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A SUSTAINABLE TRANSPORT SYSTEM FOR SWEDEN IN 2040

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Abstract

Images of a sustainable Swedish transport system for 2040 are outlined in this paper. Emissions of carbon dioxide are assumed to be the critical factor for sustainability. Improved energy efficiency in transport technology is necessary to reduce energy use, but, it is concluded, is not sufficient if transport volumes continue to increase. Images of the future indicate that it would be possible to increase leisure travel somewhat. In order to make that possible, much commuting, for example to the office or for daily shopping, is replaced by, for example, telecommuting from teleoffices and by teleshopping. Freight transport is also limited in images of the future.

INTRODUCTION

Modern society is dependent on an efficient transport system. The transport system, however, causes a number of serious health and environmental problems and uses considerable quantities of finite resources, primarily fossil fuels.

What could a future Swedish transport system, compatible with sustainable development, look like? The purpose of this paper is to study the basis for such a transport system and illustrate what it might look like. The approach is based on backcasting (Dreborg, 1996; Robinson, 1990). The leading idea in backcasting is first, to develop images of desired futures focused on a societal problem, and later to discuss how these future states could be attained. The images are not intended for detailed town and country planning, but as a basis for public discussion about future transport. It is hoped that the paper will help to clarify what types of choices society is facing and the magnitude of changes that are required to attain a sustainable alternative. The focus in this paper is on the images of the future, whereas paths to this state are not discussed.

Some of the central features in these images are the technical properties of vehicles, the structure of built-up areas, human values and behavioural patterns, and the use of information technology (IT). Since sustainable development requires that great changes in society take place, we have chosen a long time perspective. Our images aim at the year 2040.

All journeys, including for example air trips abroad, made by persons resident in Sweden have been included in our analysis. Ideally, the total goods transport used for the consumption in Sweden should be included. However, the statistics is poor. Therefore, all goods transport within Swedish borders has been included. Imports made by sea and airfreight are however also included.

WHAT DOES SUSTAINABLE DEVELOPMENT IMPLY FOR THE TRANSPORT SECTOR?

Briefly, sustainable development means, firstly, that the effects of human activities should be limited to what nature can sustain over a long term. Secondly, that resources should be preserved for the needs of future generations and thirdly, that all people should have an equal share of the current resources. In this paper, we have focused on carbon dioxide emissions, which cause an enhanced greenhouse effect. Furthermore, we have assumed an equal use of energy per capita on a global basis. The purpose of this section is to discuss how much energy is available to the transport sector on a sustainable basis. The arguments are further developed in Hunhammar (1998).

The transport system is one important source of net carbon dioxide emissions. The net emissions from fossil fuels seem to be the critical factor in reaching a sustainable development, although other problems, such as emissions of nitrogen oxides, are also important. If the use of fossil fuels is considerably reduced, the future use of energy will depend on the availability of renewable energy. Nuclear energy is not assumed to play an important role in a future global energy system. The global potential of renewable energy has been estimated based on four global energy scenarios (Grübler *et al*, 1995; Ishitani and Johansson, 1996; Johansson *et al*, 1993; Lenssen and Flavin, 1996). The available energy has been distributed globally on an equal per capita basis. A third of the energy available (i.e., today's EU average level) has been allocated to the transport sector.

Two different energy levels have been used to reflect the uncertainties of what a sustainable energy use would actually be. In the first alternative, the energy supply is based entirely on renewable energy, with electricity, methanol/ethanol, and hydrogen as energy carriers. All fossil fuel use is phased out. This would lead to an energy availability for the Swedish transport sector at approximately one third of its current use (35 TWh/year[1] for transports compared to 105 TWh/year in 1995). The second alternative is adjusted to a stabilisation of the carbon dioxide content in the atmosphere at 450 ppmv[2]. This would permit some fossil fuel use and lead to an energy availability of approximately half of what is used today (50 TWh/year). For Sweden, the second alternative would require the per capita emissions of carbon dioxide to be reduced by 80%. It must be emphasised, however, that the higher energy level constitutes a greater environmental risk than the lower level.

