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Options for Sustainable Passenger Transport;

An Assessmant of Policy Choices

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Key words

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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 infrastructure, 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 govemment 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 extemalities. 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 1989[2]. 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 1990[6]. These trends account for an increase in the extemal costs of transport, in comparison to other sectors in the economy. It appears, for example, that the CO_2 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 govemment 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 enviromnent and safety. - now and in the future -, the socio-economie 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 CO_2 emissions is expected to be one of the most difficult to achieve. An indication of the reduction needed for CO_2 emissions may be the targets in the Toronto-declaration, which indicate a 50% reduction by 2025 at a global leve1 [8]. For Western countries this would probably imply a reduction of 80-90% to compensate also for the expected increase of CO_2 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 extemal 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 2030 [10]. 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 system [11]. The same may account for the development of air traffic. When the mobility leve1 is not reduced largely, the introduction of more innovative technological options, which are more environmentally benign is necessary.

There are in genera1 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 genera1 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 govemmental 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 extemalities and carry the largest and stil1 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. Succes 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 leve1 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 tempora1 distribution of demand and the high leve1 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 efftcient 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 fust very high and may be prohibitive for many prospective users, especially when entirely new infrastructure 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 organisution*** is of major importance for thé 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 ispossible that a diffuse pattem of working and living areas will emerge (the 'chains and zones' scenario). This spatial pattem requires a transport system with a criss-cross design, while the transport demand per road segment or link is relatively low. A second extreme pattem is that of a hierarchical spatial organisation; a limited number of metropoles, which are the main economic and population centres are at the top of this hierarchy. In their service areas we fmd several so-called europoles 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 leve1 of demand is likely to be proportional to the hierarchy of urban areas, namely metropoles, europoles 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 pattem 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 govemmental policies*** (at the European as well as at lower scale levels) affect the possibilities and competitiveness of transport modes. Govemments decide most of the user costs by subsidizing and taxing modes and fuels. It is also the govemment 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 govemment 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 intemational 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 extemal 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 als0 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 smal1 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 Califomia, 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 CO_2 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 electra-magnetic field which is connected to a concrete or steel monorail infrastructure. In principle, people movers use very smal1 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 altemative 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 extemalities 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 extemalities, 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 natura1 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 stil1 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 extemalities 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 CO_2 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 ahnost 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 leve1 of demand, since the capital investment costs are high, while the marginal costs per extra user are low (until a certain leve1 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 leve1 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 leve1 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 train***[25]. 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 genera1 the extemal effects are comparable to those of the HST; the CO_2 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 stil1 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 smal1 space which is required for these systems and the low extemalities, 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 leve1 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 altematives 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 stil1 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 2[26], which contains als0 the CO_2 emissions of these fuels[27].

- Table 2 about here -

The biggest advantage of altemative 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 **ad**-vantages 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 **ad**-vantages of the reduction of CO_2 emissions.

Despite these problems, it is likely that several of these **fuels will** be **intro-duced** and adopted in the coming decades, because of the generally lower negative extemalities 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 politica1 **dependence** on oil producing countries **may** als0 **contribute** to the introduction of altemative 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 govemment **policies** do not change. As a **consequence** the negative extemalities **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 extemalities. 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 altemative 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 govemmental 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 altemative fuels). It is not effkient 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 leve1 of (concentrated) demand will occur. The same holds at the urban leve1 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.

Als0 striking is the fact that the new options are in genera1 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 application of altemative 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 expensive, 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 altemative fuels. It is also possible to introduce compulsory selling targets, as is the case in Califomia. 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 govemment may do this by purchasing zero-emission cars for several govemmental 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 extemalities 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: Enviromnent, global and local **effects, Lisbon, 4th-6th May,** ECMT, Paris, 1992.

8. WMO, World conference on the changing atmosphere implications for global security, ***Proceedings Toronto 1988,*** **Geneva,** WMO-report no. 710.1988.

9. B. **Rutten,** ***Reductie van de CO_2-uitstoot van de personenauto door voertuigtechnische maatregelen beschikbaar op de*** korte ***termijn,*** Centrum voor Energiebesparing en Schone Technologie, Delft, 1990.

10. P.A. Okken, ***Drastische CO_2-reductie: Hoe is het mogelijk?,*** ECN Policy Studies, ECN-C-93--036, Petten, 1993.

ll. See **also:** K.M. Gwilliam and H. Geerlings, New **technologies** and their potential to **reduce** the enviromnental impact of transportation, ***Transportation Research, vol. 28A***, no. 4, **pp. 307-319, 1994.**

12. See **also:** P. Nijkamp, Roads toward environmemally sustainable transport, ***Transportation Research, vol. 28A, no. 4,*** pp. 261-27 **1, 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).

14. P. Nijkamp and S.A. Rienstra, Private sector involvement in the exploitation and fmancing of transport **infrastructure,** The ***Annals of Regional Science,*** 1995 (forthcoming).

15. RPD (Dutch National Physical **Planning** Agency), ***Perspectives in Europe; Exploring options for a European spatial policy for North- Western-Europe***, department of VROM, The Hague, 199 1.

