Discussion Paper for the Symposium

“Future Challenges of Transport and Environment”

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1 Preface

In democracies today, the focus of policy normally is on the next election period, or at best on the next decade. However, decisions have to be made today in order to achieve a more sustainable future. Even if politicians talk about possible solutions to challenges, e.g., of the alarming signals of climate change, they prefer to opt for magic technological solutions like hydrogen and fuel cells or the extended use of bio fuels. This ignores past experience that such “solutions” themselves create new problems for sustainable development. So, hydrogen and fuel cells will be, as long there is no technology breakthrough, much more expensive than other propulsion systems and than any other energy source. There are some problems related to an extended use of bio fuels in a limited world, like competition with food production or with water resources. It is well accepted that large infrastructure systems like energy production or transport networks will not be transformed into a more sustainable structure in a short time frame. Therefore, an early action plan has to be developed and implemented as soon as possible. In the energy sector, there are some positive signs. In Germany or California, for example, long-term goals for the provision of carbon-free electricity production exist and the necessary legal structure has been adopted by legislators. It is clearly much easier just to change from electricity production with coal to wind or solar than it is to adopt the equally necessary measures to improve energy efficiency dramatically.

In the transport sector, however, the situation is much more complicated. All existing forecast scenarios show high growth rates of transport activities and personal motorized vehicle ownership, combined with a strong increase in fuel use and greenhouse gas emissions. The challenges of transport and environment include, in addition to the problem of greenhouse gases, high pollution levels in the “megacities” of the developing world, in combination with a high level of congestion, land use changes causing losses of biodiversity and agricultural land, noise damage and other environmental problems.

The biggest threat to mankind is the impact of global climate change. To avoid dramatic environmental damage, significant reductions in greenhouse gas emissions from all sectors are required, including the transport sector.

The concentrations of these gases need to be stabilized at a level sufficient to limit the increase of the global mean temperature to an amount not exceeding 2°C above pre-industrial levels. To lower the risk of exceeding the 2°C limit, global GHG emissions should be limited, according to today’s knowledge, to a concentration of 450 ppm CO_2e. The necessary reductions published in the latest IPCC report are in the range of 50% - 60% by 2050 compared to 1990 levels. So as not to hamper economic development in developing countries, developed countries will have to reduce their greenhouse gas emissions by more than 80%.

In the baseline projections from the World Business Council for Sustainable Development (WBCSD), personal transport activity is expected to grow at an average annual rate globally of 1.6% per year up to the year 2030, and on this point growth rates differ widely by region (WBCSD 2004). The baseline scenario projections up to

2050 made by IEA/SMP based on recent trends in various indicators and adjusted for expected deviations due to factors such as existing policies, population projections, income projections and expected availability of new technologies, show a dramatic increase of transport volume and the related environmental indicators. In the reference scenario projection, global transportation fuel use increases by a factor of nearly 2.5 between 2000 and 2050. The total fuel use, by mode, will grow significantly for all modes but buses, with the biggest growth occurring for light-duty vehicles, freight trucks, and air travel. Light-duty vehicles provide the biggest overall increase, accounting for nearly 40% of the total increase. Though air transport has the highest growth rate and will more than triple its fuel use between 2000 and 2050, its overall increase is significantly less than that of light-duty vehicles, and somewhat less than freight trucks. Like fuel use, world transport CO_2 emissions from vehicles are projected to increase by a factor of 2.4, from about 4.6 Gt in 2000 to 11.2 Gt in 2050. Also, like fuel use, the vast majority of the increase in CO_2 will be in non-OECD (i.e., developing) regions. In the current reference scenario, transport (well-to-wheels) CO_2 emissions account for about 24% of all energy-related CO_2 emissions. This includes all transport modes except domestic and international shipping, which when added, will increase the transport share by a couple of percentage points. (However, the high greenhouse impact of non CO_2 emissions like NO_x, diesel particulates and water, especially from air transport, should not be overlooked.)

Against the background of these challenges, business-as-usual development in the transport sector is not viable. To reverse these trends, a number of different reduction options have to be adopted together. It is absolutely essential that we develop a robust, long-term strategy for the transport sector with a comprehensive set of reduction measures.

To reverse the abovementioned trends, a future strategy has to include:

- Reduction of vehicle energy consumption for all modes using existing technology for high-efficiency potential.
- Development of strategies for non-transport alternatives, in combination with sustainable land use planning.
- A modal shift to more environmentally-friendly modes, quickly implemented for passenger and freight transport
- Increased use of renewable energy in the transport sector as well, taking into account climate-efficiency as well as cost-efficiency, together with an optimal allocation of limited renewables in combination with safeguards against the increase of the carbon intensity of existing fossil fuels.

A much more radical approach is needed to address the “Challenges of Transport and Environment”. On this basis, Walter Hook, Rudolf Petersen, Wiebke Zimmer and Uwe Fritsche have developed a contribution paper for discussion at the symposium, “Future Challenges of Transport and Environment,” which will take place on 24 and 25 June 2008, in Berlin.

Axel Friedrich

2 Summary

Future challenges in transport and environment involve various aspects: high growth rates of transport activities and personal motorized-vehicle ownership, megacities with massive air pollution, regions with very high population density, health impacts from noise, land use changes, economic stress from growing infrastructure needs and rising mobility costs, and so on.

To avoid substantial environmental, economic and social damage, the problem of global climate change requires significant reductions in greenhouse gas emissions. To limit the risk of exceeding the 2°C increase in global average surface temperature, it is crucial that greenhouse gas emission reductions by 2050 be in the range of 50% - 60%, compared to 1990 levels, with significant reductions already seen by 2020-2030.

Against the background of these challenges, business-as-usual development in the transport sector must be regarded as no longer acceptable.

Transport Demand Reduction

The challenges to achieving environmentally sustainable transport are similar all over the world but different in detail between highly industrialized countries on one hand, and the developing world, on the other. Both have very different starting points, and different paths towards sustainability.

For all societies, transport growth is a crucial aspect. The high, specifically transport-related energy consumption of the industrialized countries is the consequence of high per-capita passenger and tonnage mileage. Environmentally, this has turned out to be a dead-end street. Sustainable development must aim at a reduction of those high levels of p-km and t-km. In the short run, increases in transport demand have to be mitigated.

For developing countries, social and economic progress is linked to transport growth – but there are some lessons to be learnt. Today, we know that motorized transport has a social cost, as does the vicious cycle of road construction and urban sprawl. Sustainable development demands that we channel mobility and mitigate transport volumes. Social and economic progress is facilitated by access and by connectivity, but not by kilometers driven.

It will be very difficult to implement policy strategies for Transport Demand Reduction (TDR) such as Mitigation. The concept of “fair prices for transport” has broad acceptance in theory but is undermined in practice. In rich as well as in developing countries, private car use receives the most political support, and the same is true for aviation services. (Just to name the most environmentally adverse passenger transport modes.)

Car dependency is connected with inefficient land-use structures. Most people in the wealthy parts of the world are urbanites in terms of social behavior and life-style but have settled in suburbia. They favor the private car, which enables them to put together all the disparate aspects of their daily life. Integrated spatial planning is the key to sustainable urban futures, and it is an absolute must if developing countries are to avoid the failures seen especially in the US (and Canada, Australia).

Car-dependent societies may need some 50 years to resolve their structural deficiencies. In general, European cities and conurbations are better-off because they still have the potential for walking, cycling and public transport. In rapidly developing countries, it is important to avoid establishing the nucleus for car dependency but rather give preference to sustainable modes. A good bus system is important but not enough, in the long run, to persuade an increasing number of car owners not to drive their automobiles daily.

When it comes to freight transport, the commercial interests of the trucking and shipping industry often are misunderstood as being identical with common wealth. It is true that there is a general correlation between GDP and per-capita passenger kilometers driven, as well as ton-kilometers. But this does not justify the simplistic arguments that (a) transport must increase further in wealthy countries, and (b) developing countries should copy that recipe. Correlation is not causality; there are other supportive production factors, too.

Now, the idea of simply continuing on the transport growth path is colliding with realities of the energy market and climate change. The era of cheap fossil fuel is over, and there will be no cheap renewable fuel as a substitute. No technological fix can be invented that would allow today's large, powerful, high-performance cars to be used by two billion or more global citizens. Similar limitations can be identified with respect to road freight, aviation and international shipping. Technical progress will solve some problems but cannot replace the need for transport growth limitations.

Shifting to Cleaner Travel Modes

Changing vehicle technology or fuel types will not in itself solve the problem of increasingly transport-related greenhouse gas emissions, nor should it. Most people driving to work in New York, Beijing, or Delhi, sitting in polluted traffic jams, getting no exercise, and feeling road rage, probably do not feel that the status quo is worth preserving, certainly not at the cost of destroying the planet's ecosystem. But, they are trapped in systems which subsidize and confer status upon automobile travel while providing no equally comfortable and high-status alternative. The modal share of private vehicle travel can be reduced and replaced with public transit, walking and cycling trips through four broad types of interventions: changes in engineering, economics, logistics, and land use.

We can change the way we design our roads, giving priority to safe cycling and fast bus services, by building Bus Rapid Transit services (BRT) and bike lanes. Sometimes this is a zero sum game, where a lane is taken from motorists and given to bikes and buses, but frequently there are cases where rational redesign of the road would be a win-win solution, improving travel rates for private motorists AND buses and bikes.

We can charge more rational prices for the use of roads and parking in ways that are also win-win solutions. Many motorists would prefer to have the option to buy their way out of congestion rather than have a lower-cost but more time-consuming trip. Sophisticated congestion-control fee solutions and High-Occupancy Toll lanes would provide commuters with more options: motorists could pay nothing and take indirect, less congested routes, or pay more and take faster routes. Charging more for parking doesn't penalize people wishing to park, it penalizes short term parkers at the expense of long term parkers. Rational parking pricing redistributes accessible parking to those parking for shorter periods of time.

We can change the logistics of bus services. Bus operations are generally based on historical segmentation of markets rather than on the rational delivery of transit services. There is enormous room for optimizing bus services both with and without BRT systems. Most of the key advances in Bogota's TransMilenio were the result of cutting periphery systems operations more than the result of physical design. We can change the logistics with a BRT system. We can change the logistics of freight. We can change the logistics of private car and private bicycle use, too, by providing car sharing and bike sharing services.

The mayors of the largest cities in the world have the power to change not only their own cities but other cities through their example. Most mayors are pragmatic, looking for popular and practical solutions to everyday problems. Enormous success has been achieved by showing dynamic mayors what other progressive cities have done, and providing them with the technical support they need to make similar changes.

When Paris made it safe and cheap to bike to work, and provided rental bikes, over 1 million people switched to biking in the first 18 days. When Bogota built 50 kilometers of high quality Bus Rapid Transit (BRT) and 250 kilometers of bike lanes in only three years, over 100,000 people a day switched from their cars to BRT, and another 250,000 people switched over to biking. When London imposed a congestion fee, 70,000 people left their cars at home and switched to bicycles and buses which now traveled 20% faster. When Seoul tore down its elevated city-center freeway and built a BRT system, it revitalized its city center. Most citizens in Paris, London, Bogota, and Seoul do not feel like they have made a sacrifice: most feel like their formerly blighted cities have become more livable, lively, and culturally rich places to live and work.

According to Goodwin, in OECD countries, much research suggests that by applying such measures under present conditions, "reductions in car use on the order of 20% to 30% are realistically achieved, in a reasonably short period of time."[1]. In developing countries, which are in the process of motorizing, it should be possible to stabilize or slightly increase the modal share of public transit and walking, thereby avoiding the rapid increases projected for private vehicle use.

Improvement of vehicle specific efficiency

Even if most scenarios agree that TDR and modal shift must be integrated elements of sustainable mobility, today, specific vehicle technology options to respond to environmental challenges, such as energy efficiency measures and alternative fuels for vehicles, are gaining the most support from politicians and the business community. Their support is probably based on the assumption that individual mobility would not be restricted by implementing these options.

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[1] Goodwin, Phil. 2008. "Policy Incentives to Change Behavior in Passenger Transport," Paper presented at the OECD International Transport Forum, Leipzig, Germany, June 2008, p. 17.

There is an impressive variety of technology options to improve the fuel efficiency of passenger cars: in the next 10 to 15 years it is technically feasible to reduce the specific fuel consumption by more than half while retaining today's vehicle characteristics. If reductions in power and vehicle size are taken into account, even higher reductions can be achieved. Depending on the stakeholders involved, a broad range of cost estimates exists for those technology options. However, even if high cost estimates are assumed, life-cycle costs are estimated to lead to cost savings due to the reduced fuel consumption – a fact which will gain more importance in the light of increasing oil prices.

But the projected rise in greenhouse gas emissions from cars cannot be compensated by fuel efficiency technologies alone if the characteristics of cars are not changed as well. To mitigate global climate change, rethinking the concept of "the car" has to be initiated as well: Are the current requirements of power, size and comfort adequate in the long term, given the needs of climate protection? And what is needed for smaller, less-powerful and more fuel-efficient passenger cars to become more widely accepted?

Fuel efficiency regulations for passenger cars can help to push more fuel efficient vehicles onto the market and – to avoid rebound effects – they should be combined with increased fuel taxes.

Furthermore, even if there are fuel-efficiency optimized cars on the market, it is not certain that they will be purchased. Car taxation can be used to encourage more widespread purchasing of more fuel-efficient vehicles. Credits for exceptionally efficient vehicles with refunds related to cost savings from reduced fuel consumptions could stimulate the demand for efficiency technologies. Their production rate would be sped up, and therefore the costs would be reduced by scale effects.

Also important are new communication strategies to make smaller and lower powered cars more attractive on all sides of the equation - manufacturers, governments, NGOs and press are the basic protagonists needed to support a rethinking of automobilization. A code of good practice for car marketing and advertising in order to promote more sustainable consumption patterns should be initiated. The trend towards "supersized" and "superpowered" vehicles has to be reversed as quickly as possible, including tailoring vehicle size to the purpose associated with each car journey. The goal should be new kinds of mobility services.

Similar to passenger cars, a broad range of technical measures for heavy duty vehicles exists to significantly reduce their fuel consumption. But, in contrast to passenger cars, standards to measure fuel consumption of the entire vehicle fleet are lacking. Such procedures based on an on-the-road coast down test for each individual truck model are needed as a basis for fuel consumption regulations and consumer information.

Alternative propulsion techniques are under discussion as well, focusing on electrification of power trains through the use of fuel cells or batteries. But, in order to substantially reduce greenhouse gas emissions, the alternative fuel source (hydrogen or electricity) has to be supplied from renewable energy sources, even if electric cars offer significantly higher tank-to-wheel efficiency levels compared to combustion engines. In addition to further development of full-performance electric and fuel cell vehicles, the competing use options for renewables need to be considered, e.g., stationary energy demand for heating and electric appliances.

Alternative Transport Fuels

Three principal "alternative" fuel options are currently under discussion: biofuels from various feedstocks and conversion routes, and hydrogen and electricity from a variety of primary energy sources. All can "drive" sustainable mobility only if they are derived from renewable sources, and if their environmental and social profiles are more favorable than those of fossil options.

Given the wide range of cost and greenhouse gas emission profiles of biofuels, and the rather large uncertainties in future developments of feedstock supply and downstream conversion, one can assume that, in the longer-term, only a few biofuel systems will be competitive in terms of their sustainability performance: biofuels derived from residues and wastes, and those derived from perennial plants grown on land with low carbon soils, especially marginal and degraded lands. Furthermore, compressed biomethane (BioCNG) from high-productive "two-culture" schemes and from short-rotation coppice might be feasible options. The role of 2nd generation conversion technologies will become key, as these routes allow converting "non-competing" biomass feedstocks into biofuels.

There will be a broad range of possibilities for future transport energy provision and it is clear that the private economic cost of transport fuels will be far higher than those of today, whatever mix of sources, carriers, and conversion systems there may be in the future. Therefore, the role of efficiency becomes critical, not only in terms of environment, but also in terms of the affordability of mobility. However, mobility is the need to transport goods and people in efficient ways. The limits of technology-based options alone require rethinking of the car itself as well as thinking in terms of systems of transport technologies and services beyond the individual automobile.

In conclusion, it has to be stated that there is no silver bullet for solving the majority of the problems that transport and related policy are facing today. All options discussed must be implemented together: the reduction of transport demand in combination with sustainable land use planning, the shift to cleaner travel modes and the extensive tapping of vehicle-related efficiency potentials together with sustainable alternative fuels. A clear and comprehensive perspective is necessary as to which options have the most promising potentials to reduce transport demand and greenhouse gas emissions of the transport sector. To unleash the potential of effective and efficient sustainable transport, a clear and robust mid and long-term strategy for the transport sector is necessary. In consequence, additional measures are urgently required so that the transport sector can live up to its role in contributing to sustainable development.

3 Transport Demand Reduction (TDR)

Rudolf Petersen

3.1 The Need for Transport Demand Reduction

The General Context

Man-made global warming and fossil fuel shortages will remain top priorities in the energy and transport sector for this century. There are no simple solutions at hand; most likely, no miracle or technical invention will keep mankind from having to move to far lower energy consumption levels. Wealthy societies must change their way of living, and highly-populated developing countries will never reach today's level of energy consumption associated with a Western life style. (In the context of this paper: OECD countries´ mobility patterns.)

Energy consumption and CO_2 emissions from transport are increasing. In order to reach overall CO_2 reduction goals, it will also be necessary for all sectors to contribute to CO_2 savings. For the time being, transport energy consumption and CO2 emissions are closely related to each other. (This may change in the long run but not within the next few decades.)

The challenges are:

- To reduce transport energy consumption in highly motorized (OECD) countries;
- To mitigate growth in transport energy consumption in developing countries.

For the purpose of this paper, it is assumed that the transport sector has to reduce CO_2 emissions in proportions comparable to other sectors. The target is a 50 percent overall emission reduction by 2050.

For a global target of 50 percent, this figure will not be sufficient to be reached by highly industrialized countries with their specific emissions rates of 12 or even more than 20 tons of CO_2 emissions per capita. The developing countries will need increasing amounts of transport and thus increase energy use and GHG emissions, if they are to achieve social and economic progress. In order to give them a fair chance to develop, OECD countries will have to reduce CO_2 emissions by some 80 or 90 percent.

(This is admittedly a very rough estimate just to give an idea of the challenge the US, EU, Japan and others are facing. It also is true that, within OECD countries, the specific transport CO_2 emissions differ by a factor of about 2.)

Options for transport CO_2 reduction

There is a vast amount of literature about future increases in transport demand but far less about strategies to mitigate demand. In the literature, often the terms "mobility", "transport" and "traffic" are mixed, and Transport Demand Management (TDM) is seen as management of traffic flow or strategies to reduce vehicle kilometers. Others see

TDM as strategies to shift from private cars to mass transportation and from freight trucking to rail or short-run shipping.

But modal shift is not identical with TDM; shifting demand to more sustainable modes is desirable but will not solve the problems caused by transport demand growth at all. This paper is based on the assumption that sustainability concerns make it necessary to reduce or at least mitigate passenger kilometers and ton kilometers.

Transport CO_2 emissions can be addressed by numerous measures, but these logically depend upon a few basic approaches. Those are

- to reduce (mitigate) the amount of transport, i. e., aim for fewer passenger kilometers traveled (p-km) and fewer freight ton-kilometers (t-km);
- to shift towards transport modes with less specific CO_2 emissions per p-km resp. t-km (for instance, travel by rail rather than by the private car);
- to reduce the specific energy consumption (and CO_2 emissions) of each transport mode by technical improvements, i. e., to make engines and vehicles more efficient;
- to shift from fossil to alternative fuels with less or zero Carbon content.

There is no doubt that the third and fourth of these options are gaining most support from politicians and the business community. These options seem to deliver relatively simple solutions, without requiring the transport industry and/or transport users to undergo major changes.

But it is not clear that technical improvements can go far enough to satisfy the CO_2 reduction requirements in the transport sector. Will there be enough alternative fuels for both wealthy and developing societies? Certainly not for everyone if it means driving today's vehicle types. Those perspectives will by discussed in another paper.

Transport demand and mode shift

Most scenarios assume that modal shift and transport demand reduction must be integrated elements of sustainable mobility (see for instance, the EST project of the OECD). Modal shift and transport demand are closely related to each other:

- Car ownership creates special mobility patterns which often are not suitable for public transport (pt). Long-distance car trips will be substituted by pt, bike or walking to relatively close locations. Some activities will be cancelled.
- During the last decades, private car mass motorization has created spatial structures unfavorable for other modes. The same is true for goods transport: the production and distribution structures are adopted to truck transport. Spatial orientation will change, with fewer trips and lower trip distances.
- In air traffic, only short-distance flights may be replaced by bullet trains; for most flights there is no other mode as substitute. Significant emission and energy reductions can be achieved only with fewer and/or shorter trips.

This leads to the conclusion that transport volumes need to be reduced, or transport growth be mitigated. It is, of course, not possible to name a “right level” of transport, this depends on social, economic and environmental factors. But one fact is clear: It is not possible to increase passenger and ton kilometers indefinitely. It can be assumed that in regions with already dense transportation networks, the economic advantage of additional road construction is smaller that the social and environmental cost. (Here the effect of induced traffic must be taken into account.)

Individual and societal interests

In developing countries, the per-capita car, truck and flight kilometers are far below those of the US, the EU or Japan. Those countries that are now rapidly moving towards "Western" (i. e., OECD) patterns in life style and production structures must consider whether it is economically reasonable to reach OECD countries' transport levels. Fuel costs are far higher than some decades ago and will continue to rise – the eras of cheap oil are gone and will never come back. Both highly-motorized and developing countries must rethink their economic and social structures with respect to transport.

From the individual perspective of Chinese citizens, they have the same right to drive big cars on beautiful highways and take low-cost holiday flights, as North Americans Europeans and Japanese citizens do. But it is questionable whether it is in the national interest to follow the Western patterns.

The idea that transport demand has to be reduced, or demand growth mitigated, is not agreed upon generally. There are two main arguments against Transport Demand Reduction (TDR):

(a) The moral argument: It is not only against humans´ rights to actively reduce transport demand but it is necessary that governments invest in even more roads to also satisfy latent demand. Better and more roads in this context are elements of individual freedom (the right to use the automobile as fast as technically possible, without congestion).

(b) The economic argument: GDP and national welfare will grow with the advent of more passenger and ton kilometers, industries will become more competitive, and so on.

Some thoughts about argument (b): As with all other human activities, increases in passenger and ton kilometers must be limited. There is no doubt that transport contributes to economic wealth – and many countries need better transport infrastructure and more transport - but this has to be balanced against the externalities. As has been mentioned above: There must be a level of transport infrastructure within a region where advantages of more transport outweighs more cost. With all externalities, more GDP will be generated with fewer passenger and ton kilometers.

The following graph (Pastowski 1997) explains this argument. With an extremely low level of transport, economic and social activities cannot be supported. The least developed countries typically suffer from a lack of transport infrastructure, especially in rural areas. It is very costly for farmers to bring their products to urban markets, or even to harbors. Passenger transport is characterized by daily trip rates common in industrialized countries (about 3 trips per day within about 60 minutes) but over short distances. A lack of infrastructure and transport services hinders education and medical services. More and better transport would increase economic well-being dramatically. The environmental damage would increase, too, but the benefits would probably lead to a positive cost balance.

In countries with an already dense infrastructure and comprehensive transport services, additional transport volumes will not bring those social and economic improvements that can be expected in the least developed regions, while the environmental damage of additional roads and additional emissions added to already high transport levels may lead to a greater social cost. The overall balance of more transport would probably be negative.

These considerations are rather schematic. The cost increases will, for instance, depend on specific emissions, vehicle maintenance, and so on. But, basically, it is a plausible approach to locate the situation in OECD countries on the right side of the graph (with high p-km and t-km), while transport in developing countries would be located at the left side. The conclusion: The former would benefit from less transport while the latter would benefit from more.

