Climate and economic research in organisations and from a macro perspective

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Abstract: This is a synthesis of a doctoral thesis focusing on future strategies to meet rigorous principled emission and energy efficiency targets and to modulate the impact of travel policies, technical components and behaviours in economically advantageous ways. The modelling frameworks developed throughout the thesis build on a target-orientated approach called backcasting. Sustainable travel strategies are analysed from two main viewpoints. The first four studies focus on company travel planning, where behavioural modelling proved to be an important tool for deriving target-orientated travel policies consistent with employee preferences. The latter two studies focus on strategies and preconditions to meet future emission targets and energy efficiency requirements at a macroscopic regional level by 2030. Backcasting's role as a generic methodology for effective strategic planning is discussed.

Keywords: SSD; strategic sustainable development; backcasting; greenhouse gas emissions; traffic planning; company travel planning; mobility management; ICT.

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Biographical notes: Markus Robèrt has a PhD in Infrastructure at the School of Architecture and the Built Environment at the Royal Institute of Technology in Stockholm (also MSc in Engineering Physics at the Royal Institute of Technology). He is now working as a researcher in urban planning at the Royal Institute of Technology, and a private consultant, developing strategies for travel-related climate targets at a number of large companies and organisations. In his research, discrete choice modelling serves an essential role in the evaluation and analysis of individual preferences and attitudes regarding company travel planning and mobility management strategies.

1 Introduction

The overall aim of this thesis was to devise and evaluate sustainability strategies of the urban transport system in general, and business and commuter travel in particular. Traffic planners all over the world face the same type of urban transport dilemma of how to strategically plan for maximising urban mobility, while at the same time minimising the associated emissions, congestions and accidents.

Transport accounts for 31% of energy use in the EU, where emissions from road traffic account for about 23% of total CO_2 equivalents and are expected to increase (European Environmental Agency, 2004; European Commission, 2005). Because of the rapid growth and dominant use of fossil fuels, and the transport sector's need for relatively refined fuels, may prove the transport sector to be the most difficult to monitor and the most difficult to include in emission trading programmes – in particular as regards private vehicle travel (Coussan et al., 1997; STEM, 2005). Besides economic, social and ecological impacts originating from expanding traffic infrastructure, urban sprawl, and use of land in the expanding renewable energy sector, we also see many other local problems from inefficient traffic systems and increasing traffic loads. Examples are congestion and undesirable increases in travel times, stress, respiratory diseases, cancer and accidents (Department of Health, 2004; WHO, 2006). Furthermore, there are indications that we might well be approaching a tipping point where unexpected climate shifts appear as the cause of the global temperature increase. From this perspective it is important that no energy sector lags behind in the search for strategies preventing climate change. The need for good examples is even more crucial in a situation where new economies enter the market (primarily China and India).

Achieving future emission targets and managing the coming transition to renewable fuels will place heavy demands on future production and manufacturing processes to make those efficient as regards energy, land use and other resources. Consequently, the competition for renewable fuels will increase in the future (Åkerman and Höjer, 2006) and most likely there will be limitations in supply, at least in the next coming decades (Azar et al., 2003; Iglesias and Apsimon, 2004). Thus, efficient energy use, both in the transport sector and in other sectors of the society, is a prerequisite for a smooth transition to a renewable fuel system where unexpected synergy effects and benefits from economies of scale could be discovered.

In order to avoid hasty headlong decisions at a later date, when requirements on energy efficiency are likely to become even more acute, it is important to analyse road-users' acceptance and potential market shares of alternative travel modes. World-wide, there are numerous examples of cities introducing various forms of *mobility management* solutions in order to encourage citizens to choose more resource-efficient travel alternatives. Mobility management represents the 'software' in the traffic infrastructure, improving integration of public transport, walking and cycling in the road network, encouraging collective car use (e.g. car sharing or ride matching), finding ways to substitute physical travel to virtual means of communication (e.g. videoconferencing and teleworking) and developing new standards for intelligent transport systems in order to monitor flow and reroute traffic (McCullough, 2004).

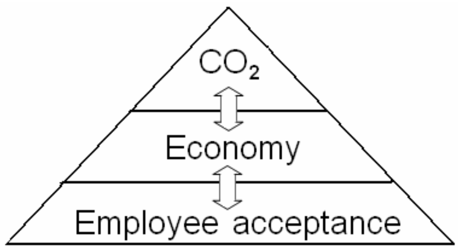
1.1 The company perspective

Companies are potential key players in the development of mobility management and a sustainable transport system and may chose different means to exploit this potential by:

1. analyse employee travel behaviour and willingness to adopt more resource-efficient travel alternatives in the creation of target-oriented travel policies, and
2. use the aggregate results from the analysis of employee preferences to open a market-oriented dialogue with actors regarding employee criteria for choosing more resource-efficient travel alternatives.

However, a problem when discussing sustainability terms in private companies is that the time perspective is generally considered too long (see e.g. the Brundtland Commission's definition[1]). Thus, an obvious prerequisite for implementing sustainable travel policies targeting, e.g. emission reductions in private companies, is that the sustainable long-term emission target is transferable to short-term and mid-term targets that can serve as flexible platforms towards the longer term (Ny et al., 2005). Such shorter targets should give sufficient return on investment, in a sufficiently short time, to sustain the transition, including the indirect value from increased work efficiency among employees, improved public relations and promotion of own products or services. Furthermore, the successful launch of company travel policies is strictly dependent on the social dimension of sustainability, concerning employee acceptance of alternative travel behaviour. This relationship, entailing all three dimensions of sustainability, is illustrated in Figure 1, where the emission target could be perceived as the 'tip of the iceberg', entirely dependent on the development of the lower segments (economic feasibility and employee acceptance). This bottom-up approach formed the basis for the backcasting frameworks developed at a company level in this thesis.

