Backcasting as a Tool for Sustainable Transport Policy Making: the Environmentally Sustainable Transport Study in the Netherlands

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This paper describes the backcasting approach used in the OECD's Environmentally Sustainable Transport (EST) Study, in which several countries participated. The backcasting approach can be seen as an innovative tool for policy making, which aims at generating alternative images of the future. These images have been thoroughly analysed as to their feasibility, consequences and policy implications. Here, results and implications for backcasting shown in the Netherlands case study are highlighted and conclusions drawn that EST criteria will only be attainable if a substantial increase in development of technology and stringent behavioural adaptations, with changes in economic structures at an international level, are assumed. If EST is to be realised, measures will have to be taken and instruments will have to be implemented in the short term. Timely implementation will probably mean a necessary radical change in the current Dutch policy 'life cycle'.

1. Introduction

What will the transport system look like if current transport emissions are reduced by 80-90%? What are the policy instruments available and when will they have to be implemented to realise these sharp emission reductions? These were the questions addressed in the OECD project on 'Environmentally Sustainable Transport' (EST) (OECD, 2000; 2001; 2002). The EST project differs from other studies on sustainable transport in the following ways. Firstly,

the EST project is based on a 'backcasting' approach, in contrast to traditional sustainable transport studies that focus on doing what is necessary to achieve a desired future rather avoiding an unwanted future. Secondly, a wide range of very stringent environmental criteria are used, and explicit attention is paid to the time-paths of events necessary to meet the criteria. Thirdly, the social and economic implications of EST are addressed. This paper describes the backcasting approach for policy making and its application to the Netherlands' EST case study.
Section 2 starts with an overview of scenario studies and a general description of the backcasting methodology, while section 3 describes how the backcasting approach is applied in the Dutch case study. Finally, section 4 presents the conclusions and discusses the results.

2. The backcasting approach to scenario-building

2.1 Characterisation of backcasting

Scenario studies have been performed in abundance since the 1950s. The scenario methodology study was originally developed for the United States federal government in the 1950s at the Rand Corporation to study how nuclear wars could start (Martino, 1983). It was popularised as a business tool by Shell Oil in the 1970s. Shell's planners, armed with descriptions of how consumers and countries might react to oil shortages, for example, were better equipped than many of their competitors to deal with the shock of the oil crisis of 1973 and its aftermath. One of the first definitions of a 'scenario' dates back to Kahn and Wiener in the mid-sixties: scenarios are 'hypothetical sequences of events for the purpose of focusing attention on causal processes and decision points' (Kahn & Wiener, 1967). In the 1960s many companies, like Shell, started scenario studies based on Kahn's principles because of facing increasing problems with 'traditional' prediction methods. Shell's primary aim with scenario studies was to allow it to make plans without having to predict developments everyone thought of as unpredictable. The starting-point for the scenarios was identifying 'predetermined' and 'undetermined' elements. The predetermined elements are the same in each scenario, while the undetermined elements are elaborated in several ways depending on possible future developments, and thus result in different future images (Van der Heijden, 1996). In the literature, the term 'scenario' is used in several ways. A customary definition of scenario in the Netherlands is 'a description of society's current situation (or a part of it), of possible and desirable future societal situations, and the series of events between current and future situations' (Becker et al., 1982).
Two kinds of scenarios can be distinguished: projective and prospective. A projective scenario's starting point is the current situation; extrapolation of current trends results in future images. A prospective scenario's starting-point is a possible or desirable future situation, usually described by a set of goals or targets established by assumed events between the current and future situations. Backcasting is therefore capable of highlighting discrepancies between the current and desirable future, and incorporating large and even disruptive changes. Constructing projective scenarios is also called 'forecasting'; constructing prospective scenarios is called 'backcasting'. Backcasting is a term introduced by Robinson (1982) to analyse future (energy) options. Robinson states that 'the major distinguishing characteristic of backcasting is a concern not with what futures are likely to happen, but with how desirable (energy) futures can be attained'. Backcasting is thus

explicitly normative, working backwards from a particular desired future end-point to the present to determine the physical feasibility of that future and what policy measures would be required to reach that point' (Robinson, 1990). Dreborg (1996) described differences between forecasting and backcasting studies from a philosophical view, perspective, approach and methods, and techniques (see Table 1). The merits of backcasting should, to a large extent, be judged in the context of discovery, a creative process to get ideas, rather than the scientific justification, i.e. to employ ideas and demonstrate the validity of scientific results. The forecasting approach seems to rely fully on causal determinism, i.e. mathematical models are built with the intention of forecasting the future development of a system given a set of initial conditions, e.g. transport demand models forecast future travel behaviour patterns under given socio-economic developments. In comparison to forecasting, the use of mathematical models for backcasting is much less common. Backcasting allows more room for intentional explanations of desires and beliefs to explain human behaviour. These cannot be completely predicted by a causal model. Furthermore, the use of very operationalised, complex, theoretical explanations may diminish the role of fantasy, imagination and intuition. However, several special kinds of models are sometimes used such as normative and system dynamics models (see also Section 3.4).

Table 1: Differences between forecasting and backcasting studies

Level	Forecasting	Backcasting
1. Philosophical view	context of justification causality determinism	context of discovery causality and intentions
2. Perspective	dominant trends likely futures possible marginal adjustments how to adapt to trends	societal problem in need of a solution desirable futures scope of human choice strategic decisions retain freedom of action
3. Approach	extrapolate trends into the future sensitivity analysis.	define interesting futures analyse consequences and conditions for these futures to materialise
4. Methods and techniques	various econometric models mathematical algorithms	partial and conditional extrapolations normative models, system dynamics models, Delphi methods, expert judgement

Source: Adapted from Dreborg (1996).

Forecasting scenario studies are common in transport studies to assess problems due to current and future transport activity, based on the continuation of current socio-economic trends. According to the OECD (2002), forecasting is an appealing method for policy making where setting goals may be controversial, or, when desired goals are either not known or considered unattainable. This also holds for evaluating the impacts of politically acceptable policy measures. Moreover, an approach based on forecasting is likely to be incremental and seen as responsibly cognisant of current realities. Backcasting studies are less commonly applied in transport studies. Prospective scenario studies seem to have been first constructed in energy studies for Sweden, starting in the 1970s to analyse alternative policy options as a response to the oil crisis, e.g. Johansson & Steen (1978) and Johansson et al. (1983). Since the late 1980s, several backcasting studies have been conducted for transport sector in the Netherlands: see, for example, the trend-breach scenarios for passenger transport (Peeters, 1988), freight transport (Peeters, 1993) and the Sustainable Economic Development Study (DEOS) (IVM 1995). More recently, Steen (1999) also conducted a backcasting study for Sweden to analyse a sustainable transport system for the year 2040. The EU-POSSUM project (Banister et al., 2001) was the first to assess European transport policies as to their consistency and feasibility by means of a qualitative scenario approach based on backcasting. In this project, a set of scenarios was constructed for the period up to 2020 to meet the targets of regional development, efficiency and environmental protection. The OECD's EST project is one of the most recent backcasting studies for the transport sector. The major difference, compared with earlier studies, is that a wide range of very stringent environmental criteria is used, and explicit attention is paid to the time- paths of events necessary to meet the criteria.

2.2 A backcasting approach outlined

There is no standard recipe for developing a mechanical method for generating scenarios. Developing scenarios may involve several analytic and research methods, quantitative as well as qualitative. However, developing a scenario is more than applying a specific technique. Some helpful guidelines can be found for developing scenarios in the literature, especially the general outline of a backcasting method proposed by Robinson (1990), who states that 'in order to undertake backcasting analysis, future goals and objectives need first to be defined, and then used to develop a future scenario'. The scenario is evaluated in terms of its physical, technological and socio-economic feasibility and policy implications. Iteration of scenario is usually required to resolve physical inconsistencies and mitigate adverse economic, social and environmental impacts that are revealed in the course of analysis'. The general structure of the backcasting method is shown in Figure 1.