16. M. **Wegener,** Reduction of CO_2 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 intemational symposium on automative technology and automation,*** dedicated conference on electric, hybrid and altemative fuel vehicles: progress in technology **& infrastructure,** Aachen, 13-17 September, pp. **77-84, 1993.**

21. R.H.M. Emmerink, K.W. Axhausen, P. Nijkamp en P. Rietveld, The economics of motorist information systems revisited, ***Transport Reviews, vol. 14,*** no. 4, pp. **363-388, 1994.**

22. S.E. Shladover, **Potential** contributions of intelligent **vehicle/highway** systems (IVHS) to reducing transportation's greenhouse gas production, ***Transportation Research, vol. 27A,*** no. 3, pp. **207-216, 1993.**

23. P. Nijkamp and J.M. Vleugel, **Success factors** for high ***speed*** rail networks ***in*** Europe, ***International Journal of Transport Economics. vol. 20,*** pp. **255-270, 1993.**

24. G. Ellwanger and M. Wilckens, Hochgeschwindigkeitsverkehr **gewinnt an** Fahrt, ***Internationales Verkehrswesen, vol. 45,*** no. 5, pp. **284-290, 1993.**

25. See **also:** L. Miller and M. **Wackers,** Transrapid Maglev system: technical readiness and corridors of application, ***Journal of Advanced Transportation, vol. 27,*** no. 1, pp. **49-64, 1993.**

26. Source: P.A. Okken, ***The challenge of drastic CO_2 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.

29. D.S. **Bunch,** M. Bradley, T.F. **Golob,** R. Kitamura **and** G.P. **Occhiuzzo, Demand** for clean-fuel vehicles in Califomia: a discrete-choice stated **preference pilot** project, ***Transportation Research, vol. 27A,*** no. 3, pp. 237-253.1993.

30. H. Grieb and B. Simon, Pollutant emissions of existing and future engines for commercial aircraft, ***in:*** U. Schuman ***(ed.), Air traffic and the environment: background, tendencies and potential atmospheric effects,*** Springer Verlag, Berlin, 1990.

Table 1 Tentative scores of new technology options[1]

	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	n.a.	+	--	+	--	++	+	--
-fuel storage and distribution	-	-	+	+	+	n.a.	+	-
CO_2 emissions	-/+	+[2]/++[3]	++	++	++	-/+	-/+	++
Noise annoyance	-/+	++	++	-/+	+	-/+	++	++
Extra space needed	-	--	-	--	--	+	++	++
Social Acceptance	-/+	++	+	-/+	-/+	++	++	-/+
Adoption	-	-	+	+	+	++	-/+	-/+
Expected government support	-/+	+	-/+	++	-/+	+	-	-/+

Notes:
(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 CO,-emissions form alternative motor fuels relative to gasoline

(standardized units, gasoline = 100)	C[redacted]ission
methanol from coal	150 - 170
methanol CMP'	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, electricity	< 5

Notes:

(1) CMP = Combined Methanol and Power (e.g., once through-coal gasification)

(2) Including losses in power generation.

Source: Okken (1991).

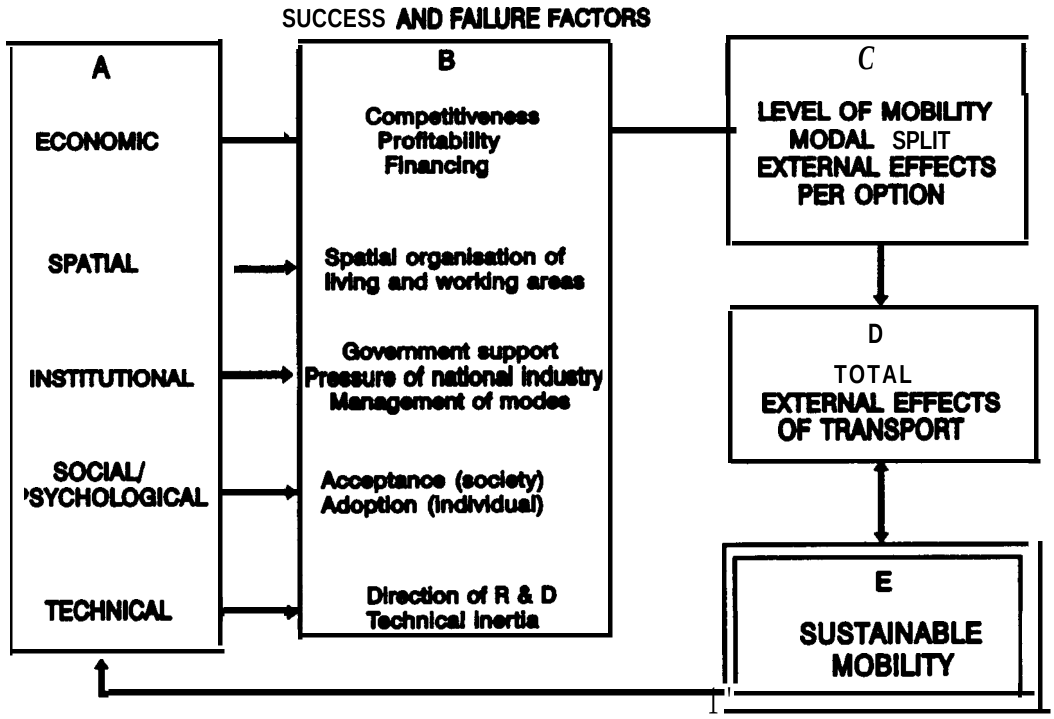

Figure 1 *Success and failure factors of new transport modes*