Figure 1 The feasibility of emission reductions for a profit-maximising company is strictly dependent on the economic payback, which in turn demands employee acceptance of the alternative travel policies



To date, sophisticated traffic modelling techniques and travel choice analyses have been developed mainly to provide cost benefit assessments of new infrastructure investments and optimised private vehicle traffic, where the focus is often placed on objectives such as traffic flows and vehicle times, while overlooking others, such as improved mobility for non-drivers. All energy sectors (where the transport sector sets a good example) might well approach a paradigmatic shift where limits for emissions and energy use will meet stricter conditions in the future.

Thus, the challenge for future traffic planners and company managers aiming to achieve long-term environmental, economic and social sustainability is to incorporate all these dimensions, where the first constitutes the upper limit in the planning process in order not to harm the other in the long-term perspective. However, this does not necessarily mean that we need to reduce economic growth and quality of life. On the contrary, by taking boundaries for natural capital into account at an early stage in the planning process, decision-makers could well create win-win situation by being one step ahead in the global adaptation to a more resource-efficient economy when the demand for best practices and know-how is growing, and this might well be turned into a market advantage.

From this perspective, the original objectives of the thesis were twofold:

1 To identify potential win-win situations from more resource-efficient travel, both at a regional level and from a company perspective, and to demonstrate how the three dimensions of sustainability (environment, economy, social aspects) could move in parallel.

2 To develop tools for policy assessments based on the target-orientated approach of backcasting (see Section 2.1), where traffic modelling in general and discrete choice modelling in particular (see Section 2.2) provide strength in the identification and evaluation of strategies consistent with conceptual targets for sustainability.

One of the key findings in this thesis was that, regardless the size of the system (e.g. a company or a city region), a structured policy assessment framework that measures quantitative improvements from alternative policy decisions at an early stage in the planning process is of considerable importance. Such a framework can be used to prioritise and make efficiency assessments between alternative strategies, solve strategic problems related to trade-offs in the planning situation, and avoid unexpected rebound effects from simplistic mono-dimensional solutions. Furthermore, it can identify driving factors (e.g. cost reductions or improved work conditions for employees) that might encourage and finance more far-reaching sustainability targets further ahead. In particular, for private companies intermediate sub-targets coupled to short-term payoffs are essential to meet targets over longer time frames.

1.2 The structure of the thesis

The thesis consists of six studies. Although all these studies touched upon the issue of sustainable travel and mobility management, the perspective differed to some extent. The first three studies – Robèrt (2005), Robèrt and Börjesson (2006) and Robèrt (2008) – are based on field studies of mobility management from a company perspective, discovering the potential of large companies to influence resource efficient travel behaviour by launching unconventional mobility management services and travel plans. In the fourth study – Robèrt (2009) – a model was developed to transform emission targets to policy-related changes in employee travel behaviour. Studies five and six – Robèrt and Jonsson (2006) and Robèrt et al. (2007) – analysed strategies to achieve a sustainable transport system from a regional perspective, where mobility management together with various forms of travel demand measures filled an important role in the strategic toolbox towards emission and energy efficiencies at a macro-orientated scale.

1.3 Climate change and peak oil

Globally, the current transport system faces a double dilemma: climate change and the approaching peak in fossil fuel production. In the next two sections, these two catalysts toward a more energy-efficient and renewable fuel-driven transport system are reviewed.

1.3.1 Evidence of global warming – a summary based on IPCC reports

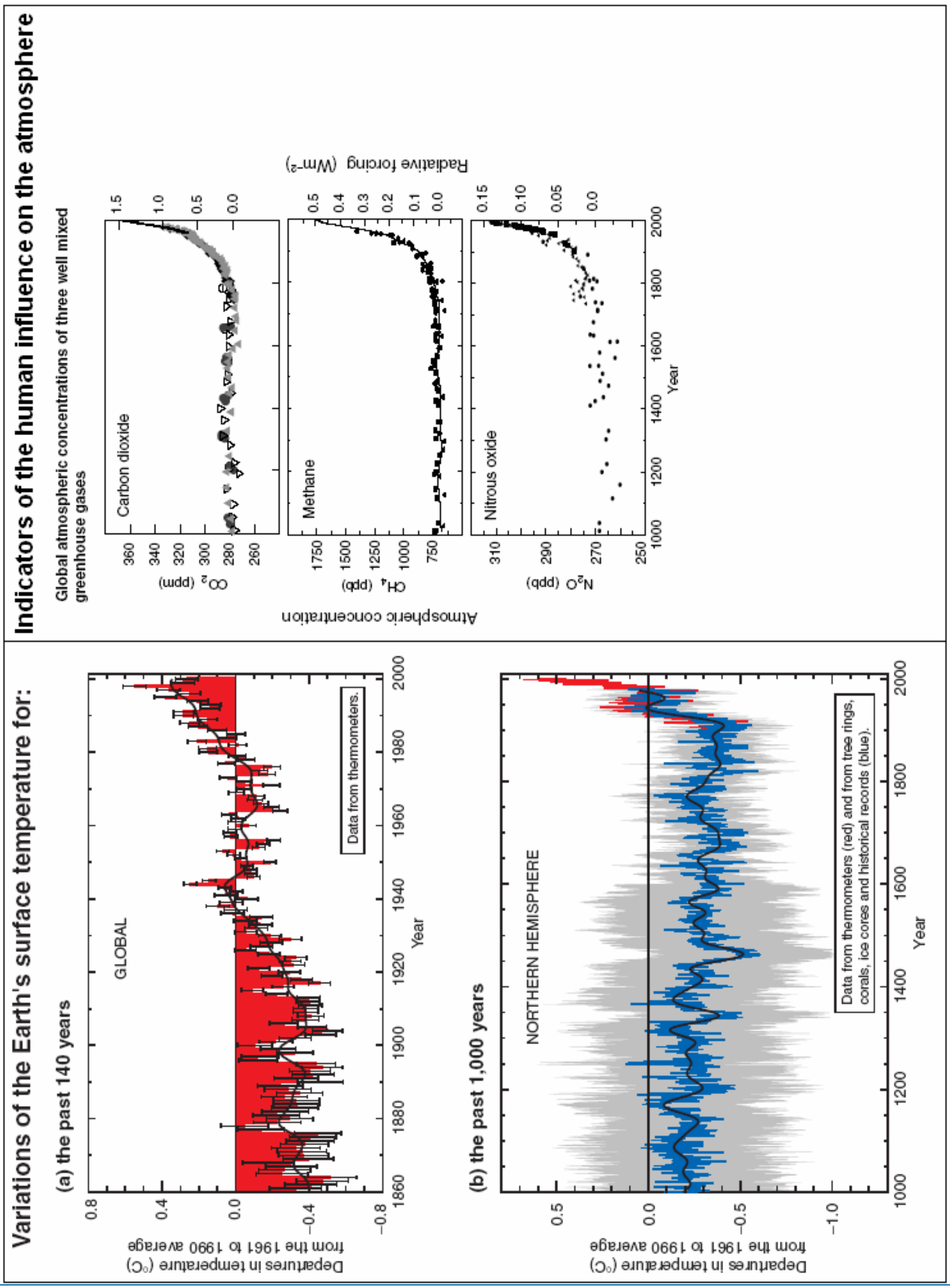
The United Nations Environmental Programme (UNEP) and the World Meteorological Organization (WMO) established the Intergovernmental Panel on Climate Change (IPCC) in 1988. The purpose was to gather research world-wide on climate change and to provide policy-makers and decision-makers with effective strategies to counteract such change. Many hundred scientists world-wide are involved in providing the IPCC with climate-related research.

