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Options for Sustainable Passenger Transport;

An Assessmant of Policy Choices

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**Options for sustainable passenger transport;
an assessment of policy choices**

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sustainable transport, new technologies, transport policy

Abstract

If the current trends in transport are not **changed**, a sustainable transport system is not feasible. In order to **achieve such** a **state**, new technologies **may** be an interesting option. In this context several **success** and failure **factors** for the introduction of new technologies are analyzed in this article. These possibilities are identified in different **areas**, notably **economic**, spatial, institutional, social/psychological and technological fields. Within this context the following new options are discussed: the electric **car**, people movers, subterranean **infra-structure**, telematics, the high speed train, the high speed maglev train, shuttles in **vacuum** tunnels and alternative fuels. Finally , some policy choices, which **may** stimulate future technical developments, are discussed. It is concluded that an **active** government policy **may** stimulate the introduction of new technologies, which **may** give a substantial contribution to achieving a sustainable transport system.

1. Introduction

An **efficient** transport system is a sine qua non for maintaining our welfare and for a continuing **economic** development. Transport, **however**, also **causes many** negative externalities. This is partly due to the **huge** growth of mobility, over the past few decades: the volume of passenger kilometres by **car**, train and bus in Western-Europe ¹ has increased by 246% between 1965 and 1989². The number of airplane kilometres flown by the **main** Western-European **companies** has at the same **time** increased by more than 700% ³. One of the consequences of this large increase in mobility is a growth in the **quantity** of negative **externalities** caused by transport, **such** as the emissions of **harmful** and polluting **gases** (which are **inter alia** responsible for smog and the greenhouse effect), noise, stench and visual annoyance, fragmentation of landscapes etc. The increase in environmental externalities has been expedited by the continuing trend of modal shift in favour of the private **car**, which is the most detrimental form of **motorized** transport (**besides** the airplane). The modal split for train, **car** and bus in Western-Europe has **changed** from 14, 73 and 13% in 1965 towards 7, 85 and 7 % ⁴ in 1989 ⁵ respectively. The Commission of the EC mentions a **rise** of the **modal** share of the airplane from 2.2 % in 1970 towards 5.6 % in 1990⁶. These trends account for an increase in the external **costs** of transport, in comparison to other sectors in the **economy**. It appears, for example, that the CO₂ emissions caused by transport in OECD-countries have increased by 30% in the period 1973-1988, whereas in industry these emissions decreased by 8 % and in other sectors the increase was 11% ⁷.

With stagnant government **policies** and individual attitudes, a further increase in mobility and a growing modal share of the private **car** and the airplane **can** be expected. Therefore it is **clear** that these trends have to be curbed in order to attain a sustainable environment. Sustainability has not been defined clearly yet, **however**. In this article we use the following **definition** for sustainable transport: 'transport **demand** (leading to mobility) is satisfied in **such** a way that, within **accepted** limits of quality of environment and **safety**, • now and

in the future -, the socio-economic function of mobility is maintained or enhanced as **much** as possible'.

One of the **main** environmental problems is the emission of **greenhouse-gases**, of which the reduction of CO₂ emissions is expected to be one of the most difficult to **achieve**. An indication of the reduction **needed** for CO₂ emissions **may** be the targets in the Toronto-declaration, which **indicate** a 50% reduction by 2025 at a global level⁸. For Western countries this would probably imply a reduction of **80-90%** to **compensate also** for the expected increase of CO₂ emissions in developing countries. These targets have been **accepted** by several Western countries as a standard for future emission reduction. It **may** be assumed that the transport sector **also** has to curb its emissions with about the same percentage, so this **may** be an indication of the necessary **changes in the** transport system.

One of the possibilities to **reduce** the external **effects** of transport is to curb the growth of mobility, especially by **car** and air. In several, mainly **Northern-European countries**, this has become a major topic in transport policy, at least officially. There is **however much** resistance in society against these **policies** which **makes** their introduction difficult.

Another possibility is to stimulate new, environmentally more benign technical options. First among these is to improve existing transport modes. It is expected that the energy consumption of **conventional-fuel cars** - which **causes** most emissions - **may** decrease by **15-22%** per kilometre in the period **1990-2000**⁹, **after** this period 25 % autonomous efficiency improvement is expected up to 2030¹⁰. Because mobility **may** grow with at least the same **rate**, total energy use **will** not decrease **however**, so this development is not **sufficient** to attain a sustainable transport system¹¹. The same **may** account for **the** development of air traffic. **When** the mobility level is not reduced largely, the introduction of more innovative technological options, which are more environmentally benign is necessary.

