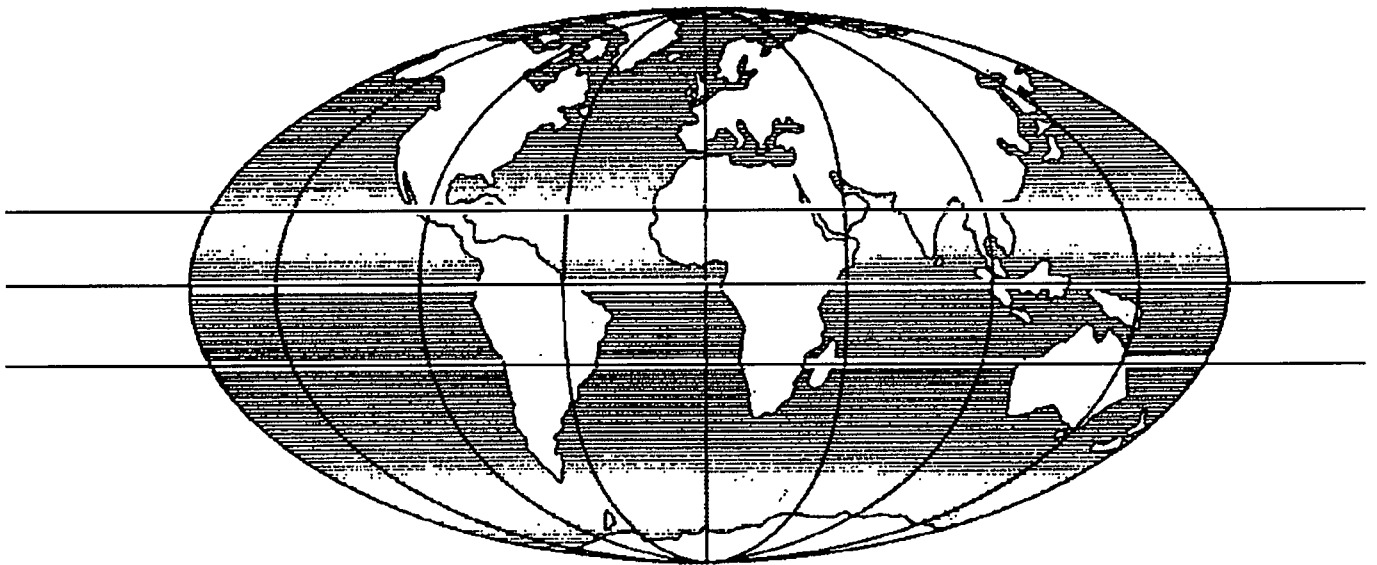




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TITLE Public transport and car use in developing cities: energy and environmental issues

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PUBLIC TRANSPORT AND CAR USE IN DEVELOPING CITIES: ENERGY AND ENVIRONMENTAL ISSUES

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1. INTRODUCTION

In the last few decades, worldwide car ownership has grown at an unprecedented rate. The consequences for urban congestion, global pollution, and depletion of non-renewable energy sources and other environmental impacts could be catastrophic if this trend continues unabated. In developing countries this is exacerbated by many factors including poor traffic management and maintenance of roads and vehicles.

Several options for improving environmental conditions exist, among which is the introduction or improvement of mass transit systems. They are generally more efficient than motor cars in terms of energy expended per passenger kilometre and can do much to alleviate city centre congestion.

The principal mass transit options available for developing cities are metros, busways and light rail transit (LRT). Metros have a high passenger capacity and can be operated at high speeds, but at extremely high cost. (Fouracre *et al*, 1990). Busways are a cheaper and more flexible alternative, with good passenger carrying capacity, but with a rather poor image (Gardner *et al*, 1991). LRT has been widely thought to offer an intermediate solution being cheaper than a metro but with a better image and a higher capacity than busway, (although a recent study has cast doubt on the suitability of LRT for developing countries (Gardner *et al*, 1994).)