According to the IPCC (2001, 2007), 'The atmospheric concentration of carbon dioxide (CO_2) has increased by 31% since 1750. The present CO_2 concentration has not been exceeded during the past 420,000 years and likely (90–95% confidence level) not during the past 20 million years. The current rate of increase is unprecedented during at least the past 20,000 years. It is not possible to estimate the exact influence of human use of fossil fuels and the greenhouse effect. However, when comparing historical temperature trends at earth's surface with the increased concentrations of human emissions of greenhouse gases during the last century, a strong correlation is evident (Figure 2). Palaeo-atmospheric data, e.g. from trees, corals and sediments and from air trapped in ice over hundreds of millennia, are providing information about climate history on earth.

The upper left graph of Figure 2 shows the temperature of earth's surface during the past 140 years. Evidently, there is a clear temperature increase starting at the time of the industrial revolution – pointing at a causal relationship between temperature and human activities (use of fossil fuels). During this period, the surface temperature of earth has increased by 0.6 ± 0.2°C. In the lower left-hand graph of Figure 2, the average temperature during the last millennium points to a relatively steady state during the time before the industrial revolution. The blue curve represents the year-by-year average and the black curve represents the 50-year average. The grey region is the 95% confidence level representing uncertainties in measurements before the instrumental age, based on proxy variables (glacier layers, etc.). The IPCC has concluded that, with a 90–99% confidence level, the 1990s was the warmest decade and 1998 the warmest year of the millennium. Based on global model simulations, the IPCC further predicts that the coming century will be the warmest century in 10,000 years (90–99% confidence level).

The three right-hand graphs in Figure 2, representing concentrations of greenhouse gas emissions during the last millennium, indicate a substantial increase in emissions from human activities during the industrial era. The IPCC have concluded that this increased concentration of greenhouse gas emissions is mainly caused by combustion of fossil fuels (99% confidence level). The rest (about 10–30%) is predominantly due to changes in land use, especially deforestation. As the concentration of CO_2 increases, land and water will take up a decreasing fraction of CO_2, causing a net increase in greenhouse gases in the atmosphere. Hypothetically, this net increase in greenhouse gases might reach a threshold level, where global temperature increases in an uncontrollable, self-propelled positive feedback loop. The exact point at which this tipping point would cause a collapse in the climate system is not known. It is believed that the rapid creation of the Sahara desert, about 5500 years ago, was caused by such a collapse, where deforestation exceeded a certain threshold level.

Figure 2 Variations in the surface temperature of earth and the concentrations of atmospheric greenhouse gases (see online version for colours)



Source: Adapted from IPCC (2001)

Carbon cycle models indicate that stabilisation of atmospheric CO_2 concentrations at 450 ppm would require global anthropogenic CO_2 emissions to drop below the 1990 level within a few decades and to continue to decrease steadily thereafter. According to the target defined in the Kyoto protocol (UNFCCC, 2007), the EU-15 nations have decided to create a 'bubble' that involves a collective reduction in emissions of 8% below 1990 levels by 2008–2012. Eventually CO_2 emissions will need to decline to a very small fraction of current emissions.