There are in general two **distinctive** directions of technological R & D: **first**, the development of new fuels, and **second**, the development of new **collective**

transport modes. These two directions lead in general to two extreme designs of future transport systems: in the **first** place a system in which **collective** modes dominate the scene and in the **second** place a system in which individual modes are dominant. In **practice** both systems are likely to **operate** parallel in future, **however**. It is **clear** that irrespective of the road chosen, a **drastic** technical **development** is necessary to **achieve** environmental goals ¹².

This article analyzes the problems inherent in the introduction of new technological transport options; it **also** investigates which governmental policy choices are involved with and **may** stimulate the introduction of new **technological** options.

First, several success and failure factors which affect the introduction of new transport options and systems are discussed. In Section 3, an overview of new modes for both **short** and long distance transport is presented. In Section 4, we **will discuss** the possibilities of new fuels shortly. Finally, some policy conclusions are drawn.

The options discussed **will** be compared primarily with the existing **car** and airplane technology, because these modes are dominant in **causing** negative externalities and carry the largest **and** still growing share of travellers. The scope of the analysis is limited to passenger **traffic** in Western-Europe and the **time** horizon chosen is 2030. A more detailed analysis is presented in Nijkamp et al. (1994) ¹³.

2. Success and Failure Factors in the Introduction of New Technologies

Several success and failure factors, which are important for the introduction of new transport options and systems **can** be distinguished. These factors emerge from different dimensions or scientific disciplines (see box A in Figure 1).

▪ Figure 1 about here ▪

Each one of these dimensions is related to one or more success or failure factors, shown in Box B. It should be noted that **many** of these factors are positively interrelated . Thus, success or failure factors are likely to stimulate others in the same direction. **Also**, it is important to note that failure factors act as barriers, and that a single failure factor **often can** prevent the introduction of technological innovations.

Until now new transport modes have failed **to compete** with the existing **car** and air **technologies**, which **makes** investments in these modes **unprofitable**. This is to a large extent an **economic** failure ¹⁴. The low costs of conventional **fuels**, along with the present level of service make new options **often** not attractive for investors and users. **Collective** modes of travel are **often** dependent on a high occupancy **rate** and therefore need a high density of **demand**. The **fixed** costs of the investments (mainly **infrastructure** costs) are relatively high, while the capacity is **very** large. Therefore, it is necessary to divide these costs among **many** users. Another problem is the temporal distribution of **demand** and the high level of **demand** in peak **hours**, **resulting** in an unprofitable **excess** capacity outside these hours. New modes have to offer a better service and **short(er)** waiting **times** (hence a high **frequency**) than existing modes, while **also** an attractive **average** speed is needed. Since users **also** ask for door-to-door transport, it is **also** important that the **whole** transport chain is efficient and **attractive**. For the High Speed Train (HST) for example, it is important that the transport to and from the stations is efficiently organized.

Other problems **may** be found **in the financing** of new modes and their **infrastructure**. For new modes **very** large investments not only in the technology itself but **also** in a complex and geographically distributed logistic system **may** be required to compete with the **level** of service provided by the **car** in short and medium distances and by air in **very** long distance travel. **Also**, the initial **investment** in new modes implies that the marginal costs are at first **very** high and **may**

be prohibitive for **many prospective** users, especially **when** entirely new **infra-**structure has to be constructed. Another problem of entirely new modes is that the construction is in the beginning **very** expensive, because there is little experience with the new technology. For subsequent **projects** these investments **may** be lower, because of experience gained and returns to **scale**. It is evident that **when** the use of new modes should be stimulated, their **price/quality** ratio should be better than that of the existing modes.

The future **spatial organisation** is of major **importance** for the efficiency of a future transport system. The **importance** of a balanced organisation of living and working **areas** for reducing transport **demand** is widely recognized. This balance should not only be quantitative but **also** qualitative.