POTENTIAL OF INCREASED EFFICIENCY

Technology holds a significant potential for decreasing most of the environmental effects caused by human activities. For example, new technology can often decrease emissions of sulphur and nitrogen oxides considerably. The use of energy and the emissions of carbon dioxide, however, seem to be more difficult to reduce to sustainable levels. There is often a technically unavoidable trade-off between decreasing emissions of nitrogen oxides and increasing energy efficiency. The results of our analysis of the technological potential for more energy-efficient transport are shown in Tables 1 and 2 (Steen *et al*, 1997). The efficiency improvement potentials could lead to a reduction of between 30% and 75% of energy use, and are generally higher for passenger transport than for freight transport. Estimates have been based on available technologies and refer to fleet averages. Speed and load factors have not been changed as compared with current levels.

Table 1 – Estimated potential for improved energy efficiency until 2040 for passenger transport (fleet average). Speed and load-factors are kept at 1995 level.

	kWh/ passenger-km, 1995	Potential change until 2040	kWh/ passenger-km, 2040
Car, combustion mode (<100 km)	0.75	-75%	0.20
Car, electric mode (<100 km)			0.10
Small electric city vehicle			0.07
Car, combustion mode (>100 km)	0.32	-65%	0.12
Bus (<100 km))	0.22	-60%	0.09
Bus (>100 km)	0.13	-40%	0.07
Ferry, 75% on passengers (20 knots)	0.60	-30%	0.42
High speed ferry (40 knots)	1.80	-30%	1.30
Rail (<100 km))	0.16	-50%	0.08
Rail, 200 km/h (>100 km)	0.11	-50%	0.05
Air	0.70	-50%	0.35

There are a number of obstacles to attaining these efficiency improvements. One change needed includes the system's culture of certain important players. The motor industry is, for example, inclined to make heavy steel cars.

Table 2 – Estimated potential for improved energy efficiency until 2040 for freight transport (fleet average). Speed and load-factors are kept at 1995 level.

	kWh/ tonne-km, 1995	Potential change until 2040	kWh/ tonne-km, 2040
Lorry (<100 km)	0.70	- 40%	0.42
Lorry (>100 km)	0.25	- 30%	0.17
Rail	0.05	- 30%	0.03
Ferry, 25% on goods (20 knots)	0.20	- 30%	0.14
Cargo ship	0.05	- 30%	0.04
Air	3.00	- 50%	1.50

IS NEW TECHNOLOGY ENOUGH TO ATTAIN A SUSTAINABLE TRANSPORT SECTOR?

Today's transport system is not sustainable, but has new technology the potential to make it sustainable? In order to address this issue, the potential described above was combined with the growth trends in transport volumes. If, for example, the forecasts of the Swedish traffic boards (Banverket, Vägverket and VTI, 1993) are combined with the potential efficiency improvement, the resulting energy use is almost as large as it is today, see Figure 1. It is obvious that a considerable increase in volume is not compatible with a sustainable society. If, however, future transport volumes remain similar to those of today, we will obtain a result at about 50 TWh (i.e., at the higher of our two assumed levels for sustainable energy use in the transport sector). Thus, highly improved transport technology is an important, though not sufficient, component for attaining sustainability.