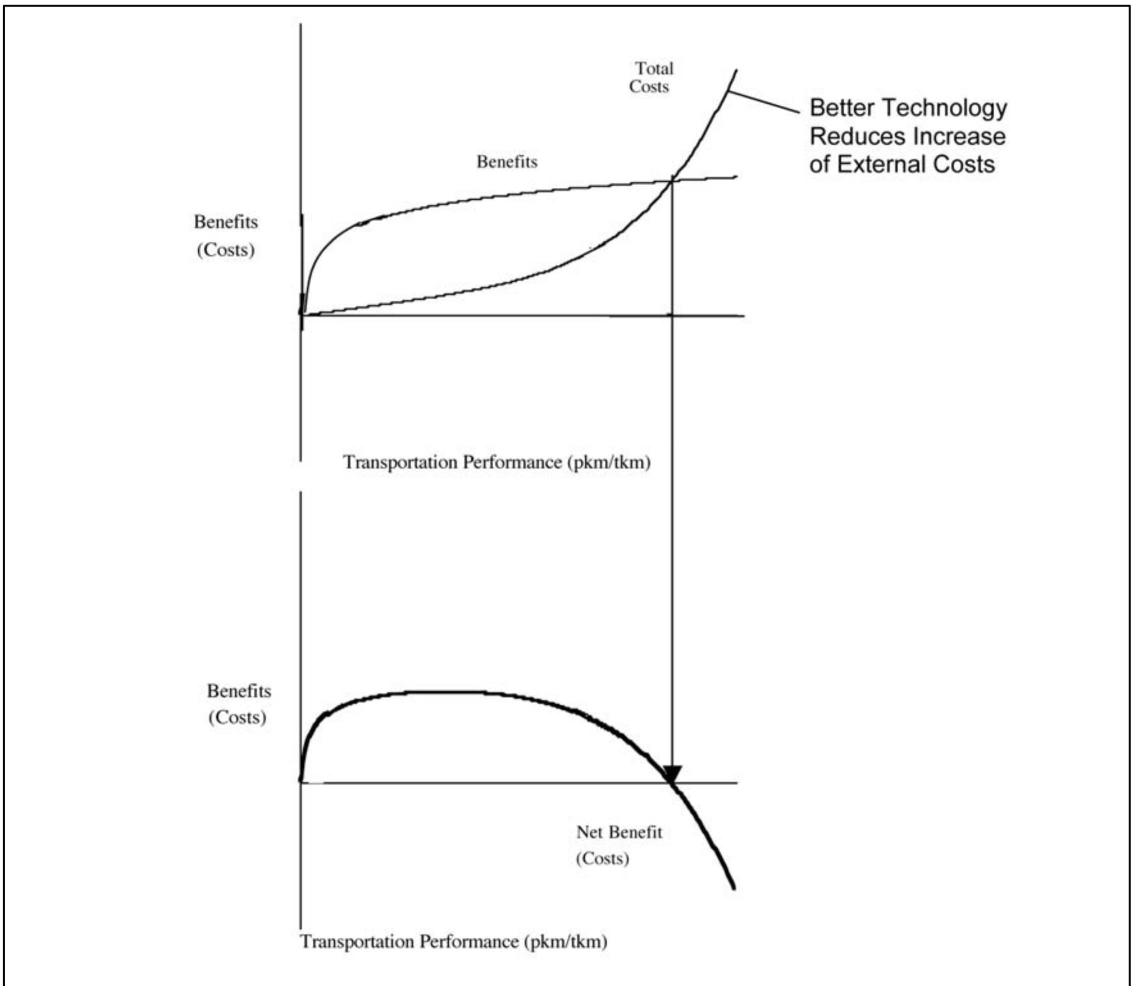


Figure 1: Transport benefits and social cost (following Pastowski 1997)

Many politicians and business people do not dare to think about the macroeconomic advantages of less transport. They hope for new technologies, new fuels or some other miracle to reduce the social cost. This would enable our societies to drive forever. But, given what experience has taught us, there will be no miracle. (And just to make sure:

Our wealthy life style of the past and of today is based on exploitation of nature and of other countries. With bio-fuels, we are merely trying to extend this principle.)

In this paper, the necessary changes are exemplified at the level of passenger car use and – to a minor extent - at that of truck transport. The ideas presented can be adopted at the levels of air traffic and shipping as well.

3.2 The Main Problem: An Automobile Society

People need access to other peoples' activities, and because typically these activities take place at different locations, people need spatial mobility. When these locations are very distant from each other, trip distances are accordingly great. In wealthy countries with well-designed road networks and high household incomes, average trip distances are significantly higher than in countries without high car ownership.

The explanations for high per-capita p-km in wealthy countries are manifold, and include individual life-styles as well as differences in the cost of land between urban and rural areas. Although most vehicle kilometers are driven outside urban areas, the urban structure is of importance for car ownership rates, car dependency and overall car kilometers driven within a country. Economic activities are highest in cities and in suburban settlements around them, and although in Western countries many urban citizens have moved far out into the countryside, they keep their urban habits, including leisure and shopping patterns.

This has led to the traffic problems typical in densely populated areas all over the world, with congestion and air pollution. In OECD countries, planners have been trying for decades to solve problems by extending the road network but have failed to solve any of those problems. Urban transport planners in developing countries are merely reliving this lesson.

Car dependency in OECD Countries

In all highly motorized countries, urban regions have undergone suburbanization. In detail, there are large differences in spatial structures between, for instance, the US on one hand and European countries, on the other. There were – and still are – different economic actors and planning regulations which have contributed to the fact that the (North) American way of living and housing depends much more on the private automobile that the European way does.

A car-oriented transport system is not sustainable. All societies highly dependent on the car will have to face the challenge to reduce automobile dependency. This topic is not new, and planners are searching for better urban structures with less car traffic. There are numerous studies about different modal shares, trip distances and trip purposes in various countries. Amongst others, the work of Newman & Kenworthy (see Kenworthy/Laube 2002) has focused attention on the relationship between population density and per-capita vehicle mileage (as well as energy consumption) in large cities around the world. Especially in the US, Canada and Australia, the spatial structures of housing, working, shopping and leisure make the private automobile the preferred mode to serve trip demands.

Some urban data are given in the Table 1.

Some key land use and transport characteristics of the seven case study cities (1995) (based on Kenworthy and Laube, 2001)

Factor	Hong Kong	Singapore	Munich	Stockholm	New York	Phoenix	Perth
Population	6,311,000	2,986,500	1,324,208	1,725,756	19,227,361	2,526,113	1,244,320
Number of jobs	2,980,151	1,700,900	768,700	838,800	10,108,808	1,035,214	521,810
Metropolitan GDP per capita ($US, 1995)	$22,969	$28,578	$54,692	$33,438	$34,935	$26,920	$21,995
Urban density (persons/km^2)	32035	9353	5566	2902	1804	1039	1089
Cars per 1000 people	46	116	469	386	444	531	658
Length of freeway per capita (metres per 1000 persons)	13.0	44.2	45.3	130.4	112.8	178.9	42.6
Passenger car passenger kilometres per person	930	3570	5913	8460	12,845	15,082	13,546
Public transport passenger kilometres per capita	3,675	3,143	2,622	2,317	1,266	100	642
Percentage of daily trips by walking and cycling (%)	34.1	16.3	32.3	28.0	16.1	4.9	9.1

Table 1: Urban data in several cities (Kenworthy/Laube 2001)

Population density and car use are closely related to each other; only with increased private car ownership it was possible to spread settlements out over large areas. However, when urban areas are supplied with additional roads and parking lots for cars, more and more space is occupied which cannot be used for housing and offices. For each car occupying road and parking space, one urban inhabitant or one office worker is pulled out into suburbia. Average trip distances increase.

The urban data exemplify only part of the problems with car traffic. As has been mentioned above, car ownership is not only putting pressure upon the city itself but also increases the kilometers driven outside the cities and metropolitan areas. When people own a car, they adapt their holiday and leisure activities to the new possibilities. These activities are specifically car-oriented and cannot be engaged in by more sustainable transport modes.

The challenge for OECD countries is clear: Reduction of car dependency, revitalization of the cities as places of residence.

The challenge for developing countries is: Keep dense and mixed-use cities alive, avoid sprawl and waste of precious space, and avoid car dependency.

Both wiser choices by developing countries and changes towards less car use in OECD countries are linked to each other. As observed by Nobel Laureate Pachauri:

> *"This excessive and growing reliance on private vehicular transport is certainly something that doesn't suit large, populous countries like China and India," Pachauri said. "So we have to find a different model for that -- much more efficient and better railway systems, much better local transport in terms of use of public transport options," he told reporters on the sidelines of the Boao Forum for Asia held in the southern Chinese island province of Hainan.*
>
> *Pachauri acknowledged that investment in better public transport alone would not be enough to curb growth in private car ownership. Lifestyle changes stemming from better awareness of environmental issues would be important as well, he said. That, in turn, places responsibility on Western countries. "You won't get lifestyle changes in the developing world unless the developed world also makes some efforts to bring about those changes," he said.*

Basically, transport growth in itself is not seen as a problem by developing countries. On the contrary, transport growth is a necessary element of social and economic progress. People need better access to work locations, education, medical and other services. Developing countries need more and better roads (and rail) to satisfy the needs of the people. But the problems occur in mega-cities, where economic success, growing income and car ownership meet. The trends are similar in all emerging countries (although different in detail).

On one hand we have Latin-American countries with completely liberalized markets where – comparable to the US – commercial developers are driving the land-use trends, by building apartment houses and single houses. On the other, there is, for instance China, with state planning agencies steering land-use development, with political priorities pressing to create urgently needed housing in high-rise settlements located outside the city's ring roads.

There are close links between the life-style values of the societies in high-income and in developing countries: In the rapidly developing countries, people want to enjoy the same habits and products as everyone else. Alternatives to the automobile only will be accepted when they have become common in wealthy countries. Even the fact that the economic prerequisite of auto mobilization, cheap oil, has faded away, is not sufficient to lead people to question the viability of the automobile as long as the US (and others) don't change.

Is it inescapably true that increased income means more cars? Statistically speaking, the main factors affecting the level of Passenger Car Use are

- Income
- Length of roads
- Availability of public transport
- Availability of parking
- Oil products prices
- Cost of vehicle ownership

The correlation between income and car ownership is just one, there are many other factors – and other strategy options for planners and policy makers. Citizens of Hong Kong and Shanghai have high income but far fewer cars than, for instance, Bangkok. There are better models for urban development than Bangkok.

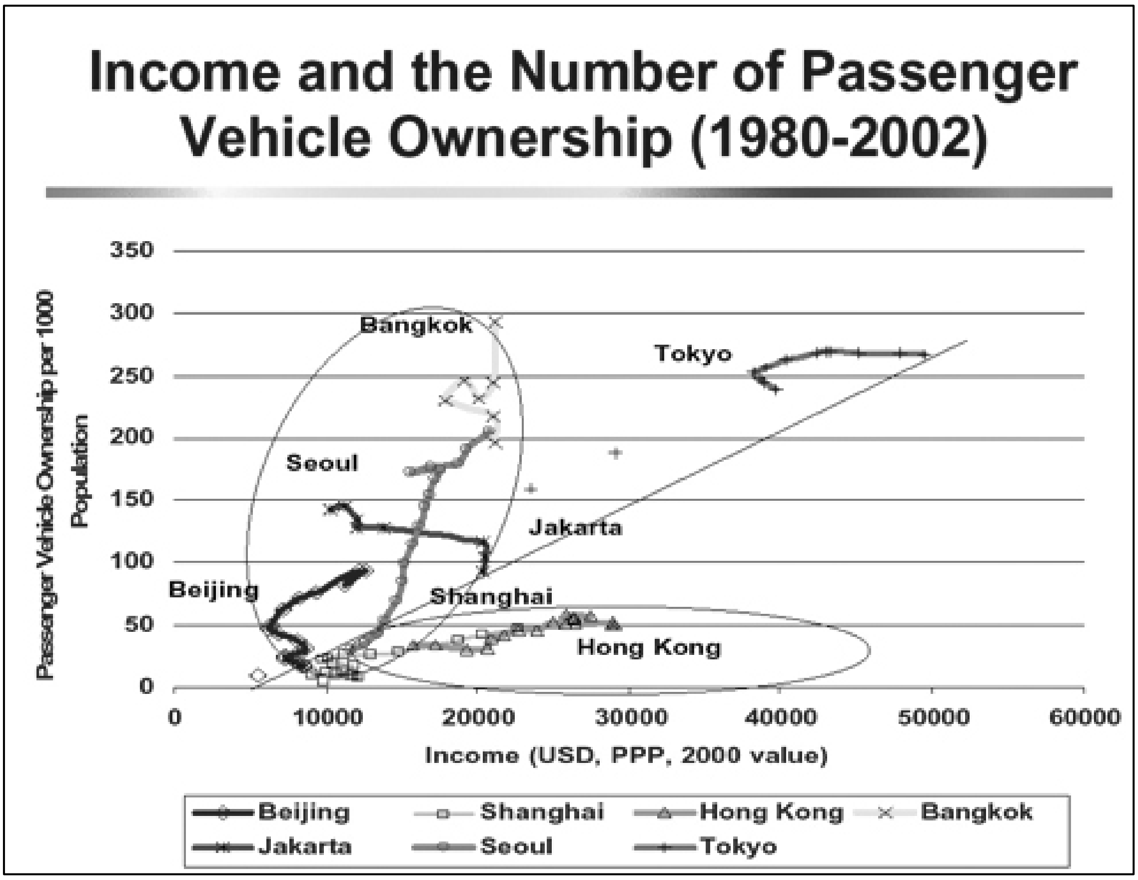


Figure 2: Passenger car ownership and income (APERC 2005)

Car-oriented transport policy at the expense of the majority

It is a fact: a car-oriented mobility policy is a policy for the “happy few”. For decades to come, only a minority of citizens will enjoy the pleasures of car ownership. The large income-gap between the population in prospering large cities and the rural population will remain for decades, and rural emigration will continue, leading to continuous urban growth. These people will require housing and access to food and jobs. It is inevitable that travel will increase. The question is: Where will the places of activities be, how long will the trip distances be, and which travel modes can provide the best solution?

> *"Growth in the use of motorized transport takes place at the expense of NMT, which frequently has resulted in reduced access to transport for (absolute) urban poor and other vulnerable groups." (Melhuish/Huizenga/Shipper ADB 2005).*

While the mobility of the poorest is based on NMT whose conditions are undergoing degradation with the increase of motorized traffic and competition for road space, the motorized modes also compete with each other for space: public buses vs. cars. Passenger and vehicle kilometer data (see, e.g., Bangkok) prove that sparse road space should rather be given to buses instead of private cars because of the better load factors.

This insight is not new but is nevertheless not often followed. For example, the Draft Structure Plan KL 2020 says about the results of a previous plan of 1984:

> *“However, the primary objective of achieving a significant modal shift from private to public transportation has not been achieved mainly because of the lack of integration between land use planning and the rail-based public transport network and between the various modes of public transportation.“*

Why was the mode-shift not successful but car use exploded? Because national policies, commercial land-use development and major road infrastructure investments supported private car use. The settlements, the high-level jobs for officials, managers and academia grew in car-oriented areas. It is no surprise that this kind of development is not in line with the idea of “shifting to public transport“ cited above.

3.3 The Second-Largest Problem: Road Freight Transport

About Freight Transport

While automobile use to a large extent is the result of private preferences rather than of rational optimization, decisions about freight transport are made by professionals in terms of cost calculations. In order to minimize production and distribution costs, commercial actors will try to minimize transport volumes and transport distances, as they try to minimize other cost factors. “Freight transport is derived more from demand from activities within the production, trade and sectors than an activity desired in its own right.” (WG Transport OECD 2003).

> Freight transport is characterized by contradicting interests: society desires to have more specific and cheaper products while at the same time complaining about truck nuisance effects. The first is part of a buyer's market logic, he is not able or willing to transfer his individual citizen's interest into consumer behavior.

Businesses are rational entities and they will go where it makes sense for them to go. If it makes sense for businesses to produce certain products thousands of miles away from where the consumers live, low transport prices will support this. On the other hand, if transport rates are high, the actors will look for other production locations (or consumers in other regions). The latter is in line with the idea of how to reduce transport demand in the freight sector.

Question: Is it possible to benefit from the creativity of a globally free economy, of open markets and globalization, with less freight transport? It does not seem to be possible: There is broad consensus between industry, politicians and economists to reduce transport barriers, which means: Reducing transport cost, for instance, by additional investments in transport infrastructure. But how far should this go?

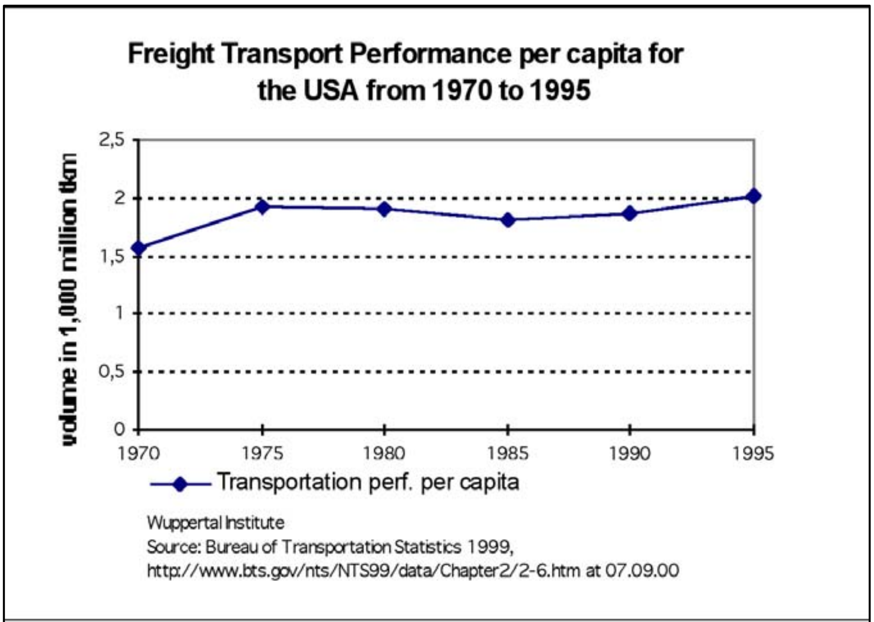
The Situation

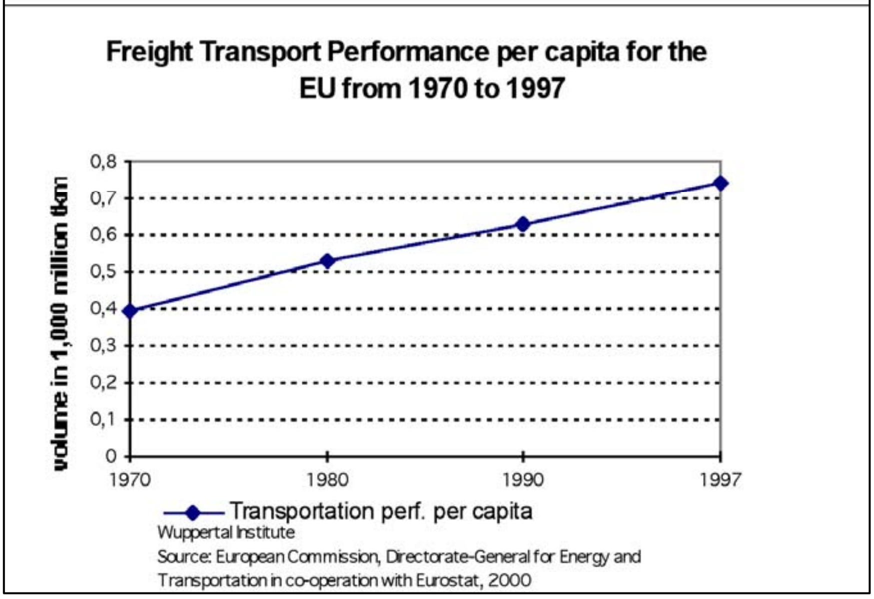
> All governments set restrictions on transport –at least the infrastructure is limited. In other areas of policy making, it is accepted by citizens and businesses that public budgets are limited, and not all restrictions can be removed. We accept waiting times at passport control and in all kinds of public services but when it comes to traffic bottlenecks, private car drivers and the trucking industry call for more roads.

Road network extensions financed by already scarce and deficient budgets may reduce transport costs but other public spending will suffer. The question is how much priority should be given to transport (for investments, taxes, subsidies, accepted externalities) – and what would be the consequences of a more restrictive infrastructure policy.

The one key aspect in discussing freight transport is the mode choice. With production and consumption structures becoming ever more differentiated, the high flexibility of trucking made road freight transport benefit from the general increase in t-km. At best, rail freight was stabilizing in absolute numbers but in rapidly declining relative shares. (This is the European situation, rail success in the US may be different.)

But the topic of this paper is not mode share but the general freight transport volume in t-km. Is higher GDP inevitably linked with a freight t-km increase? Will China also reach the per-capita ton kilometers of the EU or even the US?





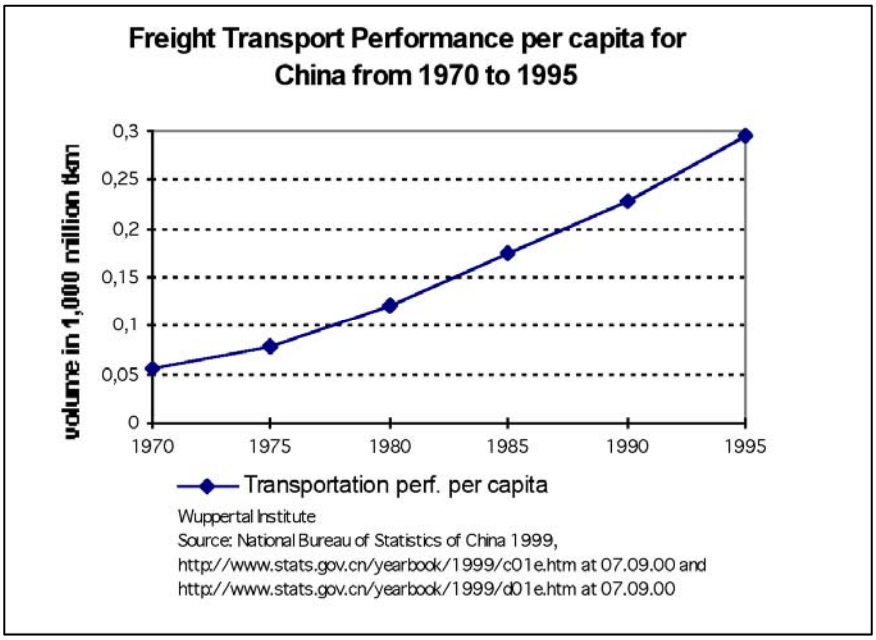


Figure 3: Freight Transport Performance per capita for different regions

The last figures are some 10 years old but the message is clear: Per-capita goods transport in China is far lower – will it reach the EU and/or US level? Which strategies could contribute to wealth growth without, or with a low t-km increase?

Freight transport increase everywhere

In recent years, growth in transport volume in the EU as a whole (EU-15 and EU-25) has closely followed growth in GDP and there have been no clear signs of decoupling of transport volume growth from economic growth (EU - Term 2007). Only GB has reduced the t-km/GDP ratio over several years, but it is not yet clear if this indicates a general shift.

The Mobility Study of WBCSD estimates doubling total t-km by 2050. There are increases in all regions, not only in China and India, but also for instance in the US. Will fossil fuel shortages and fuel costs have no impact on this?

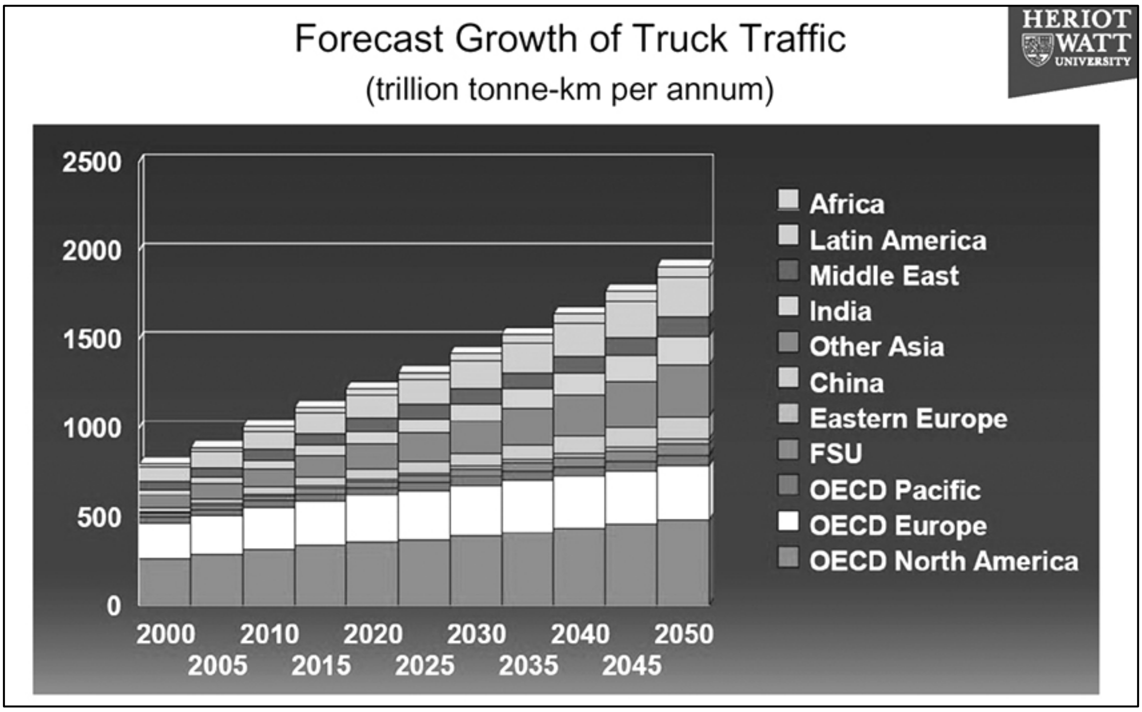


Figure 4: Forecast Growth of Truck Traffic, Source: McKinnon 2008

The reasons for t-km increase cannot be discussed here in detail. There is a common understanding in the literature that on a global scale shipment distances (km per tons transported) will increase further, and the number of transshipments per product will continue to grow with more out-sourcing of components.

Concerning structure of shipments, there is a continued decrease in density and increase in shipment frequency. The trend of consumers buying products over the Internet will increase the use of medium-size trucks for home delivery. (Smaller and more frequent shipments favors truck vs. rail, see discussion about freight mode shift in other paper.)