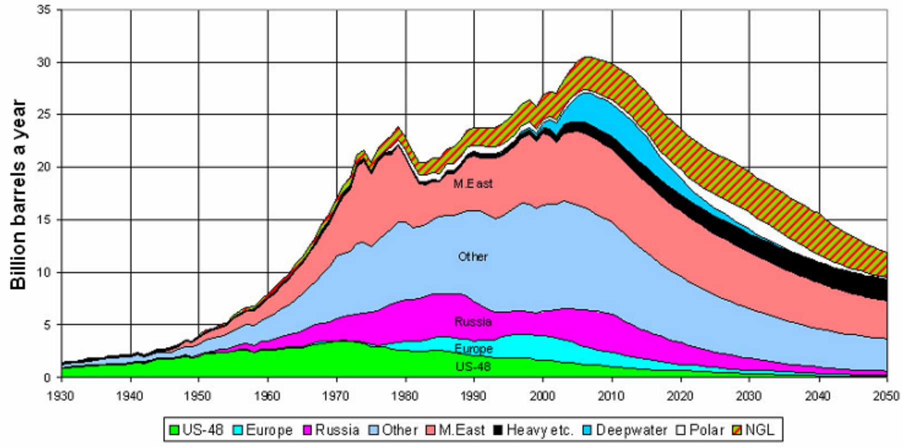
1.3.2 Peak oil – will fossil resource constraints accelerate the attainment of future emission targets?

There are reasons to believe that the required rate of reduction in greenhouse gases reviewed in the previous section might not be too unrealistic, because cheap production of fossil fuels might cease well within this century. Depending on the assumed growth in demand for oil during the next few years, the global peak in fossil oil and gas production might occur already in the time period 2008–2018 (Robelius, 2007). This would induce a breaking point where demand for oil would exceed supply in the first half of this century, resulting in substantial price increases for fossil fuels (Campbell and Laherrere, 1998; Droege, 2002; Aleklett and Campbell, 2003; Urry 2004). Taking these predictions into account, future emission targets might be more easily attained because of the depletion of fossil resources, and the question would then be more of the character 'What measures should be taken in order to make the transition to renewable fuels as non-problematic as possible?' Thus, the approaching energy transition is both a question of *mitigation*, as well as question of *adaptation*.

Even though the exact time frame for the depletion of easily accessible fossil fuels is a matter of discussion, one thing is clear: there might be reason to be risk-averse and take precautions even at an early stage, before energy prices move toward instability. Unless we prepare for the shift to a more sustainable traffic system in time, the transformation might be devastating (Purcell, 2000). The search for feasible paths to a sustainable traffic system is even more urgent considering the explosive traffic expansion that is underway in the developing countries as these strive to reach the same standard of living as the developed countries (Wegener, 1996).

The global peak of fossil oil production (Figure 3) in combination with rapid economic growth in the developing world implies tightened requirements on technological efficiency and restricted use of energy in all sectors of society (Aleklett and Campbell, 2003; Robèrt et al., 2007). Future competition for energy resources and associated increased energy prices will most likely influence future car use and travel patterns in a more energy-efficient direction. In addition, there are also constraints on other natural resources apart from fossil fuel, e.g. metals and encroachment on ecosystems by traffic infrastructure (for references see Ny et al., 2006; Robèrt et al., 2007).

Figure 3 Graphical presentation of global peak oil (see online version for colours)



Source: Adapted from Aleklett and Campbell (2003)

1.4 Mobility management and company travel plans

Future emission targets and limited energy resources will probably drive the price balance between fossil and renewable types of energy to a successive transition toward renewable energy sources (e.g. biomass, wind, hydro and solar power). These energy sources will all play an important role in the production of renewable fuels such as ethanol, methanol, biogas and hydrogen (Nonhebel, 2005; Worldwatch Institute, 2006; Schäfer et al., 2006). These energy sources need to satisfy future transport demand in competition with other uses of land. In order to avoid local problems such as congestions and health-related problems, while at the same time not infringing personal mobility, energy-efficient vehicles and mobility management services will most likely have an increasing importance in the future (Robèrt and Jonsson, 2006; Robèrt et al., 2007; Poudenx and Merida, 2007).

In many cities in industrialised parts of the world, more cost-efficient and energy-efficient urban mobility is encouraged through subsidised company travel plans and specific mobility management initiatives targeting less car-dependent personal travel (Rye, 1999; Newson, 2000; Robèrt, 2007). The concept of travel plans is referred to as an efficient measure to reduce employee commuting by private car and business travel within companies. It is defined as a package of measures developed by an employer to encourage employees, visitors or customers to switch to more economically and environmentally efficient forms of transport (both commuter travel and business travel). Turning sustainable development into win-win strategies may be a deliberate part of sustainable market-orientated traffic planning for private companies. There is an urgent need for companies to set good examples and show that mitigating the environmental impact does not necessarily conflict with short-term economic growth. Thus, from a traffic planning perspective aimed at climate targets, it is crucial to identify potential incentives to companies considering travel plan initiatives.

There is an obvious potential for IT as a cornerstone in resource-efficient company travel plans. Moving electrons will always be more energy-efficient and cost-efficient than transporting people. Arnfalk (2002) distinguishes two potential efficiency improvements from use of IT in the transport sector:

- *Substitution*, *which* implies that an electronic application partially or fully replaces a trip, *e.g.* telecommuting instead of commuting to work, electronic mail instead of posted letters or videoconferencing instead of face-to-face meetings.
- *Efficiency improvement*, where IT technology helps provide the same service with less transportation efforts, e.g. in the form of car-sharing or ride-matching systems facilitated by IT.

In many scenarios concerning the role of IT in sustainable development (e.g. Höjer, 2000), great importance has to be attributed to service users if the scenarios are to be realised. Thus, when analysing the impact of IT on sustainable travel, it is important to start out from the key players in the context, the potential users of these travel alternatives (i.e. to analyse individual preferences).

2 Modelling of sustainable travel strategies

2.1 The backcasting approach

The concept of backcasting is a strategic target-orientated approach generally applied when planning in complex systems (Robinson, 1982; Dreborg, 1996; Höjer and Mattsson, 2000). This approach is well applied on any level of sustainable transport research. Applying principle targets (Robèrt, 2000; Ny et al., 2006), e.g. emission reduction targets or targets for energy demand, rather than scenario planning and relatively fixed images of the future allows greater flexibility in the planning process where many decision makers are involved and many possible investment paths might comply with principle targets. It is often easier (and smarter) to agree on early investments that are flexible with regard to principle targets, and re-evaluate as the process unfolds and technical evolution keeps changing the conditions, than to agree on relatively specific distant futures. Priority is given to such early investments that can (a) tackle existing circumstances (e.g. budget constraints, economic payback, public opinion, political climate, etc.) *as well as* (b) serve as flexible platforms for various investment paths towards compliance with the principle target.