There are two extreme spatial patterns thinkable at a *European scale*¹⁵. In the **first place**, it is possible that a diffuse pattern of working and living **areas** will emerge (the 'chains and zones' scenario). This spatial pattern requires a transport system with a criss-cross design, while the transport **demand** per road segment or link is relatively low. A **second** extreme pattern is that of a hierarchical spatial organisation; a limited number of metropolises, which are the **main economic** and population **centres** are at the top of this hierarchy. In their service **areas** we find several so-called europolises and next numerous smaller cities; this scenario is called the 'specialisation and concentration' scenario. In **such** a spatial structure a transport system **may** develop with the same **hierarchical** structure, as the level of **demand** is likely to be proportional to the hierarchy of urban **areas**, namely metropolises, europolises and smaller towns. The continuing development of chains and zones, which **can** be amenable to **sustainability** criteria only if land-use patterns offer a balanced mix of residential, employment, commercial and leisure opportunities, is probably likely, given prevailing market preferences. **However**, the chances of a **concentrated development** pattern to **sustain** environmental criteria are likely to be **much** greater, as by **definition**, distances are shorter and **demand** densities **higher**, which gives **collective** modes a greater potential.

Similar to the case of the European or national scales, at the **urban scale** compact cities **may** be viewed as supporting the success of new collective modes, whereas dispersed urban sprawl is a failure factor for the reliance on collective modes ¹⁶.

Institutional factors are important for the introduction of new **technologies**. **Supportive governmental policies** (at the European as well as at lower scale levels) affect the possibilities and competitiveness of transport modes. Governments **decide** most of the user **costs** by subsidizing and taxing modes and fuels. It is **also** the government which plans, implements and **finances** most **infrastructure** ¹⁷. As mentioned above, **the** spatial policy is of major **importance** for the success of new modes. Another type of influence is found in **steering** private R & D, which the government **can** stimulate by subsidies, public acquisition and funding research programs .~

Another institutional factor is the strategy regarding **national industries**. In countries with large **car** industries for example, measures to **reduce car traffic** and compulsory environmental targets **will be difficult** to introduce because of pressure by these **industries** (an example of this is subsidising the purchase of new **cars** in **France** and **Spain** to support employment in the **respective car** industries). A similar problem is the **lack** of international standards, as has been the case with the different High Speed Train (**HST**) systems in Europe. This is unnecessarily expensive and **may hamper** the development of transnational rail networks. On the other hand, this pressure **may also** work **out** positively. It is, for example, questionable whether the high speed Maglev train between Hamburg and Berlin would have been constructed without pressure from interested **industries**.

Finally, the management of transport systems (especially collective modes) **may** be regarded as a success or failure factor. The management of railway **companies** for example, is **organized** nationally and is largely **bureaucratic**. Therefore, a more flexible operation of the railways - especially at transnational sections - seems to be **difficult** in the current situation.

Other factors which influence the success of new options are *social-psychological barriers*¹⁸. **The social acceptance** of new options is of major importance, especially **when** entirely new infrastructure has to be constructed. It appears **often** that there is **much** resistance in society, because of the high **costs** and **the** negative external impacts of **the** construction of infrastructure and the operation of some new modes (e.g., visual and noise annoyance). This is especially the case **when** the infrastructure is constructed in rural **areas**, which do not directly **benefit** from the new mode (as is for example the case with several HST-links).

If the system is **accepted however**, it is not sure that the system **will also** be used by individuals (**the adoption** factor). **Many** factors influence this: there has to be a travel need; the new possibility must be identified and **recognized** by potential users and **finally** the advantages and disadvantages of the new and old modes have to be weighed subjectively. Sometimes in this choice **process** the advantages of existing modes are overestimated, while the advantages of new modes are underestimated. *Psychological barriers* may also play a role. **When** trains are driven unmanned or in long tunnels people **may feel** unsafe, for example. This **may** be the case with unmanned people movers and transport through the Channel tunnel. Other psychological factors **may** be associated with a sense of privacy, comfort and security .

Finally , **technical success and failure factors** are important. The R & D activities of **companies** may have several **directions of development** , which are important for the **time** it takes to develop new modes and for the opportunities of the new mode to **compete** with existing modes. Conflicting **objectives** to which R & D activities are aimed, **often result** in a trade-off **between** these **objectives**. For example, **safety** targets favour bigger and heavier **cars**, while for **environmental** reasons smaller and lighter **cars** are preferred. In **practice** it appears **often** that **much** more attention is paid to marketing possibilities, while **environmental** factors are considered to be less important. In the American **car** industry , for example, **six times** as **much** money is invested in **the** development of new **car** paints than in energy **efficient technologies**.

