# 6.

# TECHNICAL SOLUTIONS – IMPROVED TRANSPORT TECHNOLOGIES

*by Jonas Åkerman*

## 6.1 Technical developments

The level of technology used in the Baltic region for transportation purposes differs significantly between the various countries. Generally, post-communist countries use older and less effective technologies. This does not always mean, however, that specific fuel consumption (energy per vehicle-km) is lower in western countries. The more advanced technology in, for example, western cars has to a great extent been used to increase the power and comfort of the vehicle rather than to decrease its fuel consumption. Another reason is that western cars are generally heavier and more spacious. The result is that Russian cars, for example, do not have a much higher specific fuel consumption than the average car in western Europe. On the other hand, the specific emissions of HC, CO and $NO_x$ are lower in western cars, especially when catalytic converters are used. This is often offset, however, by the fact that car travel per capita is much higher in western countries.

There are a lot of powerful actors such as car manufacturers and oil companies who are opposed to any significant change from the present fossil-fuelled car, be it the introduction of biofuels and/or a change of vehicle concept (for example, the replacement of steel by composite materials). Consequently, relatively impotent actors like one or a few small countries cannot themselves induce the introduction of completely new technologies. However, the average technology used in the Baltic region is far from the best available, so much can be done just by closing this gap. Another important option, especially in western countries, would be to encourge people to buy lighter and less powerful cars.

***Table 6.1 Comparison between different types of cars***

| | Fuel efficiency (l/100 km) | Power (kW) | Curb weight (kg) |
|---|---|---|---|
| Typical Western car: Ford Sierra | 8.6 | 74 | 1100 |
| Typical Polish car: Fiat 126 | 6.5 | 17 | 600 |
| Most fuel efficient car sold in Sweden 1995: Suzuki Swift | 4.9 | 50 | 750 |
| Future hybrid vehicle | < 2.5 | 10/40 | <700 |

Although the possibility of decreasing *specific* energy use or *specific* emissions (per vehicle-km) exists, it is important to bear in mind that an improvement of this kind might very well be offset by an increase in the volume of traffic. Although we in this chapter will be concerned mainly with the energy-use and emissions of vehicles, it is important to remember that other activities are also necessary to accomplish a functioning transport system. The indirect energy needed to build road vehicles and roads, to maintain roads and to produce the fuel for these purposes amounts to about 50–60 per cent of the energy used for propelling all road transport vehicles.

## 6.2 How much can the car be improved?

As already mentioned, western cars are not generally any more fuel-efficient than cars in post-communist countries but they are certainly more powerful and heavier. The potential for fuel-saving, even without sacrificing performance, is great as is indicated in Table 6.1. This may be accomplished by lighter materals (like aluminium or composites), lower drag coefficient, lower rolling resistance and some sort of hybrid-electric drive.

A series hybrid-electric vehicle uses a small engine (or a fuel cell or gasturbine as in Volvo's concept car ECC) sized to the average load. Peak-power is taken from the buffer store which most often is batteries. This means that the power of the engine can be about five times smaller (about 10 kW) than that of a conventional car. The engine drives a generator so it runs only at its optimal condition. This increases energy-efficiency and permits more efficient emission-control. Since it is an electric motor that is coupled to the wheels, it is also possible to recover most of the braking-energy into the buffer store (which in most cases is batteries).

It should be noted that actual emissions of $NO_x$ and some other substances (with the exception of $CO_2$) from cars are notoriously difficult to estimate. The average actual emissions of $NO_x$ from cars may be as much as four times higher than official tests indicate. These differences are mainly due to malfunctioning emission-control systems and 'off-cycle emissions' due to hard acceleration, high speed, extreme weather conditions, etc.

It is estimated that $NO_x$ emissions per vehicle-km in a post-communist country like Lithuania are about five times those in a western country like Sweden. This figure is probably of the correct magnitude but should be used with caution because of the uncertainty of the test results mentioned above. The difference may be increasing as a growing proportion of western cars are equipped with catalytic converters.

