strategies.

Together, these findings indicate that motivation to engage in pro-environmental travel behaviours is influenced by moral constructs. Indeed, some argue that environmental concern and behaviours are most strongly linked to values (Schwartz, 1977), particularly altruistic and biospheric orientations (de Groot and Steg, 2008), and the

activation of pro-environmental personal norms (Stern, 2000). A personal norm is activated when individuals realise the consequences of their behaviour (for instance, towards the environment) and when they feel personally responsible for the behavioural consequences. This increases the likelihood of engaging in altruistic behaviour, such as reducing car use in favour of more sustainable, but less convenient and comfortable, modes of transport. However, personal norms are only translated into altruistic behaviours when a person feels able to execute them and when there are no perceived barriers or high costs involved (Schwartz, 1977).

Previous research supports this stance and suggests that environmental personal norms play a marginal role in predicting actual travel mode choice while emerging as a significant predictor of intention, or motivation, to choose green modes of transport (see Klöckner, 2013 and Lanzini and Khan, 2017, for meta-analyses). Pro-environmental personal norms were, for instance, found to only have an indirect effect on e-bike use in a recent Norwegian study (Simsekoglu and Klöckner, 2018). This indirect-only relationship between environmental personal norms and behaviour is not necessarily bad news, as it still offers a potential benefit, as expressed by Klöckner (2013, p. 1036):

> […] personal norms are relatively stable compared to attitudes and intentions. If a personal norm is created, the effect of that norm can last for a long time.

When there is an inconsistency between personal norms and behaviour it could be due to a lack of perceived behavioural control to perform the behaviour, which is a strong determinant of travel behaviour (Javaid et al., 2020). This is often the reason for the attitude-behaviour gap, which refers to the difference between what our attitude to something is, versus our behaviour in relation to it (Milfont and Duckitt, 2010). A similar gap in decision-making theory, conceptualised as bounded rationality (Simon, 1955), refers to the restraints, such as time and cognitive skills, that prevent people from making perfectly rational decisions. One can argue that the general desire to act in accordance with one's moral values is also limited, or bounded, by rationality. To facilitate sustainable travel behaviours, it is therefore important to minimise the discrepancy between pro-environmental, and rational, modal choices. For instance, the convenience of the e-bike may increase the perceived behavioural control to reduce car use for some people. But it is also important to emphasise the need for hard, structural conditions that facilitate sustainable means of transport, for instance by pricing and taxation, physical measures that re-distribute road space and priority, measures that restrict access and parking for cars, sustainable and integrated transport- and land-use planning, and so on (Buehler and Pucher, 2011; Marshall and Banister, 2000; Pucher and Buehler, 2017; Santos et al., 2010). The significant effect of climate morality on motivation to decrease private car use, as found in this thesis, could be a factor that increases the acceptance for such hard, structural measures that facilitates sustainable travel behaviours.

Attitude-based segmentation needs to be assessed in practice

In Paper III, the use of the SEGMENT model showed that car users with similar demographic characteristics differ profoundly in their modal split, and that this difference was better described by attitudes compared to demographics. Thus, in line with previous research, segmentation based on demographics appears to be insufficient in predicting travel behaviour and motivation to change behaviour (Anable, 2005, 2002). One exception is that between car users and non-car users, where demographics do matter; non-car users are younger, have fewer children, and are more often students.

How can attitude-based segmentation be used, then, in practice to find appropriate segments to target? Several segmentation procedures including attitudinal survey items have been introduced by researchers (Anable, 2005; Damant-Sirois et al., 2014; Diana and Pronello, 2010; Haustein and Hunecke, 2013; Haustein and Møller, 2016; Li et al., 2013; Poortinga and Darnton, 2016; Thøgersen, 2018; Wolf and Schröder, 2019). However, the extent to which these are feasible in practice, both in terms of influencing the effectiveness of soft measures and in terms of being reproducible simply and practically, is unclear. The SEGMENT model proposed by Anable and Wright (2013) is an exception as this has some empirical support and provides an online instrument for the segmentation procedure (Ladbury, 2013). However, the results from Paper III did not support the notion that the segments were motivated by different kinds of messages. A similar conclusion was made recently in a study that assessed the effectiveness of different messages on segments retrieved from the SEGMENT model (Pangbourne et al., 2020). The authors suggest that segmentation by travel attitude may not be an effective way to target behaviour change messaging, although it may be a useful tool in designing other elements of behaviour change interventions (Pangbourne et al., 2020). In Paper III, the indication of assimilation bias suggest that messages need to be aligned with the current beliefs and behaviours of the target audience. The best way to do that remains to be investigated.

Target the low-hanging fruit

Paper IV demonstrated that preconditions for motivation to change behaviour (based on attitudes, travel time, and past behaviour) were significantly correlated with the TTM-stages. This is useful knowledge because segmentation based on the TTM is easy to execute, while it still provides valuable information about the stage groups' attitudes towards decreasing car use (Bamberg, 2007; Biehl et al., 2019; Mundorf et al., 2018).

Which segments should, then, be targeted? This question depends primarily on the purpose of the intervention. If measures need to be implemented in a specific context, for instance, to relieve congestion at a school or workplace, the target is already defined to some extent.

However, the purpose of soft measures is often less constrained with the aim to reduce car use as much as possible. Although it is tempting to implement soft measures where

car use is high, caution needs to be taken regarding potential boomerang effects. This could happen when the message of a campaign is misaligned with the attitudes and behaviours of the target group (Beale and Bonsall, 2007; Petty and Cacioppo, 1986). Individuals may dislike being told what to do and may be sceptical towards campaigns in general, which could lead them to engage in the opposite behaviour, or simply disregard the information (Kavvouris et al., 2019), also known as psychological reactance (Brehm, 1966). Indeed, the results from Paper III indicated that marketing messages promoting sustainable transportation were judged in line with assimilation bias, meaning that people interpret information in such a way as to be assimilated into pre-existing beliefs. The segment with the highest level of car use (the Devoted Drivers) was also the one that reported the lowest motivation to change behaviour.[6] This means that it is considerably more difficult to approach a segment that has shown no interest in changing behaviour in comparison to car users with an open mind to change. As demonstrated in Paper IV, the highest threshold in preconditions for motivation to change travel behaviour was between the first and the second stage in the TTM (pre-contemplation and contemplation), which reinforces this notion.

Intervention studies that still have attempted to target pre-contemplation segments such as Devoted Drivers, report low or absent compliance levels (Innocenti et al., 2013; Lattarulo et al., 2018; Tertoolen et al., 1998). Thus, soft measures targeting car users with no intention to change bear the risk of boomerang effects and are unlikely to induce behaviour change. If such segments are to be targeted, it would likely require a combination of hard and soft travel demand measures (Steg, 2007; Stradling et al., 2000). However, failing to induce a behaviour change might not be a complete failure if the participants have progressed in their behaviour change ladder (Forward, 2019). This could, for instance, mean that pre-contemplators proceed to contemplation after an intervention (such as an information or marketing campaign), which can be assessed by measuring stage allocation before and after the intervention (Bamberg, 2013). However, this line of reasoning assumes that people's stated stage allocation post-intervention remains relatively stable, which is not always the case (De Nooijer et al., 2005).

From a practitioner's perspective, perhaps segmentation need not be more complicated than simply asking people whether they are willing to decrease their car use or not. This approach has been used in practice for many years, including the behaviour change technique known as IndiMark, which segments the population into three main groups: regular users of sustainable travel modes; non-regular users who are interested in receiving information on alternatives to the car; and those who are not interested in

[6] When analysing the free-text responses in the national survey data, it became clear that a reactance effect led many respondents to express their strong dissatisfaction with the fact that their car use was implicitly questioned. Some even went so far as to (incorrectly) accuse the study of being financed by the Swedish Green Party.

taking part (Brög et al., 2009). This would mean identifying car users who are willing to try an alternative to the car. In the language of the TTM, targeting the contemplation and preparation stages would be a sound strategy since these have 'ambivalent' attitudes towards car use (Forward, 2014) and may therefore be open to change.

In Paper V, such a targeting strategy was applied in the recruitment of individuals who would get the offer to participate in the e-bike trial. These were frequent drivers with an equally high frequency of car use as the Devoted Drivers (80% car trips), but with a different attitude towards driving. A large substitution effect from car to e-bike was demonstrated in this sample. Targeting such segments offers the largest potential to reduce car use, which is often the objective for the actors that finance and implement soft measures (Stopher et al., 2009). Moreover, individuals who are positive towards taking part in an intervention are more likely to realise a change (Strömberg et al., 2016), which could lead to substantial spillover effects through social interactions (Hsieh, 2020), resulting in positive effects beyond what is measured directly. However, researchers might look further into the obstacles preventing pre-contemplators from shifting mode of travel. After all, this is the segment with the highest car use and there might be possible car use reductions that are within these individual's complete volitional control. Naturally, these narrower measures that target specific car user segments can be combined with measures aimed at the community in a wider sense, with the purpose to influence social norms more generally (Winslott Hiselius and Smidfelt Rosqvist, 2015).

6.4 Concluding remarks

This thesis has shown that innovations can advance the implementation of soft measures, both as a means for promoting more sustainable travel choices, but also as a means for enhancing evaluations. It has also identified limitations with innovations and pitfalls in the application of these in practice. Further, the thesis contributes knowledge about how pro-environmental travel modes can be marketed, what factors influence motivation to reduce private car use, as well as different perspectives on segmentation and which target groups soft measures could be aimed at.

Based on previous research, it is not possible to conclude whether smartphone applications are effective in changing travel behaviours, which is also the conclusion from Paper II. However, there seems to be some potential in using apps for driving behaviour change, although their success could depend on several design features as found in Paper I. Regarding their effectiveness, results from previous research are mixed, and more studies are needed in this emerging field before any conclusions can be drawn about their general effectiveness and contribution to soft measures.

However, smartphone applications can contribute significantly to facilitate more rigorous evaluations of soft measures. This development is long-awaited and much needed in a field where evaluations are notoriously criticised for low methodological quality, which ultimately challenges the use of soft measures in practice. Collecting data from users' smartphones deals with many issues related to self-reports in travel behaviour research. It also provides more fine grained data which makes it possible to detect smaller effects. This could, to some extent, compensate for having small sample sizes, like the sample used in Paper II.

Another methodological improvement for soft measures is to offer interventions to control groups as well, which may lead to fewer dropouts from field experiments and, in the end, a higher acceptance for using control groups in practice.

The use of e-bikes is growing at a rapid pace around the world. While there are many potential benefits of this mode of transport, several of these depend on a substitution effect that has not been properly assessed in previous research. This thesis demonstrated in a randomised controlled trial that e-bikes have a considerable car-substitution potential. The average increase in the modal share of cycling was 21%, with an equal reduction in the share of car use, as expressed in distance travelled. This extent of substitution shows that the e-bike can seriously compete with the car, although mainly for commuting and other single-purpose trips. An interesting research strand ahead is evaluating how other types of electric vehicles influence mode choice, for instance, electric cargo bikes (see for instance the study by Bjørnarå et al. (2019)). Due to the higher speed of the e-bike and the potential for regional cycling, investments in regional cycle highway networks seems promising for extending its benefits outside of urban areas (Götschi et al., 2017; Grigoropoulos et al., 2021; van Lierop et al., 2020).

Regarding the marketing of pro-environmental travel behaviours, the results show that messages should promote altruistic feelings connected to health, the environment, collective responsibility, and morality. Hence, organisations that, for instance, promote public transport through messages such as 'together for a sustainable future', seems to have chosen an effective communication strategy. In contrast to expectations, attitude-based segments did not report different preferences with regards to the type of marketing messages, but rather, assimilated the information according to prevailing beliefs.

In line with previous research, motivation to reduce car use is heavily influenced by a moral obligation to reduce one's carbon emissions, although attitudes towards cycling and car use, past behaviour, and travel time are influential as well. An index of these determinants correlated with the TTM stages which indicate that the stage model is suitable for identifying segments to target in interventions. The results consistently show that the most car-oriented segments are significantly less motivated to change behaviour. At the same time, the thesis demonstrates by example that soft measures aimed at car users with an open mind to try a new means of transport have the potential

for considerable behaviour change. From the perspective of maximising the shift from cars to alternative means of transport, soft measures should target such segments. However, there might be other purposes that require measures to be aimed at other segments and this decision lies ultimately with the organisation that executes the measure. Due to the influence of assimilation bias, it is important to design measures in a way that limits potential reactance from the target group, while encouraging sustainable travel behaviours.

6.4.1 Limitations

The content analysis in Paper I was conducted independently by the author of this thesis and is, therefore, more sensitive to researchers bias than if the analysis had been conducted by a group of researchers. Another limitation is that the conceptual model developed in Paper I could not be assessed empirically. Since the data collection for Paper II was conducted in parallel with the production of Paper I, there was no possibility to examine the development and implementation process of the MSA in light of the model by adapting the survey questions accordingly. Instead, a brief comparison was made within the thesis (see section 6.2 on page 73).

One limitation of Paper III is that the effect of the marketing messages on actual travel behaviour was not investigated. Therefore, the analysis is restricted to *motivation* to decrease private car use. In relation to this and Paper IV, one could question whether the stated motivation to decrease private car use from being exposed to the marketing messages reflects the 'true' motivation. Indeed, one limitation is the use of such a proxy for motivation. However, based on the principle of assimilation it seems reasonable that these would correlate well enough for conducting the analyses and make the subsequent inferences, which were made in Paper IV.

A few issues made it difficult to examine the process underlying behaviour change with quantitative methods. First, the data material in Paper II did not allow for an analysis of the extent to which the UTAUT determinants influenced travel behaviour. Second, in Paper V, the time interval was too short to include an analysis of which determinants influenced the travel behaviour change resulting from the e-bike trial. As such, the psychological survey items included in the study were not utilised in this thesis. Nor were the results from a replication study carried out during autumn 2020 in a similar municipality not possible to include here. This would have added to the aim of evaluating the process of change, as well as validating the results from Paper V.[7]

Another limitation with Paper V is that the long-term effects of the intervention were not studied, which was due to time constraints. However, a follow-up survey was

[7] However, this work is ongoing.

conducted four to five months after the e-bike intervention by the partner organisation VGR. Although this is good, longitudinal studies must not be only performed by the actor who carries out the intervention in order to minimise the risk of bias.

6.4.2 Further research

The soft transport policy field is constantly developing which requires a parallel companion in research that critically assess soft measures and identifies ways of improvement. Here are some suggestions for further research connected to segmentation, motivation, and evaluation of soft measures.

Regarding segmentation, research can continue in the attempt to identify suitable target segments and most critically, assess the feasibility of using segmentation and provide practical insights into how it can be applied.

Further research can evaluate the effectiveness of attitude-based segmentation in practice and continue to explore motivational determinants for mode shifting in different groups. Advanced methods for collecting psychometric data from online communication platforms and the identification of segments through machine learning techniques offer a potential avenue for travel behaviour change. However, this raises serious privacy and ethical concerns (Wolf and Schröder, 2019).

Several challenges remain in evaluating soft measures, one of the more pressing being the difficulty in conducting longitudinal field experiments. Researchers would make a significant contribution by evaluating the long-term effects of soft measures. Further, more rigorous studies need to replicate field experiments to test the external validity of individual evaluation studies. Following this, meta-analyses can provide more robust estimations of the effectiveness of various soft measures. Another intriguing aspect of evaluation is the potential spillover effects from soft measures. A recent study shows that such spillover effects can be equal in size to the effects realised for the intervention group (Hsieh, 2020).

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Alfred Söderberg

15 April 2021

Appendix A: Questionnaire items

Paper III

Table 16
The survey questions used in Paper III for segmentation according to the SEGMENT model.

Question	Scale
Q1: Have you driven a car or van in the past 12 months?	yes; no
If Q1 = yes	
Q2: For most journeys, I would rather use the car than any other form of transport	strongly disagree; disagree; neither/nor; agree; strongly agree
Q3: I like to drive just for the fun of it	
Q4: I am not interested in reducing my car use	
Q5: Driving gives me a way to express myself	
If Q1 = no	
Q6: How likely are you to drive in the next 12 months?	very unlikely; quite unlikely; neither/nor; fairly likely; very likely
All	
Q7: I am not the kind of person who rides a bicycle	strongly disagree; disagree; neither/nor; agree; strongly agree
Q8: I feel I should cycle more to keep fit	
Q9: I find cycling stressful	
Q10: Cycling can be the quickest way to travel around	
Q11: I like travelling by bicycle	
Q12: I am not the kind of person that likes to walk a lot	
Q13: I feel I should walk more to keep fit	
Q14: I like travelling by walking	
Q15: I am not the kind of person to use the bus	
Q16: In general, I would rather cycle than use the bus	
Q17: I feel a moral obligation to reduce my emissions of greenhouse gases	
Q18: People should be allowed to use their cars as much as they like	

Note: The survey also included the marketing messages statements, TTM statements, and demographic questions concerning age, gender, education, occupation, residential location, relationship status and children living at home.

Table 17
The items used in Paper IV for the regression modelling and the TTM statements used for behaviour change stage allocation.

Question/statement	Variable name	Scale
Do you have a driving license?	Driving license	yes; no
Do you have access to at least one bicycle or e-bike?	Access to a bicycle	yes; no
Do you live within 500 m of a public transport station?	Live within 500 m of PT-station	yes; no
Do you own or have access to a car for commuting?	Access to a car	yes; no
What mode of transport do you usually use to go to school/work?	Usual commute mode	car; public transport; bicycle, walk, other
How long is your travel time from home to school/work?	Travel time	less than 10 min; 10-20 min; 21-30 min; 31-45 min; 46-60 min; more than 60 min
What statement best describes how you travel in everyday life?	TTM	'I use the car for the most part and do not intend to change the mode of transport within the next six months'. 'I am using the car for the most part, but I am considering replacing some car journeys with other modes within the next six months'. 'I am using the car for the most part but have begun trying other modes instead over the last six months'. 'For the past six months, I have only used the car as a complement to other means of transport'. 'For the past six months, I have only used modes other than cars'.
I am the kind of person who rides a bicycle	Identify as cyclist	strongly disagree; disagree; neither/nor; agree; strongly agree
I feel I should cycle more to stay fit	Concerned about health	
Cycling can be the quickest way to get around	Perceive cycling as fast	
I like riding a bicycle	Like cycling	
Driving a car is part of my identity	Identify as a driver	
I am the kind of person who uses public transport	Identify with a PT	
I feel a moral obligation to reduce my greenhouse gas emissions	Climate morality	
People should be allowed to use their cars as much as they like	Advocate private car use	

Appendix B: Papers

Paper I

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Promoting sustainable travel behaviour through the use of smartphone applications: A review and development of a conceptual model

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ABSTRACT

The negative effects of transport in terms of pollution, congestion and climate change has urged the need for higher shares of cleaner and more efficient modes of transport, especially in urban settings. While new technology can solve some of these issues, behaviour changes has also been identified as an important factor to achieve a modal shift from cars to walking, cycling or public transport. This study investigates how ICT has been used to influence behaviour change and synthesizes key aspects into a conceptual model for creating a behaviour change support system (BCSS) for smartphone applications. A literature review concerning behaviour change and ICT in the fields of transport, health, energy and climate was conducted to gather empirical evidence which forms the foundation of the conceptual model. The empirical findings were tested and verified against a theoretical framework consisted of The Transtheoretical Model, Theory of Planned Behaviour, Diffusion of Innovations and the concept of Gamification. The results suggest that customization to the user, relevant and contextualised information and feedback, commitment, and appealing design are important aspects when influencing users to behaviour change through smartphone applications. The conceptual model provides further knowledge of key aspects to consider when developing persuasive tools that aims to encourage more sustainable modes of transport.

1. Introduction

The global transport sector accounts for 23 percent of CO_2 emissions from fossil fuels, and is the sector that contributes most to global warming after electricity and heat production (IEA, 2016). While measures such as energy efficiency, higher incorporation of renewables in the fuel mix and increased production of renewable energy have led to a slower rate of growth of electricity and heat generation emissions, measures to reduce CO_2 emissions from the transport sector have not been as effective. Since 1990, global emissions from transport have increased by 71 percent (IEA, 2016).

For Sweden, conversion to a low-carbon energy system has accelerated faster in relation to the rest of the world, thanks to good resources in water and nuclear power, as well as the introduction of district heating instead of oil-based heating to housing. The industry mainly uses biofuels and electricity, however, energy use in transport is still dominated by petroleum and aviation fuel products (Sweden Energy Agency, 2015). Of Sweden's total emissions, transport constitutes one third, of which road traffic accounts for 93 per cent (Sweden Energy Agency, 2015; Environmental Protection Agency, 2016).

At the beginning of 2017, the government presented a proposal for a new climate law, aiming to reduce emissions by 85 percent by 2045 in Sweden, compared with 1990 levels. They also proposed to set a target that emissions from domestic traffic should have decreased by 70 percent by 2030, compared to 2010 levels (Government Offices of Sweden, 2017).

Research has shown that technology, innovation and economic factors alone will not suffice to achieve the climate and environmental objectives set for the transport sector (Nilsson et al., 2013). Sustainable development also requires changes in our behaviour and a development in which car travel decreases (Hiselius and Rosqvist, 2016). According to Anable et al. (2006) there is often a gap between individuals' concerns of climate change and the actual travel behaviour that is performed. It does not, therefore, need to be inadequate knowledge of climate change which is the main problem, but rather how it is translated into practice when choosing modes of transport.

To deal with the inefficient use of transport capacity, Transport Demand Management (TDM) emerged as a concept for restricting access for car traffic and reallocating space in favour for walking, cycling and public transport (Banister, 2011). From this, a similar approach

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referred to as Mobility Management (MM) has become an increasingly common tool, especially in Europe, in the past 20 years to achieve different transport goals (Litman, 2010). It is a concept for encouraging sustainable transport and managing the demand for car journeys by changing travellers' attitudes and behaviours (Van Acker, Van Cauwenberge and Witlox, 2013). Mobility Management is often referred to as soft actions as the concept rarely includes, however complements, infrastructure solutions and thus focusing on information campaigns, price mechanisms and policies (Litman, 2010).

As digitization begins to influence more community functions, new opportunities emerges for what information and communication technology (ICT), can be used for. A relatively new area is the use of smartphones as a platform for performing Mobility Management actions and influence travel behaviours (Semanjski et al., 2016). A number of studies have investigated ICT and collection of travel data (Wells et al., 2014; Gerike et al., 2016; Semanjski and Gautama, 2016) and some have also evaluated its potential for behaviour change and a tool for promoting sustainable modes of transport (Parvaneh et al., 2014; Poslad et al., 2015; Castellanos, 2016).

Earlier research on Mobility Management often includes behavioural and attitudinal theories (see for example Anable et al., 2006) to answer questions related to the attitude-behaviour gap, where consumers express concerns about environmental issues but fail to translate this into sustainable actions (Anable et al., 2006). A range of different techniques to induce voluntary travel behaviour change has also been developed over the years, such as personalized travel plans (PTP), individualized marketing schemes and organisational travel plans, to mention a few (see Cairns et al., (2008) for an ample review). While the intentions for this study is similar to those investigating how to optimize Mobility Management campaigns, it also aims to expand the knowledge on how to further influence mobility behaviour through smartphone applications, with support in theory. This could be described as an integrated four-step procedure, which includes adopting, shaping, changing and keeping sustainable travel behaviours with assistance of app-technology. This approach offers new possibilities as well as new challenges. By combining behavioural change techniques (BCTs) (Abraham and Michie, 2008) and ICT, research can start experimenting with the opportunities to gamify data and visualize messages differently to appeal to the user. However, fundamental but equally important challenges exists such as getting the targeted population to actually use the application in question. This extended approach demands for a wider scope of theories to be used, certainly behavioural change theories but also theories linked to gaming and adoption of new technologies.

In a recent review of persuasive technologies to promote sustainable mobility, also called behaviour change support systems (BCSS) (Oinaskukkonen, 2010), Sunio and Schmöcker (2017) concludes that too little effort is given on grounding BCSSs in explicit behavioural change theory. Developing a successful BCSS depends not only on the creative and appropriate implementation of the behaviour change techniques, but also on explicitly grounding it on established theoretical constructs from behavioural theories (Arnott et al., 2014). Support for this suggestion can also be found in a significant meta-analysis by (Webb et al., 2010), who argues that a thoroughly rooted BCSS in theoretical foundation is positively correlated with its effectiveness. The potential for smartphone applications as carriers of behaviour change messages should, we argue, not be stalled by ignoring the underlying mechanisms of behaviour change developed from theory.

To the best of our knowledge, so far, the only BCSS grounded in behavioural theory is one called Quantified Traveller (Jariyasunant et al., 2015) which is based on Theory of Planned Behaviour (Ajzen, 1991). Although highly influential in the field of travel behaviour, TPB has been criticized for disregarding the time dimension of behaviour change, which is the mere foundation of other behaviour change theories, like The Transtheoretical Model (Prochaska and DiClemente, 1982). In TTM, change is defined as an incremental, gradual and dynamic process, involving progress through a series of stages. It has been argued that a combination of continuous models and stage models, such as TPB and TTM, can help to explain the process of behaviour change (Forward, 2014). For this purpose, we used a theoretical framework consisting of both Theory of Planned Behaviour and The Transtheoretical Model but also Diffusion of Innovations (Rogers, 1995) and the concept of Gamification (Deterding et al., 2011) to review the content of previous research on behaviour change and ICT and draw conclusions about best practices for developing a BCSS.

There are currently expectations that ICT could be a useful tool for influencing travel behaviours (Brazil and Caulfield, 2013) and earlier research has asserted future platforms for persuasion and behaviour change to be mobile (Fogg and Eckles, 2007). However, there is a lack of research exploring these new platforms for behaviour change in the light of actual behaviour change theory, as pointed out by Klein et al. (2014) as well as Sunio and Schmöcker (2017). It is this knowledge gap in the research that this study seeks to investigate. The authors of this study has conducted a review of previous research on behaviour change and ICT. Apart from providing an overview of one particular field, the rationale for writing a literature review paper is also to add value (Wee and Banister, 2016) which in this study is performed through applying theories on research findings as well as synthesize the results into a conceptual model.

1.1. Purpose and research questions

The purpose of the study is to investigate how behavioural change techniques can be implemented in smartphone applications to encourage sustainable travel behaviours. This by (1) examine conclusions from previous research in which the combination of behavioural change techniques and ICT has been studied in the field of transport as well as in other areas, and (2) using a theoretical framework consisting of The Transtheoretical Model, the Theory of Planned Behaviour, Diffusion of Innovations as well as the concept of Gamification, to analyse empirical findings and thus increase the knowledge of how behaviour change support system (BCSS) could be improved.

The aim is to provide knowledge of key aspects to consider when combining behaviour change techniques with ICT and to develop a conceptual model that highlights these aspects, grounded in previous research and theory.

2. Theory

To analyse the results extracted from the literature review we applied the theoretical framework on the stages of adopting, shaping, changing and keeping sustainable travel behaviours with the use of smartphone applications. We made the assumption that these four stages are vital to consider when developing a BCSS, from adopting the tool to recognizing the new behaviour as a habit. Although this division makes for better theoretical overview, in reality we consider them very much integrated, both in practice and in theory. However, as a theoretical overview our approach can be described as in Fig. 1. By taking this approach we seek to get a holistic, theoretical perspective on developing a BCSS, as requested in previous research (Klein et al., 2014; Sunio and Schmöcker, 2017). With "Adopting" we refer to the crucial process in which the user utilize the smartphone application and engage with its content. Although many people today interact with smartphones (in Sweden, 81 percent have access to a smartphone and 65 percent use it daily), there is still a large proportion, especially among elderly, who struggle with adopting the new technology (Findahl and Davidsson, 2016). We acknowledge this limitation for the general adoption of a BCSS. There is however a strong increase in smartphone ownership worldwide (Pew Research Center, 2016). "Shaping" is where the application should inspire the user to contemplate about her/his current attitudes towards mobility and consider how their personal mobility could be more sustainable. "Changing" is the process in which

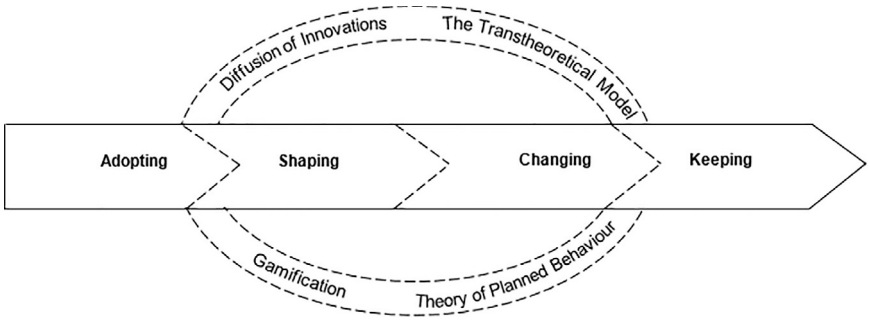

Fig. 1. Theoretical overview of framework application on four integrated stages of behavioural change with the use of a BCSS.

the BCSS ought to guide the user towards accomplishing her/his goals and thus making the necessary changes to succeed. "Keeping" is the final step in which the user might need sustained motivation in order to implement the new behaviour as a habit.

