TRANSPORT AND ENERGY

The Challenge of Climate Change

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RESEARCH FINDINGS

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Transport and Energy: The Challenge of Climate Change

Research Findings

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International Transport Forum Leipzig 2008
Transport and Energy: The Challenge of Climate Change
Research Findings[1]

Introduction

Preparations for the discussions between Ministers and transport sector stakeholders at the 2008 International Transport Forum on *Transport and Energy: the Challenge of Climate Change* involved the organisation of a number of workshops and production of several publications by the Joint Transport Research Centre (JTRC) of the Forum and the OECD. This note summarises the findings of that work and the research workshops held on the opening day of the Forum. Full publications and workshop presentations can be found on the Forum website www.internationaltransportforum.org . These research findings are organised as follows.

Section 1 presents a short synthesis of key greenhouse gas emissions indicators for the transport sector; detailed sectoral and national indicator tables are included in the annex. These draw from the preliminary report of the JTRC Working Group on Greenhouse Gas Emissions Reduction Strategies in the Transport Sector. The preliminary report is available on the web (OECD/ITF 2008) and the group will publish its full report in the fall of 2008. Section 1 also discusses data quality issues following a joint IEA-ITF workshop on energy indicators for transport (IEA-ITF 2008).

Section 2 presents a short summary of the Transport Outlook, released at the Forum, focusing on CO_2 emissions from road transport, which accounts for by far the largest part of transport sector emissions.

Sections 3 to 6 present conclusions from the workshops held on the first day of the Forum covering:

3. Advances in Energy-Efficient Transport Technologies;
4. Changing Behaviour in Passenger Transport;
5. Reducing CO_2 Emissions in Goods Transport;
6. Transport CO_2 Emissions in Emerging Economies.

Section 3 integrates the findings of a Round Table meeting on *The Cost and Effectiveness of Policies to Reduce Vehicle Emissions* held by the JTRC in January 2008, and the results of a Symposium *Towards a Global Approach to Automotive Fuel Economy* organised jointly with the FIA-Foundation, the IEA and UNEP in May 2008.

Section 7 discusses the limits to the potential for biofuels to contribute to mitigating transport sector greenhouse gas emissions, and summarises a Round Table meeting organised by the JTRC in 2007.

Section 8 discusses transport sector oil dependency and integrated policy responses to security of supply, mitigation of CO_2 emissions and managing congestion. It summarises discussions at another Round Table workshop organised by the JTRC in 2007.

Section 9 identifies research work to be undertaken in follow-up to the Forum. Section 10 summarises key conclusions.

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[1] These research findings were prepared by the Secretariat of the ITF and do not necessarily reflect the views of Member Countries.

1. Greenhouse Gas Emissions from Transport

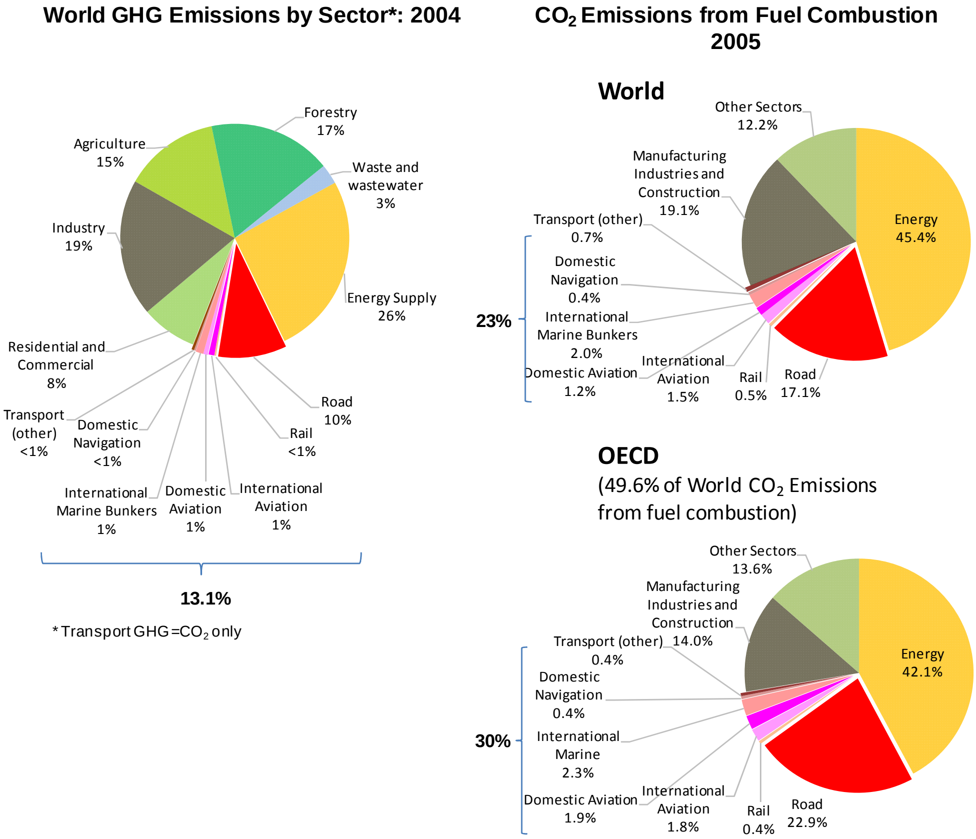
Transport is a key economic sector, supporting economic development and growth, and facilitating exchange. At the same time, the transport sector is a significant and growing contributor to greenhouse gas emissions. Transport is responsible for 13% of all anthropogenic emissions of greenhouse gases and 23% of world CO_2 emissions from fossil fuel combustion. In the OECD countries transport accounts for 30% of CO_2 emissions from fossil fuel combustion. The sector is 95% dependent on oil and accounts for 60% of all oil consumption. Transport is increasingly exposed to oil price instability and supply shocks.

In most countries, transport CO_2 emissions are growing faster than total CO_2 emissions: CO_2 emissions from fuel combustion in International Transport Forum countries grew 18% from 1990 to 2005 whilst transport CO_2 emissions grew by 23% over the same period. For OECD countries, these figures are 17% and 30%, respectively.

Transport activity varies greatly between countries and is growing at different rates. Car ownership for example varies from over 800 cars per thousand in the US to less than 10 in India. World-wide, car ownership is expected to triple between 2000 and 2050 (WBCSD 2004). Projections for the future suggest continued strong growth in transport volumes in all modes, especially in non-OECD countries. Air passenger traffic is expected to be 2.5 times higher in 2025 than in 2005 (Boeing 2007) and air cargo is expected to be three times higher in 2025 compared to 2005 (Airbus 2007). Similarly, shipping volumes doubled from 1985 to 2007 and the fast growing container sector is expected to triple from 2000 to 2020 (OECD/ITF 2008). Road transport accounts for by far the largest part of CO_2 emissions from the sector (Figure 2) and this will remain the case in the coming decades despite more rapid growth in shipping and aviation.

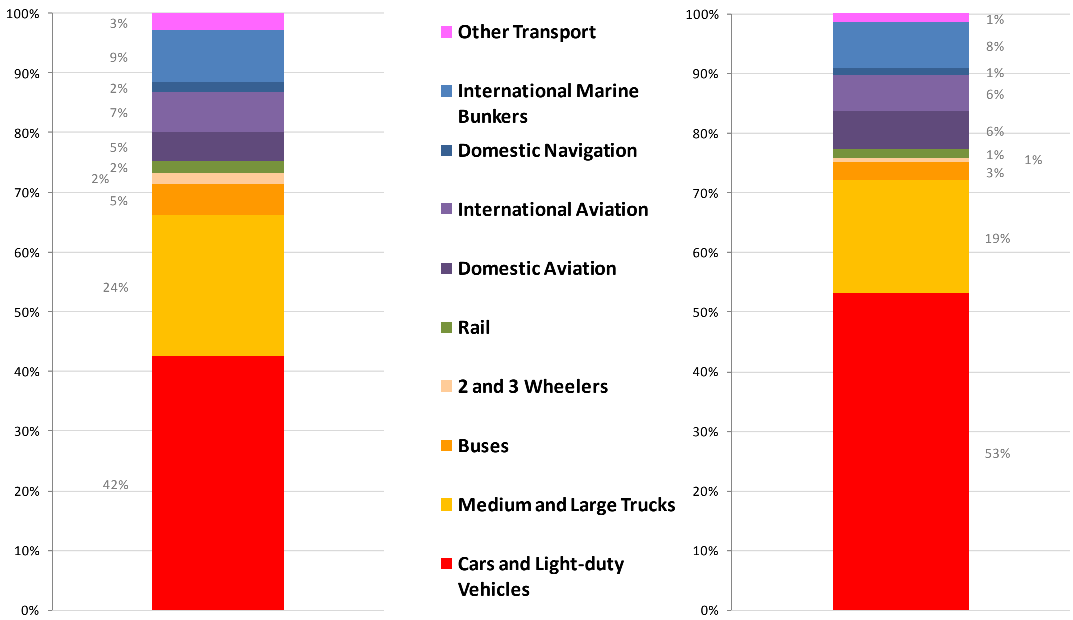
Whilst the data available on transport activity and CO_2 emissions is sufficient to track these general trends, the quality and coverage of data would need to be improved if specific targets were to be set for emissions of greenhouse gases from transport sector activities, for example in the form of an emissions trading system. The deficiencies were examined at a joint IEA-ITF workshop in early 2008 (IEA-ITF 2008) and joint efforts will be made to improve the quality of indicators published in the future. It is generally recognised that the most reliable data available on transport CO_2 emissions is derived from fuel consumed, such as that published annually for a very large number of countries by the IEA. However, recent CO_2 emissions estimates for shipping prepared by Intertanko for the IMO (OECD/ITF 2008) calculating CO_2 emissions on the basis of shipping activity find emissions to be twice the level reported by the IEA on the basis of fuel sales; a striking illustration of the uncertainties that can arise from incomplete data.