It might be useful to give some practical examples about the underlying reasons for the overall t-km growth. The case of “The well-traveled yoghurt” (Wuppertal Institute in the 90s) has become a classic example, but there are more, especially in the food sector.

- Food is traveling further and further (between 1000 and 2000 miles on average) to reach consumers. (food US)
- Britain imports 61,400 tons of poultry meat a year from the Netherlands and exports 33,100 tons to the Netherlands. Britain imports 240,000 tones of pork and 125,000 tons of lamb while exporting 195,000 tons of pork and 102,000 tons of lamb.
- 126 million liters of liquid milk was imported into the UK and, at the same time, 270 million liters of milk was exported from the UK. (1997)

This system is unsustainable, illogical, and bizarre, and can only exist as long as inexpensive fossil fuels are available and we do not take significant action to reduce carbon dioxide emissions.

It has been estimated that the CO_2 emissions attributable to producing, processing, packaging and distributing the food consumed by a family of four is about 8 tons a year (= 2 tons per capita).

Currently, no “natural” level of saturation can be seen for this trend of steadily increasing activity measured in t-km. However, this does not mean that such a level does not exist nor does it mean that any such “natural” saturation level would be compatible with what society currently regards as sustainable. (Ahman Sweden 2004)

3.4 Policy Targets and Chances for TDR

3.4.1 Addressing Passenger Car Use in Urban / Metropolitan Areas

Lessons learned

The policy instruments suitable to reduce transport demand have been well-known in principle for decades: spatial planning, taxes and subsidies, legal standards, public investments. So-called “soft policies” may be useful to create support for political actions but are not sufficient: “Appeals on Sustainable Mobility” are useless: In democratic societies, few individuals voluntarily will adopt a technically or socially feasible innovation that does not meet personal needs or desires. “When the future is on trial, the ultimate judge always will be the consumer.” (Long)

Although different societies have to find their own particular paths to sustainability, there are some lessons to be learned from highly motorized (OECD) countries.

- Concerning suburbanization
  - urban land costs support private and commercial shift
  - public services (energy, telephone, water, garbage, medical services, etc) subsidize settlements outside the cities while urban costs should be lower
  - public costs need to be internalized and change the tax patterns between urban and suburban locations.
- Concerning passenger car use:
  - To own a car means to use a car – it is bought for commuting but changes the concept of space for social and leisure activities.
  - If you don’t have a car, you don’t need it, you always can sort it out in another way. But if you start to use one occasionally, and you feel more comfortable, then you get used to it.
  - A car owner is no “homo economicus”, reacting on an objective cost basis but has his own bundle of psychological costs.
- Concerning transport infrastructure:
  - In densely populated areas, road network extensions are not useful to solve congestion problems; the congestion will come back within a short time.
  - Road construction initiates linear development (i. e., commercial investments along the road), rail construction supports concentric investments (i. e., around major rail stations).

- o OECD Countries: stop sub-urbanization, stop road construction

The last recommendations on infrastructure might be the most provocative point. Common wisdom says that congestion would increase emissions and fuel consumption. It would be of public interest to build more roads to solve congestion.

But this is not true; several studies have proven the opposite. For example the British Transportation Board finds

> *"(…) that increasing highway capacity would increase emissions. Although fuel is saved by reducing congestion for a while, the additional capacity induces new traffic that increases emissions overall. The O.E.C.D. states that the provision of additional road infrastructure is rarely a solution, but rather adds to the problem. 15 Intelligent highway systems (e.g. high tech traffic control and incident management systems) could both reduce emissions caused by congestion, and also increase emissions by expanding highway capacity."*

Vision for sustainable urban transport

Which vision can be looked to for a sustainable urban future? The historical urban success story has been based upon the functional mixture of spaces, which has got lost because of the undue preference for private motor vehicle transport. The European city has maintained more compact forms and functioning mixes than, for example, most US regions. This asset can be built on for future sustainable structures. For those urban regions which have lost their structure, it is necessary to develop visions for the next 100 years and start implementing step-by-step strategies.

Developing countries may benefit from the mistakes and the lessons of Europe and the US (and others). One main thought: Urban land is a scarce, precious resource - sustainable cities will manage transport and land-use interaction in order to reduce the kilometers to be driven, and the tons of goods to be transported. The locations of social and economic activities have to be chosen very carefully to reduce transport demand in general, and enable comprehensive use of sustainable transport modes. The benefits of environmentally favorable land-use structures will not only consist of improved urban functionality but also include preservation of urban green spaces for the people, and for natural habitats.

> Now, the mistakes have been made and the goals for (more) sustainable transport have been defined – but what are the solutions and the strategies?

There are two main tools:

- urban and regional planning for access and "green" mobility
- economic instruments to influence cost of transport

Because of the interlinkages and the basic similarity in argumentation, the economic instruments will be discussed in Chapter 3.4.2 - Freight Transport. Here, only a few remarks shall be made on economic instruments for passenger car use.

It is useful to let car users pay for road use directly by a kilometer-based toll. It is technically feasible to differentiate the user fee by region, day/night, congestion, etc. The rates may be adjusted according to the overall goal of reducing total distances driven. A city -centre access fee could prove counterproductive by supporting suburbanization, and may have a negative impact on central development. This may result in even more traffic kilometers in the periphery.

Urban and regional planning for sustainable mobility

Urban space has to serve a variety of human needs: housing, working, places for social interaction, for leisure, and for mobility of persons and goods. Human beings also deserve to have access to nature within their living areas, green spaces for rest and recreation. Trees and green fields help to provide healthy living conditions by cleaning the air of air pollutants, absorbing noise, and regulating humidity of the air. Beyond this direct anthropocentric perspective, conservation of natural habitats is necessary for maintaining the ecosystems all life on earth depends on.

To create or to preserve a livable urban environment, the requirements of these functions have to be balanced against each other. Land-use planning serves this process of balancing competing demands on limited urban areas.

> Where should developing countries look for models: US or (old) European urbanity? In Europe, a relatively stringent land-use planning has steered development – at least to a certain extent. Public transport continues to play an important role, although the private car also is dominating in many cities. City centers have maintained the role of high-class shopping areas, and a livable urban environment still attracts pedestrians.

There is a comprehensive literature about urban mechanisms, including planning recommendations for new settlements and arguments on how to make best use of road areas. (See for instance: GTZ Sourcebook No 4b “Land-Use and Transport” (Petersen 2004).)

Small trip distances and a high level of sustainable modes (pt, walking, cycling) are linked to each other; both depend mainly on spatial structures. Additionally, it takes traffic regulations and the political will to support “green” mobility at the expense of car use. Land-use planning must aim at putting “the right location at the right place”. Offices and shopping facilities must be accessible by high-level pt. It must be forbidden to locate any facility with high customer flows anywhere outside the city. (In the Netherlands, this principle is called ABC-Planning, see Martens/Griethysen 1999. See also Buchanan et al. 2001).

In order to maintain good spatial conditions it is necessary to

- Implement urban land-use plans with requirements for settlement density,
- Define preferential locations for certain purposes – e. g. shopping centers only near PT stations,
- Formulate and implement standards for transit-oriented development,
- Ban developments attracting large amounts of traffic at remote locations that only would be accessible by car.

Some concrete targets

Sustainable urban mobility must mainly consist of these modes: public transport, walking and cycling. A realistic objective (for OECD countries) would be for a mix of these modes to account for at least 70 percent. Car use then would be below 30 percent of daily travel. If this target were to be reached, the trip distances would be reduced automatically.

A spontaneous argument against reducing car use may mention the necessity for car use for work and business trips. On one side, there would be the possibility for mode shifts for many trips, while on the other side people should be aware that most car trips are for leisure and socializing. Here, the time restraints are not as serious as in business. If we add to the portion of shopping trips those dedicated to “recreational shopping”, it adds up to far more than 50 percent of all daily trips that are not job related.

Apart from environmental and energy aspects, reduced car use could contribute to human health. Health experts and pediatricians are sounding alarms on increasing obesity, physical weakness and motion deficits.

The 30 percent figure clearly is a schematic target for cities without considering the specific spatial structures. In some cities, conditions for public transport would be very favorable (for instance in Zurich) while in other cities, walking or cycling would provide the greatest mobility share. At least the 30-percent target would give a direction of what to push for.

National and local governments should commit themselves to maximum shares of passenger car kilometers, the targets would be different according to social and geographical situation. The targets should be the basis for additional budget revenues from international taxes on air and sea transport (for the national budgets), for the local budgets, the national levels could raise road fuel taxes.

On German highways, driving speeds have grown constantly over the years. Despite all public debates about congestion problems, in reality, most car kilometers are driven at free flow conditions with speeds of about 130 kph. If there were the political will to reduce car kilometers, speed limit regulation should be fostered. Environmentalists are arguing for 100 kph limits on highways, 80 kph on rural roads and 30 kph for urban traffic. This will not only result in direct fuel savings per km driven but also in reduced kilometers driven.

3.4.2 Freight Transport

In Europe, the current freight transport volume has been officially identified as a problem, and the decoupling of freight transport t-km and GDP as a key issue (EU White Paper on Transport Policy 2001). It must be admitted that this is not linked to any concrete actions for reduction of t-km but at least it says that there must be ways to more wealth without more transport.

It also should be considered that GDP is a rather inadequate indicator for wealth because it neglects the externalities. When the EU finds it desirable to “decouple” GDP and transport growth, this is a poor target. It would be better to aim at mitigating total transport volumes.

True Cost of Transport

There is a general understanding amongst economists that transport services should pay for the cost imposed on society. Within the EU, it is politically agreed upon that costs for road construction and maintenance should be borne by transport-related taxes or road user fees (toll).

The German toll system once was implemented with the idea that trucks should pay the true cost of driving on the autobahn. But since the introduction of the system, the construction and maintenance costs have not been covered – for several reasons. (The higher toll rates of Switzerland[2] were not politically acceptable. Also, the decisions to apply a toll only on autobahns and only for trucks of more than 12 tons GVW [3]discredited the concept. The dramatic increase in light-duty trucks is supported by the fact that these are excluded from the toll scheme.)

All trucks should pay user fees on all kinds of roads. It is not acceptable to mix fuel tax revenues with road cost. Road pricing based on truck weight and distance driven is a better way to recover road costs because fuel taxes undercharge heavy vehicles.

Social and environmental costs of transport

No consensus has yet been reached about internalization of environmental and social effects of transport. (In this case: of road transport).

Whilst the exact amount of social and environmental costs of trucking is under discussion, there is a general understanding within the scientific community that a major part of the social cost is externalized. In other words: there is a need to increase taxes and/or road user fees.

Underpricing of freight transport supports unsustainable production and market structures. Wages get lost because work places are shifted towards other regions with low income levels. When, additionally, the highway network is continuously extended, financed by public budgets, other production factors like labor cost or education suffer even more. Dedicated highway funds are major barriers to improved logistics since they reduce the incentive for more efficient shipping.

Internalization of external cost is in line with free markets because it corrects market distortions. If these deficiencies were corrected, production and trade decisions would be made with lower transport distances and/or sustainable modes. (The same principle should be applied for rail and other modes unless there were special reasons for it and subsidies were justified. It is not a value in itself to give subsidies for rail.)

Supportive strategies for TDR: spatial planning and traffic regulations

If we assume that all external costs of transport were correctly integrated into taxes and tolls, what would be the result for freight transport demand?

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2 Since 2001, Switzerland has levied a distance-related heavy vehicle fee (HVF) with the key aims of restricting the increase in heavy freight traffic on the roads, promoting the transfer of goods traffic to rail and relieving the strain on the environment. The size of the fee is based on tonne-kilometres traveled on Swiss territory. Monitoring during the first five years of operation has shown that the upward trend prior to implementation has been reversed. By the end of 2005, the total number of kilometers traveled was 6.5 % lower than in 2000 (see TERM 2008)

3 Involvement of vehicles 3,5 - 12 t total weight is planned by EU until 2012

Most likely, the changes in freight transport amounts would be rather limited. Transport cost constitute small shares of product cost, in most goods sectors the share is below some 2 percent. Significant higher shares have been found in construction materials and food. A simulation study assuming a 60 percent increase of transport costs in German long-distance hauls resulted in a reduction of freight tons by 2 percent, and of ton-kilometers by 5 percent.

This leads to the conclusion: "True cost pricing" with external cost calculated in this or similar amounts will not change the transport trends significantly. The problems of calculating external cost cannot be discussed here in detail. Focusing on the GHG aspect, it is worth mentioning that costs of CO_2 emissions are calculated as avoidance costs, which in stationary sectors (especially in private housing) is far lower than in the transport sector. In the scientific literature, there are no attempts to integrate the indirect cost of car and truck dependency into the external cost scheme.

Basically, it is not necessary to justify taxes with any external cost calculations. There is no legal argument why taxes should not be as high as is necessary to reach certain political goals, for instance to reduce transport volumes or to reach certain and/or mode shift. But it will be politically rather difficult to support such a strategy.

The Swiss success in mitigating long-distance truck traffic was reached by applying road user fees and offering rail corridors for truck and container hauling. No publications have been found about that aspect, or whether total ton kilometers have been reduced.

Beside the direct economic instruments, it would be possible to increase transport cost indirectly. The idea would be to make transport less attractive and initiate other production and consumption structures. The most obvious approach aims at road capacity, also traffic regulations. Switzerland had imposed a maximum gross vehicle weight of 28 tons which made it rather costly to cross the Alps there. It is not clear what effect resulted with respect to European road freight transport in general – the heavier trucks made their way to Italy through France or Austria.

But in general it would be possible to increase user costs by imposing truck bans on certain roads or at certain times. Or one could think about a strategy to reduce maximum truck speed. (The speed limit approach could be useful for passenger car kilometers: With average travel time being constant over time, reduced travel speed would lead to fewer kilometers driven. If, for instance, maximum speeds on highways were to be 100 kph, and on other roads 80 kph, travel times will increase. Because in the average travel time budgets are constant, distance would be reduced. Leisure trip distances would shrink immediately, while other trip purposes may take a few years.)

Long term vision: dematerialization and short distances

It sounds trivial, but it may be useful to re-think: There are two possibilities to reduce ton kilometers: (a) to reduce masses of goods (tons) and (b) to reduce distances (kilometers).

Some thoughts about mass reduction or dematerialization: Resource consumption is a general issue in the environmental debate – the topic is not restricted to non renewable energy. Each metal or plastic part of any product carries an invisible burden of materials and energy resources “from cradle to grave”, in other words: during the whole chain from raw material to being handled as garbage (or being recycled).

The concept of dematerialization aims at reducing the amount of materials. (See, for instance, the work of Wuppertal Institute on material flows and dematerialization). The approach also would reduce freight ton kilometers. (On the other hand: The concept to reduce garbage to zero and re-use and recycle all products and materials has led to additional freight transport: One may need fewer truck kilometers to dump the garbage than for transporting it to special facilities for re-use.)

The idea to reduce distances aims at regional production and consumption circuits. For food, this will be elaborated below in the next paragraph. In terms of transport, the optimum would be to create closed material circuits within a city region. “Diagrammatically, cities could move from linear consumers of resources and producers of waste, to a circular metabolic model which recycles its own waste.“ (Girardet)

These ideas have been mentioned as visions, but in the long run they may become more popular. Some further remarks on approaches for lower t-km (see TDM Encyclopedia Internet Victoria Transport Policy Institute):

- Reduce total freight transport by reducing product volumes and unnecessary packaging, relying on more local products, and siting manufacturing and assembly processes closer to their destination markets.
- Encourage policies that reduce total freight traffic volume, including more local production, reduced product weight and packaging, reduced empty backhauls, and reduced waste production.
- Encourage businesses to consider shipping costs and externalities in product design, production and marketing, for example by minimizing excessive packaging and unnecessary delivery frequency, and relying on more local suppliers.
- Increase land use accessibility by clustering common destinations together, which reduces the amount of travel for goods distribution.

Local food production for less freight kilometers

Rapid urbanization leads to a continuous extension of the city into the rural suburbs, bringing large areas under the direct influence of the urban centers. Not only forests, but also other natural vegetation has been replaced by infrastructure, residential homes, office space, industries and other commercial buildings, as has farming, especially vegetable gardening, which for many years contributed to the urban citizen’s food supply.

This development, which has taken place in highly industrialized countries, is being repeated at far higher speeds in developing countries with high population growth.

Traditionally, Chinese cities have been known to mix agricultural activities within the urban setting. The rapid urban growth and the economic boom have contributed to the destruction of that close relationship and to food security. As an example: Shenzhen, which was once a small farming community, is now a megacity, and still growing. This was to be an early example of Chinese dynamic development, due to the fact that the Chinese government had designed it as an open economic zone.

The Shenzen City Government seems to see the loss of local food supply as a problem, as it states on its website: “With Bao'an and Longgang districts urbanized in 2004, Shenzhen has no rural areas and no farmers. But the city continues to develop modern urban agriculture. During the 11th five-year program, the city plans to invest 8.82 billion yuan in 39 key agricultural projects...“ This sounds surprising to free-market economists but can be interpreted as an integrated planning approach: The city cares for regional food production and distribution chains, mitigating freight transport kilometers.

UBA has estimated the transport reducing effect of regional production mainly for farming products at 5 %. This refers to a modification of transport distances. A rather different aspect of food transport has been received from mass reduction (Hoffmann/Lauber_ERNO 2001). Health information linked with sales statistics has proven that Germany’s health problems are also a result of an excessively high calorie intake. The authors calculated transport energy and CO_2 savings of up to 14% when the transported food amounts were reduced to basic human caloric intake requirements.

4 The Politics of Shifting to Cleaner Travel Modes

Walter Hook

The struggle to reduce transportation sector CO_2 emissions in time to prevent catastrophic ecological damage is winnable, though the battle will not be won primarily because of global agreements about climate change. The climate change benefits in transport will have to come as the fortunate residual outcome of decisions made mostly by municipalities and customers for other reasons. The economic, public health, and social welfare impacts of transportation decision-making are far more powerful political drivers of the two trillion dollars in annual global transportation investment. Therefore, successful efforts to reduce transport sector greenhouse gas emissions have been 'win-win' interventions that simultaneously address economic, public health, and social welfare concerns, and highly visible interventions that make for good politics.

Most key transport sector investment decisions are made not by rational economic actors but by governments pandering to special interests, so there is rarely any difficulty finding major transport sector improvements that will significantly reduce CO_2 emissions while also making perfect sense from an economic, public health, and social welfare perspective. Determining optimal solutions, selling them politically, and getting them implemented is never an easy task, but there have been unprecedented successes in the last decade.

If we leave the possibilities of changing vehicles and fuels to our colleagues with greater expertise in this area, there remain only a few ways to change the environmental impact of our transportation systems:

- change the infrastructure
- change the operations using the infrastructure
- change the pricing of the use of infrastructure
- change the land use around the infrastructure.

If we assume any three of these are fixed, it is easy to determine an economic or environmentally optimal solution for the fourth. If we assume that all of these are variable, there are no tools readily available to determine an optimal outcome. As a result, there is enormous scope for innovation by teaming up engineering, logistics, economic, and planning expertise to devise solutions that are economically and environmentally optimal assuming all four are variable.

Decision-makers historically have assumed that land use, transport systems operations and prices are reasonably fixed, so changes in the transport sector have generally focused on solutions which optimize infrastructure to handle passenger demand generated with given transport services, given pricing structures, and given land use. Governments generally design new roads without changing operations, prices, or land uses. New metros, new bike lanes, even new Bus Rapid Transit systems (except in rare cases) are often primarily engineering solutions to optimize the use of a given right of way by multiple modes with different passenger load factors. Engineering solutions are generally implemented with almost no reference to the actual economic costs of providing those services. As a result, most of our transportation systems, even our public transportation systems, are wildly inefficient, creating a huge opportunity for the increased use of logistic, economic, and planning tools to reduce their greenhouse gas emissions.

Even within the realm of purely engineering solutions, there is a huge scope for further optimization. Building an undifferentiated road is sometimes, but not always, economically and environmentally optimal. If the traffic is homogeneous (private cars) and not congested, then free-flowing traffic generally minimizes fuel use to reach a destination. However, with more heterogeneous traffic, the way a road is designed will affect mode choice, and some modes are more fuel efficient than others. Walking and cycling are obviously the most fuel efficient, consuming only the fuel required to produce the caloric intake of the person. Public transport's fuel efficiency is a function of how many people are on the vehicle and the fuel efficiency of the vehicle.

For example, when calculating the CO_2 emissions impact of a transport project in Latin America that has an impact on modal shift, we would use the following table. Knowing the CO_2 impact of a project that induces modal shift, one needs to start with some basic parameters about CO_2 emissions of the existing vehicle fleet per kilometer. Then one needs to know quite a lot about existing travel patterns, and how they are changing (in all but a few places, private motor vehicle kilometers are increasing, for instance).

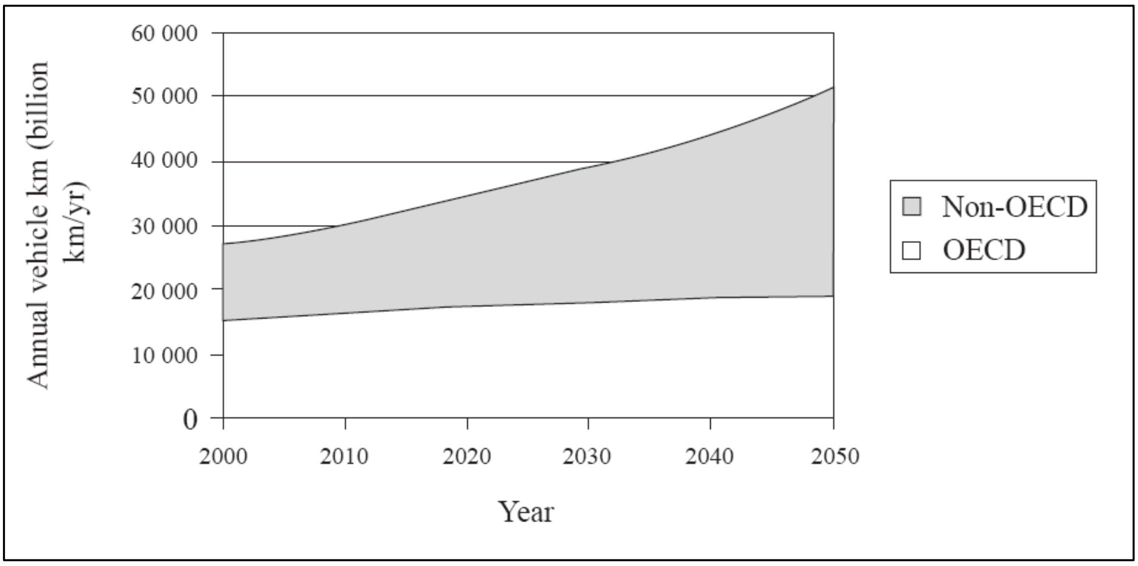

Figure 5: Vehicle use by region (vehicle-km travelled) (IEA/SMP 2004)

Then one needs to have a fairly accurate sense of how any specific intervention will impact these vehicle kilometers by vehicle type. To have any real sense of this, one generally needs to have a traffic model. A traffic model is not going to have very many vehicle categories (big bus, small bus, car, truck, etc, but no differentiation that does not affect passenger car equivalents), so some assumption will need be made about further breakdowns of the vehicle fleet based on aggregate data about the overall vehicle fleet.

CO2 Emissions Per Passenger Kilometer				
	Vehicle Type	**CO2/Veh km**	**Pass**	**CO2/Pass Km**
Buses	Pre-Epa91	2600	65	40
	EPA91	2100	65	32
	EPA94	1100	65	17
	Inter-urban	1097	65	17
	Pullman type	1097	65	17
Articulated	Euro II	1000	130	8
Minibuses	Pre-Epa91	2600	15	173
	EPA91	2100	15	140
	EPA94	1100	15	73
	Inter-urban	1097	15	73
	Pullman type	1097	15	73
	Subtotal			
Trucks	Light and semi-hea\	1097	1	1,097
	Heavy duty	2000	1	2,000
	Subtotal			
Private	Catalytic	300	1.2	250
	Non-catalytic	506	1.2	422
	Average	403	1.2	336
	LPG	343	1.2	285
	Brasilian Vehicle Fle	250	1.2	208
	Subtotal			
Taxis	Catalytic	300	0.5	600
	Non-catalytic	506	0.5	1,012
	Subtotal			
Commercial	Catalytic	396	1	396
	Non-catalytic	600	1	600
	Diesel	330	1	330
	Subtotal			
Motorcycles	**2-temp**	450	1	450
	4-temp	220	1	220
	Subtotal			
Non-motorised	Bicycles	0	1	-

Table 2: CO_2 emissions per passenger kilometer

People choose their mode of travel generally based on the lowest generalized cost of making the trip by a given mode. The generalized cost of the trip includes door-to-door travel time of the trip plus the marginalized cost of making the trip. If you already own a car, the marginalized cost of a car trip is only the cost of fuel, but if you share a car you pay a marginal cost closer to the actual economic cost of the car plus its use. If you think you will be killed, then obviously the marginal cost of making a trip by this mode (i.e., you are literally paying with your life) is going to be higher for this mode.