Diffusion of Innovations (Rogers, 1995) is a theory that seeks to explain how innovations are spread within group of societies. According to the theory, innovation could be a behaviour, technology, service, structure, system, an object or idea that is considered by society to be new. Diffusion is the process where innovations is communicated via different channels over time among members of a social system (Rogers, 1995). The theory is particularly valuable in gaining insights in what qualities makes innovations spread, the importance of social networks that spread the word about innovations, as well as the significance of identifying different user segments and their needs.

Theory of Planned Behaviour (TPB) (Ajzen, 1991) is a theory whose purpose is to explain human behaviour. The theory assumes that attitudes towards a certain behaviour, subjective norms and perceived behavioural control together form an individual's intentions and behaviours (ibid.). It has been used in a variety of studies to explain and predict behaviour in fields such as sociology, psychology, environment and health (Anable et al., 2006). TPB is the most common and influential theory used to explore the attitude-behaviour gap (Armitage and Conner, 2001). TPB has also established itself in research on travel behaviours in order to increase the knowledge of how sustainable modal shares can increase through changing behaviours of travellers (Bamberg et al., 2003; Jariyasunant et al., 2012; Semanjski and Gautama, 2016; Semanjski et al., 2016). Semanjski and Gautama (2016) has identified TPB as well-established in research related to Mobility Management, which further motivates for its use as part of a framework to analyse how individuals can be encouraged to more sustainable travel behaviours.

The Transtheoretical Model (TTM) (Prochaska and DiClemente, 1982) is a theory that seeks to explain the process of behaviour change. It considers behaviour change to be a dynamic process rather than an isolated event and consists of several steps. TTM has been used primarily to explain health-related behaviour changes, but in recent years also to understand travellers modal choice (Forward, 2014). Bamberg (2007) for example, used TTM to try to describe the decision-making process for motorists who switched to public transport. The result showed that the expected consequences of the changed travel pattern were perceived as more positive further along the behaviour change process.

Gamification is the use of game elements/game mechanisms in activities that are traditionally unrelated to gaming to enhance the user experience of a particular activity (Deterding et al., 2011). In recent years, the concept has been applied in a number of areas for the purpose of influencing behaviours and increasing the motivational power of the user, but without much consensus on how the concept should be formulated and what the actual benefits are (Seaborn and Fels, 2015). This is also true in the transport sector, where there are a number of examples of scientific studies where attempts have been made to change travel habits using gamification (Castellanos, 2016). The concept is interesting for this study since it brings new perspectives on motivational trigger points which indeed could be combined with data collected via smartphone applications.

3. Method

3.1. Literature review

A literature search was being conducted on electronic sources in multiple data bases. The review followed PRISMA guidelines (Moher et al., 2009) for literature reviews by including the four phases of the PRISMA flow diagram: Identification, screening, eligibility and included papers evaluation. To obtain multiple perspectives, the search included other fields apart from transport where behaviour change techniques were combined with ICT. Since smartphones today are the most widely used digital tool for travellers to access travel information, (Poslad et al., 2015; Klecha and Gianni, 2018) it made sense to construct keywords that would allow research about application-based ICT for smartphones. The keywords consisted of constructs with different combinations of the terms "travel/transportation/mobility behaviour", "behaviour change", "smartphone/application", "mobile device" and "persuasive technology". The timeframe was set for 2008–2017.

The search were performed in February 2017 and then repeated in September to ensure we covered recent research findings before making final conclusions (see the flow diagram in Fig. 2 for details). The majority were scientific articles and a small number consisted of conference material and dissertations. Three criteria determined whether the literature could be considered relevant to the study or not. To be included in the study, it was required that the material fulfilled the following: (a) it must be peer-reviewed, (b) focused on some form of behaviour change and (c) investigated the use of apps, smartphones or other types of ICT relevant to the study. After fulfilling the search a snowball review was conducted, where references from the articles in the literature search were screened for additional eligible papers. After reconciliation with the above criteria, a total of 32 articles were included in the review to be analysed.

3.2. Data extraction process using content analysis

The articles were independently examined for information that provided knowledge of behaviour change with the help of ICT-appliances. This was made through a content analysis, which means analysing data without preconceived categories to allow new insights to emerge (Hsieh and Shannon, 2005). The content was carefully analysed

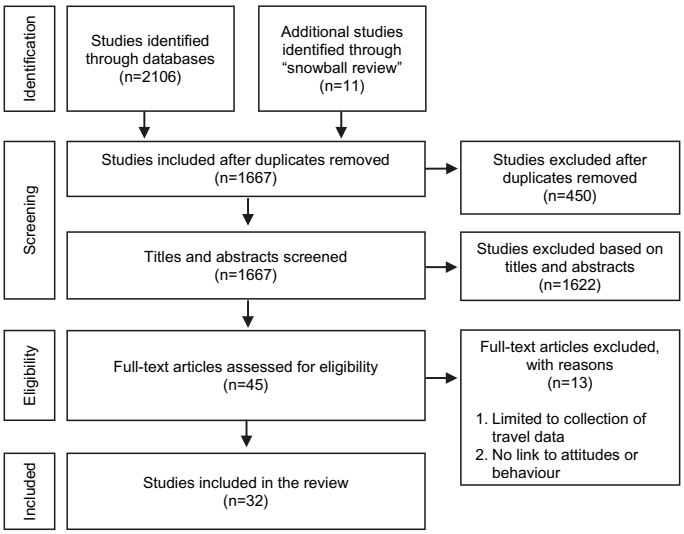

Fig. 2. Study inclusion flow diagram.

to identify key concepts and findings that later could be sorted into categories, also described as inductive category development (Potter and Levine-Donnerstein, 1999). When performing the inductive category development, three researchers took part in a workshop to discuss possible categories and which to go further with. The content analysis was, however, performed by one independent researcher and herein lies potential bias. The categories were tested against the theoretical framework to evaluate if the findings from earlier research correspond with relevant theories or not. From this outcome a conceptual model was constructed, based on empirical evidence and the theoretical framework.

4. Literature review

Research on ICT and behavioural change has been conducted in several fields, of which four were investigated in this study. The majority (27/32) of the articles concerns transport and mobility or health and fitness while three items are energy-related and two address environmental and climate issues (see Table 1). This means that the following analysis will be strongly characterized by the two first mentioned fields, which however, is of less concern since it is the synthesis of the result that is interesting and not necessarily what the parts say separately. Less than half of the reviewed articles used any kind of theory or concept which suggests a gap between theory and empiricism, where empirical research lacks reference to theory and where theory is not sufficiently rooted in empirical research, which is also recognised in earlier research (Klein et al., 2014; Sunio and Schmöcker, 2017). The theories mentioned, however, are the Theory of Planned Behaviour (Martiskainen and Coburn, 2011; Jariyasunant et al., 2015; Semanjski and Gautama, 2016; Semanjski et al., 2016; Pronello et al., 2017), Random Utility Theory (Brazil and Caulfield, 2013), Rational Choice Theory (Martiskainen and Coburn, 2011), Information-Motivation-Behavioural Skills model (Aliabadi et al., 2016), Gamification (Wells et al., 2014; Poslad et al., 2015; Castellanos, 2016; Coombes and Jones, 2016) and Nudging as well as Behavioural Economics theory (Gilliland et al., 2015).

5. Analysis

5.1. Findings related to the theoretical framework

From the literature review, 26 findings were identified which concerns different aspects of BCSSs (see Table 2). Upon review of these, four distinctive categories were identified, namely (1) customization to the user, (2) information and feedback, (3) commitment and (4) appealing design. The findings were sorted into these four categories and then analysed based on the theoretical framework of the study.

5.1.1. Customization to the user

A recurring observation from the articles is the importance of adapting ICT and behavioural change to the user and its needs, rather than a standard format of one size fits all (ex. Anagnostopoulou et al., 2016; Poslad et al., 2015; Tang et al., 2015; Coşkun and Erbuğ, 2014; Gilliland et al., 2015; Kraft and Yardley, 2009; Dennison et al., 2013; Anda and Temmen, 2014). Several studies also pointed to the need to contextualize the content and thus make it more relevant to the user (Hargreavesn et al., 2010; Coşkun and Erbuğ, 2014; Poslad et al., 2015; Aliabadi et al., 2016; Anagnostopoulou et al., 2016). TPB assumes that individuals' behaviour is influenced by habits but governed by logical reasoning. According to the theory, better information should therefore benefit the individual and strengthen confidence in the innovation at question.

According to Diffusion of Innovations, it is the product that needs to be adjusted to the individual instead of the opposite. Rogers (1995) identified five key criteria that determine between 49 and 87 percent the acceptance of an innovation, namely: its relative advantage over similar products, how well it complies with prevailing norms and values, ease of use and simplicity, if a trial period is offered and if the results can be observed by the user. Rogers (1995) further stated that one needs to understand the needs of the user and adjust innovations to match the requirements of the segment (innovators, early adopters, early majority, late majority, laggards).

Both the reviewed articles and the above-mentioned theories support the findings that focus on adjusting content to the user and can

Table 1
Compilation of empirical material, by theme, source and purpose.

Theme	Source	Purpose
Energy	Anda & Temmen (2014)	Provide examples of how smart energy meters along with community engagement can reduce energy consumption in households
	Hargreavesn et al. (2010)	Qualitative field study on how individuals interact with smart energy meters and how it can affect the behaviour of consuming less energy
	Martiskainen & Coburn (2011)	Identifying which factors contribute most to energy-efficient household use using smart energy meters
Health and fitness	Aliabadi et al. (2016)	Identify desirable features for an application that prevents HIV in men. Focus groups with 33 participants
	Baranowski & Frankel (2012)	Describe different forms of ICT for behavioural change and its strengths and weaknesses to affect children to more healthy behaviour
	Chaplais et al. (2015)	Systematic literature review on the effects of smartphone usage as a tool for treating obesity among children
	Chen et al. (2015)	Evaluate the quality of the most popular health applications and quantify the techniques used to encourage behaviour change
	Coombes and Jones (2016)	Aims to get children more active by encouraging them to walk and cycle in their neighbourhood using tracking technology with a reward scheme. Evaluates the impact of the "Beat the Street-scheme" on active travel to school in Norwich, UK
	Dennison et al. (2013)	Explore young adults (n = 19) perspective on health and behavioural applications to find out what motivates them to use such applications. Focus groups and qualitative interviews
	DiFilippo et al. (2015)	Systematic literature review to study the nutritional applications' ability to improve adult knowledge and behaviour about diet and nutrition
	Fanning et al. (2012)	Perform a meta-analysis of research that examined ICT to encourage physical activity, evaluate its effectiveness and provide suggestions on how future implementation should be designed
	Gilliland et al. (2015)	Investigate the effects of "SmartAPPetite", an application designed to encourage healthy and locally produced food
	Kraft & Yardley (2009)	Compile knowledge and suggest future studies on ICT as a tool for changing health-related behaviour
	McKay et al. (2016)	Systematic literature review on research that examines the impact of health applications on behaviour to identify best practice
	Tang et al. (2015)	Investigate young people's experiences and values of using internet and application-based health information as well as what they value in the context
Climate and environment	Coşkun & Erbuğ (2014)	Investigate which app features are important to successfully encourage and long-term sustainable choices based on 17 users' recommendations of four different applications
	Sullivan et al. (2016)	Quality assessment of existing travel and dietary apps capable of calculating CO2 emissions and health effects to influence behaviour change
Transport and mobility	Anagnostopoulou et al. (2016)	A review of existing approaches and prototype systems which describes and classifies the persuasive strategies used for changing behaviour in the domain of transport. Also examines the results and recommendations derived from pilot studies
	Berger & Platzer (2015)	Evaluate "SmartMo" as a tool for collecting travel behaviour data and gain insights on their attitudes towards the application. 97 participants in the study
	Bothos et al. (2014)	Focus on persuasive strategies supported by a choice architecture approach and incorporated in a smartphone application, aiming at providing urban travellers with a solution that will influence them to consider sustainable options
	Brazil & Caulfield (2013)	Investigate the impact of travel and CO2 calculators on users' travel behaviour
	Bresciani et al. (2016)	Presented the projects "Opti-LOG" and "Sharing Cities", which are joint-venture collaborative projects to initiate more sustainable mobility and energy-saving society through behavioural change. The project includes public and private actors as well as community citizens
	Castellanos (2016)	Study the effects of financial incentives via mobile phones to encourage more sustainable travel. 20 participants in the study for two weeks
	Jariyasunant et al. (2015)	Describe the development, application and analysis of a computational travel feedback system called Quantified Traveller (QT).
	Klecha and Gianni (2018)	A review of 14 different applications with focus on utilised technology, behaviour change strategies and citizen participation in the development process.
	Parvaneh et al. (2014)	Study the effects of personal travel information, taking into consideration personal preferences. Comparative descriptive and normative travel information
	Poslad et al. (2015)	Study the impact on the behaviour of various travel incentives through the use of Tripzoom in the European cities of Enschede, Gothenburg and Leeds for six months
	Pronello et al. (2017)	Assessing the effects on travel behaviour of a multimodal real-time information navigator for smartphone, developed within the project Optimod'Lyon
	Semanjski et al. (2016)	Examine the potential of smartphones as tools to deliver incentives to achieve a more sustainable travel behaviours, as well as identify different attitude profiles. 3400 participants over six months
	Semanjski & Gautama (2016)	To bridge psychology, marketing and ICT in transport research and evaluate the automatic segmentation of the eight attitude profiles within SEGMENT
	Sunio and Schmöcker (2017)	Review of existing behaviour change support systems (BCSS) designed to promote sustainable travel behaviour. Extracts the persuasive features and evaluate their persuasive potential by using the persuasive systems design (PSD) model that has been used to evaluate BCSSs in the health domain.
	Wells et al. (2014)	To develop a platform that, using gamification, encourage users to reflect on their travel behaviours

thus be seen as an important component in the development of a BCSS. Individual alignment is in line with TTM, which divides the five-stage transition process (pre-contemplation, contemplation, preparation, action, maintenance) to determine at which stage of the process individuals are. The eight attitude profiles (Semanjski et al., 2016) uses similar approach as they segment the users according to their attitude towards sustainable travel modes. In this manner, information, feedback and incentives can be adjusted depending on whether the user is in an early or late stage of the behaviour change process.

According to TPB, it is possible to influence the intentions of individuals by influencing and drastically changing the prerequisites for one or more of the three components: the individual's attitude and values towards the behaviour, the social norm in relation to the behaviour and experienced control of performing the action (Bamberg et al., 2003). By contextualizing and customizing content in, for example, an application for smartphones, the perceived control should increase as the individual will be equipped with more relevant information.

Table 2
Categorization of findings from the literature review.

Category	Findings	Source
Customization to the user	1. Applications should customize information, goals and challenges	(Kraft and Yardley, 2009; Dennison et al., 2013; Anda and Temmen, 2014; Coşkun and Erbuğ, 2014; Gilliland et al., 2015; Poslad et al., 2015; Tang et al., 2015; Anagnostopoulou et al., 2016)
	2. Use of attitude profiles increases knowledge about which segments are more willing to change travel behaviour	(Anagnostopoulou et al., 2016; Semanjski and Gautama, 2016; Semanjski et al., 2016)
	3. Contextualization is important to the user	(Hargreavesn et al., 2010; Coşkun and Erbuğ, 2014; Poslad et al., 2015; Aliabadi et al., 2016; Anagnostopoulou et al., 2016)
	4. The focus should be on the whole household rather than just the individual	(Hargreavesn et al., 2010; Anda and Temmen, 2014)
	5. Perceived control is an important factor in the choice of performing a certain behaviour	(Coşkun and Erbuğ, 2014)
	6. Participatory design methods, in which end-users actively participate in the stages of design and development of BCSS, is unusual but could increase acceptance and usefulness of the application	(Klecha and Gianni, 2018)
Information and feedback	7. It is unclear whether normative information is better than descriptive in trying to influence behaviour change	(Parvaneh et al., 2014)
	8. Reflective learning could be an alternative approach to persuasion	(Bothos et al., 2014; Klecha and Gianni, 2018)
	9. Credible information and data is important to the user	(Hargreavesn et al., 2010; Dennison et al., 2013; Anda and Temmen, 2014; Coşkun and Erbuğ, 2014; Gilliland et al., 2015; Tang et al., 2015; Aliabadi et al., 2016; Anagnostopoulou et al., 2016)
	10. Measurement and overview of behaviour is important to the user	(Martiskainen and Coburn, 2011; Dennison et al., 2013; Gilliland et al., 2015; Tang et al., 2015)
	11. Mobility is very habitual and information can play a role in shifting modes only if it becomes meaningful enough to give users significant reasons to break their routine, changing the cognitive foundation of intentions and behaviour	(Bothos et al., 2014; Coombes and Jones, 2016; Pronello et al., 2017)
	12. Feedback is important for the user to change behaviour	(Kraft and Yardley, 2009; Hargreavesn et al., 2010; Dennison et al., 2013; Anda and Temmen, 2014; Bothos et al., 2014; Gilliland et al., 2015; Poslad et al., 2015; Tang et al., 2015)
	13. Applications should provide relevant knowledge of environmental and climate-smart behaviour according to users	(Dennison et al., 2013; Coşkun and Erbuğ, 2014; Gilliland et al., 2015)
	14. Incentives in the form of reward can work both positively and negatively when trying to influence behaviours	(Coşkun and Erbuğ, 2014)
	15. Carbon dioxide calculators have little effect on travellers if they for example value short travel times higher than low CO2 emissions, but can be useful for comparing modes and increase awareness of unsustainable behaviour	(Brazil and Caulfield, 2013; Bothos et al., 2014)
	16. Incentives that are not linked to any product do not seem to inspire behavioural change to a greater extent in some segments	(Poslad et al., 2015)
	17. Daily reminders do not necessarily have a positive effect on the quality of data collection	(Berger and Platzer, 2015)
Commitment	18. Higher motivation and involvement leads to a greater extent to positive results	(Kraft and Yardley, 2009; Hargreavesn et al., 2010; Martiskainen and Coburn, 2011; Gilliland et al., 2015; Jariyasunant et al., 2015; Castellanos, 2016; Coombes and Jones, 2016)
	19. Gamification can extend the commitment of the user	(Kraft and Yardley, 2009; Baranowski and Frankel, 2012; Berger and Platzer, 2015; Chaplais et al., 2015; DiFilippo et al., 2015; Poslad et al., 2015; Castellanos, 2016)
	20. Gamification does not necessarily increase sustainable travel in itself, but on the other hand increases engagement at least in a short perspective	(Wells et al., 2014; Coombes and Jones, 2016)
	21. Long-term commitment is a key issue for ICT to change and maintain the behaviour of the user	(Kraft and Yardley, 2009; Martiskainen and Coburn, 2011; Baranowski and Frankel, 2012; Chaplais et al., 2015; DiFilippo et al., 2015; Gilliland et al., 2015; Castellanos, 2016; Coombes and Jones, 2016; Pronello et al., 2017)
	22. Applications need to be fun to engage some users	(Dennison et al., 2013; Aliabadi et al., 2016)
	23. Gamification that challenges and triggers contest behaviours could be used for motivational purpose	(Coşkun and Erbuğ, 2014; Wells et al., 2014; Chen et al., 2015)
Appealing design	24. Appealing and simple design is important to the user	(Hargreavesn et al., 2010; Martiskainen and Coburn, 2011; Dennison et al., 2013; Coşkun and Erbuğ, 2014; Berger and Platzer, 2015; Poslad et al., 2015; Tang et al., 2015; Aliabadi et al., 2016; Klecha and Gianni, 2018)
	25. The integrity aspect is important to the user	(Dennison et al., 2013; Berger and Platzer, 2015; Aliabadi et al., 2016; Castellanos, 2016)
	26. Individuals appreciate the ability to personalize the application	(Fanning et al., 2012; Wells et al., 2014; Gilliland et al., 2015; Poslad et al., 2015; Semanjski et al., 2016; Sullivan et al., 2016)

5.1.2. Information and feedback

Information and feedback emerged as an important category for encouraging individuals to perform the desired behaviour (Kraft and Yardley, 2009; Hargreavesn et al., 2010; Dennison et al., 2013; Anda and Temmen, 2014; Coşkun and Erbuğ, 2014; Gilliland et al., 2015; Poslad et al., 2015; Tang et al., 2015; Aliabadi et al., 2016). Most importantly, credible information and data were considered important as well as the ability to measure their performance and get feedback on one's behaviour in relation to individualized goals. Incentives/rewards may be necessary for individuals to switch to more sustainable means of travel (Poslad et al., 2015), but can also be counterproductive if they are perceived as unnecessary or irrelevant (Coşkun and Erbuğ, 2014).

According to TTM, individuals who undergo the behavioural change stages continuously assess the balance between the pros and cons of the changed behaviour (decisional balance) (Prochaska and DiClemente, 1982). Information and feedback can therefore be used to clarify the benefits of the change and counter-argue the disadvantages. This balance is different through the change process, for example, the cons of

the new behaviour have more weight for individuals during pre-contemplation. However, in the next stage of contemplation, individuals are more likely to understand the benefits of the changed behaviour but still overestimate the effort/costs of the change and are thus still ambivalent in their behaviour and not yet quite ready for the change (Bamberg, 2007). Thus, in the first stages, focus should be on raising the positive aspects of sustainable travel and providing credible information that reinforces these arguments in combination with short-term rewards (Forward, 2014). In the third stage, preparation, the benefits have become quite obvious to the individual, though one could still experience the change difficult, which means that they may need guidance to move on to the next stage. In the action stage, the experience of the new behaviour has probably shown that it was easier than expected and the benefits were reminiscent. At this stage, however, the new behaviour has not yet become a habit, which is why it is important that the experience feels good and rewarding to avoid the risk of the individual returning to old behaviour patterns.

According to TPB, behaviours can be predicted by individuals' attitude towards the action and their perceived control, that is, their experience of how capable they are to perform the action (Ajzen, 1991). With this in mind, information and feedback within BCSSs should be designed to positively affect the attitude towards sustainable travel and also aim to strengthen individuals' belief that they are capable of actually replacing the car in favour of walking, cycling or public transport. For example, information about the consequences of an action can influence attitudes in a targeted direction (Abraham and Michie, 2008). In spite of this knowledge, the question remains on how normative information should be. A number of studies express the importance of normalizing sustainable travel so that individuals and society sees the unsustainable alternative as different – not the contrary (Oinas-kukkonen, 2010; Hiselius and Rosqvist, 2016). Also, the Theory of Planned Behaviour sets the social norm as a factor individuals take into account in their choice of behaviour, indicating that it would be a good idea to influence these via normative information (Bamberg et al., 2003). At the same time, the risk that individuals may ignore information could be greater at normative than descriptive information, as it could be perceived as less objective and more deceptive (Parvaneh et al., 2014). An alternative approach to normative and persuasive information could be that of reflective learning, which advocates systems to "foster open-ended reflection, meaning for users to reflect on what it actually means to be sustainable in a way that makes sense in the context of their own lives" (Klecha and Gianni, 2018). The question of which information that would be appropriate and adapted by the user may depend on which user segment the individual belongs to, which again stresses the importance of appropriate segmentation techniques.

5.1.3. Commitment

Engaging the user appears as a key issue when it comes to changing behaviours using ICT (Kraft and Yardley, 2009; Martiskainen and Coburn, 2011; Baranowski and Frankel, 2012; Chaplais et al., 2015; DiFilippo et al., 2015; Gilliland et al., 2015; Castellanos, 2016; Coombes and Jones, 2016; Klecha and Gianni, 2018). After all, it seems to be of less significance if an application is sophisticated as long as users neglect it because it is uninteresting. A number of studies highlighted the problem of declining application interest rates over time, as long term involvement on the other hand more often leads to positive results (Kraft and Yardley, 2009; Hargreavesn et al., 2010; Martiskainen and Coburn, 2011; Gilliland et al., 2015; Jariyasunant et al., 2015; Castellanos, 2016; Pronello et al., 2017). For example, Pronello et al. (2017) found that mobility is a highly habitual activity which is not easily interrupted, except for short periods. This analysis is in line with TTM, which means that behavioural change is a process that takes time and thus requires long-term commitment (Prochaska and DiClemente, 1982). According to TTM, the change process is not linear, but is often characterized by several relapses to old behaviour patterns (Bamberg, 2007). Diffusion of innovations also points out the renewal of products as a central principle for successful dissemination and long-term survival of innovations (Rogers, 1995; Robinson, 2009). Continuous improvements are here pointed out as important for maintaining consumer interest and commitment over time (Robinson, 2009) and should ideally be carried out during stages of design and development with input from actual users (Klecha and Gianni, 2018).

Several studies are optimistic about Gamification and its potential to extend the commitment of the user (Kraft and Yardley, 2009; Baranowski and Frankel, 2012; Berger and Platzer, 2015; Chaplais et al., 2015; DiFilippo et al., 2015; Poslad et al., 2015; Castellanos, 2016). That gamification would have a positive impact on participants' involvement is also supported by Seaborn & Fels (2015). The gaming industry has succeeded in motivating its target groups with mechanisms that provide constant feedback and motivate individuals to reach a distant goal. It is those processes that gamification could use to build a digital platform around something real. What is needed is data, and since large quantities can be gathered via, for example, travel applications, the possibility to gamify the experience should be virtuous. At this point however, research have not been able to determine which specific game elements work best to prolong commitment (Berger and Platzer, 2015; Poslad et al., 2015; Castellanos, 2016). It probably also depends on context and what kind of attitude profile is the target group for behavioural change (Seaborn and Fels, 2015).

5.1.4. Appealing design

Throughout the articles, the importance of an appealing and simple design of BCSSs was emphasized to keep the interests of users (Hargreavesn et al., 2010; Martiskainen and Coburn, 2011; Dennison et al., 2013; Bothos et al., 2014; Coşkun and Erbuğ, 2014; Berger and Platzer, 2015; Poslad et al., 2015; Tang et al., 2015; Aliabadi et al., 2016). Designing to create user-friendliness is thus important for users to quickly understand and be able to use the application. Some studies found that individuals also appreciate the ability to personalize the design, thus improving the adaptation to the user.

Gamification can, as mentioned earlier, be used to increase user involvement. This can also be reflected in the design of the application. According to Seaborn & Fels (2015), game elements should have a user-centred approach, where external rewards, points, pins and/or marks should be based on the users' motivational trigger points.

Simplicity and ease of use are one of the five key criteria that affect the acceptance of an innovation, according to Diffusion of Innovations theory (Robinson, 2009). New ideas and innovations that are easy to understand are accepted earlier than those that require the user to develop new skills.

But while focusing on simplicity, a number of studies have also shown the importance of respecting the integrity of the user (Dennison et al., 2013; Berger and Platzer, 2015; Aliabadi et al., 2016; Castellanos, 2016). The processing of collected data must respect user integrity and ensure that sensitive information remains accessible only for intended actors. Clarifying this in the design should be central to ensure that individuals are comfortable using the application.

5.2. Developing a conceptual model for behaviour change support systems

After analysing the four categories via the theoretical framework, they all appear as adequate for creating a conceptual model that helps us to better understand what considerations are important when constructing a BCSS (Fig. 3). First of all, customization to the user appear to be crucial in order to contextualise information, feedback, goal setting, stimuli, motivational mechanisms and other content within the BCSS. For that reason, "Customization to the user" is the starting point of our conceptual model and also an influencer of "Information and feedback" and "Commitment", since both of these parts should be grounded in the users' needs as well. Our approach is that these three parts in combination will contribute to an "Appealing design", which in itself also needs to be simple and user friendly. The arrow design is a reminder

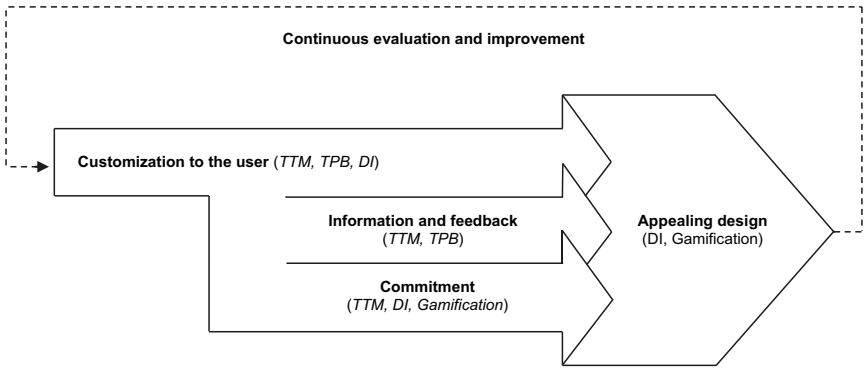

Fig. 3. A conceptual model for combining behavioural change techniques with ICT to create a BCSS.

that the development of BCSSs is a process rather than a "quick fix", which benefits from continuous evaluation and improvement, preferably with input from the users themselves (Klecha and Gianni, 2018).

The suggested model can be used to guide the implementation process of behaviour change techniques into smartphone applications to create a BCSS. It has a user-centred focus and advocates that information, goals and feedback is adjusted to individuals through segmentation techniques. In this way, chances are greater that the user is provided with contextual and relevant content that is useful to individuals (Anagnostopoulou et al., 2016). The model emphasizes the importance of engaging the user to maintain motivation through the behavioural change process. Motivating the user is important because the performance has proven to be better the higher the interaction with the application is (Kraft and Yardley, 2009; Martiskainen and Coburn, 2011; Gilliland et al., 2015; Castellanos, 2016). A simple and user-friendly interface should characterize the design itself.

