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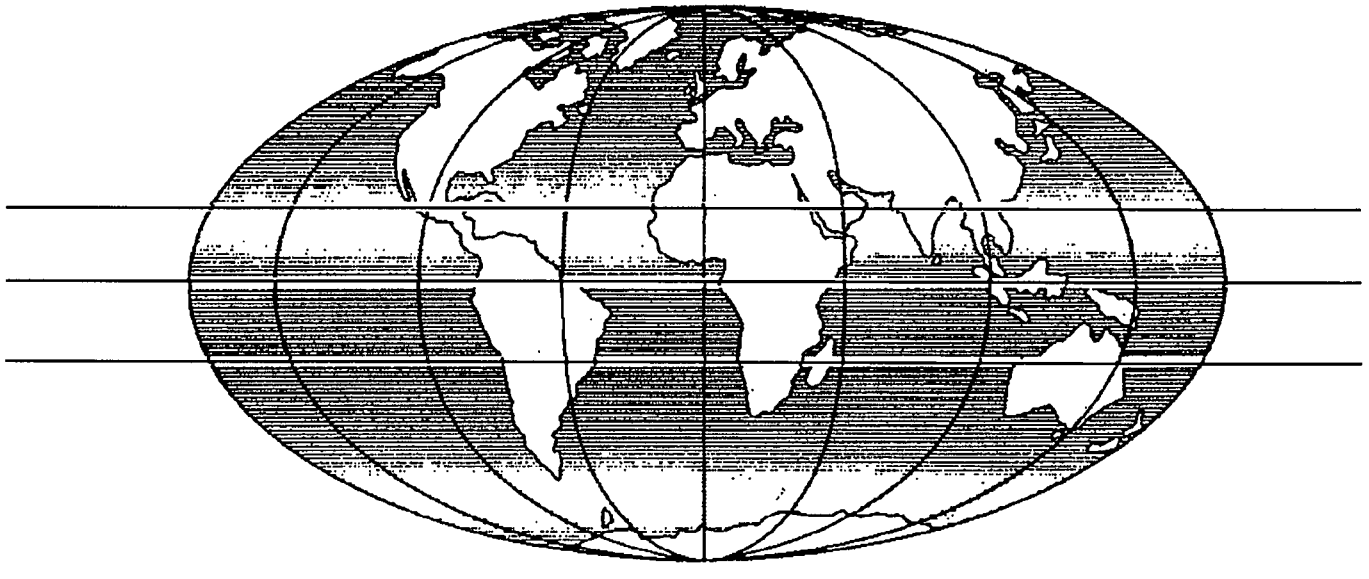

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WHICH TRANSIT?

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1 INTRODUCTION

The provision of cheap and abundant public services of all kinds was seen as a priority aim for the governments of the former communist countries of East and Central Europe. This included the provision of frequent and inexpensive public transport services in the major cities. Many capital cities have extensive networks of every form of public transport system, including bus, trolley bus, tramway and metro services. In Prague, for example the tramway extends over 250km, providing a door-to-door service to many areas of the city. The lavish appearance of the Moscow metro stations was a symbol of pride for a city in which very few could expect to have sole access to a car.

The later periods of the communist era were characterised by neglect of all kinds of infrastructure, and by an ever increasing fascination with grandiose projects. Investments, that are now seen as mistakes, were made on a grand scale, for a variety of reasons.

The part that mass transit will play in the growth or decline of cities can be crucial. Difficult decisions lie ahead regarding where and when mass transit systems should be introduced, re-furbished, or removed. This paper describes the strengths and weaknesses of the available options. The decision making process itself is also examined.

It is difficult to generalise on the merits of the available options. Any comparison will be forced to resort to estimation and interpretation. The aim of this paper has been to do this as fairly as possible, whilst providing a broad overview. More details of the figures quoted are given in the TRL trilogy of mass transit reports by Fouracre et al. (1990), and Gardner et al (1991,1994). Other information has been taken from Armstrong Wright(1993).

2 MASS TRANSIT OPTIONS

The term mass transit as used here refers to any urban transport system carrying large volumes of people, usually along well-defined corridors connecting suburbs to city-centre. This paper focuses on those mass transit systems that commonly use a reserved right-of-way for some, or all, of their route length, this includes;

Metro: A metro is often referred to as an underground railway, but can be any grade-separated urban railway. The track and electric vehicles are similar to suburban railways, though with closer station spacing. Trains may have 6-8 cars, with a total capacity of up to 3,000 passengers.

