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TITLE Environmental criteria for the selection of mass transit options for developing cities

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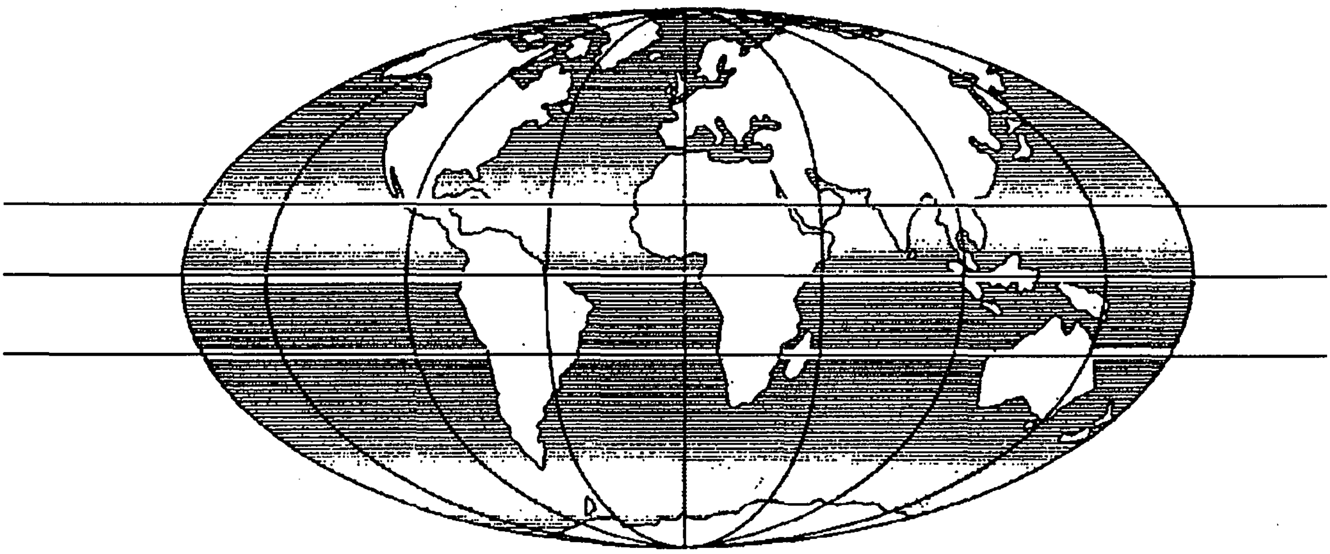

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ENVIRONMENTAL CRITERIA FOR THE SELECTION OF MASS TRANSIT OPTIONS FOR DEVELOPING CITIES

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1. INTRODUCTION

In the last few decades car ownership worldwide 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, still with good 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. However, a recent study has cast doubt on the suitability of LRT for developing countries (Gardner *et al*, 1994).

This presentation 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 less developed countries (LDCs).

2. TRANSPORT-RELATED POLLUTANTS

The first obstacle in environmental research is that there is no single indicator to quantify the problem. Pollution can be described as any physical or chemical byproduct of human activity which poses a threat to human wellbeing, natural ecosystems and climate at local, regional or global levels.

2.1 Air pollutants

One of the most serious negative impacts of transport is the gaseous products of combustion, evaporation or spillage of fossil fuels which potentially are very damaging to human health and the environment generally.

The chief gaseous pollutants are carbon monoxide (CO) and dioxide (CO_2), 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 CO_2, are responsible for the current rise in global warming. Particulate emissions include lead halides from petrol combustion which is toxic and the unsightly, malodorous black smoke from diesel engines.

2.2 Noise and Vibration

Noise 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. Excessive use of car horns is a noteworthy feature of many developing cities.

3. SOURCES OF POLLUTION

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?

3.1 Contribution of transport

Manmade pollutants come from at least three sources: vehicular, industrial and residential. Data published by Sinha *et al* (1989) show that the vehicles are responsible for 22% of global manmade CO_2 emissions and 28% of global energy consumption. Between 75 and 95% of emissions from mobile sources come from road transport (Faiz, 1991).

The bulk of global transport-related emissions is produced by the USA and other highly industrialised countries (Fig. 1). Nevertheless a significant contribution is made by the LDCs where the problem of *urban* air pollution is becoming increasingly serious. The fast pace of urbanisation and growing reliance on road transport in LDCs is predicted by Karmokolias (1990) to lead to an increase of 220% in the demand for motorcars between 1988 and 2000 compared to 12% for OECD countries and 133% for Eastern Europe.