Figure 1: ***Transport accounts for a significant share of CO_2 emissions***



Sources: CO_2 from Fuel Emissions, IEA, 2007; and National reports to the UNFCCC

Figure 2: ***Modal shares of transport CO_2 emissions, 2005.***



Source: CO_2 from Fuel Emissions, IEA, 2007

2. Transport Outlook: future emission paths from transport and policy potential

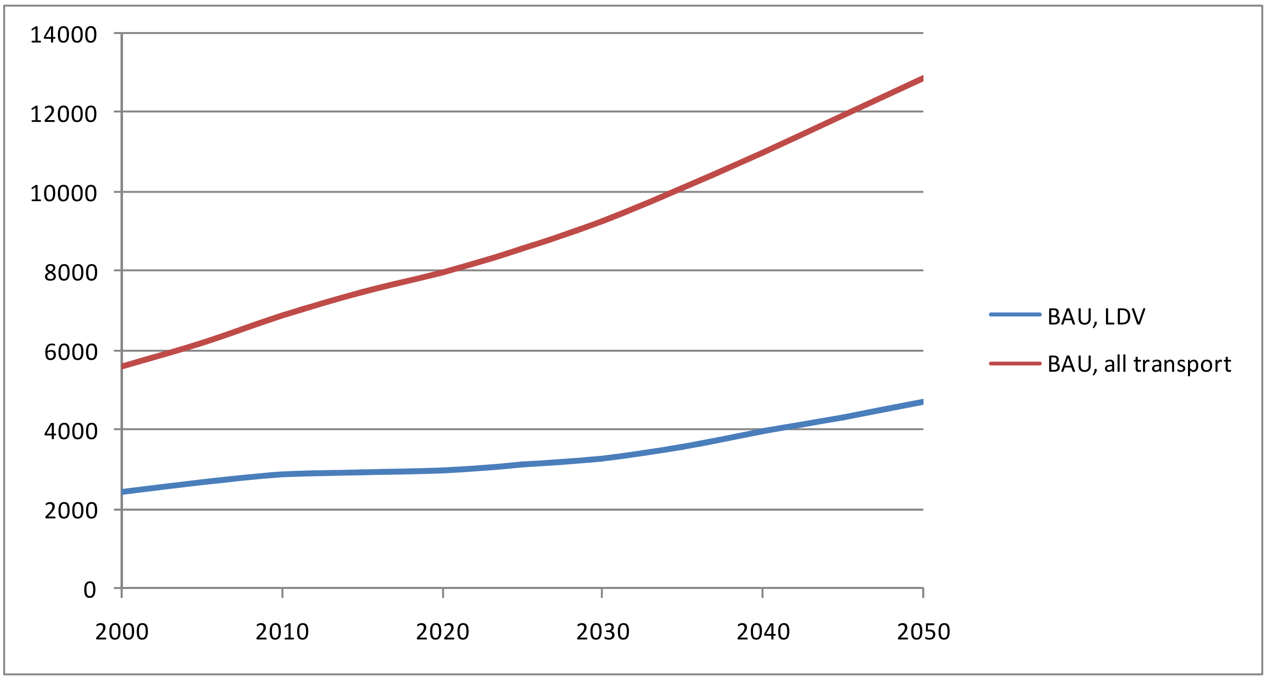
Modelling the developments of transport activity and potential trends in CO_2 emissions provides invaluable information for policy making. It can provide a quantitative illustration of the way alternative policy measures influence emissions over time and indicate the maximum limits to the mitigation potential of particular interventions. Just as importantly it can illustrate the degree to which uncertainties in key assumptions on the economic behavior of the sector affect emissions trends and the relative effectiveness of alternative interventions under different conditions.

The short outlook developed by the ITF (OECD/ITF 2008b) tests the potential of key policy instruments for mitigating emissions from road transport, and particularly from light duty vehicles, the largest source of CO_2 emissions from transport. It also examines uncertainties in the baseline scenario for the development of CO_2 emissions from transport. The work uses the most transparent and robust model developed to date for the sector, the MoMo model constructed and maintained by the International Energy Agency and initially developed for the World Business Council for Sustainable Development (IEA 2008). The main findings and insights are as follows:

- In the Business as Usual (BAU) scenario, CO_2-emissions from the transport sector are expected to grow by 120% by 2050 compared to 2000 levels. Emissions from light-duty vehicles grow more slowly, but are still 90% higher in 2050 than in 2000. **See Figure 3.**
- Sensitivity analysis on the light-duty vehicle module of the BAU scenario suggests that emissions may grow faster than in the standard BAU scenario. The main reason is the growth of traffic in emerging economies. Using income elasticities for vehicle use similar to those observed in the USA over the past 40 years implies faster growth than assumed in the BAUl Scenario. **See Figure 4.**
- The projections illustrate "where demand would like to go", in the sense that it is assumed that sufficient energy supplies are available to meet demand without sharply rising prices. It is not straightforward that this indeed will be the case.
- Rapid improvement of the fuel economy of light-duty vehicles and freight trucks by about 30% would reduce emissions and may even stabilize them for these modes over the next two decades. This approach is particularly powerful when implemented on a global scale. **See Figure 5.**
- In the longer run the expected growth in vehicle fleets and usage outstrips these fuel economy improvements, leading to rapid growth of emissions. Stabilizing emissions from light-duty vehicles over this horizon would require fuel economy levels of around 3.5l/100km (67 mpg; 80 g CO_2/km) by 2050, around the world.
- It is sometimes argued that improving fuel economy by about 30% would be cost-effective, though it does require government intervention to shape consumer choice and manage risk for industry investment decisions. The projections suggest that ambitious targets, like stabilizing emissions from cars through 2050, require further technological change that could entail significant economic cost. The task for research is to direct policies to promoting the most cost-effective ways of reaching ambitious targets.
- Fast improvements of fuel economy may stabilize emissions over the next two decades. Such results may induce complacency, which the long run analysis shows would be misplaced if a goal of stabilizing vehicle emissions were to be adopted. For this, long run emissions standards would need to be established soon, in order to facilitate the more costly switch to low-carbon technologies and provide the certainty required for industry to make the necessary investments.

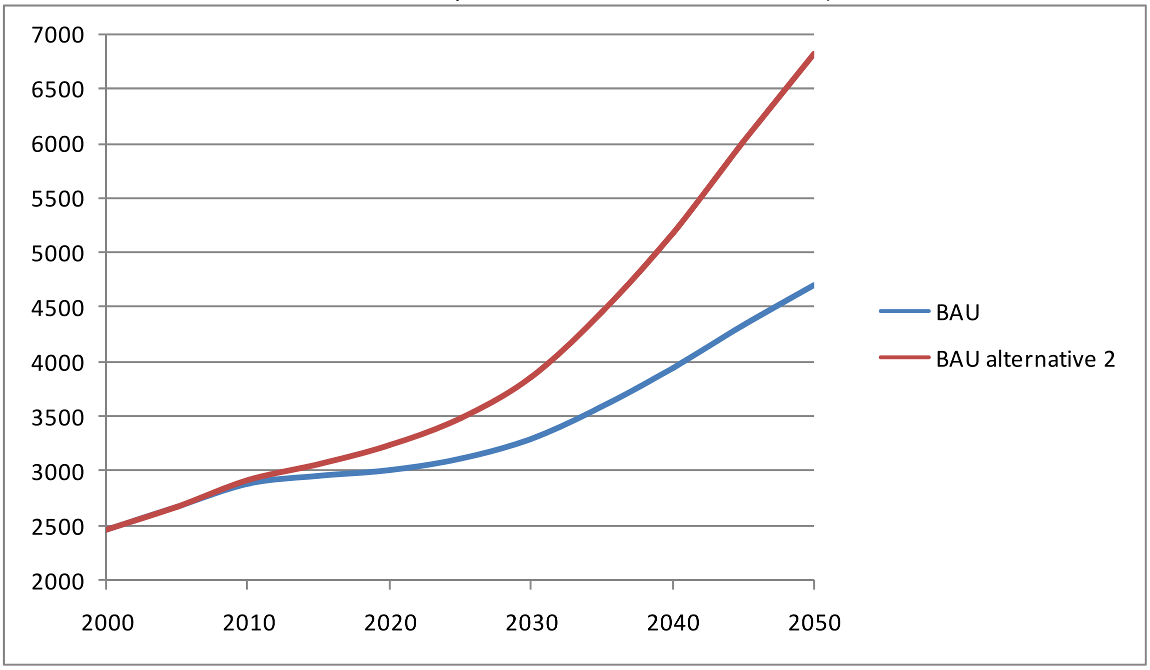
Figure 3. ***Cars account for half of all transport sector emissions.***

World CO_2 Emissions from Transport, Business as Usual (BAU) Projection, 2000 – 2050,
(Mt of CO_2-equivalent, tank-to-wheel emissions: LDV is light-duty vehicles)



Source: ITF calculations using the IEA MoMo Model Version 2008

Figure 4. ***CO_2 emissions from cars could grow much faster than commonly forecast.***
World light duty vehicle CO_2 Emissions, 2000 - 2050 : BAU compared to the outlook if rising incomes result in growth in demand for driving in non-OECD countries that tracks past trends in the USA (alternative 2) (Mt of CO_2 equivalent, tank-to-wheel emissions)

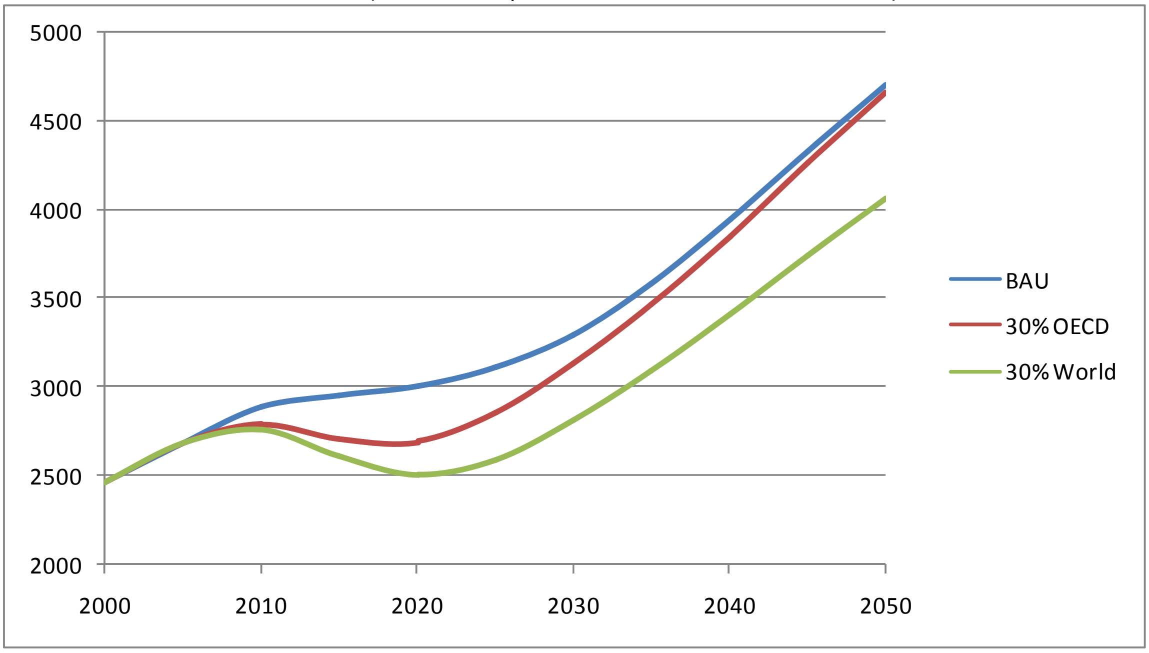


Source: ITF calculations using the IEA MoMo Model Version 2008

Figure 5. ***The fuel economy measures taken in emerging economies have a big impact.***

World light duty vehicle CO_2 Emissions: BAU and scenarios for rapid short term fuel efficiency improvement in OECD countries "30% OECD" and in all countries "30% World", 2000 – 2050

(Mt of CO_2 equivalent, tank-to-wheels emissions)



Source: ITF calculations using the IEA MoMo Model Version 2008

3. Advances in Energy-Efficient Transport Technologies

Potential

Many research engineers and economists argue that considerable improvements in the fuel economy of conventional power-trains are possible and cost-effective at social discount rates. For example, Part I of the UK government's King Review (King 2007) states that the take-up of such "near to market" technologies can improve fuel economy of new cars by about 30% in the UK within a decade through advances in conventional automotive technologies. Further improvements, up to 50% by 2050, are feasible but require advances that include battery electric and hybrid vehicles. Battery electric vehicles potentially offer reduced emissions, if low-carbon electricity can be generated on a much larger scale.

For the USA, Heywood (2008) finds similar orders of magnitude for improved fuel economy (keeping vehicle quality constant). Critically, if we are to deliver significant reductions in CO_2 emissions we need to ensure all of the technological potential is used to improve fuel economy, not to increase performance. In this situation, achieving 30% improvement in new cars within a decade is realistic.