A great proportion of the vehicles entering the market in post-communist countries are imports of second-hand western European and Japanese cars. A considerable number of these cars are in very poor condition and are only regarded as scrap in their countries of origin. Emissions from these vehicles may be very high since it is indicated that the worst 20 per cent of western cars contribute some 60 per cent of the emissions. A related problem is the chronic shortage of spare parts in post-communist countries. The condition of cars and their environmental properties thus further deteriorate.

The catalytic converter is a very important innovation that in practice reduces HC, CO and $NO_x$ emissions by approximately 80 per cent. (Much higher figures are often quoted by car manufacturers but these almost always relate to ideal conditions.) This may, however, not be enough to reach sustainability, especially since car travel is rapidly increasing. One important task is to reduce the so-called cold-start emissions which represent a considerable proportion of emissions from a car equipped with a catalytic converter. Another problem is the reliability of the entire emission-control system during a car's whole life-span.

## 6.3 Lorry, bus and rail

Lorries are generally a fast-growing sector even if the absolute volume is still quite small in post-communist countries. Another problem with this sector is the relatively low (compared to cars) potential for improvements in energy-efficiency and emissions. Most lorries, especially the heavy ones, use diesel engines. These are already very energy-efficient and the potential for improvement in this sense is relatively small. Diesel engines do not emit very much CO or HC but $NO_x$ emissions are considerable and difficult to reduce. The same type of catalytic converter that is used in petrol cars cannot be used. In 1980, $NO_x$ emissions from cars in Sweden amounted to twice those from lorries. In 1995, however, emissions were about the same for both mainly because of the introduction of catalytic converters in cars.

The bus is generally an energy-efficient means of transport; about three times better than the car. Emissions from diesel buses are, however, a problem especially since they often occur in densely populated areas. The possibility of decreasing emissions is about the same as for lorries.

In general, rail transport is energy-effective. However, the environmental properties of rail transport depend to a great extent on what primary energy source is used. As a consequence, the effect of replacing diesel locomotives with electric locomotives depends on how the electricity is generated. If it is produced by coal or oil, the emissions of $CO_2$ will, in many cases, increase although there is the potential for decreased emissions of HC, CO and $NO_x$. If, on the other hand, the electricity is produced by, for example, wind power or biofuels, the gains may be substantial.

## 6.4 Air and sea transport

Although the volume of air travel is lower in post-communist countries than in the West, the relative amount of fuel consumption and carbon dioxide emissions is often greater. The volume of air travel in Russia is still probably of the same magnitude as the volume of car travel. This in turn means that the total fuel consumption of (civil) aviation is about twice that of cars.

The aircraft used in eastern Europe are generally much more energy-intensive and polluting than western aircraft. The fuel consumption of Russian aircraft is about 50 per cent higher per seat-km than that of western aircraft. This was during the communist era offset by extremely high load factors at nearly 100 per cent (65 per cent is typical for western airlines).

Since it is the exhaust gases that create the propelling force in a jet aircraft, no after-treatment, like a catalytic converter, is possible. The only way to reduce emissions is to modify the combustion process. Unfortunately, there is a slight trade-off between low fuel-consumption and low emissions of $NO_x$. Higher temperature in the combustion chamber generally means better energy-efficiency but, at the same time, the generation of $NO_x$ increases. Despite this, the long-term potential for reducing $NO_x$ is not negligible. It may be around 70 to 80 per cent compared with present western aircraft.

Freight ships are generally a very energy-efficient means of transportation at least when the volume of goods is significant. For passenger transport, the case is not so simple. On the contrary, a passengers-only ship travelling at 20 knots often uses about as much energy per passenger-km as a modern aircraft (which is about twice as much as a car). When, as is often the case, a ship carries both passengers and freight, the situation gets more complex, since it is not evident how the energy used should be allocated to freight and passengers respectively.