3.2 Internal Combustion Engines

Table 1 shows typical average emissions for three basic modes of passenger transport in the UK. The two public transport modes are generally 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 testing standards in most developing cities are low, and average vehicle ages are higher. Even some new vehicles, locally produced and based upon superseded Western models, are unlikely to incorporate the latest fuel-efficient engine-management systems. Fuel quality in LDCs is also often poor, e.g. high lead content and low octane rating of petrol and high sulphur content of diesel.

In many countries the fastest rising form of private transport is the 2-stroke powered two-wheeler. In cities such as Bangkok and Bombay, these could pose the biggest threat of all. 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).

Table 1: Comparison of Average Emissions from Passenger Road and Rail in the UK in 1988 (g/passenger-km)

	Cars & Taxis	Passenger Service Vehicles	Electric rail
CO	5.57	0.29	0.03
NO_x	1.16	0.39	0.49
HC	0.61	0.06	0.001
CO_2	126.73	35.00	117.02

Source: TEST (1991)

3.3 Electric Power

Electric vehicles such as trams and trolleybuses have the advantage that they emit no on-street pollutants. Electricity as a power source is theoretically more adaptable than petrol or diesel. 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 emissions at the point-of-use. In cases of developing cities without a history of electric buses, however, there will be problems relating to maintenance and availability of spare parts.

4. METHODS OF REDUCING TRANSPORT RELATED POLLUTION

There are a number of approaches that can be applied, not necessarily 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 types of engine 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). Urban pollution in developing countries is exacerbated by several factors including roadside activities, lack of roadspace, driving styles and urban infrastructure provision hindering the orderly flow of 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 2) and savings in energy (Fig. 2) are possible.

Table 2: Potential annual savings per person in air pollution from using public transport instead of driving to work

	HC	CO	NO_x	SO_x	PM[a]
kg	13.47	99.50	7.05	0.14	0.12
%	98.6	97.3	85.1	46.1	27.6

Source: TEST (1991)

[a] *Particulate matter*

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 cites. The most important point is that buses in LDCs, particularly those in private hands, operate at very high load factors. Whatever the emission levels *per engine*, therefore, the emissions *per passenger* 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, while lacking the prestige 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. Operation on segregated tracks would also reduce emissions and fuel consumption because of fewer stops.

Power for electric urban railways can be generated remotely, and a single plant is easier to retrofit with add-on devices for the scrubbing of exhaust gases than are multiple sources. In an underground railway in a tropical 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. A modern underground metro system can cost over one billion US dollars. 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 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 energy consumption and environmental impact of transport will be less.

The most convincing argument for the reduction of emissions and energy consumption via town planning means comes from a paper by Newman and Kenworthy (1991). Figure 3 shows that cities of a certain type have very much lower energy consumption than sprawling cities such as Los Angeles. This poses very basic questions about how we want to live. With increasing income, comes the choice of residential type. 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.

Construction or extension of a mass transit system for a city with potential for expansion 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.

5. ENERGY CONSUMPTION

Although this report has focused on environmental matters, the issue of energy consumption is closely related. Many of the measures proposed to reduce emissions also improve energy efficiency. Energy use of a mass transit system is a complex process comprising not only that for vehicle use (propulsion, lighting, heating, air conditioning and operation of doors) but also for vehicle construction and maintenance, right of way and station construction, operation and maintenance, secondary trips to and from stations and switches with other transport modes.

6. POLICY ISSUES

The means available for reducing transport-related environmental damage discussed above are unlikely to be effective in LDCs without some major policy changes. The greatest threat to the environment in LDCs comes from the rapid increase in personal motorised transport. The aims of a sustainable policy must be to contain the adverse impacts of this growth. As Karlicky (1991) points out, however, 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 not the best option for commuting to work on high density corridors.

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 has been successfully applied in Singapore 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, then, would be one that accepts the inevitability of rising car and two-wheeler *ownership*, even in developing countries. The aim should be to stem the associated growth in *use*, preferably by the provision of an attractive mass-carrying, but low-cost, public transport alternative.

7. CONCLUSION

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 this problem will increase significantly.