The model uses established theories (TTM, TPB, DI) and Gamification as support functions in the different parts of the model. The categories are visualized together with the theories/concept that have been used in verifying and developing the findings from the literature review. The purpose of including these is to clarify what perspectives that has characterized the different parts of the conceptual model. Generally, the behaviour change theories TTM and TPB are most influential in the first parts of the model. The reverse applies to Gamification, which is more relevant when it comes to creating processes that involve the user, as well as in designing and visualize content. Diffusion of Innovations emphasizes the importance of starting from the consumer, constantly renewing innovation to create long-term commitment, as well as designing products that are simple and user-friendly (Rogers, 1995). This theory is thus well suited to keep in mind through the entire development process.

6. Discussion

The purpose of this study was to investigate how behaviour change techniques can be combined with ICT in the creation of a BCSS that encourage sustainable travel behaviour, as well as developing a conceptual model that highlights important aspects to take into account in such an implementation process. The results contributed in its entirety to answering the questions that guided the research process.

Previous research points to ICT in general, and smartphone-applications in particular, as a promising tool for influencing behaviour change. The results indicate, however, that it requires a user-centred focus, providing individuals with information, feedback and goals relevant for their specific needs to be of value in the process of changing behaviour. This is in line with the persuasive systems design (PSD) model (Oinas-kukkonen and Harjumaa, 2009), which represents an extensive conceptualization for technology-based persuasion (for further application of the model, see Sunio and Schmöcker, 2017). To allow for relevant and contextualised contents, segmentation of target population would indeed be essential, which also goes in line with earlier research on conventional Mobility Management campaigns (Meloni et al., 2017).

Some studies indicated that the change was more successful the more individuals used and interacted with the intended BCSS (Kraft and Yardley, 2009; Hargreavesn et al., 2010; Martiskainen and Coburn, 2011; Gilliland et al., 2015; Castellanos, 2016; Coombes and Jones, 2016). Commitment over time thus emerged as one of the most important factors for successfully influence behaviour change. However, previous research also stressed the need for more empirical research on how long-term commitment is achieved. Gamification seems promising and several studies recommend further research in this area (Berger and Platzer, 2015; Poslad et al., 2015; Castellanos, 2016). The theoretical framework contributed to verifying and developing the results obtained in the literature review. TTM supports an individualized approach and segmentation. The theory can also explain to some extent how information and feedback should be designed based on the users' motivational balance that characterizes the transition between the behaviour change stages (see 5.1.2). It also supports the observation that long-term commitment is important for individuals to complete the change process and to reduce the risk of relapse into old habits. According to Theory of Planned Behaviour, attitudes towards behaviour, social norms and perceived control are the main influencers of individuals' behaviours. Customized information and feedback that reinforces the user's perceived control, as well as content that normalizes sustainable mobility choices should therefore be advocated by the theory. However, TPB is unable to explain more closely how normative information and feedback should be. Diffusion of innovations supports segmentation, customization to the user, continuous improvement to create commitment as well as simplicity and user-friendliness. It also advocates proliferation through social channels, which is supported by some of the reviewed articles and supported by (Ploderer et al., 2014) although no conclusive studies are not yet available to shed light of the efficacy of social channels in BCSS (Sunio and Schmöcker, 2017). Gamification emphasizes the importance of creating processes that induce motivation and commitment, based on the users' motivational trigger points. The challenge with that approach is to know what the individual motivational driving force is. An alternative is to use different attitude segments instead and design the application so that users can customize

certain parts as they like. The concept seems promising based on previous empirical studies but is also at an early stage, where more research is necessary to understand which processes work best.

7. Conclusions and further research

Based on previous research and theory, a conceptual model that highlights key aspects to consider when creating a behaviour change support system (BCSS) were developed. Customization to the user, contextualised information and feedback, commitment and appealing design emerged as essential aspects when developing persuasive smartphone applications. We strongly suggest segmentation of intended target population to enable better customization to the user. This would provide enhanced conditions for user-centred information campaigns, tailor-made objectives and more contextualised content. In previous research on ICT to influence behaviour change, there are several examples of how parts of our conceptual model have been used fragmentarily, usually with mixed results. To the best of our knowledge, there is yet no study on BCSS that takes a holistic approach grounded in theory. It would therefore be potential to work on the model empirically to investigate its appropriateness to influence behaviour change, as theory-based research has showed to be more effective than purely working with behaviour techniques (Webb et al., 2010).

An observation that permeates the reviewed articles is the need for more research with larger and more extensive data collection to enable generalisations on the efficacy of BCSSs to change behaviours. We advocate more empirical studies to be grounded in behaviour theory. Gamification seems to be promising for sustained user engagement, but require further research to conclude what particular mechanisms that should be implemented. We also stress the need for studies exploring adequate segmentation techniques related to mobility, developing tailored messages and content for different segments and also evaluating the effects of these.

Finally, future research should continue to explore the important possibility of measuring actual travel behaviour change with the use of smartphone technology. A successful tool for collecting travel data by smartphones would be essential, in particular for quantitative research, but also for making informed planning decisions regarding mobility ahead.

Disclosure of interest

The authors declares that there has been no conflicts of interest concerning this article.

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Paper II

sustainability

MDPI

Article

Evaluating a Mobility Service Application for Business Travel: Lessons Learnt from a Demonstration Project

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Abstract: Business travel contributes to significant greenhouse gas emissions, and there is a need for measures that reduce the demand for trips made with energy-intensive means of transport. In this study, a mobility service application (MSA) introduced in 13 Swedish organisations was tested and evaluated to facilitate booking and handling of business trips, in particular public transport. A before and after study consisting of surveys and interviews with employees at the organisations were conducted. The results show that the MSA was mostly used for regional and local public transport trips, and the users stated that the MSA made it easier to travel by public transport, although this particular result should be seen as tentative due to the small sample size. Three factors that influence the success of a new MSA as a means to increase sustainable business trips were identified: management control and proactiveness; perceived improvement of intervention; functions and technical sufficiency. The results also highlight the need to establish organisational conditions that facilitate sustainable business travel, such as coherent travel policy, accessibility to sustainable modes of transport, and a culture that encourages environmentally friendly behaviour. The study suggests improvements that can be made to similar interventions and strategies that can be introduced to promote sustainable business travel.

Keywords: business travel; mobility service application; ITS; public transport; mobility management; before-after study

1. Introduction

Fossil fuel use is a primary contributor to human-induced carbon dioxide emissions, which aggravate global climate change [1]. Transport is responsible for almost 25% of global energy-related greenhouse gas emissions [2]. In Sweden, this share is even higher (33%) primarily because electricity generation and heating in Sweden is less dependent on fossil fuels [3] Both in Sweden and globally, transport is increasing its share of emissions [2,4]. At the beginning of 2018, the Swedish climate policy framework came into force, stating that by 2045, Sweden will have net zero emissions of greenhouse gases into the atmosphere and should thereafter achieve negative emissions. A separate target was set for the transport sector, declaring that emissions from domestic transport, excluding

domestic aviation, will be reduced by at least 70% by 2030 compared with 2010 [5]. Hence, promoting more sustainable and energy-efficient travel behaviour is of substantial interest, and there is mostly a consensus among transport researchers on the need for levels of transport to be reduced in order for the sector to contribute to more sustainable development [6,7]. In order to reach these ambitious targets a number of measures need to be introduced including changing transport behaviour [8,9].

Organisations generate a great deal of business travel globally. In Sweden, according to the latest national travel survey (RVU Sweden, 2011–2014), business trips account for 10% of the total number of passenger kilometres travelled per person and day [10]. Business trips by air have mainly been in focus within media as part of the "flight shame movement" while business trips by car have gained less interest even though they constitute a larger share of total passenger car kilometres per person and day (9% according to RVU Sweden). Further, local and regional public transport authorities have rarely prioritised business travel in their plans though a majority of trips carried out are over short distances less than 10 km and 40% are shorter than 5 km [10].

Thus, there is a great and untapped potential to contribute to the policy objectives of long-term sustainability in the transport sector by reducing the number of business trips made by cars. Various transport policy measures are available to reduce people's car use and to increase the use of more sustainable transport modes [11]. Some of these are referred to as 'soft' measures, that focus on voluntary changes such as, campaigns, travel plans for organisations or free public transport tryouts. Such measures aim to motivate individuals to voluntarily change their modes of transport to more sustainable ones [12] and have been implemented in several countries including Sweden [13]. Recently, soft measures have been studied in combination with information and communication technologies (ICT) to further promote a shift away from private car use [14,15]. While many studies focus on commuting trips [16], previous research has not sufficiently explored the role of business travel in the transition to a more sustainable transport system. Research on travel behaviour in workplace intervention contexts is needed to advance the understanding of how sustainable business trips can be facilitated in practice [17].

Further, the ongoing digitalisation has opened the possibility to combine mobility services with ICT to create a package of mobility solutions. Currently, there is a trend of new forms of shared mobility services (referred to as mobility as a service or MaaS) being developed to facilitate a multimodal and sustainable travel behaviour by reducing the need to own a private car [18]. Several evaluations have been made on these services concerning individual travel behaviour to explore its implementation issues and potential sufficiency in replacing car journeys [19,20]. The use of ICT also offers the possibility to avoid the need to travel through the use of digital applications providing virtual access to work, meetings, healthcare, education, etc., in what is referred to as accessibility as a service or AaaS [21]. Virtual meetings are ICT-enabled accessibility services that substantially can, given the right conditions, reduce the need for business travel [22,23]. However, recent studies have questioned whether mobility services such as MaaS will be able to decrease private car use [24], and suggested that expectations might be inflated [25], demonstrating the need for more research investigating the sustainability of these new services. Moreover, few studies have investigated the implementation of mobility services in organisations to promote more sustainable business trips.

The current study aims to fill in this research gap by demonstrating a new mobility service application (MSA) for business trips in Sweden and to evaluate it within the context of organisational travel management and practices. Survey data and interviews were used to analyse participant's travel behaviour change, perceptions of business trips, how they think their organisation manages such trips, and what they thought of the MSA as a support to facilitate more sustainable business trips.

This paper is organised as follows: Section 2 includes background and summarises previous research on business travel and mobility services. Section 3 introduces the analytical and theoretical framework. Section 4 describes the methodology, research design and design of the study. Section 5 presents the results of the survey and interviews separately, and Section 6 discusses these results. The study's conclusions are presented in Section 7.

2. Background

2.1. Business Travel Behaviour

Business travel can be defined as people travelling for work-related purposes. Davidson and Cope [26], divide business travel into individual business travel, which comprises the regular trips necessary to carry out employment tasks; and business tourism which includes a variety of business meetings and events and is sometimes associated with MICE (meetings, incentives, conferences and exhibitions) industry. Business travel does not only relate to the individual traveller's behaviour and conditions, but also to policies and the organisational culture around business travel. Hence, theories and models for individual travel behaviour, such as the theory of planned behaviour and the transtheoretical model, cannot easily be applied.

Business travel is commonly regulated in a corporate travel policy with associated guidelines regarding travel and its administration. Business travel is often managed through business travel agencies providing similar services to traditional travel agents, such as making reservations, issuing tickets and providing advisory services. However, even if a travel policy is present, research has shown that employees enjoy relative large freedom, particularly management, to decide on whether to take a trip and by what travel mode [27].

According to Gustafson [28], developing and implementing a travel policy is a cornerstone in an organisation's effort to control its travel activity. The main objective of the travel policy is to establish common rules and routines. It contains regulations on how to travel, what means of transport and what suppliers to use, what degree of comfort is allowed (e.g., economy or business class), what kind of ticket to use, and so forth. The travel policy also specifies what administrative routines travellers should follow, such as pre-trip approval, booking procedures, payment routines and expense report management.

Travel policies often deal with guidelines regarding virtual meetings such as audio-, web-, and videoconferencing as well. These alternatives have shown to be a useful measure for reducing the environmental load. An active investment in increasing the proportion of virtual meetings in 19 government agencies in Sweden (REMM—virtual meetings in authorities) resulted in an average reduction in CO_2 emission from business travellers per employee by 25% over a seven-year period, which can be compared to other Swedish authorities where corresponding emissions decreased by 6% during the same period [4]. Easily accessible information about the virtual alternatives and a smooth booking process, preferably closely linked to the travel alternatives, is an important success factor [29,30].

There are also some evaluations carried out for business sales activities indicating a potential to increase the number of trips by public transport. The local public transport agency in Stockholm (SL) conducted a follow-up study of a sales activity towards companies where companies were provided with special company tickets to be used in service. The study indicated that of those receiving the company ticket, the share of trips by public transport increased by 27% and the number of trips by car decreased by 20% [31]. In a study by Forward [13], the effect of a free travel pass resulted in a more positive attitude towards bus usage, with a large number having either changed or having started to change their behaviour. When the same people were contacted three months later, 50% still used public transport.

2.2. Mobility Services

New, smart mobility solutions for business travel can create better conditions for organisations to contribute to sustainable transport policy objectives, by providing incentives to travel by public transport, walking and cycling, or having virtual meetings. Many actors in Sweden and internationally are now highlighting "mobility as a service" as a priority area for developing a more sustainable transport system. Some experiments with integrated mobility services, mainly aimed at private travellers, have been carried out. Karlsson, Sochor and Strömberg [32] who studied the effects of a MaaS field trial in Gothenburg, found that users were generally satisfied with the service and that 48% reported less private car use during the experiment. However, even though these have

shown positive results, there are a number of problems that need to be solved if this type of service is to be established. Offering an MSA to facilitate more public transport use does not always succeed in convincing people to do so. A number of studies have shown that it is also important to increase the quality of the service [33].

Barriers and Facilitators

In order to achieve higher quality and satisfaction, the focus should be on how to satisfy the traveller's needs. Previous studies have shown that some of the most important requirements are: ability to buy tickets and be able to integrate different ticket systems, real-time information, and information on the entire route including transfers and personal information [34–37].

An important advantage of an electronic ticket is that it reduces the uncertainty about the waiting time. A further advantage is that it can give the user information about their travel. Dekkers and Rietveld [34], found that 58% liked the fact that their ticket gave them insight into how they travelled and what it costs. According to Link et al. [38], an important obstacle to using public transport is that all the different bus companies had their own, special cards and ticket systems. A single, standard card for the whole of Sweden would simplify travel. This is also supported by Turner and Wilson [39], who argued that an integrated ticket systems could offer greater flexibility and simplicity for passengers.

Provision of real-time information is becoming an increasingly fundamental part of the services offered by public transport companies and is considered to be the most important characteristic [35,40]. Real-time information can help travellers feel more in control, but it can also increase their sense of security [41]. Travellers need detailed information both before and during the trip, and especially when changing. When it comes to disruptions, travellers need clear guidance on how to continue their journey [42].

A trip with many exchanges often involves a high degree of uncertainty [43] and can be an important barrier to travelling with public transport [36,42]. Therefore, the traveller needs information both before and during the trip [33,43]. This information is not only about real-time information but also how to get to the station/stop, what the station/stop looks like, what service is offered and where and how the exchange itself can be done. Preferably, the information should be adapted to individual preferences.

Customised service can provide users with additional support for choosing multimodal transports [37]. Personal travel information is also expected to lead to a reduction in car journeys [44]. Studies have also shown that customised information is something the traveller wants [38]. A problem that may arise in connection with this is an intrusion on personal integrity, but studies have found that this is not a problem as the benefits seem to outweigh the disadvantages [38].

The presentation of information and usability are other important aspects. The customer is demanding a system that is reliable, understandable and easy to read [45]. This means that public transport operators should try to design systems to be as user-friendly as possible [46,47] and do not require a large amount of training and specialisation [46].

3. Theoretical and Analytical Approach

To demonstrate and evaluate the implementation of an MSA for business trips, the present study analyses the individual traveller's behaviour and conditions as well as the organisational culture and management practices related to business travel.

For this more comprehensive approach, we use 'the unified theory of acceptance and use of technology' (UTAUT), defined by Venkatesh et al. [46]. The UTAUT aims to explain user intentions to use an information system and subsequent usage behaviour. The UTAUT states that perceived usefulness (performance expectancy), perceived ease of use (effort expectancy) and norms (social influence) affect technology adoption intention via behavioural intention, which in turn leads to behaviour; whereas facilitating conditions directly antecede behaviour [48]. Table 1 presents the definitions of these determinants.

Table 1. Factors that influence technology adoption according to the unified theory of acceptance and use of technology (UTAUT) [49].

Performance expectancy	Defined as the degree to which an individual believes that using the system will help him or her to attain gains in job performance. Five constructs that pertain to performance expectancy are perceived usefulness, extrinsic motivation, job-fit, relative advantage, and outcome expectations.
Effort expectancy	Defined as the degree of ease associated with the use of the system. Three constructs capture the concept of effort expectancy: perceived ease of use, complexity, and ease of use.
Social influence	Defined as the degree to which an individual perceives that important others believe he or she should use the new system. It refers to the way in which individuals change their behaviour to meet the demands of a social environment.
Facilitating conditions	Defined as the degree to which an individual believes that an organisational and technical infrastructure exists to support the use of the system.

The holistic approach in UTAUT fits well to analyse the implementation of an MSA in businesses because it considers both individual and organisational factors that are subject for investigation in this study. The application of the theory in this study is illustrated in Figure 1.

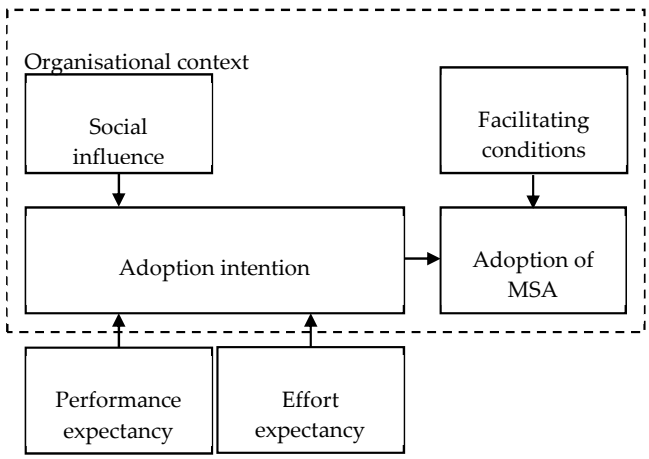

Figure 1. The analytical framework used to evaluate the implementation of the mobility service application (MSA).

4. Methods and Research Design

Through surveys and interview studies, quantitative data were combined with qualitative data. This mixed-method approach enables an analysis of the context, implementation, design and function of the evaluated MSA.

4.1. The MSA

Samtrafiken is owned in equal shares by all regional public transport authorities and most of the commercial public transport operators in Sweden. Samtrafiken connects all public and private transport operators, coordinate public transport data and develops and manage ticketing and payment standards. Over three years (2017–2019), Samtrafiken provided a service consisting of a mobile web application where, among other things, employees of recruited companies, authorities and organisations could manage their business trips by public transport and car. The project was based on the idea that employees should only need one tool regardless of the mode of transport. The MSA provided timetable information as well as the purchase of tickets for local and regional buses, commuter, regional and national train services, registration of car trips, and reporting of travel expenses. Each region had its own outline of the MSA. Through the MSA, the trips by public transport were paid through a monthly invoice including a financial statement from Samtrafiken to the companies, authorities and organisations that were recruited.

Samtrafiken coordinated the project with a reference group consisting of representatives from 6 regional public transport authorities (Hallandstrafiken, Region Kronoberg, Samtrafiken, Stockholm public transport authority, Upplandstrafik and Östgötatrafiken). Through the reference group, users of the MSA were recruited continuously during the first two years of the project. In other words, the researchers who authored this paper did not control the selection of participants. However, throughout the project, the researchers followed the implementation process and evaluated the MSA and its use. In total 13 organisations were recruited and appointed contact persons were provided with information material about the MSA to be distributed in each organisation. Participating actors also provided Samtrafiken with contact information (email addresses) to involved employees, facilitating the evaluation of the MSA.

4.2. Recruitment and Procedure

The total number of persons in the initial target group was 525, employed at four companies, eight public authorities and one NGO. Via the Netigate survey tool, a before and after study was carried out in that an email was sent to each participant with a unique link to the web survey. By this approach, targeted reminders can be sent to those who have not answered the survey (wholly or partially). The e-mails for the before study were sent out in two rounds, in March 2017 and during February–June 2018. The web survey was distributed as new participants came to the project's knowledge, hence the extended sending period in 2018. Up to three reminders were sent. Trough participating organisations, information on the MSA was spread via workplace meetings, leaflets and emails. In the after study, an email with a web link was solely sent to those who in the before study stated to make business trips. The mailing was made in mid-April 2019. Three reminders were sent. These individuals were also contacted via email with a request for an interview. Statistics on the number of persons in the target group and the number of responses received in each study are presented in Table 2.

Table 2. Number of persons in the target group and responses in the studies.

	Study Population	**Responses**	
Survey (Before study)	525	250 (48%)	where of 193 (77%) carry out business trips
Survey (After study)	193	77 (40%)	where of 35 (18%) used the MSA
Interviews (After study)	193	40 (21%)	where of 20 (50%) used the MSA

4.3. Design of Studies

4.3.1. Survey

The questions in the before and after study were based on two previous studies on travel behaviour [50,51] with some revisions following discussions within the project group. The before-after study consisted of a short travel survey concerning business trips (distance, transport mode, number and frequency of business trips) but also questions regarding attitudes towards various transport modes and perceived possibility to use these modes for business trips. The after study also consisted of questions related to the use of the MSA presented to those stated to have tried the MSA. Of 77 respondents in the after study, 35 respondents used the MSA. Responses from both groups (users and non-users) were analysed in order to analyse the effect of the MSA and for the users, to also gain knowledge on various aspects of the MSA.

In the before-after study, respondents were asked to answer some questions about business trips related to their perceived possibility to use public transport, how easy they think that is for them, and to what extent their near colleagues use public transport. The first question was stated as 'How possible is it for you to travel by bus/train for business trips' (performance expectancy)? The second was a statement saying, 'You think that using the bus/train is difficult' (effort expectancy). The third question was 'Your closest colleagues, who also make business trips, how often do you think they travel by bus/train' (social influence)? Each question was asked once for bus trips and once for train trips, and the scale was from 1 to 7, where 1 was impossible/totally agree/very seldom and 7 was very

possible/totally disagree/very often. The mean score was then computed from the bus/train questions to get an average public transport score for each determinant. Histograms were produced to control for the assumption of normality, which indicated roughly normal distribution for effort expectancy and social influence, but the third determinant, performance expectancy, seemed to deviate from this assumption. The Kolmogorov-Smirnov and Shapiro-Wilk tests suggested that the data are normally distributed for effort expectancy (p = 0.200 and 0.428) and social influence (p = 0.200 and 0.57). Conversely, for performance expectancy, both tests were statistically significant (p = 0.006 and 0.001, respectively), indicating a normality violation for that variable.

Attempts were made to normalise the performance expectancy variable using three different transformations (square root, reflected inverse, and log base 10) but neither succeeded to improve the shape of the distribution for the variable. Therefore, it was decided to omit that variable from the analysis and proceed with tests on effort expectancy and social influence. Significance tests were conducted between the before-after study for MSA users and non-users respectively too see whether the MSA influenced these two determinants.

In the after study, the respondents were also asked how often the MSA has been used for different types of business trips using scale 1 = never and 7 = always. In the after study, the users also answered questions about how good the application had been regarding various functions. The functions, graded on a scale from 1 = very bad, 7 = very good, were technology, login, real-time information, invoice handling and information on where to find stops. Finally, questions about virtual business meetings were asked, how they use such meetings today and if it would be useful for them to have that kind of service in the MSA.

4.3.2. Interviews

Ten individual interviews and nine focus groups were conducted (a total of 19 interviews) with a total of 40 people, see Table 3. The definition of a focus group here is when an interview takes place with two or more people. In some organisations, several interviews were conducted. There were 12 organisations represented. For practical reasons, seven interviews were conducted over the phone. On average, an interview took between 1 and 1½ h. The interviews were conducted during February and March 2019. In most cases, the interviews were conducted at the informant's workplace. The recruitment to the interview study was carried out before the after study; thus, it was not possible to identify the MSA users preceding this. Thus, in the interviews, there was a mix of respondents that used the MSA, tried to use the MSA but did not succeed for any reasons, and non-users of the MSA.

Table 3. Statistics on interviews carried out.

Organisational Level	Number of Organisations	Number of Interviews/Group Interviews	Total Number of Persons Interviewed
Municipal authorities	3	9	18
Regional authorities	2	2	3
Authorities and organisations on the national level	2	3	5
Companies owned by a regional authority	1	1	1
Companies owned by a municipal authority	1	1	2
Privately-owned companies	2	5	8
NGO	1	1	3

Interviews were conducted to gain a deeper understanding of how business trips are planned and implemented, how temporal and organisational constraints affect opportunities to manage business trips, and the extent to which an MSA meets these needs. Interviews also provide an understanding of how this type of service works for the organisation (both administrative and organisational aspects).

Semi-structured interviews were used to ensure that a number of important issues were covered in all interviews, but also to provide opportunities for respondents to bring up issues the interviewer had not considered [52]. Interviews thus took the form of conversations in which the interviewer

asked open-ended questions and follow-up questions within relatively broad pre-defined themes. The following themes were addressed during the interviews:

- Distance to work and means of transport;
- Frequency of business trips, distance and means of transport;
- Travel Policies;
- Virtual meetings;
- Meeting and travel culture;
- Questions about the MSA.

The analysis took a content analysis approach [53]. The interviews were recorded with the informant's consent and then transcribed. After that, the transcripts were coded and analysed thematically. Initial coding mainly used the pre-defined themes from the interviews; subsequent coding and analysis developed themes and sub-themes in an interplay between the empirical data and existing research and theory [54,55]. The most important analytical themes that emerged from this process are presented in the following sections and discussed in relation to the UTAUT.

In the presentation of the results, quotes from the interviews are used to illustrate the respondent's reasoning. These are reproduced verbatim but may have been adjusted for reading comprehension. If the text needs clarification, this has been written in brackets.

5. Results

5.1. Surveys

5.1.1. Differences between MSA Users and Non-Users

Firstly, we compare various statistics on MSA users and non-users in order to see whether there are any significant differences in the populations that may influence the evaluation of the intervention. According to the before-study, the travel behaviour of the users of the MSA (35 persons) and the non-users (158 persons) is similar except that the users of the MSA had significantly higher shares of business trips made by train and commuter train, see Table 4. The overall share of public transport for business trips is high (46%–44%) compared to statistics from the national travel survey on the number of trips where only 10% of the business trips are made by public transport. The mean age for the MSA users was 48.4 and 44.9 for the non-users. Women were overrepresented in both groups, 71% for MSA users and 61% for the non-users. Both groups had high access to a bicycle pool (83% for MSA users and 69% for non-users) and fairly high access to a car pool (60% for MSA users and 50% for non-users) while only a small proportion in both the groups had their own company car (14% for MSA users and 10% for non-users).

Table 4. Independent samples *t*-test to explore potential differences between the groups regarding business travel modal share (number of trips), as stated in the before-study.

	Car	Car (Passenger)	Bus	Train	Commuter Train	Bicycle	Walking	Other
MSA users %	22	11	12	24 **	10 *	11	6	4
Non-users %	24	14	12	22	8	9	8	3

** $p < 0.01$, * $p < 0.05$.

The use of virtual meetings is similar between MSA users and non-users (approximately 75% in both groups state that they are using virtual meetings for business). The majority of both groups have virtual business meetings 1–3 times/week. Further, there were no statistically significant differences between the groups when asked questions regarding their experiences with, and attitudes towards virtual business meetings (Table 5). The result indicates that the technology for virtual meetings is neither good nor bad and that the respondents are slightly positive towards the idea of having the possibility to book virtual meetings in an application. The scores are somewhat lower when respondents were asked to rate the suitability of their business trips to be made virtual, their

employer's encouragement to use virtual meetings, and the respondent's perceived ability to arrange such meetings.

Table 5. Independent samples *t*-test to explore potential differences between the groups regarding attitudes towards, and experiences with, virtual meetings, as stated in the before-study.

	We Have Good Technology for Virtual Meetings	We Have Good Technology, But Virtual Meetings Are Not Encouraged by My Employer	My Business Trips Are Suitable for Virtual Meetings	I Feel Confident in How to Arrange Virtual Meetings	It Would Be Useful to Be Able to Book Virtual Meetings in an Application
* MSA users	4.22	4.22	3.11	2.56	4.19
* Non-users	4.71	3.71	3.65	3.43	4.44

* 1 = Do not agree at all, 7 = Fully agree.

5.1.2. Changes in Attitudes and Perceptions Towards Public Transport

As shown in Table 6, the only significant difference was for the MSA users in relation to effort expectancy, suggesting that they perceived it easier to use public transport after the use of the MSA. However, due to the small sample size, caution should be taken to generalise these results.

Table 6. Paired samples *t*-test to explore potential differences between the before and after study for MSA users and non-users.

	MSA Users		Non-Users	
Determinant	**Before**	**After**	**Before**	**After**
[a] Effort expectancy	4.57	4.94 *	4.66	4.76
[b] Social influence	4.14	4.54	3.98	4.49

* $p < 0.05$, [a] 1 = totally agree, 7 = totally disagree, [b] 1 = very seldom, 7 = very often.