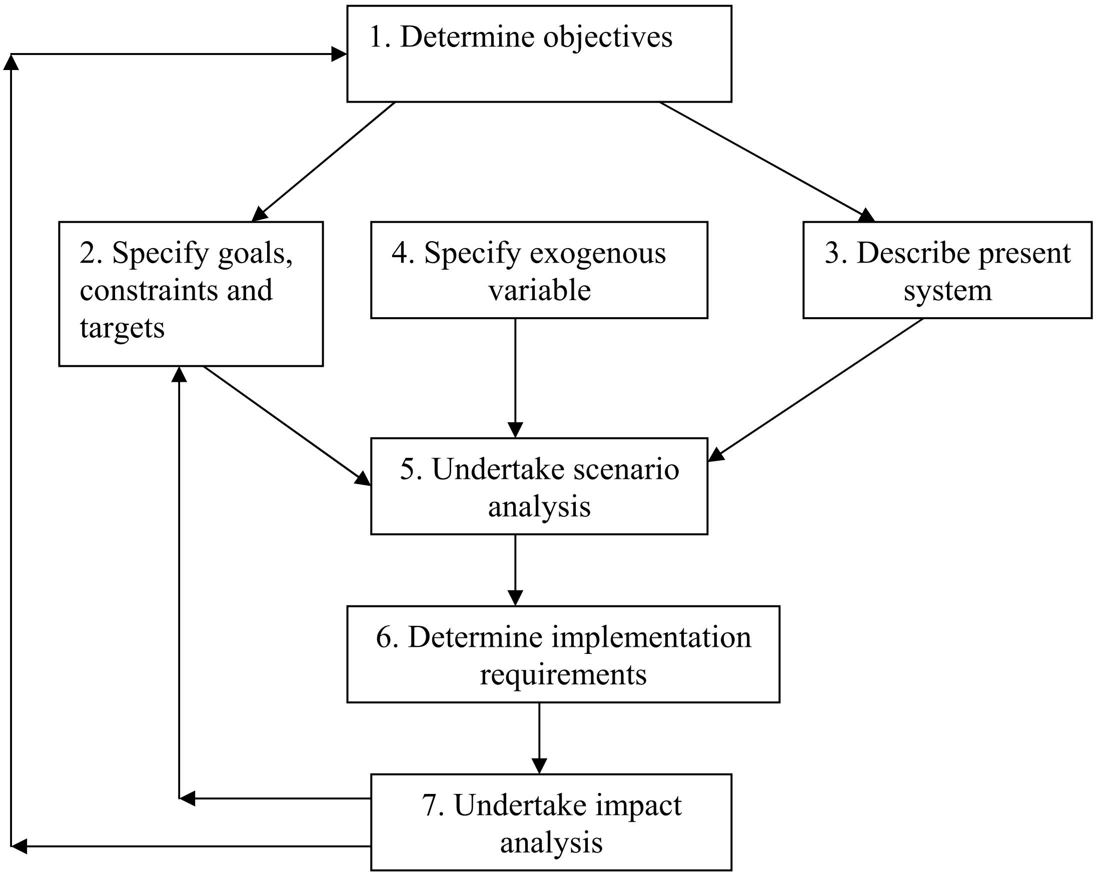

Figure 1. Outline of a general backcasting method (Source: adapted from Robinson, 1990).

The backcasting method can be summarised in steps.

- Step 1 is meant to determine the objectives, i.e. to describe the purpose of analysis, determine temporal, spatial and substantive scope of analysis, and to decide the number and type of scenarios.
- Step 2 should specify concrete goals and targets for the scenario analysis based the objectives outlined in the first step. Where possible, qualitatively goals should be expressed in terms of quantitative targets to provide a measurable point of reference for the scenario analysis.
- Step 3 is meant to describe the present system, e.g. consumption and production processes and the transportation system, including an analysis of the main driving forces behind measures and main developments.
- Step 4 is to specify exogenous variables, e.g. assumptions on economic growth, demography, the stability of the supply of fossil fuels, prices of fossil fuels, incomes and international relationships.
- Step 5 should see the scenario analysis carried out, i.e. a scenario generation approach will be chosen, and future processes at the endpoints and mid-points analysed to develop the scenario(s) and to iterate the analysis as required to achieve internal consistency.
- Step 6 is to determine the implementation requirements, i.e. ascertain the behavioural and institutional responses required for implementation of the scenarios and the policy

measures necessary at different spatial levels to influence the driving forces behind measures and main developments, e.g. pricing policy, regulations and infrastructure policies.

- Finally, in Step 7 an impact analysis will be undertaken to: (a) consolidate scenario results, (b) analyse social, economic and environmental impacts, (c) compare results of step 6(a) and (b) with the goals and targets, as set down in step 2 and (d) iterate analysis (Steps 2, 4 and 5), required to ensure consistency between goals and targets, and results.

This approach should not be seen as a formal method for backcasting studies but as a general outline of a backcasting method. The framework may be useful for structuring the backcasting exercise, describing and linking the several scenario-building steps, and ensuring consistency between goals and results. However, one shortcoming of Robinson's approach, and most existing backcasting studies, is the lack of attention for the time-paths for the events between the base and target years. In the POSSUM study (Banister et al., 2000) the Robinson approach was extended to include policy measures, packages and implementation time-paths. Here, we also consider it important to include time-paths in a backcasting study. First, many technical measures need a pre-implementation period, e.g. at least 15 to 30 years, to fully renew the vehicle stock for road vehicles and trains, ships and aircraft. Secondly, especially land-use and infrastructure measures, but also other measures, need to be planned long before their implementation. Thirdly, the technology for several measures has to be developed. Fourthly, the effect of measures is only complete after a relatively long period after implementation, especially land-use and infrastructure measures. This is also true for other measures influencing firm and residential locations. Finally, the acceptability of and the influence on government expenditures will also have to be taken into consideration, especially if expensive measures are assumed.

The backcasting framework described above is general, and can in principle be applied to several fields. In the EST project, the backcasting approach is applied to the transport sector. In the remainder of this paper we will describe the Dutch EST case study, following the steps from Robinson's outline, including policy measures and time paths. A detailed description of the Dutch case study can be found in Geurs & Van Wee (2000).

3. The Netherlands' EST case study

3.1 Objectives, targets and constraints (Steps 1 and 2)

The overall objective of the OECD study was to characterise environmentally sustainable transport and establish guidelines for policies whose implementation could lead to realising EST. See the contribution of Wiederkehr et al. in this volume for an overview of the OECD EST project. The OECD has defined EST as: *transportation that does not endanger public health or ecosystems and meets needs for access consistent with (a) use of renewable sources below their rates of regeneration, and (b) use of non-renewable resources at below the rates of development of renewable substitutes* (OECD, 1996). The OECD concluded that for transportation to be sustainable, transportation should not result in exceedances of generally accepted international objectives for environmental quality, it should not reduce the integrity of ecosystems, and it should not contribute to potentially adverse global phenomena such as climate change and stratospheric ozone depletion. There are international guidelines (WHO, IPPC, UNECE, etc.) for all of these ecological targets.