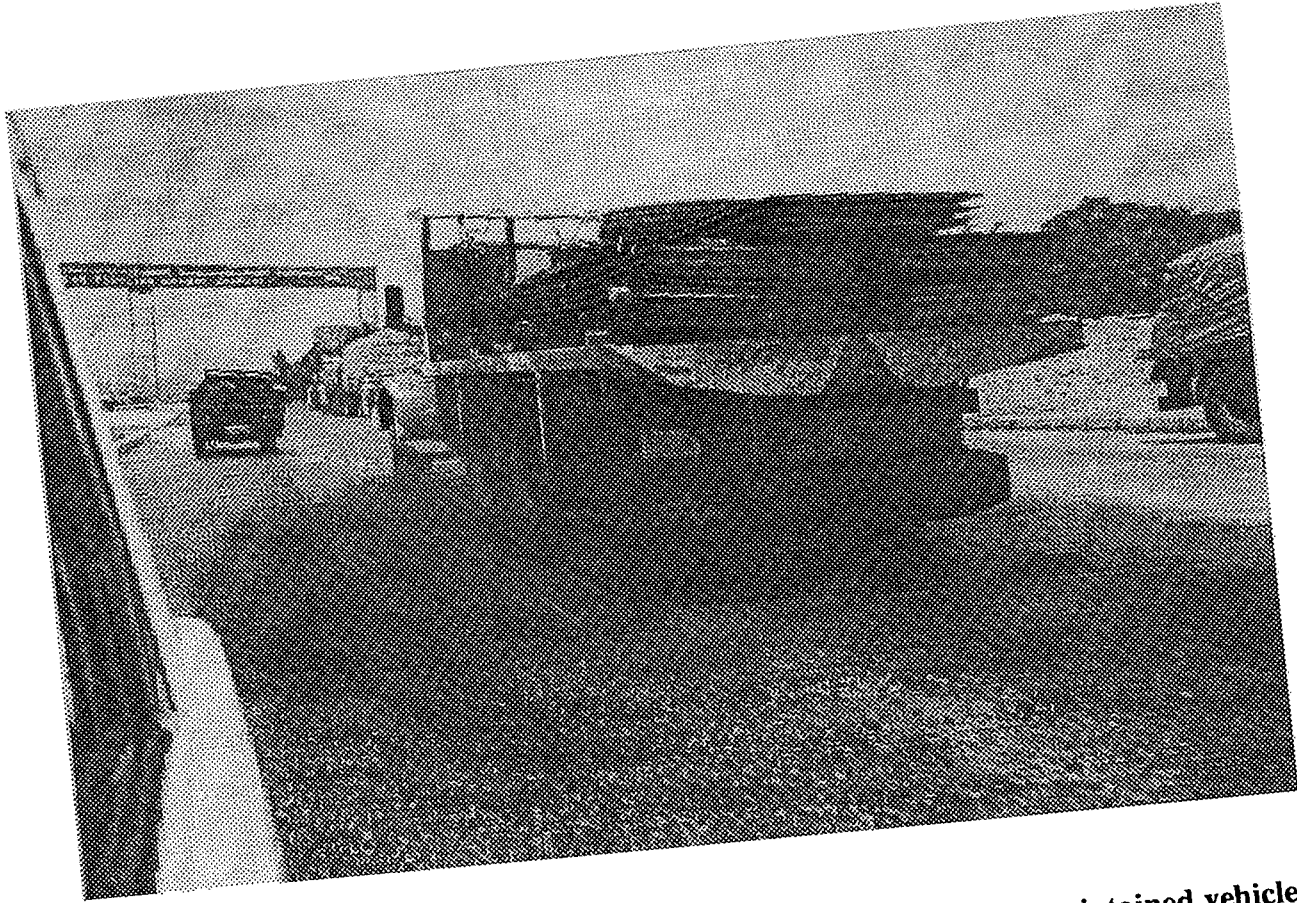
This paper outlines the contribution that transport makes to the world's environmental problems. It then comments on the policy options available to improve transport efficiency, with particular reference to mass transit improvements, which are discussed in relation to key environmental issues. These include not only pollution and other physical impacts directly affecting human wellbeing, natural ecosystems and global climate, but also socio-economic and urban infrastructure characteristics of developing countries.