5.1.3. Use of the MSA

The analysis of information from the before-after study reveals that there was no significant change in modal share when using the MSA. This may be due to the relatively high use of the respondents using public transport from the beginning but also due to infrequent use of the MSA. According to results, the application was only sometimes used for trips within the region (average 3.09) and rarely for trips to another region (average 2.32) and within the business location (average 2.39). Regarding the use of the MSA, the after study included questions regarding what type of trips the MSA had been used for (multiple answers were possible). The response options consisted of local bus journeys, regional trains/bus journeys and long train journeys. Almost 70% had used the application for regional train/bus trips. In total, 45% used the MSA for local bus journeys while 25% used it for long-distance train journeys.

5.1.4. Perception of the MSA

The result indicates that the MSA was perceived as neither good nor bad. Characteristics on the MSA scored somewhat higher (technology 5.25 and login 5.12) compared to aspects regarding information and administration (real-time information 4.89, invoice handling 4.71 and information regarding stops 4.19). Worth noting is that these are the answers from the group that used the MSA. Those who tried to use the MSA but cancelled due to problems are not included.

5.1.5. Summary

The result from the surveys indicates that the MSA was just tested occasionally, mainly by users who already had a fairly high use of public transport. The MSA users and the non-users had similar experiences and attitudes from using virtual meetings, and both groups indicated that it might be useful to incorporate virtual meetings in a future travel application. The results show that the MSA users thought it was less effortful to use public transport after they had experienced the application.

A similar difference could not be found in the non-user group. The trips made using the MSA consisted mainly of regional trips by train and bus. The functionality of the MSA was graded as satisfying (neither good nor bad) by the users. In the end, these results only give us a vague picture of the employees' need and use of an MSA for business trips due to the limited use of the MSA. In order to gain a deeper understanding, we now turn to the result based on the interview study.

5.2. Interviews

From the interview material, a number of barriers and facilitators that affect the uptake of sustainable business trips in general, and an MSA in particular, were identified. In analysing these findings, three themes were developed: (1) management control and proactiveness; (2) perceived improvement of intervention, and; (3) functions and technical sufficiency. The following sections examine more closely the contribution of these themes in light of the UTAUT theory.

5.2.1. Management Control and Proactiveness

Several respondents reveal that their organisations encourage sustainable business trips by promoting the use of bicycles and public transport. The fact that there are available alternatives that are easy to choose is an important reason why sustainable business trips take place. One of the municipalities that participated in the study offers electric bicycles to their employees and has also given the opportunity to try an electric bicycle and a public transport travel card for private trips. In another organisation, campaigns have been implemented to reduce car commuting by raising parking fees and reducing the number of parking spaces. In several organisations, guidelines are saying that employees must use rental cars or pool cars that run on renewable fuels for business trips instead of using their private car. Common to most of these organisations is that they have developed and implemented a travel policy designed to steer towards a vision or long-term goals, often related to reduced carbon dioxide emissions.

It is common that the travel policies implemented in the studied organisations instruct the employees not to fly domestically, that trips should be made by public transport and that one should question whether one needs to travel at all. However, the respondents state that in many of the studied organisations, the travel policy is unknown to the employees, or has weak support and is considered unclear. One interviewee state that the travel policy is not clear and tough enough to lead to sustainable business travel in practice:

> Sometimes it is hard to argue why you want to take the train to Europe, even if you are prepared for it to take longer. (male employee at municipal authority).

Several of the respondents mention that time is given priority over choosing the most environmentally friendly way of travelling. For instance, a manager in a municipal organisation thinks that it is the HR department's responsibility to develop a travel policy. On the other hand, another respondent responsible for the travel policy at her organisation explains how important it is for management to follow the guidelines:

> There was a suggestion that everyone would walk, cycle or ride a bus, which the management thought was good, but then only one of them complied with the proposal. This [the management] is a very important group. Unless the management is involved, it will not work. It feels frustrating. It gets lonely. (female employee in an organisation on the national level).

A travel manager at a company says employees need to understand why it is important to make business travel more sustainable for it to happen. He further believes that the management must lead by example and implement clearer guidelines that are followed up continuously:

> It is not enough to say that now everyone should use electric cars, but you have to understand why, you have to build this common understanding of who we want to be and what kind of society we want to contribute to. (male employee at a company).

There are also examples on the opposite. In one of the municipalities, there is a green travel plan that works to stimulate sustainable travel. Some employees in the municipality mention that the management team talks a lot about the plan and about using public transport. Another municipality is discussing whether it is worth attending some of the meetings to better utilise their time and resources. If participation is necessary, the opportunities to participate online should be considered according to the travel policy.

How business trips are communicated and managed in workplaces has an impact on the organisational culture. Organisations with coherent travel policy and management attitude seem to have a more streamlined organisational culture with regards to sustainability and business trips. In organisations with less management control and proactiveness, respondents report that attitudes diverge considerably between co-workers on these issues. This could have a significant influence on behaviour. According to the UTAUT theory, social influence affects an individual's behaviour, especially in mandatory settings, where the compliance mechanism is particularly influential [48]. In an interview with two respondents working at a regional authority, several examples are given on how car use is indirectly encouraged by management; managers drive in their cars, the organisation's conference facility is only reached by car for "getting away from work", and free parking is available at the workplace. It is also considered advantageous to travel in your car. Higher mileage allowances than the Swedish tax agency's recommendations promote driving a car. Furthermore, there are advantageous car company contracts. The car is also considered to be a status mark in some organisations, and it appears that the higher up the hierarchy one gets, the better the company car.

> If you do not have a company car, you have mileage allowances that many see as an extra income to finance the private car. (male employee at a company B).

> … but it also has no consequences when you take the car, no one says anything, no one even says that "we have a travel policy". (female employee at company A).

Despite the apparent discrepancy in some organisations between their policies for business trips and how trips take place in practice, there are several examples of strategies that seem to have a positive effect from a sustainability point of view. Developing and implementing a travel policy which is anchored with senior staff members and management is one such strategy. Another is to make sustainable business trips more viable through incentives that promote cycling and public transport (green travel plan, pool cars, easy access to e-bikes and public transport tickets), and disincentives for car trips (less parking and higher fees, a prohibition to use the private car for business trips, etc.). Finally, the respondents suggested that it is crucial to create an organisational culture that promotes sustainable business trips to facilitate social norms that reward pro-environmental behaviours.

5.2.2. Perceived Improvement of the MSA Intervention

The respondents with experience from the MSA (tried or used) generally had a mixed opinion on whether the MSA made it easier to make more sustainable business trips compared to the current system. The perception of improvement that people relate to the new system is essential for a successful diffusion. According to Venkatesh et al. [46], performance expectancy is the strongest predictor of intention and the higher the perceived relative advantage of the innovation is compared to the idea it supersedes, the more rapid its rate of adoption is likely to be.

Generally, respondents were positive about the idea with an MSA or a similar system as a support for increasing sustainable business trips, regardless of whether they had positive or negative experiences with it. It was particularly desirable to have one system that offers all means of transport, in line with the MaaS-concept.

> It would be great if you could book a rental car in the app, book a taxi and a bicycle. More like a travel app where you can pay for all types of transport. That would be neat. (female employee at a privately-owned company).

At some workplaces, employees had to borrow a joint travel card for business trips with public transport. In these cases, employees thought it was particularly convenient to have the MSA instead, although one shortcoming was that there were too few ticket-options which sometimes led to more expensive trips than would be the case with the company's travel card. Still, the fact that the MSA bundled travel expenses automatically was perceived as a significant improvement for many respondents compared to the current system where employees must claim reimbursement afterwards for each business trip.

> Yes, it has saved me time. I do not need to report every [business] trip but can do it in lumps. (female employee at a privately-owned company).

The fact that the application can save time on the individual level is crucial because it can further be perceived to enhance job performance, which has been shown to significantly increase intention [48]. However, one respondent thought that the administrative benefits on the organisational level should have been shown to the employees as well to increase the general understanding of why the new system was implemented.

Larger organisations usually have a procured travel agency that handles business trips for employees. Some respondents indicated that the travel agency they were already using was working relatively well, and consequently, they saw less value with the MSA because they thought they already had a sufficiently good business travel booking system. Some stated that they did not use the MSA because they thought they had to book business trips through the procured travel agency. The least need for the MSA was for those who usually walked or biked to business meetings. This shows the importance of relating to current systems and the needs of different users.

> … [the MSA] can become far too complex if all wishes are to be taken into account. It can then be difficult to use. (focus group interview within an organisation on the national level).

5.2.3. Functions and Technical Sufficiency

Many of the respondents had comments related to the function of the MSA; its technical sufficiency, and the support received/not received to alleviate technical issues. The comments were primarily related to either purely technical weaknesses such as login problems, or functional deficiencies such as lack of ticket options. According to UTAUT theory, such issues are linked to effort expectancy and affects intention to adopt new interventions [48].

As previously mentioned, respondents appreciated that the MSA handled travel expenses. However, the aggregated invoice that was compiled at the end of each month was problematic for the administrative staff and accountants, who found it challenging to match trips with respective projects. Functions that some respondents thought missing were the possibility to book an overnight stay in combination with the trip, book tickets for a group of people, and more ticket options in general. Another issue was that purchased tickets came in the format of a text message and this unusual format made drivers suspicious of whether the ticket was real or not. One interviewee who thought that the MSA was useful in general, complained about the requirement to report administrative information before the ticket purchase:

> When I buy a ticket, I must enter the customer number and project cost centre. It's okay, but I have to do it before I buy the ticket. I am often on the move and often forget to buy the ticket on time so when I am at the station, I must remember the customer number and the cost centre. ... It would be great if I could put it in after I bought the ticket. (female employee at a privately-owned company).

Several respondents experienced technical weaknesses with the MSA. The interface was not like that of a real smartphone application, but more like a website. It was perceived to be slow, and some respondents had to log in every time which was time-consuming. The login procedure was too complicated and quickly forgotten if business trips were not made very often. When these problems arose, some respondents perceived that they did not get enough technical support. Despite these

limitations, respondents were generally positive towards the MSA and maintained that there is a need for a better system than the current solutions.

> … I believe in these kinds of trials ... but as the MSA looks right now it needs to be improved before it can be used on a large scale. (employee at a non-profit organisation).

Although it seems obvious that developers of MSA:s should take functions and technical sufficiency seriously, it seems that the development of increasingly sophisticated MSA:s (both in terms of functions and interface) also leads to higher expectations and demands from users. The respondents often compared the evaluated MSA with existing travel applications provided, for example, by the national passenger train company SJ, with comments such as: 'The MSA must be easy to use, much like SJ's app'. Thus, a better concept for business trips must also be combined with a user-friendly interface and technical sufficiency.

5.2.4. Summary

In summary, the interviews highlighted the importance of facilitating organisational conditions that favour sustainable business travel. Management needs to take responsibility for implementing and anchoring a travel policy, making sustainable transport accessible, and creating an organisational culture that encourages pro-environmental behaviour, and lead by example. The respondents who used the MSA were generally positive to it as a means of managing business travel. The automatic handling of travel expenses was especially appreciated, but there were also shortcomings (technical and functional) that prevented use as well as wishes to include a greater range of transport services. The results also show that an MSA needs to be integrated with existing systems and guidelines to avoid conflicts that might otherwise occur to the user.

6. Discussion

This study aimed to evaluate a new MSA for business trips within the context of organisational travel management and practices. The findings suggest that participants were generally positive towards the MSA and that there is potential to improve conventional systems managing business trips. Still, there is a heterogeneity aspect of users and actors to consider when designing interventions promoting sustainable business trips. Different levels of actors influence practices related to business travel, and our findings demonstrated the importance of involving the management in the facilitation of travel policies, travel cultures, and other facilitating conditions such as convenient accessibility to sustainable modes of transport and discouragement of unsustainable ones. New MSAs must be compatible with existing systems within the business travel practice, be well functioning and perceived as an improvement compared to the conventional system, to be utilised. This study also demonstrates some methodological challenges with evaluating new mobility applications. We discuss these issues in more detail below.

6.1. Evaluating the MSA

The survey results indicated that effort expectancy got more favourable for MSA users, providing tentative results that the intervention could have increased the ease associated with the use of sustainable business trips. This insight was reinforced by the interviews where several respondents stated that the MSA made it easier to travel by public transport, partly because of the automatic handling of travel expenses. At the same time, many stated that the MSA had several shortcomings that need to be addressed to make it competitive. In addition to the purely technical aspects, the MSA was expected to offer more ticket options and be easier to use. An important reason for not using the MSA was that existing business travel booking systems were either procured and thus employees had to use that service, or that existing booking systems were more flexible and offered more personalised service. Earlier research has stressed the need to adjust interventions to the need of the user and to contextualise content to make it more relevant to the user [56–58]. While it often is more practical to develop one system for all, previous research has stressed the need to adapt systems for users with diverging needs and expectations in order to increase the uptake of

interventions for sustainable mobility [14]. Some respondents in this study felt that the current booking system has an advantage in that it offers personalised service, which includes not only the trip itself but also the booking of overnight stays. Should problems arise, it can be felt like security to be able to contact a booking manager who can solve the situation. However, several pointed out that the current system also had its shortcomings and that there was a potential to introduce a booking system similar to the evaluated MSA, especially if such a system made it possible to book several different types of transport services, and also accommodation. From the responses to the survey to judge, there also seems to be reasons to include the possibility of booking virtual meetings in such an MSA.

There are many factors that play a role in the choice of transport, which is hardly controlled by just one application. However, it seems that the current business travel management system lacks features that make it easy to make sustainable travel choices. Thus, there should be potential for new systems that are designed in line with the user's preferences and needs, while at the same time facilitating sustainable business travel.

6.2. The Crucial Organisational Context

From the interviews, it became clear that business travel is produced within an organisational context that differs significantly between organisations. Travel policy, access to travel modes and to virtual meetings, and organisational culture are all contextual factors beyond the individual's direct influence when deciding whether to go travelling or not, or choosing means of transport for a business trips. These factors are determined by the management, who was often referred to by employees as a cause for weak compliance to sustainable business trips. Although the majority of organisations had a travel policy, many respondents claimed that employees either did not follow it or knew it existed and that this was often ignored by management. The important role of managers in promoting sustainable business trips have been stressed in earlier research. Gustafson [26] found that travel managers often operate below management and that one reason for weak compliance with travel policies is employees' high levels of autonomy over business trips decisions. They prioritise travel time, comfort and convenience over costs and environmental impact. Further, senior staffs and managers might not support the travel policy in practice. As pointed out by Gustafson [26], travel managers often have lower hierarchical positions and lower status than many of the travellers whose travel they are supposed to manage. Lo et al. [17] found that social norms and managerial control were more important in determining business travel frequency and mode choice than commuting travel mode choice.

Although organisations differed on travel policies for business travel and how these are applied in practice, there were examples indicating that a well-established travel policy, incentives that promote cycling and public transport in combination with restrictions on car travel, and the development of an organisational culture that promotes sustainable business travel, creates the favourable conditions for employees to make more sustainable business trips, or to choose a virtual meeting alternative.

6.3. Methodological Reflections

Although the offer to participate in the study was given to a relatively large sample (n = 525), the proportion of participants who used the MSA and completed the surveys was too small to adequately analyse the quantitative effects of changed travel behaviour as a result of the MSA. The participants who did use the MSA and completed the surveys (n = 35) were already travelling more with public transport compared to the non-users. This was also true for the respondents in the interviews. One weakness was that the researchers in the project were not the ones who introduced the MSA to the participants, but it was done by practitioners linked to the organisations. This reduced the ability to control the representability of respondents. The share of MSA users (18% of the respondents making business trips) is in line with the theory of diffusion of innovation estimating the segments of innovators and early adopters to 20% [59], indicating a bias in the analysed sample towards these groups. The problems with attrition and self-selection bias in app-based intervention

research have been raised in another paper of this issue [60]. As put forward by these authors, it is challenging to retain participant's interest over time, especially for app-based interventions that suffer from higher dropout rates than other interventions due to a gradual loss of interest in new applications. Moreover, self-recruitment of participants "tends to raise interest in already motivated subgroups of the general population, frequently individuals with high environmental awareness and pro-environmental attitude who may even have already adopted sustainable consumption patterns…" [60]. The participants in this study were recruited from organisations, which is usually an advantage considering that management can encourage participation and thus increase both the number of participants and the heterogeneity of these. In the current case, the engagement of management differed between organisations and a lesson is thus to secure their involvement to increase participation rates. The issue of dropouts was evident in this study as well; only 35 of 193 respondents used the MSA for the full test-period. The dropout was also due to the fact that the MSA had technical weaknesses, and that some participants already had sufficient tools to manage their business travel. Therefore, future studies should carefully consider what type of information and incentives could increase participation.

7. Conclusions

The evaluation of a new MSA to support sustainable business travel indicates that the intervention was mostly used for local and regional public transport trips and that it may have made it easier to travel by public transport. When implementing a new system, it is essential to take into account factors that can be influenced by both the intended user and the organisational context in which the system is intended to be implemented. Specifically, we present three factors that affect the success of a new MSA as a means of increasing sustainable business trips: management control and proactiveness; perceived improvement of intervention, and; functions and technical sufficiency. The results highlight the crucial role of management that should take responsibility for establishing a sustainable travel policy, making sustainable transport accessible and creating an organisational culture that encourages environmentally friendly behaviour.

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Paper III

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The effect of marketing messages on the motivation to reduce private car use in different segments

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ABSTRACT

This study explores marketing messages promoting sustainable transport and reported motivation to reduce private car use within different segments. A stated preference survey targeting a sample of 1300 residents in Sweden was conducted, and exploratory factor analysis was used to identify underlying dimensions of a set of 19 marketing messages. Self-efficacy and collective efficacy were defined as latent factors, and the latter was found to be a better motivator for all segments. For the most car-advocating segment, however, the factors (both self- and collective efficacy) was unsuccessful in inducing any reported motivation to reduce private car use. Assimilation bias seems to influence the respondent's interpretation of marketing messages.

1. Introduction

Transport systems in many cities today face challenges related to congestion and air pollution. Furthermore, the global transport sector accounts for 25% of CO_2 emissions from fuel combustion and contributes most to global warming after electricity and heat production (IEA, 2018). In order to meet emission reduction targets for the transport sector, a variety of measures within vehicle efficiency, alternative fuels, and behavioural changes are needed (IPCC, 2014; Stanley et al., 2011).

Although there have been, for some time now, a wide agreement among transport professionals that private car use needs to decrease in order to reduce the negative externalities from transport (Schwanen et al., 2011), little has been accomplished in this field (Banister, 2008). Despite encouragement and economic incentives to replace car trips with sustainable transport modes, research and practice have found a substantial resistance from people to reduce car use (Innocenti et al., 2013; Lattarulo et al., 2018). There is an evident perception-gap between what ought to be done to reach transport climate goals, and the commitment toward these goals from key actors within society (Cohen et al., 2016; Gössling et al., 2018). On the one hand, governments fear to introduce regulation forcing pro-environmental behaviour on people due to the risk of losing precious political capital (Ockwell et al., 2009). On the other hand, demanding individual responsibility ignores the social and structural conditions that prevent people from acting (Andersson et al., 2020).

One strategy used by cities and municipalities has been to conduct campaigns that encourage voluntary travel behaviour change and facilitates support for car-restricting policies. Such campaigns have been applied in several European cities with positive outcomes (reductions in private car use of around 10%) (Banister, 2008). In Sweden, persuasive messages are often included as part of the campaigns. An example is the bicycle campaign launched by the city of Malmö that used the message 'inga löjliga bilresor' (no ridiculous car trips) to influence social norms related to driving. However, these types of messages are not common in non-Scandinavian countries, which may represent an unused potential for use in transport demand management contexts. Further, studies on the effect of such messages are relatively uncommon in transport research, although with some exceptions (e.g. Beale and Bonsall, 2007; Hess and Bitterman, 2016). For example, Mir et al. (2016) found that communicating the consequences of air pollution could provoke individuals to act more environmentally friendly and influence the intention to use more sustainable modes of transport. Likewise, some studies have explored the effect of different framing interventions, such as CO_2 valence framing (Avineri and Waygood, 2013; Waygood and Avineri, 2018), and fiscal versus environmental messages (Cohen--Blankshtain, 2008).

To increase the efficiency of campaigns, market segmentation has been identified as a tool to enable target-specific information and

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Table 1
Description of segments (from Semanjski and Gautama (2016)).

	Segment	Short description
High-car accessibility	Devoted drivers	Do not intend to reduce car use and think successful people drive. They do not use public transportation, nor cycling, and think walking is too slow. They are not motivated by fitness and have a very low moral obligation to the environment.
	Image improvers	Like to drive, see the car as a way of self-expression and do not want to cut down car use. They do not use public transportation but see cycling as a way of expressing themselves and a good way to keep fit. They have neutral or moderate environmental attitudes.
	Malcontent motorists	They do not like to drive and find it stressful. They have moderately strong intention to reduce car use but are not motivated to increase the use of public transport, although they prefer it more than cycling. They walk but do not see any advantage to walking, except for fitness. They have a small level of environmental consciousness.
	Active aspirers	Have a high moral obligation to the environment and are highly motivated to use active transport modes, predominantly cycling, as they believe that it is quick and provides freedom and fitness. They are not public transport users and see problems with using it.
	Practical travellers	They use a car only when necessary as they think that it reduces the quality of life. They prefer cycling to the use of public transportation and would walk when it seems more practical. They are not motivated by climate change and see local pollution and congestion as issues. They are highly educated and above-average part-time working.
Low-car accessibility	Car contemplators	They do not use a car, have the highest proportion of non-driving licence owners, but would like to as they see cars as status symbols. They see many problems with public transportation use and find it, the same as cycling, stressful. They believe walking is healthy and have a neutral or moderate attitude towards the environment.
	Public transport dependents	They think people should be allowed to use cars and would like to see less congestion (they consider more roads as an appropriate solution). They use public transport, although they perceive it to be slow. They do not cycle but would like to walk more for fitness. They are not motivated by the environment and are the least likely to start driving.
	Car-free choosers	They think that cars lead to unhealthy lifestyles and do not like to drive. They prefer cycling as they feel a high moral obligation to the environment. Alternatively, they will choose public transport, which they do not consider stressful nor problematic, and walking. They are more likely to be women.

incentives to groups that are more susceptible for its meaning (Andersson et al., 2018; Haustein and Hunecke, 2013). Although the use of market segmentation to promote sustainable transport has increased significantly in recent years (Li et al., 2013; Poortinga and Darnton, 2016; Thøgersen, 2018), few studies have investigated how marketing messages related to sustainable transport are received among different segments (Cheng et al., 2011; Hess and Bitterman, 2016).

Thus, the overall purpose of this study is to gain a better insight into how messages and segmentation can be used to promote sustainable transportation. More specifically, the aim is to evaluate how marketing messages that have been used to promote sustainable transport influence segments reported motivation to reduce private car use. A further aim is to identify underlying dimensions that affect the interpretation of such messages in order to understand how sustainable transport can be promoted more effectively.

2. Literature review

2.1. Transport-related segmentation

Local authorities with constrained budgets need evidence on which specific groups of car users are more inclined to change travel habits, in order to help them introduce policies that have a significant impact on car use (Ali et al., 2018). In Europe, MaxSumo is one example of a segmentation-model that has been used within mobility management-campaigns (Hiselius, 2014; Van Acker et al., 2013). MaxSumo segment populations based on behaviour change stages inspired by The Transtheoretical Model (TTM) (Prochaska and Diclemente, 1986; Prochaska and DiClemente, 1983). Several segmentation studies have used stated preference surveys based on attitudes, for instance towards mobility, health, and climate change (see for example Anable, 2005; Prillwitz and Barr, 2011; Li et al., 2013; Poortinga and Darnton, 2016; Thøgersen, 2018). Another example is the European project SEGMENT, in which a tool for consumer market segmentation was developed based on the Theory of Planned Behaviour. SEGMENT was created to increase the efficiency of mobility management-campaigns that aim to persuade people into changing travel behaviour and adopt more energy-efficient forms of transport (Anable and Wright, 2013). Semanjski and Gautama (2016) took this model further when they successfully mapped the segments in crowdsourced mobility data, collected via smartphones. This could enable the delivery of personalised messages to individuals belonging to specific segments (Andersson et al., 2018).

2.2. Marketing pro-environmental behaviours

Messages promoting pro-environmental behaviours have typically been researched in relation to environmental, health, and economic benefits (Avineri and Waygood, 2013; Bolderdijk et al., 2013; Loureiro and Veloso, 2017; Nisbet and Gick, 2008; Steinhorst and Klöckner, 2017). Campaigners have used the same dimensions when framing messages promoting sustainable transport in Sweden (Hiselius and Rosqvist, 2015). Acting environmentally friendly can boost an individuals' status, and have been shown to impact peoples' behaviour (Milinski et al., 2006), particularly when altruistic behaviour of conservation could be exposed to social networks and affect ones' reputation (Griskevicius et al., 2010; Steg et al., 2014). Earlier research outside the transport domain has compared the outcome of environmental and economic messages for promoting pro-environmental behaviour, concluding that messages emphasising the environment outperform economic messages in terms of inducing attitude and behaviour change (Bolderdijk et al., 2013; Steinhorst and Klöckner, 2017).

Marketing research has demonstrated that attitudes toward advertisement influence attitudes toward what is advertised (for a meta-analysis, see Brown and Stayman, 1992), meaning that effective advertisement can shape opinions about a brand, through brand cognition (consumers' perception of a brand) as well as brand recognition (consumers' ability to recognise a brand). Some researchers have suggested that the liking of an ad may be the best indicator of advertisement effectiveness (Haley and Baldinger, 2000). However, the response to a persuasive message is related to both emotional and evaluative dimensions of pre-communication attitudes, which also play a role in determining attitudes to what is advertised (Abou-Zeid and Ben-Akiva, 2012; Petty and Cacioppo, 1986). If people find persuasive messages to align with their attitudes and behaviours, they are more

Table 2
Comparison of demographic characteristics between the segments.

	High-car accessibility					Low-car accessibility		
	1. Devoted Drivers 15%	2. Image Improvers 25%	3. Malcontent Motorists 15%	4. Active Aspirers 11%	5. Practical Travellers 17%	6. Car Contemplators 2%	7. PT Dependents 4%	8. Car-free Choosers 11%
Women	41%[8]	44%[8]	44%[8]	56%	47%[8]	45%	59%	65%[1,2,3,5]
18-30	16%[8]	18%[8]	22%[8]	19%[8]	20%[8]	42%	38%	44%[1,2,3,4,5]
31-50	36%	37%	33%	38%	39%	32%	25%	35%
51-65	25%	30%[8]	23%	26%	21%	26%	25%	13%[2]
>65	23%[6,8]	14%[6]	23%[6,8]	17%[6]	21%[6,8]	0%[1,2,3,4,5,8]	12%	8%[1,3,5,6]
Kid(s) at home	29%[6,7]	36%[6,7,8]	27%[7]	35%[6,7,8]	38%[6,7,8]	10%[1,2,4,5]	10%[1,2,3,4,5]	17%[2,4,5]
Married/live with a partner	69%[8]	74%[7,8]	64%	71%[8]	73%[7,8]	55%	43%[2,5]	46%[1,2,4,5]
Elementary	26%[4,5,8]	18%	17%	12%[1]	13%[1]	20%	12%	11%[1]
Upper secondary	33%[4,5]	31%[4,5]	20%	18%[1,2]	19%[1,2]	23%	37%	26%
University degree	41%[3,4,5,8]	51%[4,5]	63%[1]	70%[1,2]	68%[1,2]	57%	51%	63%[1]
Studying	3%[4,7,8]	6%[8]	8%[8]	12%[1,8]	10%[8]	29%	27%[1]	28%[1,2,3,4,5]
Working	63%	69%[8]	59%	63%	63%	58%	55%	54%[2]
Retired	24%[6,8]	15%[6]	24%[6,8]	19%[6]	21%[6,8]	0%[1,2,3,4,5,8]	14%	9%[1,3,5,6]
Main city	50%[5,7,8]	56%[5,7,8]	64%[8]	58%[7,8]	72%[1,2]	60%	82%[1,2,4]	84%[1,2,3,4]
>5000 inhabitants	17%	14%	16%	15%	15%	33%	14%	14%
<5000 inhabitants	33%[5,6,7,8]	30%[5,6,7,8]	20%[7,8]	27%[5,6,7,8]	13%[1,2,4,8]	7%[1,2,4]	4%[1,2,3,4]	3%[1,2,3,4,5]
Drivers' license	99%[6,7,8]	98%[6,7,8]	94%[6,7,8]	94%[6,7,8]	97%[6,7,8]	61%[1,2,3,4,5]	64%[1,2,3,4,5]	66%[1,2,3,4,5]
Access car	97%[3,4,5,6,7,8]	97%[3,4,5,6,7,8]	86%[1,2,6,7,8]	87%[1,2,6,7,8]	89%[1,2,6,7,8]	36%[1,2,3,4,5]	31%[1,2,3,4,5]	22%[1,2,3,4,5]
Access bike and/or e-bike	66%[2,4,5,8]	94%[1,3,7]	72%[2,4,5,8]	95%[1,3,7]	96%[1,3,7]	82%	53%[2,4,5,8]	91%[1,3,7]
Access bus and/or rail stop within 500 m	71%[7,8]	75%[7,8]	82%[8]	80%[7,8]	83%[8]	91%	95%[1,2,4]	98%[1,2,3,4,5]

Items in superscript indicate which means are significantly different from each other (ANOVA Post Hoc analysis (Tamhane's T2) searching for differences among all combinations of groups ($p < 0.05$)).

likely to accept the message, which in turn increase the likelihood of the message being considered and part of the receivers' attitude-construct (Petty and Cacioppo, 1986), also referred to as assimilation bias (Lord et al., 1979; Whitmarsh, 2011). A study that investigated marketing for public transport found that the impact of marketing crucially depends on the attitudes and beliefs of individual consumers (Beale and Bonsall, 2007). It is, therefore, reasonable to assume that people will respond differently to a given marketing message depending on their structure of attitudes and behaviours.