Although policy should be designed to support the development of technology for the long term without picking winners, there is a fairly widespread view that electric vehicles will outperform fuel cell technology in terms of reduced cost/complexity and total CO_2 emissions because of the additional losses incurred by using H_2 as an energy vector.

The costs of introducing mainstream technology, to improve fuel economy by some 30% are small in the sense that any increase in the purchase price is compensated by savings on fuel within two to three years. One example quoted was a seven speed double clutch transmission which improved fuel economy by about 7% compared to a standard manual box, at no additional cost.

The current costs of improving fuel economy by 50% are higher. An example quoted was a lithium-ion battery powered electric car with a driving range of around 100 km, estimated to cost about $5000 more than an equivalent conventional vehicle. Including costs for more complex hybrid propulsion systems could inflate the additional cost to some $7000, or roughly 20% to 30% more than a conventional car. Historical data suggest that motor industry cost reduction, post regulation and with a mass market, is typically in excess of 50%. Current industry cost estimates can therefore be expected to lie at the top of the range of likely costs.

Market imperfections

The availability of cost-effective improvements does not imply that attaining ambitious greenhouse gas abatement targets is easy or costless, for at least two reasons. First, imperfections in vehicle purchase markets may prevent the take-up of the available improvements. Second, as suggested in Section 2 above, it is unlikely that adopting the cost-effective improvements alone will be sufficient to attain ambitious targets such as stabilization or reduction of transport sector emissions of greenhouse gases.

With respect to vehicle purchase market imperfections, a number of barriers to the take up of this technology are cited including information problems, consumer myopia and loss aversion, sunk costs, and regulatory uncertainty (OECD/ITF 2008c). The result is that vehicle purchase decisions reflect implicit discount rates that are well above the discount rates employed in the public sector, for road investments for example. A US National Research Council study (NRC 2002) found in a study of CAFE fuel economy standards that a net present value to the consumer of $405 as a result of the fuel savings achieved by increasing fuel economy from 28 to 35 mpg translated into an expected net loss of $32 when typical consumer loss aversion is factored in. This gives an idea of the size of the incentives required to steer consumers towards more fuel efficient vehicles.

Regulatory standards

The market imperfections mentioned have been observed in an era of declining real fuel prices. It is conceivable that higher fuel prices will induce consumers and producers to pay more attention to fuel economy in their purchase and production decisions. But as such one should not expect higher energy costs to resolve the imperfections as high fuel taxes in Europe have not resolved the issues in European markets. Hence, the market imperfections justify policy interventions, possibly in the form of better information provision and/or fuel economy regulation. The strictness of standards should ideally be determined by the size of the market failure compared to the costs of the technologies required to improve fuel efficiency. It is not clear that existing or proposed regulations are designed to remedy the imperfections mentioned, and there is unfortunately little empirical basis for determining these costs. Engineering estimates for the costs of new technology tend to ignore effects of economies of scale and learning as technologies move from the lab to the market. Costs may fall manyfold in the early phases of commercialisation as for example the experience with the introduction of catalytic converters shows, but no systematic understanding of such scale effects is available.

New short term standards are in the final stages of negotiation in the USA and EU. Long run standards would be a valuable complement to increase regulatory certainty for manufacturers faced with long investment cycles for bringing new technology that involves much more than incremental improvement to market. This could facilitate the development of battery electric vehicles that will be needed if growth in demand for vehicles and vehicle use is not to rapidly outstrip emissions reductions beyond a twenty year horizon.

Minimising the costs of intervention

The design of government intervention can have a very large impact on both effectiveness and costs. On the basis of the argumentation above, there is a rationale for combining emissions standards with fuel taxes (OECD/ITF 2008c), differentiated vehicle taxes and improved consumer information. Differentiated vehicle ownership and circulation taxes can be used to guide consumers to purchase vehicles that make use of technology advances to improve fuel efficiency rather than power, weight and comfort. Over the last few decades conventional (gasoline) vehicle technology has shown a natural rate of improvement of around 1% a year. In the USA, almost all of this potential has been taken up in power and weight increases; in Europe, half of the potential was used for performance and half of it to improve fuel economy (Heywood 2008).

Standards are generally varied around an average target level according to the weight of the vehicle in order to avoid extreme differences in the costs of meeting standards between companies producing different types of vehicles. This can lead to unnecessary costs if the standard is differentiated in steps between different segments of the car market, potentially creating perverse incentives for manufacturers to squeeze vehicles form one segment to another. A smooth curvilinear differentiation of the standard avoids this danger. A footprint[2]-based differentiation is thought to outperform a weight-based approach according to many, simply because using weight can reduce incentives for manufacturers to reduce weight – a very effective way to reduce fuel intensity.

A more extreme case of unnecessary costs from segmentation is seen in Europe where vehicle ownership and circulation taxes are increasingly differentiated according to CO_2 emissions according to detailed segmentation of the market. The pattern of segmentation varies markedly from one country to another. The level of tax payable differs greatly too. Manufacturers face a fragmented market where tax bands and tax levels change frequently, increasing costs and inhibiting the response to differentiation in any one country by effectively creating niche segments too small to make optimisation worthwhile. National labelling systems for vehicle fuel efficiency, moreover, are frequently based on an entirely different segmentation of the market. There is a clear role for international coordination to coordinate the way the market is structured through segmentation. Again, for tax differentiation, a formula to link tax rates to CO_2 emissions rates without steps avoids the problem.

Vehicle components

Some of the most cost effective technologies for reducing CO_2 emissions are not susceptible to influence by vehicle emissions standards, or are only partially affected. These include low rolling resistance tyres, particularly in the replacement market, low friction lubricating oils and efficient electrical systems and ancillary electric motors. Improved technologies are already available in all these areas and offer emissions reductions of the order of 5 or 10% at no, or very low, cost. They require specific intervention if

[2] Area delineated by the four wheels of the vehicle.

they are to penetrate markets systematically – voluntary agreements with industry, fiscal incentives or regulatory and labelling schemes.

The most significant of these technologies is idle-off stop-start systems for cars. Large emission reductions are achieved in urban driving conditions (over 20%) for systems that add around 600 Euros to the price of a car. The absence of stop-start cycles in the tests used to certify vehicles for sale means that fuel efficiency standards and differentiated vehicle taxes provide no incentive for the adoption of stop-start systems. Mild hybridisation, combining regenerative braking with stop-start systems, are similarly handicapped despite a potential to cut CO_2 emissions 30% in urban driving conditions.

Efforts to harmonise test cycles world-wide at the UNECE World Forum for Harmonization of Vehicle Regulations will consider improvements to correct for some of these deficiencies. This work should be pursued as a matter of urgency and accelerated as far as possible if it is to keep pace with technological development.

4. Changing Behaviour in Passenger Transport

Policy levers

Governments have several levers to help guide travel decision-making in a way that produces the largest benefits, including mitigation of greenhouse gas emissions, at the lowest possible costs. Salon and Sperling (2008) propose developing the appraisal and planning process to provide an integrated climate policy instrument for local governments in the form of city carbon budgets. This would mean integrating climate change policy with transport policy, using instruments that involve influencing the pattern of land use development, the intensity of car use and the efficiency of public transport systems. This approach combines an enforceable cap with the full freedom and flexibility to select locally appropriate measures.

The full range of levers includes:

- Investment choice and financing for road and public transport networks;
- Pricing of parking, road use and public transport;
- Vehicle and fuel taxation;
- Rules regarding traffic, parking, access and use of the network;
- Transport infrastructure planning and its coordination with relevant land-use planning systems;
- Policy appraisal processes and methodologies, which have a real impact on transport decision-making.

Transport authorities have in the past largely treated travel demand as an exogenous factor that simply must be catered for, resulting in a series of "predict and provide" infrastructure development projects. A growing realisation that such policies not only meet expected demand, but induce additional demand as well, and that catering to demand when prices are below social costs eventually is ineffective, has led many authorities to re-assess their approach. The construction of new roads or the freeing-up of existing capacity leads to a decrease in travel times and thus to a decrease in the generalised cost of travel. Consumers respond to this by adapting their trip-making frequency, patterns and mode choice. The "induced" impact of new capacity is not bad in itself as it can reflect suppressed demand but it can erode the expected benefits of road construction or widening schemes. The induced travel effect can also come into play as a result of any successful policy to draw cars off the road which, without flanking measures, increases available road capacity. Conversely, reductions in available road capacity have been found to have lasting impacts in reducing traffic demand. As in other sectors (electricity, water) there is a growing focus on managing demand for transport infrastructure to contain the negative consequences of unmanageable traffic growth.

The potential to change passenger behaviour

Goodwin (2008) notes that although travel behaviour is sometimes described as ”too difficult to change” there are very many kinds of behavioural choice. These are in constant flux and subject to a wide range of incentives. A key point often overlooked is that small net changes in transport demand often hide significant changes in specific household behaviour, masking potential for specific policies to change behaviour. A net increase in passenger kilometres of 2% might hide the “churn” resulting from an important number of households decreasing their travel (-20%) as compared with those increasing their travel (+22%). Goodwin cites evidence to suggest overall reductions in car use of up to 20-30% are possible. Tony May (May, 2008) also points to a potential of -20% car travel in European urban areas from the deployment of a comprehensive and self-financing package of measures.

There are many more travel choices over and above choosing between cars and public transport, including the volume and location of travel, using other modes notably walking and cycling, driving style, car ownership, and where to live and work and shop. In general responses are often rather small in the short run, but build up to very much more flexible life-style choices in the longer run, in which habits are eroded and new ones form. There is a large volume of empirical and case study evidence about the effect on travel behaviour of changes in price, speed of travel, quality of travel, information availability and other factors which can be influenced by public or private interventions. A common characteristic is that these interventions have mostly been chosen for objectives other than carbon reduction, including congestion reduction and quality of life improvements. Where such interventions produce net benefits there are carbon benefits for zero real resource cost.

Available studies on fuel price elasticities over the short- and long-run (5-10 yrs) show clear and emerging regional differences, but there are two principal findings that are both robust and important:

- The main response to increasing fuel prices is to decrease fuel consumption (via vehicle choice, vehicle size choice, changes in driving styles) rather than decreased car travel. The elasticity of fuel consumption is at least twice as high as the elasticity of travel volume.
- Long-term elasticities are at least twice as long as short-term elasticities which indicates that many behavioural responses (vehicle purchases, housing and job decisions, etc…) take time to have an impact. This holds true for both the elasticity of fuel consumption and of travel volume.

Goodwin’s summary of elasticity values (Table 1) differs from those found from a recent comprehensive study of responses to fuel price changes in the United States (Small and VanDender, 2007). Lee (2008) also finds lower short-run traffic volume elasticities with respect to fuel price than the Goodwin review, ranging from -0.078 to -0.171 for the greater metropolitan Seoul area depending on the alternative modes to the car likely to be chosen – bus, subway or a combination of the two. While there is no clear explanation for the difference in estimated elasticities, there are several plausible factors that likely play a role. The principal factor is the income effect – the United States has higher per-capita income than many of the countries whose elasticity values are referenced by Goodwin et al. Per capita incomes have risen in the United States as fuel price elasticities have fallen, as can be seen from the Small and Van Dender’s estimates for 2000-2004. Higher incomes cause the share of fuel expenditures in total expenditures to decline, which may lead to lower elasticities. Higher incomes also lead to higher values of time, so that time costs of travel become relatively more important than fuel costs. Higher fuel costs then translate into proportionally smaller increases in the generalized price of travel (which is the sum of time and money costs), and assuming that drivers respond mainly to this generalized price, this reduces the elasticity with respect to the money costs. Note, however, that by the same logic higher fuel prices will lead to more elastic responses, which is consistent with the large effect that current fuel prices are having on the sales of relatively fuel-intensive light trucks in the USA.