Regardless of the size of the system (company, region, global community), the backcasting approach is well suited for integrating policymakers from different angles in the dialogue, since it may keep rigorous track of objectives while still leaving room for discussions and re-evaluations at the level of detail as progress is made. In creating an illustrative map of state descriptions, between which feasible backcasting paths could be drawn, decision-makers are inevitably confronted with the following questions:

1 Where would we like to go, i.e. what target is set for the future?

2 Do the present conditions meet with the target?

3 Where are we heading if no target-orientated actions are taken?

4 What are the most efficient strategies to reach target fulfilment and what measures should be prioritised over others, considering key aspects such as the emission reduction potential, long- and short-term economic payback, individual preferences and social aspects?

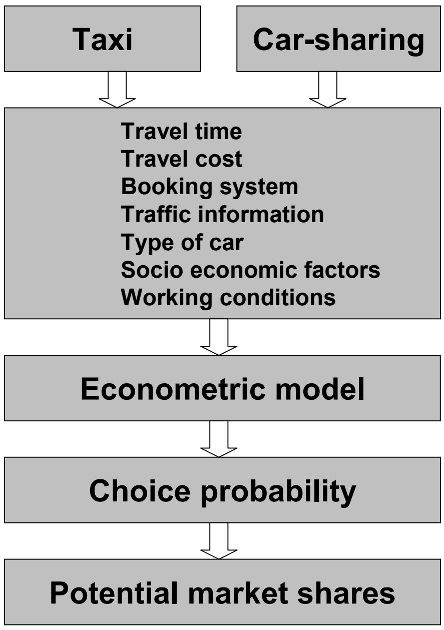
Efficiency assessments and strategic planning often involve many stakeholders serving different roles in the planning process (e.g. local transport providers, the municipal authority, company leadership, purchase managers, staff managers and environmental managers at the company). Hence, from a planning perspective it is crucial that all actors share a common vision of target achievement, but viewed from different angles (emission reductions, cost savings, health aspects, increased use rates of mobility management services).

2.2 Discrete choice modelling

2.2.1 Utility functions and the logit model

Since the aim from a company policy perspective is to find ways to influence an employee's behaviour (e.g. towards choosing a new, more energy-efficient travel alternative), it is necessary to identify the conditions in which the individual is willing to do this. Let us take the example of investigating the potential to replace taxis with car-sharing for local business trips. The two alternatives are associated with some more or less attractive attributes (e.g. travel times, travel prices, certain conveniences), which we assume give a certain pleasure or, in microeconomic terms, *utility.* In our econometric models this utility is used to create the *utility function* in order to estimate the choice probability between the alternatives. The general modelling procedure is pictured in Figure 4, using the example of estimating the choice probability between the two alternatives car-sharing and taxi. In order to derive the choice probability between car-sharing and taxi, we use the associated attributes of the two services (e.g. travel time, travel cost, type of booking system, etc.), and various socio economic and work-related factors that might influence the choice probability. The choice probabilities can ultimately be used to derive likely market shares over the total population, as dependent on the individual's perception of the adherent attributes (see Thomas, 1997, Louviere et al., 2000; Greene, 2000).

Figure 4 Graphical representation of the modelling procedure when deriving the choice probability and the market shares between two alternatives



In econometrics, binary choice models are used to predict the probability that travel mode *a* is preferred to travel mode *b*. As discussed, each of the two choices *a* and *b* could be associated with some known attributes, giving the utilities U_a and U_b. The probability of choosing mode *a* instead of mode *b* is then the probability that U_a is greater than U_b:

$$P_a = P(U_a > U_b) \tag{1}$$

The utility for an individual to choose alternative *i*, having *k* attributes, can be expressed as an additive linear function of the different attributes x_{ki} with the weights β_{ki}:

$$U_i = \alpha_i + \beta_{1i}\, x_{1i} + \beta_{2\,i}\, x_{2i} + \ldots + \beta_{Ki}\, x_{Ki} + \varepsilon_i, \qquad i = a,\, b \tag{2}$$

The variables x_{ki} represent quantifiable attributes, such as time consumption, cost, or different comfort aspects associated with each alternative. The core of discrete choice analysis is to estimate the weighting or preference parameters β_{ki}. By collecting data from people's choices between the different feasible alternatives (employee travel surveys), the β_{ki} parameters can be estimated in the models. The β_{ki} parameters reflect the respondents' perceived importance of each specific attribute (i.e. the β_{ki} parameters weigh the influence of each attribute on the choice probability). From a company policy perspective, this information is of vast importance in order to select and prioritise travel policies that would give a significant effect on employee travel behaviour. Also, it helps determine what segments of the employees are more easily influenced than other (different departments, age groups, geographical localisations, professions, etc.).

The term α_i stands for the 'alternative specific constant', also termed the 'intercept parameter'. This constant compensates the utility function for hidden attributes, not included in the model. The term ε_i in equation (2) is called the *random* component or the disturbance. This term represents attributes that cannot be measured explicitly and that vary among individuals, e.g. measurement uncertainties and model misspecifications. The assumption of the density distribution of these disturbances is what determines the type of choice model. For references on discrete choice modelling and background theory, see Ben-Akiva and Lerman (1985).