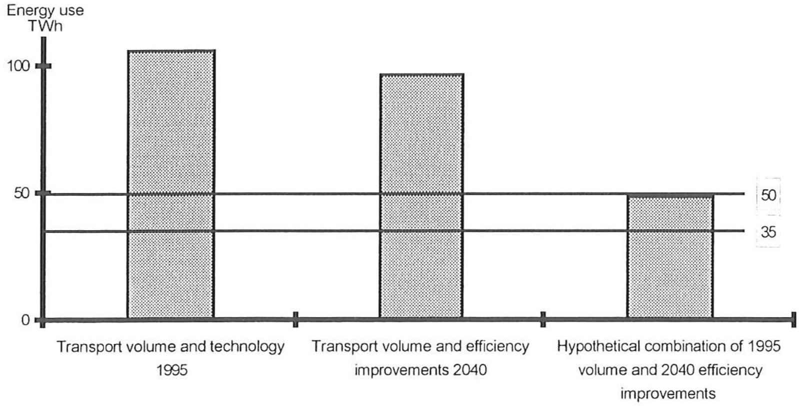

Figure 1 – Energy use in the transport sector. The left-hand column indicates present-day (1995) energy use in the Swedish transport sector. The middle column builds on forecasts of expected increases in transport volume in combination with a realisation of the estimated technology potential. The right-hand column indicates the transport volume of 1995 in combination with hypothetical realisation of the technology potential in Table 1 and 2. The figure shows the two assumed levels for sustainable energy use in the transport sector.

INCREASING TRANSPORT VOLUMES—DRIVING FORCES AND SOLUTIONS

It is obvious, from our analysis, that the increase in transport volumes must be halted if sustainable development is adopted as a societal goal. In this section, we discuss some of the driving forces behind increasing transport volumes, but we also mention some factors that may help in halting the increase. We begin by discussing possible saturation levels for both goods and passenger transport, and conclude that no spontaneous saturation is in sight. We then point to the difference between geographical accessibility and functional accessibility. Dematerialization is proposed as one important factor for reducing transport of goods, and the role of the motor car is discussed in relation to passenger transport. In the latter part of this section, we follow a line of argument in which we distinguish between desired and structurally enforced travel. We claim that if transport is to be reduced, planning should concentrate on reducing enforced travel and the transport of goods. Based on this view, we point out the importance of the development of information technology and the potential of alternative urban forms.

Is it possible to observe any saturation trends for today's transport volumes? For daily short-distance travel, time may, in the long-term, turn out to be a limiting factor. However, for long-distance travel, particularly by air, time budget constraints would be of little or no importance, even if air travel were to increase for example ten times. The possibility of making good use of the time spent on public transport may even lead to acceptance of long-distance commuting. Furthermore, the trend towards faster means of transport generally implies higher energy use and more emissions per kilometre travelled.

Regarding freight transport, it is also difficult to see any sign of saturation. On the contrary, worldwide trade is encouraged at present. One of the principal aims of, for example, NAFTA and the EU is increasing trade. This will most probably lead to an increased amount of freight transport. Several factors, which together make the flow of goods smoother (e.g., decreasing transport costs and fewer trade barriers), are today contributing to a rapid increase in freight transport.

In order to reduce the transport of goods, several things can, or should, happen. A sustainable use of materials, based on dematerialization in society would reduce the flows of materials and thus the need for transport of goods. Lighter and more durable products and more focus on functions than on products could contribute to achieving this. Finally, a reduction of transport distances, not least by significantly reducing exchange of similar products between countries, could also contribute to reducing the transport of goods.

The development of transport technology and infrastructure has facilitated the mobility of both passengers and goods. As geographical accessibility has increased, there has, in some cases, been a decrease in functional accessibility. Examples of this are the closing-down of local shops and the growth of shopping centres on the outskirts of cities. Travelling then becomes a necessity and it becomes more difficult to get along without a car. Thus in some case increased mobility can be a sign of decreased wealth (Daly and Cobb, 1990). This illustrates the need to consider the long-term structural consequences of increased mobility.

Today the car may be regarded as the leading object of modern society (Hagman, 1997; Lefebvre, 1990). Besides it's transport function it is associated with symbolic values, such as status, power, and freedom (Sandqvist, 1997). But many car users also face a cognitive dilemma in driving—it is practical to have a car, but you should not use it for environmental reasons (Lindén, 1994). Today the car coexists with other means of transport, but there is a risk that the car will outrival other means of transport for short and medium length distances, so that in future people will not be able to get anywhere without a car.