The current situation is that critical levels and loads are typically exceeded by at least a factor of 2 to 5; therefore improvements of 50% to 90% will be needed to achieve acceptable risk levels. The following quantitative criteria for EST were derived from the ecological targets: 50% reduction in CO_2 emissions globally and 80% for OECD countries, compared to the 1990 level if stabilisation of CO_2 emissions is to be achieved; 90% reduction in nitrogen oxide (NO_x) and volatile organic compounds (VOC) emissions, compared to the 1990 level if acceptable health risk levels in urban areas are to be achieved (See the contribution of Wiederkehr et al. in this volume for a more detailed description). Furthermore, each case study used additional criteria for particulate matter, noise and land-take. The additional criteria for the Dutch EST study for 2030 are 90% emission of particulate matter (PM_{10}) emission, compared to the 1990 level; a negligible level of serious noise nuisance, a good living environment in urban areas, stabilisation of the direct land-take for transport outside urban areas at the 1990-level, and indirect land use reduced by 50%. The description of the results from the Dutch case study focuses on the emission targets.

The EST project applies the following starting-points:

- Scenario study target year is 2030. The analysis is also valid for a later point in time (e.g. 2040 or 2050) but not substantially earlier, as the implementation time of measures and policies is too short.
- EST is characterised by environmental criteria only. Social and economic goals for the transport sector are not explicitly taken into account. The EST CO_2 target is, for example, much higher (80% emission reduction to be realised in 40 years time - 1990 to 2030) than the Kyoto target (6% emission reduction in 20 years - 1990 to 2008/2012) which represents a compromise between environmental and financial/economic consequences. Here, social and economic impacts are addressed in the impact assessment stage.
- EST is applied to the entire transport sector, including aviation and shipping. Other sectors of the economy are assumed to achieve the same emission reduction targets;
- The geographic scope of the Dutch case study is the entire Dutch territory. Other OECD countries are assumed to achieve the same emission reduction targets.

3.2 Present system and exogenous developments (Step 3 and 4)

The Netherlands can be characterised as a relatively small Western European country, with high densities of both population and economic activities, and a very open economy. The Netherlands is the world's sixth largest exporting country, and has become a hub of international commerce, with a transport infrastructure centred at the port of Rotterdam (the busiest port in the world) and Amsterdam-Schiphol airport. Like other Western European countries, the private car is the dominant mode for passenger traffic. However, in contrast to almost all other countries, the bicycle is an important transport mode in the Netherlands. That is, bicycle ownership is among the highest in the world (the number of bicycles owned roughly equals the number of inhabitants), and cycling currently accounts for about 25% of all trips (up to 40% in Dutch cities) and 7% of all passenger kilometres (almost equalling the number of rail passenger kilometres) (CBS, 2002).

To describe the present transport system and likely trends, a business-as-usual scenario was constructed, showing the continuation of present trends in transportation up to 2030, moderated by likely changes in legislation and technology. The business-as-usual scenario was constructed at the start of the project in 1996, using 1990 as the base year. The scenario is consistent with dominant trends in the transport sector from the last decade (see for a review OECD, 2003). In short, private car traffic grew by about 25% in the 1990-2000 period, mainly due to economic and demographic developments, and despite transport policies to curtail car use. That is, fiscal measures implemented were limited and therefore had little effect on traffic volume. Road freight transport continued to grow relatively strong due to economic and logistic developments. The number of tonne kilometres by road transport increased by about 30% in the 1990-2000 period, whereas rail and inland shipping increased by about 15%. Transport policies in the last decade have not been very effective in influencing the modal shift and efficiency in the freight sector. Despite increased road traffic volume, emission performance in the transport sector has improved, except for CO_2, due to tightened EU (Euro) emission standards. NO_x, NMVOC, CO and SO_2 emissions from mobile sources decreased by 24, 43, 42 and 20% between 1990 and 2000, respectively; CO_2 emissions increased by about 30%. However, the decrease in NO_x emissions is still far below the ambitious national policy target set in the early 1990s (i.e. a 20% and 75% reduction for 1995 and 2010, respectively, compared to the 1986 level). However, the increase in CO_2 emissions from road traffic contradicts the target of a desired reduction (i.e. zero growth and 10% reduction for 2000 and 2010, respectively, compared to the 1986 level) (NEPP 1989; STSP 1990). Furthermore, little progress has been made with regard to noise emissions. Since 1980 about 40% of the Dutch population has continued to experience noise nuisance from roads, railways, ports, airports and industry (RIVM, 2002).

The most important changes in (categories of) determinants for the business-as-usual scenario follow. *Technological improvements* to reduce emissions are mainly influenced by new legislation; i.e. emissions from cars have been effectively reduced by (EU) emission standards (e.g. the introduction of the three-way catalyst). Under the current policy, technological improvement will probably be modest (i.e. EURO3 and EURO4 standards are assumed in the business-as-usual scenario). *Behavioural change* has a potentially large influence on future transport emissions. However, attitudes and travel behaviour in given circumstances (population size and composition) are assumed to be constant. For the period up to 2015, the business-as-usual scenario is based on existing transport forecasts using Dutch national transport models for passenger and freight transport (RIVM, 1993) within the context of national economic and population forecasts. This assumes a constant annual economic growth of 2-2.5% and a population growth of 14% between 1990-2030. For 2015 to 2030, non-linear or exponential trend extrapolations and corrections to these are made on the basis of the driving forces described above, and assumptions and general expectations. The assumptions and forecasts are consistent with the latest National Environmental Outlook (RIVM, 2000), providing transport and emission forecasts for the 2000-2030 period.

The resulting transport and emission levels for the business-as-usual scenario for 1990-2030 are shown in Table 2. CO_2 emissions will increase more than 30% in the business-as-usual scenario; NO_x emissions are reduced by about one-third, VOC emissions by more than 50% and PM_{10} emissions by more than 20%. Clearly, business-as-usual emissions will be much higher than the EST criteria: the business-as-usual scenario is far from being sustainable according to the emission-related EST criteria. If the EST criteria are to be met, CO_2 and PM_{10} emissions will have to be reduced by 85-90% of the business-as-usual scenario emissions in 2030, NO_x emissions by 85% and VOC emissions by 75-80%.

Table 2: Vehicle use and emissions in 2030 - business-as-usual scenario (index 1990 = 100)

			Emissions			
	Unit	**Volume**	**CO_2**	**NO_x**	**VOC**	**PM_{10}**
Cars	veh. km	175	131	25	30	23
Vans	veh. km	325	253	108	79	191
Lorries	veh. km	275	230	99	53	82
Heavy lorries	veh. km	275	230	68	36	89
Buses	veh. km	120	100	37	12	36
Motorcycles	veh. km	150	140	128	150	150
Mopeds	veh. km	100	83	86	93	100
Inland shipping	tonne km	175	137	140	137	140
Deep sea transport	tonnes	150	120	120	120	120
Rail passengers	pass. km	140	127	302	95	266
Rail freight	tonne km	200	105	157	135	234
Aircraft	passengers	350	252	350	252	198
Total transport emissions	(index 1990=100)		159	67	46	78
EST criteria	(index 1990=100)		20	10	10	10

3.3 The Backcasting Analysis (Step 5)

In contrast to the business-as-usual scenario, the EST scenario is not based on an analysis of current driving forces and societal trends or transportation models. The backcasting analysis is based on the business-as-usual scenario to describe the expected developments between 1990-2030, and selected measures to calculate the necessary effects of measures which meet the targets in a ‘trial-and-error’ scenario-building process, using expert judgement, and existing literature and model simulations. Brainstorm sessions were held with Dutch experts, and expert judgements from the experts involved in the other EST country studies and OECD were also included. Existing knowledge and the literature on transport alternatives and future transport systems also contribute to this groundwork. Specific models such as normative or system dynamic models have not been used, as their implementation is very time-consuming. Normative models describe how a system could or should meet certain (sets of) targets, and can be used to find the ‘optimal’ situation to reach certain targets. This approach is taken in the Sustainable Economic Development Study (DEOS) (IVM 1995), in which a special backcasting model was developed to optimise added values of Dutch economic sectors on the condition that environmental targets are met. System-dynamic models are based on a theory of causal structure and its relationship to dynamic behaviour. These models allow feedback between the system components. Especially the ‘open’ structure and the dynamic character of the models have several advantages in backcasting studies; they can be used in a ‘trial and error’ procedure to analyse possible routes to reach certain targets. Perhaps the most well-known example of system dynamic modelling is the modelling work as described in the report of the Club of Rome (Meadows et al., 1972) and its follow-up report (Meadows et al, 1992). In the EST project, a system dynamics model was developed to analyse the economic impacts of EST for Germany (see OECD, 2001, and the contribution of Schade and Rothengatter in this volume).

