Travel to the future: the role of the bicycle in an environmentally sustainable transport system

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Summary

What will the transport system look like if transport emissions are reduced by 80%-90% by 2030? What are the policy instruments available and when will they have to be implemented to realise these sharp emission reductions? What are the social and economic impacts of such an environmentally sustainable transport system? These questions has been addressed in a pilot study for the Netherlands carried out as part of the OECD project on Environmentally Sustainable Transport (EST). This paper describes the results of the study, focusing on the role of the bicycle in an environmentally sustainable transport system. The main conclusions are:

- EST can only be met if mobility patterns radically change and future technological development is much greater than in the past. The role the bicycle in the transport system will strongly increase; the share in total passenger transport kilometres will triple;
- To achieve a strong reduction in motorised transport and a shift to non-motorised transport, a system of tradeable CO_2 emission permits is considered to be the most important instrument. Land use policies and improving bicycle facilities are primarily seen as instruments to improve accessibility;
- If the shift towards non-motorised transport is to be realised, measures will have to be taken and instruments implemented in the short term, mainly because of the long pre-implementation and implementation period of land-use and infrastructure policies;
- The economic impacts of the shift from motorised passenger travel to non-motorised travel are probably small: Dutch society will function reasonably well with less motorised transport. Moreover, EST will have significant social benefits: differences in travel behaviour and thus access to social and economic opportunities between income groups will be smaller, traffic safety increases and public health will improve.

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1. Introduction

What will the transport system look like if transport emissions are reduced by 80%-90% by 2030? What are the policy instruments available and when will they have to be implemented to realise these sharp emission reductions? What are the economic and social consequences of such a transport system? Eight countries, Germany, Switzerland, Austria, France, Norway, Canada, Sweden and the Netherlands, addressed these questions in six pilot studies conducted in the OECD project "Environmentally Sustainable Transport" (EST). Pilot studies for the Central Eastern European countries (CEI), Japan and Italy are also currently being carried out. This paper summarises the results of the EST study for the Netherlands done by the Dutch National Institute of Public Health and the Environment (RIVM) by order of the Dutch Ministry of Housing, Spatial Planning and the Environment (see Geurs & Van Wee, 2000). Focus is on the role of cycling in an environmentally sustainable transport system, and the function of the different types of policy instruments in the attainment of EST.

In the OECD project very sharp emission reductions are assumed to be necessary for the realisation of EST. The OECD (OECD, 1996) described a sustainable transport system as one where (i) generally accepted objectives for health and environmental quality (e.g. such as those from the World Health Organisation concerning air pollution and noise) are met, (ii) where ecosystem integrity is not significantly threatened (e.g. critical loads and levels for acidification), and (iii) where potentially adverse global phenomena (climate changes) are not aggravated. The following quantitative criteria for EST were derived: 50% reduction in CO_2 emissions globally and 80% for OECD countries between 1990 and 2030 if stabilisation of CO_2 emissions is to be achieved; 90% reduction in nitrogen oxide (NO_x), volatile organic compounds (VOC) and particulate matter (PM_{10}) emissions between 1990 and 2030 if acceptable health risk levels in urban areas are to be achieved (OECD, 1999).

In the OECD project "forecasting" as well as "backcasting" scenarios are constructed, a business-as-usual scenario and an environmentally sustainable transport (EST) scenario, respectively. In the EST scenario, measures are assumed to meet the EST criteria (see above).

The rest of the paper is structured as follows. Section 2 describes the main results of the business-as-usual scenario and section 3, the EST scenario. The scenario descriptions are focused on passenger transport. Section 4 describes an instrument package and a possible instrument-implementation time path for the EST scenario, while section 5 outlines the social and economic impact assessment. Section 6 presents the conclusions of the Netherlands pilot study.

2. The Business-As-Usual Scenario

The business-as-usual scenario (BAU) is a reference scenario showing the continuation of present trends in transportation, moderated by likely changes in legislation and technology. This scenario does not necessarily conform to current governmental policies in the Netherlands. In general, the BAU scenario for the period up to 2015 is based on the transport forecasts carried out for National Environmental Outlook 3 using Dutch national transport models (see Van Wee *et al.*, 1996). For the period of 2015 to 2030, trend extrapolations and corrections to them are made on the basis of assumptions and general expectations.