Because walking and waiting for buses takes time, if parking is available at the doorstep of both home and work, and there is no congestion, as incomes rise and travel time becomes more valuable relative to travel cost, everyone will drive cars all the time because on a road with mixed traffic, private motor vehicles will travel faster than busses because busses have to stop to pick up and discharge passengers, and they do not stop at your doorstep but at a bus stop some distance away.

As a result, a transportation policy that addresses congestion by supplying additional roads and parking at no additional marginalized cost to the driver will result in ever-increasing private vehicle mode share, and ever-increasing fuel consumption as incomes rise. Alternatively, if congestion is contained primarily by having businesses and residents relocate to less congested locations of ever lower urban density, then private vehicle trips *and* trip distances both increase. This is roughly what we have experienced in the US, and a big reason why the US generates nearly a quarter of global CO_2 emissions.

Because a bus with many passengers, a bicycle, or even a motorcycle for that matter, consumes a fraction of the road space of a private car, congestion can be alleviated by shifting people from private cars into more efficient users of road space. This shift in mode is also a shift in mode to a trip which generates lower CO_2 per kilometer.

As a result, alleviating congestion by building more toll-free roads may have a short term benefit of reducing fuel consumption, but its medium term effect is likely to lead to more people driving and more people relocating to more distant locations.

For this reason, the GEF Secretariat in OP 11 did not authorize the construction of new roads as something that reduces GHG emissions, only those interventions that induce a modal shift to more energy efficient modes.

Engineering interventions to induce modal shift

To do this, it sometimes makes sense to segregate the use of the road by providing bus lanes, sidewalks, or bike lanes. This measure only makes sense it if actually increases the speed of travel by these energy-efficient modes.

In other cases, using the same traffic mix but with a different function of the road, it may make sense to remove all segregation of the road users, so that pedestrians mix in the middle of the roadway with trucks, buses, private cars, bicycles, piano delivery men, etc. This has the opposite benefit, of slowing down private motor vehicles to speeds more similar to walking and cycling. A recent innovation has been to realize that a residential street might be safer, quieter, more likely to encourage travel by energy efficient travel modes and to increase property values when sidewalks are removed, allowing vehicles and pedestrians to mix in the middle of the road.

It is dangerous, however, to assume that bus lanes or bike lanes will always induce modal shift towards these modes. Bus lanes, if overcrowded, might actually slow down vehicle speeds. Bus rapid transit systems built where there are no passengers may increase CO_2 emissions. Bike lanes built as part of a congested sidewalk will slow down cycling speeds. Thus the specific impact needs to be studied on a case-by-case basis. Carefully defining the function of the road and the existing and potential users of the road is always the first step.

Because the status quo of un-tolled mixed-traffic road use is so frequently sub-optimal from both an economic and CO_2 perspective, there is enormous scope for possible improvement.

Any major road corridor that has an existing or potential demand for public transit passengers, say anywhere above 2000 (roughly the number of passengers that can generally be moved in a single lane with mixed traffic) and where there is congestion or where congestion may soon emerge might benefit from some measure of bus priority. Every road serving any volume of trips under 10 kilometers with speeds over 40 kph should be designed to accommodate safe travel by bicycle. These two simple rules, if actually applied, would require a fundamental redesign of a huge portion of the world's city streets.

In the developed world, particularly the US, Canada and Australia, where transit volumes are low due to low density, simple bus priority or bike and pedestrian safety engineering measures are probably enough to increase bus speeds somewhat relative to car speeds, and to reduce the cost of bicycle travel (less perceived risk) to induce some modal shift.

In the developing world, where bus travel is more robust, increasing bus speeds is not only a question of busses being blocked by mixed traffic congestion. Often there are so many busses on the road that bus congestion also slows down bus speeds. Once transit volumes rise above 4000 – 6000 passengers per direction per hour (pphpd) a curbside bus lane begins to congest and bus speeds slow. With all engineering measures taken to optimize a single lane bus lane, Bus Rapid Transit such as in Curitiba can move up to 12,000 – 15,000 pphpd without speeds slowing down. By simply adding a second lane to the busway and multiple stopping bays, one can probably maintain maximum speeds (say 25 kph) until about 20,000 pphpd. Above that, it was thought impossible to maintain high bus speeds at higher pphpd. To do so, one needed to leave the realm of engineering and look into the logistics of bus operations.

Modal shift and CO_2 reductions from optimized operations

In order to maintain bus speeds once ridership increases above 20,000 pphpd, one needs to turn to the logistics of bus operations. This is the area with the greatest scope for additional innovation. Most of the secret to squeezing out that extra BRT capacity to over 40,000 pphpd in TransMilenio was achieved by modernizing operations. The physical infrastructure of a BRT system might be perfect, yet its CO_2 emissions may be double that of TransMilenio because bus operations are poorly optimized in relation to passenger demand.

Because bus passengers are not all boarding and alighting at the same place, the speed of their travel can be increased by giving them more direct services. Bus service speeds can be optimized by providing express bus services between high-volume origins and destinations. TransMilenio has the most complicated routing structure of any BRT system in the world because it provides the most options for passengers to minimize their intermediate stops. There are multiple bus route options even on a single bus corridor, and multiple options for passing from one corridor to the next, with different combinations of sub-stops. The careful matching of express services to demand can only be done on systems with passing lanes throughout the system so, to date, only TransMilenio has this capability.

Many bus systems could dramatically reduce their CO_2 emissions and increase their profitability if they simply optimized their routing structure by increasing load factors. Most bus systems operate with their buses half empty for large sections of their trips and for large parts of the day simply because services cannot be easily adjusted to changes in demand. In wealthier countries, if fuel prices were to rise significantly, it may become profitable for bus operators to switch to smaller vehicles for off-peak service.

Sometimes shifting from direct services to trunk and feeder services can increase load factors and reduce CO_2 emissions. TransMilenio removed 6 buses for every new

TransMilenio bus, and replace smaller buses with larger buses, generating enormous CO_2 benefits.

Advances in the reduction of CO_2 in the freight sector all involve advances in logistics.

Even the management and operation of individualized vehicle fleets have been an area of impressive operational innovation in recent years. If individuals shared cars or bicycles instead of owning their own cars or bikes, the parking needs for the vehicle fleet could be dramatically reduced. The logistics of having enough vehicles to meet demand is the secret to these systems. In dense urban areas, space is at a premium. Car sharing and bike sharing have found a market niche based on this simple principle. The CO_2 benefits of bike sharing are enormous. Car sharing has the added benefit of shifting more of the full cost of car ownership onto the marginal cost of car use, discouraging daily use.

Modal shift and CO_2 reduction through pricing

If one assumes that the infrastructure is already built, one has to optimize the price of using this service. Congestion charging for roads and mass transit systems is increasingly popular and can bring about significant CO_2 improvements in some cases.

Most of what is called congestion charging is actually a far cry from optimal congestion charging. Optimal congestion charging would charge motorists a fee at every congested point, normally a junction, at the exact level required to remove the congestion. Flat full-day fees for entering a central business district reduces congestion and car use but it are about 50% less efficient than an ideal point-specific congestion charge.

Designing BRT systems in an iterative process with financial modeling, using variable pricing options, is part of the next wave of BRT system development driven by public-private financing arrangements. If you cannot accommodate more passengers on a specific line, increasing the fare on that line and using it to subsidize the fare in under-utilized parts of the system can be considered.

Market-based parking charging is also an area of recent innovation. People cruising around looking for parking generates needless CO_2 because parking is being undercharged. Increasing parking fees to maintain 15% vacancy rates is optimal from an economic as well as a CO_2 perspective.

Methodologies for setting optimal tolling are fairly easy to come by, but political interference in pricing decisions in the transport sector are the rule rather than the exception, even among otherwise stridently free-market oriented governments. Thus, the realm for improvement is huge, and recent political successes indicate that sometimes rational pricing can also make for good politics.

With economic instruments, as important as the charge on the use of infrastructure is what happens to the revenue. At what point does the optimal solution for the use of the money raised from a congestion charge lead to a decision to again expand infrastructure? There is no clear decision-making principle to guide this, and again we are in the realm of the political. The CO_2 ramifications of congestion charging depend entirely on where the money is spent. If the congestion charge is spent entirely on constructing new roads in auto-dependent suburban locations, the CO_2 ramifications of a congestion charge, or an increased gasoline tax for that matter, may be disastrous. If all of it is spent on mass transit, bike lanes, and deficit reduction, it could be extremely positive.

Conversely, congestion charging within mass transit systems has generally been fought by transit advocates for fear that the higher price would drive away passengers and increase CO_2. However, when a transit line is overcrowded, as is the Metrobus line for Insurgentes in Mexico City, if the government charged more to use that line, the money could then be used to reduce the cost of service in locations where excess capacity existed, or to improve station maintenance and security, or even to expand the system itself. Sometimes, increasing fares is a better solution for transit passengers and for CO_2 in the long run than keeping fares low and having people drive because the system is too crowded, because while demand might be nearly the same, in one scenario the system makes a lot more money.

Changing land use

Land use changes have proven to be hard to influence, but not impossible. Moribund land uses in transit-accessible locations or in city centers are typical of developed and, increasingly, developing country cities as well, and in developing countries the governmental mechanisms for implementing this transition are frequently missing or clumsy. Changing land use rules can sometimes help, but only rarely. Curitiba allowed densification only along its BRT corridors, while restricting development in auto-dependent locations, with excellent results in stabilizing long term transit ridership. Some Asian governments like Hong Kong, Japan, and Singapore have managed through public-private partnerships to actively encourage linkages between rail system developers and real estate development in transit-friendly locations. Less has been done with accessible low-income housing, but there is huge scope for progress.

The political feasibility of measures to bring about modal shift

Until recently, most governments around the world promised to meet CO_2 goals to reduce transport sector emissions primarily through technological changes in vehicle fleets and fuels. There was an overwhelming belief that it was politically impossible to bring about a change in travel behavior because people loved their motor cars and politicians would be unable to induce people to give them up without committing political suicide.

This has proven in the last decade to be completely false. Existing transportation systems are so dysfunctional from so many perspectives that the public is fed up with the status quo and ready to reward bold politicians willing to address the seemingly intractable problems of congestion, air pollution, and poor quality of urban life. Politicians willing to challenge the disproportionate economic power of transportation industry lobbyists are more frequently being rewarded. This change is based in part on more fundamental changes in the economic structure.

Half a decade ago, the industrialized economies were recovering from World War II, and the United States was clearly the pre-eminent economic hegemonic power. In that context, the suburbanization of America was necessary to maintain global economic growth by stimulating the demand for cars, homes, and the products that fill the suburban home. These industries were responsible for the lion’s share of US GDP.

Deindustrialization, however, changed the political economy of transportation decision-making. Like all heavy industry, the automobile industry is no longer the economic superpower in the developed world that it once was. It is now a superpower in China, India, Mexico, and Brazil, but much less so in the US and Europe.

While the labor cost of providing a person with a cup of coffee and a chair overlooking a bustling urban street has remained roughly static over the past decades, the labor cost of building a car has dropped to a fraction of what it was in the early Post-War era. As a result, adding a car to the road in the US now generates a fraction of the number of jobs that it generated back in 1950, and in the future most of these jobs will be generated in the emerging economies of China, Brazil, and India. Hence, it probably made more sense economically in 1950 to dedicate 25 square meters of public space to every parked car than to providing space for another café, but in 2008 the economics have shifted in favor of using the space for a sidewalk café.

The big money today is in communications, computers, entertainment, finance, insurance, health care, and other sectors where it is not easy to standardize production to low-wage workers. Competitiveness today requires a production milieu suited to 'information-intensive' industries. This requires access to a low-cost, healthy, highly-educated workforce, and such a workforce tends to thrive in the same sort of cosmopolitan areas like Paris, New York, Shanghai and Amsterdam that also have successfully minimized their dependence on private car ownership. These are cultures that spend their money on entertainment and recreational experiences rather than on consumption. These cities are adding population while First World manufacturing cities are losing population. These are the structural changes that make it politically possible for a major revolution in transportation systems to be effected within a time frame soon enough to reduce the threat of global warming.

This means that there is suddenly no shortage of corporate allies in battles for fundamental change in transportation policy. To take one example, the most powerful and vocal proponents of congestion charging in New York City were the Partnership for New York City, an institution that represents the largest and most powerful corporations in New York City. Amsterdam, London, Singapore, Venice, Tokyo: these cities have some of the lowest rates of motor vehicle use, and they have some common characteristics. They were all societies where wealth primarily accrued through commerce, trade, and export-oriented industry, rather than through landholding. The Bogota Chamber of Commerce was supportive of TransMilenio, the pre-eminent BRT system in the world, and Singapore, a city with the tightest travel demand management system in the world and transit-oriented development patterns, is also one of the most pro-business governments in the world. In other cases, like London, the leftist-oriented Mayor pushed through the first major congestion charge in a democratic metropolis, while, on the other hand, the leftist candidate in Bogota defeated a center-right candidate pushing for better low-cost mobility for the poor. Transportation policy is almost *ideologically inconsistent*, which means that alliances can be formed across the political spectrum with different branches of the private sector.

A growing number of cities around the world, in both developed and developing countries, are facing problems of transport-sector air pollution, congestion, limited parking, urban blight, lack of public space, and lack of opportunities for exercise.

Rewarding cities that show a willingness and determination to change to fuel-efficient transport systems with high-quality technical assistance can be a powerful tool for change. Municipalities are generally eager to receive technical assistance from recognized international experts with solutions to these everyday problems.[4] Increasingly, due to accelerating globalization and the efforts of ourselves and others, success in one city rapidly stimulates repeat successes in other cities. Within one year after Paris opened its Velib bike sharing program, Buenos Aires, Mexico City, Washington, D.C. and Sao Paulo were all developing bike sharing programs. But news about high-profile failures also spread rapidly. Long-anticipated problems with the Delhi 'BRT' system were reported in Guangzhou two days after the system opened. The rapid dissemination of information on newly successful transport sector interventions can help hasten the replication of successes.

Those areas where major success has been achieved in recent years include the following, roughly in order of their effectiveness:

- Bus Rapid Transit systems
- Traffic demand management
- Increasing bicycle and pedestrian use
- Brownfield redevelopment, transit oriented development, and urban revitalization
- Freight logistics and its relationship to changes in retail business

Other critical areas where we are not aware of any major successes include:

- Explosive growth in air travel
- Shipping and water travel, ports,
- Anything else you can think of not mentioned above.

Each of the areas where interventions have been successful share certain similar characteristics. First, all of them reduced CO_2 emissions, but also category emissions, while improving public safety, quality of life and social equity. Secondly, each project was sufficiently high-profile to attract the interest and commitment of the political leadership, which means they put their best technical people on the project. In each case, politicians believed they would benefit from successful implementation, and in most cases they did. All aimed at reasonably high 'status' interventions where the public identified the implementation as 'progress' rather than as some sort of constraint on development, and politicians saw potential political reward for successful

[4] ITDP alone currently works as a formal advisor to the following municipalities on their transportation and air quality issues: Guangzhou, China; Harbin, China; Ahmedabad, India; Delhi, India; Jakarta, Indonesia; Mexico City, Mexico; Johannesburg, South Africa; Cape Town, South Africa; Dar es Salaam, Tanzania; Dakar, Senegal; Sao Paulo, Brazil; and New York City, USA. In the past, we have worked with Budapest, Hungary; Warsaw, Poland; Krakow, Poland; Prague, Czech Republic. Finding additional cities interested in receiving technical support on these pressing issues is constrained only by the capacity to supply the assistance.

implementation. This political reward was complimented by, but rarely primarily based on, concerns about climate change.

Finally, this process of change is greatly accelerated by facilitating the participation of constructive private sector firms in lucrative markets. Getting bus operators and their consortiums actively promoting and bidding on BRT projects, getting bike-sharing and car-sharing companies interested in emerging markets, getting bike manufacturers interested in emerging markets, finding creative contracting opportunities for turning parking management firms into urban public space management companies, turning road construction firms into transportation systems management firms, finding progressive real estate developers interested in profiting from urban revitalization, transit-oriented development and brownfields revitalization, all of these efforts are critical to redirecting the trillions of dollars of private investment that drive transportation system development.

4.1 Bus Rapid Transit Systems

Bus Rapid Transit is a technology in much the same way that a car is a technology, and just as the car's technology can be changed to be made cleaner through technological innovation, BRT is a comparatively young technology in the process of rapid technological innovation, and these innovations have enormous potential to reduce greenhouse gas emissions. The significant advantages that busses have over rail-based systems in terms of flexibility of operations has only been explored at a very preliminary level by TransMilenio, and few other systems have moved beyond the basics.

Brief History of BRT

The most important change in transportation systems since the later part of the 19^{th} century, according to MIT Professor Ralph Gakenheimer, has been the rapid proliferation of Bus Rapid Transit since the year 2000. Bus Rapid Transit was invented by Jaime Lerner, the mayor of Curitiba, Brazil, in 1974. By giving busses exclusive lanes, and special bus stations that interface with the bus in the same way that a metro station interfaces with a metro rail car, BRT was able to create a high-speed, high-capacity public transit service using bus technology. The specific characteristics include paying to enter the BRT station rather than while boarding the bus, entrance to the bus from a station platform at the same height as the bus floor, and simultaneous boarding and alighting on the bus from as many as four 1.1 meter-wide doors. All these innovations reduced the boarding and alighting time per passenger down to 0.3 seconds. The buses also have an exclusive right-of-way that physically prevents cars from entering. In Curitiba, as in most Latin American BRT systems, delays at intersections were reduced by restricting turning movements and signal phases, not by any traffic signal transit pre-emption. It also had a very simple routing structure, excellent branding, and other characteristics of a metro system.

Curitiba's BRT system managed to move about 12,000 – 15,000 (with articulated buses) passengers per lane per hour per direction (pphpd), at speeds around 20 kph with stations about 540 meters apart, on average. Previously, curb-side bus lanes were only able to manage about 4000 - 6000 pphpd and at much slower speeds, except in special circumstances.

From a climate change point of view, Curitiba's BRT system was of particular importance. Curitiba is one of the wealthiest cities in Brazil, and has one of the highest car ownership rates of Brazil's major metropolitan areas. Despite this, alone among the major cities in emerging economies, Curitiba managed to stabilize its public transit mode share from 1974 into the 1990s at about 70%. Other cities in Latin America, including those that had invested heavily in metro systems, witnessed continuing declines in the modal share of public transportation. Mexico City, for example, with the best metro system in Latin America, saw its public transit mode share drop from 80% to 72% from 1980 to 1990 despite huge investments in its metro system.

Curitiba also changed its zoning rules to encourage high-density, transit-oriented developments along the BRT system, while restricting development elsewhere. This has not really been replicated anywhere.

In the 1980s, partially emulating Curitiba, Sao Paulo, Belo Horizonte, Porto Alegre, Goiania, and other Brazilian cities also built central median busways, but these systems differed from Curitiba in significant ways. All of these systems were 'open' BRT systems where existing buses and their existing routes were simply relocated into central median bus lanes. Because no new buses were procured, it was impossible to achieve the sort of metro-like bus-station interface. Boarding and alighting times per passengers remained much higher, at around 1 second or more per passenger.

Furthermore, in other Brazilian cities, the BRT facilities only existed on the trunk corridors but did not penetrate the city centers. Upon reaching the city centers, the buses entered into mixed traffic, and usually terminated at a depot. This had a lot to do with the way in which bus services had historically been allocated to different private operators. In many Brazilian cities, private operators were given control over different sections of the city's public transit market, divided up like slices of a pizza. This resulted in major difficulties for passengers wanting to pass through the city center. In fact, the main reason that full BRT of the type seen in Curitiba did not spread to other Brazilian cities was due to resistance on the part of the private bus companies to route restructuring and greater public sector control over their operations. (See Ardila, 2004)

From the 1970s until 1998, no other city in the world implemented a 'true' BRT system with all the characteristics of Curitiba's. The first to do so was Quito, Ecuador, under the leadership of Municipal Planning Director Cesar Arias. This system had trunk routes and feeder routes, route restructuring, coherent branding, closed pre-paid boarding stations, it penetrated the city center, and had most of the elements that made Curitiba a success. It took the intervention of the National Guard to overcome resistance from the bus operators to implement it.

Quito's system, like Curitiba, was not implemented with any particular attention paid to potential bicyclists. In Curitiba, bicycle use increased gradually to about 5% of total trips, ironically with the cyclists largely using the bus lanes. This was an unintended consequence of the exclusive bus lanes being not fully occupied, particularly off peak, and has had a positive CO_2 impact, but bus-bike fatalities are very high. Quito is far more hilly, so there have been fewer cyclists using the bus lanes. Nonetheless, planning for cyclists in the corridor is important.

BRT Mania, 2001 - 2008

Then, suddenly in the last decade, Bus Rapid Transit has swept the globe in a truly historic transformation. The success of Bogota's TransMilenio lies behind a large number of these systems. TransMilenio, by introducing passing lanes, sub-stops, and a complex set of express routes optimized to the demand and internal to the BRT system (express busses operate outside the bus lanes in Curitiba), managed to achieve an unprecedented 35,000 pphpd at speeds of 28 kph, which earlier were only believed possible in rail-based systems. Almost all TransMilenio corridors have Grade A cycling facilities along them as well.

The CO_2 benefits of the system resulted from several complimentary factors. First, it stabilized transit-mode share and increased cycling-mode share from 0.5% to about 5% of total trips. About 10% of TransMilenio passengers previously used their automobiles. Secondly, by increasing speeds, bus size, and load factors (passengers per bus) TransMilenio was able to reduce dramatically the number of bus kilometers serving the same population of transit riders, so the CO2 emissions generated by the bus system overall were greatly reduced. Thirdly, TransMilenio introduced quality-of service-contracts that placed stiff penalties on private operators for poor engine maintenance, thus improving fuel efficiency. The busses themselves operated on standard Euro II diesel, which was marginally better than the traditional busses used in Bogota but still not all that clean.

With Bogota as an international state-of-the-art best practice model, ITDP and many other organizations have sent delegations from hundreds of cities around the world to see TransMilenio. These delegation visits are virtually perpetual, with 2 to 5 delegations visiting per month. Former Mayor Penalosa is also a singularly charismatic speaker, and he personally spoke with dozens of mayors and municipal leaders around the world. This process started dozens of BRT projects around the world. Experts involved in TransMilenio were sent to advise other cities developing BRT projects. ITDP then documented the technical secrets of TransMilenio and other BRT systems in the *BRT Planning Guide*, published in 2007 and downloaded free by thousands of users.

Some form of BRT system has opened in the following cities since 2001: Beijing, China; Dalian, China; Chengzhou, China; Hangzhou, China; Delhi, India (opened April, 2008); Pune, India; Jakarta, Indonesia; Seoul, Korea; Mexico City, Mexico; Leon, Mexico; Guatemala City, Guatemala; Perreira, Colombia; Guayaquil, Ecuador. There are probably more, and a dozen others are under construction.

Since the opening of TransMilenio in 2001, however, ***none of these new systems have broken any new ground from a technical perspective, and almost all of them offer a quality of service inferior to TransMilenio's.*** Of all the new systems built since 2001, only Perreira, Colombia and Guayaquil, Ecuador are fine systems with most of the attributes of a full BRT system, but they serve much smaller cities. Virtually all the other systems suffer from fairly serious flaws, planning mistakes, operational failures, and other problems. TransMilenio itself, meanwhile, is facing fairly serious problems. We now face a situation similar to Brazil in 1980, where vested interests have regrouped to destroy the reputation of the BRT, emphasizing the worst elements of less successful projects from around the world. The world urgently needs another BRT home run or the cause of sustainable transport may be set back by decades.

Problems with the New BRT Systems

-----TransJakarta

Jakarta was the first ‘closed’ BRT system in Asia. The system that was finally built had all the features of a proper trunk BRT system: prepaid boarding and alighting stations, at-level boarding and exclusive lanes. The stations and the busses only had one door, however, so the busses and stations became overcrowded despite having only about 4000 pphpd. The system also has no feeder bus network, so demand is low, but this problem was never resolved because the system couldn’t actually handle additional passengers anyway. The system had a host of additional problems.

The lessons of Jakarta are complex. A close level of cooperation with the agency of government actually doing the work is a necessary prerequisite for a positive program outcome. Having the confidence of the most senior decision-makers is necessary for this to happen, and building this trust takes time, and is extremely difficult if the government officials involved are not very ethical or transparent.

-----Chinese BRT

The first proper busway, a light BRT, was built in Kunming with technical assistance from a Swiss Sister-City project with Zurich. The consultant, Ernst Joos, was initially told to design a light-rail or tram system, but when there were insufficient funds, they converted it to a BRT system. This system opened in the late 1990s and although it did not have full BRT characteristics, it was well-designed and worked reasonably well.