Table 1. **Review of Recent Fuel Price Elasticities**

		Short-term	Long-term
Goodwin, Dargay and Hanly (2004)			
Summary of 69 Studies undertaken from 1992-2004	Fuel Consumption	-0.25	-0.60
	Traffic Volume	-0.10	-0.30
Small and Van Dender (2007)			
US 39-year cross-sectional time series of data at the State level (1966-2004)			
1966-2004	Fuel Consumption	-0.074	-0.363
	Fuel Intensity	-0.035	-0.193
	Traffic Volume	-0.041	-0.210
2000-2004	Fuel Consumption	-0.041	-0.237
	Fuel Intensity	-0.031	-0.191
	Traffic Volume	-0.011	-0.057

Small and Van Dender's results suggest that fuel consumption by passenger vehicles has become more price-inelastic over time, and that it is increasingly dominated by changes in fuel efficiency rather than in amount of driving. Their results identify two main reasons for this: rising incomes and falling real fuel prices. One of these – rising incomes – can be presumed to characterize the future as well, even if falling real fuel prices probably cannot[3].

Lee finds that the cross-elasticity of public transport fare prices to car travel is insignificant whereas car users' responsiveness to changes in parking prices measured in terms of car travel volume is greater than their responsiveness to fuel prices, highlighting the importance of parking policy over public transport fare policies in seeking to change overall volume of car travel.

Effects of "Soft" Influences on Travel Choice

Recent research has examined measures that change behaviour without changing the speed or cost of travel but instead seek to provide better and more targeted information to travellers on travel options. Cairns (2004) in a review of the literature found that such measures coupled with new opportunities to

[3] Price elasticities are not, of course, the only factor determining CO_2 emissions; see for example the discussion of fuel efficiency regulation and vehicle tax differentiation in the preceding section.

change behaviour arising from teleworking, car pooling, school travel plans etc., could result in a reduction of urban peak-hour road traffic of as much as 21% in the UK (11% nationwide) given sufficient support. However, these studies often target small groups of travellers and it is unclear whether these results can be scaled up to the population at large.

One clear finding on the psychological determinants of travel behaviour is the importance of habit in travel decision-making. Goodwin (2008) notes that people rarely base their daily travel habits on reasoned best-interest after weighing all the travel options available to them, even when they have all the necessary information on travel costs and options. Travellers are more likely to make decisions by force of habit. Thus interventions seeking to change travel behaviour should focus on providing information at those times when travellers are developing new heuristic rules or travel habits (e.g. when moving into a new area, when acquiring a driving licence, when changing jobs, etc). This finding may be of particular interest for policies seeking to develop public transport use. Information campaigns in the context of mobility management initiatives in the workplace have proven to be particularly effective in this context.

Ecodriving

Ecodriving has become a key element of national strategies to reduce CO_2 emissions in a number of countries. Ecodriving has significant potential to deliver CO_2 reductions quickly and cost-effectively; there appears to be a savings potential of 10 percent of surface transport sector emissions. Critics of ecodriving state that it is difficult to keep the habit once the training is over, especially in case of private drivers where economic incentives are not as obvious as in case of commercial operations. However, in-car equipment such as gear shift indicators, cruise controls and on-board computers giving feedback on fuel consumption help improve fuel economy. Instrumentation alone can deliver around five percent savings and provide and incentive to maintain and even improve driver performance after training. Cars are increasingly equipped with on-board computers that have an instantaneous fuel consumption readout function. Making this the default display would be a cheap and effective way to promote fuel-efficient driving. Introducing more advanced technology to run cars in an ecodriving mode as standard could achieve significant fuel savings. Ecodriving is already required to be taught to novice drivers under EU regulations. Testing ecodriving skills as a part of the driver licensing examination might result in significant CO_2 emissions savings (OECD/ITF 2007).

Avoiding Oversimplifications

Travel behaviour is embedded in a web of other behaviours and decisions (Bonnafous 2008). It cannot be dissociated from work, housing, household, leisure and other social and economic systems that have an impact on the number and nature of trips taken. Isolated measures that seek address only one component of travel decision-making may have unintended consequences due to the complex interactions involved – e.g. measures to reduce work-related trips can lead to an increase in leisure-related trips. Another example of counter-intuitive policy outcomes are parking restriction measures to reduce the number of car-trips lead to an increase in increase in congestion due to “cruising” for rare parking spaces. Some basic and transparent accounting for the complexity of trip-making decisions must be integrated into transport and land-use policies to avoid the most extreme unforeseen consequences.

Policies seeking to influence travel behaviour – especially fiscal and pricing policies – have a real impact on the distribution of costs and benefits. Policies that might bring about the greatest change in behaviour and those that are most efficient from an economic perspective may not be the most fair from a social perspective. This finding cannot be ignored since the acceptability and the durability of pricing and fiscal policies often hinges on it. Impacts on lower-income households that are "captive" automobile users are particularly sensitive. Flanking measures that address the redistributive impacts of pricing and fiscal policies are important. At the same time, one may question whether distributional objectives should be pursued through transport policies and whether efficiency improvements in transport should be given up because of distributional issues. Other policy instruments, targeting income distribution, appear more suited to attaining equity targets.

5. Reducing CO_2 Emissions in Goods Transport

World-wide, freight transport accounts for roughly a third of transport sector CO_2 emissions. Freight transport increases with the expansion of economic production but growth is reinforced by the increasing average distances freight is carried. This has happened because transport costs have fallen relative to other costs in the production and distribution of goods and because of specialisation of production as trade barriers have been removed. Differences in labour costs between regions are likely to remain an important determinant of freight flows in the foreseeable future. Rising incomes in developing economies tend do reduce wage differences, but this is a gradual process, slowed down by restrictions on international labour mobility. The global distribution of freight flows is sensitive to differential cyclical movements among countries, but expectations are that growth will remain strong[4]. Freight activity is therefore set to continue to expand strongly but there are opportunities to mitigate CO_2 emissions.

Technological innovation

Technological innovations have the potential to deliver significant fuel efficiency gains. These include more fuel efficient engines, aerodynamic improvement, engine downsizing, fuel efficient NOx emission control systems and improved tyres. Around two-thirds of fuel efficiency gains in trucks are expected to come from improvements in engine and exhaust systems. Some of these innovations are likely to be adopted without any support or regulatory pressure. Most commercial operators expect a 3 year payback for fuel economy improvements and have more capacity than private consumers to make investments in anticipation of future fuel savings. Nevertheless, they exhibit some of the risk aversion to investing in uncertain future fuel savings noted in the section on vehicle technologies above. This has led one government, Japan, to introduce regulatory standards for heavy duty vehicles. The full potential for aerodynamic improvement may require specific intervention as it relies partly on trailer design and coordination between trailer and automobile manufacturers.

Ecodriving

Although the fuel costs of transport are only a small part of the cost of delivered goods, and not a very large part of the overall logistic costs of freight movement, they do represent a major cost item for transport companies. Shipping lines have responded to recent fuel price increases by reducing ship speeds, although if capacity did not currently exceed demand the effect would not have been so marked. The larger trucking companies train their drivers and monitor driver performance and style to encourage fuel economy. Immediately after ecodriving training, average fuel economy improvements of between 5-15 per cent have been recorded, for example in the Austrian national programme for commercial vehicles (OECD/ITF 2007). Data on the UK Freight Best Practice programme confirms a potential of 10 percent fuel savings from ecodriving. There is little evidence available regarding the long-term impacts (>3 years) of

[4] E.g. Financial Times, Asia exporters find ways around US storm, 21 May 2008.

ecodriving training, although a few studies on companies with truck and bus fleets that provided one-off training with no follow-up incentive programmes recorded a 2-3% residual improvement in fuel consumption. A number of strategies are available to maintain the habit of ecodriving once training is over. In commercial fleets, IT applications are available that monitor fuel economy in real time and provide instantaneous readouts to drivers, or to fleet managers via mobile communications systems. Voluntary government partnership agreements, based on quantified CO_2 reductions targets, are a very useful tool for maximising the effectiveness of private sector ecodriving initiatives.

Logistic organisation, vehicle loading and truck km charges

Improving the utilisation of vehicle capacity reduces emissions and can be achieved in a number of ways: better matching of return hauls, more space-efficient loading systems, consolidation of loads in larger vehicles, more transport-efficient order cycles and inter-company coordination to match loads and delivery routing. The spatial distribution of warehousing facilities can also be modified to reduce vehicle kilometres travelled. Many logistics service providers and large retailers have voluntarily sought such rationalisation of activities to improve their carbon footprint. Voluntary agreements with government and provision of information by government have also been used to promote CO_2 emissions reductions in this way.

Logistic improvements have also been driven by the introduction of electronic truck kilometre charges in Switzerland, Germany and Austria. The introduction of the Heavy Vehicle Fee in Switzerland increased charges per vehicle kilometre 20% (with a simultaneous increase in maximum vehicle weight limit), resulting in a reduction of 12% in vehicle kilometres driven and roughly a 7% cut in CO_2 emissions (DETEC 2004). The German government reports a 13% cut in empty loads from a much smaller price increase (one third the Swiss increase) on introduction of its heavy vehicle fee.

Modal efficiency considerations

In principle, increasing the efficiency of transport systems should deliver CO_2 benefits. Liberalisation of railways, where it has been successfully implemented, has allowed railways to better manage their potentials and reduce energy consumption per ton-km hauled. Depending on the mix between diesel and electric traction for freight trains and the fuel used to generate electric power, rail can move goods long distances with significantly lower CO_2 emissions than road haulage, on condition that the rail operation itself is efficient. Some governments have successfully provided grants to shift freight from road to rail to reduce CO_2 emissions at reasonable cost with careful targeting.

More generally governments can influence freight modal split through a coherent policy of charging for the use of infrastructure across the modes. In a majority of countries, trucks are charged at levels below the marginal cost of using the roads, whilst in some countries rail freight covers its full costs, notably on the large, private freight railways of North America. On the other large freight railways too, in Russia, China and India, competition is distorted as profitable freight services tend to be used to support passenger services, increasing rail freight rates. Pricing road use at marginal cost (including congestion and environmental costs) would create the conditions for a more efficient modal split. However, it is sometimes argued that even with appropriate pricing structures the potential for a major modal shift is limited to a number of corridors where demand is sufficiently dense to make rail or barge freight attractive (Notteboom 2008).

Summing up, the overall picture for CO_2 emissions from freight is similar to that for passenger transport: technological improvements are available to reduce emissions per unit of output, and at least some of those are low-cost or even "no regret", but it is far from straightforward that take-up of these options is sufficient to curb emissions in the face of expected traffic growth rates. Even the take-up of the cheaper options requires innovative policy.

6. Transport CO_2 Emissions in Emerging Economies

Development imperative

Adequate transport infrastructure and services are essential for economic development and improving welfare. As developing countries grow, transport activity will also grow. This growth should be welcomed but steered to take a more sustainable path than would be the case without intervention from government to provide a planning, regulatory and pricing environment that promotes welfare for all citizens. This includes improving air quality and road safety, and managing congestion. These local problems likely will, and probably should dominate the agenda of governments in emerging economies but policies to address them also provide opportunities to mitigate CO_2 emissions.