In the business-as-usual scenario, cycling is expected to maintain their current position in the transport system. In the Netherlands, the bicycle is an important transport mode, i.e. bicycle ownership is very high (the number of bicycles owned equals the number of inhabitants), cycling currently accounts for almost 30% of all trips and 7% of all passenger kilometres (see Table 1). The number of bicycle kilometres in the Netherlands almost equals than the number of rail passenger kilometres

Table 1: The share of transport modes in total number of trips and kilometres (per person per day) driven in 1995

	car	public transport	bicycle	walking	other	total
trips	48%	5%	29%	19%	3%	100%
kilometres	75%	10%	7%	3%	3%	100%

Source: CBS

However, road-based motorised traffic will strengthen their position: car use will increase by 75% in the period 1990-2030, lorry use by 175%. As a result, the business-as-usual emission forecasts show a-far-from-sustainable transport system: BAU emissions will be much higher than the EST criteria (see Table 2). If the EST criteria are to be met, CO_2 and PM_{10} emissions will have to be reduced by 87% of the BAU scenario emissions in 2030; for NO_x emissions this is 85% and for VOC emissions, 78%.

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

	Unit	Volume	CO_2	NO_x	VOC	PM_{10}
cars	veh. km	175	131	25	30	23
rail-passenger	pass. km	140	127	302	95	266
bicycle/walking	pass. km.	100	0	0	0	0
lorry	veh. km	275	230	84	44	85
inland shipping	tonne km	175	137	140	137	140
rail-freight	tonne km	200	105	157	135	234
Total transport emissions			159	67	46	78
EST criteria			20	10	10	10

3. A Vision of an Environmentally Sustainable Transport System

This section addresses the question what an environmentally sustainable transport (EST) system might look like. EST has two main characteristics: (i) overall motorised mobility has to be reduced significantly and (ii) the remaining demand for mobility has to be met with vehicle categories having the lowest unit impact. The EST scenario shows a trend breach in both technological development and behaviour. In the EST scenario, about 60% of the reduction of CO_2 emissions in passenger transport is the result of changes in technology, about 40% the result of reduced mobility levels, mode shifts and more efficient vehicle use (higher occupancies).

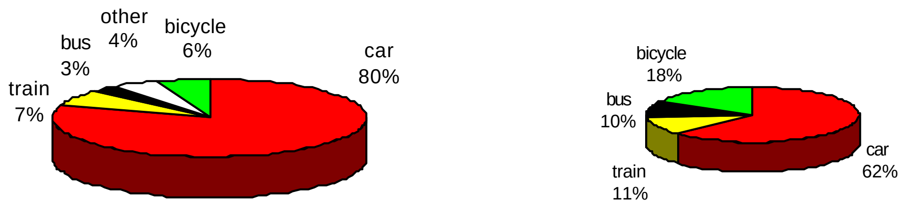
Mobility patterns have to change significantly: people will have to work in or closer to the locations/regions were they live and commute more by slow modes. Average trip distances are shortened and origin–destination patterns have changed, thus reducing total passenger mobility by 35%. The role of motorised transport must change radically: car use is reduced by 50% compared to the BAU level in 2030 due to shorter distances per trip, high vehicle occupancies and a shift to rail, i.e. about the same number of car passenger kilometres in 1970 can be driven in 2030 according to this scenario.

In EST, where trip distances are much shorter than in BAU, non-motorised modes are important for ensuring a sufficient level of accessibility to social and economic opportunities. Cycling will increase substantially, i.e. passenger kilometres will double, the share in total passenger transport will triple.

The role of public transport (in terms of passenger kilometres) in EST is assumed to be the same as in the business-as-usual scenario: a decreased number of passenger kilometres due to shorter trip distances is assumed to compensate for the shift from car use to rail (see Figure1).

Figure 1: Passenger transport volumes and mode choice in the business-as-usual (BAU) and environmentally sustainable transport scenario (EST) in 2030.

BAU: 227 billion pass. km in 2030 EST: 146 billion pass. km in 2030



To achieve heavy emission reductions, vehicle technology will have to be substantially improved. In EST all cars are assumed to be hybrid, with very fuel-efficient engines (running on LPG or another kind of gas) and end-of-pipe techniques to reduce NO_x and VOC emissions, i.e. de-NO_x catalysts and vaporisation control measures. Rail transport emissions are reduced due to the technical improvements of trains (regenerating braking energy, light materials, less rolling resistance, improved aerodynamics) and the use of sustainably produced electricity (100% electrical traction).

The changes necessary to attain the EST criteria will have also major impacts on freight transport sector and other sectors of the economy. The freight transport sector must change radically, i.e. a shift from road transport to rail and inland shipping, a better logistical organisation of all modes, a heavy reduction in transport distances, and highly improved vehicle technology. Changes in others sectors of the economy include those in the agricultural sector (i.e. more regional production and consumption) and the energy sector (i.e. a large share (40%) of energy has to be produced sustainably).