3 Review of the six studies in the doctoral thesis 'Mobility Management and Climate Change Policies'

3.1 Climate and economic research in organisations based on employee travel behaviour

Robèrt (2005) developed a backcasting approach integrating discrete choice modelling as a tool for dealing with uncertainties related to future employee behaviour when implementing company travel plans.

Some travel-related alternatives might give negligible economic or environmental benefits under current conditions, but might work as platforms for future development of more environmentally friendly technologies. However, for this to be realised in practice, the new alternatives must first reach an acceptable user uptake rate in order to make them economically feasible. Determining the employees' conditions for choosing alternative travel modes is therefore an essential first step in the discussion of practical paths towards a long-term sustainable target. This is also relevant from a traffic planning perspective, focusing on the potential of supporting and integrating company policy with respect to employees travel plans, as an effective traffic control measure.

To that end, Robèrt (2009) developed a transparent and easy to manage framework to assist companies, municipalities and other organizations in reaching climate travel targets in consistency with economic payoff and employee acceptance. The backcasting framework supplemented with econometric modelling presented in Robèrt (2005), was further developed and concretised involving the following four parts:

1. definition of a relative emission reduction target at the company, in consistency with economic payoff and employee acceptance,
2. mapping of the present situation at the company, in relation to target description, involving staff travel patterns and preferences, individual and collective emissions and costs, benchmarking to compare companies internally,
3. a policy-oriented transformation of the backcasting target, transforming the emission reduction to potential numbers of employees switching to alternative travel modes or virtual communication means,
4. alternative sets of company policies and strategies that would arrive at target achievement.

The model applied for deriving the number of employees (*X*), switching from travel mode 1 to 2, corresponding to the backcasting emission target in the company, is derived through:

$$X_{kl}^{j} = \frac{\hat{Y}_t \sum_i \sum_j \sum_m s_{im}^{j} u_{im}^{j}}{\frac{1}{N_k^j} \sum_i \left(s_{ik}^{j} u_{ik}^{j} - s_{il}^{j} u_{il}^{j} \right)} \qquad i = 1, \ldots N_1^j$$

where:

i = individual in the company

j = travel type (e.g. business trip or work commute)

X_{kl}^{j} = average number of commuters with travel type j, using travel mode $m = k$, switching to alternative travel mode $m = l$, in order for the company to achieve backcasting target $\hat{Y}_t$ at time t (i.e. the year the backcasting target is set).

u_{ik}^{j} = emission per km with present travel mode $m = k$ for travel type j by individual *i.*

u_{il}^{j} = emission per km with alternative travel mode, $m = l$ for travel type j by individual *i.*

m = travel or communication means among M alternatives (e.g. car, aviation, video conference).

s_{ik}^{j} = annual distance traveled by individual *i* with current transport mode, $m = k$ for travel type *j*.

s_{il}^{j} = annual distance traveled by individual *i* with alternative transport mode, $m = l$ for travel type *j*.

N_{k}^{j} = total number of employees with travel type *j*, using current transport mode $m = k$.

In a backcasting framework, the relative reduction *Y* is used as a fixed target variable, i.e. a predefined percentage reduction for the company (the most extreme case would be to set this variable to 1 (100%), which would correspond to a long-term target of zero net contribution to the greenhouse effect.

Detailed cost-benefit analysis of current business travel in relation to more efficient communication and travel alternatives supplements the ranking procedure of policy sets derived in the statistical and econometrical models. Empirical results from organisations applying the model so far (>30,000 employees), indicate that companies in general have a potential to influence its employees' travel behaviour towards more economically and environmentally efficient alternatives – if the right instruments and incentives are identified (Robèrt and Börjesson, 2006; Robèrt, 2008). Furthermore, the average cost cut potential of climate efficient travel planning in companies through the modelling framework is in the range of 200–500 Euro per 1000 employees and year.

3.1.1 Productivity effects from adoption rates of alternative communications

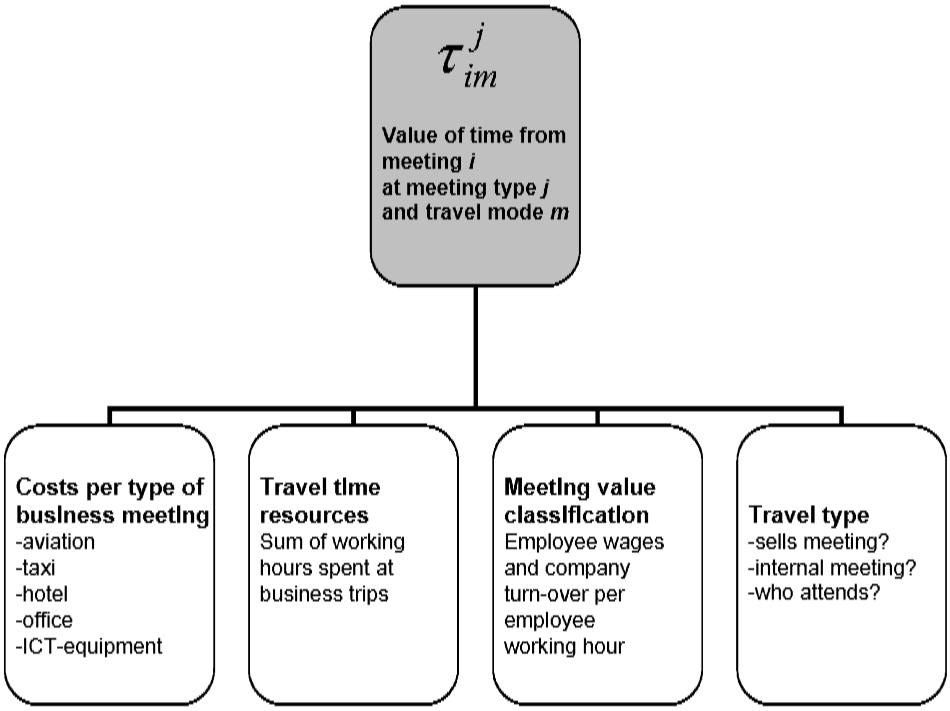
Besides the pure cost-cut potential, Robèrt (2009) lists a number of motives for companies to consider travel planning:

1. to be foresighted and prevent risks with unstable energy prices and stricter demands on travel,
2. improve public relations and raise the standard for environmental audits by incorporating profound climate strategies for employee travel,
3. provide employees with good communication and transport alternatives in order to attract efficient, competent and healthy staff.