The present trend in sea transport is for increasing speeds. The introduction of catamarans, especially as passenger ferries, is one way of accomplishing this. For a given speed, a catamaran is more energy-efficient than a conventional ship, but, when the speed is doubled from 20 knots to 40 knots, as is often the case, the result instead is increased specific fuel-consumption.

Mainly because of the lack of regulations (the technology is available), the emissions of $SO_2$ and $NO_x$ are often great. In 1987, the $SO_2$ emissions from shipping in the Baltic Sea was about 85 kton. This is about as much as the total of Swedish emissions. The emissions of $NO_x$ from shipping in the Baltic Sea are of the same magnitude as the emissions from road transport in Sweden (around 160 kton in 1990). Nearly half of the shipping emissions come from ferries.

$SO_2$ emissions are proportional to the content of sulphur in the fuel if no cleaning of sulphur oxides is used. The most common method of reducing emissions from ships' engines is to desulphurize the oil before it is used. $NO_x$ emissions may be reduced by approximately 90 per cent by using selective catalytic reduction (SCR) of the exhaust gases. The method is commercially available and very cost-effective as regards the Swedish emission fee of 40 SEK/kg $NO_x$. The cost of cleaning for newly built ships is 3–8 SEK/kg $NO_x$ and is 6–15 SEK/kg $NO_x$ for installation in older ships.

## 6.5 How far can the technical solutions take us ?

Technical improvements can be discussed at different levels: long-term potential and short-term possibilities. The long-term technical potential for reducing energy-use and, consequently, emissions of $CO_2$ is considerable as shown in Table 6.2. The potential for passenger transport is generally greater than for cargo transport. It is important to note that these figures assume no changes in vehicle speeds or load factors which also represent a large potential for reductions. Energy-use increases exponentially with speed for a given vehicle. The present trend, however, especially for rail and sea transport, is that technical development is used for obtaining higher speeds rather than reduced energy-use.

The conclusion to be drawn is that, even if the full technical potential were to be realized, this would not be sufficient to reduce $CO_2$ emissions to what could be called a sustainable level. Technical improvements are necessary but not enough. It is also important to notice the dynamic effects of technical development. The introduction of more fuel-efficient vehicles may in itself increase the volume of traffic. This may be counteracted, for example, by increasing taxes on fuel.

Regarding $NO_x$ emissions from cars, the long-term technical possibilities seem promising. A combination of hybrid electric vehicles, catalytic converters and devices for taking care of cold-start emissions could probably drastically reduce emissions from cars. A reduction of more than 95 per cent of the emissions from a modern car without a catalytic converter is within reach.

When it comes to diesel engines in lorries, buses and some trains, the situation is worse. $NO_x$ emissions could be greatly reduced by replacing diesel egines with spark-ignition engines (like petrol engines) or gas turbines. This would, however, be at the cost of an increase of about 30 per cent in fuel consumption and $CO_2$ emissions.

$NO_x$ emissions from aircraft may, in the long term, be the most troublesome since air travel now has a doubling-rate world-wide of only some 15 years. The effects of emissions of $NO_x$ at high altitudes (in the upper troposphere or in the stratosphere) are quite poorly understood but may very well be severe. At the same time, the technical potential for reducing emissions is probably lower than for other means of transport.

Apart from the potential of future technical development, it should not be forgotten that much can be done with available technology. A lot of fuel can be saved and emissions reduced just by choosing the most fuel-efficient cars already on the market. It can indeed be questioned whether the citizens of western countries really need such heavy and powerful cars as they presently drive. Better maintainance of the vehicles is another, probably very cost-effective measure, especially for reducing emissions of HC, CO and $NO_x$.