2. TRANSPORT-RELATED IMPACTS

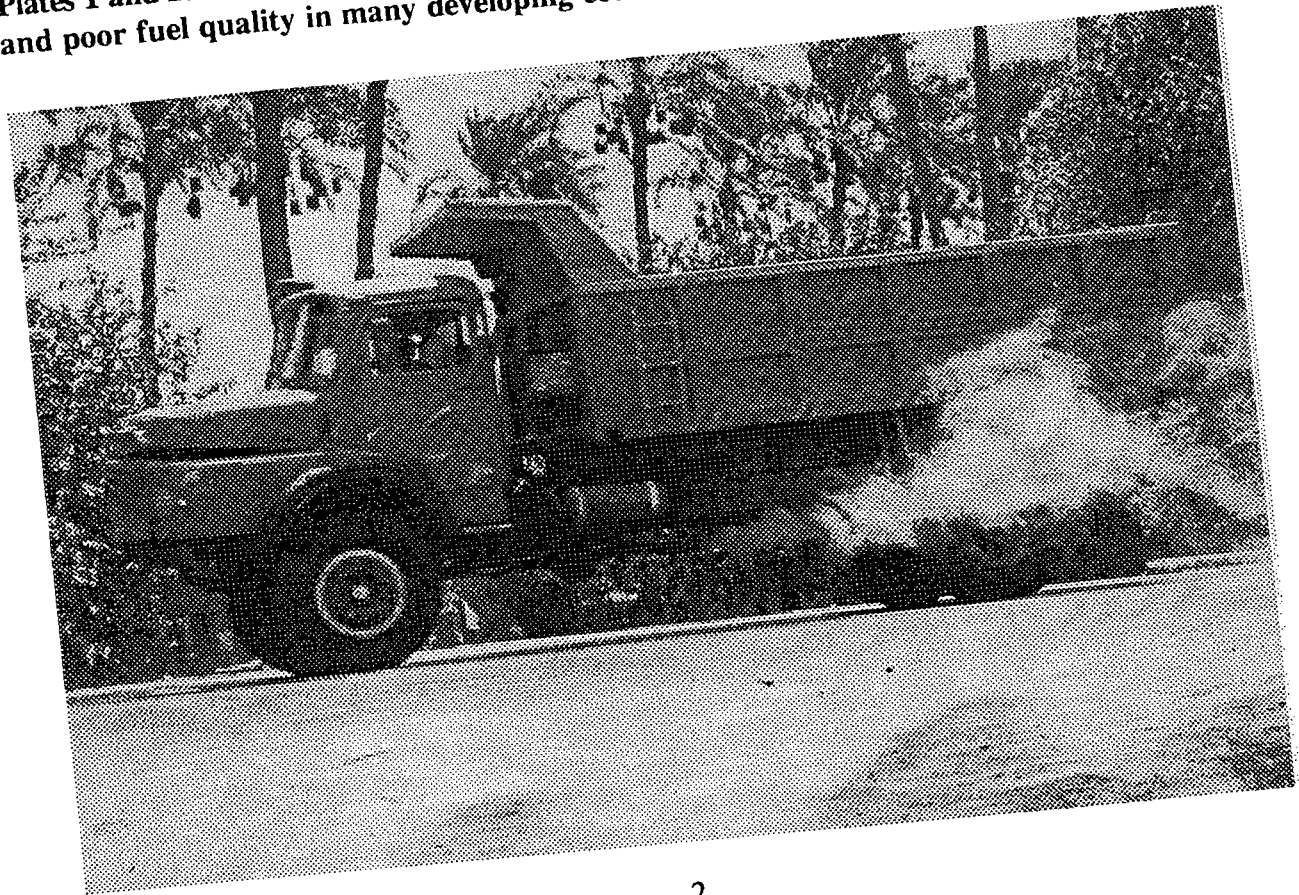
The first obstacle in environmental research is that there is no single indicator to quantify the environmental impacts. Land transport, in particular road transport, has a number of major effects in a least 6 different domains (Table 1).

Undoubtedly, one of the most serious impacts, closely linked to energy consumption of fossil fuels, is air pollution. Gaseous products of fuel combustion, spillage and evaporation are also potentially very damaging to the environment and to human health.

The chief gaseous pollutants are carbon monoxide (CO) and dioxide (CO₂), hydrocarbons (HC), sulphur oxides (SO_x) and nitrogen oxides (NO_x). Many of these, as well as secondary pollutants, e.g. ozone and peroxyacetyl nitrates, are hazardous to human health as irritants, allergens or carcinogens. On a regional scale SO_x and NO_x are the cause of soil and water contamination from acid rain and, globally, many exhaust gases, chiefly CO₂, contribute to the current rise in global warming. Particulate emissions include lead halides from petrol combustion which are toxic and the unsightly, malodorous black smoke (see Plates 1 and 2)



Plates 1 and 2: Heavy smoke emissions are a consequence of old, badly maintained vehicles and poor fuel quality in many developing countries.



from diesel engines. The latter is believed to be associated with a rise in the number of asthma cases in the UK.