In December 2004, the Beijing system opened. The cities of Hangzhou, Dalian, Chongqing, Changzhou, and most recently Jinan all have opened BRT systems since 2004. They all vary in terms of quality and details. There are many nice system elements, but none of them compare to the sort of capacity or speed achieved with TransMilenio.[5]

The planned Guangzhou BRT system is being closely watched by technical experts because the operational design is somewhat unique. The busway is in the central median but the stations are split, one on the right side of each direction, rather than having a single shared central station, because they could not get permission from the national government to operate busses with doors on both sides of the bus. Rather than restructuring the bus routes to create trunk and feeder services as in Bogota, Quito, and Curitiba, the Guangzhou system is designed to accommodate almost all of the existing bus services in the corridor without requiring anyone to transfer. As a result, most of the bus routes operate for stretches in mixed traffic, enter the express corridor, and then exit the corridor. In order to keep the stations from saturating (the usual problem with ‘open’ BRT systems) they built the stations with extremely high

[5] Some basic information is available at http://www.chinabrt.org/

capacity by having passing lanes and multiple sub-stops at each station. The platforms are low, only 30 cm, which will be at-level with a low-floor bus but requires a procurement of new buses with doors on both sides of the bus. The system designers (Karl Fjellstrom of ITDP and Xiaomei Duan of GMTDC) argue that this will combine the benefits of 'direct' service bus routing (no transfer penalties) with the benefits of high-speed closed services on the trunk corridors.

There will be options for paying both off-board at the station entrance, and also on-board for the part of the route when the bus is operating in mixed traffic.

To avoid multiple signal phases at the intersections, the few buses that are turning have to leave the busway well before the intersection and then turn with the normal traffic. As with anything new, there may be unanticipated problems.

-----Indian BRT

All of the initial system design activities in India suffered from a common problem. They all initially assumed that the basic BRT infrastructure could be copied from Quito or Curitiba or Bogota and then built on any road with sufficient right-of-way, with no thought at all about what bus operation would use the facilities. In fact, the best BRT systems are designed around a specific operational plan, where the ridership and boarding and alighting passenger estimates at each station are known. None of the cities had a functional traffic model to actually predict the number of passengers the system might need to carry, or what existing bus routes might need to be rerouted. There was great uncertainty even in the traffic counts. In Delhi, the BRT system had to accommodate a huge number of existing bus routes. Bus speeds inside the BRT system are as low as 12 kph, compared to 27 kph in Bogota, largely due to bus congestion at the stations. The public and press reaction to the system was extremely negative, though the opinion of bus passengers was generally more positive. After a tense period, the Delhi Government basically agreed that mistakes had been made but that they would continue the project with some revision.

The Ahmedabad BRT system is likely to look superficially much better than the Delhi system. The station design is nicer, and it is likely to be a semi-closed BRT system. The problem in Ahmedabad is that the first-phase corridors have very limited demand on them; the better corridors have very narrow streets with huge volumes of motorcycle traffic, so the benefits will be minimal.

-----Metrobus, Mexico City DF

Mexico City's first BRT system also opened in 2004 or 2005. The system is carrying 250,000 daily passengers without having any feeder bus services, but the system is not of the highest quality and the city paid a fairly high price for both the bus operations and the ticketing system.

Other cities in Mexico are also building BRT. Leon has a good system and Guadalajara is now working on one. The State of Mexico has also planned one though it may have been pre-empted by an elevated highway project.

-----BRT in Brazil

Curitiba still remains the only full BRT system in Brazil, though some say that Goiania is also a true BRT. Curitiba has recently added passing lanes to one of its BRT corridors so that express buses can be accommodated, which will bring the Curitiba system into line with best practices. Jaime Lerner therefore recommended to Mayor Serra of Sao Paulo that he develop a high-end BRT system. The Celso Garcia corridor in Sao Paulo, designed by Logit with support from Hewlett, would be high-end and bring high-quality urban characteristics to the corridor, but it fails to penetrate the CBD and will again deposit passengers on the edge of the CBD or enter mixed traffic at the most congested part of the trip.

-----Other BRT Initiatives

Africa has several BRT initiatives underway. There have been numerous South African delegations sent to Bogota organized by ITDP and others. There are BRT projects now in Johannesburg, Cape Town, Port Elizabeth (Nelson Mandela Bay), Durban, and Pretoria (Tshwane). Dar es Salaam is also implementing a BRT project. Accra, Lagos, Casablanca and Dakar all have some sort of BRT efforts underway, and Addis Ababa, Kampala and Nairobi are also in the early stages of planning. The strategy in Africa is to get Dar and Johannesburg built in the best way possible.

-----BRT in the US

In the US, there are some busways but to date none with full 'BRT' characteristics. The closest are the Orange Line in Los Angeles, Eugene, Oregon's BRT, the Euclid Avenue line in Cleveland, lines in Las Vegas and Pittsburgh, and the Silver Line in Boston. Others are in the planning stage.

Through the Looking Glass: Problems with TransMilenio Itself

The success of TransMilenio is by far the most important factor in the rapid dissemination of BRT throughout the world since 2001. Unfortunately, the TransMilenio itself currently has some fairly significant problems, mainly due to political changes in Bogota. In part, TransMilenio has been a victim of its own success. The main criticisms are focused on overcrowding on the trunk lines and slow speeds on the feeder buses, but speeds have dropped on the trunk lines as well. The system is also faced with financial distress, and the model of 'fully self-financed operations' is threatening to break down.

Lessons from the BRT Programs and Next Steps

BRT is an immature technology, so the potential for further innovation is great. The lessons with BRT all over the world are becoming clear. Physical design, contracting structures, ticketing systems, operational control systems, integration with cycling and pedestrian facilities, optimizing urban design, and optimization of operations are all areas where the state of the art is still evolving, and where new systems can still break new ground to improve speed, comfort and convenience, and quality of service.

There are enough examples now of modestly successful BRT systems in almost all parts of the world that purely promotional efforts are less important than before. What is necessary is to ensure that at least one or two World Class BRT systems are built in a few cities, systems that push the state of the art to a new level. Nothing can compare to the impact that actually seeing TransMilenio has on city decision-makers. And we need to have some additional high-level successes. This means cities willing to surpass the achievements of TransMilenio.

Particularly crucial right now are extremely successful systems in China, South Asia, the US and Africa, where the legitimacy of BRT as an alternative still lies in the balance.

4.2 Travel Demand Management

The most direct way to reduce CO_2 emissions in the transport sector is to restrict travel demand by private motor vehicle. This can be accomplished through congestion charging, alternative license plate schemes, parking reform, creating traffic cells, and the removal, shrinkage or prevention of the construction of future road infrastructure.

4.2.1 Congestion Charging

Congestion charging has been discussed as an option since a seminal economic article by Nobel Prize winning economist William Vickery in the 1950s.

1. Singapore

The first example of something resembling a congestion charge was implemented in Singapore in 1975. At that time, it was an 'area licensing scheme', where motorists wishing to enter the central business district (CBD) had to have a special second license on their windshield. The license cost $3 per day or $60 per month. If they did not have this license, drivers had to pay a fine. It was enforced by police standing on gantries around the city center. This very low-technology solution was relatively cheap to implement and worked well. It cut congestion significantly and played a key role in maintaining a public transit mode share in Singapore of around 63% today, which is extremely high for being one of the highest per capita income countries in the world. The system was expanded in 1990 to also include highway tolls.

The area licensing scheme was not exactly a congestion charge because whether or not there was congestion you had to pay to enter the zone, and the charge did not vary during times of the day that have more congestion. In 1998, Singapore upgraded to an electronic road pricing (ERP) scheme. The ERP operated with a small electronic unit inside the vehicle. The car operator has to put cash on the payment unit in advance, create an account with the payment system manager, and pay in advance. Each time the vehicle passes a gantry, a charge is deducted from the cash card or unit. There were initially 33 gantries in 1998, most of these in a ring around the CBD, and by 2005 the number of gantry points expanded to 48, with a growing number of them on congested areas of major highways. In this way, the charge is set based on a rough approximation of actual congestion conditions on the road, so it is closer to a real congestion charge than the ALS. The system required a set of enforcement cameras that took a picture of any car that passed through without a valid electronic cash unit on board. These enforcement cameras were generally placed on the same gantries.

The impact of the ALS and ERP in Singapore was as follows. When the system first opened, trips into the CBD by private car were cut in half in one year, and the number of car trips into the CBD has still not risen to the same volume as the pre-toll level despite a 250% increase in the vehicle fleet (Singapore LTA).

2. Nordic Cities

Several Nordic cities introducing a ring toll around their CBD, including Troningen, Oslo, and Riga. These ring tolls were a flat toll for entering the CBD on any of the major roads that did not vary with congestion and used simple toll gates. There were very few roads accessing the CBD and a couple were actually closed. These toll gates introduce travel delay, but they were required by law to accept cash payments. This succeeded in reducing traffic by 3% - 5%, and increased mass transit use by 6% - 9%. None of these systems vary charges according to congestion level or time of day.

3. London

London reviewed these experiences and decided to implement an electronic cordon charge costing £8. The idea was to avoid the need to open payment accounts and electronic systems for both the cash points on the gantry and the camera enforcement system. Instead, they set up an 'enforcement only' system, where it is incumbent on the driver to pay in advance by a variety of means. If one has not paid, when the license plate is recognized by an enforcement camera, and you are ticketed with an £80 fine if you don't pay by midnight. The idea of this system was to reduce the operational costs of the tolling scheme, but in practice the operational costs were higher than in Singapore. This system had limited flexibility to move away from a flat charge, and as such did not vary with congestion levels at specific times of day or on specific streets.

The system opened in 2000. The system decreased congestion delay by about 30%, it increased bus speeds by about 20%, introduced considerable mode shift to the bus system, bicycles, and some motorcycles (not covered by the charge for technology reasons) and decreased ridership by private cars and the metro somewhat. It brought about significant reductions (13% - 15%) in NOx and PM10.

By offering temporary discounts to cleaner vehicles, the scheme was also used in London to encourage people to purchase cleaner vehicles. These discounts cannot be made permanent, however, or the congestion mitigation effect will ultimately be undermined with the generalization of the cleaner technology.

Politically, Phase I of the London system was successful, and Mayor Livingstone was re-elected. The expansion of the system had less demonstrable benefits, however. The charge has now increased to £12 for a bigger zone. Livingstone lost his re-election bid, not primarily because of this but because of a general trend against Labor nationally and some unrelated scandals. The new Conservative mayor has promised to reduce the congestion charging zone and bring the fare back to the Phase I system. Even under the higher £12 fare (around $20), the increased charge has been unable to halt the recovery of motor vehicle traffic. It is quite possible that in wealthy cities like London, the fare will have to be quite high to maintain a constant level of vehicular use, and already at £12 the equity of an extremely high charge is being questioned.

4. Stockholm

In 2006, Stockholm initiated a trial congestion charge. Their system used a cash box/cash card technology similar to that used in the Singapore ERP system. Stockholm, like Singapore, has very limited access points, and only 13 points control access to the CBD. Each of these was given a gantry with a cash point. The charge for entering the control zone varied during the time of day from 0 – 20 SEK, but not by location. The capital cost of the technology to implement the system was significantly higher than London's ($260 million compared to $150 million) but lower to operate ($26 million compared to $180 million), and the revenue was a lot lower ($105 million/year compared to $350 million/year) Congestion dropped by 25% on the specific roads where the toll was applied, 30 – 50% less delay time in queues, an estimated 10-14% reduction in CO_2 emissions, and other category emissions dropped by around 10%.

Politically, the congestion charge was a trial and voters were allowed to retain or reject it in a referendum in 2006. The measure was approved by the general voters by a fairly narrow margin. The Social Democratic government that implemented the charge lost the re-election campaign, but because of the referendum, the new government decided to reimpose the system, and it was reinstituted permanently in 2007.

5. Other congestion charging systems under discussion.

This successful European experience with congestion charging soon spread to other cities. Sao Paulo, New York, Shenzhen, Mumbai, and San Francisco all mooted congestion charging schemes. New York City got the farthest, but it was ultimately rejected by the New York State Assembly in the Spring of 2008.

6. Conclusions: Hope and Scope of congestion charging

The rapid fall in the cost of telecommunications and the evolution of IT systems is making congestion charging a lot more feasible than in the past. The political success of the London and Stockholm systems indicate that, at least in cities with fairly high transit-mode share and high-income populations, congestion charging can be politically successful and also successful at controlling the growth of transport sector CO_2 emissions. There is a huge scope for continuing innovation in the field. As communications and IT costs come down, it is possible to place image sensors and charging points on every traffic light and make micro-charges against a cash card depending on the specific congestion conditions observed by sensors at that specific location. Such a system would be optimal from a perspective of social welfare and allocation of scarce road space.

Ultimately, the political success or failure of the system depends a lot on the complexity of the legal challenges faced, and what the public believes the money will be spent on. The CO_2 impact also depends on how the money is used. If all the revenues raised were earmarked for road expansion, it is quite possible that a congestion charge over time would increase rather than decrease motor vehicle use by dramatically increasing the supply of road infrastructure. If all the revenue is earmarked for public transit, as was the case in London, it depends on how this affects overall fiscal support for transit. In the case of London, much of the benefit was lost because the national government reduced their support for London's public transit by roughly the same amount. In New York, it was intended to be used for public transit, but there was a heated debate about whether to use the money for the capital program or for subsidizing operations. Subsidizing operations, i.e., freezing fares, was by far the most popular use of the funds according to sampling polls.

There is thus a lot of scope for advocacy and technical assistance for cities interested in congestion charging.

4.2.2 Parking Reform

As with congestion charging, there are new parking charging technologies, but also, and perhaps more interesting, a lot of potential for innovative contracting, where, for example, a private firm might be given the right to collect parking fees but in exchange for this be required to invest in, or maintain, street furniture in the neighborhood, or operate a bike sharing system, etc.

Parking is a classic case of where we don't know if it makes more sense to vary the supply (increase or decrease aggregate parking), the parking charge (site-specific parking fees), or the land use (restrict vehicle intensive land uses in parking constrained locations).

There is school of thought that market-rate parking charging is a form of demand management superior to the congestion charge. Currently, many cities around the world significantly undercharge for on-street parking. Transportation experts now know that it is optimal to have a parking occupancy rate of about 85% so that a driver can readily find a parking spot. In dense urban areas, inevitably on-street parking is under charged, and occupancy rates in popular locations are over 95%, forcing motorists to circle around for a long time before finding a parking space, thus generating needless CO_2 and other emissions. Under-charging for on street parking just means that all the spaces will be taken by the shopkeepers themselves and their staff by early in the day, forcing the multitude of customers to walk long distances. If curbside-charging were optimized, then customers would be able to find a space, and the employees and shop owners would park farther away, reducing aggregate walking time significantly.

Parking is also critical because all trips must involve a walking trip, and because walking is the slowest form of travel: the farther you have to walk to reach that mode, the longer your travel time. According to Knoflacher, if you can park directly in front of your house and your office, this is always going to be faster than walking to the nearest bus stop and waiting. Only when you have to walk farther to get your car than you do to take the bus or your bike will these alternative modes become faster door-to-door. On-road congestion charging does nothing to change this dynamic.

Parking reform is also a better access point if the objective is also to reclaim or reconfigure some street space to enhance the cycling and walking environment.

Parking reform has both an on-street and off-street element. In off-street parking, the battle is primarily over zoning codes with parking maximums or minimums and traffic impact assessment requirements and how they are enforced. Historically, in the US, zoning laws required new developments to build very high levels of parking based on some statistical averages for specific land uses. The averages were driven by suburban developments so the impact of this was to turn downtowns into suburban parking systems, where questions of transit accessibility were not considered. Though Europe has for a long time had parking minimums and also parking maximums in the city center, the US is far behind in this, and many developing countries have followed the US model, though the minimums tend to be lower than in the US.

On-street parking is primarily about the rates charged. All the experts say a 85% occupancy is economically optimal so charging should be set accordingly. The reason for this is that it minimizes the time drivers have to circle around looking for parking, and it rationally allocates scarce parking in the most convenient locations to those patrons likely to spend the least time at the destination, thereby minimizing aggregate walking times. The technology exists to actually monitor the occupancy of on-street parking places within a zone and adjust the parking fees automatically, though I have yet to find any examples of this being implemented. It can be simulated easily through trial and error of having variable time of day charges set at fixed rates in specific locations and adjusting them until the 85% occupancy rate is observed.

The CO_2 impacts of this theoretical ideal are not so clear cut. If parking is optimized from a pricing perspective (as Shoup would certainly argue), then the average walking trip between the car and the destination will drop on average. From the point of view of discouraging car use, having all commercial parking fully occupied by residents may be optimal, as it forces people to walk a long distance to reach their destination. On the other hand, this also generates a lot of needless CO_2 from circulating traffic.

It also greatly depends on how the parking revenue is spent. If the money is spent building additional off-street parking garages, then the CO_2 impacts of increasing parking fees could be quite negative. However, examples like Pasadena, where on-street parking revenues have been used to improve public space, could have extremely positive CO_2 impacts.

Most interesting in parking is finding ways to unlock the innovative and logistical power of the private sector to optimize parking systems while generating revenues for climate-friendly solutions. In a few cases, private companies like Central Parking are being contracted by cities to manage on-street parking, optimize parking fees, and to also manage the security and maintenance of public space in the zone. Interviews with public officials indicate that the main problem with this solution is that the parking companies do not necessarily offer the best quality service or the best deal in the non-parking services. There is nonetheless enormous scope for governments to use clever contracting processes to attract consortiums capable of optimizing both functions, or to simply have parking management revenues earmarked to the city and then using the revenues for climate-friendly transport interventions through standard municipal competitive tendering.

Documenting global, particularly European, best practices in parking policy is a critical next step, and this must include best practices in terms of the contract structures and administrative structures. In the US, there is some advocacy work on this underway in New York City by Transportation Alternatives, and internationally advocacy in this area has only just begun with some preliminary work in Mexico and Dar es Salaam by ITDP. There is enormous scope for expanding this area of intervention, and great interest on the part of municipalities.

4.2.3 Other demand-management measures

1. **Traffic Cells**

There is a school of thought that traffic cells are a better way to manage traffic than through charging. There are often many zones in a city that are important destinations, generally the central business district, but also entertainment districts, residential districts, etc. It is generally optimal not to have major transportation links serving long distance trips at higher speeds pass directly through important destination zones. This is because the designs generally employed to optimize a road whose primary function is to link two popular destinations at high speed (limited access, limited cross-streets, limited signals, etc) are particularly ill-suited to areas which have highly complex movements of extremely short trips which typify certain destination zones.

A simple strategy for improving the quality of life and the air quality in such ‘destination’ zones is to simply make it impossible, via the selective use of one-way streets or the severance of through-streets, to pass *through* the zone. This will force traffic with destinations outside the zone onto peripheral streets, significantly reducing traffic inside the zone. If such a strategy is employed for private motorists, while transit vehicles and bicycles are allowed to pass directly through the zone, this can significantly increase the advantages of public transit and cycling as a mode choice by affecting relative travel times rather than travel costs.

Oxford, England, developed one of the first and better-known traffic cells linked with direct transit services, with very significant improvements in bus ridership. Paris’ Quartiers Verts, or green quarters, do precisely this in popular commercial and entertainment destinations. Such a strategy is often employed in European cities with historical centers. Mexico City has partially done this in the Centro Historico and is open to this as a general strategy. Sao Paulo would be a perfect place to implement such a scheme but as of yet the city has done virtually the opposite, made it possible to pass through the center at high speed in a car (through an underground road) or on one of the two metro lines, while making it all but impossible to pass through the city center on a bus. In the US, there is fairly limited experience with such traffic cells.

Traffic cells can be employed in combination with congestion charging and parking charging, or independently. The question is simply what is easiest to get the political leadership to implement.

2. Alternative License Plate, HOV and HOT schemes

Mexico City, Bogota, and Sao Paulo all implemented traffic restrictions where vehicles with odd or even license plates (Mexico City and Sao Paulo) or license plates ending in a specific number (Bogota) were not allowed to enter the city center on certain days. These programs have led to a one-time reduction in motor vehicle trips into the central business district with significant short term reductions in traffic, particularly in lower-income cities with fairly limited vehicle ownership. The problem with all of these methods is that, over time, they lose their effectiveness. In Sao Paulo, the traffic levels under this *rodizio* scheme returned to original levels within about six years. In Bogota and Mexico City, the same phenomenon has occurred. The problem is simple: people just buy more cars to get around the ban, so they usually keep a very old and polluting car with the alternative license plate for use on those days when the ban is in effect. With motor vehicle costs falling in relative terms over time and incomes rising, such schemes are not an ideal solution and they are politically unpopular. It is probably fairer to the public to allow them to simply pay a fee when they need to enter the city center than restricting access to the city center to those people wealthy enough to afford multiple vehicles, and this is less likely to encourage the use of older, more polluting vehicles.

Jakarta has a variation of this called a three-in-one scheme, where only vehicles with three or more passengers are allowed to enter the CBD. This program has worked somewhat, leading to a triple peak in the traffic, one before the 3-in-1 comes into effect, one at the natural peak, and one after it is no longer in effect. It has also spawned a market for ‘jockeys’, young boys who for a fee will get in your car to create the necessary 3 passengers.

HOV lanes are, of course, used all over the world to encourage people to share vehicles. These have been somewhat effective, mostly on highways, and work well in combination with express bus services that use highways for part of their route. There has recently been some experience in combining such special highway lanes with a tolling option, or what is called ‘HOT’ lanes, “High Occupancy or Toll”. HOT lanes. Minnesota, Texas, and Colorado have all opened HOT lanes. HOT lanes are a particularly important strategy for the US and possibly Europe, where it is rare to find corridors where public transit demand is above 2000 pphpd. In many auto-dependent cities in the US, there are almost NO existing corridors with demand levels high enough to justify converting an existing lane to BRT from a pure efficiency point of view. In these conditions, it is important to allow other types of vehicles to use the same infrastructure, whether it is taxis, trucks, emergency vehicles, or car pools. The important thing is that the regulatory structure optimize the use of the lane so that it does not congest and also minimizes congestion in the remaining vehicle lanes.

3. Blocking or Removing Highways

A growing number of cities are actually removing highways or refusing to build new highways. The most famous case is the removal of the major highway over downtown Seoul that was torn down in recent years. The highway was so blighting that the economic effects of the road itself were far more negative than the economic benefits of serving the traffic. Seoul upgraded its bus system to a light BRT system serving the same corridor, and the result was a huge shift to mass transit. Milwaukee, Wisconsin has also torn out some highways, and San Francisco never rebuilt some elevated highways that fell during the earthquake.

In some cases, older elevated roads serve no important traffic function, yet severely blight neighborhoods. Such roads can often be removed. The Sheridan Expressway in New York is one such road that may be dismantled.

Some cities, particularly in the developing world, are still building new elevated highways. Mexico City, Santiago, and most Chinese and Indian cities recently built or are still building elevated highways in congested downtown areas, blighting large areas of the city. Sao Paulo wants to open the Anhangabau pedestrian zone to car traffic again.

Sometimes it is possible to organize citizens’ groups to fight these major new highways, or to simply convince mayors not to built them, or to tear down existing highways.

Some highways can be blocked on procedural grounds. Often a major urban highway will bring a large part of the city into violation of the ambient air standard, and will antagonize local citizens groups. Fighting a major highway, however, is likely to lead to confrontation with the municipal authority, and as foreigners it is an uncomfortable position to be in and tends to undermine cooperation in other areas. Empowering local advocacy groups to fight such battles without playing a visible role is often the best approach, but generally convincing mayors to focus on mass transit projects instead is the most effective means of diverting resources and attention away from such projects. A good offense is generally more valuable than a good defense.

4. **Downgrading Roads from Highways to Boulevards and Turning One-Way Roads into Two-Way Roads**

Boulevards are designed to accommodate a variety of longer and shorter distance trips handled by a variety of modes. In the 1960s and 1970s, many two-way urban boulevards were turned into high-speed, one-way urban highways. From a traffic speed perspective this appears to be an attractive option, but it often decreases the directness of route, increases pedestrian fatalities, significantly increasing vehicle kilometers traveled and inconveniencing bus passengers and cyclists. Surabaya, Indonesia’s excessive one-way street system is estimated to generate a needless 7000 km of vehicular traffic. As part of Paris’ modernization program, it completely redesigned the Boulevard Magenta, changing it from a high-speed road to a boulevard.

In Sao Paulo, the rodizio, a ring of high-speed, one-way roads that circle and blight the city center, used to be a series of tree-lined two-way boulevards. Returning this back to a two-way boulevard with bus lanes and bike lanes would dramatically transform downtown Sao Paulo.

4.3 Increasing Cycling and Walking

Increasing bicycle and pedestrian infrastructure

Sometimes mayors are supportive of cycling, and willing to invest significant resources in the expansion of their bicycle infrastructure. Cycling in Europe, the US, and in some developing countries is increasing. Of the major US cities, Chicago and New York have probably done the most to increasing cycle infrastructure. Ridership in these cities has increased by about 4 times over the last two decades, though from a very low baseline, and cycling still represents less than 1% of trips. In Europe, there are many major cities with excellent cycling facilities. Most Dutch and Danish cities have amazing cycling infrastructure, and much of this is recent, having been built largely since the 1970s. Mode shares of over 30% of total trips are typical in Dutch and Danish cities. Many German cities also have excellent facilities. Paris has dramatically expanded its cycling infrastructure over the past decade, as have a growing number of English cities.