Private Motorised Transport Fleet Growth

Car ownership has entered a phase of exponential growth in the largest emerging economies. Regulating for cleaner fuels and for all new cars to be equipped with catalytic converters will be essential to improving air quality. Regulating fuel efficiency will be essential to containing growth in CO_2 emissions and fuel consumption, with the balance of payments implications that has for most emerging economies. Auto fuel is untaxed and indeed subsidised in many middle and low income countries. This kind of support to business and to low income families is financially unsustainable, as recent oil price increase have demonstrated, and inflates fuel consumption and CO_2 emissions.

The fuel economy of new cars sold in emerging economies is relatively high. In India and China the average performance of new cars already matches or exceeds the US targets for 2020. This is mainly because of the small size and low power of the cars in developing countries. In turn this reflects fuel pump prices that are higher relative to incomes than in OECD countries (despite fuel subsidies).

Fuel economy is clearly important to consumers and they can be assisted in making the best choice of car by vehicle testing and labeling schemes. Brazilian car manufacturers have recently entered into a voluntary agreement with the government to begin testing popular ranges of vehicles for fuel economy and provide information to consumers at sales outlets. Testing facilities exist in other emerging economies but have not been used as yet to measure fuel efficiency, concentrating on exhaust emissions. There is scope for governments and independent associations, such as automobile clubs, to develop testing and labeling schemes to "mobilise the demand side potential". Driving in heavily congested traffic and on poor roads, characteristic of many developing countries, increases fuel consumption greatly and therefore specific tests for fuel economy that reflect these conditions may be required to ensure the information provided is reliable.

Ownership of auto manufacturing is increasingly global but markets differ widely. The technologies currently being developed in the US, EU and Japan for fuel efficiency are suited to high power vehicles and come at a cost that is much higher in relation to car prices in emerging economies than in OECD countries. The technology solutions for improving fuel efficiency in the short term are therefore different in emerging economies. Idle stop-start systems offer the most cost effective savings in emerging country conditions, because of the extent of congestion in urban areas[5]. Small electric vehicles with limited range for urban areas might also be suited to conditions in the emerging economies. In the long run, engine downsizing in OECD markets and increasing incomes in developing economies will drive a degree of convergence. Despite the differences in technology, the approach for governments to promote fuel efficiency is universal: fuel economy standards to reduce commercial risk for car manufacturers producing fuel efficient vehicles; complementary tax policy[6] to steer technological improvements towards increasing efficiency rather than power. Regulatory standards can also be designed to discourage up-sizing of the fleet as is the case in China. Fuel tax policy is an important factor and can also influence the pattern of imports of second hand cars, which supply a large part of the market in many developing economies. Ending fuel subsidies is difficult, especially in periods of high fuel prices, but inevitable.

Motorised two and three wheelers are a major part of traffic in many emerging economies, and they are less readily susceptible to the demand management measures discussed for cars below. They are important as they provide essential mobility to families on modest incomes, but they are also the source of serious local air pollution, even if their CO_2 emissions are modest. Some Chinese cities limit the number of motorcycle registrations, and the country produces 15 million electric bicycles a year as a locally clean alternative. These nevertheless add to power demand from a coal based, CO_2 intensive, electricity industry. In these circumstances an electric bicycle is associated with a similar level of CO_2 emissions per km driven on well-to-wheels basis as a good petrol driven motorbike. In India the Tata Nano car is aimed at the more affluent end of the motorcycle market, with much improved safety compared to transporting families on motorcycles one of its attractions. If it and similar low cost cars prove a commercial success, they will accelerate the already rapid growth in car fleets in emerging economies, underlining the need to manage urban road space more effectively.

The freight transport sector is showing rapid growth of road haulage and erosion of the share of rail and waterway traffic. Trucks generally have poor fuel efficiency and emit high levels of air emissions. Reduced diesel tax rates, aligned with tax on kerosene for cooking and heating, should be ended to provide incentives for more fuel efficient vehicles and more efficient logistics organisation. Taxes on imported used vehicles can be differentiated to eliminate the worst performing trucks. For cars, trucks and buses, inspection and maintenance programs have proven effective in reducing air emissions and maintaining design fuel-efficiency.

In rural areas road infrastructure development is driving rapid motorisation of transport. India plans to connect all its villages to all-weather roads by 2012. Carts pulled by animals are often replaced by locally produced, three wheelers. The impact on CO_2 emissions will be significant.

Demand Management

The rapidly expanding cities in emerging economies pose a major challenge for mitigating CO_2 emissions and present the greatest opportunities for curbing emissions growth. Car ownership is increasing most rapidly in the cities. The pattern of land use determines transport demand, and transport infrastructure development pays a major role in determining land use. Integrated land use and transport planning is therefore critical to shaping transport demand and promoting the kind of compact urban development, served by public transport, that enables large numbers of people access to jobs and services without reliance on the most fuel intensive, CO_2 intensive and polluting kinds of motorised transport.

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5. These systems are also cost-effective in OECD countries but the largest gains in efficiency in high income countries over the next two decades will come from downsized engines with turbo-chargers.
6. Tax on vehicle ownership and road use differentiated according to fuel efficiency rating.

Land use planning on its own is, however, a relatively weak instrument, vulnerable to the pressures of property speculation, encroachment and squatting. Restrictions on land use may unduly distort property prices, with undesirable allocational and distributional consequences. The main source of income for many local authorities is from leasing land for new development. Land use policies are insufficient to manage demand for road space if road use and parking are free of charge. When road and parking space go un-priced, excess demand is inevitable in densely populated cities with rising incomes. Road pricing and parking charges are not the preserve of OECD countries as the most successful and technologically advanced urban congestion charging system operates in Singapore. It was first introduced as a simple paper permits system for access to the city centre, deployed early in development of the city. It has evolved in scope and technological sophistication to keep pace with rising levels of traffic. A road pricing system was designed for Hong Kong a number of years ago and although not yet implemented this might provide a model for other cities in China. In Latin America a number of major cities are considering introducing urban tolling. Singapore also manages car ownership by auctioning permits, a system already adopted in Shanghai.

Parking charges, with enforcement of parking regulations, are a much more widely applicable instrument for managing demand for road space, and are quite effective in inducing a modal switch to transit (see section 3). Parking policies proved critical in managing the rapid increase in car ownership in transition economies in Central and Eastern Europe; these economies saw extremely rapid growth of congestion in their main cities in the 1990s, only brought under control once parking began to be regulated and the regulations enforced. Some Japanese cities require proof of off road parking space for registering cars and this system might be adopted elsewhere. More generally policy towards parking should be made explicit. Some cities in OECD countries have required new dwellings and offices to be built with off road parking, only to find this encourages car use; others have restricted provision of off-street parking in residential buildings and taxed office parking space in order to discourage car use. Policies need to be consistent to achieve predicable outcomes.

Expertise on demand management, where it exists, resides chiefly in local authorities rather than central government. Overseas development aid from donor countries and the technical assistance programs of international finance institutions should direct resources to making this expertise available to counterparts in recipient countries.

Public Transport

In some emerging economies, notably India, rapid urbanisation has been accompanied by a decline in public transport services, exacerbating the expansion of private motorisation. Elsewhere, public transport investments have greatly improved urban mobility and move more passengers per ton of CO_2 emitted; Curitiba and Bogota are notable examples of cities that have developed bus rapid transit systems, which are many times cheaper and more flexible than many rail systems. Integrated ticketing systems that facilitate interchange between BRT, local bus and rail systems are effective in promoting use of public transport. The timing of investments in public transport is critical because rising incomes permit an exponential growth in motorised vehicle ownership. Generally the earlier the investment the more successful it will be in managing private road traffic growth. Once a city is dependent on private motorised transport it is difficult to create a market for public transport. International Financial Institutions can play a critical role in funding public transport in the early stages of urban expansion. They can also provide critical technical assistance in establishing sustainable financing frameworks, through fare revenues and subsidies that provide for adequate maintenance of vehicle fleets, without which public transport systems rapidly deteriorate.

The International Financial Institutions can also have a critical role in supporting governments develop the institutional capacity to develop public transport and integrate land use and transport planning more generally. Technical assistance of this sort is more valuable in the long run than overseas development assistance to support investment projects, such as metro systems, linked to exports of technology.

7. Biofuels

Performance of biofuels in reducing greenhouse gas emissions

There is a wide range of performance of biofuels in terms of life-cycle energy and greenhouse gas emission balances (OECD/ITF 2008d). Performance differs between fuels and even for a single fuel and feedstock, performance varies greatly according to production process and farming practice. In the worst cases biofuels result in significantly higher emissions of greenhouse gases than gasoline or diesel.

There is a wide range of uncertainty in the estimation of emissions of CO_2 from the soil and emissions of N_2O in the cultivation of feedstocks. These emissions vary according to soil type and farming technique and can account for a large part of the overall greenhouse gas emissions for some conventional biofuels.

For biofuels that provide relatively low greenhouse gas abatement (up to around 30%), such as ethanol produced from corn and many other grains, the range of uncertainty can be larger than the average expected benefit. Therefore there is a risk that such fuels provide no benefit or even produce higher rates of greenhouse gas emissions than oil products.

On a small scale, biofuels are currently produced from whey and waste cooking oil with relatively large greenhouse gas savings compared to fossil fuels, of around 70%. The only large-scale production of biofuels to approach this level of performance is Brazilian sugar cane ethanol. However, it requires tax subsidies to be viable, amounting to around USD 1 billion a year.

Most other large-scale biofuel production (ethanol from sugar beet and sorghum; biodiesel from rape, soy and palm oil) achieves around 30% to 50% greenhouse gas savings, but requires large subsidies.

Costs and alternative policies

Views differ over just how much biofuel might be produced sustainably. But most biofuels are expensive, particularly when environmental costs are factored in. Only at sustained high oil prices are biofuels likely to be produced commercially. With subsidies restricted to a level that reflects their contribution to greenhouse gas mitigation, much production would otherwise cease. Improving energy efficiency in transport has much greater potential, and at lower cost, than promoting biofuels for reducing energy supply vulnerability and reducing greenhouse gas emissions.

Taxes related to the carbon content of fuels, including for biofuels, would also be more cost-effective than subsidies or biofuel targets as they target CO_2 emissions directly. Fuel-excise tax systems are very similar to a tax on the carbon content of fuels, albeit at a high rate in some cases. In Europe, current excise rates are roughly equivalent to a carbon tax on petrol and diesel of around Euro 200/t CO_2-eq, around ten times the current cost of CO_2 in the European emissions trading system. Support for ethanol in the USA is currently estimated to cost double this level at the country's best performing ethanol plants. The same is true for rapeseed biodiesel produced in the EU.

Advanced biofuels

Future generations of biofuel feedstocks and production processes are likely to have lower greenhouse gas emissions and may be more cost-effective. Such biofuels may be able to meet up to 10% or 20% of current transport energy demand, but no more than this without major advances in technology (Jones 2007).

Ligno-cellulosic ethanol produced from some feedstocks in pilot plants already performs much better than most conventional biofuels in terms of greenhouse gas emissions and performs as well as the best Brazilian sugar cane ethanol. However, the economics are unproven and for large-scale production the potential supply of ligno-cellulosic ethanol is limited by cost and the land available for energy crops. There is a rationale for supporting research on advanced biofuels but this does not extend to open-ended support.