In the EST project, each country study developed three 'backcasting' scenarios, consistent with the EST criteria: (i) a 'high-technology' scenario containing only technological changes, (ii) a 'mobility management' scenario containing only mobility changes and (iii) a 'combination' scenario, combining technological and mobility changes. This article describes the results from the 'combination' scenario for the Netherlands, which in the article is simply referred to as the environmentally sustainable transport (EST) scenario. Technological progress includes (i) incremental changes in current vehicle categories and technology (the vehicle categories from the business-as-usual scenario are assumed to use best technical means) and (ii) the introduction of new vehicle and fuel technologies, e.g. electric cars, fuel cell vehicles. Behavioural changes imply an overall reduction of motorised mobility and remaining demand for mobility has to be met with vehicle categories having the lowest unit impact.

The basic assumptions of the EST scenario

- The greatest implications in terms of costs of technology and changes in society can be omitted by combining technological changes and mobility management strategies (e.g. traffic management, road pricing). It is very unlikely that 80-90% energy use and emission reductions in the transport sector can be met only through technological changes. Firstly, this would imply the availability of CO_2-neutral and clean energy sources on a large scale, not only for the transport sector but also for other sectors, and not only for the Netherlands but also other (European or other) countries. Furthermore, (large-scale) introduction of new vehicle and fuel technologies is likely to remain very expensive in the next two or three decades, whereas some non-technical measures are very cost-effective (e.g. Van Rumpoy et al, 2003). Besides, new vehicle and fuel technologies will also have significant impacts on travel behaviour patterns as they will increase transport costs considerably.
- The extent to which people are able to participate in activities may not change significantly, whereas the locations of activities, travel distances and travel mode choice may change radically.
- Technological changes can be potentially realised if necessary barriers are timely overcome and challenges are timely addressed. Future development in technology has to be much stronger than in the past. As an illustration, fuel efficiency improvement of new cars in the Netherlands was about 25% between 1980 and 2000, whereas in the EST scenario we assume an 80% fuel efficiency improvement between 2000 and 2030.

Specific assumptions, as outlined below, have also been made on technology development and non-technological changes (changes in transport activity, modal shifts and efficiency improvements) in passenger transport and freight transport.

Assumptions on technology

- All cars are very fuel-efficient hybrid vehicles with conventional combustion engines and end-of-pipe techniques to reduce NO_x and VOC emissions, i.e. de-NO_x catalysts and vaporisation control measures. Cars are smaller, lighter and power capacity has been downsized; they are about 80% more fuel-efficient than current (new) cars. Although technically feasible, large-scale introduction of CO_2-neutral fuels into the car stock is not assumed because of the high costs involved. Hydrogen cars are likely to remain expensive - even with optimistic assumptions on economies of scale - because of the high cost of vehicles and the refuelling infrastructure. Costs range from 250 to over 3000 euros per tonne CO_2 (Kolke, 1999; Keith and Farrell, 2003).

- CO_2-neutral fuels are introduced into the freight transport sector. Heavy-duty vehicles and ships are assumed to have a 50% market share of fuel cells in combination with sustainably produced hydrogen. Compared to cars, these modes require a much less extensive hydrogen distribution infrastructure and make less stringent demands on the performance of hydrogen storage systems (Keith and Farrell, 2003). Other freight vehicles are much more fuel-efficient (50% lower CO_2 emissions) than in BAU. For shipping a 'modest' share of fuels cells is assumed to prevent relatively recently built ships from being scrapped or significantly altered. NO_x emissions from conventional ships (50% market share) are reduced by de-NO_x catalysts.
- Rail transport emissions (from passenger and freight trains) are reduced as a result of the technical improvements in trains (regenerating braking energy, light materials, less rolling resistance, improved aerodynamics) and the use of sustainably produced electricity (100% electrical traction).
- The introduction of new technologies to reduce emissions in the air transport sector (e.g. hydrogen aeroplanes) is relatively expensive compared to other (transport and non-transport) technical options. Even conventional technological improvements to improve fuel efficiency and reduce engine emissions may highly increase travel costs, i.e. a 1% improvement in the NO_x emission factor of new aircraft increases real aircraft prices too by 1% (AERO, 2003). In the EST scenario we assume that improved engine technology, aircraft design optimisation (e.g. larger wingspans, lower optimum speeds) and higher load factors may reduce energy use per passenger kilometre by 45% compared to the business-as-usual aircraft (see Dings *et al*., 1997).
- Technology development is very prominent in the energy sector. A large share of sustainable energy production (wind, solar, etc.) is assumed (40% share), whereas other (fossil fuel) electricity production (60% share) is highly efficient (80% efficiency versus 50% in the business-as-usual scenario).

Passenger transport assumptions

- Average trip distances are shortened and origin–destination patterns have changed, reducing total passenger mobility (by 35% compared to the BAU level in 2030). Car use is reduced by 50% compared to the business-as-usual level in 2030 as a result of shorter trip distances and a shift to rail. For example, about the same number of car passenger kilometres in 1970 can be driven in 2030 in the EST scenario but with a much higher population size and using totally different vehicle types. Car occupancy levels increase by about 30% compared to the current level.
- The level of rail passenger kilometres is the same as in the business-as-usual scenario in 2030; a decreased number of passenger kilometres due to shorter trip distances is assumed to compensate for the shift from car use to rail.
- Due to the modest technology development in the aviation sector, air travel will have to be reduced substantially (by about 75%) to meet the EST criteria in 2030: a 15% reduction compared to the 1990 level. Short-distance (European) air travel will be replaced by (high-speed) rail transport and (to a lesser extent) rigid airships. Long-distance (intercontinental) business air travel will have to be largely replaced by telematics and long-distance leisure trips will have to be made less frequently.

Freight transport assumptions

- A strong shift from road transport to inland shipping and rail transport, i.e. the share of road transport in the total number of tonne kilometres is reduced from about 60% (business-as-usual) to 25% in 2030. The share of inland shipping increases from about 38% to 45%; rail transport increases from about 4% to 30%. The model split is more-or-less the same as in the trend-breach scenario study for freight transport (Peeters, 1993).
- A shift towards larger vehicles and fewer empty trips (higher load factor) is the result of a logistical optimisation for road transport (resulting in a 35% lower CO_2 emission per tonne kilometre) and inland shipping and rail (both 20% lower CO_2 emission per tonne kilometre). The effects are more-or-less the same as in the trend-breach scenario study.
- To reduce national and international freight transport distances and volumes, changes in production and consumption structures at an international (European) level are necessary. There is more local/regional production and consumption of food, resulting in a reduction of average food-related transport distances of 40%. There is less consumption of goods and goods for consumption keep longer, reducing non-food goods production and thus transport volumes by 20%. A shift in the pattern of origin and destination of non-food goods reduces average non-food-related transport distances by 25%.