The result of the assumed changes is given in Table 3, showing total CO_2, NO_x, VOC and PM_{10} emissions to be below the EST criteria in 2030.

Table 3: Vehicle use and emissions for the EST scenario in 2030 (index BAU 2030 = 100)

	Unit	Volume	CO_2	NO_x	VOC	PM_{10}
car	pass. km	50	10	6	6	9
rail-passenger	pass. km	100	10	18	0	0
bicycle/walking	pass. km	200	0	0	0	0
lorry	tonne km	25	6	4	6	6
inland shipping	tonne km	755	29	15	29	26
rail-freight	tonne km	485	77	119	0	0
Total transport emissions			10	8	15	13
EST criteria			13	15	22	13

4. An implementation pathway for environmentally sustainable transport

4.1 Which instruments are available for the attainment of EST?

In the Netherlands EST project, a combination of regulatory and pricing instruments is considered the most plausible way to realise the envisioned changes in mobility patterns, complemented with land-use and infrastructural policies to support and facilitate EST and to increase the (social) feasibility of EST. This instrument package for passenger transport comprises:

- *A system of tradeable CO_2 emission permits:* This instrument is considered the most important in the attainment of EST. People receive a CO_2 budget (of 160 kg CO_2 per inhabitant older than 12 years in 2030) and are free to buy or sell permits at market price. If a person wants to spend his entire CO_2 budget on car use – and does not buy extra permits – the number of car passenger kilometres is limited to about 8000 (passenger) kilometres using a fuel-efficient hybrid car. As a result, people 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, e.g. the higher the energy efficiency of the car and the better the driving behaviour, the more vehicle kilometres can be driven with the same CO_2 permit, (iii) modal split changes, e.g. bicycling and walking will increase. The system will be gradually implemented so that the CO_2 budget per inhabitant 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;
- *Land-use instruments:* the role of land-use policies in EST differs from the current one in transport policy (i.e. 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 changes in mobility patterns (shorter average travel distances and less motorised travel). Improved accessibility is the result of the combination of both improving bicycle infrastructure and land use policies, such as building in high densities and mixed land use. Furthermore, locations of activities (e.g. work, recreation and shopping) must be close to residential areas. The demand for new housing and working locations will primarily be met within existing urban areas. New urban areas are built so as to realise “compact cities”. Furthermore, the Dutch employment location policy for new employment locations for “the right business in the right place” (e.g. new offices should be build near railway stations), combined with pricing measures, will be expanded to include re-location of existing companies/businesses;

- *Infrastructure policy:* The role of infrastructural policies to improve bicycle infrastructure in EST also differs from the current one in transport policy. In current policy, encouraging bicycle use is very often seen as a way to reduce car use. However, because the impact of (only) improving bicycle infrastructure on car use is very small, the bicycle receives poor attention in current Dutch policy, e.g. the per passenger kilometre government expenditure on public transport is about 100 times higher than on the bicycle (i.e. to reduce motorised mobility and related emissions). In EST, improving bicycle facilities is not primarily seen as an instrument to reduce car use but to improve accessibility to social and economic opportunities. Infrastructural policies comprise: motor vehicle infrastructure in cities and towns with 40,000 to 100,000 inhabitants will be largely converted to non-motorised infrastructure. Not only include separate bicycle lanes on the roads but also high-quality parking facilities at many places are realised. The number of barriers (mainly: roads) to be crossed will be reduced to make cycling more comfortable and safer, mainly by prioritisation at traffic junctions (the bicyclist has priority and not the motorised vehicles) and also by building multi-level crossings (leaving cyclists and pedestrians at the ground level and motorised traffic below the surface);
- *Regulations:* promotion of good health and "quality of life" will mean that transport in urban areas will have to be almost completely electrical or non-motorised. Vehicles with a conventional combustion engine will not be allowed in centres of cities with more than 40,000 inhabitants; however, access for electric or hybrid vehicles operating in the "electric mode" in these areas will be allowed;
- *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 tradeable CO_2 emission permits after 2015;
- *Speed control measures:* to increase traffic safety for cyclists and pedestrians (and also to reduce the attractiveness of car use and to promote shorter distances) speed limits will be lowered at all road types. Vehicles will be equipped with on-board speed adaptation systems for systematic maintenance of the lower speeds.
- *Telematics:* Local or regional multi-company buildings with telecommunication facilities - to the main offices - are located at town peripheries. Furthermore, telecommunication will be used to replace long-distance passenger travel.
- *Education and information:* education and information are important instruments for achieving public acceptance of the necessary changes towards EST, especially the system of tradeable CO_2 permits;
- *Instruments outside the transport sector:* several instruments will be necessary to reduce emissions in other sectors of the economy to a (more) sustainable level. Flexible housing and employment markets are a necessity for shorter trips between home and work. Fiscal instruments stimulate moving closer to one's working location. Furthermore, several instruments will probably be necessary to achieve a 40% share in the sustainable energy production and a highly efficient level of conventional energy production.