Table 1: Environmental effects of road transport

Domain	Effect
Air	Air pollution
Water resources	Pollution of surface and groundwater by surface runoff. Modification of water systems by road building
Land resources	Land-take for road infrastructures. Extraction of road building material; disposal of road construction materials.
Solid waste	Vehicle wastes (oil, tyres, vehicle parts) Vehicles withdrawn from service. Materials used on roadways for ice and snow-removal (sand, gravel, salt etc.)
Noise and vibration	Acoustic pollution and vibration affecting all urban dwellers and urban activities.
Accidents	Death, injury and damage to property, to drivers, passengers and other road users. Risk of transport of hazardous substances. Risk of structural failures of old or worn road facilities.
Others	Disruption or severance of social, cultural or commercial communities. Visual and aesthetic encroachment by elevated road structures. Visual hinderance of congested highways/streets. Overcrowding by parked vehicles.

Pollution can be described as any physical as well as chemical byproduct of human activity which poses a direct or indirect threat to human wellbeing, natural ecosystems and climate at local, regional or global levels. Another important form of traffic pollution prevalent in urban areas is noise. This can have subjective and physical impacts such as behavioral effects, fatigue and progressive and irreversible impairment of hearing. Vibration may threaten the structural integrity of buildings. Several factors influence traffic noise emissions. These include traffic volume, surface quality of road or track, vehicle age and state of maintenance. Indiscriminate and persistent use of car horns is a noteworthy feature of many developing cities.

3. SOURCES OF POLLUTION

Manmade pollutants emanate from at least four sources:

- **Vehicular:** Motor cars, buses, lorries and other road-based vehicles consuming petrol or diesel. Trains and other rail-based vehicles consuming diesel or electricity. Emissions include smoke, dust and the gases whose impacts are briefly summarised earlier in Section 2.
- **Industrial:** Fixed sources of pollution are those involved in chemical manufacture, oil refineries, metallurgical processes, fertiliser manufacture and power stations running on coal, oil or nuclear fuels with consequent emissions of gaseous pollutants, smoke and dust and the risk of leakage of radioactive contaminants.
- **Domestic:** Household activities (e.g. cooking, heating, lighting) dependent on the burning of wood, coal and oil.
- **Agricultural:** Pesticide spraying of crops. Fuel consumption and consequent emissions by agricultural machinery.

3.1 Contribution of transport

Before deciding how much effort and attention should be devoted to the environmental impact of transport, it is important to establish;

What proportion of pollution in a typical city is due to transport?

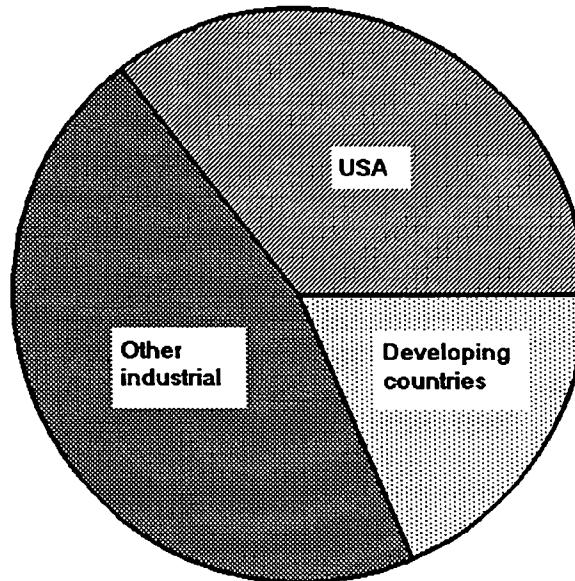
and

How big a reduction is it reasonable to expect from sustainable policy and technology changes?

On a global scale, data published by Sinha *et al* (1989) show that vehicles are responsible for 22% of global manmade CO₂ emissions and 28% of global energy consumption. Between 75 and 95% of emissions from mobile sources stem from road transport (Faiz, 1991).

The bulk of global transport-related emissions is produced by the USA and other highly industrialised countries (Fig. 1) where motorised vehicle ownership is far higher than in developing countries (Table 2). Nevertheless a significant contribution is made by developing countries where the problem of *urban* air pollution is becoming increasingly serious. Contribution of transport activities to pollution in urban areas is as high as 60 - 70% (Varshney, 1995). Vehicle ownership in several developing countries is rising at a substantially faster rate than in Japan, the USA or the former Federal Republic of Germany (Table 2) and the fast pace of urbanisation and growing reliance on road transport in developing countries is predicted by Karmokolias (1990) to lead to an increase of 220% in the demand for cars between 1988 and 2000 compared to 12% for OECD countries and 133% for Eastern Europe.