The contribution of technological and non-technological changes

The EST scenario combines strong technology development and travel behaviour changes as the most plausible route to the attainment of EST. To illustrate the importance of technological and non-technological changes to the realisation of EST, their relative contributions to realising the CO_2 target have been analysed. For the total transport sector, technological and non-technological changes are equally important; both contribute to about 50% of the CO_2 emission reduction. The contribution of technology is, however, more substantial for passenger transport (about 60%), and less substantial for freight transport (about 40%) where the contribution of mode shifts and transport demand reductions is somewhat higher. If the EST emission reduction targets (especially the CO_2 criterion) are assumed to be lower (or the time period for implementing EST is much longer), the contribution of technological changes to the attainment of EST is likely to increase, for two reasons. Firstly, surveys show that public support for technology development as a solution to environmental problems is much stronger than changes in lifestyle and (travel) behaviour (e.g. see NFO Trendbox, 2002). Secondly, technological options are then more likely to be more cost-effective.

3.4 Implementation requirements (Step 6)

The EST scenario shows a trend breach in technology development, lifestyles and travel behaviour. For implementation of policy instruments that would result in realisation of these trend breaches we assume a fundamentally different society in 2030 than the current and the 'business-as-usual' society of 2030. This implies that many problems with implementation can be expected and many barriers will need to be overcome. In this section we describe a package of instruments which – if implemented – would result in the realisation of the EST target set, and a possible time-path for implementation. Both can be characterised as a 'what if' analysis, i.e. what instruments are necessary and when do they need to be implemented to meet the EST criteria by 2030. The instrument package and implementation time-path do not offer a blueprint for sustainable transport; instead they should be taken as an illustration of a possible and plausible path towards realising EST.

The development of the package of instruments assumes the following starting points:

- Existing policy instruments will probably not be sufficient to realise the large emission reductions envisioned by EST. Innovative transport policy instruments will have to be developed and implemented. A system of CO_2 emission permits for both passenger and freight transport forms the main element in a package of instruments aimed at realising EST. Other instruments are necessary for supporting or facilitating EST and increasing the (social) feasibility of implementation of EST.
- Implementation of such a package implies that many changes outside the transport sector have already taken place: i.e. changes in political, societal, economic and spatial contexts. Instruments will also need to be implemented to reduce emissions in other sectors of the economy to a (more) sustainable level. Here, we will focus more on the instruments within the transport sector, and less on those outside this sector.
- A strong level of international co-operation will be necessary to achieve the sharp emission reductions. We assume that other countries are also in the process of striving to realise EST and will thus work on similar instrument packages.

Tradable CO_2 emission permits. A system of tradable CO_2 emission permits will have several effects. People receive a free yearly CO_2 budget (and are free to buy or sell permits at market price) and will try to optimise their travel patterns within their budget. Possible effects are: (i) a reduction in the number of passenger kilometres, depending on the total CO_2 budget for passenger transport and the price of buying extra CO_2 permits, (ii) less energy use per vehicle kilometre, so the higher the energy efficiency of the car and the better the driving behaviour, for example, the more vehicle kilometres can be driven with the same CO_2 permit; (iii) modal split changes, so that the use of non-motorised transport will increase, for instance. The initial yearly CO_2 budget per capita (within the EST CO_2 emission ceiling) is equivalent to about 8,000 kilometres using a fuel-efficient hybrid car or only 1,400 kilometres using conventional BAU vehicles. Freight transport companies do not receive a CO_2 budget, mainly for practical reasons. CO_2 emission permits can be bought on a ‘permit market’ at market price. The system for both passenger and freight transport will be gradually implemented so that the CO_2 budget per inhabitant and the number of CO_2 permits for freight transport can be gradually reduced to the desirable CO_2 emission level for 2030. The time-path will be announced in advance to promote anticipative behaviour. The tradeable emission system has two important advantages: the system is effective (realisation of the CO_2 target is guaranteed) and has positive equity impacts. That is, the unconditional allocation of quota firstly gives all inhabitants access to a baseline of motorised mobility which makes a large contribution towards keeping to a minimum price increase. Secondly, high-income groups pay more to retain their current travel behaviour pattern than low-income groups (as they travel more and farther). As an illustration, fuel costs in EST would increase for low-income groups (less than 14,500 Euro per year) by about 9% (and total transport expenditures about 1%), whereas fuel costs for high-income groups (more than 25,000 Euro per year) would more than double (and total transport expenditures increase by about 10%)[1].

Other pricing instruments. Pricing-policy instruments like increasing fuel taxes and road pricing will be necessary for the short-term/medium-term instruments. These pricing instruments will eventually be replaced by the system of tradable CO_2 emission permits after

2015. Furthermore, subsidies will promote: (i) new vehicle technologies, (ii) freight transport standardisation to facilitate transfers and (iii) multi-modal freight transport companies.

Spatial-planning/land-use instruments. The role of land-use policies in an environmentally sustainable transport system differs from the current one in transport policy, which is to reduce motorised mobility and related emissions. In EST, land-use policies are aimed at increasing accessibility to social and economic opportunities for cycling, walking and public transport to facilitate the required changes in mobility patterns (shorter average travel distances and less motorised travel). Improved accessibility is the result of the combination of improving bicycle infrastructure and land-use policies, such as high-density building and mixed-land use. Thus, people are able to show that more activities fall within their CO_2 budgets. New urban areas are built so as to realise ‘compact cities’. Furthermore, the Dutch employment location policy for new employment locations ‘the right business in the right place’, combined with pricing measures, will be expanded to include re-location of existing companies and will comprise supporting and regulatory instruments. To promote multi-modal freight transport, production and distribution locations are to be situated within rail and inland shipping infrastructure. A location policy for new and existing road, rail and inland shipping transport companies, comprising both supporting and regulatory instruments, will have to be developed and implemented.

Regulations. Promotion of good health and ‘quality of life’ will mean that transport in urban areas will have to show (almost) zero emission. To realise this, vehicles with a conventional combustion engine will be restricted in city centres, whereas zero-emission vehicles (electric vehicles, hybrid vehicles operating in the ‘electric mode’ or fuel cell vehicles) will be allowed. NO_x and VOC emission regulations will be introduced to implement end-of-pipe emission reduction techniques. Furthermore, speed limits, not only on motorways but also on other road types, will be lowered to reduce the attractiveness of car use, to promote shorter distances, to save energy per kilometre driven and to reduce noise nuisance and accidents. Vehicles will be equipped with on-board speed adaptation systems for systematic maintenance of the lower speeds.

Infrastructure policy. To facilitate the assumed non-motorised transport growth, in which bicycle use is expected to double, road infrastructure policy must change radically. For example, motor vehicle infrastructure in middle-sized cities and towns will be largely converted to non-motorised infrastructure. Investments in public transport will be mainly necessary at the local and regional level. Note that rail passenger growth, expressed in passenger kilometres, is assumed to be the same as in the business-as-usual scenario. Its higher share in trips is compensated by a reduction in trip distances, resulting in a relative shift to medium-distance trips, partly at the regional level, creating a need for investments at this scale. Furthermore, a network of urban distribution centres will be introduced to increase load factors and reduce vehicle kilometres (of mainly light-duty vehicles). A combined transport system will be developed to promote multi-modal freight transport by constructing a network of road/rail, road/water and rail/water transfer terminals. A better European organisation of rail transport and rail infrastructure networks will be necessary to increase the share of rail transport in international freight transport, e.g. European-level multi-modal transfer terminals and computer systems to facilitate transport handling.

Other instruments. Education and information are necessary instruments for gaining public support for the system of tradable CO_2 permits and other measures and promoting the advantages of sustainable transport. Furthermore, telematics is important to provide non-physical access to different opportunities, especially to replace long-distance business travel.