One of the **main** problems is **also** the so-called *technical inertia*. It takes a **very** long **time** to develop and introduce new **technologies**. Therefore, it is possible that options cannot be introduced fast enough. An example **may** be the Maglev high speed train (although here **also** other **factors** play a role). **Already** in 1962 a test track was constructed, while it is expected that the **first** train **will** run in the year 2000 (a network **will** - if ever - be constructed **much** later). In **general**, therefore, technical options which are stepwise improvements of existing transport systems (like HST and telematics) have a better **chance** to be **introduced**, because the option **can** be adopted step by step (the HST for example, **may** initially or permanently use existing **infrastructure** and stations). In this case it is also easier to connect them with other modes.

3. The **Introduction** of New Transport Options

Several new transport systems are likely to evolve in future, replacing some of the existing **car** and airplane **traffic**. Several options, which **will** be **discussed** in this **section**, are presented in Table 1, together with the **main** characteristics of these options. The values given are only tentative; it is possible that other options **may** be introduced as well. Therefore this table does not claim to be complete.

• Table 1 about here •

It is important to make a distinction between short and long distance travel, because the problems associated with these **categories may** differ significantly. For instance, the profitability in short distance **traffic** is especially small for **collective** modes, because they do not attract **many** passengers (e.g., due to **the** relatively long waiting **times**). This is for example shown by the **modal** split in

the Netherlands (1993): 40% of the **car** and only 16 % of public transport trips are shorter than 5 kilometres ¹⁹.

3.1 Modes for the **short** distance (< 20 km)

An option which **may** be **introduced** for short distance traffic **may** be the **electric car**, which **can** replace some of the existing **car** traffic ²⁰. In California, the development of these **cars** is stimulated by the regulation that 2% of the **cars** sold in 1996 should be electric; in the year 2000 this share has to **reach** 10%. The **main** problem of electric **cars** is the battery, which limits the driving range to 70-100 km, allows only a moderate maximum speed (70-100 **km/h**), has a long charging **time** (on **average**, 8 hours) and a high price (\$2.500 - \$10.000); the battery has to be replaced 1 to 3 **times** during the life **time** of an **average car**. While it **can** be expected that these problems **will** be reduced, it is not likely that they **will** be **solved** completely. This **will** make the adoption of these **cars** difficult. Given the expected operational constraints, electric vehicles are likely to serve mainly as **second cars** in urban use. Households which **can only afford** one **car** are likely to purchase a more versatile technology, namely the **conventional** gasoline powered **car**. Another problem of electric **cars may be** that they - especially in compact cities - increase the need for parking **space**. The price of electric **cars** is expected to become about equal to the price of a conventional **car** (the price is now **much higher**), **when** the battery is not taken into account.

Another problem is that the low price of electricity (**because** no exciseduty is levied on electricity) **may** increase mobility. **Also, much space may** be required for the **infrastructure** needed for charging the batteries. As a **consequence**, this option fits better in the concept of a diffuse than of a compact city.

The CO₂ emissions of electric **cars** are dependent on the way in which electricity is **produced**; they are in **any** case lower than those of conventional fuels (see **also** Table 2). It **may** be assumed that reducing emissions of electric power plants **may** be easier and cheaper than reducing the emissions of fuel **cars**, because electricity production takes **place** at an immobile source at a large **scale**. Other advantages of electric **cars** are the low noise and stench annoyance.

A **second** option, which **may** be **introduced** in urban **areas** is the **people mover**. This option **may** use the so-called Maglev-technology, in which trains glide on an electro-magnetic field which is connected to a concrete or steel monorail infrastructure. In **principle**, people movers use **very** small vehicles, which **may** be driven automatically, so a large part of labour costs **may** be saved. A high frequency is possible, which reduces the waiting **times** in comparison with current urban **collective** modes. People movers are until now only found in airports and large amusement parks.

Problems with the introduction are primarily related to the high costs, which **makes** them not attractive for commercial **companies**. People movers **may** only be attractive at high **demand** transport links, because of the high capacity. A spatial organisation in **the** direction of a compact city is desirable to make this mode more attractive, therefore. A problem **may** be that entirely new **infrastructure** is needed (although it is smaller than that of conventional modes). This **may** especially be a problem in the compact city, **where** the mode has to **compete** with alternative land uses. **Social** acceptance **may cause** problems because of **this**, too. A psychological barrier **may also** arise, **when** there is no **human** driver on the train.

