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In Search of Sustainable Transport Systems

Peter Nijkamp
Jaap Vleugel

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Peter Nijkamp Jaap Vleugel

Economic & Social Institute
Free University
De Boelelaan 1105
1081 HV Amsterdam

PN584JV

1. Introduction

At a world-wide scale, transport by road and air have grown rapidly and are projected to continue this growth pace in the coming decades. There is also a broad recognition that further mobility growth would become unacceptable, as transport and mobility are among the major sources of environmental degradation. And it is therefore conceivable that in recent years intense debates have started on the question as how to curb the environmental stress from our mobile network society (see also the Green Paper of the European Commission 1992). In principle, several options can be envisaged in order to alleviate the external costs of modem transport systems: mora1 conviction, strict regulations (and enforcement thereof), user charge principles (e.g. ,road pricing, Pigovian taxation), sophisticated environmental-benign technologies (e.g., route guidance, zero-emission cars) and alternative modes of physical planning (e.g. ,compact city design). Whatever the ultimate options chosen may be, it is clear that any reduction target in environmental stress has to be assessed from both an environmental sustainability viewpoint and from a cost-effectiveness viewpoint (cf. Tisdell 1991). Such an assessment may be based on evaluation criteria that are intemal to the transport system or on criteria that mirror an overall systemic efficiency and sustainability . This provokes the question of the most appropriate leve1 of reduction of environmental pollution by the transport sector vis-à-vis other economic sectors.

The nowadays popular notion of **sustainable development (see** WCED 1987) does not offer quantitative criteria which would guide policy-makers and planners in their efforts to reach a process of change in which resource use, productive investments, technological development and institutional changes are brought in harmony with one another. Consequently , a policy strategy aiming at a more sustainable transport system has to identify quantitative criteria which would offer guidelines on the maximum allowable contribution to environmental degradation by the transport sector (cf. Verhoef and Van den Bergh, 1994; Vleugel, 1994). This presupposes knowledge on the total permissible pollution in a given area and in a given time frame, as well as know- ledge on the share of the transport system in this total volume of pollution (for different emittents). The aim of this paper is to develop some thoughts on the question of identifying the maximum allowable pollution share by the transport sector, assuming a critical leve1 of maximum resource use, a maximum carrying capacity , a maximum environmental utilisation space, a maximum sustainable yield or some other critical threshold leve1 for environmental decay. We will use here the notion of **maximum environmental capacity use** (MECU) to indicate the maximum resource use of a given environmental capita1 stock that - in a given time period - is compatible with both socio-economie objectives and environmental quality conditions now and in the future. The question we want to answer in this paper is whether at the sectoral level, viz. that of the **transport system,** the idea of a transport-specific MECU - denoted here as MECUTS - can be operationalized. We will look in particular at altemative new possibilities, with particular emphasis on economic backgrounds, to control pollution emission in the transport sector. Before commencing this task, we will first in the next section offer some background information on the issue of sustainable development in the context of transport systems.

2. Environmental Stress: Backgrounds

Most human activities (including transport and mobility) generate environmental stress. Often the nature or the size of this effect does not cause serious harm, but in our modem network economy the spatial interaction in terms of physical movement of people and goods has risen to an unprecedented degree, with the result that modem transport systems are causing severe environmental degradation. This holds for all modes of transport, although some modes - notably road transport - cause significantly more damage (see for an illustrative overview Tables 1 and 2).

Table 1 about here

Table 2 about here

It is clear from Tables 1 and 2 that each transport mode - be it private or public - contributes to environmental degradation. There is no environmentally benign transport activity , but some modes are less harmful than others.

A peculiar feature of transport is its **integrating** function in a network economy: transport is a derived activity which is dependent on and determined by all other economic activities. Besides, transport - and its necessary infrastructure - has also a structuring impact on the space-economy . Consequently, the assessment of environmental impacts of the transport sector is not an easy task, as transport is only a small1 part of a long chain of subsequent activities. This chain can be decomposed as follows:

- production (including delivery of raw materials) and sales of goods;
- ownership and use of transport vehicles:
  - individual modes
  - collective modes
  - integrated multimodal transport systems
  - logistic chains and structures;
- depreciation and scrap policy for old vehicles;
- extraction of raw materials for physical infrastructure;
- construction and maintenance of infrastructure.

Effective environmental policy in the transport sector presupposes sufficient insight into the driving forces of human activities, in terms of both nature and size in our 'post-Fordist' way of living. Two main categories are (see Opschoor 1992):

- **material** processes, such as economic progress or technological innovations.