Effectiveness of subsidies

Subsidising large-scale production and consumption of conventional biofuels fails to deliver a significant contribution to the strategic goals of reducing greenhouse gas emissions or improving the security of supply of fuels for transport. It is an inefficient way of providing income support to rural communities and it consumes large amounts of taxpayers' money (USD 4 billion in 2007 in the USA in tax subsidies alone; USD 4 billion in 2006 in the European Union in tax subsidies; and between USD 13 billion and USD 15 billion in the OECD as a whole for support overall), without commensurate benefits. Germany has now begun to reduce subsidies for biofuels and the United Kingdom is expected to reduce the current excise duty differential of 20p/litre (Euro 0.29/litre) over time.

Policy reform

Volumetric production targets for biofuels fail to provide incentives to contain costs, to avoid environmental damage or even to ensure greenhouse gas emission reductions are delivered. Carbon content targets for fuels, accompanied by certification, are a better alternative.

California, the Netherlands, Germany, Switzerland, the United Kingdom and the European Commission are developing systems of certification to regulate the market for biofuels. These systems are aimed at improving environmental outcomes. If governments continue to promote biofuels, then greater selectivity is needed in the choice of producers and processes to be subsidised. Without this refinement of policy, through certification linked to subsidies, although there may be progress towards targets for production and consumption of biofuels, there will be disappointment in the higher level objective of reducing greenhouse gas emissions. Moreover there are likely to be unwelcome side effects for other sustainability goals.

It should be noted that certification systems are not well suited to addressing the indirect impacts of biofuel production. Certification can only guarantee to influence the supply chain. It can be used to modify farming and biomass harvesting methods in order to limit the environmental impacts of farming. But certification can not be used to control any displacement of existing farming activities induced by an expansion of biofuel production, with consequent land-use change outside the area farmed to produce biofuel. Separate measures will be required to protect valued natural and semi-natural ecosystems, from all kinds of development.

The range and sometimes poor performance of today's biofuels in terms of greenhouse gas emissions is in part a result of the absence of regulations or incentives to select biofuels according to their environmental profile. The challenge for the development of biofuel certification systems is to provide such incentives cost-effectively.

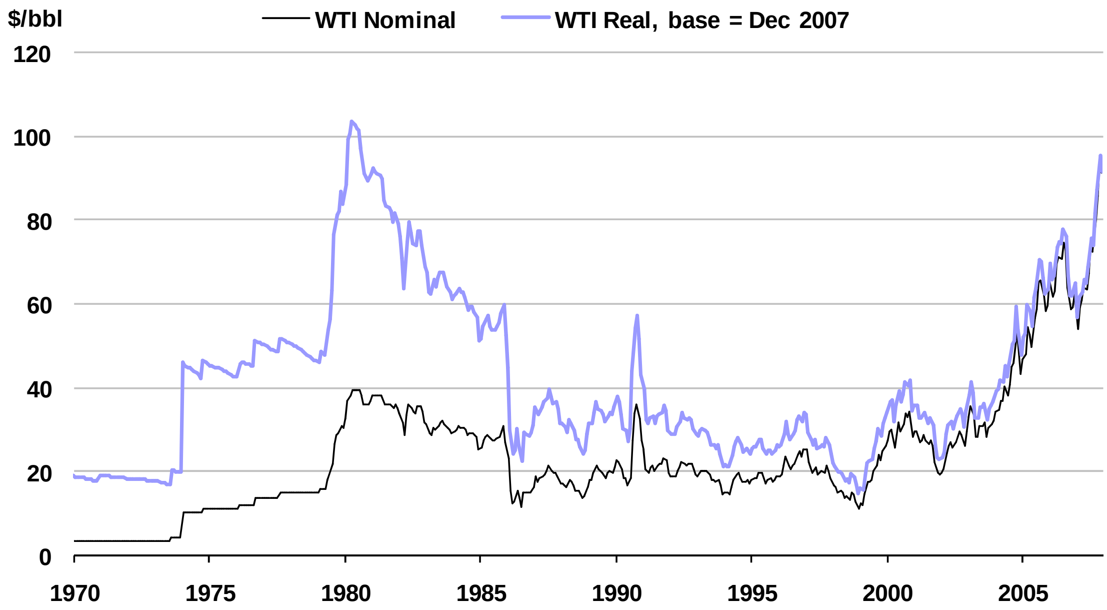
8. Responding to Oil Dependence: integration with CO_2 emissions mitigation and transport policies

Oil demand and prices

The transport sector's demand for oil is less price sensitive than any other part of the economy. This is partly because demand for transport services is relatively insensitive to price and partly because substitutes for oil in road transport are currently far from cost-effective. Evidence from the USA suggests that as incomes rise, transport sector oil demand becomes even less price sensitive. This implies that oil consumption is set to become increasingly concentrated in the transport sector. It also implies that relatively limited fluctuations in demand can have increasingly significant effects on oil prices.

Oil prices approached their historical 1980 peak in real terms in November 2007 (Figure 6) when the ITF and OECD convened a round table on oil dependence in the transport sector (OECD/ITF 2008e). Prices climbed further to 130 dollars a barrel by the end of May 2008 when the Forum met. Because of growth in incomes since 1980 and the reduced oil dependence of OECD economies, the economic impact of high prices has been weaker than during earlier oil price peaks, at least through 2007. Moreover, the current high prices are a result of strong economic growth rather than a supply shock as was the case in the oil crises of the 1970s. Nevertheless, the transport sector is the most exposed part of the economy to oil prices.

Figure 6. **Spot crude oil price 1970-2007: real and nominal prices**



Notes: Price sources: Dow Jones for pre-Jan 1985 data, Platts monthly Cushing spot west Texas intermediate (WTI) crude from Jan 1985; Deflated taking December 2007 baseline and using monthly OECD consumer price index data.

Source: IEA.

OPEC market power

OPEC market power is expected to increase. OPEC, and particularly the Middle East, will see its share world oil supply increase because production of conventional oil from other parts of the world has either peaked and entered a phase of permanent decline or reached a plateau for the foreseeable future. OPEC will therefore be in a strong position to defend high prices against a background of rising demand, particularly from the emerging economies.

That is not to say prices will inevitably rise further or even stay at current levels. They could also fall substantially if economic growth weakens, particularly in the increasingly interdependent US and Chinese economies. Price instability is likely to persist. This creates uncertainties that delay major investments in new oil production and refining capacity, as well as in fuel efficient car technology.

Non-conventional oil, fuel efficiency and alternative fuels

In the longer term, non-conventional oil resources could supply a large part of oil demand at prices from around $40 a barrel. The conventional view is that reserves of tar sands, oil shale and coal are sufficient to provide for decades of further growth in oil consumption but this is challenged by some academics who believe coal supply has already peaked (Aleklett 2007). As non-conventional oil sources become more critical to world oil supply, a better understanding of their availability and the economics of production is increasingly important.

Policy responses to growing OPEC market power can seek to either promote non-conventional oil production in non-OPEC countries or reduce oil consumption. Policies to promote alternative fuels are also relevant but of limited short term potential as discussed in the section on Biofuels above. Non-conventional sources of oil are associated with more than twice the emissions of greenhouse gasses from conventional oil. Their development may therefore be constrained by climate policy.

Fuel efficiency standards and carbon taxes

Intervention to internalize the costs of CO_2 emissions from transport serves to both mitigate climate change and reduce oil consumption at the same time. Carbon taxes are the preferred instrument of many economists to achieve this because they provide incentives for attainment of the environmental target at least-cost. However, vehicle fuel efficiency or CO_2 emissions standards have some advantages, not least in terms of political acceptability. They are also able to correct the difference between social and private discount rates at the point of vehicle purchase. Differences between social and private discount rates, and imperfections in consumers' decisions on what fuel economy to buy, may justify standards even if taxes reflect external costs.

Standards are vulnerable to being undermined by the rebound effect – i.e. the cost savings resulting from increased fuel efficiency may be taken up by additional driving or upgrading of the power or weight of the vehicles purchased. There is considerable agreement that the rebound effect in terms of increased driving is small (at most 20%, often much smaller[7]), so that standards do translate into substantial reductions in fuel consumption. To the extent that the rebound effect is a problem, it indicates a failure to price CO_2 emissions and other transport externalities correctly. This suggests that if a standard is the

7. US data suggests that with rising incomes price elasticities for private road passenger transport have declined. As a consequence, there has been a change in the way drivers respond to higher fuel prices, with the vehicle-kilometres driven less sensitive to the price of fuel than the fuel efficiency of vehicles.

primary tool adopted for reducing transport sector CO_2 emissions a secondary tax element is required – ideally in the form of a carbon tax or alternatively through fuel taxes or differentiation of taxes on vehicle purchase or ownership. It also increases the urgency of introducing tools to manage congestion.

Policy integration

Transport, environment and oil security policies interact in a number of ways and there are trade-offs beyond the environmental impacts of developing non-conventional oil. Dieselisation of the car fleet, initially triggered by relatively low taxes on diesel fuels, has been the cornerstone of progress in Europe to reduce CO_2 emissions from the transport sector. As a consequence, the market share of diesel has grown strongly and has reached almost 70% of road transport fuels in the EU. But there are limits to the degree to which the refining process can switch production from one type of fuel to another without consuming large additional amounts of energy to convert oil products. The excess diesel demand in Europe is currently met through trade, with diesel imported from Russia and the USA and gasoline exported from Europe to America. If any other major car market were to follow the dieselization path, diesel prices would rise sharply and CO_2 emissions could increase.

Two important issues arise when the energy security and greenhouse gas emissions from transport are viewed from a broader perspective. First, there is the question of how to distribute greenhouse gas abatement efforts among different sectors. Cost-effective CO_2 abatement strategies should aim to distribute efforts over sectors efficiently. The challenge is to minimize simultaneously CO_2 abatement costs, potential losses in the competitiveness of industry and the costs of energy import dependence. In this sense, the large share of transport in total CO_2 emissions in itself provides little guidance on how large this sector's contribution should be, although it needs to be recognised that the political process very likely will request a substantial contribution from transport to cutting overall emissions.

Second, intervention to reduce greenhouse gas emissions from the transport sector needs to be integrated with policies to reduce the other external costs of transport – local air pollutants, accidents and especially congestion. Congestion costs greatly outweigh the cost of CO_2 emissions from transport according to most studies. The large impact on CO_2 emissions (-20%) of congestion charges in London and Stockholm suggests that congestion management can facilitate the attainment of CO_2 reduction targets in congested areas.

9. Follow-up

Discussions at the Forum identified a surprising lack of research funding for low carbon technologies, currently only 1-3% of public research and development budgets in the United Kingdom for example. Given the political and research consensus on the importance of global warming and the primary role of technology in reducing greenhouse gas emissions, more resources should go to R&D to reduce CO_2 emissions from transport and other sectors – notably carbon capture and storage for the power sector. The priority for transport technology is development of advanced electric batteries but governments should avoid picking winners as by its very nature research is risky and some avenues of research will fail. Risks need to be spread and research into other long term technologies such as hydrogen fuel cells is also therefore indicated. Economic research priorities emerging from debate in the form include the design of indicative long term vehicle efficiency standards and efficient instruments to manage greenhouse gas emissions from international maritime and air traffic.