4.2 Timing of implementation of instruments

When do the instruments have to be implemented if EST is to be achieved by 2030? This paper shortly describes the methodology and results of the implementation time-path (see Geurs & Van Wee (2000) for a detailed description). In this study, an implementation time path for the instruments

is constructed by using the backcasting method: i.e. if we assume the instrument to have its full effect by 2030, the start of the policy implementation phase can be calculated backwards. Furthermore, the concept of the “policy life cycle” is used, consisting 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 of technical emission reductions in the Netherlands in the past, mainly outside the transport sector, showed that the average acceptance and adjustment phase took about 6 years, the average implementation phase about 18 years (Van de Peppel *et al*, 1997). Here, it is assumed that pre-implementation phase takes about five years; for relatively “easy” instruments (e.g. information instruments) this period will be shorter and for “difficult” instruments (e.g. tradeable 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, of say 1 to 5 years, whereas land-use and infrastructural measures 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 (at least) 15 years.
From the implementation time-path it can be concluded that a timely implementation of the instruments necessary to achieve the changes in mobility patterns envisioned by EST will only occur if (i) the current policy life cycle radically changes, i.e. the pre-implementation period must be shortened, (ii) in the short term a start is made with the implementation of the land-use and infrastructural instruments (e.g. shift from motorised to non-motorised infrastructure), given the long implementation and adaptation period of those instruments.

5. Economic and social impacts of sustainable transport

5.1 Economic impacts

To quantify the economic impacts of an environmentally sustainable transport system (compared to the business-as-usual situation), a simplified assessment methodology was developed by the University of Karlsruhe (Rothengatter, 1998). The approach allows to assess the order of magnitude of macro-economic changes based on data provided by “input-output” tables of national accounts. Important to note is that the assessment is restricted to 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), but includes multiplier effects to incorporate forward and backward linkages to other sectors of the economy. From the economic impact analysis it can be concluded that:

- The macro-economic impacts of the changes of the shift from motorised transport to non-motorised passenger travel (in terms of GDP and employment losses) are probably small. It can be expected that the Dutch society will function reasonably well with fewer private cars. The largest reductions in value-added and employment are found in road freight transport, aviation and marine transport, i.e. long-distance freight transport will decrease substantially because of the changes in origin-destination patters and production and consumption. The losses in these sectors cannot be fully compensated by value added and employment gains in other sectors (the railways and local business).
- The changes in all transport-related sectors result in a loss of material welfare for the entire economy, i.e. GDP in EST is about 4-8% lower than in BAU in 2030, the total loss of

employment is about 1-3%. This means that the average yearly GDP *growth* in the EST scenario will be a few tenths of percentage points lower than the business-as-usual scenario, the total Dutch employment level will be a few percentage points lower in 2030.

- The total loss of material welfare (GDP) for the year 2030 can be largely - but probably not fully – compensated gains in non-material welfare (expressed in reductions in external costs). The non-material value of the combination scenario is calculated by estimating the external cost savings for air pollution, noise, traffic accidents and congestion in monetary terms. Total monetary external cost savings for the combination scenario compared to the BAU scenario are about 1 to 4% of the Dutch GDP in 2030. These figures probably underestimate the total non-material value because the external costs of direct and indirect land use, loss of landscape, ecological disturbance and waste are not incorporated.

The economic impact analysis did not include a micro-economic evaluation using welfare economics. However, it can be expected that on a micro-economic level the current (and BAU) difference in consumers surplus for a car trip and a similar non-motorised trip will be reduced. In other words, in BAU a car trip will still be highly valued by individuals because of instrumental characteristics (e.g. flexibility, less travel time to destinations) and affective characteristics (status etc.), whereas the costs of the trip are modest. In EST, the consumer surplus of a car trip will be much lower because the car trip will be valued lower (e.g. the car will have a lower accessibility level to opportunities in urban areas compared to alternative non-motorised modes), whereas the car-trip costs are much higher (CO_2 permits have to be bought if the current mobility patterns are to be maintained). Thus, on a micro-economic level (individual) losses of EST for passenger transport – compared to BAU - will probably be relatively low.