  These processes also include 'counter production' serving to alleviate environmental degradation caused by the economy (e. g . , catalytic converters, antinoise screens etc). Given this bias in our GNP composition and definition, the plea for a green GNP is conceivable.

- **structural** factors, such as institutional factors (e.g., the social security system) and ideological motives (e.g., belief in economic progress). These backgrounds often lead to a situation where a choice in favour of more polluting - rather than less polluting - activities is made, as is also witnessed by the popularity of individual transport modes.

In our modem society an in-built automatism to favour less sustainable activities - and hence also less sustainable modes of transport - appears to exist. This can be explained from three background factors in a network society which will now concisely be discussed, viz. **separation, market failure** and **policy inertia**.

Separation in a network means a lack of direct behaviourial connectivity among actors, so that causes and impacts show a distance in terms of **scale** (e.g., micro versus macro interests), **time** (e.g., current versus future generations) and **geographical space** (e.g., the NIMBY phenomenon). Separation in the transport sector takes place, since:

-individual contributions to environmental pollution (e.g., the use of a single car) are usually only marginal;

-the link from a global (or macro) environmental problem to individual behaviourial adjustments is not straightforward;

-behaviourial changes by (a group of) individuals will discourage other (groups of) individuals to adopt the same strategy (the so-called **prisoner's dilemma).**

Consequently , most actors in the transport sector follow a **free rider** strategy . This means that voluntary behaviourial changes are not likely to take place, so that rational individual behaviour appears to provoke the so-called **tragedy of the commons** (Hardin 1968). This intrinsic conflict between individual (or group) interests and collective (or macro) values is often referred to as **the social dilemma.**

Market failure refers to the lack of a proper price system for market transactions. Since environmental goods such as fresh air or quiet do not have an unambiguous value mirrored in a commonly accepted and paid for price level, a distortion in choice behaviour takes place. Such extemalities lead to underpriced goods and cause a higher leve1 of use than would be desirable from a social perspective. This phenomenon of market failure in the transport sector has provoked recent debates on 'user charge' and 'road pricing' principles. It has to be admitted that a policy for coping with market failures is from an economic viewpoint a sound strategy , but in practice many impediments appear to exist (e.g., lack of information, distributional effects, etc.). A survey of arguments can be found in Emrnerink et al. (1994).

Finally , **policy inertia** has to be mentioned. The existence of market failures has generated a wide array of policy initiatives in order to alleviate the associated extemal effects. In many cases however, such initiatives were uncoordinated or insufficiently based on reliable information on behaviourial responses of travellers. Examples are incompatible combinations of regulations, subsidies and charges in the transport sector. As a result, an improvement did not - or insufficiently - take place, so that then a case of so-called **government or invention** failures emerged (see e.g. Barde and Button 1990). In Table 3 a concise overview of various failure processes in the transport sector is given.

Table 3 about here

The problem is however that - in view of govemment interests in public transport - a 'clean' economic framework for the transport sector as a whole is hard to identify, so that a frame of reference for effective environmental policies for the entire transport sector is badly missing. As a result, we observe a great deal of inertia in policy initiatives, so that environmental management in this sector is characterized by second-best or even third-best strategies. Sustainable transport policies are therefore extremely rare.

3. Maximum Environmental Capacity Use of the Transport Sector (MECUTS)

There is no doubt on the need to reduce environmental emissions of the transport sector. Table 4 contains - in summary form - the results of three distinct Dutch scenario's for the year 2010, followed by the required reduction in emissions in the same year. These figures illustrate clearly that the accepted environmental standards will hardly be met in the year 2010.

Table 4 about here

Next, in Tables 5 and 6 the necessary reductions in emission by the transport sector - both passenger transport (Table 5) and goods transport (Table 6) - implied by formulated policies are given. These figures cover transport by road, rail and air. It is clear from this information that the air pollution by road transport has to be reduced significantly, while at the same time also the personal mobility has to decline. Finally , substitution from road to rail is foreseen. Such goals can of course only be achieved, if these policies are supported by progress in transport technology , new ways of physical planning etc.

Table 5 about here

Table 6 about here

Before addressing in greater detail the issue of (the identification and measurement of) MECUTS, we will first pay some more attention to MECU in general. Environmental capacity has to be interpreted in terms of functions provided by environment and nature (cf. Costanza and Daly 1992; Turner 1993). Such functions concern in particular:

- **economic** functions (e.g., a resource base, recreational opportunities)
- **ecological** functions (e.g., regulation, absorption, signalling)
- **cultural** functions (e.g., landscape beauty, educational values)

The question then is whether it is possible to establish a tolerance leve1 of maximum use of such functions based on principles of environmental sustainability. It goes without saying that the identification of such critical threshold levels (e.g., in terms of carrying capacity, maximum load, maximum sustainable yield) is fraught with difficulties. Nevertheless, in policy practice we observe that govemments are increasingly inclined - despite some degree of ambiguity and arbitrariness - to accept such critical threshold levels as signposts for environmental strategies, using the minimum regret principle (or any other meaningful risk principle) as a major justification. Consequently, notwithstanding some ranges of uncertainty, more and more countries define standards on carbon dioxide, nitrous oxides, methane and other greenhouse gases.