People movers **may** substantially **contribute** to diminishing externalities in cities because they have a low energy intensity per passenger kilometre, provided they are a substitute for private **car** use. Congestion **may** be reduced too, as **well** as stench and eventually noise **annoyance**.

3.2 Options for short and long distance transport

In recent years more attention is paid to the advantages and disadvantages of constructing **subterranean infrastructure** for conventional modes (for example the discussion in the Netherlands about the 100 kilometre Betuwe freight rail **section**). The emissions of **gases will** not be diminished by this technology, but several other externalities, like segmentation of landscapes, stench, **noise** and visual annoyance **may** be reduced to a large extent (compared to **building** more surface road infrastructure). It is **clear however**, that constructing subterranean

infrastructure is **very** expensive, which **makes** it only attractive in **areas** with a high value (urban and natural **areas**). Psychological barriers **may** occur **when** the tunnels are **very** long.

A development which **may** improve the current **car** system is the **development** of guided vehicles. One **may** think of **physical guidance**, for example by connecting **cars** temporarily with **each** other and guide these 'trains'. This option is **however** still in an early stage of development, so little **can** be said about this technology.

Guidance **may also** be implemented electronically by **means** of **telematics**. These systems **may** include a variety of **means**, which use some way of **interactive** communication. This **may provide real-time** efficient route recommendation to the driver as **well** as information about congestion. Thus, **car** drivers **may** save on travelling distance **and time**. The savings in travel **time** differ in several studies from 4% to **20%**, dependent on the system and its market penetration ²¹. These savings make them attractive for users, although the market penetration **will largely depend** on the **price** of the system. The introduction is **also** attractive for governments, because the existing infrastructure **will** be used more efficiently, which saves construction **costs** and **space**. The most important problems with these options are the high introduction **costs** and the standardisation of the systems. Telematics **may however contribute** to **making** the **car** transport system more efficient and therefore diminish the negative externalities to some extent. There **may however also** be some disadvantages: the use of roads **may** increase, **also** mobility **may** grow since congestion **can** be avoided more easily, this **may** again increase emissions. **Also** other 'intelligent vehicle highway systems' **may contribute** to reductions of CO₂ emissions ²².

3.3 Options for long **distance** transport

The most **well-known** option which is designed for long distance **traffic** is the **High Speed Train (HST)** ²³. This type of train is under development in almost **every** European country, while several sections have been opened **already** in

France, Germany, Italy and Spain. In total a network of 30.000-35.000 kilometres has been planned, the estimated costs of the network are \$220 billion ²⁴. When new infrastructure has to be constructed the economic profitable maximum speed is 275-300 km/h, technically higher speeds are possible, but this increases the infrastructure costs too much. With this speed the HST may compete with the airplane on distances up to 500 kilometres. It is important however, that there is a high level of demand, since the capital investment costs are high, while the marginal costs per extra user are low (until a certain level of demand). When demand is not sufficient for a profitable exploitation of new infrastructure, it is possible to improve existing infrastructure; this reduces the maximum speed however, which makes the HST less attractive.

Because a high level of demand is necessary, the HST fits best in a hierarchical spatial organisation (the spatial specialisation and concentration scenario). To improve the accessibility of the HST stations a development towards compact cities is also preferable. As long as the prices of conventional fuels will not be raised, it is not likely that this mode will become profitable on most links, however. Another problem may be the level of acceptance when entirely new infrastructure has to be constructed (especially in rural areas). It is also important that the exploitation of these links is flexible, so that intervention is easier when market circumstances change (for example, when airplane tickets become cheaper). An institutional problem may be that the railway companies nowadays are nationally oriented and their management is not very flexible.

When the HST succeeds in replacing part of the car and airplane traffic, this option could contribute to a reduction of the emissions of greenhouse gases. The problems of fragmentation of the landscape, as well as noise and visual annoyance do not disappear, however.

A competitor of the HST may be the Maglev high speed train²⁵. In Germany the construction of a link between Hamburg and Berlin has started recently (284 km, estimated costs \$9.5 billion); also in the United States and Japan Maglev technologies are being developed, these are not yet under construction. The

maximum speed of the train is 500 km/h, which **may** make it **competitive** with the airplane at distances up to 800 kilometres. The **success** and failure **factors** are largely comparable with the HST; the Maglev has some **specific** advantages and disadvantages, **however**.

Advantages, in addition to a **higher** speed, are that the train **can** take **steeper** hills, which **may** make this option more attractive in hilly **areas**. The acceleration power is **higher** too, which make this train more attractive at smaller distances. Another advantage is that the space claim of the infrastructure is somewhat smaller.