Busways and bus lanes: Both include right-of-way for the exclusive use of buses, segregated by lines or by physical means. Busway transit would include additional features like well-designed bus stops, special operating methods (bus convoys or express operations), efficient fare collection methods, and clearly defined routes with names like 'green line' or 'circle line'. Busways, have good carrying capacity, have flexibility and are cheap to install, but still suffer from a poor image;

Light Rapid Transit (LRT), thought by many to offer an intermediate solution; with lower costs than a metro, but with a better image than a busway. Some systems, including those of Manila and Istanbul, use exclusive track and high platforms similar to a metro. Other systems have at-grade crossings and low level platforms. LRT trains may be made up of two or three cars, with a total capacity of up to 750 passengers.

Trams are a basic form of LRT that have limited rights of way, sharing roadspace for much (if not all) of their route length with ordinary traffic. Tram cars are likely to have lower capacity than LRT cars, and are usually operated singly or in pairs. Most of the systems in E. and Central Europe come under this category.

3 PERFORMANCE INDICATORS

There are many popular misconceptions about the relative performance and costs of the three main mass transit options. Many promoters (and some transport professionals) have produced graphs, sometimes with un-labelled axis, showing buses at the bottom, metro at the top, and LRT somewhere in the middle. There has been, until now, little research evidence to support or refute this hierarchy.

For the purposes of this paper, the options will be compared primarily by cost, capacity and speed. Other factors that will influence choice of mass transit system are also discussed.

3.1 COSTS

Out-turn cost data vary according to design standards, construction procedures, exchange rate variations, and so on. The overall capital costs for a complete system are estimated in Table 1. The more grade-separation, tunnelling, use of heavy rolling stock and sophisticated control equipment, the higher the cost.

Table 1. Capital costs of mass transit schemes: costs in US$ millions (1993 prices)

	Bus lane	*Busway transit*	*Tram*	*LRT*	*Metro*
Capital cost per route km.	*< 0.5*	*2.0-10.0*	*5.0-15.0*	*10.0-30.0*	*40.0-90.0*

Note: includes rolling stock, except in case of bus lanes

There is little doubt, then, that a metro is an order of magnitude more expensive than a busway. A new scheme involving underground construction could easily exceed one billion US dollars. At such prices city (and even national) economies can be affected.

Operating costs

The key components of operating a transit system are labour, energy and replacement of materials. Estimates of operating cost per passenger km are given in Table 2. These costs include depreciation on equipment, but not on the initial infrastructure or any financial charges. Given that capital costs can equal operating costs over the lifetime of a rail project, it is clear that operating cost alone is not a good indicator of the price a city will pay.

Table 2. Operating costs of mass transit systems costs in US cents (1993 prices).

	Bus on bus lane	*Busway transit*	*Tram*	*LRT*	*Metro*
Operating cost per passenger km.	*3-8*	*8-12*	*3-12*	*12-15*	*15-23*

** excludes depreciation and interest charges (extensive in the case of metro)*

Financial Performance

Little is known of the financial performance of low-cost mass transit schemes. In the case of busways, the scheme's performance is usually subsumed within the total financial performance of the participating bus company; neither would it be normal for the capital costs of the track to be included in bus company accounts.

Very few public-sector bus or rail services, if any, are able to rely entirely on direct revenue. Table 3 gives some indication of the cost recovery that can be expected from typical

systems. Very different results can be achieved from LRT and Metros according to the income of passengers, population density, and depending on the political decision of whether to maximise occupancy or minimise subsidy. Hong Kong, which is a very special case, has a farebox/operating cost ratio of 2.2, but two-thirds of the metros studied by Fouracre et al. (1990) required operating subsidy.

Table 3: Approximate estimated ratio of operating costs recovered from farebox.

	Buses with Privately operators	*Public Sector Buses*	*Tram*	*Metro*
Percentage of costs recovered from farebox	*100+*	*62*	*40-60*	*20-160*

3.2 CAPACITIES

Although the majority of European Cities are built to a pattern and density such that extremely high corridor flows are not common, the capacity of a scheme at some peak points may be an issue. The TRL research placed a high priority on fieldwork at the site of mass transit systems in order to judge the actual capacities, and the factors which influence it. The results are shown in fig 1. It is clear that the two largest cities of the World; Mexico City and Sao Paulo; and the highly densely populated Hong Kong, have conditions producing flows only a metro could carry. For many other cities, however, and for the secondary corridors on the largest cities, alternatives are available.

TRL research has questioned the generally accepted idea that LRT has a higher capacity than busways. In fact the opposite appears to be true. Even in Manila, where the LRT is operating under near-saturated conditions, and where there is full segregation from other traffic; passenger flows are less than on several busways.