Yet another clear economic motive for organisations to consider travel planning and virtual communication means is the potential to reduce loss of employee working hours. With exception to the actual meeting (i.e. the purpose of the trip), driving car or taking the plane to business meetings, accommodations, etc. causes a quantifiable productivity loss to the employer. In situations where it is possible to change travel mode from, e.g. car to train, or from plane to video conference some of the unproductive travel time could be transformed into productive working time.

Figure 5 represents the generation of a company- and individual-specific 'value of time-parameter' (τ) for individuals *i* going on a business trip with travel mode *m* at meeting type *j* (sells meeting, internal meeting, project meeting, etc.).

Figure 5 Generation of a 'value of time-parameter' could be used as an efficiency indicator in the creation of company travel policies regarding various travel modes or virtual communications at different meeting types



The definition of the value of time-parameter allows us to make explicit analyses of company productivity gains from various substitution rates of present business trips. The aggregate productivity gain in the company from employees changing from present travel mode 1, to a more time efficient mode 2, at a particular meeting type *j* could be expressed as:

$$\hat{P}^{j}_{kl} = \frac{M^{j}_{kl}}{N^{j}_{k}}\left(\sum_{i} t^{j}_{ik}\tau^{j}_{ik} - t^{j}_{il}\tau^{j}_{il}\right)$$

$\hat{P}^{j}_{kl}$ = productivity-effect of switching from travel mode k to l

t^{j}_{ik} = travel and meeting time for individual i with mode k at meeting type j

t^{j}_{il} = travel and meeting time for individual i with mode l at meeting type j

M^{j}_{kl} = number of trips exchanged from mode k to l

τ^{j}_{im} = average cost per unit of time (meeting i, mode m, type j)

N^{j}_{k} = present number of trips with travel mode k, meeting type j

This backcasting framework, called CERO, is now (December 2009) applied in 15 large companies, municipalities and other public authorities in Sweden to assist the development of cost-efficient travel plans towards climate targets. The CERO-analyses are also utilised by policy-makers and public transport providers in order to determine consequences and feasibilities of alternative strategies and to create a more market-oriented public transport system in connection to large companies.

3.2 Exploring backcasting strategies towards a regional emission target for 2030

Robèrt and Jonsson (2006) carried out a backcasting study at regional level, analysing the potential of mobility management services and company travel planning discussed in previous company-based studies, as strategic tools in reaching drastic emission targets for greenhouse gases in Stockholm by 2030. The targets were based on the United Nation's (IPCC) recommendations for an acceptable CO_2 level in the atmosphere, corresponding to a 70% reduction from the present level. The study focused on a range of specific transport policies, vehicle technologies and renewable fuel shares that would comply with target achievement.

To analyse the effects of various traffic policies and mobility management services at a macro scale in the Stockholm region, the transport modelling system SAMPERS (Johansson, 2001; Beser and Algers, 2001) and EMME/2[2] was applied, which allowed experimentation on three alternative types of policy measures contributing to achieving the emission target:

1. reduced transport volumes from company travel planning and potential future adoption of alternative, less car-dependent 'mobility management services', e.g. car-sharing, ride-matching, telecommuting, videoconferencing, cycling and public transport;
2. specific travel demand measures such as traffic tolls, car-free streets, increased fuel taxes and free public transport;
3. increased share of renewable fuel vehicles and fuel efficiency regulations on private vehicles in the transport system.

In spite of the most drastic travel demand scenarios experimented with by Robèrt and Jonsson, (2006), a renewable fuel mix of at least 50% was required in order to reach the emission target. However, increasing the individual travel choice set (by attractive mobility management alternatives and virtual communication) will most likely be of increased importance in facilitating a market-orientated transition to more energy-efficient travel behaviour, if fossil fuel prices continue to rise as a consequence of national emission targets and the imminent peak oil dilemma.

Furthermore, although this was not an attempt to explore the costs and benefits fully, some numbers on the potential savings are illustrative. For example, reducing private vehicle kilometres only to a marginal extent implied significant savings in accident costs and emission costs. Reducing all private vehicle trips by 10% corresponds to 750 million SEK (1 Euro = 9.35 SEK at the time of the study) savings of accident costs and 360 million SEK savings of emission costs, implying a total annual socioeconomic saving of 1.11 billion SEK. These savings should be kept in mind when discussing the investment costs of infrastructure and renewable energy systems for the future.

3.3 *Mobility management and renewable fuels from a planning perspective of the energy transition beyond peak oil*

As discovered by Robèrt and Jonsson (2006), future emission targets are strongly dependent on renewable fuel assets. From this perspective, Robèrt et al. (2007) focused on the biofuel potential of Swedish biomass, in relation to the energy efficiencies from personal travel at a regional level. The backcasting target consisted of a full transition to domestically produced biofuels in the transport system of Stockholm County by 2030, without exceeding the proportional share of national bioenergy assets. In particular, the study focused on the energy efficiency potential of synthesising energy-efficient vehicles, various travel demand measures and mobility management services under the influence of tightened conditions on the energy market after the global peak of fossil oil and gas extraction. Due to potential synergy effects, it is likely that the largest energy efficiencies and emission reductions would be achieved from a variety of measures rather than focusing single-mindedly on one at a time. Thus, various mobility management and company travel planning measures might serve a more substantial role at a macro scale if combined with travel demand measures and increased demand for energy efficiency in the future. As an illustrative numerical example of the energy efficiency in a synthesised compound strategy scenario, the backcasting target was met when only 65% of the regional proportion of biofuels was set aside for the transport sector.