Instruments outside the transport sector. Flexible housing and employment markets are a necessity if shorter trips between home and work are to be realised. Fiscal instruments stimulate people to move closer to their job locations. By 2030, regional demand and supply of housing will be much more in balance compared to the current situation and the reference scenario. The international orientation of the agricultural sector will have to become more local or regionally focused on food production. Furthermore, implementing instruments to reduce emissions in the industrial sectors of the economy will contribute to a lower level of produced goods and thus to less need for freight transport. Instruments outside the transportation sector will probably also contribute to the changes needed to reduce freight transport distances and total produced volumes. Stringent targets for the rest of the economy will, for example, result in longer lifetimes of several goods, reducing the produced and therefore transport volumes of these goods. Several instruments will also be necessary to achieve the changes envisioned in the energy sector.

An implementation time-path for each policy instrument can be constructed using the backcasting method: i.e. by assuming the instrument to have its full effect by 2030 and then calculating backwards to determine the start of the policy implementation phase. The concept of the 'policy life cycle' is also used. It consists of three phases: (1) a recognition (or acceptance) phase, (2) a policy adjustment phase and (3) a policy implementation phase. Analysis of policy life cycles for technical emission reductions in the Netherlands in the past, mainly outside the transport sector, showed the average acceptance and adjustment phase to take about 6 years and the average implementation phase about 18 years (Van de Peppel et al., 1997). Here, the pre-implementation phase is assumed to take about five years; for relatively 'easy' instruments (e.g. information instruments) this period will be shorter and for 'difficult' instruments (e.g. tradable CO_2 permits) it will be longer. The implementation phase of mobility measures depends heavily on the instrument type: regulations and information instruments may have a relatively short implementation period, e.g. 1 to 5 years, whereas land-use and infrastructure policies will require a long implementation and adaptation period. The full effect of these measures is long-term, taking place in approximately 15 to 20 years. The implementation phase of technical measures, assumed to consist of full replacement of road vehicles, will take up to 15 years. In general, the implementation time-paths are assumed to work on a two-phase basis: i.e. the more 'traditional' instruments (e.g. fuel taxes, car-free urban centres) are assumed to be implemented within few years from now and be eventually replaced by non-traditional instruments (e.g. the tradable CO_2 permit system and access restrictions for vehicles with conventional combustion engines in central urban areas).

In conclusion, a package of many different instruments inside and outside the transport sector will be necessary if EST is to be achieved by the year 2030. Innovative policy instruments need to be developed and implemented, and the role of existing instruments may change. A timely implementation of these policy instruments will only occur if the current policy life cycle is radically changed and a start is made with the implementation of the land-use and infrastructural instruments in the short term.

3.5 Impact analysis (Step 7)

A key dimension of a backcasting study is impact analysis. Here, we will shortly describe the analysis of the environmental, economic and social implications of the EST scenario compared to the business-as-usual scenario for 2030.

Environmental impacts

The environmental impacts of the EST scenario will result directly from the backcasting analysis itself: total CO_2, NO_x, VOC and PM_{10} emissions are below the EST criteria in the EST scenario in 2030 (Table 3). The CO_2 criterion is the most difficult one to meet. Technology developments needed to reduce CO_2 emissions contribute, to a large extent, to meeting the other emission (NO_x, VOC, PM_{10}) criteria; limited additional measures, such as end-of-pipe measures, are necessary meet these criteria. In contrast, several additional (non-technological) measures are needed to meet the land-take and urban environment criteria, such as traffic restrictions, and land-use regulation and control measures. The EST criteria can be met only if a high increase in technology development and stringent behavioural adaptations are assumed, along with changes in economic structures at international level.

Table 3: Vehicle use and total CO_2, NO_x, VOC and PM_{10} emissions for the EST scenario in 2030, index business-as-usual 2030 = 100)

			Total emissions			
	Unit	**Volume**	**CO_2**	**NO_x**	**VOC**	**PM_{10}**
Passenger transport						
Car	passenger km	50	10	6	6	9
Rail	passenger km	100	10	18	0	0
Bus (public transport)	passenger km	200	71	16	32	64
Mopeds/motorcycles	passenger km	25	15	15	15	13
Bicycle	passenger km	200	0	0	0	0
Aircraft	passengers	25	13	13	13	13
Freight transport						
Lorry	tonne km	25	6	4	6	6
Inland shipping	tonne km	73	29	15	29	26
Rail	tonne km	486	77	119	0	0
Total transport emissions	(index BAU 2030 =100)		10	8	15	13
EST criteria	(index BAU 2030 =100)		13	15	22	13

Economic impacts

EST is likely to have major impacts on the functioning of the transport sector but also on other sectors of the Dutch economy. In other words, agriculture for an international market has to disappear to a large extent and a large share of energy has to be produced in a sustainable manner. Several assessment methods were used within the OECD project to analyse the economic impacts; see OECD (2001) for an elaborate description. In the Dutch case study, a simplified assessment method called ‘Impact Path Analysis’ (IPA) was applied to assess the order of magnitude of macro-economic changes based on data provided by 'input-output' tables of national accounts. The assessment focuses on transport-related sectors of the economy (i.e. road-vehicle manufacturers, secondary car business and transport services, railways, airlines, the tourist industry and retail business). It also includes multiplier effects to incorporate forward and backward linkages to other sectors of the economy. In the German case study, the IPA method provided results with such comparable order-of-magnitude effects as the much more advanced System Dynamics Modelling approach (see OECD, 2001, and the contribution of Schade and Rothengatter in this volume). However, the IPA method gives relatively higher economic impacts, since it focuses on first-order impacts resulting from higher prices and demand side restrictions, and does not include second-order feedback mechanisms. These mechanisms increase productivity in the long run and may offset negative economic impacts. In addition to the IPA method, which gives an indication of impacts of EST on material welfare, external cost savings (including climate change costs, air pollution, accidents, congestion costs) are estimated for the business-as-usual and EST scenario to indicate the non-material welfare gains of EST.

The EST scenario has major impacts on the transport sector; the share of value added for the transport sector in Dutch GDP decreases from 9% for the business-as-usual scenario in 2030 to 3% for the EST scenario. Economic losses are especially high for the road-freight transport sector, and airline and shipping industries, sectors which are traditionally considered to be of great importance for the Dutch economy. The transport service sectors and tourist industry will also experience economic losses. On the other hand, the rail transport sector will increase substantially, and the retail trade and domestic hotel and restaurant sectors will profit from a scaling-down of businesses and higher consumption levels. In addition, the strong developments in technology will induce positive side-effects through productivity improvements and changes in the economic structure. These positive impacts can largely, but not fully, offset the economic losses in the transport sector. Total loss of GDP, including direct and indirect effects, is about 4-8%, and total Dutch employment is about 1-3% lower compared to the business-as-usual scenario in 2030.

In conclusion, implementing EST will have significant economic impacts, but is not likely to result in a total collapse of the economy; average annual GDP *growth* for the period up to 2030 will be 0.1 – 0.2% lower than under the business as usual scenario. External cost savings, given uncertainties in cost factors and the difficulties in putting a price tag on several externalities, may add up to about 1-4% of GDP. Thus, if external costs are used as an indicator for non-material welfare, total loss of material welfare in 2030 can probably be largely, but not fully, compensated by gains in non-material welfare.

Social impacts

An analysis of social impacts of transport scenarios is challenging. Social impacts can take on many forms, some of which are particularly difficult to estimate with any precision; perceptions as to the relative importance of different sorts of social impacts may also vary widely. Moreover, relatively little work seems to have been done to develop methods, tools and techniques to rigorously estimate probable social effects of transport changes. To date, social impact assessments typically focus on accessibility impacts, traffic safety, noise and air quality, visual impacts and severance (see Forckenbrock et al., 2001, for example, for a recent overview). An analysis of the social impacts of the EST scenario is especially difficult, as both transport and society as a whole will have to be fundamentally different in comparison to business-as-usual and the current situation. A comprehensive analysis of social impacts, facilitated in recent guidebooks in the UK (DfT, 2000) and the United States (Forckenbrock & Weisbrod, 2001), is thus beyond the scope of this study. Alternatively, the social implications of EST were analysed qualitatively on the basis of a number of social factors identified that were thought important and sensitive to changes in mobility. These factors, based on Adams (2000), were used as a framework to qualitatively describe the expected social differences between the BAU and the EST scenarios for the Netherlands for 2030.