*Table 6.2 Long term (30-40 year) technical potential for reduction of specific energy use compared to present average technology used in Western Europe.*

| Mode of transport | Potential for reduction of specific energy use |
|---|---|
| Car | >75% |
| Lorry | >40% |
| Bus | >60% |
| Air | >45% |
| Sea | >30% |
| Rail (person) | >50% |
| Rail (goods) | >30% |

# Sustainable Urban Planning and Transport

by Finn Kjærsdam

## TOWNS AND TRANSPORT

There are significant correlations between town planning, urban transport, and the use of energy and polluting emissions. But while the relationships between the amount of urban transport, the use of energy and the polluting emissions are approximately proportional, the correlation between town planning and urban transport is more complicated. In general, the internal relationships between housing, employment and shopping are important. The longer the distance between these functions, the higher the energy consumption. This is caused by two factors, namely, increased transport work and more journeys by car, which increase consumption per mile.

Urban transport is reduced when these relationships are balanced within each urban society and the functions are distributed across the region. Concentrating them in the regional centre increases traffic.

Urban transport seems to be minimized in towns and cities in developed societies of between 20,000 and 300,000 inhabitants with a high number of cars. Households with cars travel twice as many miles as households without. With the increased number of private cars in the Baltic region, the problems described above must be expected and the solutions mentioned must be applicable.

## THE OUTER CITY

Migration from rural areas to cities, further industrialization, continuously growing consumption, growth of the service sector, developments in building technology and the explosive increase of private transport all present demands on cities that cannot be immediately met within the existing frame of operation. Solutions to problems have been sought by heavy-handed reconstruction of town centres by their total replacement. Old industry, workshops and housing have had to yield to the expansion of city occupations, government offices and large department stores.

At the same time, access to city centres has been increased by the development of extensive traffic systems including urban motorways linking the new central business district to existing urban areas and also to the new suburban residential and industrial areas.

Increasing encroachment of towns has interfered more and more with the hard-earned rights of the citizen. This has resulted in continuously growing opposition to the plans including confrontations with the citizens, grassroots organisations, etc. and less belief by citizens, planners and politicians that planning was for the common good. But planning has to be for the common good to be able to infringe the right of property in a free society.

Including citizens in the planning process was one obvious solution to this. Citizen participation changed the content of planning and resulted in preventing politicians from carrying out many of their more heavy-handed plans. Total clearance and city-centred plans were replaced by conservation and renovation proposals and centres located outside the urban area were supported so that the central area could be relieved of the growing pressure.

This altered the basis for urban planning. It made it possible to improve existing central areas by suitable conservation and housing-oriented renovation and to develop necessary public and private services, recreational open spaces and traffic improvements.

The cost of supporting areas outside the centres is increased transport. It has been demonstrated that the establishment of new out-of-town centres increases the transporting of citizens inside as well as outside the city; customers using out-of-town centres travel twice as far by car and public transport as local customers.

Two-centre cities increase energy consumption.

## THE COMPACT CITY

There are energy savings to be found by increasing density in built-up areas. It has been shown that in a town with 30 inhabitants/hectare the use of energy for transportation is 20 per cent lower than in a town with half that density. According to this, urban-growth problems should be partly solved by the regeneration of debilitated urban areas and a more intensified use of the existing urban structure.

This has made it possible to keep undeveloped areas, close to the city, free from urban development and for them to serve instead as ecological zones contributing towards the city's oxygen renewal, maintenance of the ecological cycle and the recreation of its citizens.

It has also been shown that transport and energy-consumption increase significantly when the distance between housing and the city centre increases. The energy consumption of households 40 kilometres from the city centre is close to twice as much as that for households located in the city, if local shopping and service facilities are bad, and 30 per cent higher if there are good local services.

The increase in energy consumption in relation to the distance to the city centre is lower for offices and lowest for manufacturing industries. This means that, where spare space in the city centre is restricted, housing rather than offices and offices rather than manufacturing industries should normally be preferred. On the other hand, offices should be avoided in the suburbs.