Figure 1: Share of the world's transport emission of CO₂



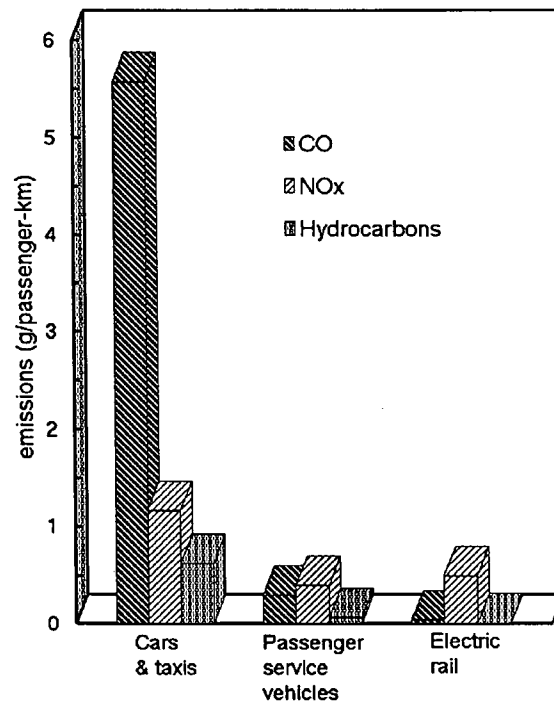
Source: Based on Sinha et al (1989)

3.2 Internal Combustion Engines

Figure 2 shows typical average emissions for three basic modes of passenger transport in the UK. The two public transport modes are less polluting than cars and taxis. In developing cities, the private car is potentially a very serious environmental threat. Standards of vehicle maintenance and vehicle roadworthiness in most developing cities are generally low, and vehicles are ageing. Even new vehicles, locally produced and based upon superseded Western models, are unlikely to incorporate the latest fuel-efficient engine-management systems available in the developed world. In addition, fuel quality in developing countries is also often poor, e.g. with high lead content, low octane rating of petrol and high sulphur content of diesel.

In many countries the fastest rising form of private transport has been the 2-stroke powered two-wheeler (Table 2). In cities such as Bangkok and Bombay, these could pose the biggest threat of all. In Pune, India for example, two wheeled motorised vehicles have increased from 1,315 registered in 1960 to 295,000 in 1994, an increase of more than 22,000%. CO and hydrocarbon emissions of 2-stroke motorcycles are as much as ten and twenty-two times respectively more than for motorcars (Faiz *et al*, 1990). However, the manufacture of 2-stroke engines is likely to be superseded, as technological improvements make alternative forms of power available.

Figure 2: Comparison of average emissions from passenger road and rail in the UK in 1988 (g/passenger-km)



Source: TRST (1991)

3.3 Electric Power

Electric vehicles such as trams and trolleybuses have the advantage in that they emit no on-street pollutants. Electricity as a power source is theoretically more adaptable than petrol or diesel in that the primary source of energy can be switched between coal, oil and gas combustion, hydroelectric or nuclear sources.

Trolleybuses were commonplace in Britain in the first half of this century and are still widely used in many countries of the former Soviet Union. They are road-based mass transit vehicles having the advantages of LRT and trams with respect to low noise levels and the absence of any emission at the point-of-use. They are utilised in Kathmandu, Nepal and are being re introduced in Paris and many US cities. Hybrid IC (internal combustion)/electric buses - making use of regenerative braking - are more efficient and have lower emissions than conventional buses in congested traffic (Pellegrin 1996). In cases of developing cities without a history of operating electric trolley buses there may be problems relating to maintenance and availability of spare parts, though this has not generally been the case in Kathmandu.