Our analysis concludes that EST will reduce inequalities in the costs and benefits of transport: differences in travel behaviour, accessibility of economic and social opportunities, and quality of life among societal groups will be less pronounced. Travel behaviour impacts are strongest for high-income groups, since people with higher incomes travel more than other income groups in BAU. Social polarisation in accessibility to social and economic opportunities is reduced. Accessibility is especially improved for people depending on non-motorised modes and public transport, both because of improved infrastructure, particularly for non-motorised modes, and because of the changes in land use (more mixed-land use, higher densities). Furthermore, as a result of lower transport volumes and improved technology, traffic safety will considerably improve, especially for vulnerable groups, and health problems related to local air pollution and noise will be strongly reduced. Especially low-income groups will benefit from this, as these groups live more than average in neighbourhoods with a low environmental quality. EST thus increases social equity: the distribution of costs and benefits derived from the land-use/transport system among societal groups is less pronounced. This is due to a large extent to a side-effect of the implementation of the package of policy measures. However, the system of tradable permits, which initially distributes CO_2 budgets equally among the population, also contributes to this effect.

4. Conclusions and discussion

The OECD's Environmentally Sustainable Transport (EST) project is one of the most recent examples of the backcasting approach to policy making, aiming as it does, to generate alternative images of the future that have been thoroughly analysed for feasibility, consequences and policy implications. The major difference with respect to earlier backcasting studies is, firstly, that a wide range of very stringent environmental criteria is used, i.e. 80-90% emission reductions between 1990-2030, a negligible level of noise nuisance in 2030, stabilisation of land-take for transport outside urban areas and a good living environment in urban areas. Secondly, explicit attention is paid to the time-paths of events necessary to meet the criteria and thirdly, focus on the social and economic impacts of the scenarios is also explicit.

From the Netherlands' case study it can be concluded that all of the EST criteria will be only be met if we assume a high increase in technology development, and stringent behavioural adaptations and changes in economic structures at international level. This means that (i) future technological progress will have to be much greater than in the past, (ii) mobility patterns must radically change (i.e. shorter trip distances and less reliance on motorised transport) and (iii) freight transport must be different (i.e. fewer goods transported over shorter distances with less reliance on road transport). It is very unlikely that the EST criteria can be met only through technological changes. This would, firstly, imply the availability of CO_2-neutral and clean energy sources on a large scale, not only for the transport sector but for others as well, and not only for the Netherlands but also for other countries, European or countries beyond. Secondly, the noise, land-take and liveability criteria can not be met with only technological changes; several additional measures are needed, such as traffic restrictions and land-use regulation and control measures. Finally, a large-scale introduction of new technologies is likely to increase transport costs, which will also have significant impacts on travel behaviour patterns.

Current Dutch transport policies are clearly not sufficient for attaining an environmentally sustainable transport system according to the EST criteria. Innovate policy instruments need to be developed and implemented. A system of tradable CO_2 emission permits for both passenger and freight traffic is considered crucial for achieving EST, especially to meet the 80% CO_2 emission reduction target within a policy package containing instruments necessary to support or facilitate EST and increase the (social) feasibility of implementing EST. Furthermore, the role of existing policy instruments, particularly land-use, infrastructure policies and telematics in EST differs from the current one in transport policy. In current policy, these policies often are seen as instruments to reduce car use and related emissions, whereas in EST the instruments are primarily taken to improve accessibility; due to changes in land use (e.g. building in high densities, mixed land use), improved bicycle and ICT infrastructure, people can - physically or non-physically - access many opportunities comfortably, without using motorised transport.

If EST is to be realised by 2030, measures will have to be taken and instruments implemented in the short term to accommodate the necessary instrument pre-implementation period (policy acceptance and adjustment phase) and the long implementation period for technical, land-use and infrastructure changes. A timely implementation of the instruments so as to realise the EST scenario will probably mean a necessary radical change in the current Dutch policy life cycle. Implementation of the instrument package will be very difficult since the implication here is that many changes outside the transport sector have already taken place: changes in the (international) political, societal, economic and spatial context. In addition, measures will also need to be taken to reduce emissions in other sectors of the economy to a (more) sustainable level.

Introducing EST will have major impacts on economic performance of the transport sector, especially for the road freight, shipping and aviation sectors in the Netherlands, sectors which are traditionally considered important for the Dutch economy. However, the economic losses in the transport sector can be partly offset by gains in other sectors (e.g. rail sector, retail industry) and productivity gains due to technology development. The overall impact on the total Dutch economy will be fairly limited; average annual GDP growth for the period up to 2030 will be 0.1-0.2% lower than under the business as usual scenario, and total Dutch employment would be a few percentage points lower. If external costs are used as a measure of non-material welfare, total loss of material welfare in 2030 would be largely, but not fully, compensated by gains in non-material welfare. However, the economic appraisal method used is rather simplified and probably overestimates the economic impacts of EST. More complex appraisal methods used in other EST country studies, e.g. the system dynamics model developed for the German case study, show that second-order productivity gains may - on the long run - more than offset negative (first-order) economic impacts resulting from higher prices and demand side restrictions. More research is necessary to analyse the economic impacts of EST in more detail for the Netherlands, which would need to include impacts of production and consumption structure changes at an international (at least European) level and measures taken in other sectors of the economy to attain a (more) environmentally sustainable society. If other sectors strive for the same emission reductions as the transport sector, the overall impact on the Dutch economy will be higher, but additional losses are probably less than proportional to the emission reductions since emission abatement costs are relatively high for the transport sector (e.g. see Peake, 1997; Rompuy et al., 2003).

EST will reduce inequalities in the costs and benefits of transport: differences in travel behaviour, accessibility of economic and social opportunities, and quality of life among societal groups will be less pronounced. As a result of reduced transport volumes and improved technology, traffic safety is improved and health problems related to local air pollution and noise are reduced. The OECD project analysed the social implications of EST qualitatively, on the basis of a number of identified social factors thought important and sensitive to changes in mobility. More comprehensive social impact analysis will be necessary to give a more detailed analysis of the potential social costs and benefits of EST.

The realisation of Environmentally Sustainable Transport with 80-90% emission reductions for the transport sector within a time period of three decades does not seem realistic given the current political, economic and societal context. The difference between the EST and business-as-usual transport policy is so large that a timely implementation can only be expected if public awareness changes radically, for example, as a result of increased climate instability causing extreme drought, flooding and/or food supply problems. The realisation of the 80% CO_2-emission reduction target for the transport sector, in particular, implies substantial travel behavioural, societal and economic changes. If the CO_2 emission reduction target is assumed to be lower, or the time period for implementing EST much longer, the contribution of technological changes to attaining EST is likely to increase, thereby decreasing societal impacts and increasing public support. Furthermore, the assumption that the transport sector achieves the same emission reduction targets as other sectors of the economy also contributes to relatively strong societal impacts. However, more cost-effective technologies are available in other sectors, especially for greenhouse gas emission reduction and PM_{10} emission abatement. The introduction of a system of tradable CO_2 emissions for all sectors of the Dutch economy will be particularly more cost-effective than only for the transport sector or for each sector individually, and when introduced EU-wide or possibly world-wide.