In the developing world, from the 1970s until the 1990s, Chinese cities were the most cycling-friendly cities in the world, with some cities like Tianjin having over 60% of their trips by bicycle, and with even heavily motorized cities like Guangzhou having a 25% bike mode share into the 1990s. Highway interchanges featured fully grade-segregated cycling facilities, commercial areas virtually all had secure guarded and extremely inexpensive bicycle parking, and it was in essence a paradise for cyclists. In the 1980s, as families became richer, many people switched from overcrowded buses and walking to cycling, to the point where many roads were congested with bicycles. In the 1990s, national cycling policy turned against the bicycle to encourage both increased bus ridership and the consumption of automobiles and motorcycles. The East Coast cities that hosted automobile manufacturing facilities were the most aggressive in tearing out their cycling facilities, while Western cities without auto manufacturing, such as Chengdu, tended to retain their cycling infrastructure. In Guangzhou, bike use dropped from something like 26% in 1990 to under 5% by 2005, while in Chengdu and other western cities, it stabilized around 30% to 40%. This drop was actually reflected in targets embedded in the municipal master plans.

Somewhere around 2005, a growing number of cities started to realize that this policy was causing a lot of traffic congestion and air pollution. Particularly in the south, motorcycle use was exploding with adverse social consequences, such as increased motorcycle-based crime, but also pollution and accidents. This led to a backlash against motorcycles, and a growing tolerance for bicycles again as of today. After a decade of tearing out bike lanes in Shanghai, Guangzhou, and other East Coast cities, bicycle use is recovering and new cycling facilities are being built.

In India, bicycle use varies greatly from city to city. Bike infrastructure in India is decades behind China, and virtually non-existent, though bike mode share was pretty high, around 9% in Delhi in the early 1990s. Bike mode share has been dropping fast in India since then. The new BRT systems being designed in Delhi and Ahmedabad both have good cycling facilities designed into them, and their success or failure is tied to the fate of the BRT movement. Cycle rickshaws still constitute an important part of the commercial traffic in some secondary cities and in parts of Delhi, and modernizing them and incorporating them into modern traffic system designs is something ITDP and IIT TRIPP have done where we can.

In Africa, there are only a few examples of successful cycling facilities being built, despite many efforts on the part of the World Bank, ITDP, and other organizations. Most of what has been built has been substandard from a design point of view. Tamale in Ghana is supposed to be one of the few good practices, and Accra has some disconnected bike lanes, as does Cape Town. Intercity roads in Tanzania have some slow-moving vehicle lanes and good pedestrian facilities, and Temeke in Dar es Salaam has some nice innovative traffic calming designs. Otherwise, there isn't much that I am aware of.

In Indonesia, little has been done to improve cycling. Yogyakarta has some satisfactory bike lanes but they are occupied by motorcycles. We tried a cycle rickshaw modernization project there and it failed: they just couldn't compete with motorcycle and motorcycle taxis. Becak use is dropping rapidly so all becak fleet owners are sitting on huge stores of them, and they are not willing to buy new ones. Probably someone should buy up the best of them and put them in a museum or something. It is one of my fantasies to open a becak museum. Any volunteers?

Integration with other intermediate vehicles

Motorcycles are probably our future, like it or not, and three-wheelers will remain a part of the vehicle mix in some places like South Asia, but could and perhaps even should spread to Africa. Bike infrastructure itself is very difficult to design in the context of heavy motorcycle use. Motorcycle use is exploding in parts of China, in South and

Southeast and East Asia, in Latin America and in parts of Africa. The motorcycle and motor rickshaw combine very low cost, fuel efficiency, and efficient use of scarce road space, with relative speed and comfort. The main drawback is the emissions they create, and the noise, the safety problems they cause, and the degree to which they can degrade public space. From a CO_2 point of view, a shift from bicycle to motorbike is bad, while a shift from four-wheeler to two and three-wheelers is probably good, so the CO_2 implications of growing motorcycle use are not so straight forward.

Roads will increasingly need to be designed for heterogeneous traffic. Preliminary designs for motorways with special motorcycle lanes are being tested in Brazil. In Kuala Lumpur and even in Holland, bike lanes are to be shared with motorcycles. It may be that rather than segregating more and more types of heterogeneous traffic, it will ultimately be that more and more high-volume streets will be designed using the 'shared streets' post traffic calming concept for slow-speed smooth-flow vehicle integration.

Probably in some cities in China it will be possible to simply ban motorcycles and encourage people to use cleaner and quieter normal bicycles or more space-efficient buses, but in other cities it is probably more realistic to design streets for safe heterogeneous traffic at slower steadier speeds, while cleaning up emissions.

Bike Parking

For bike parking, Japan has state-of-the-art parking facilities at many major train stations, and China has built some good functional facilities but could still do a lot more. The Netherlands has great facilities at its rail stations. Germany has some great bike parking facilities also. Bogota's TransMilenio Phase II has a great free bike parking facility that is included in the price of the ticket. The Bike Station group in Long Beach has built some very nice bike parking, rental and retail facilities in downtown Long Beach, in Santa Barbara, and about a dozen other cities, with a new facility at Union Station in Washington in the works. They benefit from high class architecture, and a sort of branding that makes the model attractive. There is no reason why this bike station effort could not be commercialized, however, and turned into a transitional phase for a broader bike sharing program.

Just as BRT stations are ideally not all uniform, but vary in size and offer a variety of transit passenger services depending on how big the station is, with the most extreme case being a huge transfer facility where a mall developer might build a PPP transfer and shopping facility, bike parking can be thought of in a similar way.

At a major transit hub, like a rail station, one might need a Type I facility, a huge multi-service facility which provides all bike-related amenities, from bike parking retail sales, daily rentals, repairs, showers, lockers, maybe even books and information about cycling and transportation, maps, coffee, all the amenities. Potentially, this Type I facility can also be a place to get a shared bike. This is the sort of thing being planned at Union Station, and that exists at some rail-station bike parking facilities in Europe, though interestingly in Washington, D.C. there is no relation between this facility and the bike sharing program. Why not? These are not needed everywhere, only in very high volume destinations.

Phase II facilities might only have guarded parking for private bikes and shared bikes, some minor repairs, and minor retail. Phase III might have only parking for private and shared bikes. Phase IV might be only a bike rack. If a person can rent and return a bike at any Phase I or Phase II Bike Station, then you already have a mini bike-sharing network. It was irritating to me that in Holland you have to return your rental bike to the same train station where it was rented. By franchising the bike stations, one could allow renters to return them to any facility, with much greater convenience. This then moves on to bike sharing.

Bike-Sharing and Car-Sharing

Paris Velib has revolutionized the prospects of bike-sharing systems. Starting in the late 1990s, there were credit-card based bike-sharing systems in place in a dozen or so European cities, including Rennes, Amsterdam, Vienna, Lyons, Oslo, Brussels, Stockholm, Helsinki and Barcelona, but they were small in scale. With bike sharing, scale matters a lot. In Paris, bicycle-mode share increased by only 48% from a very low baseline from 2001 to 2006, despite a huge investment in good cycling facilities. The French did surveys to determine the obstacles to bike use, and bike parking both at home and the office was the main problem. The bike sharing system overcomes this problem because they are parked on the street.

Velib opened in 2007 with 10,648 bicycles and 750 parking stations, and was set to have 20,600 bicycles and 1451 stations by the end of 2007. There is a parking station every 300 meters in the center of Paris. The system attracted over 1 million rides in 18 days, and is getting nearly 100,000 rides per day, some percentage of which were previously motor vehicle trips.

There is no question that the link between on-street advertising and bike-sharing is part of what made this a success. A big corporation like DeCaux or Clear Channel would never have been bothered with bike-sharing if there were not some lucrative contract associated with it. Because DeCaux and Clear Channel are major corporations, they are now promoting bike-sharing all over the world, and this is a dynamism that we NGOs can rarely match. Buenos Aires, Sao Paulo and Mexico City, are all talking about bike-sharing programs, and these are just the ones we know about.

A few things about bike-sharing can be improved upon, and questions remain:

First, the system is more expensive to operate than it needs to be because people guessed wrong about the number of parking spaces they needed and the fleet size they needed at each parking stand. Some places are oversubscribed, some undersubscribed, and to compensate the company needs to shift bikes around, which costs a lot and generates some CO_2. Optimizing this from the outset is a modeling exercise that someone should work on, and I am sure it could cut the operating costs a lot.

The contract structures are also important. If one company comes in with a contract in Zone I, expanding the system to a wider zone with a compatible technology is difficult to do without violating competitive tendering. Either when the contract is initially tendered the winning firm should win the rights to a very large area, even if not implemented all at once, or else the contract needs to stipulate that whatever payment system is put into place must be open to expansion and use by other firms with compatible technology.

Other questions for bike-sharing include how these facilities relate to other bike rentals and sales, and why there needs to be a DeCaux or Clear Channel to implement them. Currently, Paris bike-sharing only has parking for Velib bikes, which means that normal cyclists have to find somewhere else to park, but there is no reason why some normal private bike parking could not be provided at the same time. Velib is also oriented to short-term rentals, but sometimes long-term rentals are what you want. Interaction between the Bike Share and the Bike Station concept would make for some interesting new possibilities, as discussed above.

Car-sharing is also taking off due to successful firms like Zip Car. ITDP is not particularly expert in this field but the US DOT issued an evaluation of US car-sharing programs, and certainly they are an important part of allowing families with children to live car-free. How to facilitate their spread into developing countries is an excellent area of intervention, and could be done in collaboration with corporations interested in this.

Modernizing the Human-Powered Vehicle itself

Though this should really be discussed by those working on alternative vehicles and fuels, since I suspect this will not occur, it is discussed here. In developed countries, the bicycle and human-powered vehicle supply itself is not really an obstacle to bike use. People are rich, and the cost of a bike relative to incomes is so low that one can buy virtually any type of bike reasonably easily in the developed world.

In the developing world, however, the situation is different. Bicycle markets in India are heavily protected, monopolistic, and resistant to innovation, and consumers are often very poor and highly sensitive to price and quality. In Africa, users are very poor, many markets are protected by tariff barriers, and the lack of any domestic supply contributes to high costs.

ITDP had a major project to modernize the Indian cycle rickshaw, and the new design took off, selling over 300,000 units and winning over as many as 15% of the customers from previously motorized modes. This project was a reasonably big success in the field, but the process of innovation stopped when the new design was accepted. What is needed is a commercially-driven process of continual innovation in human-powered vehicle technology, and this is difficult to induce because the profit margins are too low to attract innovative entrepreneurs or for ‘sexy’, first-time products to yield enough of a premium to encourage innovation. There are also monopolistic conditions in the vehicle supply sector. Aggressive international bike firms, in partnership with new entrepreneurs in emerging markets, if they were to partner, could greatly improve the quality and reduce the cost of good quality non-motorized vehicles, and thus become a force for continual innovation.

ITDP’s California Bike project in Africa succeeded in demonstrating to South African bike companies that a market exists for better quality bikes in Africa, selling over 7000 lower-cost, higher-quality bikes. The brand name is going to be taken over by ProBike and hopefully become a Pan Africa franchise.

4.4 Transit Oriented Development, and Urban Revitalization

The simple goal of encouraging high-density development along high-capacity transportation corridors, and low-density development along low-capacity transportation corridors seems trivial theoretically, but politically speaking it is exceedingly rare. The problem looks completely different in different contexts, and therefore has to be approached differently.

In the US, the decline of the central city and the resulting automobile-based transportation system resulted from a combination of push and pull factors, varying from the structure of housing finance, a history of racism, subsidization of private car travel, weak municipal control over criminal activity, and reasonably standard problems of old building stock, like old machinery, developed under different economic conditions, being obsolete to the economic needs of the modern economy, and the relative costs of facilitating this transition.

The US has made enormous strides in the last few decades in terms of slowing down and reversing the process of central city decline, though the process is highly heterogeneous. New York City has added population since 1980, and has finally reached an all-time high, after several decades of losing population after World War II. The density of the city and transit ridership are growing rapidly and this process is projected to accelerate. There were many factors behind this turnaround, some of them macroeconomic, but some of them with relevance to an action agenda.

Large areas of New York were badly blighted, with disinvestment and criminal activity. Turning these areas around required not only transport system investments (the NYC MTA was saved by a massive investment in infrastructure renewal starting in the 1980s), but also the creation of a variety of public-private partnerships for consolidating and redeveloping land (the Empire State Development Corporation), infrastructure modernization and investment, and pro-actively marketing these areas of the city and attracting major investors. In addition, Business Improvement Districts were created that did a lot to bring activities to the areas, improve street cleaning, security, installation and maintenance of high-quality street furniture, and promotional activities.

These interventions are now well established in the US and Europe, but virtually unknown even in the better developed parts of the developing world.

In post-socialist Central and Eastern Europe, the dynamics of urban restructuring were fundamentally different. Huge international developers were desperate to invest in the central cities of Central Europe but were prevented from doing so largely by regulatory barriers intended to protect indigenous capital, and by a complex maze of property title complications related to restitution claims from pre-Socialist times, to corrupt and opaque land-privatization processes after the transition, and a host of bureaucratic regulatory problems that served no particular purpose other than to drive any developer to the suburbs just to escape the regulatory tangle. This mess was as true for brownfields and blighted historical neighborhoods as it was for transit-accessible old railway yards. ITDP, together with former real estate developers, US experts from the APA and brownfields experts from the EPA, helped the Czech national government and several municipalities initiate brownfields revitalization programs to overcome these barriers. The lessons learned are fascinating but somewhat specific to transitional economies that have gone through a process of de-militarization and de-industrialization. We succeeded in facilitating the redevelopment of several brownfields sites in the Czech Republic and established a valuable precedent. In Budapest, ITDP's partner organization, CAAG, worked with the 9th District to do some extremely innovative urban revitalization but this was only possible because the properties had remained in the hands of the District government. ITDP Europe has excellent information on this that could be very valuably extended to Eastern Europe and municipalities in former Soviet states, where similar issues are frequently confronted.

ITDP started urban revitalization programs in Sao Paulo and Mexico City, where the problem of city center blight was emerging as well, with a dynamic somewhat different from that in the US but with some similar characteristics. In both Mexico City and Sao Paulo, the government had yet to develop the sort of legal mechanisms required, let alone the institutions required for the government to seize derelict properties (even if they are in tax arrears), assemble the properties, improve the infrastructure, and attract investors. In the Centro Historico of Mexico City there was the additional confusion of the properties being historic landmarks enmeshed in a needlessly restrictive historical preservation legislation. As a result of the restrictions on private investment, valuable historical properties are being allowed to collapse and be used as surface parking. Business Improvement Districts have been discussed but are generally viewed with suspicion. These problems were also exacerbated by poor parking regulation, criminality, and other problems.

Convincing governments of the need for such institutions, getting them to focus on a specific revitalization strategy, and giving them the legal powers to bring about intelligent change in urban form, is an enormously complex task, but an important one if the city centers are not to be allowed to decay.

In China, most of the land remains indirectly or directly government property, so it has been extremely easy to increase the density of urban development. Any time a mass transit system is built, or even a road widened and a bus service added, the properties along the infrastructure tend to be torn down and replaced with high rise buildings by private developers. Transit-adjacent development is an automatic process in China, and there is no real 'urban blight' in the sense as used in the US. However, much of this high density development is not well designed to encourage a pedestrian-friendly environment or a smooth interaction with surrounding mass-transit systems. Convincing Chinese developers to implement more humane and pedestrian-friendly design could help a lot.

4.5 Freight and logistics and their relationship to changes in retailing

In many parts of the developed world, particularly in Europe, emissions from private passenger vehicles are stabilizing while emissions in the freight sector are growing rapidly. It is not yet well known what impact the transition to Internet-based commerce is going to have on transportation systems, but it is likely that it can help households live car-free (virtually everything can be delivered to the door), but will increase the amount of trips by delivery vehicles.

The impact of replacing corner retail establishments with big-box retail chains is still an unknown, but the following is known based on past ITDP research. Firms like Ikea and Wal-Mart claim that their freight systems greatly rationalize trucking, which is a key to their competitiveness, and which they claim reduces CO_2 emissions. This is entirely possible, though one must also look at what the introduction of this type of big-box retail store does to the travel patterns of their customers, and this is not clear.

In China, Wal-Mart is as frequently located on a pedestrian mall in the inner city as it is on an orbital motorway. Such a big-box store probably has fairly efficient internal freight logistics, and since the customers tend to arrive using mass transit or bicycle, there is nothing particularly wrong with this model. In Latin America, it is likely to be located on a highway, but likely to serve primarily residents from smaller towns and rural areas who may actually be traveling less far than they used to. In Central Europe, it could be in the city center or on a major arterial or transit hub, or on an outer ring road. The more transit-friendly the location, the more likely its consumers will generate lower emissions, and we will assume that trucking is reasonably efficient. In the US, these facilities tend to be huge generators of traffic, and this traffic generation is probably greater than the benefits gained from efficient internal freight logistics.

In conclusion, these big-box retail chains are sensitive to government policy. If they locate in a downtown area in the US or Central Europe, and that downtown area allows them to build a massive 2000-unit parking garage, the impact of the development on local emissions will be very bad. If the government encourages them to locate in transit accessible locations, it will be less bad. In short, the main problem lies with the impact on consumer travel behavior more than the logistics of freight itself.

In Europe, there is also a problem that a lot of the railways are publicly owned, and many of them are not particularly well managed. In Central Europe, they often serve as slush funds for certain political parties, are very subject to political manipulation, and hence they are often not terribly competitive. In the US, freight railways are largely private and they have managed to maintain mode share in heavy long-distance freight distribution. Fixing this problem in Europe, encouraging rail freight and combined transport, is bound up in the problems of privatizing the state railways, which is a messy and complicated business.

Certainly one thing that will help is fully internalizing the costs that trucking freight imposes on the road network. Trucks are responsible for a disproportionate level of wear and tear on the roads, and road-user fees are rarely structured in a way which fully reflects this. It was a long political battle to even allow governments in Europe to charge through trucks fees for road damage and environmental problems that they caused, because the EU blocked this on the grounds of constituting barriers to free trade, and in fact many were proposed in ways that were prejudicial to foreign trucks. Recent revisions in the EU Eurovignete System, I believe, allow for eco-taxation of trucking under certain circumstances.

There are also some national road-user fees imposed on trucking in Germany and under discussion in the Netherlands which should help end the pricing distortions that favor trucking over rail freight. Germany charges a fee for trucks over 12 tons on

12,000 km of its autobahn system. The system uses 500,000 on-board GPS units to track and bill the trucking companies.

5 Technological Opportunities in the Transport Sector

Wiebke Zimmer, Uwe Fritsche

Even if most scenarios assume that transport demand reduction and modal shift must be integrated elements of sustainable mobility, today, specific vehicle technology options to respond to environmental challenges, such as energy efficiency measures and alternative fuels for vehicles, are gaining the most support from politicians and the business community. Their support is probably based on the feeling that individual mobility would not be restricted by implementing these options. The question which has to be stated in the beginning of the this chapter is to what extent the tapping of vehicle specific energy efficiency, a change in consumer behavior in terms of power, size and comfort and alternative fuels, can contribute to climate protection.

5.1 What options are in sight for improving the fuel efficiency of passenger cars?

The number of vehicles will dramatically increase in the business-as-usual scenario in the coming decades with regard to passenger cars as well as heavy duty vehicles. As stated in the handbook of the automotive industry, the global number of vehicles will nearly double from around 0.8 billion today to up to 1.6 billion in 2030. Even by furthering transport demand reduction and a modal shift, significant improvement of vehicle fuel efficiency will remain a major factor for reducing energy demand – for passenger cars as well as for heavy duty vehicles.

The passenger car is the transport mode most discussed in this context. In principle, fuel efficiency can be optimized directly through engine and drive train designs or by reducing the external driving resistance, which is affected by factors of weight, aerodynamics and rolling resistance. Against the background of the current global political discussion, various studies have been published on the potential of technical options for reducing the fuel consumption of passenger cars[6]. The studies state in common that there is a wide range of technology-based reduction potential which will be described in more detail in the following sections[7].

Improving the conventional internal combustion engine – up to 30 % reduction

Most of the cars sold worldwide are still based on conventional internal combustion engines. Even if they have been improved continuously in recent decades, they still carry a huge optimization potential.

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6 (Ricardo 2003), (CARB 2004), (NESCCAF 2004), (IEA 2005), (TNO 2006), (WI 2006) (Concawe 2007)

7 It has to be kept in mind that some of the studies are based on different test cycles, different time scales and different regional scopes which imply different fuel consumptions as starting points of the analyses. However, the scales of the reduction potentials can be compared with each other if they do not incorporate extreme driving cycles such as pure urban driving with high stop-start shares.

The efficiency of gasoline engines can be improved by downsizing the engine. The gasoline engine has a relatively low efficiency in partial load and can be brought into better efficiency ranges if the engine has smaller dimensions. This may be combined with variable valve timing and lifting and wider transmission gear ratios to further improve the efficiency. Collaterally, there are fuel consumption benefits due to the reduced engine weight. Engine downsizing combined with turbo charging could result in efficiency enhancements of 9% to even 30 % compared to today's gasoline engine (CARB 2004, IEA 2005, TNO 2006).

Further potential gains for gasoline engines could be reached by direct injection which is already state of the art for diesel engines. Depending on the configuration, the potential gains provided in the literature state a range of between 10 % and 16 % fuel efficiency improvements (WI 2006).

The possibilities for reducing the fuel consumption of diesel engines are significantly less because diesel engines have already been optimized in the past by means of turbo charging or electronic direct injection. However, due to a further downsizing, the reduction of engine friction, cylinder deactivation and optimization of thermal management, efficiency can be improved further by around 15 % in total (TNO 2006).

Using hybrid systems

Combustion engines can be combined with an electric motor in hybrid concepts. Micro hybrids are currently experiencing their serial market introduction as start-stop systems, with reduction potentials of 3 % to 7 % depending on weather they include regenerative braking (TNO 2006). The first mid and full hybrids are already available, and have gained wide recognition since some celebrities are outspoken owners of such cars. The difference with the micro-hybrid concept is that the electric motor assists additionally the combustion engine in the mid hybrid, and has pure electric drive capacity in the full hybrid. However, hybrid vehicles also have higher weights due to the battery and the electric motor.

Data on the reduction potential of mid and full hybrids vary remarkably in the literature, which is partly a result of test cycles used[8], given that a huge part of the reduction potential comes from the start-stop situations in inner urban driving, and that some studies account for the downsizing of the combustion engine in the hybrid concept. TNO 2006 specifies the short term fuel reduction potential as around 11 % for the mid system and 22 % for the full hybrid, CONCAWE 2007 as 28 % for a gasoline engine and 37 % for a diesel hybrid. According to CARB 2004, the potential for a moderate hybrid lies around 29 % and the long term potential after 2015 for an advanced hybrid with a downsized engine could be even up to 50 % compared to a gasoline car of 2002. Thus, the reduction potential of hybrid electric vehicles could be significant, but is associated with the high price of a complex technology.

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[8] The US EPA has revised its test cycle in 2007 to better reflect real driving conditions. EPA's older test cycle had overestimated the fuel efficiency of HEV vehicles up to more than 30%. Even with the new test cycle, fuel efficiencies are 4% - 10% above real driving experiences for most vehicles. (INL 2008)

Improving transmission systems – up to 8 % reduction

Besides engines, the transmission system can be optimized as well. Transmission losses and limited gear ratios for different driving speeds, amongst other things, can lead to efficiency improvements of vehicles. Different transmission concepts – such as continuous variable transmission or the dual-clutch – offer possibilities for shifting the engine's operating point into more efficient regions. Different transmission systems have an efficiency improvement potential of up to 8 % (IEA 2005, TNO 2006, WI 2006).

Decreasing vehicle weight – more than 10 % reduction

Overall vehicle weight has a profound effect on its fuel efficiency. Vehicle weight has increased dramatically due to up-scaling and adding comfort and safety features. In addition, vehicle weight also increases the rolling resistance by elastic deformation of the tires and friction in the bearings. The substitution of materials using aluminum, magnesium, high strength steels and fiber-reinforced composites are the most discussed and implemented aspects in the context of lighter vehicles. However, it has to be kept in mind that for some of these materials production is more energy-intensive than for conventional materials and fewer recycling options may exist. By making changes to vehicle architecture, components can be decreased or minimized and weight can be reduced without the need for more energy-intensive materials The literature cites fuel reduction potentials by weight reduction of between 5 and 10 % in total (King 2007). In the long term, weight reduction by two thirds of vehicle weight may be possible due to the development of composite materials, but high costs for such a strategy are to be expected (Toyota 2008).

Furthermore, reducing weight is one key element with regard to future technologies which use high weighted components such as batteries and fuel cells. Due to their additional weight, they may deteriorate efficiency gains if the overall vehicle weight is not significantly reduced.

Decreasing air and rolling resistance– more than 10 % reduction

By optimizing rolling resistance and reducing friction in the bearings, fuel savings of 3 % to 7 % can be reached (IEA 2005, WI 2006). Aerodynamics influence a vehicle's fuel efficiency. Improved aerodynamics result in a fuel reduction of up to 5 % or more at higher speeds (IEA 2005, WI 2006). Drag resistance and the "shadow" behind a vehicle contribute to its aerodynamics as well and can be influenced by the design of the car.

What potentials in fuel savings can be reached in total and at what cost?

As has been shown, there is a variety of technical measures for significantly reducing the fuel consumption of passenger cars. The measures described cannot be implemented in just any combination; some measures cannot be used together since they tap the same potentials. Thus, they cannot all be jointly implemented. However, a study for the European Commission takes technology packages into account, leading to a maximum reduction of around 35 % for diesel cars and 45 % for gasoline cars in Europe by the year 2012 (TNO 2006).