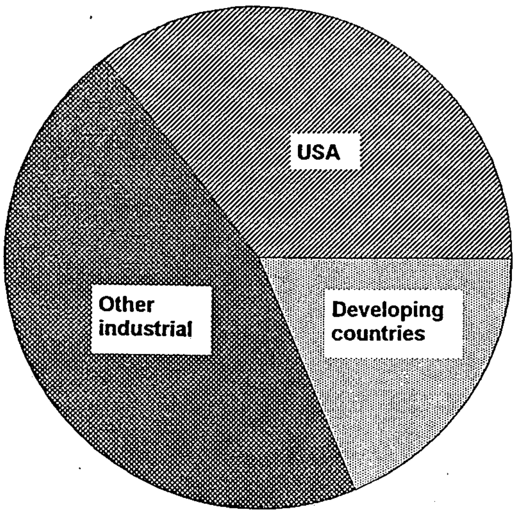
Improvements in vehicle technology and fuel chemistry are unlikely to keep pace with predicted increase in motor traffic over the next 20 years. Any benefits from improved traffic management schemes may be offset, to some extent, by the release of suppressed travel demand.

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 this must be accepted, policies such as road pricing can be adopted to curb unnecessary car *use*.

There is potential for drawing many car owners away from excessive use of their vehicles to a mass transit system, with substantial savings in energy consumed and emissions per passenger kilometre. Passengers will be attracted by a service which is fast, frequent, clean and comfortable. Several factors including flexibility of routing and low construction costs point to bus-based transit systems as an affordable option for many developing countries.

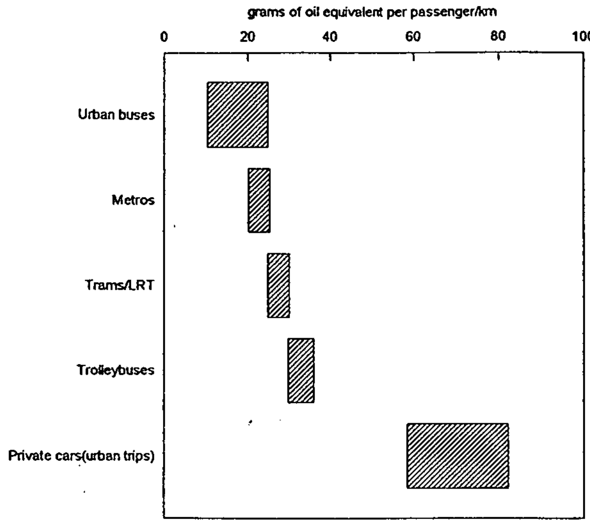
Where a city has great potential for expansion, development of a mass transit system should be considered alongside land use.

Figure 1: Share of world's transport emission of CO_2



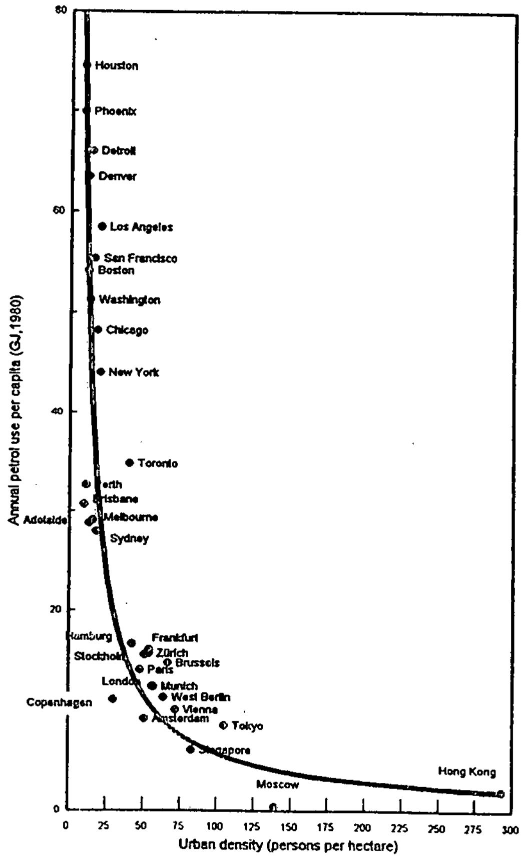
Source: Based on Sinha et al (1989)

Figure 2: Energy efficiencies of urban transport modes



Source: Beauvais & Pillet (1981)

Figure 3: Urban energy intensity in relation to population density



Source: Newman & Kenworthy (1991)

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