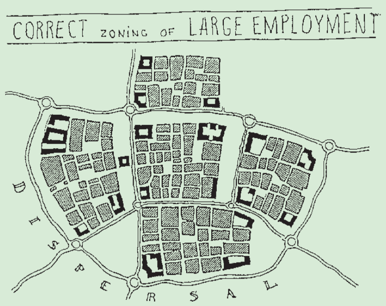
## TOWNS WITHIN THE TOWN

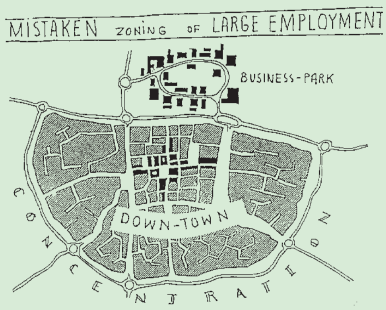
Many cities are located where road and water transport routes meet. In such cases it is important to ensure a balance of housing, employment, shopping and services on each side of the river. This minimizes both the volume of urban transport and the need for more bridges and tunnels.

This principle can be transferred to the whole city. If a mixture of functions is ensured, in a balanced interplay, in the different parts of the town, traffic can be reduced. This is what is called towns within the town.

It has been shown that parts of a town with no local services have a 20 per cent higher energy-consumption than parts with good local services.

A problem with such a solution is that of more sophisticated employment. Trades and services will normally recruit a local labour force while more




specialized companies which recruit highly qualified employees will often recruit their labour force from other parts of the town.

## PLANS SUPPORTING PUBLIC TRANSPORT

It is not only the distance to the city centre but also the distance to the public transport system which affects the use of transport. The longer the distance to public transport, the more and longer the car journeys as far as shopping and travelling between home and work is concerned. At least this is valid where work is employment in an office. On the other hand, there may not be a correlation between the use of cars and the location of manufacturing industry.

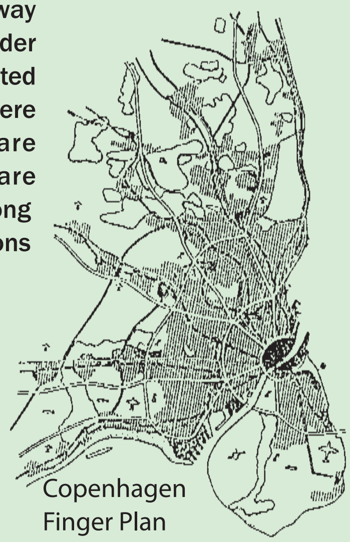
In other words, it is important to ensure that housing and offices are close to the public transport system.

## THE LINEAR TOWN

In towns of limited size, a linear layout can be a good solution. This means that the town is built along a public transport route such as a tramway so that there is a tram stop within walking distance for all residents in the town. Furthermore, all shopping and office areas should be located at stops on the public transport route. In larger linear towns the energy savings produced by a more effective public transport system are lost due to longer car journeys.

## THE FINGER PLAN

An example of a well-developed linear plan for a bigger city is the finger plan for Copenhagen. Constructed like a hand, five linear towns are established like fingers along a suburban railway system leading to the older urban area which is located at the palm. Here is where most of the offices are located while shops are lo cated along the fingers at the stations on the railway line.



Copenhagen Finger Plan

By provision of green wedges, containing agricultural land, forests and areas for leisure pursuits, between the fingers it is also possible to have easy access to nature and a contribution to oxygen renewal in the city centre.

## THE FIGURE-OF-EIGHT TOWN

In Runcorn, the concept of the linear town was developed into a figure-of-eight ribbon town. A rapid route exclusively for buses follows the figure-of-eight, linking all the neighbourhood centres, the main centre, places of employment and institutions.

It has been demonstrated that the use of public transport in Runcorn significantly exceeds the use of public transport in other towns of the same size.

Runcorn