Disadvantages are in the **first place** that the Maglev infrastructure is not compatible with current rail infrastructure, while the new infrastructure is **also** more expensive. The technology is expensive too, partly because it has not been **introduced** at a large scale. Considering the plans to introduce a large scale HST-network and **the fact** that it is not **efficient** to construct the two modes for the same transport links, large scale introduction in Europe does not seem likely. In countries **where** there is little rail infrastructure nowadays (e.g., the United States), large scale introduction might become more attractive, especially if the **costs will** be lowered because of returns to scale.

In general the external **effects** are comparable to those of the HST; the CO₂ emissions are somewhat **higher** and the noise annoyance is somewhat lower.

A last option for **the** long distance transport is **the** use of **shuttles through vacuum tunnels**, which connect subterranean stations; this **makes** the construction of a large subterranean network necessary. In the Netherlands the 'High Speed Tunnel Transport System' (HSTT) and in Switzerland the 'Swiss Metro' concept have been proposed. These systems are still in an early development stage. It is estimated that these shuttles would have a maximum speed of about 500 km/h, which **can** be attained within 5 kilometres. An advantage **may** be that the subterranean stations **can** be constructed in the **centres** of cities and that the frequency **may** be high, so that they are able to **compete** with the airplane. A major advantage is the small space which is required for these systems and the

low externalities, because the shuttles are **very** energy **efficient** and **cause** little annoyance. It is clear **however**, that the construction costs are high, so that a high level of **demand** is necessary. To arrive at more operational conclusions, the feasibility of these systems has to be investigated further.

4. Alternative Fuels

Near the introduction of new modes **also** alternatives for conventional fossil fuels have been or might be developed, which **may reduce** the emissions of harmful **gases**. These fuels **may** be used **also** in fuel **cell** or hybrid (with **electricity**) vehicles. The introduction of these fuels **will** not be discussed at length, **however**, because they are mostly still in an early stage of development. Therefore it is **often** difficult **to say how** these **cars will** score on the discussed **success** and failure **factors**. The most important fuels are presented in Table 2²⁶, which contains also the CO₂ emissions of these fuels²⁷.

• Table 2 about here •

The biggest advantage of alternative **fuels** are their lower greenhouse gas emissions, while the existing **car** and air transport system **can** be used still. This **may** favour the **social** acceptance of these fuels.

There are **however** several bottlenecks, which have to be solved before large **scale** introduction is possible. In the **first place** the production costs are **much higher** than those of conventional **fuels**²⁸. Another problem is that they restrict **car** users: the driving range, maximum speed and acceleration potential of the **car** is mostly lower. Especially the fuel costs and range of the vehicle appear to have a significant influence on the **demand** for clean-fuel **cars**²⁹. Other

problems are found in the new **infrastructure**, which is needed to store and distribute some of these fuels (**where** safety **aspects** are **also** important) and the high **costs** involved. It is likely therefore, that new fuels (especially hydrogen) **will** be **introduced first** in airplanes, because then a limited number of fuelling stations is needed. There are for example some prototypes of liquid hydrogen airplanes under development by a German-Russian consortium.

Another problem is that alternative fuels **often cause** other environmental problems. Therefore a trade-off is required, in which **all** direct and indirect **advantages** and disadvantages are weighed. For example, the application of liquid hydrogen airplanes increases the emissions of water in the stratosphere, which in turn increases the greenhouse effect ³⁰. So this has to be weighed against the **advantages** of the reduction of CO₂ emissions.

Despite these problems, it is likely that several of these **fuels will** be **introduced** and adopted in the coming decades, because of the generally lower negative externalities and because the current **car** and airplane system **can** largely be maintained. In addition to the environmental **reasons**, the scarcity of fossil oil and the political **dependence** on oil producing countries **may also contribute** to the introduction of alternative fuels.

5. Conclusions

It is expected that the trends of a rising mobility and a further shift of the modal split in favour of **car** and airplane traffic continue in future, especially if government **policies** do not change. As a **consequence** the negative externalities **will** continue to increase, while they have to be reduced in order to make the transport sector (more) environmentally sustainable.

Several technological options have been developed which **may reduce** these externalities. A successful introduction is dependent on **many success** and failure **factors, however**.