Table 2: Road vehicle fleet growth and ownership in selected countries

Country	Annual growth (%/yr, 1982-86)			Ownership Vehicles per 1000 people (1986)
	Motor cars	Trucks/buses	2 & 3 wheelers	
Cameroon	11.8	29.5	9.1	16
Kenya	3.2	3.7	4.0	11
Bolivia	8.6	24.5	6.9	37
Brazil	8.9	7.3	25.6	106
Thailand	8.8	4.4	9.5	64
India	8.2	11.2	25.4	10
China	41.6	14.8	44.9	7
Japan	3.0	4.1	7.0	538
USA	2.4	3.5	-5.6	744
former Federal Republic of Germany	3.3	0.4	-2.2	511

Sources: EEA (1990), World Bank (1989), Komor et al (1993)

4. METHODS OF INCREASING TRANSPORT ENERGY EFFICIENCY AND REDUCING POLLUTION

There are a number of approaches that can be applied to improve the energy efficiency and cleanliness of a city's transport network, none of which may necessarily be mutually exclusive. The main basic categories are:

- Technological improvements in transport vehicles.
- Improvements in general traffic management.
- Modal shift towards cleaner and more energy-efficient mass transit modes.
- Land use and policy changes.

4.1 Technological advances

The principal means by which new technology might contribute to environmental improvements are:

- fuel chemistry, e.g. unleaded petrol and low-sulphur diesel,
- new or improved engine design and
- add-on devices for existing engines such as catalytic converters and particulate traps to cut down on smoke emissions.

The fundamental problem surrounding improvements in vehicle technology lies in the prediction that these will be offset to some extent by an increase in the growth of traffic over the next 25 years (Wootton and Poulton, 1993).

4.2 Traffic Management

Congestion is a fundamental contributor to pollution from urban traffic. Vehicles under stop/start conditions use up to three times more fuel and cause three times more emissions than those in free-flowing traffic (Joumard *et al*, 1990). The orderly flow of traffic in developing cities is hindered by several factors such as roadside activities, lack of roadspace, and an urban (and institutional) infrastructure which is not adapted for motor traffic.

It is likely, therefore, that a series of low-cost intermediate measures to ease traffic congestion could help to improve the environmental damage from transport. Such measures would include optimisation of traffic signals, and the provision of segregated routes for more efficient (e.g. high occupancy) vehicles.

4.3 Shift to Mass Transit

As it seems unlikely that either traffic or vehicle improvements will result in the magnitude of saving required, the best solution might be to encourage or require the use of more efficient transport modes. If a tenfold improvement in the efficiency of an engine is not possible, for example, then an alternative is to ensure that the engine transports ten times more people. Given a significant modal shift from private to public transport, substantial reductions in emissions (Table 3) and savings in energy (Fig. 3) are possible.

Buses are mostly diesel-powered and produce on-street emissions. There are mitigating circumstances, however, which mean that they, at least in the short term, might be the most appropriate for developing cities. The most important point is that buses in developing countries, (particularly those in private ownership), generally operate at very high load factors. Whatever the emission levels *per engine* the emissions *per passenger carried* will be low. The flexibility of routing of buses also means that average journeys can be shorter, with less need for interchange than with rail journeys. Rail systems can usually adjust only the frequency of service in the face of changing demand patterns. Bus services can change routes, vehicle size, stopping locations, and many other parameters.

Segregated bus priority systems (see Plate 3), while lacking the prestigious image associated with rail-based systems, have been shown to have a favourable passenger carrying capacity. Over 25,000 passengers per hour per direction have been recorded for Porto Allegre, Brazil (Gardner *et al*, 1991). In addition, bus public transport systems have the advantages of a positive income/operating cost ratio and a low capital cost. Buses operating on segregated tracks would also have lower emissions and fuel consumption than city buses because of fewer stops and starts.

Table 3: Potential annual savings per person in air pollution from using public transport instead of driving to work

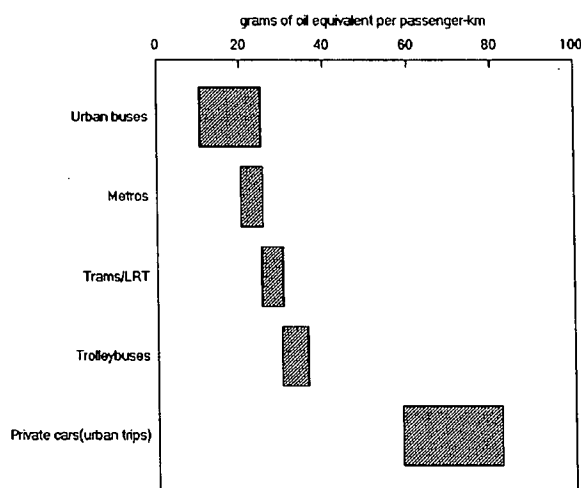
	HC ^a	CO	NO _x	SO _x	PM ^b
kg	13.47	99.50	7.05	0.14	0.12
%	98.6	97.3	85.1	46.1	27.6

Source: TEST (1991), BC Transit (1990)

Note: ^aHydrocarbons, ^bParticulate matter

Power for electric urban railways can be generated remotely, and a single plant is easier to retrofit with add-on pollution control devices for the scrubbing of exhaust gases than are multiple sources. In an underground railway in a typical developing city, however, energy requirements for motive power are only a proportion (maybe around half) of the total energy requirements. The remainder is needed for air-conditioning, escalators and buildings supply. Substantial transmission losses may also be incurred in reaching the outer limits of large networks.