One may in genera1 assume that such environmental envision standards are fixed according to a leve1 that keeps the existing stock of environmental resources more or less intact (see Pearce et al. 1989). This then defines in operational terms the MECU in general, but it does not yet show the distributional consequences of such generic sustainability policies. Thus the sector-specific reduction of pollution is at stake here. In this framework various policy principles can be distinguished:

an equal percentage reduction of pollution in all sectors
a sector-specific reduction in pollution that is proportional to the environmental stress caused by that sector
a sector-specific reduction in pollution that is based on sectoral tost-effectiveness measures for pollution abatement
a sector-specific reduction in pollution that is inversely proportional to the intensity of environmental measures taken by that sector in the past
a sector-specific reduction in pollution that is proportional to the growth rate of its pollution in the past years.

Such distinctions are also loosely related to the concept of strong and weak sustainable development, depending on the question whether overall environmental quality improvement is strived for or whether environmental quality decline in some sector or region can be compensated for by improvement elsewhere.

Clearly, in a dynamic economy technological progress may alleviate some of the problems inherent in the limits of a MECU, but this needs to be supported by behavioural and institutional responses (e. g . , the potential offered by global computer networks).

The above observations apply to a large extent also to MECUTS, where two problems appear to emerge: (i) which is the share of the transport sector in overall reduction of pollutants, and (ii) which is a share of sub-sectors within the transport system in terms of the pollution reduction ? The answer to such questions depends on various evaluation factors, viz.:

- the nature and size of effluents by the transport sector
- the costs of emission reduction in the transport sector
- the modal split and composition of passengers and freight in the transport sector
- the spatial extemalities caused by various transport activities
- the volume and distribution of renewable and non-renewable resources used by subsectors in the transport system.

In trying to assess a proper leve1 of MECUTS, it has to be recognized that such levels may be site-specific due to lack of other choice (e.g., modal) opportunities in transport (Whitelegg 1993). For example, Newman and Kenworthy (1991) found in their comparative study on energy consumption and automobile dependence that land use intensity is in many cities the decisive factor. The more intensive urban land use, the shorter the travel distances and the higher the opportunities for public transit. Differences of 20 to 30 percent in gasoline consumption have been found between American and European cities. This suggests that urban land use intensity might also act as a principle for allocating a certain leve1 of environmental utilisation to segments of the transport sector. A related problem is of a distributional nature (see Sachs 1983): higher income people appear to live in genera1 in lower densities and hence are forced to use the car because of absence of profitable public transport in low density areas. This, if quota systems based on the MECUTS notion would be allocated to (segments of) the transport sector, it may mean that certain groups are disproportionally hit, which may lead to much public opposition. Clearly, the above remarks do not only apply to residential density, but also to industrial density, retail and service density etc. (see also Kasanen and Savolainen 1993).

A specific problem is caused by the modal split of the transport sector. Once a leve1 of MECUTS has been established and accepted, the next question is how much the share of rail systems vs. road systems vs. waterway systems etc. would have to be. This would imply a confrontation of the performance of each transport mode (e.g., in terms of person km or tonne km) with the volume of effluents caused by it. Again the same type of policy principles as mentioned above for distributing the emission constraints may in principle be used.

Clearly, at the very end one may even raise the question how much individual vehicles would have to be affected in their operation. This brings us into the area of so-called **mobility quota,** which would mean that a maximum permissible distance to be driven by a vehicle in a certain period (or the maximum amount of fuel to be consumed by a car in a given period) - without any extra charge (in the form of a Pigovian tax) - would have to be established. Needless to say that theoretically such an option is comparable to quota systems in resource management, but this solution may lead to substantial problems regarding implementing and controlling such a system because of the 'large numbers' case in transport. In future, this problem may be solved by smart technology , however.