Alternatively, cars may be used only in the niches where their special properties make them clearly superior to other means of transport. Examples of such niches are journeys to sparsely populated areas, suburban connecting traffic, and trips to holiday cottages. This type of development may involve increased differentiation of vehicles for different purposes. For example, large vans would be used for the conveyance of goods, small electric vehicles or electric bicycles for certain journeys in built-up areas, and medium-sized hybrid cars for family summer trips. Moreover, an enlarged market for different kinds of car-rental would give all holders of a driving licence access to vehicles dimensioned for different purposes, even if they do not own a vehicle themselves. Small environmentally friendly electric vehicles intended for short-distance transport could partially resolve car drivers' cognitive dilemma.

If sustainable transport is desired, conscious measures must be taken to limit transport volumes. Structurally determined daily journeys for such purposes as work, services, or shopping can probably be reduced without challenging today's values. These journeys are enforced in the sense that we are compelled to make them for our living, due, for example, to current infrastructure and work organisation. In many ways, a reduction of this type of journey, for example, through increased doorstep delivery services and teleworking at a nearby office or at home, would be a positive development. Other journeys, especially leisure-time experience-oriented journeys, are valued more highly (Berg, 1996; Tengström, 1994). Some places have a value of their own, and sometimes even the travelling itself can have a value. If this travelling is to decrease, people will have to partially dispense with experiences they look forward to, such as those at their summer houses or holiday resorts.

When discussing limitations of transport volumes, it is crucial to distinguish between the short- and the long-term perspective. If some general policy measure, such as an increased CO_2 tax, were to be introduced in the short term, it is likely that leisure travel would be cut more than for instance work travel (Mills, 1998). The reason for this is that commuting to work is necessary for everyday life. In the short term, commuting cannot be replaced, since a reduction in commuting distances implies a change in work and urban structures. In order to forestall a situation where high transport prices force people to give up leisure travel, alternative developments may be interesting to assess. For example, can information technology in combination with alternate urban forms help to reduce enforced travel?

The future development of information technology could lead to increased traffic. However, it also has a potential for replacing transport. In future it will be possible for companies to form networks instead of workplaces, which opens opportunities for multinuclear urban forms with high accessibility to workplaces, but with short commuting distances (Höjer, 1998). Purchases and certain services can be handled by means of information technology, and transport can be better co-ordinated in sparsely populated areas.

According to our analysis so far, it seems that transport volumes should not increase in order to reach a sustainable development. Transport can be divided into the transport of goods, desired travel, and enforced travel. In the images of the future that follow in the next section, we have presumed that the reduction of enforced travel and goods' transport will be preferable to reductions in desired travel. The reduction of goods' transport is accomplished through dematerialization and shorter hauls. Much enforced travel is rendered unnecessary by a change in today's working patterns, resulting in a structure where many people work in network organisations. This requires changes in the present infrastructure and location of functions. A crucial prerequisite for realisation of these images is that the public demands a sustainable development.

IMAGES OF THE FUTURE - SWEDEN 2040

The images are based on the assumption that leisure travel (desired journeys) will, in the long run, generally be preferred to other kinds of travel (enforced travel) and to a wider assortment of goods. This means that measures should be taken to render much freight transport and enforced travel unnecessary. The technology potential described in this paper has been used in all our images of the future.

The main alternative among the images is called *NODE Low*. The word *Low* here indicates that the use of energy for transport is in accordance with the lower of our two energy levels, (35 TWh/year). Since only renewable energy is used in this image, the environmental risk is also low. Main fuels are electricity, methanol, and hydrogen. The word *Node* indicates the high importance given to the nodes in the networks of organisations, telecommunication network and public transport network.

The images build on a society based on neotraditional structures and network organisations (Berg, 1996; Bieber *et al*, 1994; Britton, 1994; Höjer, 1998; Ingelstam, 1995; Nifles, 1991). The neotraditional structures refer to values that emphasise a local spirit of community, involving both leisure-time activities and the production of services and goods. This does not mean, however, that long leisure-time journeys are excluded. The basis of the network organisation is that information technology (IT) makes it possible to carry out work of many different types at a number of network nodes, so-called teleoffices. Here people in global networks can keep contact with each other via IT. The nodes constitute local centres in a city structure with several nuclei. The teleoffices, which are equipped with a great variety of communication devices, also form the basis of local service facilities and shops (Nilles, 1996). Various establishments for leisure-time activities are located nearby. The nodes are linked together by means of environmentally friendly public communication. In sparsely populated areas teleworking at home is more common.