The goal of any marketing effort is to influence peoples' attitudes to stimulate corresponding behaviours. For several decades, researchers have attempted to explain the attitude-behaviour relationship (see for example Ajzen, 1991; Ajzen and Fishbein, 1970), and it has been established that attitudes have an impact on behaviour, as long as the individuals have the possibility to perform the predicted behaviour (Kim and Hunter, 1993). The magnitude of this relationship depends on several factors. According to a meta-analysis by Glasman and Albarracín (2006), attitudes correlate with behaviour more strongly when they are easy to recall (accessible), and stable over time. For that reason, direct experience (such as trials), which increase accessibility to the attitude object, predict future behaviour more strongly. The authors also found that the attitude-behaviour relation was strongest when attitudes were confident, information was relevant, and when information about the attitude object was one-rather than two-sided. Research also suggests that advertisement repetition systematically can influence attitude-behaviour consistency and that repeated ad exposures can be just as predictive of subsequent behaviour as direct experiences (Berger and Mitchell, 1989). Despite the significant advertisement-attitude-behaviour relationship, it is important to recognise the limitations of this chain in changing persistent behaviours. This has been evident in the case of environmental issues, especially travel behaviour, where a pro-environmental attitude does not guarantee pro-environmental behaviour, resulting in the 'attitude-behaviour gap' (Geng et al., 2016; Polk, 2004).

3. Methods and data

The data collection consisted of a web survey, which included questions about demographics, accessibility, segmentation, and marketing messages. Exploratory factor analysis and significance tests were conducted to analyse the results. The following sections present more details about the survey, the marketing messages, the model used for segmentation, and the statistical analyses.

3.1. Web survey

A web-based stated preference (SP) survey was designed to collect the data. SP methods are commonly used to analyse and predict human behaviours in hypothetical scenarios (Loureiro et al., 2003), and was chosen because it enabled us to explore the complex relationships between respondent's attitudes, segmentation profile, and cognitive motivation when exposed to marketing messages. These concepts would be extremely difficult to capture through a revealed preference study, particularly with adequate sample size.

The survey was conducted with the help of Swedish Kantar Sifos' probability-based internet panel consisting of approximately 100,000 inhabitants 16–79 years of age. The panel members are randomly recruited through nationally representative telephone surveys, and the panel is continuously filled with new members to prevent them from becoming survey 'experts'. The panel members are recruited by e-mail with a link to the questionnaire and if they choose not to participate, another panel member is contacted instead. Those who agree to participate receive compensation in the form of bonus points that can be redeemed for movie tickets or gift cards.

The sample was stratified to match the national conditions regarding gender and age, and analytical weights were used to adjust for potential skewness. These weights were used to compensate for the over-representation of respondents with higher education (the sample had 10% more highly educated participants than the Swedish average) and the underrepresentation of older respondents. The geographical scope was limited to seven out of the nine municipality groups according to the

Table 3
Marketing messages used in the study (n = 994). Theme abbreviations: $ = economy, E = environment, H = health, S = status.

Marketing message	Theme	Mean	SD
1. We all must help to reduce our climate footprint. The result will be a sound environment that future generations also need!	E	3,73	1103
2. Those who mostly walk, cycle or ride transit are doing something good for the environment.	E	3,64	1085
3. Research shows that public transport users are walking on average four times more per day than do car drivers, therefore reducing the risk of acquiring severe non-communicable diseases.	H	3,60	1082
4. Those who cycle and go by public transport not only improve their health but also contribute positively to other people's health.	H	3,57	1079
5. Did you know that cyclists have a 52% lower risk of dying of heart disease and a 40% lower risk of dying from cancer?	H	3,53	1131
6. You save about 350 euro per month if you live without a car and instead go by public transport and even more so if you cycle or walk.	$	3,37	1235
7. Bicycles run on fat and save you money. Cars run on money and make you fat!	H, $	3,37	1272
8. If Sweden is to achieve its climate targets, then generally every third car trip must be replaced with more environmentally friendly alternatives.	E	3,36	1191
9. By cycling instead of taking the car to work, you save money and contribute to society at the same time! Try it!	$	3,28	1164
10. The car traffic in Sweden induces a socio-economic loss above 10 billion euros in adverse health effects.	H	3,21	1165
11. In the government budget, support for investments in cycling infrastructure increased by 50 million euros in 2018.	$	3,17	1184
12. If you want to improve your health, you should ride a bicycle instead of driving a car. If the distance is a problem, then an electric bike can be an option.	H	3,14	1194
13. Many Swedes use public transport to get to school or work every day. Thanks!	S	3,13	1184
14. It may seem inconvenient, but studies show that over 60% of those who test an electric bike continue to use it!	–	3,08	1080
15. The environmental impact per bus passenger is only 65% of the private car user in rural areas and 40% in urban areas.	E	3,04	1088
16. Beginning in 2018, you can get 25% of the cost subsidised by the government when purchasing a new electric bicycle.	$	3,02	1279
17. The car used to be a status symbol, but today other values are more important, such as taking care of oneself and the environment. Such values are usually related to cycling or public transport.	S	2,95	1175
18. Few things today can be considered more modern and prestigious than commuting by bicycle.	S	2,62	1137
19. Swedish Olympic champion Björn Ferry has decided to be fossil-free in 2025. If he can do it you can!	S	2,59	1182

classification made by the Swedish Association of Local Authorities and Regions (2016). The two excluded municipality groups consist of rural municipalities where the population is less than 15,000 inhabitants in the largest urban area or where the commuting rate for work outside of the municipality is low (less than 30%).

From this panel, 1300 individuals 18–65 years that usually commute to school or work were recruited to participate. The questionnaire was fielded in February 2018. To ensure all analyses were based on the same individuals, an analytical sample was defined, including only individuals with valid information (i.e. no missing responses) for all variables used in the statistical analyses (n = 1185). Further, mischievous respondents (MRs) who knowingly make phoney responses meant to cheat the researcher, were removed by applying Hyman and Sierra (2012) distribution-free, sample-size-unconstrained, backwards-stepping MR algorithm. The lowest variance deletion rule was used to clean the data (Thøgersen, 2018). The respondents were considered mischievous if the variance of their responses to the 19 message items was below 0.25 (16% of the sample). This reduced the analytical sample to 994 individuals.

The questionnaire involved four parts: 1) the sociodemographic characteristics of the respondents; 2) their accessibility to travel modes, driver's license, and their daily commuting trip length and modal choice; 3) attitudinal questions used for the segmentation, retrieved from Anable and Wright (2013); and 4) the marketing messages.

3.2. Marketing messages

The framework for the marketing messages was established through a literature review, including studies that used marketing messages to promote pro-environmental behaviours. Four themes were found, namely economic (Bolderdijk et al., 2013; Steinhorst and Klöckner, 2017); environmental (Avineri and Waygood, 2013; Hiselius and Rosqvist, 2015); health (Loureiro and Veloso, 2017; Nisbet and Gick, 2008); and status (Griskevicius et al., 2010; Milinski et al., 2006). The literature was supplemented with marketing material from campaigns previously carried out to promote sustainable transport in Sweden. Such material was found at regional public transport authorities, municipalities working with Mobility Management, train operators, and organisations supporting bicycling and public transport. 19 marketing messages were selected and some were adjusted to fit the themes of economy, environment, health, and status. The messages are presented in the result section (Table 3).

Respondents were asked to assess their level of motivation to decrease private car use on a five-point Likert scale, from 'very unmotivated to decrease my car use' to 'very motivated to decrease my car use', in line with the scale used by Waygood and Avineri (2018). Respondents that already had low or no car use had a slightly adjusted scale: 'very unmotivated to *keep* my low level of car use', and 'very motivated to *keep* my low level of car use'. Unfortunately, it was not possible to control for the fact that respondents were exposed repeatedly to messages promoting sustainable transport since that information was missing in the data material received from the provider of the internet panel. This could constitute an exposure bias and affect the validity of the responses. However, the marketing messages were randomised for all respondents; thus, if there would be an exposure bias, we can assume it not to affect the relative outcome between the messages.

3.3. The SEGMENT-model

The SEGMENT-model consists of eight segments, five with high accessibility to a car and three with low accessibility. A description of each segment is provided in Table 1. By answering a set of 18 questions (see Appendix A), respondents are assigned to one of the segments. The authors behind the SEGMENT retrieved the 18 questions through discriminant analysis from more than 10,000 questions (Anable and Wright, 2013). The responses that people indicate to each item are weighted to determine the appropriate segment for them. For a full description of the segmentation procedure, see Anable and Wright (2013).

3.3.1. Demographic characteristics and modal split in the sample

The segments' socio-demographics and stated travel behaviours for school and work trips are presented in Table 2 and Fig. 1, respectively. These data reveal two things of particular interest for the study: First, the socio-demographics differ most between the two groups of segments with high and low accessibility to a car. The segments with low accessibility to a car (low-car group) are younger, have fewer kids living at home, and are studying more, indicating they are in an earlier life phase than the segments with high accessibility to a car (high-car group). Further, the low-car group drive less than the high-car group, suggesting a relationship between being young and driving less. However, this relationship does not predict what mode of transport replaces the car.

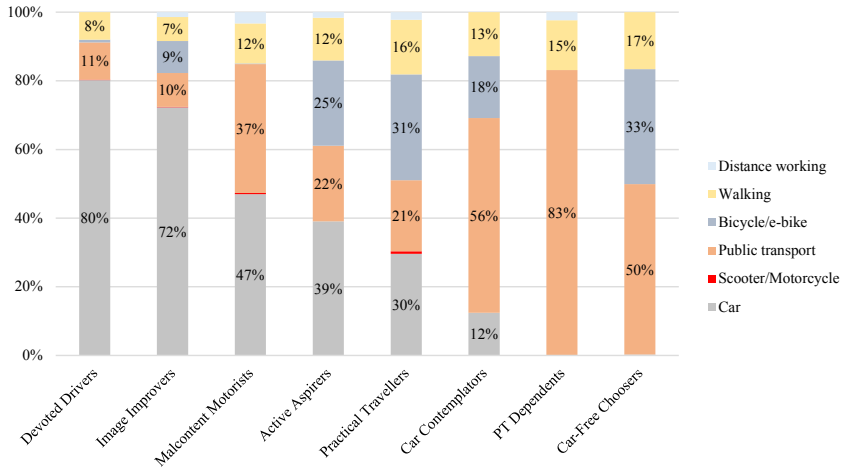

Fig. 1. Modal split of the segments school and work-journeys.

Secondly, within the high-car group, the relevance of socio-demographics to travel behaviour is low; modal choice differs significantly between high-car segments even though socio-demographics are similar. Although this is not a new discovery, it does indicate the important influence of attitudes on the choice of means of transport. Attitudes that can be influenced by marketing, as already discussed in section 2.2.

3.4. Statistical analyses

To investigate whether any common denominators unite the marketing messages, exploratory factor analysis was conducted. It is a statistical tool to identify a smaller number of 'underlying dimensions that are too subtle and complex to be easily observed and measured' (Cervero and Kockelman, 1997). Because EFA is exploratory, it suits well with an inductive research approach. The Kaiser-Meyer-Olkin measure confirmed the sampling adequacy for the analysis (KMO = 0.95), indicating that patterns of correlations are very compact, and so factor analysis should return distinct and reliable factors (Field, 2013).

A principal axis factor analysis was conducted on the 19 items with oblique rotation (Promax). Oblique rotation was chosen since we expected the factors to be correlated, which is not accounted for in orthogonal rotation that assumes factors to be independent (Pituch and Stevens, 2016). The correlation matrix with a two-factor solution supported this assumption, by revealing a reasonably large correlation between factor 1 and factor 2 (0.739) indicating that independence between factors cannot be assumed and that the oblique rotation probably provides a better representation of reality than an orthogonal rotation. This seems reasonable given that people who are more positive about reducing private car use would probably indicate a stronger motivation in general, regardless of the type of message exposed to them.

The factor loadings indicate the substantive importance of a given variable to a given factor and interpretation of loadings with an absolute value greater than 0.35 is considered appropriate (Field, 2013). The results from the EFA is presented in the results section (Table 4).

4. Results

4.1. Reported motivation to reduce private car use when exposed to marketing messages

Descriptive statistics of the messages are presented in Table 3. The mean represents the reported motivation to decrease private car use (5 = very motivated), sorted in descending order. The results indicate that marketing messages appealing to intrinsic motivation, such as environmental and health issues, induce more motivation than messages related to extrinsic motivation, such as economy and status (mean values; environment 3.51, health 3.44, economy 3.27, and status 2.76). This finding goes in line with previous research that has compared the outcome of environmental- and economic messages for promoting pro-environmental behaviour (Bolderdijk et al., 2013; Steinhorst and Klöckner, 2017). However, the perception of messages is influenced by more than just the theme in question (e.g. health or status). Framing, for instance, can influence how people respond to equivalent descriptions of the same critical information (Waygood and Avineri, 2018). This is evident for the themes investigated here because reported motivation varies for items within the same theme, ranging from 0.69 for environmental messages to 0.35 for economic messages. Thus, in order to investigate associations to underlying variables, we now turn to the exploratory factor analysis.

4.2. Exploring latent variables through factor analysis

The EFA was performed to investigate whether any latent variables capture multiple marketing messages. An initial analysis was run to obtain eigenvalues for each factor in the data. Two factors had eigenvalues over Kaiser's criterion of 1 and in combination explained 50,49% of the variance. Table 4 shows the factor loadings after rotation.

The items that cluster on the same factor suggest that factor 1 represents personal health, financial benefits, convenience, and status. Overall, these items point toward the individual gaining utility from using sustainable transportation, and that one should act pro-environmentally for reasons related to self-interest. On the contrary, the items related to factor 2 seems to be related to concerns of the environment, health (both personal and societal), collective responsibility, and morality. Note that the theoretical themes found in the

Table 4
Results from exploratory factor analysis for the marketing messages (n = 994).

Item	Theme	Factor pattern matrix	
		1 (Self-efficacy)	2 (Collective efficacy)
If you want to improve your health, you should ride a bicycle instead of driving a car. If the distance is a problem, then an electric bike can be an option.	H	**.78**	-.06
It may seem inconvenient, but studies show that over 60% of those who test an electric bike continue to use it!	–	**.77**	-.16
By cycling instead of taking the car to work, you save money and contribute to society at the same time! Try it!	$	**.66**	.14
Bicycles run on fat and save you money. Cars run on money and make you fat!	H, $	**.6**	-.00
You save about 350 euro per month if you live without a car and instead go by public transport and even more so if you cycle or walk.	$	**.57**	.10
Did you know that cyclists have a 52% lower risk of dying of heart disease and a 40% lower risk of dying from cancer?	H	**.55**	.17
Beginning in 2018, you can get 25% of the cost subsidised by the government when purchasing a new electric bicycle.	$	**.54**	-.06
The car used to be a status symbol, but today other values are more important, such as taking care of oneself and the environment. Such values are usually related to cycling or public transport.	S	**.48**	.27
Few things today can be considered more modern and prestigious than commuting by bicycle.	S	**.45**	.16
In the government budget, support for investments in cycling infrastructure increased by 50 million euros in 2018.	$	**.43**	.26
Swedish Olympic champion Björn Ferry has decided to be fossil free in 2025. If he can do it you can!	S	**.37**	.21
We all must help to reduce our climate footprint. The result will be a sound environment that future generations also need!	E	-.11	**.84**
If Sweden is to achieve its climate targets, then generally every third car trip must be replaced with more environmentally friendly alternatives.	E	-.10	**.83**
Those who mostly walk, cycle or ride transit are doing something good for the environment.	E	-.03	**.77**
Those who cycle and go by public transport not only improve their health but also contribute positively to other people's health.	H	.13	**.66**
The car traffic in Sweden induces a socio-economic loss above 10 billion euros in adverse health effects.	H	.05	**.65**
The environmental impact per bus passenger is only 65% of the private car user in rural areas and 40% in urban areas.	E	.08	**.64**
Research shows that public transport users are walking on average four times more per day than do car drivers, therefore reducing the risk of acquiring severe non-communicable diseases.	H	.24	**.4**
Many Swedes use public transport to get to school or work every day. Thanks!	S	.29	**.36**
Eigenvalues		8,23	1,36
% of variance		43.33	7.16
Cronbach's α		.87	.88

Note: Factor loadings equal to or greater than 0.35 appear in bold.

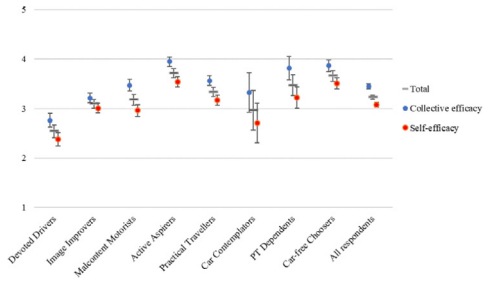

Fig. 2. Segments reported motivation to decrease private car use when exposed to marketing messages related to the latent factors of collective efficacy and self-efficacy. Means and 95% confidence intervals.

literature and referred to in many campaigns (economic, environmental, health and status) did not emerge explicitly in the factor solution. Instead, we can see the items linked to economy and status cluster to factor 1 and items relating to the environment cluster to factor 2. The items relating to health is divided, clustering to both factor 1 and 2. Health-items in factor 1 are related to personal health gains from using sustainable transport, while health-items that load on factor 2 are more linked to societal gains, except for the statement: *Research shows that public transport users are walking on average four times more per day than do car drivers, therefore reducing the risk of acquiring severe non-communicable diseases.* However, this item has quite a low loading and is therefore of relatively little importance to the factor structure compared to the other items. The same goes for the one message relating to the status-theme that cluster to factor 2: *Many Swedes use public transport to get to school or work every day. Thanks!*

Generally, the factor solution suggests an intrinsic/extrinsic motivation structure (Deci et al., 1999) and self-transcendent/self-enhancement value system (Wesley Schultz, 2001). Intrinsic motivation and self-transcendent values tend to be linked to collective efficacy and pro-environmental behaviour. Extrinsic motivation and self-enhancement values, on the other hand, are more linked to self-efficacy and less pro-environmental behaviour (De Dominicis et al., 2017). As such, we will refer to factor 1 as 'self-efficacy' and factor 2 as 'collective efficacy', two concepts that have been researched within a wide spectrum of pro-environmental behaviours (Chen, 2015; Reese and Junge, 2017). Self-efficacy focuses explicitly on the efficacy expressed by an individual and is defined as 'the belief in ones' capabilities to organise and execute the courses of action required to manage prospective situations' (Bandura, 1995, p. 2), while the definition of collective efficacy goes as 'a groups' shared belief in its conjoint capabilities to organise and execute the courses of action required to produce given levels of attainments' (Bandura, 1997, p. 477).

4.3. Motivational effect of messages related to self-efficacy and collective efficacy

To analyse the effect of messages related to self-efficacy and collective efficacy on motivation to reduce driving, mean scales were calculated for each factor. The Cronbach α for the mean scales was 0.87 and 0.88, respectively, indicating good internal consistencies (Nunnally, 1994). Fig. 2 shows the segments reported motivation to reduce private car use when exposed to the messages, divided into the two factors. The mean response from all 19 messages is included as a representation of the general motivation to reduce private car use for each segment (referred to as total). The impact of the messages related to self-efficacy and collective efficacy can then be measured as deviations from the general motivation.

Table 5
Significance tests between and within the segments.

Nr	Segment	Total (T)		Collective efficacy (C)		Self-efficacy (S)		Sig.		
		M	SD	M	SD	M	SD	T-C	T-S	C–S
1	Devoted Drivers	$2.54^{3,4,5,6,7,8,9}$	0.74	$2.76^{3,4,5,6,7,8,9}$	0.81	$2.38^{3,4,5,6,7,8,9}$	0.78	.000	.000	.000
2	Image Improvers	$3.01^{1,5,7,8}$	0.71	$3.21^{1,5,6,7,8,9}$	0.77	$3.01^{1,7,8}$	0.75	.000	.168	.000
3	Malcontent Motorists	$3.18^{1,7,8}$	0.67	$3.47^{1,7,8}$	0.73	$2.96^{1,7,8}$	0.72	.000	.000	.000
4	Active Aspirers	$3.71^{1,2,3,4,5,9}$	0.53	$3.95^{1,3,4,5,9}$	0.57	$3.54^{1,2,3,4,5,9}$	0.59	.000	.000	.000
5	Practical Travellers	$3.34^{1,2,7,8}$	0.63	$3.56^{1,2,7,8}$	0.68	$3.17^{1,7,8}$	0.7	.000	.000	.000
6	Car Contemplators	2.96^{8}	0.81	3.32	0.87	2.71^{8}	0.88	.004	.018	.006
7	PT Dependents	3.47^{1}	0.6	$3.82^{1,2}$	0.7	3.22^{1}	0.65	.000	.000	.000
8	Car-free Choosers	$3.66^{1,3,4,5,9}$	0.56	$3.86^{1,3,4,5,9}$	0.62	$3.51^{1,3,4,5,9}$	0.61	.000	.001	.000
9	All respondents	$3.23^{1,7,8}$	0.74	$3.45^{1,3,7,8}$	0.8	$3.08^{1,7,8}$	0.78	.000	.000	.000

Items in superscript indicate which means are significantly different from each other (ANOVA Post Hoc analysis (Tamhane's T2) searching for differences among all combinations of groups ($p < 0.05$)). Differences between T, C, and S explored through paired-samples *t*-test.

The results show that all segments report significantly higher motivation for the collective efficacy compared to both the self-efficacy and the total (significance tests are presented in Table 5). The self-efficacy variable, on the other hand, generates significantly less motivation to reduce driving than the total variable for all segments except for Image Improvers, where no significant difference was found between self-efficacy and the total variable.

There are differences between the segments reported motivation to reduce private car use on a general level. In particular, the Devoted Drivers seem not to be motivated by messages related to either self-efficacy or collective efficacy. Car Contemplators are positive towards collective efficacy, but negative towards self-efficacy (although the margin of error for this segment makes it uncertain). The rest of the segments show an overall positive attitude to the marketing messages. This is also true for the segments that are relatively car-dependent, such as the Image Improvers and Malcontent Motorists. Segments who mostly travel by modes of transport other than the car (e.g. Car-Free Choosers and PT Dependents) report the highest motivation, together with Active Aspirers, the segment with the highest total mean value of all segments, even though a third of the respondents in this segment actually use the car for work and school journeys on a regular day. Four segments deviate from the rest (all respondents). Devoted Drivers report significantly lower motivation for collective efficacy and self-efficacy, while Car Free-Choosers and Active Aspirers report significantly higher motivation. Image Improvers report significantly lower motivation for collective efficacy than the general sample. These differences indicate that the respondents in each segment judged messages according to existing preconditions; thus, evaluations were made to maintain initial beliefs about sustainable transport, in line with the psychological principle of assimilation bias (Lord et al., 1979).

5. Discussion and conclusions

These findings contribute to increased knowledge regarding the promotion of sustainable transport in two important ways. First, by breaking down multiple marketing messages into the two latent factors of self-efficacy and collective efficacy, and then comparing the effect of these two factors on motivation to reduce driving, gave clear indications that collective efficacy messages are superior at encouraging the use of sustainable transport instead of driving; knowledge that can be used by travel managers, municipalities, train and bus companies, and other actors working with campaigns. Second, by demonstrating the differences in how marketing messages are received by various segments we could clearly see the effect of assimilation bias, highlighting the need for aligning communication to fit the attitudes and behaviours of a selected target audience.

Although scarce within the transport research (Dastjerdi et al. (2019) is one exception), previous studies in other domains have stressed the importance of collective efficacy to motivate individuals to act pro-environmentally (Chen, 2015; Reese and Junge, 2017). Particularly encouraging are the results of Jugert et al. (2016), which showed that messages about collective efficacy increased perceptions of efficacy at the social *and* individual level, which in turn elevated personal intentions to act. If collective efficiency increases self-efficacy, it would be interesting to examine whether such communication can alleviate the notion of the 'social dilemma', where ones' efforts to tackle climate change may feel worthless by the inaction of others (Line et al., 2010). Furthermore, the fact that collective efficacy was almost exclusively related to environmental and health messages provides tentative support for addressing intrinsic values when promoting sustainable transport, a suggestion also put forward by authors conducting research on pro-environmental behaviour in other domains (Bolderdijk et al., 2013; Steinhorst and Klöckner, 2017).

In general, the findings suggest that people responded to the messages according to their pre-existing attitudes and behaviour, in line with assimilation bias. Therefore, we advocate further elaboration on segmentation and communication strategies to enable effective campaigns that target an audience susceptible to the idea of decreasing private car use. Clearly, it is not fruitful to convince Devoted Drivers to change transport mode with marketing since they oppose messages that promote sustainable transport. This goes in line with research stating that the will to change the means of transport is very low among 'persistent drivers' (Andersson, 2020; Beale and Bonsall, 2007; Lattarulo et al., 2018), suggesting that other measures are needed to influence this group. Instead, campaigns can be targeted at car-dependent segments that are open to alternatives, such as Image Improvers, Malcontent Motorists and Practical Travelers. Furthermore, it may be equally important to strengthen existing travel behaviour in younger segments already travelling by sustainable modes of transport, such as Car Contemplators, PT Dependents, and Car-Free Choosers, to increase the likelihood that they will continue to use sustainable modes of transport in later life stages.

There are some limitations to the present study. It is possible that higher community trust in Sweden made messages related to collective efficacy more appealing than would be the case in more individualistic societies with lower community trust, such as the United States. Thus, before these results can be generalised it is important to reproduce this kind of study in other countries. Future studies could seek to validate the factors retrieved from the EFA, as this is an exploratory method influenced by assumptions and interpretations. The SP method was used to collect data on individuals travel behaviour, accessibility, demographics, and motivation to decrease private car use when exposed to marketing messages. Revealed preferences, or a combination of SP and RP, would be preferable to validate the responses. It has, however, been demonstrated that stated preferences are a reasonably accurate guide to true underlying preferences and market behaviour (Lambooij et al., 2015; Loureiro et al., 2003; Wardman, 1988). Finally, though we used randomised order of messages and repeated measurements (several marketing messages within one theme-specific frame) this method entails a risk of social desirability bias that could influence the results

(Mcfadden et al., 2005).

Declaration of competing interestCOI

The authors declare that there have been no conflicts of interest concerning this article.

CRediT authorship contribution statement

Alfred Andersson: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing. **Lena Winslott Hiselius:** Funding acquisition, Conceptualization, Methodology, Supervision. **Emeli Adell:** Conceptualization, Methodology, Supervision.

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Appendix A

The questionnaire used for segmentation according to the SEGMENT-model.

Question	Scale
Q1: Have you driven a car or van in the past 12 months?	Yes; no
If Q1 = yes	
Q2: For most journeys, I would rather use the car than any other form of transport	strongly disagree; disagree; neither/nor; agree; strongly agree
Q3: I like to drive just for the fun of it	
Q4: I am not interested in reducing my car use	
Q5: Driving gives me a way to express myself	
If Q1 = no	
Q6: How likely are you to drive in the next 12 months?	very unlikely; quite unlikely; neither/nor; fairly likely; very likely
All	
Q7: I am not the kind of person who rides a bicycle	strongly disagree; disagree; neither/nor; agree; strongly agree
Q8: I feel I should cycle more to keep fit	
Q9: I find cycling stressful	
Q10: Cycling can be the quickest way to travel around	
Q11: I like travelling by bicycle	
Q12: I am not the kind of person that likes to walk a lot	
Q13: I feel I should walk more to keep fit	
Q14: I like travelling by walking	
Q15: I am not the kind of person to use the bus	
Q16: In general, I would rather cycle than use the bus	
Q17: I feel a moral obligation to reduce my emissions of greenhouse gases	
Q18: People should be allowed to use their cars as much as they like	

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Paper IV

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Is climate morality the answer? Preconditions affecting the motivation to decrease private car use

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A B S T R A C T

Persuasive messages are commonly used in campaigns promoting sustainable transport to motivate people to reduce private car use. This paper explores the preconditions affecting the motivation of people to reduce private car use when exposed to such messages. A sample of 1100 Swedish residents was analysed for the effect of variables related to accessibility, usual commute mode and attitudes. Significant variables were used to create a precondition index, which was cross-tabulated with demographic variables and stages drawn from the transtheoretical model. The results show that there are differences in the preconditions regarding motivation to reduce private car use between segments of the population. Results indicate that climate morality is the most critical factor affecting motivation, specifically the motivation of persistent drivers. Usual commute mode, car advocacy, health concern, attitudes towards cycling, car identity and travel time also influence motivation. Males, the middle-aged, people with low educational attainment, and rural residents have the least favourable preconditions concerning motivation to reduce private car use.