The main conclusions were as follows:

1 the energy efficiency potential in the urban transport sector is substantial if applying deliberate compound strategies of mobility management, future vehicle technologies and travel demand measures;

2 biofuels (e.g. methanol, ethanol, DME and Fisher-Tropsch diesel) are efficient hydrogen carriers and will thus play a vital role in the transition from fossil to renewable fuel systems in the post-carbon era, when other renewable energy sources (wind, hydro, solar, wave energy) will successively enter the market;

3 Swedish bioenergy assets in combination with a well-developed vehicle industry could be used strategically. Peak oil is a global dilemma, and countries taking the lead in adapting to this will have the opportunity to export technology and know-how to other countries as oil prices continue to rise and the need for alternative energy systems becomes acute;

4 transport modelling is needed in order to derive energy quantities at a macro scale of the transport system, incorporating negative rebound effects and fuel price effects;

5 it is necessary to conduct rigorous studies of energy efficiency potentials in *all* energy sectors before making comprehensive assessments of reasonable distributions of bioenergy assets.

A question for further research is the extent to which is it profitable to produce biofuels in Sweden in relation to production in low-cost regions in the developing world.

4 Summary and conclusions

The thesis develops a generic approach for efficiency assessments and monitoring of compound urban travel strategies meeting future demands on resource efficiency, with particular emphasis on climate and energy targets. Methods of dealing with these problems involve higher energy efficiency of traffic systems per utility. Such methods also exert positive effects on sustainability aspects other than climate, e.g. on land use for traffic infrastructure and energy production and on consumption of materials. We focused on how the regional and organisational levels of society could meet the challenge of diverting the transport system into sustainable directions, without compromising individual mobility. To a large extent, the study is characterised by a bottom-up travel demand approach, providing decision-makers with a quantitative basis for prioritising between travel strategies consistent with individual preferences.

Adaptation to future conditions regarding tougher emission restrictions and increased fuel prices beyond peak oil is a multi-stakeholder process that should be flexible over the course of time and incorporate many viewpoints and complex factors consistent with the conceptual target. In this respect, backcasting is applicable in the creation of strategic travel policies at company, regional or global level. Furthermore, long-term targets should preferably be supplemented by a chain of intermediate targets where short-term payoffs could be identified early in order to fuel the process and maintain the motivation to achieve more long-term targets. In identifying such short-term payoffs while avoiding harm to individual preferences and mobility, we found econometric modelling and traffic modelling a rewarding instrument in the search for feasible strategies in the planning process. Without a comprehensive transport modelling approach, it is impossible to quantify potential rebound effects adherent to efficiencies in the transport system and to explore how these could be counteracted by various travel demand measures. Furthermore, this work highlights the importance of implementing and synthesising both demand and supply-side policies in order to reduce energy use and greenhouse gas emissions from the transport sector.

Two complementary driving forces could be identified, potentially inducing a paradigmatic shift towards development of sustainable transport. On is a successive transition to renewable fuels, induced by hardened travel demand strategies to counteract the greenhouse effect and tougher conditions on the energy market after the approaching peak of fossil oil. Another is creation of more attractive and resource-efficient mobility management and communication alternatives that would increase the individual's set of travel choices and help renewable fuel assets to suffice.

There is reason to believe that all actors and energy sectors of society will l a vital role as a link between individuals and society at large in the coming enebe influenced by harsher future energy conditions. From this perspective, companies filrgy transition of the transport system. The main incentives for companies to launch travel plans, emerging from the analysis in the thesis would be to:

1. reduce travel costs and travel time savings from inefficient business travel and employee commuting to work since emissions and costs often go hand in hand;
2. be foresighted and prevent risks with unstable energy prices and stricter demands on travel in order to counteract the greenhouse effect and local traffic problems in the future;

3 improve public relations and raise the standard for environmental audits by developing profound climate strategies;

4 provide employees with good communication and transport alternatives in order to attract efficient, competent and healthy staff;

5 show best practice through their own products or services related to sustainable communications in relevant lines of business.

Employees spend considerable amounts of money and time on each commute. Thus, employers helping their workforce to achieve more resource-efficient travel would play an active role in improving the employees' working conditions. Empirical studies of employees' conditions for changing travel behaviour could be of significant value to market-orientated traffic planning based on a dialogue between employees and actors potentially realising employee requirements for choosing more resource-efficient alternatives (real-estate managers, public transport providers, local governments).

The all-embracing conclusion from the studies in the thesis is that target-oriented traffic planning at a regional macro scale, in combination with travel plan initiatives at companies and organisations at a micro scale, will play an increasing role in the future with stricter energy and emission conditions imposed on society. From a strategic planning perspective, the transport system of Sweden in general, and the Stockholm region in particular, has favourable prospects for the transition to a renewable fuel economy: A well-developed public transport system; relatively large national biofuel assets; a strong tradition in the engineering and vehicle industries; and relatively high public and political awareness of climate change. Peak oil and climate change are global dilemmas, and countries taking the lead in adapting to these are likely to have the opportunity to export technology and know-how to other countries as oil prices continue to rise and the need for alternative energy systems becomes acute.

To that end, the thesis highlights the research field of sustainable planning and modelling as yet another vital dimension of technological development in the approaching energy transition.

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Notes

1 A sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs (UN, 1987).

2 Information available from INRO (http://www.inro.ca).