Figure 3: Energy efficiencies of urban transport modes



Source: Beaunis & Pillot (1981)



Plate 3: A bus stop on a lane reserved for buses only. Curitiba, Brazil

A modern underground metro system can cost over one billion US dollars. Considerable energy use and environmental impact are associated with the construction of such a large project. All these factors help to explain why the energy requirements and environmental impact per passenger kilometre are similar for both electric rail and diesel bus mass transit systems. The choice of an expensive rail network is difficult to justify, therefore, on the basis of its environmental superiority to a bus-based system.

4.4 Land use and transport

Fundamental changes in living and work patterns may be necessary to attain a genuinely sustainable environmental policy. If people live nearer to their place of work, or work from home, then trips will be shorter, and the amount of energy consumption and environmental impact of transport will be low.

The most convincing argument for the reduction of emissions and energy consumption via town planning means stems from a paper by Newman and Kenworthy (1991). Figure 4 shows that cities of a type well adapted to public transport have very much lower energy consumption than car-dependent sprawling cities such as Los Angeles. This poses very basic questions about how society wants to live. With increasing income, comes the choice of residential type and mode of travel. A city such as Hong Kong is very well suited to public transport, but not everyone, given the choice, wants to live at such high density levels.

The decision to proceed with a one billion dollar metro should not be taken lightly, particularly in cities where there may be more pressing needs for health or education projects. In order to best contribute to sustainable development, a rail system, if built, should be integrated with land use planning measures. This includes the location of major centres of housing, shopping, employment and recreation close to the route alignment to minimise the number and length of secondary trips. Curitiba, Brazil, is an example where this has been implemented with considerable success (Rabinovitch and Leitman, 1996).

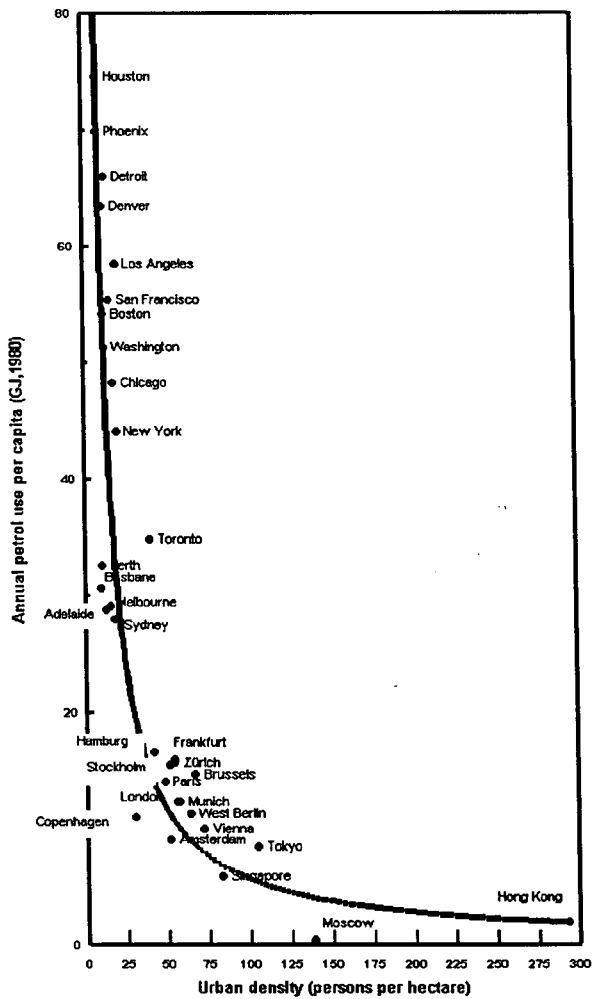
Stemming the increase in population of the world's most overpopulated cities is likely to play an important role in facilitating the development of more energy efficient multimodal urban transport networks. Lack of electrification in rural areas is likely to be a major factor contributing to mass migration to the cities (Williams, 1995). Thus solar photovoltaics, for example, while unlikely to be of any *direct* benefit to transportation, has been put forward as a cost-effective option for a non-polluting energy source for lighting in the rural developing world.