The JTRC's Working Group on Greenhouse Gas Emissions Reduction Strategies in the Transport Sector provided an interim report to the Forum (OECD/ITF 2008) and will complete its work in autumn 2008 with a report that reflects discussions at the Forum. The work is designed to assist member countries in prioritising their greenhouse gas reduction programs for the transport sector. It will address the potential for the transport sector to cost-effectively contribute to GHG reductions vis-à-vis other sectors. The study will review and analyse transport-sector greenhouse gas reduction programs and measures in member countries and other large emitters and identify lessons that are internationally transferable. The Group will evaluate the extent of the cost-effective greenhouse gas emissions reductions available in the transport sector based on the best available ex-post assessment of specific measures and provide research-based advice on the best strategies for durably reducing the contribution of the transport sector to climate change.

Many of the vehicle technology issues examined at the Forum and in this paper were explored in a Symposium *Towards a Global Approach to Automotive Fuel Economy* on 15-16 May 2008 jointly organised by the FIA-Foundation, the IEA, ITF and UNEP. This brought together 50 experts from around the world to examine the potential benefits of convergence in policies to promote vehicle fuel efficiency through regulatory standards, the design of tax incentives, fuel efficiency testing, vehicle labelling and the provision of consumer information on fuel consumption and CO_2 emissions. The co-organisers are developing a potential international initiative to better understand vehicle markets and the potential for cost-effective fuel economy improvement around the world. The initiative will provide analysis to help shape practical policies towards fuel efficiency and assist with the development of fuel economy testing, labelling and information systems.

Energy costs and climate change are critical to transport policy and will therefore be the focus of further research in the Joint Transport Research Centre. The 2009 Forum will examine globalization and transport. The environmental impacts of globalization, including CO_2 emissions, will be among the issues addressed.

10. Conclusions

Fuel efficiency

Transport CO_2 emissions are set to double over the next 40 years. Accelerated rates of improvement in fuel efficiency are the key to reducing emissions. Emissions from road transport account for 75% of transport CO_2 emissions, and although emissions from aviation and maritime shipping are growing more rapidly, road transport will still account for the largest share of emissions in 2050.

Cars account for half of transport CO_2 emissions. Cutting car emissions will have the largest effect on emissions from transport, but mitigation policies need to be based on cost effectiveness, both within the transport sector and across sectors if carbon savings are to be maximized with the limited resources available.

Cost effective technologies are available to improve light duty vehicle fuel efficiency 30%, with incremental improvement to conventional internal combustion engine and vehicle technology.

Promoting fuel efficient cars

This potential will not, however, be taken up without intervention as consumers are risk averse and heavily discount the value of possible future fuel savings. Automobile manufacturers are not able to make investments to improve the fuel efficiency of cars 30% in the face of such uncertainty.

Intervention is required to reduce this uncertainty, in the form of vehicle fuel efficiency regulations. High European fuel taxes have not overcome the barriers to investment in fuel efficiency to date, so the current high oil prices are unlikely to make regulation redundant.

Over recent decades, vehicle technology has shown a natural rate of improvement of around 1% a year. In the US all of this improvement has gone to increasing power. In Europe, higher fuel taxes and voluntary agreements have pushed half of the potential to fuel efficiency gains. Differentiated vehicle taxes can be used to steer more of the potential to fuel economy.

The detailed design of standards and taxes can have major cost implications. Many European countries have differentiated vehicle taxes according to CO_2 emissions in recent years. Each varies the level of tax by vehicle market segment. Unfortunately each country segments the market in a different way, and tax differentials also vary. The segmentation used for vehicle labeling schemes is different again. The result is the creation of a patchwork of niche markets, reducing the incentive to optimize fuel economy in any of the niches and escalating costs for industry. International cooperation to bring some order to this situation is indicated. More generally, differentiating taxes and standards to a mathematical formula, rather than by market segment, avoids the problem.

Emissions reduction potential

Rapid improvement of vehicle fuel efficiency driven by fuel economy/CO_2 emissions standards and tax differentiation, to achieve the 30% potential from incremental improvement on conventional technologies, could stabilize global emissions from cars over the coming 20 years, especially if similar policies are pursued in emerging economies. Thereafter emissions would resume strong growth, mainly as a result of rapid growth in vehicle fleets in the emerging economies.

For illustrative purposes, stabilisation of emissions from cars through 2050 could be achieved through an average new car fuel efficiency of around 3.5 litres per 100km (80 grams CO_2/km) in 2050 for all cars around the world.

This implies a 50% improvement in efficiency, and the large scale introduction of hybrid and battery electric vehicles (coupled with low carbon electricity generation). There are likely to be significant costs per vehicle to achieve this and the uncertainties for industry are large. Indicative long term regulatory standards to complement existing short term standards would be one way to address this uncertainty and facilitate investment.

Incentives for low cost vehicle components

Highly cost effective fuel efficiency improvements are also available from more efficient vehicle components – for example tyres, lubricating oils and electrical equipment. These suffer from the barriers to widespread adoption described above and require their own regulatory standards, tax incentives and labeling systems.

The most significant of these technologies is idle-off stop-start systems. Large emission reductions are achieved in urban driving conditions (over 20%) for systems that add around 600 Euros to the price of a car. The small number of stop-start cycles in the tests used to certify vehicles for sale means that fuel efficiency standards and differentiated vehicle taxes provide insufficient incentive for the adoption of stop-start systems.

Managing passenger travel demand

CO_2 emissions can also be reduced by managing demand for passenger and freight transport. This is a core preoccupation for transport ministers and local government authorities. Managing congestion has significant benefits in reducing CO_2 emissions. It requires not only integrated land use and transport planning but pricing of road space. Parking charges and enforcement of parking regulations is the essential starting point in urban areas. Road pricing of various kinds is being used effectively to manage demand.

20-30% reductions in car use have been observed over the longer term through the wide range of investment, financing, pricing and planning policies available to influence passenger choice. High quality public transport to provide an alternative to energy intensive car use is an important part of the package as is protecting road space to promote cycling and walking for travel over shorter distances. Providing information on the alternatives available can be effective in modifying daily travel patterns when it is targeted to reach people when they change jobs and houses.

Ecodriving

Ecodriving has become a key element of national strategies to reduce CO_2 emissions in a number of countries. Ecodriving has significant potential to deliver CO_2 reductions quickly and cost-effectively; there appears to be a savings potential of 10 percent of surface transport sector emissions. Critics of ecodriving state that it is difficult to keep the habit once the training is over, especially in case of private drivers where economic incentives are not as obvious as in case of commercial operations. However, in-car equipment such as gear shift indicators, cruise controls and on-board computers giving feedback on fuel consumption help improve fuel economy. Instrumentation alone can deliver around five percent savings and provide and incentive to maintain and even improve driver performance after training.

Freight transport emissions

Freight logistics and transport companies aim to limit their fuel costs, and consequently CO_2 emissions, in their business planning even when fuel is not the largest component of their operating costs. Many have internal CO_2 emissions reductions strategies based on rationalizing their activities and training drivers to consume less fuel. Governments have successfully spread these practices to a wider range of companies by providing information and training. The electronic truck kilometer charges introduced in a number of countries have had a significant impact on reshaping road haulage logistics for efficiency.

Technological development offers substantial savings in emissions from trucks albeit possibly less than with cars given the greater capacity for some commercial fleet operators to factor fuel cost savings in to vehicle purchase decisions. In developing economies there is a large potential to improve vehicle emissions by regulating imports of second hand trucks.

Rail can offer an energy-efficient alternative to road haulage on routes where traffic densities and distances are high enough. The ability of railways to grow and maintain their share of freight transport depends on efficient operation. On some of the world's major freight railways, notably in the emerging economies this is hampered by freight profits being used to support passenger services.

Emerging economies

Adequate transport infrastructure and services are essential for economic development and improving welfare. As developing countries grow, transport activity will also grow. This growth should be welcomed but steered to take a more sustainable path than would be the case without intervention from government to provide a planning, regulatory and pricing environment that promotes welfare for all citizens. This includes improving air quality and road safety, and managing congestion. These local problems will, and should dominate the agenda of governments in emerging economies but policies to address them also provide opportunities to mitigate CO_2 emissions.

The rapid expansion of cities provides the greatest challenge. Land use planning, integrated with transport policy and the development of public transport systems are central to steering cities away from over-dependence on cars. Land use planning on its own is, however, a relatively weak instrument and insufficient to manage demand for road space if road use and parking are free of charge. When road and parking space go un-priced, excess demand is inevitable in densely populated cities with rising incomes. As elsewhere, parking regulation and parking charges are a powerful tool in managing demand and incentivising use of public transport.

Car ownership is growing rapidly in the major emerging economies and will drive an increase in CO_2 emissions. Technologies to improve fuel efficiency suited to the smaller and lighter vehicles in these markets will be different from those for the more powerful cars in OECD markets, but the stop-start systems described already are particularly suited to reducing emissions in congested cities typical of emerging economies. Regulatory standards, with improved test cycles, will be essential to constraining growth in emissions and fuel consumption.

Oil prices

Many developing economies subsidise transport fuels, inflating demand and emissions. High oil prices make this increasingly unsustainable financially. These subsidies need to be phased out despite the difficulties in ending them. A number of OECD country governments are contemplating reductions in fuel taxes to compensate current high oil prices. This has important disadvantages. High prices signal to consumers that they need to take action to reduce consumption. Removing that signal removes the incentive to invest, for example, in more fuel efficient vehicles. This will make consumers more vulnerable to future price increases. Cutting taxes also sends the wrong signal to oil producers, discouraging production and investment in new oil fields. It also protects oil producers from the potential negative impact on their revenues of price increases and diverts revenues from exchequers in oil consuming countries to oil producers. There is strong political pressure to provide social protection to parts of the economy hit hard by high fuel costs but lowering fuel taxes subsidises the rich more than the poor, as the rich consume more. Better targeted social policies need to be employed.

To reiterate a point already made, high European fuel taxes have not overcome the barriers to investment in fuel efficiency to date. Current high oil prices are unlikely to make fuel efficiency regulation, and other interventions to mitigate CO_2 emissions, redundant.

Biofuels

Biofuels have been promoted to provide an alternative to oil with subsidies and quantitative production targets. Recent grain and oil seed price increase reflect the fact that agricultural commodity prices are even less stable than oil prices, implying that biofuels do little to improve security of fuel supplies. The greenhouse gas emissions savings associated with substituting biofuels for oil products vary greatly between biofuels and especially with the way they are farmed and processed. Current subsidies imply extremely high costs per ton of CO_2 emissions saved. Some biofuels production and especially some advanced biofuels promise CO_2 emissions mitigation at reasonable cost, albeit on a limited scale. To select only the best performing biofuels certification systems are required. A regulatory framework is also required to try and limit negative local environmental impacts including destruction of biodiversity from the production of biofuels. Achieving such a framework for production of biofuels from all parts of the world presents a major challenge.

International transport and globalisation

Providing incentives for reducing CO_2 emissions from international transport, particularly shipping and aviation, is particularly challenging. The ideal instrument would be a global tax on carbon or a global emissions trading system. Achieving the necessary international agreements for this will be a slow process. Incorporating global transport services in partial, regional trading schemes loses much of the efficiency of an ideal system. The 2009 Forum on *Globalisation and Transport* will include a focus on policies to manage the environmental impacts of shipping and aviation and return to this issue.