Two types of approaches may in principle be envisaged to solve the above choice problems. One would be to compose packages of policy measures (charges, technology solutions, prohibitions etc.) and to evaluate the feasibility of each of them by means of a tost-effectiveness strategy, taking for granted a given leve1 of MECUTS, established e.g. by a govemment or transport authority. Another approach would be to investigate different reduction scenarios in subsectors of the transport system and to evaluate such policy scenarios against the background of the above evaluation factors by means of multicriteria analysis. An intermediate approach might be to specify in advance achievement levels of environmental quality, so that also a tension index can be created for the discrepancy between actual and desirable performance. This index may then be used for assessing weight factors in a goals-achievement multicriteria analysis.

It is clear that the above issues require much more substantive research, notably (see also Vleugel, 1994):

- identification of relevant and proper MECUTS indicators
- fixation of acceptable critical threshold levels
- measurement and monitoring of actual environmental performance of the transport (sub)sector(s)
- assessment and evaluation of various MECUTS options (including spatial altematives such as car-free cities, technology options such as telematics, and behavioural changes in mobility and life-style pattems)
- cost and benefit assessment of altemative pollution abatement strategies in a MECUTS context.

In reality , policy decisions seem to be based on consensus formation incorporating compromise choices regarding ecologically sustainable development of various sectors, including the transport sector (cf. Nijkamp and Blaas 1994). This also means that effective policy strategies based on MECUTS guidelines are hard to find. This can also be explained by retuming to the above mentioned three impediments which caused the social dilemma.

The first problem, **viz. separation,** can be coped with by voluntary individual intemalisation of social costs of environmental decay (e.g., less use of cars), by market intemalisation (e.g., Pigovian taxes), or by forced intemalisation (e.g., parking prohibitions) . All such measures may have a substantive impact on sustainable development, but the public resistance and the policy inertia during several decades do not offer many hopeful perspectives, although recently the tides in Europe are changing. Examples are policies for car-free cities or even 'zero-emission cities'.

The second issue, **viz. market failure,** may be dealt with by a system of standards that is compatible with MECUTS indicators. Here maximum load factors, maximum emission standards or quota for resource use may be introduced. In this context, advances in information and transport (systems) technology may provide new departures for more sustainable mobility (e.g., telematics, telecenters policies). Actually , in most cases neither mobility substitution nor reduction is achieved by means of telematics, however.

Finally, the problem of **policy reform** may be tackled by seeking for institutional reforms, such as the organization of countervailing powers (e.g. ,public transport lobbies, intemational cooperation and agreements on environmental-benign transport modes).

In view of the social dilemma and the conflict between efficiency and equity , it seems that a 'packaging' of policies - with sufficient emphasis on financial incentives, but also with strict constraints whenever needed - is offering the best opportunities.

4. Concluding Remarks

The above observations mean that in practice a fair balance has to be found between incentives and penalties, between economic and institutional (e.g., standards) measures, and between behavioural and technological responses. An interesting approach may be added here, viz. in order to make sure that also future generations would have sufficient options for environmental quality, it may be useful to think in terms of insurance strategies. The estimated annual insurance premiums that would have to be paid in order to guarantee such options would have to be attributed as additional social costs to be bome by the current economy (including the transport sector). It goes without saying that our paper on MECUTS has provoked more questions than answers, but it is clear that transportation science will need to intensify its research efforts to make sure that the transport sector will not continue to be a perseverant unsustainable evil in a mobile network society.

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Table 1 Important environmental effects per transport mode

Topic	Road	Rail	Air	Water
Climate change [1)]	x	x	x	x
Squander [2)]	x	x	x	x
Acidification [3)]	x	x	x	x
Diffusion [4)]	x			x
Spatial needs and intersection [5)]	x	x		
External safety [6)]	x	x		
Smell [6)]	x		x	
Noise [6)]	x	x	x	
Degradation of built enviromnent [6)]	x			
Aridification [7)]	x			
Removal [8)]	x			

Source: Van Wee et al. (1992), Table 2.1.1 (modified).

Notes:

1) contribution to the greenhouse effect because of energy consumption and the reduction of the ozone layer by CFCs in cooling and painting
2) e.g., inefficient use of fossil fuels and (rare) metals
3) incl. emissions by power stations
4) especially toxic chemicals like cadmium, asbestos and lead
5) for infrastructure, vehicle use and parking
6) disturbance and damage to non-users
7) infrastructure construction consumes large amounts of sand an other filling materials, which drastically changes the landscape, as large holes remain, which are increasingly tumed into lakes
8) vehicle bodies, tires etc.