4.5 Reduction in vehicle emissions

Even without a fundamental change in the mode or quantity of traffic used in commuting improvements in exhaust emissions are still possible and necessary. A study of black smoke from diesel fuelled trucks and buses in India (Rao and Pearce, 1996) showed that high black smoke emissions were accompanied by higher fuel consumption. The same relationship applies to petrol fuelled vehicles and it can be shown that it is in the vehicle operators' own interest to reduce vehicle exhaust emissions.

A necessary adjunct to this is the need for a (more) stringent routine vehicle roadworthiness inspection. The information available from a well operated system, together with the associated enforcement potential, can go a long way towards improving standards of vehicle roadworthiness with particular emphasis on exhaust emissions. This has recently been introduced in the highly polluted city of Kathmandu.

Figure 4: Urban energy intensity in relation to population density



Source: Newman & Kenworthy (1991)

5. POLICY ISSUES

The greatest threat to air quality in developing countries comes from the rapid increase in personal motorised transport. The aims of a sustainable policy must be to contain the adverse impact of this growth. However, as Karlicky (1991) points out, a distinction should be drawn

between car "ownership" and car "use". The private motor car is the perfect vehicle for short local journeys, especially for those encumbered by luggage, with children, or travelling at antisocial times. It is, however, not the best option for commuting to work on high density corridors. Ultimately, therefore, transport policies will be needed that discourage unlimited car use.

In the burgeoning economies of S.E. Asia, and in many other developing countries, the new car manufacturing industries are an important source of domestic and export growth. Korea, for example, has just overtaken the UK as the world's 10th largest car producer. Against this background, a government is unlikely to countenance policies that hinder car ownership.

Road pricing is frequently proposed as the most effective means of curbing the environmental damage done by private cars. Because of political unpopularity, however, it has only been successfully applied in Singapore where it has been in effect for almost twenty years. One of the reasons for the success of the Singapore scheme is that it was introduced in conjunction with substantial public transport service improvements. Drivers are more willing to leave their car at home if the alternative is a frequent, comfortable air-conditioned bus or metro.

An ideal policy would be one that accepts the inevitability of rising car and two-wheeler *ownership*, even in developing countries. Thus the aim should be to stem the associated growth in *use*, preferably by the provision of a mass-carrying, attractive, but low-cost, public transport alternative. In order to attract people from their cars, public transport should provide a good level of integration with all other modes, provide clean, safe stations and vehicles, well-presented travel information and good personal security.

Where the use of the internal combustion engine is essential in city traffic, measures should be taken, via in-service inspections programmes and enforcement, to ensure that it is operating at optimum efficiency. Deterrent measures, when required to attack the problems of pollution, could include restrictions on the use of low occupancy polluting vehicles in certain areas, or city wide.

6. CONCLUSIONS

Although, at present, it is the developed industrialised countries which are producing the most pollution, localised emissions in developing cities are already a serious concern and predictions suggest that the problem will increase significantly in the future. The introduction of stringent roadworthiness testing for all vehicles will help to minimise their contribution to a city's air pollution burden.

Improvements in vehicle technology and fuel chemistry are unlikely to keep pace with predicted increase in motor traffic over the next 20 years. Any benefits from improved traffic management schemes may be offset, to some extent, by the release of suppressed travel demand.

Associated with the burgeoning economies of several developing countries has been an increase in personal affluence and a sharp rise in car ownership. While the inevitability of car ownership

must be accepted, policies such as road pricing and improving public transport services can be adopted to curb unnecessary car *use*.

The review of research outlined in this paper has found insufficient evidence to differentiate the overall environmental impact of the rail-based system as compared with a bus-based alternative. High load factors, low costs and flexible operational characteristics suggest that an efficient bus service will be the most suited to developing cities. If the difference between these mass transit modes are marginal, however, it is very clear that the real villain is the private car. Every person switching from car to any form of mass transit represents a significant environmental gain.

The challenge then becomes to find an access and mobility package that will provide a genuine alternative to the car. For this to become a reality will require land use changes and a transport service that is fast, frequent, affordable, comfortable and reliable. Several factors including flexibility of routing and low construction costs point to bus-based transit systems as the most affordable option for many developing countries, but precise nature of motive power will be less important than these key requirements.

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