References

Adams, J. (2000), The social implications of hypermobility. Speculations about the social consequences of the OECD Scenarios for Environmentally Sustainable Transport and Business-As-Usual Trend Projections. In: OECD (2000), *Project on Environmentally Sustainable Transport (EST). Proceedings from the Ottawa Workshop, ENV/EPOC/PPC/T(99)3/FINAL, 20-21 October, 1998*, OECD, Paris.

AERO (2002), *Aviation Emissions and Evaluation of Reduction Options (AERO). Main report* Ministry of Transport, Public Works and Water Management, The Hague.

Banister, D., D. Stead, P. Steen, J. Akerman, K. Dreborg, P. Nijkamp, R. Schleicher-Tappeser (2000), *European Transport Policy and Sustainable Mobility*. Spon, London.

Becker, H.A., D.J. van Houten, J.T.J.M. van der Linden (1982), *Handleiding voor het ontwerpen van scenario's [manual for designing scenarios]*, Utrecht University, Sociologisch Instituut,, Utrecht.

CBS (2002), *Statline - the central database of Statistics Netherlands.*, Statistics Netherlands, Voorburg/Heerlen (http://statline.cbs.nl).

Dings, J.M.W., W.J. Dijkstra, R.C.N. Wit (1997), *European aviation emissions: trends and attainable reductions. Report of background study.*, CE Centre for Energy Conservation and Environmental Technology, Delft.

Dreborg, K.H. (1996), Essence of Backcasting, *Futures* 28 (9), 813-828

Forckenbrock, D.J., S. Benshoff, G.E. Weisbrod (2001) *Assessing the Social and Economic Effects of Transportation Projects.* University of Iowa/Economic Development Research Group, Iowa City/Boston, M.A.

Forckenbrock, D.J., G.E. Weisbrod (2001), *Guidebook for Assessing the Social and Economic Effects of Transportation Projects.* National Cooperative Highway Research Program. University of Iowa/Economic Development Research Group, Iowa City/Boston, M.A.

Geurs, K.T., G.P. van Wee (2000), *Environmentally Sustainable Transport: Implementation and Impacts of Transport scenarios for the Netherlands for 2030*. RIVM Report no. 773002013, National Institute for Public Health and the Environment, Bilthoven (available at: http://www.rivm.nl/bibliotheek/rapporten/773002013.html).

Höjer, J. (1998), Transport Telematics in urban systems - a backcasting Delphi study. *Transportation Research -D*, Vol. 3(No. 6), pp. 445-463.

IVM (1995), *Duurzame Economische Ontwikkelings-Scenario's (DEOS) voor Nederland in 2030 [Sustainable economic development scenarios (DEOS) for the Netherlands in 2030]*, Institute for Environmental Studies (IVM), Amsterdam.

Johansson, T.B., P. Steen (1978), *Solar Sweden - An outline of a Renewable Energy System.* Secretariat for Future Studies, Stockholm.

Johansson, T.B., P. Steen, E. Bogren, R. Fredriksson (1983), Sweden Beyond Oil: The Efficient Use of Energy. *Science*, 219(28 January), 355-361.

Kahn, H.A., A. Wiener (1967), *The Year 2000: A framework for Speculation.* MacMillan, New York.

Keith, D.W., A. E. Farrell (2003), Rethinking Hydrogen Cars, *Science,* Vol. 301, 18 July 2003.

Kolke, R. (1999), *Technical options for abating road traffic impacts. Comparative studies of fuel cell vehicles and vehicles with internal combustion engines*. Final report, Umwelt Bundesamt, Berlin

Martino, J. (1983), *Technological forecasting for decision making.* Elsevier Science Publishing Company, New York:.

Meadows, D.H., D.L. Meadows, J. Randers (1992), *Beyond the limits, global collapse or a sustainable future.* Earthscan Publications, London.

Meadows, D.H., D.L. Meadows, J. Randers, W.W. Behrens (1972), *The limits to growth.* Universe Books, New York.

Meadows, D.H., J.M. Robinson (1985), *Computer Models and Social Decisions. The Electronic Oracle.* John Wiley & Sons, Chichester, UK.

MuConsult (1997) *Effecten van grote prijsveranderingen.* [Transport impacts of large price increases]. MuConsult, Amersfoort.

NFO Trendbox (2002), *Milieu en economie* [Environment and Economy]. Project 110682, NFO Trendbox, Amsterdam.

NEPP (1989), *National Environmental Policy Plan. To choose or to loose.* Tweede Kamer, vergaderjaar 1988-1989, 21 137, nrs. 1-2, The Hague.

OECD (1996), *Environmental criteria for sustainable transport. Report on Phase 1 of the Project on Environmentally Sustainable Transport (EST)*, OECD, Paris.

OECD (2000), *EST! Environmentally Sustainable Transport. Futures, strategies and best practices. Synthesis Report.*, OECD, Paris.

OECD (2001), *Economic Implications of EST and External Costs, Project on Environmentally Sustainable Transport (EST). Phase 3, Report no. ENV/EPOC/WPNEP/T(2001)4*, OECD, Paris.

OECD (2002), *Policy instruments for achieving Environmentally Sustainable Transport.* OECD, Paris.

OECD (2003), *The Netherlands Environmental Performance Review*, OECD, Paris.

Peake, S. (1997), Editor's introduction. Transport, energy and climate change. *Energy Policy* 25 (14-15), pp. iii-iv.

Peeters, P.M. (1988), *Schoon op weg, naar een trendbreuk in het personenverkeer [The Netherlands travelling clean, towards a trend breach scenario in passenger transport].*, Vereniging Milieudefensie, Amersfoort.

Peeters, P.M. (1993), *Goed op weg. Naar een trendbreuk in het goederenvervoer [A new course in freight transport, towards a trend breach scenario in freight transport].*, Stichting Werkgroep '2duizend, Amersfoort.

Peppel, R.A. van de, D. Hoek, J.E. van der Ploeg, P-J. Klok (1997), *Vergelijkende beleidsanalyse: emissies, beleid en maatschappelijke aandacht.* [Comparative policy analysis: emissions, policy and public attention]. Centrum voor Schone Technologie en Milieubeleid, Enschede.

RIVM (1993), *National Environmental Outlook 3 (1993-2015).* National Institute for Public Health and the Environment, Bilthoven.

RIVM (2000), *Nationale Milieuverkenning 5 2000-2030* [National Environmental Outlook 5]. National Institute for Public Health and the Environment, Bilthoven.

RIVM (2002), *Environmental Balance 2002. Accounting for the Dutch Environment (summary)*, National Institute for Public Health and the Environment, Bilthoven (available at: www.rivm.nl).

Robinson, J.B. (1982), Energy backcasting. A proposed method of policy analysis. *Energy Policy*, pp. 337-344.

Robinson, J.B. (1990), Futures under glass. A recipe for people who hate to predict. *Futures* (October 1990), pp. 820-842.

Rompuy, J. van, G. de Ceuster, B. van Herbruggen, F. Vanhove, P. Bickel, S. Reis, T. Pregger (2003), *Marginal Costs of Abatement for Environmental Problems*. SUMMA Deliverable 9. Transport & Mobility Leuven/IER-University of Stuttgart, Leuven/Stuttgart.

Steen, P. (1997), *Transport in a sustainable society - Sweden 2040*.

STSP (1990), *Second Transport Structure Plan.* Ministry of Transport. Public Works and Water Management, The Hague.

Van der Heijden, K. (1996), *Scenarios. The Art of Strategic Conversation.* John Wiley & Sons, Ltd, Chichester.

Van Wee, G.P., K.T. Geurs, R.M.M. van den Brink, J.A. Annema (1998), Transport and the environment: the contribution of national and local policies. *Environmental Pollution* 102, S1, pag. 663-670.