At present, improvements of the conventional **car**, the HST and **telematics**

systems seem to have the best **chance** to be introduced in the coming decades. These do not require investments in alternative transport networks, therefore they **can** be introduced gradually and **can** be implemented in existing transport systems. Despite this their introduction faces problems in **many** fields. But even **when** these options are introduced it **will** not be **sufficient** to **reduce** the **externalities** of transport in order to make it sustainable, because of the rising mobility and the expected minor improvements of the **car** and airplane. Therefore **also** other technological options should be considered. **Every** option **however**, faces several problems, which are even bigger than those of the above mentioned options. Therefore an **active** governmental policy is necessary to stimulate the introduction. To make **such** a policy **efficient**, the government should have a **clear** idea about the future of transport. Therefore several policy **choices** have to be made.

The *first policy choice* is the question whether one **wishes** a transition towards a stronger stimulation of **collective** modes, or to give priority to the development of **cleaner individual** modes (for example, by subsidising the development of alternative fuels). It is not efficient to develop both systems to a large extent, because funds and R & D capacity **may** then be divided too **much**.

Essential for **this** choice is - as *second policy choice* - **the future spatial organisation**. **When** a spatial organisation is achieved like that in the **concentration** and specialisation scenario, options like HST and Maglev have a better potential, because then only a moderate number of transport links, with a high level of **(concentrated) demand** will occur. The same **holds** at the urban level for the organisation of a compact city, which offers more chances for modes like the people mover. On the other hand, electric (or other fuel) **cars** fit better in a more diffuse urban **structure**.

Also striking is the **fact** that the new options are in general not **competitive** with the **car** and the airplane, because of **the** high quality and relatively low **price** of these options. A *third policy choice* may therefore be to make the conventional **car and airplane unattractive** despite resistance in society. Two policy directions are possible in this case.

Firstly, **market** measures **may** be introduced. One **may** think of raising (and for air **traffic** introducing) taxes on conventional fuels. The introduction and **ap**-plication of alternative fuels **may** be largely stimulated in this way, while **also** the competitiveness of collective modes is increased. This last goal **can also** be achieved by the introduction of road and cordon pricing systems. An extra advantage of these systems **may** be that mobility in total becomes more **expens**-ive, which reduces mobility growth. Especially on **longer** distances market measures **may** be **successful**.

In the **second place** it is possible to apply a stronger **regulation**. One **can** think of more severe environmental **targets**, which **may** make it more **attractive** to use alternative fuels. It is **also** possible to introduce compulsory selling targets, as is the case in California. In **urban areas** it is **also** possible to **reduce** the density of the road network and to introduce a **strict** parking policy. In this way the use of collective modes **may** be stimulated.

A **fourth policy choice** is that the government **may** stimulate the introduction of new options **giving an example**. The government **may** do this by purchasing zero-emission **cars** for several governmental organisations despite the high **costs**. In **this** way the **development** of **cleaner technologies** **may** be stimulated, because it is **guaranteed** in this case that development **costs will** be paid back. As a **consequence** the **technologies** become cheaper for third parties, which stimulates their adoption. Another possibility is to stimulate the use of collective modes by public employees.

In conclusion, it is **clear** that a policy which aims at reducing externalities of the transport sector by technological options **may contribute** partly to the development of a sustainable transport system. A **main** problem **however**, is the long development and introduction **time** of these options. Therefore it is important to stimulate technical development **much** more and to make several choices as soon as possible. Otherwise measures like a severe restriction of mobility **levels** and regulations of **car** use (with large societal impacts) **will** have to be introduced to a larger extent in future than **when** technical options are introduced and stimulated now.