1. Introduction

Global transport CO_2 emissions continue to rise and constitute a quarter of the total emissions, with the highest absolute increase in road transport, which accounts for 74% of transport emissions (IEA, 2018). In Sweden, domestic transport is responsible for an even higher share (33%), mainly because electricity generation and heating in Sweden are less dependent on fossil fuels (Swedish EPA, 2018). Among the domestic transport emissions in Sweden, 93% comes from road transport, and the largest share of it (67%) comes from passenger transport (Swedish Transport Administration, 2019). Despite a broad agreement among politicians in Sweden that the transport sector needs to be de-carbonised, emissions continue to be more or less unchanged. To reach the climate target for the transport sector in Sweden (i.e. decrease in emissions from domestic traffic by 70% by 2030 compared with that in 2010), emissions from transport need to decrease annually by 8% (Swedish Transport Administration, 2019). Instead, CO_2 emissions increased by 0.3% in 2018, primarily because of the increased amount of passenger car kilometres, which counteracted the otherwise improved energy efficiency within the car fleet (Swedish EPA, 2018). Therefore, to reach the climate targets, the demand for private car use needs to decrease rapidly. Including the expected population growth, by 2050, it has been estimated that passenger car kilometres need to be reduced by a third in Sweden (Winslott Hiselius and Smidfelt Rosqvist, 2018).

At the time of this study, Sweden had almost 4.9 million passenger cars registered for use in traffic. These vehicles do not include light or heavy trucks, which are instead included in the statistics for freight transport. In 2008–2018, the car fleet expanded by approximately 12%, and according to Transport Analysis, a Swedish government agency for transport policy analysis, the trend is expected to continue in the coming years partly because of the projected population and gross domestic product increase (Transport Analysis, 2018). Bicycle sales have remained steady over the past ten years, but 38% fewer trips are now made by bicycles than in the 1990s (Svensk cykling, 2018). Similar to many other European countries, Sweden has had a significant increase in the sales of electric

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bicycles, which accounted for about 20% of the total bicycle sales in 2018.

Cars remain the dominant mode of transportation in terms of total passenger-kilometres. Nationally, car trips account for 72% of all trips. Public transport accounts for about 23%, and walking and cycling account for 2%, respectively (Transport Analysis, 2015). The large proportion of car journeys is a trend that is difficult to break. An average Swedish resident drives more than 6500 km per year. The passenger car kilometres per capita have hardly changed since 2006, though it has slightly increased since 2013. However, differences exist at the regional and municipal levels. The driving distances by car have decreased in the three Swedish metropolitan areas of Stockholm, Gothenburg and Malmö. At the same time, passenger car kilometres have increased in the rest of the country, highlighting the need for car-restricting measures that function in both more rural areas and cities.

However, implementing car-restricting measures is usually considered a political risk because of the significant barriers related to the design and acceptance of sustainable transport policies, which are referred to as 'transport taboos' by Gössling and Cohen (2014). Therefore, attempts have been made with 'soft' measures that encourage people to change their travel behaviour voluntarily. Travel programmes such as TravelSmart in Australia (Freer et al., 2010) and the Travel Feedback Programme in Japan (Taniguchi et al., 2003) provide users with information about the various aspects of their travel behaviour to encourage pro-environmental behaviours. Such campaigns have been applied in several European cities with positive outcomes (a reduction in private car use of around 10%) (Banister, 2008).

Persuasive messages are commonly included as part of the campaigns. An example from Sweden is the bicycle campaign launched by the city of Malmö that used the message 'inga löjliga bilresor' (no ridiculous car trips) to influence social norms related to driving. The effect of such marketing and communication efforts has been examined to understand its influence on the motivation to decrease private car use (e.g. Beale and Bonsall, 2007; Hess and Bitterman, 2016). Mir et al. (2016) found that communicating the consequences of air pollution could provoke individuals to act more environmentally friendly and change the intention of using more sustainable modes of transportation. Some studies have explored the effect of different framing interventions, such as CO_2 valence framing (Avineri and Waygood, 2013; Waygood and Avineri, 2018), and fiscal versus environmental messages (Cohen-Blankshtain, 2008). These studies contribute to addressing the question of how people respond to different messages. However, research investigating, firstly, why people respond the way they do and, secondly, what characteristics are related to the segments that are motivated to reduce private car use and those that are not is lacking. The first question is critical to understand the latent *preconditions* that guide peoples' motivation to decrease private car use, and the second question is important for policymakers to create efficient, targeted communication strategies. In particular, research has demonstrated the difficulties in reaching 'persistent drivers' with arguments emphasising a low-carbon lifestyle (Polk, 2003; Jia et al., 2018). As this group accounts for the largest share of passenger car kilometres (Ko et al., 2011; Smidfelt Rosqvist and Winslott Hiselius, 2018), analysing this group more closely is vital to understand their motivations to reduce private car use (Beirão and Sarsfield Cabral, 2007). In this study, the transtheoretical model (TTM) is used to segment the population and to analyse the conditions for changing travel behaviour in different stage groups.

1.1. TTM

TTM (Prochaska and Diclemente, 1986) seeks to explain the process of behaviour change. It considers behaviour change as a stepwise process rather than an isolated event. For campaign designers, the advantage of such an approach is that it enables interventions to be matched to different stages (Friman et al., 2017). TTM has been used mainly to explain health-related behaviour changes, but in recent years, it has also been employed to promote modal shifts within the transport domain (Gatersleben and Appleton, 2007; Forward, 2014). Moreover, it has been suggested as a theory for examining campaigns in the transport sector (Waygood et al., 2012). The TTM stages include the following:

- Pre-contemplation: unconcerned about the problems caused by current behaviour and have no intention to change.
- Contemplation: start to become aware of the problem, and the cost and benefits of the new behaviour weigh about the same.
- Preparation: the benefits of the new behaviour have become apparent, and the preparation to change begins.
- Action: have started to change, but the risk is still high for submitting to the old behaviour.
- Maintenance: the behaviour has started to become a habit.

1.2. Aims

This study attempts to shed light on the factors affecting the motivation to reduce private car use and how these factors are distributed in the population demographically and in the stages of TTM. The outcome from a survey exploring peoples' motivation to reduce private car use when exposed to messages advocating sustainable transport is analysed. Ordinary least squares (OLS) regression analyses are used to explore the factors affecting such motivation, and a precondition index consisting of significant variables is used to differentiate the population. Finally, a segmentation based on the transtheoretical model is used to analyse persistent drivers separately.

2. Methodology

2.1. Data collection and sample

The participants in the survey were recruited from a Swedish probability-based internet panel of Kantar Sifo, similar to the Dutch

panel used by Hoen and Geurs (2011). The panel consists of approximately 100,000 residents 16–79 years of age. The panel members are randomly recruited through nationally representative telephone surveys, and the panel is continuously filled with new members to prevent them from becoming 'experts'. The panel members are recruited by e-mail with a link to the questionnaire, and if they choose not to participate, another panel member is contacted instead. Those who agree to participate receive compensation in the form of bonus points that can be redeemed for movie tickets or gift cards.

The sample was stratified to match the national conditions regarding gender and age, and analytical weights were used to adjust for potential skewness. These weights were used to compensate for the overrepresentation of respondents with higher education (the sample had 10% more highly educated participants than the Swedish average) and the underrepresentation of older respondents. The geographical scope was limited to seven out of the nine municipality groups according to the classification made by the Swedish Association of Local Authorities and Regions (2016). The two excluded municipality groups consist of rural municipalities where the population is less than 15,000 inhabitants in the largest urban area or where the commuting rate for work outside of the municipality is very low (less than 30%). These rural municipalities were excluded because of the types of marketing messages used in the survey, which mostly relate to sustainable transportation such as walking, cycling and public transport that can be inaccessible in many rural parts of Sweden. Nevertheless, the municipality groups included in the survey cover nearly 95% of the Swedish population.

The questionnaire was fielded in February 2018. A total of 1500 individuals were recruited from the panel as part of a larger research project. Among these participants, 1100 were in the ages of 18–65 years and stated that they usually commute to school or work. The study focused on commuting trips to enable the marketing messages to be contextualised around them. To ensure that all analyses were based on the same individuals, an analytical sample was defined and included only individuals with valid information (i.e. no missing responses) for all the variables used in the statistical analyses (n = 977).

Further, mischievous respondents (MRs) who knowingly make false responses meant to cheat the researcher were removed by applying Hyman and Sierra's (2012) distribution-free, sample-size-unconstrained, backwards-stepping MR algorithm. This step is especially important when respondents are compensated for participating (Hyman and Sierra, 2012). The lowest variance deletion rule was used to clean the data (Thøgersen, 2018). The respondents were considered mischievous if the variance of their responses to the 14 message items that would constitute the dependent variable was below 0.25 (13% of the sample). This step reduced the analytical sample to 850 individuals.

2.2. Survey design

The questionnaire involved four parts: (1) demographic characteristics of the respondents; (2) their accessibility to travel modes, driving license and daily commuting trip length and mode choice; (3) attitudinal questions, and; (4) marketing messages. The original questionnaire in Swedish was translated into English by the researcher. All of the variables used in the study are presented in Table 1. Previous literature was searched to determine the factors that could influence the motivation to decrease private car use (Tertoolen et al., 1998; Steg and Tertoolen, 1999; Beirão and Sarsfield Cabral, 2007; Abrahamse et al., 2009; Anable and Wright, 2013; Damant-Sirois and El-Geneidy, 2015), which guided the design of the questions in parts two and three (see Appendix A).

The fourth part of the survey included marketing messages that were used to measure the respondents' motivation to decrease private car use. Messages promoting pro-environmental behaviours have typically been examined in relation to environmental, health and economic benefits (Nisbet and Gick, 2008; Avineri and Waygood, 2013; Bolderdijk et al., 2013; Loureiro and Veloso, 2017; Steinhorst and Klöckner, 2017). Campaigners have used the same dimensions when framing marketing messages promoting sustainable transport in Sweden (Hiselius and Rosqvist, 2015). Therefore, these dimensions were used to form the messages constituting the dependent variable in this study. A screening of messages used by the regional public transport authorities, municipalities working with mobility management, train operators and organisations that support bicycling and public transport was conducted. From these actors, 14 messages promoting sustainable transport, or sustainability in general, were chosen (Table 2).

The respondents were asked to state their level of motivation to decrease their car use when exposed to the messages, which were randomised to avoid response bias. The messages were rated on a five-point Likert scale, from 'very motivated to decrease my level of private car use' to 'very unmotivated to decrease my level of private car use', following the scale used by Waygood and Avineri (2018). For the respondents that already had low or no private car use, the scale was adjusted to 'very motivated to keep my low level of private car use' to 'very unmotivated to keep my low level of private car use'. The 14 items had high construct reliability (Cronbach's alpha = 0.93) (Meyers et al., 2013).

The aggregated responses from the 14 marketing messages were then used to compute a mean value for each respondent, forming a continuous variable that was further used as the dependent variable in the OLS regressions. The scale of this variable had a range of 14–70.

2.3. Statistical analyses

Multiple linear regression models were estimated to analyse the effect of attitudes and accessibility on the motivation to decrease private car use. Firstly, several preliminary analyses were conducted to ensure the non-violation of the assumptions of normality, linearity, homoscedasticity and multicollinearity. The histogram, scatterplot and normal P-P plots of the regression standardised residuals were used to control the data. Standardised residuals and casewise diagnostics were further used to investigate if there were any potential outliers. Two outliers were excluded based on standardised scores (> 3).

Cook's distance statistics, which is a measure of the overall influence that a single case has on a model, was used to test for cases that could arbitrarily influence the model. Cook and Weisberg (1982) suggested that values greater than one could be cause for bias.

Table 1
Overview of the variables (n = 850).

	Mean or distribution (%)	SD
Accessibility & usual commute mode		
Driving license %	0.91	0.28
Access to a bicycle %	0.89	0.31
Live within 500 m to a PT station %	0.84	0.36
Access to a car %	0.78	0.42
Usual commute mode		
Car %	0.70	0.46
PT, bicycle, walk %	0.30	
Travel time		
< 10 min %	0.17	0.36
10–20 min %	0.28	
21–30 min %	0.20	
31–45 min %	0.17	
46–60 min %	0.09	
> 60 min %	0.08	
Attitudes		
Identify as a driver	1.97	1.25
Advocate private car use	3.04	1.36
Identify as a cyclist	4.04	1.24
Perceive cycling as fast	3.3	1.4
Like cycling	3.7	1.22
Identify with PT	3.61	1.42
Concerned about health	3.14	1.37
Climate morality	3.46	1.29
Demographic		
Age	41.97	12.71
Female %	0.49	0.5
Relationship status		
Married/live with partner %	0.7	0.46
Single %	0.3	
Children living at home		
One %	0.13	0.48
More than one %	0.24	
None %	0.63	
Education		
Elementary school %	0.13	1.10
Upper secondary %	0.26	
University < 3 years %	0.16	
University > 3 years %	0.45	
Occupation		
Working %	0.81	0.49
Studying %	0.16	
Off duty %	0.03	
Residential area		
The main city of municipality %	0.68	0.78
Town ≥5000 residents %	0.14	
Town < 5000 residents %	0.18	

Conducting this analysis revealed that the 10 cases with the highest Cook's distance values were 0,015–0,008, and thus no case caused a significant bias to the model. Multicollinearity was further tested by conducting collinearity diagnostics in linear regression and including all independent variables. The general guideline that VIF values above ten or tolerance values below 0.1 suggest multicollinearity was used (Field, 2013). The maximum variance inflation factor was 2.02, and the tolerance values varied at 0.50–0.89, indicating no collinearity among the independent variables.

The attitudinal survey questions were measured on a five-point Likert scale (strongly disagree, disagree, neither/nor, agree and strongly agree). When running the multiple regressions, some of these variables were non-linear that would make treating them as continuous variables inappropriate. Therefore, dummy variables were created for each category within the variables, and neither/nor served as the reference category. Thus, accounting for potential thresholds in the data and presenting a more nuanced picture of how the independent variables influence the dependent variable became possible (see Páez and Whalen (2010) for a similar approach). This issue is elaborated in conjunction with Table 3.

Upon completion of the regression analysis, an index consisting of the significant variables was created to explore the trends in how the preconditions for the motivation to reduce private car use are distributed within the sample and in the TTM stages. The following procedure was undertaken to compute the index. First, a new variable was created for each of the significant predictors, and each significant category was loaded with the estimated coefficients retrieved from the regression. As the index should be a

Table 2
Messages used for measuring motivation to decrease private car use (n = 850).

Item	Mean	SD
1. We all must help to reduce our climate footprint. The result will be a sound environment that future generations also need!	3.83	1.05
2. Those who mostly walk, cycle or ride transit are doing something good for the environment.	3.72	1.04
3. Research shows that public transport users are walking on average four times more per day than do car drivers, therefore reducing the risk of acquiring severe non-communicable diseases.	3.69	1.05
4. Those who cycle and go by public transport not only improve their health but also contribute positively to other people's health.	3.66	1.01
5. Did you know that cyclists have a 52% lower risk of dying of heart disease and a 40% lower risk of dying from cancer?	3.64	1.06
6. You save about 350 euro per month if you live without a car and instead go by public transport and even more so if you cycle or walk.	3.48	1.19
7. Bicycles run on fat and save you money. Cars run on money and make you fat!	3.45	1.26
8. If Sweden is to achieve its climate targets, then generally every third car trip must be replaced with more environmentally friendly alternatives.	3.41	1.17
9. By cycling instead of taking the car to work, you save money and contribute to society at the same time! Try it!	3.36	1.11
10. The car traffic in Sweden induces a socio-economic loss above 10 billion euros in adverse health effects.	3.26	1.13
11. In the government budget, support for investments in cycling infrastructure increased by 50 million euros in 2018.	3.21	1.15
12. If you want to improve your health, you should ride a bicycle instead of driving a car. If the distance is a problem, then an electric bike can be an option.	3.17	1.17
13. Beginning in 2018, you can get 25% of the cost subsidised by the government when purchasing a new electric bicycle.	3.05	1.27
14. The environmental impact per bus passenger is only 65% of the private car user in rural areas and 40% in urban areas.	3	1.06
Cronbach's α	0.93	

composite variable showing what significantly influences motivation to reduce private car use, weights were only allocated to the categories that were significant in the regression. The non-significant categories (and reference categories) were set to 0. Second, all the new variables were summed into a continuous variable in which each respondent had a value positioned on the index scale. Different methods are available for aggregating indicators to form a composite index, and the most common are the 'additive methods that range from summing up unit ranking in each indicator to aggregating weighted transformations of the original indicators' (Matteo Mazziotta, 2013). The latter method was used to compute the precondition index: the significant predictor coefficients were used as weights and aggregated to form an index. Third, the variable was transformed into a categorical variable for further analyses. The range produced by the respondents was used and equally divided into four categories, with the lower range indicating unfavourable preconditions, the higher range indicating favourable preconditions and 0 being neither favourable nor unfavourable preconditions.

Separate cross-tabulations were then conducted. The demographic variables (age, gender, relationship status, children at home, education, occupation and residence) and the TTM stages interacted with the index, similar to the approach used by Polk (2003). The distribution of the preconditions within the population was investigated. Thus, the demographic variables were not included directly as predictors in the multiple regressions because using them both endogenously (i.e. within the regression and index) and exogenously (i.e. in the cross-tabulation with the index) would be inappropriate.

3. Multiple regression model for the motivation to decrease private car use

A multiple linear regression model was estimated to understand which variables affect the motivation to decrease private car use while controlling for the simultaneous effects of other variables. The model was estimated using accessibility and attitudinal variables as the explanatory variables and motivation to decrease private car use as the outcome variable. The model had a Nagelkerke score of 0.47, indicating that the included exploratory variables explain about half the variance of the motivation to decrease private car use.

Some key insights emerged in the interpretation of the regression results in Table 3. In particular, feeling a moral obligation to reduce one's carbon emissions (*climate morality*) is significant and positively affects the motivation to reduce private car use compared with the reference category of being indifferent to the issue (neither/nor). Those who strongly agree to have climate morale increase their motivation to reduce private car use (on a 14–70 scale) by 4.7 points on average. Those agreeing to have climate morale is 2.2 points more motivated compared to the reference category neither/nor. Furthermore, those strongly disagreeing with the statement are, other things being equal, −7.2 points less motivated to reduce private car use. However, disagreeing is not significant: climate morality has an effect only when it is either positive or very negative.

The coefficients for agreeing and strongly agreeing to *like cycling* are significant and increase the motivation to reduce private car use with 3.4 and 3.7 points, respectively. This result is consistent with those of previous research that found stronger intentions for people to use sustainable modes of transportation if they like to bicycle. Using stated preferences, Gatersleben and Appleton (2007) found that people who like bicycling would bicycle commute under most circumstances. The relationship between attitudes towards cycling and car use intentions was further demonstrated by Handy and Xing (2011), who found that people who agree that they would limit driving as much as possible were also more likely to bicycle commute. However, the results in Table 3 show that disagreeing and strongly disagreeing to *like cycling* is not significant, indicating that attitudes towards cycling primarily influences motivation when they are positive. One possible explanation for this result is that those who do not like cycling may still be motivated to decrease their car use by instead switching to public transport, a suggestion also put forward by Handy and Xing (2011).

Strongly disagreeing and disagreeing with the statement that *cycling can be as fast as a car* on certain distances is significant and affects motivation negatively (−2.7 and −1.8, respectively). Likewise, for the *concerned about health* variable, strongly disagreeing is

Table 3
Multiple regression model (n = 848). Dependent variable: motivation to decrease private car use.

						95% C.I	
	B	SE	Beta	*t*	Sig.	Upper	Lower
Constant	43.403	2.229		19.47	0	39.03	47.78
Accessibility & usual commute mode							
Driving license (ref. no)	−1.107	1.067	−0.03	−1.04	0.3	−3.20	0.99
Access to a bicycle (ref. no)	0.383	0.966	0.01	0.40	0.692	−1.51	2.28
Live within 500 m to a PT station (ref. no)	−0.059	0.79	0.00	−0.07	0.941	−1.61	1.49
Access to a car (ref. no)	0.749	0.849	0.03	0.88	0.378	−0.92	2.42
Usual commute mode (ref: car)	3.248	0.731	0.16	4.45	0	1.81	4.68
Travel time (ref: < 10 min)							
10–20 min	0.369	0.84	0.02	0.44	0.66	−1.28	2.02
21–30 min	0.804	0.91	0.03	0.88	0.377	−0.98	2.59
31–45 min	0.013	0.957	0.00	0.01	0.989	−1.87	1.89
46–61 min	−0.201	1.144	−0.01	−0.18	0.861	−2.45	2.05
> 60 min	−3.314	1.233	−0.09	−2.69	0.007	−5.73	−0.89
Attitudes							
Climate morality (ref: neither/nor)							
Strongly disagree	−7.206	1.054	−0.22	−6.84	0	−9.28	−5.14
Disagree	−1.342	0.992	−0.04	−1.35	0.177	−3.29	0.61
Agree	2.179	0.78	0.09	2.79	0.005	0.65	3.71
Strongly agree	4.687	0.808	0.20	5.80	0	3.1	6.27
Advocate private car use (ref: neither/nor)							
Strongly disagree	2.243	0.927	0.08	2.42	0.016	0.42	4.06
Disagree	2.408	0.821	0.09	2.94	0.003	0.8	4.02
Agree	−2.805	0.891	−0.10	−3.15	0.002	−4.55	−1.06
Strongly agree	−3.885	0.858	−0.15	−4.53	0	−5.57	−2.2
Like cycling (ref: neither/nor)							
Strongly disagree	0.6	1.466	0.01	0.41	0.682	−2.28	3.48
Disagree	0.074	1.058	0	0.07	0.944	−2.00	2.15
Agree	3.366	0.824	0.14	4.08	0	1.75	4.98
Strongly agree	3.692	0.888	0.17	4.16	0	1.95	5.43
Concerned about health (ref: neither/nor)							
Strongly disagree	−2.225	0.894	−0.08	−2.49	0.013	−3.98	−0.47
Disagree	−0.025	0.933	0	−0.03	0.978	−1.86	1.81
Agree	1.196	0.794	0.05	1.51	0.133	−0.36	2.76
Strongly agree	1.604	0.861	0.06	1.86	0.063	−0.09	3.29
Perceive cycling as fast (ref: neither/nor)							
Strongly disagree	−2.655	0.935	−0.10	−2.84	0.005	−4.49	−0.82
Disagree	−1.971	0.993	−0.06	−1.98	0.048	−3.92	−0.02
Agree	−0.095	0.817	0	−0.12	0.907	−1.7	1.51
Strongly agree	−0.462	0.843	−0.02	−0.55	0.584	−2.12	1.19
Identify as a cyclist (ref: neither/nor)							
Strongly disagree	−0.858	1.522	−0.02	−0.56	0.573	−3.85	2.13
Disagree	0.641	1.202	0.02	0.53	0.594	−1.72	3
Agree	0.47	0.998	0.02	0.47	0.638	−1.49	2.43
Strongly agree	0.332	0.954	0.02	0.35	0.728	−1.54	2.20
Identify with PT (ref: neither/nor)							
Strongly disagree	−1.384	1.067	−0.04	−1.3	0.195	−3.48	0.71
Disagree	0.269	1.022	0.01	0.26	0.793	−1.74	2.28
Agree	−1.2	0.926	−0.05	−1.3	0.196	−3.02	0.62
Strongly agree	−0.536	0.833	−0.03	−0.64	0.520	−2.17	1.1
Identify as a driver (ref: neither/nor)							
Strongly disagree	1.783	0.873	0.09	2.04	0.041	0.07	3.5
Disagree	1.884	0.987	0.07	1.91	0.057	−0.05	3.82
Agree	1.282	1.161	0.04	1.1	0.270	−1	3.56
Strongly agree	−0.072	1.364	0	−0.05	0.958	−2.75	2.61

Note: All predictors were entered into the regression model simultaneously.
Nagelkerke R^2: 0.47.

significant (−2.2). Thus, those who do not see cycling as a competitive alternative to driving a car, or as a way to improve their health, are less likely to be motivated to decrease their private car use. However, the respondents who agree with these statements seem to either be motivated or not motivated; that is, there is no association in these cases. This outcome is not surprising given that people sometimes hold two or more contradictory beliefs, preferences, or values, referred to as cognitive dissonance by Festinger (1957). A person may be aware of the benefits of bicycle commuting and still be unmotivated to reduce private car use due to other barriers.

Consequently, the results highlight the need to communicate the benefits of cycling on the one hand and to remove the obstacles

that prevent people from cycling on the other hand. Earlier studies demonstrated a clear difference between the attitudes of users that have cycling experience and those of users that do not (Gatersleben and Uzzell, 2007; Rondinella et al., 2012; Fernández-Heredia et al., 2014). Suggestions have been made to implement measures that enable people to experience cycling in daily life to increase their motivation to cycle (Broach et al., 2012).

Regarding the statement 'People should be allowed to use their cars as much as they like' (the *advocate private car use* variable), the coefficients for 'strongly disagree' and 'disagree' are positive, and those for 'agree' and 'strongly agree' are negative. They are all significant and in accordance with the expected results. For example, Steg (2005) and Steg et al. (2001) found a relationship between affection for cars and the frequency of private car use. People were also found to be unlikely to voluntarily change their behaviour unless they recognise the negative externalities produced by private car use (Tertoolen et al., 1998). This finding is further reflected in the *identify as a driver* variable, in which strongly disagree significantly affects motivation positively. *Travel time* to school/work is only significant if it exceeds 60 min, thus affecting the motivation to decrease private car use negatively. Research has shown that long distances discourage commuters to use sustainable transportation (Heinen et al., 2013) and that long trips are reasonably assumed to be more challenging to influence because of fewer alternatives to promote than short trips.

Usual commute mode is significant, as using sustainable transport modes positively affect the motivation to decrease private car use compared with driving. This result is expected given the tendency people have in general to assimilate information that is consistent with their behaviour and attitudes (Beale and Bonsall, 2007; Whitmarsh, 2011).

4. Demographic differences based on a precondition index of the significant variables

To understand how the significant variables of the motivation to decrease private car use are represented demographically in the sample, an index was computed using the estimated coefficients from the multiple regression model. Eight variables were included: climate morality, usual commute mode, advocate private car use, like cycling, concerned about health, perceive cycling as fast, identify as a driver and travel time. The variables are presented in Table 4.

The procedure to compute the precondition index has been explained in Section 2.3. With the results in Table 4, the formula can be described as follows:

$$\begin{aligned}\text{Precondition index} = {} & (3.248 * \text{mode\_sust}) - (3.314 * \text{travel\_time}) - (7.206 * \text{climate1}) + (2.179 * \text{climate4}) \\ & + (4.687 * \text{climate5}) + (2.243 * \text{car\_adv1}) + (2.408 * \text{car\_adv2}) - (2.805 * \text{car\_adv4}) - (3.885 * \text{car\_adv5}) \\ & + (3.366 * \text{like\_cycling4}) + 3.692 * \text{like\_cycling5}) - (2.225 * \text{health1}) - (2.655 * \text{cycling\_fast1}) \\ & - (1.971 * \text{cycling\_fast2}) + (1.783 * \text{id\_driver1})\end{aligned}$$

Based on the coefficient weights, the scores ranged roughly from −24 to 24. However, in practice, the scoring for the population sample ranges from −16 to 16. The latter range was deemed more useful to form categories for further analyses because it better described the real preconditions for the sample. The range was equally divided into four categories, with the lower range indicating unfavourable preconditions, the higher range indicating favourable preconditions and 0 indicating neither favourable nor unfavourable preconditions. The scale of the index and the sample distribution are presented in Table 5.

Several cross-tabulations were conducted between the precondition index and the demographic variables. The results indicate that men have significantly less favourable preconditions than females and that the respondents differ significantly concerning age (Table 6). The younger cohort has more favourable preconditions than the older cohort. The categories within both *relationship status*

Table 4
Variables used and their corresponding weights in the construction of a precondition index of motivation to decrease private car use.

Predictor variables	Significant categories	Abbreviation	Sig.	Weights
Usual commute mode	PT, bicycle, walk	mode_sust	0	3.248
Travel time	> 60 min	travel_time	0.007	−3.314
Climate morality	Strongly disagree	climate1	0	−7.206
	Agree	climate4	0.005	2.179
	Strongly agree	climate5	0	4.687
Advocate private car use	Strongly disagree	car_adv1	0.016	2.243
	Disagree	car_adv2	0.003	2.408
	Agree	car_adv4	0.002	−2.805
	Strongly agree	car_adv5	0	−3.885
Like cycling	Agree	like_cycling4	0	3.366
	Strongly agree	like_cycling5	0	3.692
Concerned about health	Strongly disagree	health1	0.013	−2.225
Perceive cycling as fast	Strongly disagree	cycling_fast1	0.005	−2.655
	Disagree	cycling_fast2	0.048	−1.971
Identify as a driver	Strongly disagree	id_driver1	0.041	1.783

Note: The reference categories and the non-significant categories were set to 0 in the aggregation of independent variables.

Table 5
Scale and distribution of the precondition index (n = 848).