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ANNEX: SUMMARY DATA ON CO2 EMISSIONS BY SECTOR

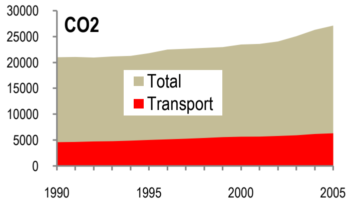
1. World
2. OECD
3. International Transport Forum members

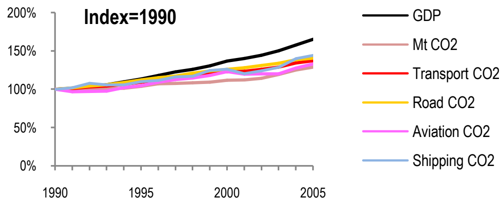
All data compiled from: International Energy Agency (2007), CO2 Emissions from Fuel Combustion: 1971-2005, International Energy Agency, Paris.

World

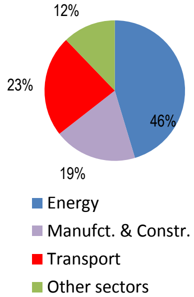
Total CO2 from Fuel Combustion including International Air and Maritime (2005)

Change 1990-2005*	Mt	2005	T per capita	2005	Kg/$2000 PPP	2005
CO2	29%	27136.36	5%	4.22	22%	0.50
Transport CO2	37%	6337.02	12%	0.99	17%	0.12
Road CO2	41%	4647.89	15%	0.72	15%	0.09
Aviation CO2	33%	729.77	9%	0.11	19%	0.01
Shipping CO2	44%	654.49	18%	0.10	13%	0.01

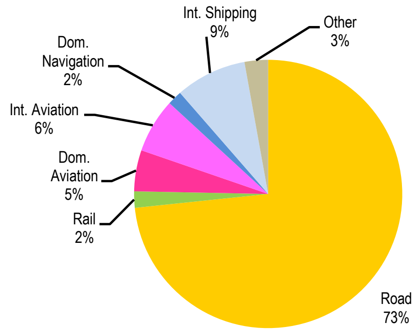




2005 Total CO2



2005 Transport CO2



Transport and the Economy	1990	1995	2000	2001	2002	2003	2004	2005	1990-2005	% per year
Population (millions)	5249.04	5660.88	6053.15	6128.12	6204.15	6280.24	6356.33	6431.68	23%	1.36%
GDP (billion 2000 US$, PPP)	33059.70	37494.37	45239.36	46385.37	47729.00	49618.71	52160.45	54618.22	65%	3.40%
CO2 Emissions										
IEA CO2 from fuel combustion (Mt CO2)*	21024.43	21807.80	23487.23	23599.03	24075.57	25090.14	26319.92	27136.36	29%	1.72%
IEA transport CO2 (Mt CO2)*	4614.07	5046.63	5677.52	5697.57	5815.29	5947.01	6202.39	6337.02	37%	2.14%
Transport as a percentage of total	*21.9%*	*23.1%*	*24.2%*	*24.1%*	*24.2%*	*23.7%*	*23.6%*	*23.4%*		
Road	3306.69	3708.65	4164.22	4231.16	4327.65	4429.07	4581.00	4647.89	41%	2.30%
Rail	147.97	111.87	118.49	115.41	119.04	125.12	118.53	124.97	-16%	-1.12%
Domestic Aviation	255.74	266.74	310.60	299.81	297.31	291.85	308.56	314.12	23%	1.38%
International Aviation	291.70	305.91	363.17	356.44	360.66	364.90	389.75	415.65	42%	2.39%
Domestic Navigation	95.71	93.11	106.86	105.84	106.41	116.04	113.66	111.06	16%	1.00%
International Maritime	357.71	404.57	466.23	439.67	456.02	466.82	520.26	543.43	52%	2.83%
Other Transport	158.55	155.78	147.95	149.24	148.20	153.21	170.63	179.90	13%	0.85%

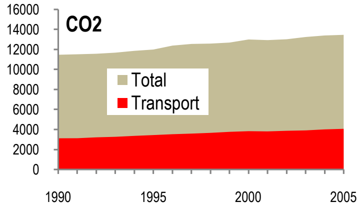
*includes international aviation and shipping

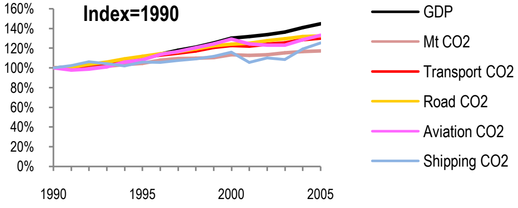
OECD

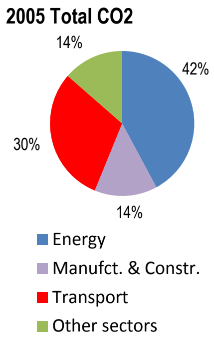
Total CO2 from Fuel Combustion including International Air and Maritime (2005)

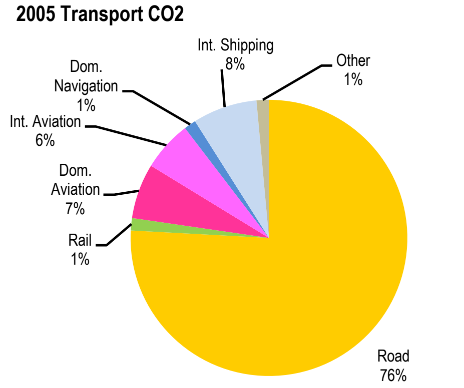
OECD	Rest of ITF	Top 10 non-ITF	Rest of World

Change 1990-2005*	Mt	2005	T per capita	2005	Kg/$2000 PPP	2005
CO2	17%	13455.07	5%	11.49	19%	0.44
Transport CO2	30%	4066.56	16%	3.47	10%	0.13
Road CO2	32%	3084.84	18%	2.63	9%	0.10
Aviation CO2	33%	501.09	19%	0.43	8%	0.02
Shipping CO2	25%	363.18	12%	0.31	13%	0.01









Transport and the Economy	1990	1995	2000	2001	2002	2003	2004	2005	1990-2005	% per year
Population (millions)	1043.68	1089.17	1130.29	1138.75	1147.15	1155.72	1164.09	1171.52	12%	0.77%
GDP (billion 2000 US$, PPP)	20945.31	23193.63	27277.81	27609.82	28045.97	28609.48	29536.70	30320.86	45%	2.50%
CO2 Emissions										
IEA CO2 from fuel combustion (Mt CO2)*	11463.83	11988.31	12992.34	12927.76	13012.55	13239.68	13391.67	13455.07	17%	1.07%
IEA transport CO2 (Mt CO2)*	3118.22	3441.88	3830.92	3808.38	3869.00	3908.61	4009.98	4066.56	30%	1.79%
Transport as a percentage of total	*27.2%*	*28.7%*	*29.5%*	*29.5%*	*29.7%*	*29.5%*	*29.9%*	*30.2%*		
Road	2329.28	2602.96	2889.81	2916.11	2972.02	3022.95	3070.78	3084.84	32%	1.89%
Rail	57.53	54.39	52.63	51.06	51.20	51.55	54.12	58.78	2%	0.14%
Domestic Aviation	236.50	235.54	265.44	257.21	253.24	249.68	259.16	262.15	11%	0.69%
International Aviation	139.78	171.94	220.53	211.10	210.61	213.48	224.61	238.94	71%	3.64%
Domestic Navigation	57.49	59.80	61.22	58.96	59.06	62.96	62.85	56.82	-1%	-0.08%
International Maritime	232.42	247.10	275.19	247.60	260.65	251.80	282.43	306.36	32%	1.86%
Other Transport	65.22	70.15	66.10	66.34	62.22	56.19	56.03	58.67	-10%	-0.70%

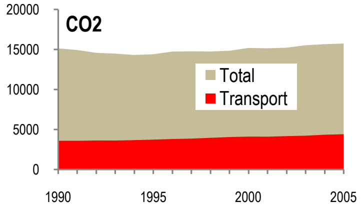
*includes international aviation and shipping

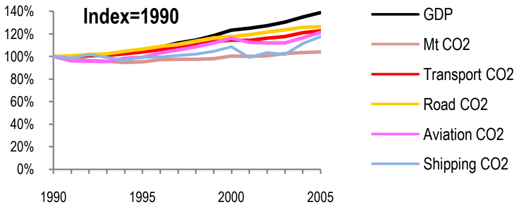
International Transport Forum Countries

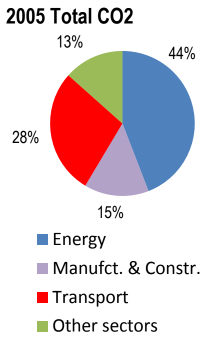
Total CO2 from Fuel Combustion including International Air and Maritime (2005)

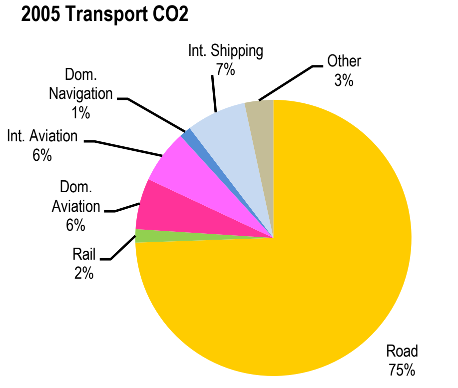
OECD-ITF | Rest of ITF | Top 10 non-ITF | Rest of World

Change 1990-2005*	Mt	2005	T per capita	2005	Kg/$2000 PPP	2005
CO2	4%	15734.25	3%	10.94	25%	0.48
Transport CO2	23%	4407.74	15%	3.06	12%	0.14
Road CO2	27%	3281.91	18%	2.28	9%	0.10
Aviation CO2	21%	538.68	13%	0.37	13%	0.02
Shipping CO2	18%	369.97	10%	0.26	15%	0.01









Transport and the Economy	1990	1995	2000	2001	2002	2003	2004	2005	1990-2005	% per year
Population (millions)	1341.63	1378.52	1407.49	1413.59	1419.60	1426.07	1432.62	1438.24	7%	0.46%
GDP (billion 2000 US$, PPP)	23488.20	24778.98	28978.11	29405.00	29930.66	30629.63	31715.03	32631.39	39%	2.22%
CO2 Emissions										
IEA CO2 from fuel combustion (Mt CO2)*	15123.48	14398.74	15181.20	15139.63	15212.68	15519.78	15654.20	15734.25	4%	0.26%
IEA transport CO2 (Mt CO2)*	3589.17	3731.26	4111.95	4103.54	4172.32	4224.25	4346.27	4407.74	23%	1.38%
Transport as a percentage of total	*23.7%*	*25.9%*	*27.1%*	*27.1%*	*27.4%*	*27.2%*	*27.8%*	*28.0%*		
Road	2593.30	2762.48	3053.52	3092.71	3151.53	3207.48	3266.84	3281.91	27%	1.58%
Rail	82.31	65.66	62.63	59.53	60.54	60.35	64.20	68.68	-17%	-1.20%
Domestic Aviation	238.05	236.03	265.93	257.82	253.81	250.24	259.79	262.92	10%	0.66%
International Aviation	206.18	205.41	251.14	242.69	243.74	247.60	258.40	275.76	34%	1.96%
Domestic Navigation	73.55	64.11	65.42	63.33	63.35	67.00	66.70	61.53	-16%	-1.18%
International Maritime	241.17	249.54	276.23	249.32	262.48	253.68	284.42	308.44	28%	1.65%
Other Transport	154.61	148.03	137.08	138.14	136.87	137.90	145.92	148.50	-4%	-0.27%

*includes international aviation and shipping