Notes

1. European **Union** minus Greece, **Ireland** and Luxembourg (because of lack of data), the Scandinavian countries, Austria and **Switzerland**.
2. Own calculations based on: ECMT (European Conference of Ministers of Transport), **Annual Trends in transport 1965-1989**, Paris, 1993.
3. Own calculations based on: Eurostat, **Basisstatistieken van de Gemeenschap**, Luxembourg/Brussels, several editions.
4. Because of round off differences the total is not 100.
5. See note 2.
6. Commission of the EC (European Communities), **De toekomstige ontwikkeling van het gemeenschappelijk verkeers- en vervoersbeleid**, Luxembourg/Brussels, 1993.
7. J. Short, **Transport growth in question**, Proceedings of the 12th International symposium on theory and practice in transport economics, **subtopic 5: Environment, global and local effects**, Lisbon, 4th-6th May, ECMT, Paris, 1992.
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10. P.A. Okken, **Drastische CO₂reductie: Hoe is het mogelijk?**, ECN Policy Studies, ECN-C-93--036, Petten, 1993.
11. See also: K.M. Gwilliam and H. Geerlings, New technologies and their potential to reduce the environmental impact of transportation, **Transportation Research, vol. 28A**, no. 4, pp. 307-319, 1994.
12. See also: P. Nijkamp, Roads toward environmentally sustainable transport, **Transportation Research, vol. 28A**, no. 4, pp. 261-271, 1994.
13. P. Nijkamp, S.A. Rienstra and J.M. Vleugel, **Comparative analysis of options for sustainable transport and traffic systems in the 21st century, phase 1: state of the art**, study as part of the Dutch National Research Program (NOP-I), theme E: sustainable solutions (Policy Research), ESI, Free University, Amsterdam, 1994. This research was carried out in cooperation with: Marina van Geenhuizen (UCL, London), Ton Rooijers (VSC, Groningen), Richard Smokers (ECN, Petten) and Johan Visser (OTB, Delft).
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16. M. Wegener, Reduction of CO₂ emissions of transport by reorganisation of urban activities, in: Y. Hayashi and J.R. Roy (eds.), **Transport, land use and the environment**, Kluwer, Dordrecht, 1995 (forthcoming).
17. See note 14.

18. C.W.F. van Knippenberg, J.A. Rothengatter and J.A. Michon (eds.), *Handboek sociale verkeerskunde*, Van Gorcum, Assen, 1989.
19. Own calculations based on: CBS (Centraal Bureau van de Statistiek), *De mobiliteit van de Nederlandse bevolking* 1993, CBS-no. N8, Voorburg/Heerlen, 1994.
20. See **also**: R.T.M. Smokers, Electric vehicles in the context of new transportation systems, in: *Proceedings of the 26th international symposium on automotive technology and automation*, dedicated conference on electric, hybrid and alternative fuel vehicles: progress in technology & infrastructure, Aachen, 13-17 September, pp. 77-84, 1993.
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26. **Source**: P.A. Okken, *The challenge of drastic CO₂ reduction*, ECN Policy studies, ECN-C--92-066, Petten, 1991.
27. See **also**: M.A. DeLuchi, Greenhouse-gas emissions from the use of new fuels **for transportation** and electricity, *Transportation Research*, vol. 27A, no. 3, pp. 187-191, 1993.
28. **Source**: see note 26.
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Table 1 Tentative scores of new technology options'

	Alternative fuels	Electric car	People Mover	HST	Maglev-high speed	Telematics systems	Subterranean conventional	Subterranean HSTT
Price/quality ratio compared to -conventional car -short distance -long distance -airplane	-/+ - -	-/+ - -	-/+ - -	- + +	- -/+ +	+ + +	-/+ -/+ -	- -/+ -/+
Proven technology	-/+	-/+	++	++	-/+	+	-	-
Compatible with existing -infrastructure -fuel storage and distribution	n.a. -	+ -	- +	+ +	- +	++ n.a.	+ +	- -
CO ₂ emissions	-/+	+ ² /++ ³	++	++	++	-/+	-/+	++
Noise annoyance	-/+	++	++	-/+	+	-/+	++	++
Extra space needed	-	-	-	-	-	+	++	++
Social Acceptance	-/+	++	+	-/+	-/+	++	++	-/+
Adoption	-	-	+	+	+	++	-/+	-/+
Expected government support	-/+	+	-/+	++	-/+	+	-	-/+

(1) ++ very positive score + positive score -/+ no clear impact - negative score -- very negative score

(2) Produced with conventional fuels.

(3) Produced with alternative methods.

Table 2 CO₂-emissions from alternative motor fuels relative to gasoline

(standardized units, gasoline = 100)	CO ₂ emission
methanol from coal	150 - 170
methanol CMP ¹	60 - 110
methanol from natural gas	90 - 95
compressed natural gas (CNG)	80
electricity ²	80
bio-methanol	10 - 30
bio-ethanol	20 - 80
hydrogen	< 5
zero-CO ₂ , electricity	< 5

Notes:

- (1) CMP = Combined Methanol and Power (e.g., **once** through-coal gasification)
 - (2) Including losses in power generation.
- Source: Okken (1991).

Figure 1 Success and failure factors of new transport modes