	I	II	III	IV
Index scale	−16 to −8	−7.99 to 0	0.01 to 8	8.01 to 16
n	49 (6%)	183 (22%)	336 (40%)	274 (32%)

Table 6
Cross-tabulation of the precondition index with the demographics (n = 848).

		I (%)	II (%)	III (%)	IV (%)	n
Gender**	Male	7	23	43	27	435
	Female	4	20	37	39	415
Age***	18–29	5	13	40	42	232
	30–50	6	23	37	33	393
	51–65	5	29	44	22	225
Relationship status	Married/in partnership	6	23	40	30	587
	Single	6	17	40	38	262
Children at home	One or more	5	23	41	31	316
	No	6	21	39	34	534
Education***	Elementary school	8	36	34	22	110
	Upper secondary	9	24	39	29	218
	University < 3 years	7	19	42	33	139
	University > 3 years	3	18	41	38	383
Occupation***	Working	6	24	41	29	684
	Off duty/parental leave	7	30	47	17	25
	Studying	4	7	35	54	137
Residence***	Main city	4	19	40	37	575
	Town ≥5000 residents	9	25	36	30	120
	Town < 5000 residents	9	29	43	20	154

Statistically significant differences within the variables examined using the Pearson chi-square test.
*** $p < 0.001$.
** $p < 0.01$.

and *children at home* are not significantly different, indicating that the precondition index is similar across these demographic variables. The cross-tabulation between education and the precondition index shows a significant difference, especially between the most educated (more than three years at a university) and the rest, which indicates that higher education provides more favourable conditions compared to having a low education. Unsurprisingly, this result is also reflected in the occupation variable, in which students have significantly more favourable preconditions than employees and those off duty or on parental leave, as students are usually young and on the verge of gaining higher education. The results in Table 6 further indicate a significant difference in residence, with urban populations having more favourable preconditions than people in suburban towns and small villages.

5. Stage of change and the precondition index

To further explore how the preconditions for motivation to decrease private car use are represented in relation to the stage of behaviour change, a cross-tabulation including the stages from the TTM was performed with the precondition index. The differences between the stages were investigated using a one-way between-subjects ANOVA (post hoc test Tukey's HSD). Previous studies allocated respondents to each stage by asking them to choose one of five statements (Godin et al., 2004). One objective is for the respondents to answer based on what they think will happen in the foreseeable future, which is usually measured as the next six months. The following statements were constructed for this study.

- 'I use the car for the most part and do not intend to change the mode of transport within the next six months' (pre-contemplation).
- 'I am using the car for the most part, but I am considering replacing some car journeys with other modes within the next six months' (contemplation).
- 'I am using the car for the most part but have begun trying other modes instead in the last six months' (preparation).
- 'For the past six months, I have only used the car as a complement to other means of transport' (action).
- 'For the past six months, I have only used other modes than cars' (maintenance).

Contemplation and preparation are the stages in which individuals are ambivalent about their current behaviour, thus making them more amenable to external influence (Forward, 2014). Campaigners usually focus on these two stages because they constitute a

Table 7
Frequencies distributed on the TTM stages (n = 848).

	Pre-contemplation	Contemplation	Preparation	Action	Maintenance
n (%)	35.5	10.1	3.7	31.5	19.2

more feasible target group than those not interested in the new behaviour (pre-contemplators) and those already practising the desired behaviour to some extent (action and maintenance). Note that the contemplation and preparation groups are usually relatively small. In this population sample, they constitute 14% of the total, as shown in Table 7. As the sample sizes are not equally distributed on the TTM stages, a Levene's test was conducted to determine whether the data meet the homogeneity of variance assumption. The test confirmed the null hypothesis (sig. = 0.559) that all the stages have similar population variances.

Fig. 1 shows the interaction between the TTM stages and the precondition index. The preconditions for the motivation to decrease private car use become more favourable proceeding to the later stages in TTM. Particularly, pre-contemplators have worse preconditions than all the other segments (significance tests are presented in Table 8). Conversely, the respondents in the maintenance stage have significantly better preconditions. The preconditions are increasingly more favourable, moving from contemplation to preparation and from preparation to action.

The highest threshold for favourable preconditions seems to be between the pre-contemplation stage and the contemplation stage. This supports the strategy of targeting those in the contemplation and preparation stages, as they would likely be more susceptible to incentives and other mechanisms promoting behaviour change. Even if the pre-contemplators have a substantial share of the favourable preconditions (55% in category III and IV), they are significantly less likely to respond positively to such mechanisms, which is a paramount challenge for policy-makers because this group carries out the majority of the car passenger kilometres (Smidfelt Rosqvist and Winslott Hiselius, 2018). Therefore, although mobility management campaigns can be successful in promoting individual and incremental behavioural changes, this strategy will probably be insufficient to influence 'persistent drivers' as long as the conditions for this group's motivation are unfavourable. (Barr, 2018). Nevertheless, previous studies showed a highly unequal distribution of emissions among the population, which is especially evident in transport (Brand and Boardman, 2008; Brand and Preston, 2010; Ko et al., 2011), stressing the need for segmented policies targeting the 'high emitters' (Anable et al., 1997; Winslott Hiselius and Smidfelt Rosqvist, 2018).

To understand which factors are suppressing the motivation to decrease private car use for the pre-contemplation segment, an additional regression analysis was conducted using the same variables as in the earlier model but only including the pre-contemplation segment. The results are presented in Table 9. The variables that are strictly non-significant (i.e. variables without any significant category) are excluded from the table.

The results provide a deeper understanding of the factors affecting the motivation to decrease private car use for pre-contemplators, most of which are similar to those in the first regression model. Therefore, the focus is to highlight a few differences between the two models.

Notably, climate morality seems to be the most influential variable in the second model. Agreeing strongly with having a moral

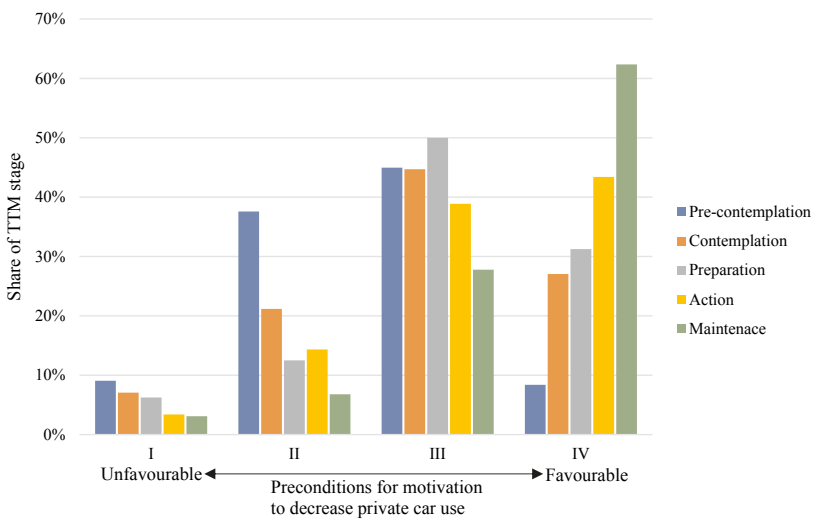

Fig. 1. Cross-tabulation of the precondition index and the TTM stages (n = 848).

Table 8
Significant differences ($p < 0.05$) in the preconditions between the TTM stages analysed using a one-way, between-subjects ANOVA followed by a post hoc test (Tukey's HSD).

		I	II	III	IV
a	Pre-contemplation[b,c,d,e]	9.1%	37.6%	45%	8.4%
b	Contemplation[a,d,e]	7.1%	21.2%	44.7%	27.1%
c	Preparation[a,e]	6.3%	12.5%	50%	31.3%
d	Action[a,b,e]	3.4%	14.3%	38.9%	43.4%
e	Maintenace[a,b,c,d]	3.1%	6.8%	27.8%	62.3%

Table 9
Multiple regression model including only the pre-contemplation segment (n = 299). Dependent variable: motivation to decrease private car use.

						95% C.I	
	B	SE	Beta	*t*	Sig.	Lower	Upper
Constant	61.692	10.2		6.05	0	41.6	81.79
Attitudes							
Have climate morality (ref: neither/nor)							
Strongly disagree	−9.947	1.841	−0.3	−5.4	0	−13.57	−6.32
Disagree	−2.283	1.584	−0.08	−1.44	0.151	−5.4	0.84
Agree	2.434	1.381	0.1	1.76	0.079	−0.29	5.15
Strongly agree	4.97	1.626	0.17	3.06	0.002	1.77	8.17
Advocate private car use (ref: neither/nor)							
Strongly disagree	−0.026	2.591	0	−0.01	0.992	−5.13	5.08
Disagree	1.601	1.735	0.05	0.92	0.357	−1.82	5.02
Agree	−4.553	1.431	−0.18	−3.18	0.002	−7.37	−1.73
Strongly agree	−5.736	1.406	−0.25	−4.08	0	−8.51	−2.97
Like cycling (ref: neither/nor)							
Strongly disagree	0.936	2.414	0.02	0.39	0.698	−3.82	5.69
Disagree	1.821	1.641	0.06	1.11	0.268	−1.41	5.05
Agree	4.793	1.446	0.20	3.32	0.001	1.95	7.64
Strongly agree	4.88	1.626	0.19	3	0.003	1.68	8.08
Concerned about health (ref: neither/nor)							
Strongly disagree	−4.685	1.791	−0.15	−2.62	0.009	−8.21	−1.16
Disagree	−0.334	1.628	−0.01	−0.21	0.838	−3.54	2.87
Agree	0.068	1.371	0	0.05	0.96	−2.63	2.77
Strongly agree	1.955	1.588	0.07	1.23	0.219	−1.17	5.08
Perceive cycling as fast (ref: neither/nor)							
Strongly disagree	−1.702	1.51	−0.07	−1.13	0.261	−4.68	1.27
Disagree	−3.418	1.59	−0.12	−2.15	0.032	−6.55	−0.29
Agree	1.136	1.678	0.04	0.68	0.499	−2.17	4.44
Strongly agree	−2.984	1.689	−0.1	−1.77	0.078	−6.31	0.34
Identify as a driver (ref: neither/nor)							
Strongly disagree	3.348	1.432	0.14	2.34	0.02	0.53	6.17
Disagree	1.865	1.563	0.07	1.19	0.234	−1.21	4.94
Agree	−0.066	1.708	0	−0.04	0.969	−3.43	3.3
Strongly agree	2.556	1.807	0.08	1.41	0.159	−1.00	6.12

Note: All predictors were entered into the regression model simultaneously.
Nagelkerke R^2: 0.513.

obligation to decrease one's carbon emissions is significant and increases the probability to be motivated to reduce private car use. By contrast, strongly disagreeing with the statement lowers the likelihood and is also significant. Further, (strongly) agreeing to the statement that people should be allowed to drive their car as much as they like is significant and negatively affects the motivation to decrease private car use. Unlike the first regression model, (strongly) disagreeing is not significant. In the second model, *usual commute mode* and *travel time* are not significant. This result may be due to the overall higher commute habit by car and the small sample size.

Consequently, among the independent variables included in the model, the most important precondition for motivating 'persistent drivers' to reduce their private car use seems to be an enhanced moral concern about climate change and how it relates to driving a car. The results suggest that the view that people should be allowed to drive their car as much as they want needs to be problematised and linked to social norms related to car identity, which would have to be replaced by alternative identities consistent with a sustainable lifestyle. Further, increasing the attractiveness of cycling and promoting it as a healthy modal choice seems to be crucial to establishing favourable preconditions that motivate 'persistent drivers' to reduce their private car use.

6. Discussion and conclusion

This study contributes to the body of transportation research that focuses on soft measures for promoting sustainable transport. By analysing the outcomes of communication efforts usually found in Swedish mobility management campaigns, climate morality is found to be the most important factor affecting the motivation to decrease private car use. Usual commute mode, car advocacy, health concern, attitudes towards cycling, car identity and travel time are also significant factors affecting the motivation to decrease private car use. Indexing these factors according to their respective regression coefficients and having them interact with the demographic variables, reveal differences between the population segments in terms of preconditions for the motivation to reduce private car use. In particular, males, the middle-aged, people with low educational attainment, and rural residents have the least favourable prerequisites concerning the factors mentioned above. Additional interaction analysis of the stages drawn from the TTM reveals that individuals who have proceeded from the pre-contemplation-stage adapt preconditions that align with those of the action and maintenance stages. Therefore, mobility management campaigns can advantageously target such segments to pick the low-hanging fruit. Indeed, some progress has been made in the design of campaigns that successfully encourage people to reduce driving in favour of public transport (Fujii and Taniguchi, 2006; Thøgersen, 2009). However, the challenge remains in communicating the need for reduced car traffic to 'persistent drivers' (Innocenti et al., 2013; Lattarulo et al., 2018). In this study, a separate modelling of the pre-contemplation segment reveals climate morality to be even more influential than that for the general sample. Therefore, a way forward for policymakers could be, amongst other interventions, to communicate the issue of climate change more strategically to 'persistent drivers' to create favourable preconditions for this segment.

Simply communicating the need to reduce private car use to drivers who are not concerned about their current travel behaviour is likely to be unsuccessful, as found in many studies (e.g. Beale and Bonsall, 2007; Innocenti et al., 2013; Lattarulo et al., 2018). Nevertheless, the demand for private car use needs to be curved across society if climate targets are to be met. Therefore, preaching to the converted is not sufficient without simultaneously targeting consumers who have a higher usage of private cars. By focusing on the preconditions for the motivation to reduce driving, campaigners can approach 'persistent drivers' and those in doubt of their mobility choice. Therefore, new communication strategies are needed to facilitate persuasive information that is consistent with the values and worldviews of 'persistent drivers'. A point of departure for such communication is to increase public awareness of the linkage between private car use and climate change (Martin et al., 2014); health issues caused by sedentary behaviour, pollution and noise (Nisbet and Gick, 2008); and the benefits of cycling (Broach et al., 2012; Fernández-Heredia et al., 2014). To align messages with different value constructs, they can be framed around various issues (Whitmarsh, 2011) such as energy security, technological innovation, welfare, compassion, future generations and justice. Research suggests that such communication needs to be constructive and motivating, morally logic or supported by moral reasoning, include common societal goals and highlight benefits that are tangible here and now (Hulme, 2009). One example is the work of Daziano et al., (2017), who showed that CO_2 emission information related to social goal contextualisation is far more persuasive than just presenting the grams per mile.

Recently, Bloomberg reported that domestic and international airline travel from Swedish airports had its weakest overall growth in passenger numbers in a decade (Hoikkala and Magnusson, 2019). This result coincides with the high number of hazardous wildfires that fuelled the debate and public concern about climate change among Swedes in 2018. The events have led to a new social norm related to flying and generated the new expression 'flying shame', which refers to the shame people feel when they fly due to the significant CO_2 emissions associated with flying (Hoikkala and Magnusson, 2019). According to a survey by the World Wildlife Fund, 23% of Swedes have abstained from travelling by air in the past year to reduce their climate impact, 6% more than a year earlier (WWF, 2019). Some 18% of Swedes have chosen to travel by train rather than air. This phenomenon needs to be investigated before any conclusion can be drawn from a possible causal relationship between climate concern and restraints from flying. For example, a meta-analysis by Lanzini and Khan (2017) showed that environmental variables predict behavioural intentions but not actual travel behaviours. Nevertheless, it raises interesting questions on the potential of a growing pro-environmental social norm as part of the urgent transition towards a low-carbon transport system. If the negative environmental effects of driving can be made as tangible to the public as flying is today, can 'driving shame' be the social norm of tomorrow?

This study has some limitations. Stated preferences were used to collect data on individuals' travel behaviour, accessibility, demographics and motivation to decrease private car use when exposed to marketing messages. Revealed preferences, or a combination of stated and revealed preferences, are preferred to validate the responses. However, stated preferences are a reasonably accurate guide to the real underlying preferences and market behaviour (Wardman, 1988; Loureiro et al., 2003; Lambooij et al., 2015). The scope of the study was limited to Sweden, and more research is needed to investigate whether the results can be generalised to other geographical contexts. Finally, a limited set of variables had to be used to explain the outcome of the dependent variable (R^2 score $\approx$ 0.50 for both models). An increased scope could have shed light on the additional variables affecting the motivation to reduce private car use, such as social norms, perceived behavioural control and other contextual factors.

CRediT authorship contribution statement

Alfred Andersson: Conceptualization, Methodology, Formal analysis, Resources, Writing - original draft, Writing - review & editing.

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Declaration of Competing Interest

The author declares no conflicts of interest in this article.

Appendix A

Survey questionnaire* (n = 1500).

Question/statement	Variable name	Scale
Do you have a driving license?	Driving license	yes; no
Do you have access to at least one bicycle or e-bike?	Access to a bicycle	yes; no
Do you live within 500 m of a public transport station?	Live within 500 m to PT-station	yes; no
Do you own or have access to a car for commuting?	Access to a car	yes; no
What mode of transport do you usually use to go to school/work?	Usual commute mode	car; public transport; bicycle, walk, other
How long is your travel time from home to school/work?	Travel time	Less than 10 min; 10–20 min; 21–30 min; 31–45 min; 46–60 min; more than 60 min
What statement best describes how you travel in everyday life?	TTM	'I use the car for the most part and do not intend to change the mode of transport within the next six months'. 'I am using the car for the most part, but I am considering replacing some car journeys with other modes within the next six months'. 'I am using the car for the most part but have begun trying other modes instead the last six months'. 'For the past six months, I have only used the car as a complement to other means of transport'. 'For the past six months, I have only used other modes than cars'.
I am the kind of person who rides a bicycle	Identify as cyclist	strongly disagree; disagree; neither/nor; agree; strongly agree
I feel I should cycle more to stay fit	Concerned about health	
Cycling can be the quickest way to get around	Perceive cycling as fast	
I like riding a bicycle	Like cycling	
Driving a car is part of my identity	Identify as a driver	
I am the kind of person who uses public transport	Identify with a PT	
I feel a moral obligation to reduce my greenhouse gas emissions	Climate morality	
People should be allowed to use their cars as much as they like	Advocate private car use	

*Excluding demographic questions concerning age, gender, education, occupation, residential location, relationship status and children, which were also asked in the survey.

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Corrigendum

Corrigendum to "Is climate morality the answer? Preconditions affecting the motivation to decrease private car use" [Transp. Res. Part D Transp. Environ. 78 (2020) 102198]

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The author regrets that the following corrections need to be made for this article. It does not affect the results of the analyses or the conclusions from the original contribution.

In Table 1, the variable 'Usual commute mode' with the values 0.70 (car), 0.30 (pt, bicycle, walk), and 0.46 (SD), should be **0.51** (car), **0.49** (pt, bicycle, walk), and **0.50** (SD).

In Section 2.1, the following sentence needs to be corrected: 'Among these participants, 1100 were in the ages of 18–65 years and stated that they usually commute to school or work'. The value 1100 should be **1300**. This also affects the sentence in the Abstract which says: 'A sample of 1100 Swedish residents was analysed for the effect of variables related to accessibility, usual commute mode and attitudes'. The value 1100 should be **1300**.

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Paper V

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What is the substitution effect of e-bikes? A randomised controlled trial

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ABSTRACT

As sales of e-bikes increase, so does the need for reliable evaluations of which means of transport the e-bike replaces, what we call the substitution effect. A randomised controlled trial with GPS data from 98 frequent drivers in Sweden was conducted to investigate the effect of the e-bike on modal choice, the number of trips, distance, as well as perceptions of the e-bike as a substitute for the car. The results demonstrate that the treatment group increased cycling on average with 1 trip and 6.5 km per day and person, which led to a 25% increase in total cycling. The whole increase was at the expense of car use, which on average decreased by 1 trip and 14 km per person and day, a decrease in car mileage of 37%. Implications for policy and further research are discussed.

1. Introduction

The use of electric bicycles (e-bikes) is growing rapidly in many cities around the world with the potential to profoundly impact mobility patterns. At the end of the 1990s, the market for e-bikes in China surged, mainly due to local bans on motorcycles in many Chinese cities (Weinert et al., 2008). From this, the growth of e-bikes in China was exponential and annual sales increased from fifty-six thousand vehicles in 1998 to over twenty-one million in 2008 (Yang, 2010). In Europe, growth per year has been an average of 34% between 2006 and 2016 with Germany and the Netherlands leading the way accounting for more than half of the sales (CONEBI, 2017). In Germany, e-bike sales were forecast to exceed one-third of all bicycle sales in the longer term, and in the Netherlands, this is already happening. The cycling culture in these countries is comparable to that in Sweden, where cycling is primarily used as a means of transport and, secondly, for recreation and exercise purposes.

There are several perspectives in which more e-bikes could affect the transport system, including the effects on traffic safety, accessibility, congestion, physical and mental health, air pollution and noise, and modal choice (Fishman and Cherry, 2016). The e-bike can replace the car on distances that are considered far too long for a conventional bicycle (Astegiano et al., 2015; Jones et al., 2016; Plazier et al., 2017), and thus has the potential to seriously contribute to more sustainable mobility, both at the local and regional level. Further, it has numerous features that are appreciated both from a user- and transport policy perspective. From a user perspective, studies show that the electric motor reduces the physical effort and perspiration of the user and is especially helpful in uphill slopes, in start-ups, and headwind (Fyhri et al., 2017). Some highlight the positive experience using an e-bike (Plazier et al.,

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2017) and some e-bike segments, especially older cohorts, state that their accessibility has increased as a result of acquiring an e-bike (Fishman and Cherry, 2016). From a transport policy perspective, the e-bike can contribute in replacing heavy, fossil-fuel driven vehicles and thus reduce the release of carbon dioxide, congestion, and local air pollution in and between cities (Ji et al., 2012). Further, studies on the physical effects of e-cycling show that it can contribute to meeting physical activity recommendations and increased physical fitness (Bourne et al., 2018).

However, many of the potential benefits of e-bikes depend almost entirely on what mode of transport it replaces. It is therefore critical to establish the extent to which e-bikes replaces other modes of transport. The term we use to describe this change is the substitution effect, which originates from consumer choice theory and defines as 'the change in demand for a good as a result of a change in the relative price of the good in terms of other goods' (Varian, 1992). In transport research, the substitution effect has been referred to both when it comes to changes in modal choice (de Haas et al., 2019; Kroesen, 2017) and changes in physical activity (PA) (Sundfør et al., 2020). However, there is no clear definition of what the substitution effect means concerning modal choice in transport research. In this paper, we suggest the substitution effect to describe the change in modal share as a result of a change in the relative attractiveness between different modes of transport. An example of this would be to relieve congestion for car traffic, thereby increasing the relative attractiveness of car use compared to public transport and cycling, thus inducing a change in modal share in favour of car use. Another example would be a change in modal share in favour of cycling, at the expense of other modes of transport, due to increased access to e-bikes.

Previous research has shown that it is especially difficult to get frequent drivers to reduce car use (Andersson, 2020; Andersson et al., 2020b; Lattarulo et al., 2018). An interesting question is therefore whether the benefits of the e-bike can support this group of drivers to change travel behaviour, especially since the potential net reductions of car use are particularly high for frequent drivers. Research has suggested that for the general commuter, e-bikes substitute around 50% of car trips (Haustein and Møller, 2016; Winslott Hiselius and Svensson, 2017). However, as Cairns et al. (2017) point out, this is the proportion of e-bike trips that were previously car trips and not the proportion of car mileage that has been replaced, as this is a less commonly reported metric. Moreover, few studies have been able to demonstrate a treatment effect, due to the absence of control groups. Despite the increasing possibility to exploit travel data retrieved from smartphones (Andersson et al., 2018), most studies still rely on self-reported survey answers where participants must estimate their travel activity post-intervention, or with a tracking device of some sort that does not cover all modes of transport.

In a recent meta-analysis of soft interventions to reduce car use, it was found that interventions on average reduce the modal share for cars by 7% (Semenescu et al., 2020). Of relevance for future studies, the authors emphasize the importance of conducting more robust experimental studies on the effects of soft measures, especially with control groups and objective measurements of travel behaviour. Further, they stress the need for studies reporting all relevant outcomes of car use, such as trips, distance, and modal share implications.

This study aligns with these requests and reports the findings from a randomised controlled e-bike trial of frequent drivers in Sweden. Analysing frequent drivers enables us to provide an upper bound for the potential substitution effect of e-bikes. Travel behaviour data and survey answers were collected via TravelVu, a smartphone application specialized in detecting trip characteristics. To facilitate future syntheses, we also report effect sizes for the effect of the intervention. The main research questions for this study is how much the e-bike increase cycling for frequent drivers and what modes, if any, are substituted and to what extent. Further, the effect of the trial on the perceptions towards e-bikes will be investigated.

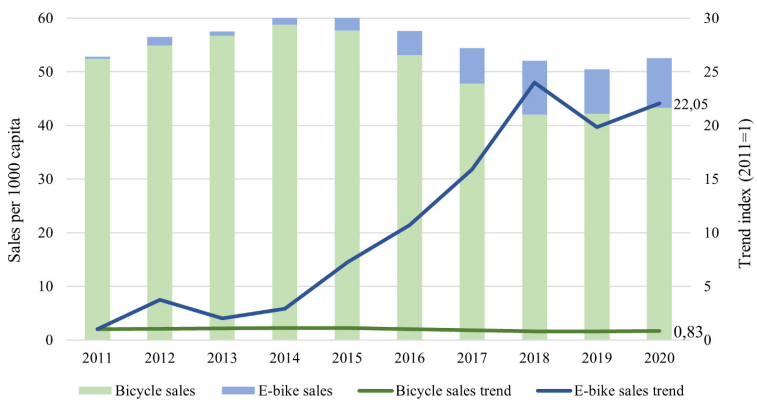

Fig. 1. Bicycle and e-bike sales (from 1st September to 30th of August) per 1000 inhabitants in Sweden (left axis) and relative sales trend (right axis). In Sweden, total bicycle sales go in waves and have been influenced by a strong increase of e-bikes in the last five years. Illustration from the author based on figures from the Cykelbranschen Swedish Bicycle Association (2020) and SCB (2020).

2. Background

2.1. E-bikes in Sweden

In Sweden, sales of e-bikes have only gained momentum in recent years but have increased significantly since then (see Fig. 1). Sales peaked in 2018 when the Swedish government introduced a subsidy for two-wheeled electric vehicles of 25%, or up to SEK 10,000, back on the purchase price. At that time, more than 100,000 e-bikes were sold with a market share of 20%. When the rebate program was withdrawn the following year, the proportion fell to 16% and increased again to 18% in 2020, which could partly be due to the COVID-19 outbreak. However, the only marginal decrease in sales between 2018-19 suggest that the rebate program did increase the demand for e-bikes. Due to the strong sales trend of e-bikes in Sweden since 2015, e-bike's market share in Sweden has now caught up with that of several other frontrunners in Europe. It is therefore important to study the effect that e-bikes have on transport in general, and the modal shift implications in particular.

2.2. Research on modal shift implications from e-bikes

The scientific literature about e-bikes increased significantly from 2008. As noted by Salmeron-Manzano and Manzano-Agugliaro (2018), most of these studies were conducted in Asia, the United States, and Europe. For the sake of comparison, we only report scientific results that originate from Europe and have focused on modal shift implications (Table 1). Apart from Sweden, the studies were conducted in the Netherlands, Norway, England, and Denmark. The cycling culture in these countries are quite like Sweden, the exception being England where cycling is less common as a means of transport. However, the study by Cairns et al. was done in Brighton, a city with relatively high shares of active transport.

Overall, the studies report that e-bikes have a positive impact from a sustainability point of view. Owning or borrowing an e-bike is associated with an increase in bike use, both in terms of the number of trips and distance travelled (Fyhri and Sundfør, 2020). About half of all e-bike trips replace car trips (Cairns et al., 2017; de Kruijf et al., 2018; Haustein and Møller, 2016; Winslott Hiselius and Svensson, 2017) and a large share of the remaining half seem to replace conventional bicycle (c-bike), and to a lesser extent public transport and walking. It is not customary to report metrics about e-bikes effect on distance travelled with different travel modes, which is problematic due to its relevance for determining energy and emissions savings. However, studies presenting distances reveal a decrease in car km per e-bike user of 20–28% (Cairns et al., 2017; Kroesen, 2017) and a decrease in car use distance as a total modal share of around 10% (Sun et al., 2020). An important aspect to consider when comparing studies from different contexts, however, is that the e-bike has the greatest substitution effect for the most prominent mode within a given location. A higher net gain environmental effect is therefore expected in more car-dependent contexts (Kroesen, 2017; Sun et al., 2020).

Even though these studies contribute with valuable knowledge on the modal shift implications from e-bikes, they employ either a cross-sectional or quasi-experimental study design that suffers from potential bias from confounding factors or a lack of internal validity. With cross-sectional data, within-person changes cannot be assessed. Further, most studies rely on self-reported survey answers which could result in over- or underestimation of effects due to social desirability bias. The absence of intervention evaluations with independent data and random assignment to treatment and control groups constitute a considerable risk of bias (Arnott et al., 2014). It also complicates synthesisations of research results, which are dependent on studies with strong study designs and complete outcome measures, something that has been strongly emphasised in previous meta-analyses (Arnott et al., 2014; Bamberg and Rees, 2017; Chatterjee and Carey, 2018; Graham-Rowe et al., 2011; Ogilvie, 2004; Ogilvie et al., 2007; Scheepers et al., 2014; Semenescu et al., 2020; Yang et al., 2010). To the best of our knowledge, this is the first e-bike study with an RCT design and the first to collect data

Table 1
E-bike modal shift implications from research literature in Europe.