Table 2 **Contribution of the transport sector to environmental pollution in the Netherlands**

Source Data 1985	**Road**	**Mobile, other**	**Mobile, total**	**Other**	**Total**
CO_2 (Mton)	21	5	26	156	182
NO_x (kton)	262	79	341	211	552
SO_2 (kton)	11	23	34	237	271
NH_3 (kton)	0	0	0	285	285
H^+ (10^9 mol)	5.0	2.1	7.2	27.9	35
VOS (kton)	221	10	231	277	508
CO (kton)	923	42	965	356	1321
Lead (ton)	1180	0	1180	223	1403
Particulates (ton)	17	9	26	68	94
Waste (Mton)	0.6	0.02	0.6	48	49
Oil (kton)	35	8	43	59	102
Wrecks (kton) [1)]	510 [1)]	p.m.	510+p.m.	0	510+p.m.
Tires (kton)	61	12	73	0	73
Noise	59/19 [2)]				
Smell	61 [3)]				

Source: Van Wee et al. (1992), Table 2.1.1a.

Notes:

1) 1986 data

2) questionnaire data: percentage of people (severely) hindered

3) idem: by traffic in 1989.

Table 3 Actors and failure processes in transportation

Process		Specific processes	
Govemment failure	Policy aims **Instruments: legal, prices**	Policy **inertia** Separation	Misjudgements , (awareness of) underestimation of environmental concerns **vis-à-**vis competing concerns
Market failure: public transport operators	Decisions regarding investments , cooperation, competition, product quality	Separation Market failure	Unwillingness or inability to supply adequate alternatives for the private **car** Extemalisation of costs
Market failure: transport user	Choice of mode, mobility leve1 etc.	Separation Market failure	Few people choose environmentally more benign transport modes Extemalisation of costs

Table 4 Emission reduction scenarios for the Netherlands; All sources

	Reductions expected in 2010 (%) [1]			Reductions needed in 2010 [1]
	Scenario I	Scenario II	Scenario III	
CO_2	+ 35	+ 35	-20 à -30	-20 à -30
SO_2	-50	-75	-80 à -90	-80 à -90
NO_x	-10	-60	-70 à -80	-80 à -90
NH_3	-33	-70	-80	-80 à -90
HC	-20	-50	-70 à -80	-80
CFCs	-100	-100	-100	-100
Effluents into river Rhine and North Sea	-50	-75	-75	-75 à -90
Waste dumping	0	-50	-70 à -80	-80 à -90
Noise, severe [2]	+ 50	0	-15	-70 à -90
Smell [2]	+ 10	-50	-60	-70 à -90

Source: VROM et al. (1989), p. 107, Table 5.1.1.

Notes:

1) percentage reduction with respect to 1985 levels

Scenario 1 = current (so-called NMP-1) environmental policy package

Scenario 11 = maximum use of all conceivable policy measures

Scenario 111 = mix of measures aimed at emission reduction and source related measures

2) idem, in terms of number of people hindered.

Table 5 Emission reduction and mobility targets for passenger transport according to recent Dutch policy memoranda

	1986	1994 (NMP/ +)	2000	2010
NO_x [1)]	163	100	40 (-75%)	40
HC [1)]	136		35 (-75%)	35
CO_2 [1)]	23.000	26.400	23.000	20.700
Spatial needs [2)]	100	100	[3)]	[3)]
Noise: ◦dB(A) [4)] ◦number of hindered (severely) % [5)]	80 61% (20 %)		74 10-15%	70 0
Foreseen mobility level with no policy changes (index)	100	124	140	172
SVV-11 policy		120	126	156
SVV-11 + NMP-policy		117	120	148
NMP-2 policy			130	135

Source: VROM et al. (1989), pp. 194-196, 205; VROM et al. (1990), p. 50; VROM et al. (1993), p. 142 and 146; and RIVM (1993), p. 22 (note 5).

Notes:

1) NO_x and CO_2 in kilotonnes per year
2) index 1986 = 100, no targets after the year 2000
3) no further intersection in rural areas and compensation elsewhere if new links are still needed. These targets are hard to reach where car ownership is forecasted to grow from 5,5 million to 7 or 8 million cars; 'stand-still' seems therefore illusory
4) peak level dB(A) per car
5) 1990 data.

Table 6 Emission reduction and mobility targets for freight transport according to recent Dutch policy memoranda

	1986	2000	2010
NO_x [1)]	122	72 (-35%)	25 (-75%)
HC [1)]	46	30 (-35%)	12 (-75%)
Noise [2)]	81-80	75-80	70
Mobility	100		140 [3)]

Source: VROM et al. (1989), p. 195-196,205; VROM et al. (1990), p. 50.

Notes:

1) NO_x and HC in kilotonnes per year
2) in dB(A) per bus/lorrie
3) wishful thinking, as in NMP (p. 194) the foreseen growth of mobility is 70 to 80%.