Conscious spatial planning and encouragement of network organisations can give built-up areas the structure we have assumed. Daily journeys that can be characterised as structurally enforced, especially journeys for such purposes as work, services or shopping, are considerably limited in this kind of structure. These journeys take place less frequently and/or over shorter distances.

Daily movement from one place to another in built-up areas mainly occurs in the form of walking, riding a bicycle/electric bicycle, or by means of frequent bus or rail transport. These types of transport have been doubled. Small electric vehicles are a complement, for example, for suburban connecting journeys. Altogether, short-distance travel by car has been halved. In sparsely populated areas, however, the car, for example in the form of an electric hybrid, is still the dominant means of transport for essential journeys.

One reason for the reduced freight transport in this image of the future is shorter transport distances. This applies especially to flows of products with a low cost/weight ratio such as foods, biofuels, and building materials. Products with a high cost/weight ratio, like electronic equipment, are still traded in global markets and so are some exotic products like coffee and bananas. An overall dematerialisation of society (e.g., through lighter and more durable products) has also contributed to the reduction in freight transport.

The system of distributing everyday commodities has largely changed its character. Many of these commodities are ordered via computer networks, and small lorries deliver to the home. Bread, fresh fruit, and other perishables can be ordered in this way, but they can also be bought in shops and markets at the nodes.

The highly diminished environmental load of short-distance journeys and freight transport has given room in our images of the future for increased long-distance leisure travel. This leads to a volume of leisure-time travelling that is about 30% larger than today's volume (see Figure 2). Long-distance train journeys have primarily increased, but there is also an increase in long-distance car journeys. Total air travel has decreased by 40 %. Some of the decrease refers to leisure trips, but the majority refers to business journeys. In Table 3 and 4 transport volumes according to mode are shown for *NODE Low*, and for Sweden 1995.

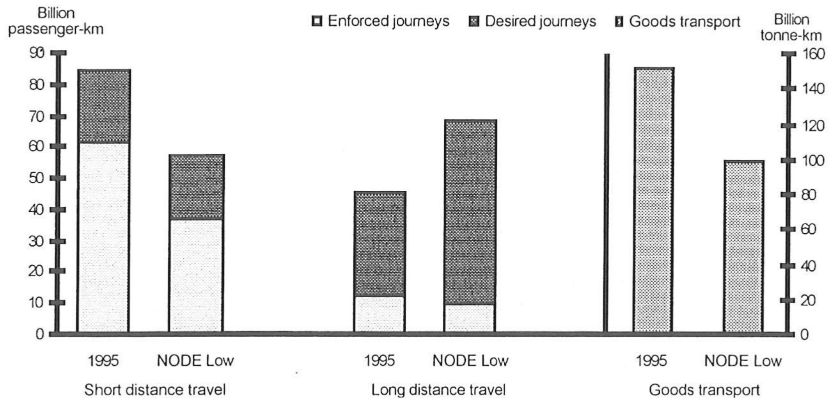

Figure 2 - Volumes of desired travel, enforced travel and goods transport in the *NODE Low* image of the future.

Table 3 - Passenger transport volumes according to mode in NODE Low compared with 1995.

	1995 (billion passenger-km)	**NODE Low 2040 (billion passenger-km)**
Car, combustion mode (<100 km)	65	8
Car, electric mode (<100 km)	0	10
Small electric city vehicle	0	10
Car, combustion mode (>100 km)	20	28
Bus (<100 km))	7	12
Bus (>100 km)	2	10
Ferry, 75% on passengers (20 knots)	4	3
Rail (<100 km))	4	8
Rail, 200 km/h (>100 km)	5	15
Air	20	12

We have also considered some alternate images, with energy constraints given by either of the two alternatives of energy use that we set up for transport (35 TWh and 50 TWh). The idea with these alternate calculations is to present the approximate dependence of energy use on travel purpose and transport mode. The same level of transport technology is assumed in all but one alternative (Steen *et al*, 1997).