5.2 Social impacts of sustainable transport

In the OECD project, a number of social factors were identified which were thought important and sensitive to changes in mobility: i.e. material wealth, land use and accessibility of opportunities, community relationships, crime, safety, health, and democracy (see Adams, 1999). These factors were used as a framework to (qualitatively) describe the expected social differences between the BAU and the EST scenarios for the Netherlands for 2030. The relationship with mobility in the past for each social factor is described on the basis of data for the Netherlands, where available. This is projected up to 2030 for both the BAU and EST scenarios using existing scenario studies. The most important social impacts (related to material wealth, land use and accessibility, safety and health) related to a shift from motorised travel to non-motorised travel are described below.

Material wealth:
Mobility is related to wealth: higher income groups have a higher level of car ownership, travel farther, use their cars more often and as a result have a higher level of access to economic opportunities, In the EST scenario, motorised transport is substantially reduced and non-motorised transport strongly increases (mainly due to a system of tradeable CO_2 permits). As a result, differences in travel behaviour between income groups will be smaller, i.e. higher income groups pay a relatively higher price for maintaining their travel behaviour than lower income groups.

Land use and accessibility:

In the business-as-usual scenario a process of national deconcentration and regional suburbanisation will continue; this negatively influences the accessibility level of economic and social opportunities for those without cars since the number of opportunities which are readily accessible by non-motorised modes and public transport decreases, thus negatively influencing people's mode choice options. In the EST scenario the accessibility differences between the car on the one hand and bicycle, walking and public transport on the other will be much lower: more opportunities will be readily accessible by walking and cycling, thus increasing people's choice of mode options.

Safety and interdependency:
As traffic increases, traffic danger increases, especially for cyclists and pedestrians. As a result, fewer people attempt to cross the road, fewer cyclists venture forth upon the road and fewer children are permitted to get about interdependently. As a result, children are denied the experience of mixing independently with their peers and learning to scope without adult supervision (Adams, 1999). In EST, due to lower urban traffic levels and better bicycle infrastructure, bicycling (and walking) is much safer. As a result, EST will permit greater independence for children.

Health:
There will be significant health benefits in EST. Firstly, more bicycling and walking involves more exercise. The guideline for healthy living ("30 minutes of moderate exercise, such as brisk walking, every day") will be met by more people. Secondly, health problems caused by local air pollution and noise nuisance (from road traffic and aviation) will strongly decrease.

6. Conclusions

This paper summarised the results of a pilot study on environmentally sustainable transport (EST) for the Netherlands for 2030, focusing on the role of the bicycle in the transport system. The main conclusions are:

- EST can only be met if mobility patterns radically change and future technological development is much greater than in the past. The role the bicycle in the transport system will strongly increase; the share in total passenger transport kilometres will triple;
- To achieve a strong reduction in motorised transport and a shift to non-motorised transport, a system of tradeable CO_2 emission permits is considered to be the most important instrument. Land-use and infrastructural policies are important to increase accessibility to social and economic opportunities for cycling, walking and public transport.
- The role of land-use policies and infrastructural policies to improve bicycle infrastructure in EST differs from the current one in transport policy. In current policy, land use policies and encouraging bicycle use are seen as instruments to reduce car use and related emissions. In EST, however, land use policies and improving bicycle facilities are primarily seen as instruments to improve accessibility: due to changes in land use (e.g. building in high densities, mixed land use) and improved bicycle infrastructure people can access many opportunities (such as schools, shops, offices, friends and family) comfortably, without using the car;
- If the shift towards non-motorised transport is to be realised, measures will have to be taken and instruments implemented in the short term, mainly because of the long pre-implementation and implementation period of land-use and infrastructure policies;

- An environmentally sustainable transport system for both passenger and freight transport will probably have significant economic impacts (e.g. GDP *growth* will be lower). However, the macro- and micro-economic impacts of the shift from motorised passenger travel to non-motorised travel are probably small: Dutch society will function reasonably well with less motorised transport.
- A mobility patterns envisioned by EST will have significant social benefits: differences in travel behaviour and thus access to social and economic opportunities between income groups will be smaller, people's mode-choice options increase, traffic safety for children and the elderly increases, thus improving their travel independence, and public health will improve.

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