In a longer-term perspective, it seems technically feasible that in the next 10 to 15 years, specific fuel consumption can be reduced by more than half by retaining today's characteristics of the vehicle. If reductions in power and vehicle size are taken into account, even higher reduction rates can be achieved.

The literature shows a broad range of estimated costs for different technologies, depending on the stakeholders involved. Cost estimates are generally higher in those made by regulated entities and lower in those made by beneficiary interest groups. Table 3 provides a rough summary with a few examples of the costs given in the literature.

Technical Option	**Additional Manufacturing Costs**
engine downsizing with turbo charging	215 € - 430 €
direct injection systems in gasoline cars	280 € - 570 €
dual clutch transmission	570 € - 900 €
start-stop-systems with regenerative braking	500 € - 650 €
mid hybrid,	1,400 € - 2,145 €
Full hybrid	2,500 € - 5,000 €
10 % lighter weight	360 € - 715 €
45 % reduction - gasoline (EU level)	~ 4,000 € - 5,000 €
35 % reduction - diesel(EU level)	~ 3,500 € - 5,000 €
20 g/km reduction (EU level)	160 € - 220 €
According to CARB 2004, Ricardo 2003, TNO 2006, IEA 2005, CONCAWE 2007, UBA 2007	

Table 3: Additional Manufacturing Cost for different technical options for improving the fuel efficiency of passenger cars

The costs estimated in the literature are mostly based on short-term analysis and do not take potential future economic effects into account. Economies of scale and continued learning may well lead to lower costs, as suggested in the theory and from experience with earlier technology introductions. As an example, costs of catalytic converters have been estimated ex ante at significantly higher levels than what is experienced today.

But even if higher cost estimates are assumed, life-cycle costs to consumers are estimated to lead to cost savings. The overall costs at the consumer level generally show reductions due to reduced fuel consumption and the resulting lifetime fuel cost savings – a fact which will gain more importance in the case of increasing oil prices. Under today’s conditions, TNO 2006 stated that the fuel economy regulation, as proposed by the European Commission, is largely cost-effective at the consumer level, even with a full pass-through of the additional technology costs.

5.2 What we need: a rethinking of “the car”

As already stated, to avoid dramatic environmental damage the problem of global climate change requires significant reductions in greenhouse gas emissions. The necessary global reductions published in the latest IPCC report are in the range of 50 % - 60 % by 2050 compared to 1990 levels. However, global CO_2 emissions of light duty vehicles are already projected to increase by more than one hundred percent up to 2050, a development which cannot be counteracted by the above-mentioned short and mid-term fuel efficient technologies alone - without touching upon a car’s characteristics. In the face of the challenges of global climate change, the question arises as to whether the concept of “the car” should itself be re-considered. After all, its practical use is quite simple: transportation of persons and goods from one place to another. Are the current requirements of power, size and comfort appropriate in the long term, given the needs of climate protection? The trend in recent decades has been going in a wasteful direction: the power of light duty vehicles in the US has increased by around 75 % compared to 1980; their weight also increased in this time frame, by around 25 %. In the EU, the same trend can be seen: it has seen a growth in power of about 60 % and in weight of around 30 %.

What could be gained in reversing the shift to higher powered and bigger cars?

Even within a single model line, the fuel consumption of passenger cars varies considerable depending on the power of the car. The difference in fuel consumption within a single car model line can be as high as 50 %. Thus, reductions of fuel consumption can be realized if the specific power is lowered by engine downsizing. In simulation studies conducted on behalf of the German Federal Environmental Agency (UBA), the fuel consumption reduction potential of a Golf V by engine downsizing was determined. The engine (1,4l TSI, 125 kW) was scaled down to 50 kW. In the new European driving cycle, the fuel saving was 27.8 %. By additional engine weight reduction, and the reduction of rolling and air resistance due to narrower tires, the simulation resulted in an overall reduction of 33.3% (UBA 2007). Downsizing engine power output mainly restricts acceleration performance and the top speed of the car, but driving safety is not affected when moderate power reductions are implemented as modeled in the UBA study. The opportunity of fuel savings due to engine power reduction is especially pronounced because it would come at no additional costs; in contrast, cars could be produced less expensively due to the materials saved.

Furthermore, the trend to bigger and heavier cars has been already mentioned before: Each 100 kg added leads to a more than 0.3 L/100km higher fuel consumption; each 100 kg saved reduces fuel consumption respectively.

Concept cars – could that be the future?

Could smaller and lower-powered vehicles enable individual automobility in the future with much lower energy requirements? Various companies have already developed or designed low energy concept cars, at least for test purposes. In Table 4, four examples are presented. For the Loremo and the Aptera, the market launch has already been announced as coming in the next two years – so such concept cars are not as far off as one would imagine. The SmILE was presented by Greenpeace in 1996. Based on the Renault Twingo, the SmILE came into existence by means of a weight reduction of

23 %, engine downsizing with turbo-charging, and improvement of the aerodynamic characteristics by 30 %, resulting in fuel consumption being lowered by 50 %. The 1-liter-car was presented by Volkswagen in 2002, with a weight of just 290 kg and a fuel consumption of one liter per 100 km – astonishingly low. Unfortunately, it is unlikely that its designer is planning to produce the car in the near future. However, it does show the feasibility of designing ultra low consumption vehicles; and – according to the UBA – the enlargement of this concept car to a 4-seater would result in a fuel consumption of around 2 L/100km.

Another concept is also being increasingly discussed in automobile application: the free piston linear generator. In such a concept, a linear generator produces electricity which drives an electric motor without the need of a battery. The overall efficiency gain for a whole vehicle by using this new type of power train is modeled as being up to 30 % (Graef 2007).

Technical Data	Loremo LS	1 Liter- Car VW	SmILE	Aptera Type 1
Illustration				
max. Speed	160 km/h	120 km/h	170 km/h	137 km/h
Consumption	1.5 L/100 km 0.53 MJ/km	0.99 L/100 km 0.35 MJ/km	3.3 L/100km 1.06 MJ/km	<2 L/100km < 0.65 MJ/km
CO_2 emissions	40 g/km	26 g/km	78 g/km	<47 g/km
Weight	450 kg	290 kg	650 kg	671 kg
Seats	2+2	2	4	2
Market launch	2010			late 2008

Table 4: Some examples for highly fuel efficient concept cars

5.2.1 What is needed for smaller, less-powerful and more fuel efficient passenger cars to become very widely accepted?

Regulations for passenger cars

Regulations for passenger cars limiting their fuel consumption or their carbon dioxide or greenhouse gas emissions are under discussion or have already been introduced by several governments around the world. At the moment, Japan has the most ambitious target at 125 g/km in 2015. In terms of absolute improvements, California and Canada are poised to make the largest gains in the next decade (An 2007). The European Commission has proposed legislation for average emissions of 130 g/km in 2012 for new cars.

The standards use different attributes as a basis, whereby the allowed level of CO_2 emissions depends on a vehicle attribute such as weight or footprint. In Japan, the front-runner approach is differentiated by weight classes, with limited effects to the market mix of different vehicle classes but improved fuel economy within a class. In China, the standard is weight-based in categories as well and requires a higher reduction for heavier vehicles than for lighter ones with the aim being to slow the purchase of heavier vehicles, and, in other words, influence the market mix of vehicles. The standard proposed in Europe allows higher emissions for heavier vehicles but the improvements to be made to these vehicles are greater than those to be made to lighter ones. Fuel reduction can thus be achieved in two ways: by changing the vehicle mix and by reducing fuel consumption technologically within a vehicle class. According to a press release from 22 April 2008 by the National Highway Traffic and Safety Administration, the CAFE standard in the US will be based on footprint in the time period from 2011 to 2015. The choice of attribute is not completely neutral, and there is a considerable agreement that footprint is better than weight (JTRC 2008)[9].

Regulations for passenger cars in most OECD countries as well as in China are at least already planned and are being set up in manifold ways. Aligning these policies to some extent and also expanding them to the rest of the developing world would guarantee a consistent fuel efficiency improvement; manufacturers would benefit in terms of more harmonized markets. But developing a kind of global standard which would also encompass different fuel consumption levels and different test procedures would take some time – for the time being, the most important step is to strengthen and further extend existing regulations in key market countries.

Fuel Taxation

Regulations for the fuel consumption of new cars is not sufficient to reduce the overall fuel demand from cars and should be combined with fuel taxes to avoid detrimental effects. Fuel efficiency gains may, again, be offset by an increase in vehicle kilometres traveled, as the past has shown, in particular if policies continue to react to this increase by augmenting automotive infrastructure. The benefit of combining fuel taxes with fuel efficiency standards will be to adjust the cost of individual automotive driving. This policy measure would guarantee that other modes of transport would be competitive and no cost reduction would engender additional automotive driving. Higher fuel efficiency has to be counterbalanced with higher fuel costs.

Rethinking cars

However, even if there are fuel efficiency optimized cars on the market, it is not a given that they will be purchased. When analyzing vehicle purchase decisions it is important to keep in mind that a vehicle is a collection of attributes of which fuel consumption is just one. Also, consumer decision is not always based on a long-term economic

[9] This is because weight-based standards may eliminate weight reduction as a method of generating efficiency improvements. Additionally, such a car attribute may invite car makers to change car specifications in order to achieve a weaker CO_2 standard. Thus, with a poorly designed standard, an incentive to add weight rather than cut emissions might result. Finally, weight is not relevant to new-car buyers. Consumers do not choose cars based on their weight. Footprint-based standards avoid such problems to a larger extent as the footprint is more difficult to change without affecting vehicle characteristics that consumers value highly.

analysis. Thus, legislation for new cars and fuel taxes alone are not sufficient to reduce the CO_2 emissions of passenger cars in an ambitious way; consumer behavior must also be addressed. Rethinking cars (as status symbols, etc.) should be initiated as well. A change in consumer behavior could be supported by:

- **Fiscal Signals:** As a policy instrument, car taxation can be used to complement other measures in order to encourage more widespread purchasing of more fuel-efficient vehicles through the use of a strong fiscal signal. The tax base of both registration taxes and annual circulation taxes should be directly related to the carbon dioxide emissions of passenger cars. A labeling scheme as exists for example in the US and the EU could – if it is well designed in a comparative way – support the decision to buy more fuel efficient cars. They probably won't have a large impact but they may help consumers compare vehicle choices and they could form the basis for financial incentive schemes.
- **Code of Good Practice:** Another important point is that new communication strategies to make smaller and lower powered cars more attractive are important on all sides of the equation – manufacturers, governments, NGOs and press are the basic protagonists to support a rethinking of automobilization. A code of good practice for car marketing and advertising in order to promote more sustainable consumption patterns should be initiated by governments, taking car manufactures on board worldwide – which also includes a rethinking of profit strategies as mentioned in the beginning: reversing "small car – small profit, big car – big profit" into "small car – big profit, big car – small profit"

  A fuel-efficient driving style also promises a significant CO_2 reduction with a focus on the car fleet. A concrete possibility to support such a driving style could be the commitment of car manufactures to add a coupon for a cost-free driver training to each new car sold – something which should be included in such a code of good practice.
- **Credits for exceptionally efficient cars:** One further idea for governments would be to offer credits for exceptionally efficient vehicles. As stated in the chapter on the additional costs for fuel efficiency technologies, the overall costs for the consumer are lower in most cases, due to lifetime fuel savings. The additional investment costs could be financed by credits and repayment would be related to the costs saved in the first years due to lower fuel consumption. This would significantly simplify investment for consumers and could bolster the decision to buy an efficient car. In consequence, the demand for efficiency technologies would be stimulated, the production rate would be sped up, and therefore the costs would be reduced by scale effects.
- **Transformation to a system of tailored cars**

  The most important aspect is to reverse the trend towards "supersized" and "superpowered" vehicles as quickly as possible. What is the point of driving a sports utility vehicle in inner-city traffic? Why use a Jeep in order to transport one person along country roads? Rethinking would also have to include tailoring vehicle size to the purpose associated with each car journey. If, for example, a large family holiday is planned once a year, then it is not necessary to drive a two-ton mini-van for the daily commute during the rest of the year. For this specific application, a larger vehicle can be rented/used; a small 2-seater would be sufficient for everyday mobility.

The goal should be a new kind of mobility services: A customized car will be bought tailored to its expected day-to-day application combined with the possibility of other cars used for special applications - a combination which could even be offered by the manufacturers themselves, transforming their role from car sellers to sellers of mobility. This would also allow for a range of cars with a very special application, such as full battery electric vehicles for inner urban applications. However, the longer-term target should include alternative transport modes in such mobility concepts as well, thus not only offering car rental for longer distances but also granting easy access and seamless integration to public transport. Similar to “call a bike”, users of trains may benefit from “call an EV” for limited urban use.

5.3 The potential gains for heavy duty vehicles

The second substantial factor in the climate relevant emissions of road transport is due to freight transport with heavy duty vehicles. What can be stated is that their reduction potential will probably be lower than that for passenger cars, because they are already optimized to a much greater extent for fuel efficiency, since the cost factor is determinant in the freight and logistic sectors. However, with the help of some technical improvements, fuel consumption can be reduced further, which is important in light of the huge and rising share of CO_2 emissions from heavy duty vehicles.

Which technologies are ready for the market?

With regard to engine optimization, improvements are available to all components of the engines, such as less moving mass in the engine, reduced friction, optimized injection pumps and valves as well as efficient combustion by means of step-by-step improvements to turbo-chargers in the case of diesel engines. Due to improved engine efficiency, 8 % of fuel can be saved in the medium term. SCR technology (Selective Catalytic Reduction) is taken into consideration, although it is rather an emission control technology for the reduction of NOx emissions; this is because it also makes room for optimized use inside the engine itself. The optimal conjunction of continuously variable transmission and changes to the engine enables reductions of 2 % to 8 % (Ellinger 2001).

As is the case with passenger cars, a trend toward higher powered heavy duty vehicles can be seen. Differences in fuel economy between two parallel engine versions with 275 and 220 horsepower were tested by VTT 2006, resulting in a 6 % – 10 % higher fuel efficiency for the less powerful engine when using the same engine load. In addition, large improvements are being pursued with regard to the power needed by auxiliaries. If the power needed by auxiliaries were halved, a fuel saving of around 5 % could be achieved (VTT 2006). Moreover, since speed essentially affects fuel consumption, lowering the speed of a truck-trailer combination from 90 to 80 km/h would reduce the need for power and fuel by some 20 % (VTT 2006).

In the context of heavy duty vehicles used for urban delivery, which involves many stop-start situations, hybrid drive systems constitute an efficient technology for significantly reducing fuel consumption. Light to mid-heavy utility vehicles with hybrid drive systems are currently being developed by several manufacturers and can be found already on the market in Japan and the USA. However, most of the hybrid delivery vehicles are still in the pilot phase. Manufacturers estimate a fuel reduction of 30 % on average for urban journeys. In long-distance traffic, fuel savings of 4 % to 6 % is thought to be possible in low mountain regions on the basis of brake energy regeneration. In addition, auxiliary drives and installations could be more efficiently operated if they had a hybrid part.

Since weight is one of the most critical factors affecting fuel consumption, the dead weight of trailers and vehicles should be minimized significantly. Fuel consumption reduction potential due to improvements in weight and aerodynamics are reported as being up to 30 % (TEC 2007, VTT 2006). Since heavy duty vehicles are categorized by their total weight, weight reduction is an important factor because reduced weight allows for a higher payload, which could lead to reduced vehicle mileage. The potential gains from optimizing the rolling resistance of heavy duty vehicles vary in the literature, falling between 5 % and 7 % depending on the driving situation and the load (VTT 2006, IVECO 2007). In addition, super-single tires weigh over 100 kg less than a twin wheel combination.

What can be further added to busses?

The options for improving the fuel economy of busses are almost the same as those for trucks. However, the realizable potential gains by optimizing air resistance are estimated as being lower since numerous measures would substantially downgrade the use value of the vehicle. In contrast, busses with hybrid drive systems are now being developed by a large number of manufacturers - in particular for inner urban public transport. Hybrid drive systems can here achieve their full potential because of the multitude of the many stop-start situations. The use of hybrid busses in numerous major cities in the USA, as well as in Japan and Germany, is yielding the first findings about the possible reduction potential and the suitability of hybrid technology for everyday use. The possible fuel savings are estimated at 20 % to 25 %, depending on the driving situation (MAN 2006). A hybrid bus test conducted by the National Renewable Energy Laboratory even produced an average reduction in fuel consumption of 37 % (EESI 2007).

Within the scope of a pilot project, a weight reduction of 50 % could be reached by using high-strength stainless steel and an electric drive train as well as motor adaptation. This is accompanied by cost reductions of 15 % to 20 % compared to standard construction, an increase in interior space (5 passengers) and a fuel reduction of over 50 % (USDE 2005, SAE 2001).

Requirements for implementing policies regarding HDVs

The development of policies with regard to fuel consumption is much more complicated for heavy duty vehicles due to the technical premises. In contrast to passenger cars, standardized norms for fuel consumption, and thus the CO_2 emissions, do not exist for heavy duty vehicles in most countries. For example, the European type of approval includes only the engine. Approval processes for entire vehicles are lacking. Information on fuel consumption for type approvals of this kind is indispensable for consumer behavior and future legislations. For example, in Japan the CO_2 emissions of heavy duty vehicles are calculated for a norm-vehicle based on the measured engine data. Since it is a standard-vehicle, there is no incentive to improve the vehicle body in terms of energy savings. More convenient would be an estimate of the driving resistance by a coast-down test on the road for each individual truck model half loaded. The CO_2 emissions can than be modeled from the engine map derived by the driving resistance (Friedrich 2008). Such procedures are needed as a basis for legislation of CO_2 limit values or taxes based on CO_2 emissions, similar to those introduced or discussed for passenger cars, in order to tap the fuel consumption reduction potential for heavy duty vehicles. They also would provide consumer information, since the differences in fuel economy between different manufacturers could be even up to 10 % – 15 % (VTT 2006).

5.4 What kind of alternative propulsion technologies are under development?

Currently, there is mainly one long-term alternative propulsion system under development: electrification of the power train in different stages by using fuel cells or batteries. But even if these technologies have a higher efficiencies than internal combustion engines, it has to be kept in mind that their overall efficiency and greenhouse gas balance depend significantly on the source of the energy carrier.

Plug-in and full performance electric vehicles

Plug-in electric vehicles represent a further development of the hybrid concept. By using a higher capacity energy storage system, full performance electric driving over a longer distance is ensured. The charging of the battery not only occurs via braking energy regeneration and the combustion engine during vehicle operation, but also via the electricity grid when the vehicle is stationary. As a result of the higher share of electric operation, a substantially higher reduction in direct fossil fuel consumption can be achieved compared to hybrid-electric vehicles. This is because the combustion engine – with its poorer efficiency level – is only activated when necessary, for example in the case of high driving speed or a low battery charge.

Full-performance battery-driven electric vehicles dispense completely with an internal combustion engine and are electrically operated in all driving situations. But a number of factors have prevented the market introduction of full-performance battery-driven electric passenger cars. The greatest impediments are the lack of adequate energy storage systems. The total power and energy requirement has to be ensured by the battery because once dispensed with, the internal combustion engine cannot assist during high power demands. In order to meet the minimal requirements in terms of vehicle performance and distance, the battery needs to have a very high energy and power density. Due to their high energy density, lithium-ion batteries constitute a storage solution and are making impressive technical progress globally at the moment, especially with regard to calendar and cycle life and safety – areas of special concern for automotive application. Barriers to their introduction on the market comprise, above all, the high additional costs and the required life cycle.

However, even in the case of greatly-improved energy storage systems, the additional weight of an electric vehicle would be significant and demand considerably lighter cars. Thus, making plug-in and battery electric vehicles technologically ready for the market is fundamentally dependent on progress in the development of high-energy batteries. In conjunction with the increasing popularity of hybrid vehicles, an increasing interest of manufacturers in the plug-in concept can be detected since plug-in hybrid electric vehicles contain basically the core technology for the electrification of the power train. In this context, a market introduction of full electric vehicles with a modest electric driving range can thus be expected in the near future.

Fuel cell vehicles

The other alternative being pursued by the automobile industry is the fuel cell vehicle. In fuel cells, hydrogen is converted to water whilst electric energy is generated to drive an electric motor. The advantage of the use of fuel cells is their high efficiency compared to conventional engines. In addition, they do not have any direct emissions apart from water. Different car manufacturers are already testing prototypes for passenger cars and busses on the road. However, serial models are far from market introduction as they still face unfeasibly high costs. Fuel cell technologies have made substantial progress in recent years, but have not yet been proven as commercially viable. There are still large technical barriers to be solved but these might be overcome by means of massive efforts in the next 5 to 10 years (CARB 2007).

One further challenge is storing sufficient hydrogen in a vehicle to power it for an adequate distance, at reasonable costs, and without an excessive weight penalty. The target with regard to a distance of at least 500 km is significantly higher than that for battery electric vehicles, meaning that fuel cell vehicles could be an interesting competitive option in the future, mainly in the higher vehicle segments with higher mileages of today’s driving behaviors. It also has to be kept in mind that adequate hydrogen generation and refueling infrastructure have to be developed, which will require high investment costs. Fuel cell vehicles can be competitive with conventional cars only if unlimited use can be guaranteed.

Timeframe for alternative propulsion techniques

CARB 2007 anticipates that in the years up to 2015 a significant production volume cannot be reached for either fuel cell vehicles or battery electric vehicles. It states that an annual production volume of 100,000 vehicles (mass production) can be first expected from 2030 onwards. Possible progress in the development of battery technology through an increased demand for hybrid and plug-in vehicles could, however, accelerate the development of battery-driven electric vehicles. Fuel cell vehicles are expected to enter into mass commercialization some 5 years earlier, according to CARB 2007. But let us not forget: around ten years ago, manufacturers announced the year for market introduction as 2004 and then postponed it to 2010. Nowadays, some car makers cite 2012 as the year in which the first fuel cell serial models can be expected; others declare the year 2020 to be a possible date for market introduction (IEA 2005). However, the currently discussed alternative technologies may both be long-term opportunities, but will not solve the challenges of transport and environment in the timeframe up to 2030.

Efficiencies of alternative propulsion techniques

Tank-to-wheel efficiencies differ widely for propulsion technologies. The efficiency of an internal combustion engine vehicle is the product of engine efficiency and the mechanical drive train, which results in a tank-to-wheel efficiency of 19 %. Optimized diesel vehicles can reach around 23 %. The fuel cell car is, with an efficiency of 48 %, more efficient due to the combination of the fuel cell and the electric drive. In principle, electric vehicles have the highest efficiency at 74 %, composed of the battery charger, the lithium ion battery and the electric drive train (IEA 2005). However, for the impact assessment of the different technologies, the fuel chain - a well-to-tank analysis – has to be taken into account as well.

The crucial point in considering alternative propulsion techniques

The utilization of advanced alternative propulsion systems will only achieve a significant overall environmental benefit if primary energy is produced by using renewable energy sources. The overall fuel chain efficiency is substantially influenced by well-to-tank efficiency and depends on how the liquid fuel (conventional fossil or bio fuel) or the hydrogen or the electricity is produced. A further efficiency loss in the hydrogen chain can be found in the compression or liquefaction process. The deployed energy carrier (hydrogen or electricity) has to be generated using renewable energy sources in order to induce a substantial breakthrough for climate protection, even when significantly higher tank-to-wheel efficiency levels are achieved by using the alternative propulsion systems compared to conventional combustion engines. Alongside the required further development of full-performance electric and fuel cell vehicles, the issue of the competitive situation in the utilization of renewable energies in the context of stationary energy demand has to be addressed regarding the supply of electricity for producing hydrogen or direct use in electric vehicles.

The last aspect to which attention should be paid when discussing alternative propulsion technologies is whether global diffusion of these new technologies can be ensured. It should be considered that developing countries will probably encounter problems introducing vehicles with a new kind of fuel. The new infrastructure that is needed could be a barrier to the introduction of such types of cars, which makes clear once again that the most important technical option for vehicles is fuel efficiency improvement – energy savings independent of the fuel needed.

5.5 Biofuels, H_2 and Electricity as Alternative Transport Fuels

In addition to reductions in energy demand by vehicles through increased efficiency, modal shift, and overall “self-sufficiency”, the choice of fuel is another option to reduce the environmental, economic and social impacts of the transport sector. In that regard, three principal alternative fuel options also related to the propulsion technologies under development are currently being discussed:

- biofuels from various feedstocks and conversion routes;
- hydrogen from a range of primary energy sources with several hydrogen production/distribution pathways; and
- electricity from a variety of primary energy sources.

All these options can deliver energy input for a sustainable mobility future only if they are derived from renewable sources, and if their environmental and social profiles are more favorable than those of fossil options[10]. In a comparative analysis, it must be acknowledged that options develop over time, i.e., their cost and environmental characteristics change dynamically.

5.5.1 Biofuels: Cure or Disaster?

The global energy scenario[11] implies that in the long-term, bioenergy – and biofuels - can play only a limited role. This is due to their comparatively low overall conversion efficiency: only some 3-4% of solar energy input is stored in the plant material, i.e., the heating value of the biomass grown. Thus, land-use efficiency in terms of net energy yield per hectare is at least 2 times lower than current solar-to-electricity technologies, and, with rising solar conversion efficiencies in the longer-term, this factor might well become close to one order of magnitude.