Table 4 – Goods transport volumes according to mode in NODE Low compared with 1995.

	1995 (billion tonne-km)	NODE Low 2040 (billion tonne-km)
Lorry (<100 km)	7	5
Lorry (>100 km)	26	10
Rail	19	22
Ferry, 25% on goods (20 knots)	4	2
Cargo ship	100	55
Air	0.3	0.15

One alternate image illustrates that if we accept the high level (50 TWh) of energy for transport, long-distance leisure travel by air can increase by 180 % compared with Node Low (or a 70 % increase compared to 1995). Another image indicates that a 20% general reduction in speed would lead to considerably lower energy use. In our specific example, leisure travel could be increased by 30 % compared with Node Low (or 70 % compared with 1995). On the other hand, if we assume a 70 % increase in the volume of freight transport from 1995–2040, total leisure travel might only be 15 % higher than in Node Low (50 % higher than in 1995), even if the higher energy level is accepted (50 TWh). Finally, an alternative with today's infrastructure (i.e., without the node structure) has been outlined. In this alternative structurally enforced journeys will largely remain at the same level, which gives little room for leisure-time travelling. On the *Low* level, leisure travel has to be reduced to only 30 % of the 1995 level, and on the *High* level it can be kept at about the 1995 level.

CONCLUSIONS

In this paper, we have argued that an acceptance of sustainable development as a goal implies that the trend towards increasing transport volumes must be broken. The potential for more efficient vehicles is large, but our analysis indicates that even with these improvements in fuel efficiency, the stated goals will not be fulfilled.

One way of limiting transport could be to enforce much higher taxes on transport. However, drastically higher prices on transport would result in reduced freedom of action for many people, as the costs of commuting to work would become high. These journeys are difficult to reduce in the short-term.

An alternative approach towards reduced transport is presented in our images. In the images, we emphasise the role of planning in such a way that it supports the use of IT and encourages people to live in areas where the need for travel is rather low. This could considerably limit the volume of structurally enforced journeys (for such purposes as work, services, and shopping). If freight transport is also reduced through dematerialization and short transport distances, there could be room for somewhat more leisure-time travelling than today, within the stated energy budget.

We have suggested one way of organising a society with low transport demands. An organisation along the lines we suggest seems to have a potential for limiting the use of energy to a per capita level that would be sustainable even on a global scale. In this society commuting and goods' transport are minimised through the development of multinuclear cities, network organisations, and dematerialization.

Certainly, there could be other "solutions" to the sustainability problems of the transport system. Our aim with this paper is not to prescribe a recipe, or present the final solution. Instead, we emphasise that great changes might be needed, at the same time as we present one way of tackling the difficulties. Our hope is that this will stimulate the emergence of alternate ideas and improved suggestions on how to build a sustainable transport system.

Finally, it must be emphasised that changes on the scale that we have sketched here cannot materialise without public acceptance. It is quite possible that such acceptance does not exist. However, if environmental threats continue to become more serious, acceptance of greater changes will increase.

ENDNOTES

[1] Due to the large share of electricity in the Swedish energy system TWh is the common energy unit even for fuels. In Swedish statistics it is also the standard praxis to add together fuels and electricity without any conversion factors. Internationally however, electricity is usually produced in a fossil-fuelled power plant with an efficiency of about 40%. Hence, the international praxis is to convert electricity to fuel equivalents by multiplying it by a factor of 2.5. The energy levels in the two alternatives compare with about half (50%) and a third (32%) of current energy use, respectively, when the Swedish method is used. With the international method, energy levels in the two alternatives represent about three-fifths (59%) and two-fifths (43%) respectively. The difference is due to the comparatively large share of electricity. Units: 1 TWh = 3.6 PJ = 0.086 Mtoe.

[2] Parts Per Million Volume. The preindustrial concentration was approximately 280 ppmv, which had risen to 360 ppmv in 1994.

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