Country	Method and sample	Modal shift implications	Source
Netherlands	A longitudinal study on 107 e-bike users from the Netherlands Mobility Panel.	After e-bike adoption, the share of c-bike km decreased from 20.3 to 2.1 per cent and the share of car km from 59.6 to 50 per cent.	Sun et al. (2020)
Norway	Before after-study with 39 e-bike purchasers and two control groups. Survey with a travel diary.	After purchasing an e-bike, total bike share km as a share of all transport increased from 17 to 49%. Walking, public transport and driving decreased. The shift was not likely to be due to a novelty effect.	Fyhri and Sundfør (2020)
Netherlands	A longitudinal study of the effects of an e-cycling incentive program with responses from 547 participants.	The share of commute trips made by e-bike increased from 0 to 68%, with an increase of up to 73% after six months of participation. 50% of the e-bike trips substituted car trips and 50% substituted c-bike trips.	de Kruijf et al. (2018)
Netherlands	SEM model with data from the Dutch mobility survey, 2013, 2014, 2015. Total of 104,239 respondents.	E-bike ownership strongly reduces c-bike km (66%) and PT km (64%), but also, albeit to a lesser extent, car km (28%).	Kroesen (2017)
Sweden	Surveyed 321 users of e-bikes identified through the customer register of one major e-bike retailer.	For the e-bike owners, the average distance e-cycled per week was 71 km. 3–12% of the e-bike trips replaced walking; 4–16% replaced public transport; 15–26% replaced a c-bike; and 47–67% replaced a car trip.	Winslott Hiselius and Svensson (2017)
England	E-bike trial with 80 employees for a period of 6–8 weeks.	Average e-bike usage was in the order of 24–32 km per week with an overall reduction in car mileage of 20%.	Cairns et al. (2017)
Denmark	Survey to 427 respondents using an e-bike regularly for at least 1 month.	64% stated they use e-bike on trips when otherwise use c-bike; 49% when normally use a car (bus: 48%; walk: 33%; train/metro: 26%).	Haustein and Møller (2016)

from smartphones to evaluate the substitution effect of e-bikes. Thus, one important contribution made by this research paper, and which distinguishes it from previous e-bike studies, is through the use of what is called the 'gold standard' in evaluation research (Bamberg and Rees, 2017; Semenescu et al., 2020).

3. Method

3.1. Study area

The e-bike trial was aimed at a major company in Skövde, a medium-sized industrial city in Sweden with 55,000 inhabitants. Skövde was chosen because of its relatively low cycling levels and due to its diversity of large companies. One thing we learned from previous studies is that the e-bike's positive environmental impact is greatest where car use is high. According to the Swedish National Travel survey (2011–14), the national average is 50% of trips by car, 14% by public transport, and 29% by walking and cycling (Statistics Sweden, 2016). The equivalent figures for Skövde are 53%, 10%, and 33% (Ramboll, 2011). Consequently, we expected a greater effect of the trial on car use in Skövde than, for example, the study made by Cairns et al. (2017), which was carried out in Brighton where car use only accounts for 40% of trips.

3.2. Sample

An invitation to participate in the e-bike trial was sent to 3200 employees through the company email address register. If interested, the employees had to fill in information about age, gender, usual travel mode and distance to work. 317 employees said they were interested to participate. Because the project team only had access to 50 e-bikes, the aim was to recruit 100 participants (half of the sample would constitute a control group). Priority was given to frequent car drivers and those living within 5–12 km to the workplace, as this group was being considered to have the largest substitution potential and benefit of the e-bike. After recruitment and written consent from the participants to use their data for research purposes, half of the sample were randomly assigned to a treatment group and the other half to a control group. Occasional dropouts were replaced by inviting another employee to participate. At the start of the trial, the sample consisted of 98 participants. In the end, 65 participants completed all measurements, of which 40 belonged to the treatment group and 25 to the control group. This sample formed the basis for all analyses. A dropout analysis revealed that those who were not included in the analysis were slightly older and had a 15% higher share owning two or more cars compared to the sample, however, these differences were not statistically different.

As can be seen in Table 2, the gender balance for the sample was highly skewed due to an overrepresentation of male employees at the company. That said, the sample was never intended to be representative of the general population but aimed to be a suitable target group for the intervention. Further, car use was extremely high; nearly all participants usually drove to work and around 70% had two or more cars within the household.

3.3. Data collection and trial overview

Travel behaviour data were collected in spring/summer 2020, using the GPS-tracker app TravelVu. This app was also used for distributing the survey. TravelVu is a semi-automated travel survey app, developed to collect travel survey data, that relies on sensors in smartphones to collect travel survey data and provides a user interface which allows respondents to check, adjust and confirm the route they travelled. It identifies 10 different modes of travel automatically and the user can use another 6 modes when adjusting the trip. Apart from transport mode, the app register start time and location, stop time and location, distance and route for each trip and start time, stop time, location and purpose each time a stationary event is detected. Further, an algorithm for learning the user's travel pattern takes previously marked as the correct mode of travel and trip purpose into account when suggesting modes and purpose of new trips. The app records switching trains or buses, as well as time spent parking or waiting. Since logging is automatic, few if any trips are missed altogether (except for those where the participant does not carry their phone with them), and the distances travelled

Table 2
Demographic characteristics of the sample.

	Treatment group (N = 40)	Control group (N = 25)
Mean age	45	52
Female	12%	12%
Education	Elementary: 5% Upper secondary: 67% Uni. <3 years: 14% Uni. ≥3 years: 14%	Elementary: 8% Upper secondary: 72% Uni. <3 years: 20%
Have a driving license	100%	100%
Number of cars in the household	One: 26% Two: 64% More than two: 10%	One: 32% Two: 60% More than two: 8%
Owns a conventional bike	86%	84%
The most common means of transport for work	Car: 88% Bicycle: 12%	Car: 100%

are measured with a relatively high degree of accuracy (Sjöman et al., 2020). The user must approve the trips made and was encouraged to do so at the end of each day. The disadvantage of this is that it requires a little more commitment from the user than if the app had been fully automated, but the advantage is that potentially incorrect measured journeys can be detected and corrected giving higher quality of data. The travel data was corroborated with the survey data which allowed the whole material to be simultaneously imported and analysed in IBM SPSS Statistics 25. Compared to collecting travel survey data with a paper and pencil travel diary, more trips are collected when using TravelVu. The largest difference is seen for walking trips while number of cycling trips only show a moderate increase, if any. For a more detailed description of the TravelVu app as a travel logging method, see e.g. (Ek et al., 2018; Eriksson et al., 2018).

A total of 50 e-bikes was at the project's disposal through Västra Götaland county council. The e-bikes were of the 'pedelecs' sort where pedalling is required, but the rider can choose to switch on battery-powered assistance. The net power of the motor is 250 W, and the support is disabled when the rider stops pedalling or when the bike exceeds 25 km/h. There are e-bike models available where the user does not have to pedal with a power of up to 4000 W and a speed limit of 45 km/h. However, these are classified as mopeds and were not used in the study.

The travel behaviour of both the treatment and control group was measured for one week at the baseline (M1). The treatment groups then borrowed the e-bikes for five weeks. They were only instructed how to operate the e-bike and that they could use it for as much as they liked. Towards the end of the trial, a new measurement was done for both groups (M2). After the treatment group had finished five weeks of e-biking, the control group were given the e-bikes and used them for another five weeks. At the end of the control group's trial period, another measurement was conducted (M3). The last trial period was done for two reasons. First, to prevent dropouts from the control group by keeping them motivated to participate. Second, to validate the results from the treatment group (albeit with no second control group for the control group). A timeline for the project is presented in Table 3.

3.4. Data sources

The app registered duration, distance, route, time, and travel mode of each trip that was conducted. The participants would then correct the travel diary at the end of each day.

The survey included questions about age, gender, education, access to travel modes, attitudes towards e-bikes and cycling. There were also psychological survey items (TPB, TTM, personal norms, habit, and perceived self- and collective efficacy) that have not been utilised in this paper. Finally, questions were added to the second and third survey round (M2 and M3) about COVID-19, see next paragraph.

3.5. Effects of COVID-19 on the study

Because the baseline measurement (M1) started at the same time as the outbreak of COVID-19 were gaining momentum in Sweden, questions were asked to the participants via the questionnaire sent out in period M2 about how the virus had affected their travel habits during the test period. The purpose was to capture how the results of the study may have been affected by the pandemic.

When asked how COVID-19 has affected participants' commuting to work, 83% responded that it was significantly affected. Only 10% stated that they were not affected at all. The number of days the participants commuted to work during the test period averaged 1.5 days per week, which differs significantly from the average of 4 days per week, which participants on average stated that they usually commute to work. However, the data indicates that other travel activities have been carried out as usual. The participants in the study performed an average of 4.3 travel activities per day during the baseline week. This is slightly higher compared to another Swedish survey showing that trips decreased to an average of 3.9 trips per person and day during the period March 10 to April 12 from 4.7 trips before COVID-19 (Trivector Traffic, 2020).

Respondents were also asked about their modal choice during the pandemic. 95% stated that the pandemic did not affect their normal use of cycling, walking, or public transport, but 20% stated that they drove less by car and the remaining 80% that their car use was not affected. Most of the respondents stated that they used the e-bike less because of the pandemic (56%), while 27% said they used it more and 17% that their use was unaffected. Some wrote that they used the e-bike less than they would under normal circumstances because the work commute, which decreased considerably due to COVID-19, was particularly suitable to be carried out with the e-bike.

In summary, the responses indicated that due to COVID-19, participants generally travelled much less to work, travelled a little less by car (which is reasonable given that the car is the dominant modal choice for the sample), and used the e-bike to a lesser extent. In the

Table 3
Timeline for intervention and data collection.

M1		M2		M3
Treat and control	Treat	Treat and control	Control	Control
March 9–15	April 2–May 7	April 27–May 3	May 8–June 15	June 1–June 7
Baseline measurement and survey		*Follow up measurement and survey*		*Follow up measurement and survey*
	E-bike trial		*E-bike trial*	
1 week	5 weeks		5 weeks	

discussion section, we will return to how this may have affected the results.

4. Results

4.1. Effect of the trial on the number of trips, distance, and modal share

The effect of the trial on the number of trips and modal shares are presented in Table 4. On average, the participants conducted 4.4 trips per day during the test periods. Between M1 and M2, the treatment group decreased their number of car trips by 1 and increased their e-bike trips by 0.6 and conventional bicycle trips by 0.3 (non-significant). The use of public transport and walking stayed at approximately the same levels. For the control group, there were no significant changes from M1 to M2. Between M1 and M3, however, the control group decreased their number of car trips by 1.1 and increased their e-bike trips by 1 and the trips by conventional bicycle by 0.5.

On average, the number of car trips expressed as the share of total trips went from 74% at M1 to 53% at M2 for the treatment group and from 74% to 75% for the control group. The share of bicycle trips increased by 8% (non-significant) and e-bike trips by 17% for the treatment group while remaining at 2–3% bicycle trips and 0% e-bike trips for the control group. The sum of cycling (bicycle and e-bike) increased on average by 25% for the treatment group. At M3, the control group increased the share of these modes by 9% and 19%, respectively, aggregating to 31% cycling, while decreasing the share of car trips down to 44%, compared to 74% in M1.

The effects of the trial on the distance covered by different modes, and modal splits, are presented in Table 5. On average, the treatment group decreased the distance made by car with 13.7 km per person and day between M1 and M2, while increasing the distance made by bicycle and e-bike with 1.4 km (non-significant) and 5.1 km, respectively. Consequently, the total cycling (the sum of regular cycling and e-cycling) increased on average from 1.7 km at M1 to 8.2 km at M2. During the same period, the control group increased the distance made by car with 4.2 km and the distance made by bicycle with 0.4 km, (both changes non-significant). Between M1 and M3, the control group decreased the distance made by car with 12.5 km on average (non-significant), while increasing the distance made by bicycle and e-bike with 1.1 km (non-significant) and 7.1 km, respectively. The total cycling increased on average from 0 km from M1 to 8.7 km at M3.

The treatment group decreased their car use as the share of total distance travelled by 21% and increased the share of e-cycling by 16% and the share of conventional bicycling by 5% (non-significant). For the control group, there were no significant changes from M1 to M2. At M3, however, the control group had decreased their car use as the share of total distance travelled compared to M1 by 26%, and increased their share of e-cycling by 22% and the share of conventional bicycling by 4% (non-significant).

The effect sizes were medium for the decrease in car trips and car distances ($d = 0.5$–0.6) and high for the effect on cycling trips and cycling distance ($d = 1.92$–6.31), according to Cohen's conventions (Cohen, 1988). The effect sizes for changes in modal shares were also high, ranging from $d = 1.17$–7.25.

4.2. Perceptions of the e-bike

The participants stated that the e-bike allowed them to cycle more often and longer distances than before, compared with a

Table 4
Paired-samples *t*-tests on modal shares in relation to the average number of trips travelled per day on each mode of transport for treatment and control group at M1 and M2 as well as M1 and M3 for the control group. Based on 2000 bootstrap samples. Means, standard deviations, and Cohen's *d* effect sizes (significant differences).

	Treatment group					Control group						
	M1		M2			M1		M2		M3		
	Nr	SD	Nr	SD	*d*	Nr	SD	Nr	SD	Nr	SD	*d*
Car	3.03	2.07	2.00*	1.79	0.50	3.38	1.87	3.76	2.23	2.29*	1.41	0.58
PT	0.02	0.09	0.02	0.09		0.10	0.21	0.04	0.13	0.03	0.09	
Bicycle	0.16	0.33	0.45	0.73		0.11	0.27	0.17	0.27	0.64*	0.68	1.96
E-bike	0.02	0.12	0.65**	0.78	5.25	0.00	0.00	0.00	0.00	0.97*	1.15	n/a
Walk	0.89	1.23	0.65	0.84		0.89	1.19	1.12	1.27	1.22	0.99	
Total	4.12		3.77			4.48		5.09		5.15		
B & e-b	*0.18*	*0.37*	*1.11***	*0.89*	*1.92*	*0.11*	*0.27*	*0.17*	*0.27*	*1.60***	*1.06*	*5.52*
Modal share												
Car	0.74	0.18	0.53*	0.22	1.17	0.75	0.21	0.74	0.24	0.44**	0.2.0	1.48
PT	0.00	0.01	0.01	0.02		0.02	0.05	0.01	0.02	0.01	0.01	
Bicycle	0.04	0.05	0.12	0.18		0.02	0.04	0.03	0.06	0.12*	0.12	2.50
E-bike	0.00	0.03	0.17*	0.27	5.60	0.00	0.00	0.00	0.00	0.19*	0.25	n/a
Walk	0.22	0.15	0.17	0.10		0.20	0.18	0.22	0.25	0.24	0.21	
B & e-b	*0.04*	*0.06*	*0.29****	*0.24*	*4.17*	*0.02*	*0.04*	*0.04*	*0.06*	*0.31***	*0.23*	*7.25*

*** $p < 0.001$.
** $p < 0.01$.
* $p < 0.05$.

Table 5
Paired-samples *t*-tests on modal shares in relation to the average distance travelled per day at M1 and M2 for the treatment and control group as well as M1 and M3 for the control group. Based on 2000 bootstrap samples. Means, standard deviations, and Cohen's *d* effect sizes (significant differences).

	Treatment group					Control group						
	M1		M2			M1	M2		M3			
	Km	SD	Km	SD	*d*	Km	SD	Km	SD	Km	SD	*d*
Car	37.4	22.8	23.7*	13.3	0.60	35.8	35.7	40.4	38.4	23.3	22.9	
PT	0.0	0.1	0.0	0.1		1.1	0.5	0.1	0.4	0.1	0.2	
Bicycle	1.1	1.3	2.5	4.7		0.5	0.7	0.9	1.7	1.6	2.8	
E-bike	0.6	2.6	5.7*	6.6	1.96	0.0	0.0	0.0	0.0	7.1**	6.6	n/a
Walk	0.3	0.7	0.1	0.2		0.3	0.4	0.2	0.3	0.3	0.6	
Total	39.4		32.0			37.7		41.6		32.4		
B & e-b	*1.7*	*3.3*	*8.2***	*6.4*	*1.97*	*0.5*	*1.3*	*0.9*	*1.7*	*8.7***	*4.0*	*6.31*
Modal share												
Car	0.95	0.09	0.74***	0.26	2.33	0.95	0.06	0.97	0.26	0.72***	0.27	3.83
PT	0.00	0.01	0.00	0.00		0.03	0.05	0.00	0.01	0.00	0.01	
Bicycle	0.03	0.05	0.08	0.15		0.01	0.04	0.02	0.08	0.05	0.09	
E-bike	0.02	0.05	0.18**	0.28	3.20	0.00	0.00	0.00	0.00	0.22**	0.3	n/a
Walk	0.01	0.02	0.00	0.01		0.01	0.02	0.01	0.02	0.01	0.03	
B & e-b	*0.05*	*0.08*	*0.26***	*0.26*	*2.63*	*0.01*	*0.05*	*0.02*	*0.08*	*0.27***	*0.28*	*5.20*

*** $p < 0.001$.
** $p < 0.01$.
* $p < 0.05$.

conventional bicycle. As can be seen in Table 6, most respondents agreed with this. This confirms the travel data showing that the e-bike was used more often and for longer distances than with the bicycle. When asked whether the e-bike can generally replace the car for most trips, the answers were not as clear, averaging 4.1 on a scale 1–7. This is reasonable given that the e-bike is seen as a means of transport that can replace the car for certain errands, but not all. Fig. 2 demonstrates this nuance. When asked to what extent the e-bike can replace the car for different travel purposes, the respondents indicate that it is mainly for work and other errands such as visiting friends and family and going to the training facility, and some extent leisure trips, that the e-bike can substitute the car. Grocery shopping, shopping in general, and dropping off and picking up one's children are more complicated tasks for which the car seems to be more indispensable.

Table 7 presents mean differences of perceived obstacles preventing participants to commute by bike to work, comparing between a conventional bicycle (for which answers were collected at M1) and an e-bike (answered at M2 for treatment group and M3 for the control group). Although the obstacles are generally ranked to be small, practicalities involving loading and unloading are the biggest obstacle regardless of whether a conventional bicycle or an e-bike is used. However, the respondents stated that the e-bike significantly reduced obstacles related to time consumption, physical exertion, and long distances. Instead, lacking secure parking was a significantly larger issue when using the e-bike, as was traffic safety and bad cycling infrastructure.

The participants were further asked to make a qualitative assessment of the e-bike, by stating the three most prominent advantages and disadvantages that influenced their e-bike experience. The answers were sorted into themes and are presented in Fig. 3. Overall, the pros outweigh the cons (some participants stated that there were no disadvantages whatsoever), but it is clear that rain, wind and cold weather is considered to be an issue for e-cycling. The other main disadvantages are practical issues like performing errands that include transport of goods/passengers, that the battery is heavy to carry around and the risk of theft. Some reported that it is time-consuming riding an e-bike compared to driving, that it has technical weaknesses such as low speed and bad geometry, and that it is heavy and expensive to buy.

The most positive aspect of the e-bike according to the participants is that it is easy and convenient to use (more than half of the sample thought so). Interestingly, several of the other benefits are related to altruistic or hedonic aspects; e-biking is good for the environment, makes one more alert and provides exercise, gives you fresh air in the morning, is fun and contributes to increased well-being. Some wrote that the e-bike's advantages were also related to time-savings, avoiding congestion and trouble finding a parking space, and cost-savings.

5. Discussion

This study reports the findings from a randomised controlled e-bike trial investigating the effect on travel behaviour and attitudes

Table 6
1 = strongly disagree, 7 = strongly agree.

	Mean	SD
The e-bike has allowed me to cycle more often than I used to before the test period	5.1	2.1
I have e-cycled longer distances than I would with a conventional bicycle	5.5	2.0
An e-bike can replace most trips I usually make by car	4.1	1.5

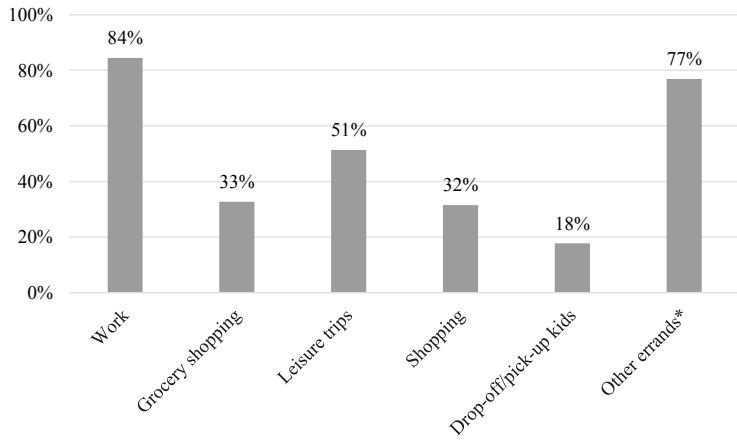

Fig. 2. Share of respondents who agreed that the e-bike can replace the car for different travel purposes. *E.g. visit friends and family, going to the health centre, or the training facility.

Table 7
Paired-samples *t*-tests on participants' rating of obstacles for commuting to work by conventional bicycle and e-bike. Means and standard deviations. 1 = no obstacle, 7 = big obstacle.

	Bicycle		E-bike	
	Mean	SD	Mean	SD
Practical obstacles (pick-up/drop-off, transporting goods)	3.24	1.94	3.27	1.84
Time-consuming	3.12	1.68	2***	1.48
Physically demanding	2.75	1.79	1.46***	1.08
Too long distance	2.65	1.65	1.57***	1.13
Bad cycling infrastructure	2.48	1.76	2.06	1.55
Traffic safety	2.21	1.57	2.13	1.59
Incentives for car commuting (e.g. a company car)	1.59	1.17	1.54	1.09
Lack of secure parking	1.57	0.93	2.24**	1.78

*** $p < 0.001$.
** $p < 0.01$.

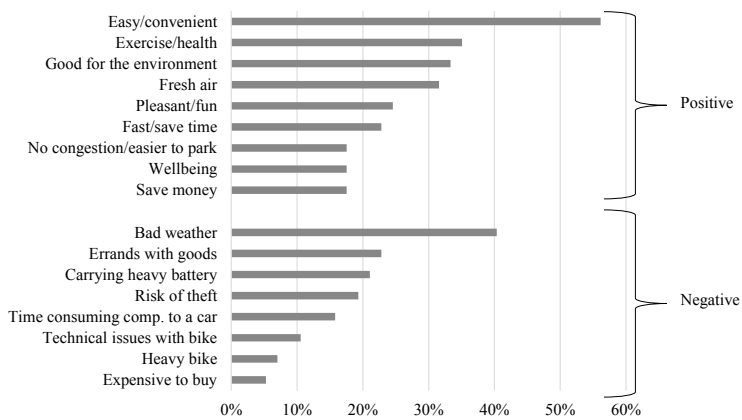

Fig. 3. Advantages and disadvantages of the e-bike according to the participants. Expressed as the proportion of participants who mentioned the aspect in question.

towards the e-bike as a substitute for the car. Travel data were collected from 98 frequent drivers in Skövde (of which 65 could be used in the analyses) through a smartphone application. This study thus responds to the need for more robust evaluations of soft transport measures by being able to demonstrate a treatment effect from objective travel data.

The results show that access to an e-bike increases the total number of bike rides by 1 trip and 6.5 km per day and person on average. This is an increase of 25% of the share of bicycle trips and a 21% increase in the bicycle's share of the total distance travelled. In contrast to previous studies, conventional cycling actually increased during the test period. Virtually all increase in e-cycling was at the expense of the car, in other words, a substitution effect of close to 100%. An interesting observation is that the total travel measured in distance decreased significantly, about 20%, when the participants gained access to the electric bicycle. This may be because the participants chose closer destinations when they had access to the e-bike. If so, the substitution effect for e-bikes may actually be even greater. Further research can examine the effect that e-cycling has on the total travel distance. The number of car trips decreased by 1 and the car distance by 14 km per person and day on average, corresponding to a 37% reduction in car kilometres. The effect on the modal split was a reduction of 21% for car use, expressed both as the number of trips and distance travelled. These results are only based on the treatment group, but it is worth mentioning that the pattern was similar for the control group's trial period.

The large substitution effect from cars to e-bikes should be seen in the light of the high share of car trips that were present in the sample at the baseline. The substitution effect reported here may be in the upper bound, underlining the fact that the potential for reducing car use (and related carbon dioxide emissions) is greatest in the segments that drive the most. Thus, the substitution effect from cars to e-bikes is likely to be smaller for the general population than found in this study. As found in earlier e-bike studies, one should consider the context and the type of target population when estimating and evaluating the impact of an e-bike intervention. For example, the reduction in car mileage of 37% as found in this study is higher than that reported by Kroesen (2017) (28%), and Cairns et al. (2017) (20%). However, their studies were conducted in the Netherlands and in Brighton, England, where the car share is lower than in Skövde. Nevertheless, this study demonstrates that the e-bike can seriously replace the car, even for frequent drivers, something that has previously proved extremely difficult to accomplish with other types of interventions (Andersson, 2020; Andersson et al., 2020a; Innocenti et al., 2013). Moreover, the reduction in car distance from 37.4 km to 23.7 km is almost at the sustainable level (21.8 km) for reaching the climate goals for the Swedish transport sector, estimated based on data from the Swedish National Travel Survey (Winslott Hiselius and Smidfelt Rosqvist, 2018). This highlights the potential of working with soft measures to reach sustainability goals.

Despite the relatively large substitution effect from cars to e-bikes, we need to stress that the e-bike does not replace all types of car trips, at least in its current form. The survey results indicate that it is mainly work trips and other single-purpose trips that are considered suitable to switch for e-bikes. Trips that demand transporting goods and/or passengers are still, for the general participant, dependent on the car. Bad weather conditions are a further obstacle that prevents people from cycling. Other issues that could be improved by manufacturers of e-bikes are the handling of the battery and the risk of theft.

Regardless of the limitations of the e-bike, it seems to provide enough benefits to increase cycling at the expense of the car. Not only is e-cycling perceived as easy, convenient, and fast, but it also provides other added values such as increased well-being, exercise, fresh air, saved money, joyful rides, and a good environmental conscience. Such hedonic and altruistic traits can be used for marketing purposes, and more research is needed to increase the understanding of the motives behind the demand for e-bikes.

Several studies of similar nature have shown the significant potential of the e-bike to contribute to a more sustainable transport system (see table 1). This study supports this conclusion and contributes by using an objective measurement instrument that does not depend on self-reports from the participants. Another strength of our study is the use of a solid RCT design that minimises the risk of bias from confounding factors that may otherwise affect the results. This was particularly important given that COVID-19 broke out in conjunction with the data collection.

As mentioned in Section 3.5, the data collection coincided with the dramatic outbreak of COVID-19. On the advice of the Swedish Public Health Agency, the Swedish government chose a softer action plan than in other European countries. Instead of a complete lockdown, Swedish citizens were encouraged to social distancing and to work from home if possible. Still, the participants in this study were affected, especially their work trips. Judging by the survey results, the majority travelled less during this time than usual and since cars were the predominant mode of transport in the population, car use was probably less frequent than under normal circumstances. This would mean that the substitution effect in this study is overestimated. On the other hand, the participants stated that the e-bike is particularly suitable for travel to and from work, and indicated that fewer work trips made them use the e-bike less than would be the case without COVID-19. This suggests an underestimation of the substitution effect. If we are to allow ourselves to speculate, then these two effects together may have cancelled each other out, which would then make the net effect unaffected.

5.1. Limitations

This study has some limitations. First, the small sample size limits the statistical power, and the sample of participants is not representative and should therefore not be generalised to the wider population. This was never the intention either, but the sample reflects a car-oriented segment. Further, even though we conducted a randomised controlled trial, this could be affected by self-selection bias in that the employees that volunteered to participate already had a desire to change their travel behaviour. As previously mentioned, the effect may then represent an upper bound for the substitution effect. Second, there is a potential disadvantage of evaluating trial periods because the limited time window may affect participants' travel behaviour, although, recent studies have found that eventual changes in travel behaviour from soft interventions tend to last over time (Fyhri and Sundfør, 2020; Semenescu et al., 2020). Finally, the effect of the weather becoming warmer and increasingly bicycle-friendly during the test period was controlled by the inclusion of a control group. However, it should be taken into account that seasonal variations can affect the effect of e-cycling.

Future studies may therefore evaluate campaigns carried out during the winter months to investigate the effects of colder weather on e-cycling.

6. Conclusions

The effect of an e-bike test in Skövde, Sweden, showed that when frequent drivers got access to an e-bike, their cycling increased by an average of 1 trip and 6.5 km per day and person, which led to a 25% increase in total cycling. The whole increase was at the expense of car travel, which on average decreased by 1 trip and 14 km per person per day, a decrease in car mileage of 37%. The modal share of the car decreased by 21% expressed both as the number of trips and distance. Most participants consider work and other singles-purpose trips to be best suitable for e-cycling. E-cycling provides many benefits for both society and the individual and our overall conclusion is that efforts to increase e-cycling are a worthwhile investment.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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