Still, one has to recognize that the growth of biomass is a “natural” phenomenon, and that photosynthesis is less a means to store energy[12] than one to provide highly organized and structured matter which can be used for myriad applications – from food and feed to newspaper and textiles, up to building materials and, as recently discussed, fuels. In that regard, biomass is unique: no other renewable energy source offers similar characteristics, and a long-term perspective requires consideration of the “double nature” of biomass as being a material and an energy carrier.

Although bioenergy is seen by some to be a panacea for a range of energy, environment and poverty problems, the sustainability performance of bioenergy and biofuels in particular depends on where and how they are produced, processed, and used.

Given the substantial – though restricted – global potential for sustainable provision of bioenergy, it could significantly contribute to transport fuel needs (Figure 6). However, the sustainability aspects of the use of bioenergy depend on developments in agriculture and forestry, as well as the overall dynamics of the food, feed and fiber markets. Its potential is further dependent on the impact of global climate change, and the regionally differentiated adaptation measures to adjust to that change.

The linkage between energy and biomass from agriculture and forestry has been described as a crucial “nexus”, a complex interaction of various driving forces, with massive feedback loops which make projections an area with great uncertainty (UN 2007). Current science allows one to depict the order of magnitude at which bioenergy could sustainably contribute to the world’s energy needs without compromising food,

[10] Economic impact of alternative fuels is difficult to determine without considering vehicle technology, and mobility demand. Given the long-term view assumed here, the economics of fossil fuel alternatives must be measured against significantly rising fossil energy costs.

[11] Source: IEA (2007), IPCC (2007), UNPD (2004) and WBGU (2003)

[12] In the long-run, “artificial” photosynthesis might be possible with a conversion efficiency of approx. 10 to 15%. This could drastically narrow the gap with solar electricity systems.

feed, and fiber requirements. A low figure can be derived from pessimistic assumptions on agricultural productivity, moderate energy and high commodity prices, and severe climate change impacts especially on soils, and precipitation patterns. The high figure assumes optimistic values of productivity increases, high energy and agricultural commodity prices, and successful adaptation to climate change.

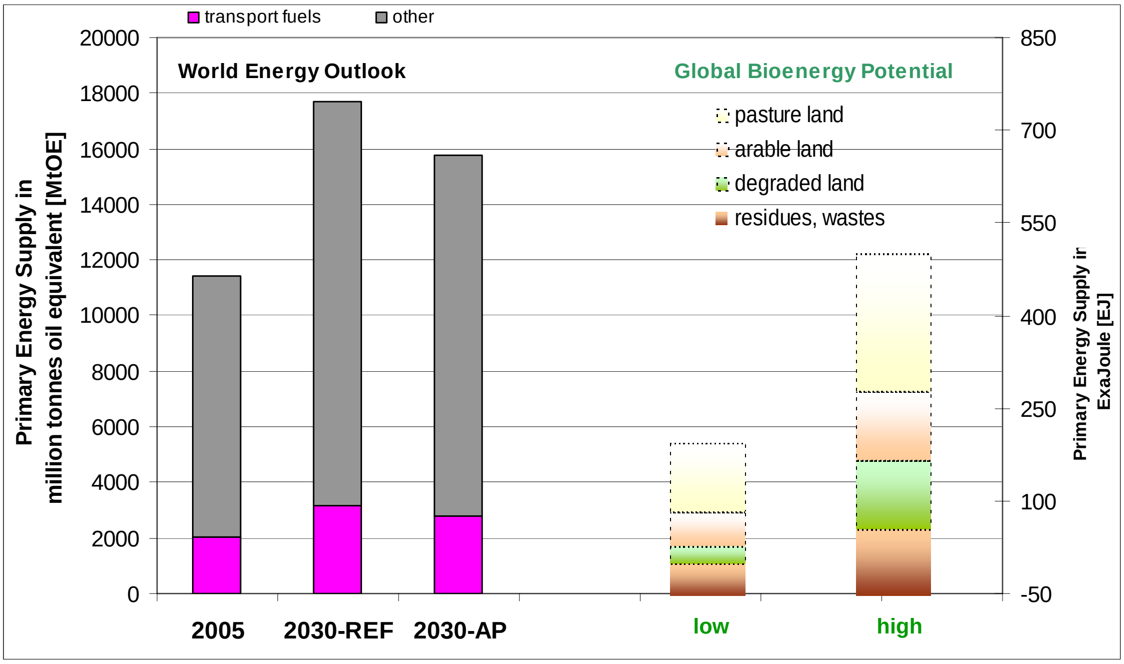

Figure 6: Global Energy Supply and Sustainable Bioenergy Potential, (*IEA 2007, Best et al. 2008)*

The long-term sustainable supply potential of biofuels is significant, and about half of the potential comes from residues and wastes. About 200 ExaJoules (EJ) of primary energy could be supplied and sustainable which translates under optimistic long-term technology assumptions into approx. 150 EJ of transport fuel equivalents, taking only the potential of biofuel feedstocks from residues and wastes and degraded land into account. This would represent more than the long-term transport fuel need in a global “sufficiency and efficiency” scenario.

Biofuels are on the rise: Among renewable energies, biofuels dominated venture capital and private equity investments in 2006. Those were approx. $ 3 billion – twice as much as investments into solar energy, about $2 billion (UNEP 2007). This increase in biofuel production and financing is driven by energy security and climate change concerns (Steenblik 2007).

With the rising use of biofuels, their positive and possibly negative impacts became an issue of research, and debate: While proponents of biofuels underline the potential for cleaner and less greenhouse-gas-intensive fuels, along with economic opportunities for farmers and rural communities, opponents argue that biofuels risk damaging biodiversity, marginalizing indigenous and local communities and possibly creating more greenhouse gas emissions than they prevent (CBD 2008). The dominant factors determining cost, environmental, biodiversity and social impacts of biofuels are

- the characteristics of the land used for producing biofuel feedstock (forestland, cropland, marginal or degraded land)[13] and
- the feedstock conversion process employed, including the feedstock characteristics (crop, grass, woody, residues/wastes).

Depending on the feedstock used, where and how it is grown and the manner in which it is processed, the greenhouse gas balance, energy yields and environmental impacts of biofuels differ significantly, but many aspects correspond to the environmental impacts of ”common” agriculture (FAO 2008; RS 2007).

On the positive side, the need for greater amounts of feedstock will create employment opportunities, and thereby may increase rural incomes since the harvesting of biomass tends to be a labor-intensive process (UNEP 2008). However, large-scale production of biofuels tends to favor industrial agricultural practices.

Biofuels from 1st-Generation Technologies

Ethanol as a substitute for gasoline is currently the dominant biofuel on a global scale. Suitable biogenic feedstocks contain high shares of sugar, or starch that is catalyzed into simple sugars and then fermented into ethanol.

Sugar cane in particular stands out as the feedstock that already provides a large amount of ethanol in Brazil. Other crops that can be converted into ethanol are cassava, maize, potatoes, sorghum, sugar beets and wheat[14]. The conversion of their starch content into sugar has a high process-energy demand, so the cost of the product is quite high. Ethanol from fermenting starch- or sugar-rich plant material is called “1st-generation” because it already exists with proven efficiencies and established economics.

Biodiesel is another 1st-generation biofuel technology: oilseed-yielding plants like castor, cotton, palm, rape, soy, etc. offer feedstocks from which vegetable oils can be extracted by physical and chemical processing (milling/refining). The oils can then be processed further into fatty acid methyl esters (FAME), also known as biodiesel[15].

1st-generation biodiesel can also be derived from perennial plants such as Jatropha that show comparatively low yields but require only minor processing inputs so their overall costs might be moderate if land and labor costs are low. Jatropha can be grown on marginal and even degraded land, and needs little irrigation during the first years.

Biofuels from 2nd-Generation Technologies

In the next decade, it will become possible to use a far greater range of lignocellulosic plant materials (so called 2nd-generation feedstocks) for biofuel production. These feedstocks include perennials such as grasses and woody plants, and residues from agriculture and forestry, as well as wastes from households, food/feed/fiber processing,

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13 Note that biogenic residues and wastes do not impose land-use or land-use changes.

14 There are many more plant species that could be suitable feedstocks for ethanol production, including perennial crops, but their yields, costs, and emission features are not well known (see EEA/JRC 2006).

15 Another route for biodiesel is to “hydrotreat” unprocessed bio-oils (from castor, cotton, palm, soy etc.) so that no transesterification is needed to stabilize the biodiesel.

and possibly algae. These 2nd-generation biofuel technologies differ technology-wise, but are similar in the following respects:

- To extend biofuel yield, the whole plant material is used as a feedstock.
- The feedstock will come from "non-food" perennial crops (in principle, woody biomass and tall grasses) and ligno-cellulosic residues and wastes (e.g., woodchips from forest thinning and harvest residues, surplus straw from agriculture).

Cellulosic biomass from fast-growing perennial crops such as short-rotation wood and tall grass crops require less agrochemical input. Furthermore, the root systems of perennials remain in place after harvest so that these crops reduce erosion compared to annual ones, and could increase carbon storage in the soil. However, high biomass yields will typically be achieved only on good soils with an adequate water supply.

The 2nd-generation biofuels can be divided into two groups:

- enzyme-enhanced fermentation for ethanol from ligno-cellulose, and
- gasification + synthesis (Fischer-Tropsch) for biodiesel.

Both routes are currently under development and might become commercially available in the 2020 timeframe. There might also be hybrid schemes which combine the two routes.

In the longer-run, 2nd-generation technologies could also enhance the output of 1st-generation systems, especially sugarcane-based ethanol and biodiesel from palm oil, as they allow one to make use of plant residues which currently cannot be converted into biofuels.

Biogas as an "in between" Biofuel

Biogas can be upgraded to substitute for natural gas (SNG) so that it can be fed into existing natural gas pipeline systems (both locally, nationally, or even for cross-border trade). Alternatively, it can be compressed into "green" compressed natural gas (BioCNG) to be used in gas-engine vehicles (busses, cars, trains, trucks, etc.). Bio-SNG can be "blended" with natural gas in any mixture.

Biogas – at least in Europe – has developed in recent years far beyond the mere fermentation of residues like dung, liquid manure, or organic household wastes: nowadays, it can be derived from "modern" bioenergy crops such as maize, wheat, and even more interestingly, from mixed or *double cropping* farming systems which can integrate various plant varieties into their rotation and give net energy yields comparable to palm oil, or sugarcane plantations[16].

Nevertheless, current markets for CNG vehicles are, with few exceptions, rather small. In the longer-term view, though, BioCNG vehicles could be a very attractive option.

Costs of Biofuels and their Competitiveness

The costs of biofuels need to be compared with those of their fossil fuel competitors, which will likely rise over time, and will depend also on, e.g., factoring in greenhouse-gas emissions. Biofuel costs depend on yields, land price, interest rates, and cost of

[16] For life-cycle emissions from "double cropping" in Europe, see OEKO 2006a.

workforce, and on dynamic effects such as scale and learning curves, but also economic feedback from agricultural markets, land use policies, and sustainability requirements.

Most forms of biofuels feedstocks have alternative uses and may be highly valued as animal feed or fuel, especially in marginal areas. Infrastructure requirements might also add to the cost of biofuels. Smaller, poorer and/or landlocked developing countries face the highest costs due to smaller scale, lack of market access, and undeveloped infrastructure. These factors limit the commercial viability of potentially cheap feedstocks.

For starch-based 1st-generation ethanol, costs depend not only on feedstocks, but also on revenues from byproducts. Ethanol from sugarcane (Brazil's case) illustrates that improved feedstock and technology learning fostered by longer-term commitment can bring production costs down to the point where (unsubsidized) ethanol becomes competitive at an US$ 50/bbl oil price level (WB 2005). The "learning curve" in Brazil for bio-ethanol took about 20-25 years, from program inception to technical maturity. With oil in the US$ 100/bbl range, even starch-based ethanol in larger plants, and even sugarcane ethanol from less efficient production, could become economically competitive.

Similar to ethanol, SVO and biodiesel from oil plants are established and proven technologies, and their costs depend heavily on feedstock (>80 percent for FAME), and revenues from by-products (cake, glycerin).

With such a high dependency on feedstock costs and price volatility in competing uses, 1st-generation biodiesel is a less attractive option unless palm oil is considered, or if new conversion processes like hydrogenation become less costly.

On the other hand, costs for small-scale biodiesel from low-input systems like Jatropha grown on low-cost marginal or degraded land with low-cost labor could be competitive with fossil diesel if production efficiency is high and by-product markets are developed.

The economy of 2nd-generation biofuels (biomass-to-liquid = BtL, and ligno-cellulosic ethanol) can currently be judged only from small pilot plants. Clearly, a drawback of the BtL route is the strong dependence on scale-up: to be competitive, capacity has to be on the order of a small oil refinery (approx. 1 million tons per year). In addition, the economics rely on low feedstock costs and on successes in cost reduction for gas cleaning, and catalytic conversion. Cost projections indicate that in the longer-term, BtL from biomass residues could become cost effective at oil prices of US$ 80/bbl, while BtL from energy crops might require a level beyond US$ 100/bbl.

With the development of genetically improved bacteria for *enzyme* production, the operating cost of ligno-cellulosic ethanol plants could be reduced drastically. Nevertheless, this route still depends on milling, heat and acid, although at less demanding conditions than today, and needs sophisticated process control. Since enzyme production today is far from the costs needed to make ligno-cellulosic ethanol competitive, significant improvements are needed – but that are conceivable in principle. Since ligno-cellulosic ethanol can make use of (nearly) the entire biomass of its feedstock (using lignin parts for process energy), its economy will be more interesting than today's starch-based 1st-generation ethanol. Expectations are that costs could come down to a US$ 70/bbl oil equivalent level within the next decade if biomass residues are used, and for dedicated crops such as perennial grasses, the competitive cost level might be in the range of US$ 100/bbl oil.

Environmental Performance of Biofuels

Today's 1st-generation biofuels – with the exception of sugarcane ethanol and palm oil biodiesel – show a 25 to 50% reduction of GHG emissions compared to their fossil competitors if overall life-cycles are taken into account. Sugarcane ethanol and palm oil-based biofuels perform better, with up to 90% reductions.

The beneficial greenhouse gas balance for those crops is diminished through GHG emissions from land-use change associated with feedstock production. A direct land use change results whenever a crop scheme is planted in an area where this form of cultivation has not taken place before. The area might have been covered by forest or other natural and near-to-nature ecosystems, but it might also have been idle or set-aside land. The quantification of direct land-use changes can be based on carbon content data from IPCC default (Tier 1) or country-specific (Tier 2) values[17]. The results of such calculations are shown in the following figure.

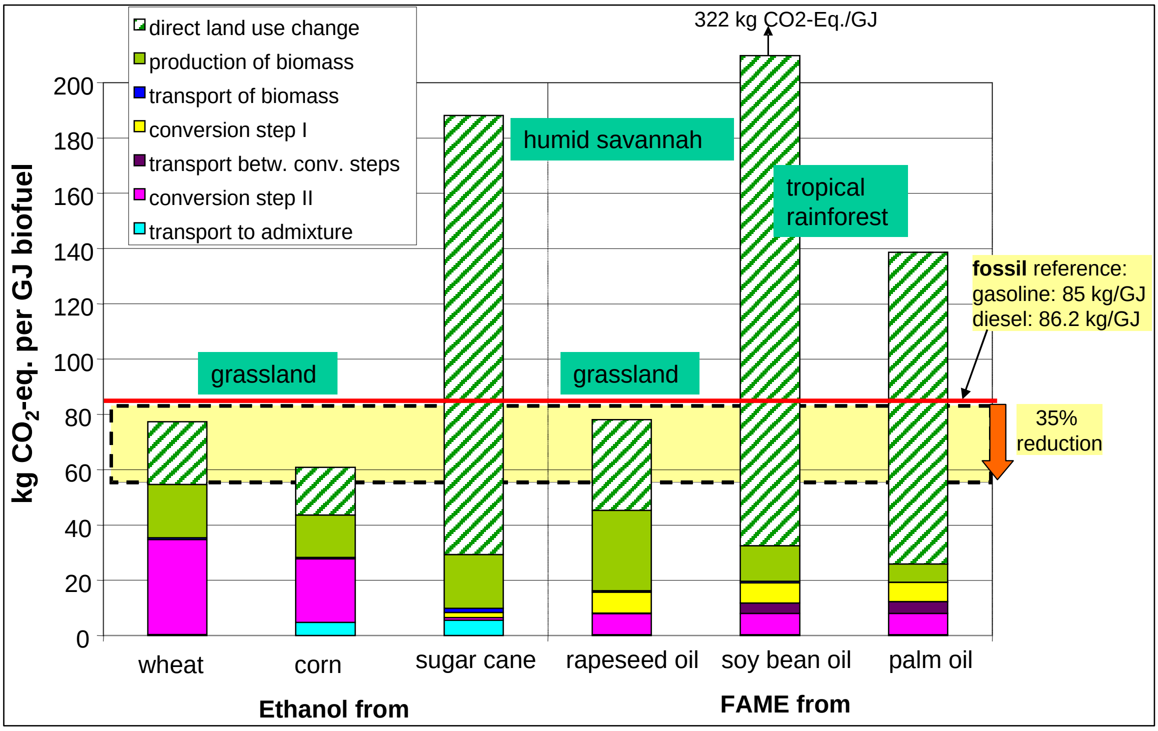

Figure 7: Life-Cycle GHG Emissions of Biofuels and Impacts from Direct Land-Use Change, (Fehrenbach/Fritsche/Giegrich 2008)

As can be seen, GHG emissions change drastically if conservative assumptions are made for direct land-use change. However, if biofuel feedstocks are grown on low-carbon soils, the impact can be positive: for example, perennial plants such as short-

[17] This is valid for above-ground carbon. Less is known for the below-ground carbon balances of land-use changes, and very few data exist on the changes in N_2O emissions.

rotation coppice store carbon in their root system so that a biological sequestration takes place and GHG emissions are reduced.

It must also be considered that, in principle, expansion of (biofuel) crop production on arable or pasture land could be associated with indirect land use change that can be described as a shift from the land use prior to biofuel production to another area where land use change occurs due to maintaining the previous level of (e.g., food) production (see e.g. Fehrenbach/Fritsche/Giegrich 2008; Searchinger at al. 2008).

For this displacement, the so-called “iLUC” factor (for indirect land-use change) has been proposed to quantify the indirect GHG emissions. An indicative order of magnitude for the iLUC factor is given below.

	kg CO_{2eq}/GJ with iLUC factor including conversion/by-products, without direct LUC			relative to fossil diesel/gasoline, including conversion/by-products		
biofuel route, life-cycle	**max**	**med**	**min**	**max**	**med**	**min**
Rapeseed to FAME, EU	260	188	117	201%	118%	35%
palmoil to FAME, ID	84	64	45	-3%	-25%	-48%
soyoil to FAME, Brazil	101	76	51	17%	-12%	-41%
sugarcane to EtOH, Brazil	48	42	36	-44%	-52%	-59%
maize to EtOH, USA	129	101	72	50%	17%	-16%
wheat to EtOH, EU	144	110	77	67%	28%	-11%
SRC/SG to BtL, EU	109	75	42	26%	-13%	-51%
SRC/SG to BtL, Brazil, tropical	34	25	17	-61%	-71%	-80%
SRC/SG to BtL, Brazil, savannah	59	42	25	-32%	-51%	-71%

Table 5: Life-Cycle GHG Emissions of Biofuels and Impacts from Indirect Land-Use Change, (Fritsche 2008)

Even if no direct land-use change is assumed, the iLUC factor will worsen the GHG balance, depending on its level of application: with a medium level of 50% risk to induce indirect land-use change, rapeseed, wheat and maize will not be reducing GHG emissions compared to their fossil fuel competitors. For a high level of the iLUC factor, only ethanol from sugarcane, and 2nd-generation BtL would still allow a GHG reduction.

Whatever the GHG balance, biofuel feedstock production could also impact biodiversity positively or – if unregulated – negatively (CBD 2008). In that regard, the clear definition of areas suitable for feedstock production, and the promotion of production schemes compatible with agrobiodiversity, are urgently needed (FAO 2008b).

Restrictions for Biofuels because of Competition for Land and Water

Arable land to grow biofuels is a scare resource, and might become even scarcer in the long-term with a growing global population, changing diets, and impacts from climate change. Furthermore, biofuel feedstock cropping requires water, and thus competes with water demand for feed and food crops. Both factors will restrict global biofuel development severely.

On the other hand, feedstock cultivation for biofuels can make use of non-edible plants such as short-rotation coppice, and can take place on land unsuitable for food and feed production (e.g., Jatropha on degraded lands). Plant varieties and cropping schemes with low water demands are more feasible for bioenergy production than for food and feed schemes, thereby, in principle, reducing competition.

Still, all options to minimize or avoid competition of biofuel feedstocks with food and feed crops will lead to higher production costs, as feedstock yields will be reduced by minimal irrigation, marginal soil fertility, and low-input farming.

Summary: Which Biofuels Can Deliver in the Future?

Given the wide range of cost and GHG emission profiles of biofuels, and the rather large uncertainties in future developments of feedstock cropping systems and downstream conversion, one can assume that in the longer-term only a few biofuel systems will be competitive in terms of their sustainability profile:

- biofuels derived from residues and wastes,
- biofuels derived from perennial plants (sugar-cane and palm for 1st-generation, and perennial grasses and short rotation coppices for 2nd-generation) from land with low carbon soils – especially marginal and degraded lands, and
- bioCNG derived from high-productive “multiple harvest” schemes with no-till cultivation.

The role of residues and wastes, and – hence – the role of 2nd-generation biofuels, will become key since these routes allow one to convert “non-competing” biomass feedstocks into biofuels.

Biomethane is an important option for all biomass feedstocks – its role will be mainly restricted by available (natural) gas infrastructure, and comparable vehicles.

Growing biomass for material use first, and making use of the energy content of biomaterials only after their product “life” has ended, offers superior performance in terms of resource and land-use efficiency and greenhouse-gas reduction. With rising oil prices, fossil-fuel based materials (e.g., plastic, textiles) will become more expensive, thus creating high-value opportunities for bio-based products.

Converting bio-residues and wastes into modern energy and transport fuels can start today with biogas, and could use “2nd-generation” technologies in the future.

5.5.2 Hydrogen and Electricity: Versatile Transport Fuels?

Currently, about 200 EJ of primary energy – mainly oil – is used for liquid transport fuels (IEA 2007). This may increase to 300 EJ by 2030, and 400 EJ by 2050 (IPCC 2007). Meanwhile, the total global primary energy demand for all energy services (electricity, heat, and transport) could be on the order of 750 EJ by 2030, and reach 1,000 EJ around 2100. This demand could nearly double in a business-as-usual scenario without major energy efficiency efforts – therefore, efficiency in all sectors is a key issue.

The amount of renewable energy that could be converted into either electricity or hydrogen is restricted by cost and environmental impacts. An estimate of the longer-term global renewables potential within sustainability boundaries shows that excluding biomass, there are approximately 500 EJ available, which could be translated into some 200 – 400 EJ of transport fuel equivalents, depending on the conversion route and vehicle technologies assumed. This means that all non-biomass renewables could meet the future long-term transport demand if more efficient transport systems are developed and implemented.

This clearly is not a valid assumption – biofuels could, as described – play some role in a sustainable global energy system, so that it will be a mix of renewable energy carriers used to meet transport energy demands.

One might also consider H_2 production from biomass – either through gasification or from direct biological processes such as genetically altered algae, or bacteria. For this, a sound sustainability assessment is not (yet) possible.

Furthermore, the restrictions of terrestrial and aquatic renewable energy systems might be overcome by going into space: orbital solar power stations have been suggested, but payload costs for installation seem to remain prohibitive unless radical changes in ground-to-orbit transport means are assumed[18].

What is the need for transport fuels being more sustainable?

In the medium-term, full sustainability requirements for all biomass, including social issues, have to be implemented globally. More feedstock production using degraded lands with more productive systems (e.g., salt-tolerant and drought-resilient species), more sustainable feedstock production using multiple cropping schemes, and agro-forestry, algae and bacteria for bioenergy production (fermentation etc.) have to be enforced in order to ensure sustainability. Research on environmentally-sound direct H_2 production from algae and bacteria is another aspect which should be supported. On a longer time scale, more cost-effective solar-thermal and geothermal electricity generation, environmentally-sound offshore wind and wave electricity generation, and algae and finally bacteria for direct H_2 production should also be targeted.

Given the huge range of possibilities for future transport energy provision, we can clearly derive one conclusion: Whatever mix of sources, carriers, and conversion systems there may be, the private economic cost of transport fuels will be far higher than those of today.

Therefore, the role of efficiency becomes critical, not only in terms of the environment, but also in terms of affordability. Only by the interaction of an extensive tapping of vehicle related efficiency potential, a shift to cleaner travel modes and the reduction of transport demand, can the thus significantly reduced energy demand of the transport sector be transformed to a high degree into renewables regardless of whether the carrier is liquid, gaseous or electric.

[18] „Sky-hooks“ have been suggested not only in science fiction. Still, the tensile strength of cables to allow for geostationary systems is not within reach of current and near-term material science.

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