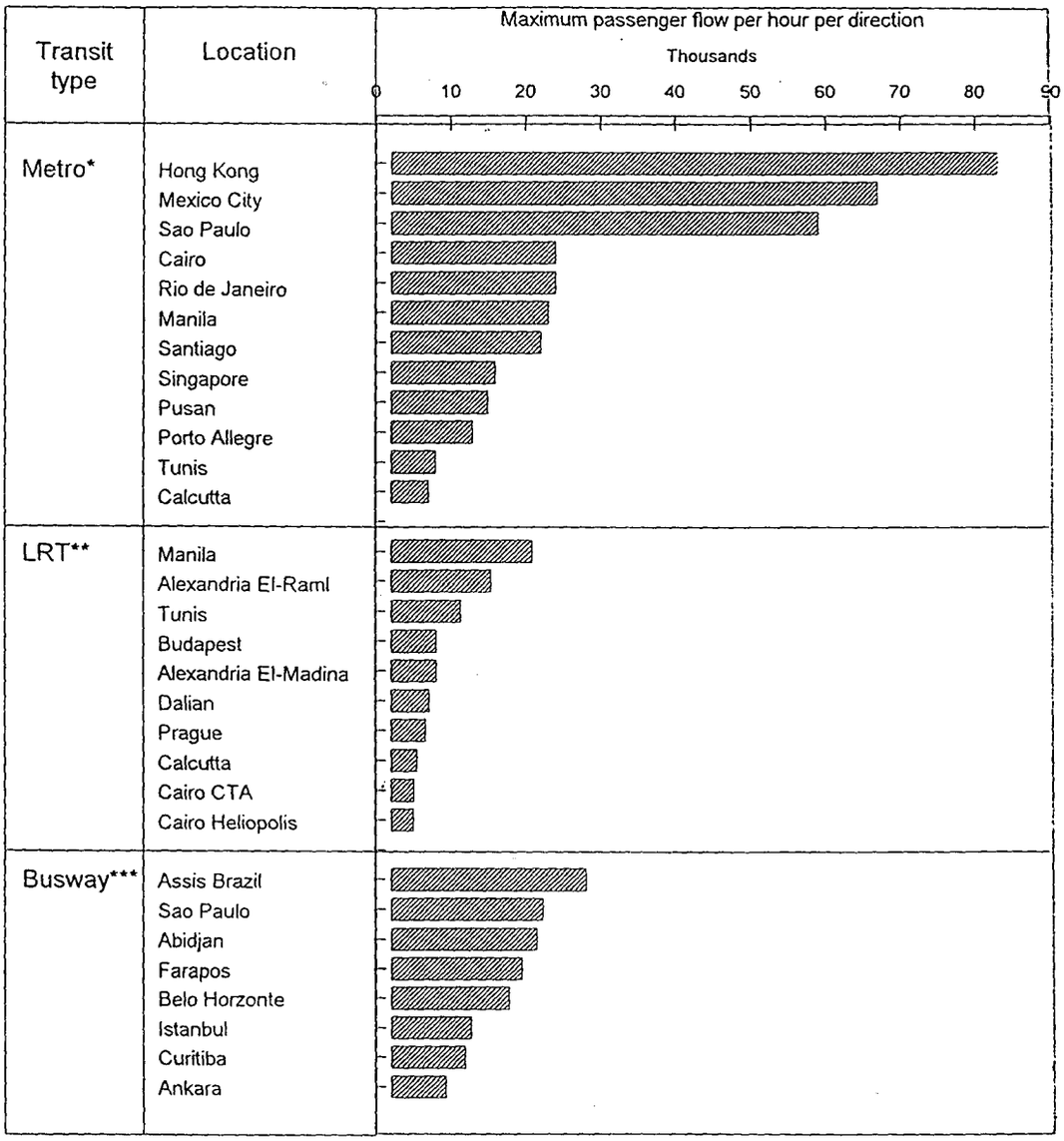
Although in theory a train with capacity of 2000 passing every two minutes would produce an hourly capacity of 60,000 pass/hr; in practice this is rarely the case. Each train must wait for the one in front to finish loading, and follow at a safe stopping distance. Short, consistent headways give higher flows, but this requires efficient scheduling and timekeeping. With on-street running in a busy city there are many opportunities for delays, and these delays can become cumulative. A high degree of segregation, such as in Manila, can help improve capacity, but this will add significantly to the costs.

In contrast, the busway has unrivalled flexibility, and appears perfectly suited to a range of conditions. Delays to a single bus affect only one hundred people, and other buses can overtake if necessary, to provide a continuous high-capacity service.

3.3 SPEEDS

An important considerations for an operator is the commercial speed. That is the average speed that can be achieved when allowance is made for passenger boarding, time at

Figure 1: Mass Transit Passenger Flows



*Fouracre, Allport & Thomson (1990)
**Gardner, Rutter & Kuhn (1994)
***Gardner, Cornwell & Cracknell (1991)

termini and for traffic control (table 4). This influences the service that can be provided for customers, but also determines the number of vehicles and drivers that will be needed.

The commercial speed is related to the maximum speed of the vehicle, and to braking and acceleration characteristics (Vuchic, 1987). It might thus be expected that electric trains would be significantly faster than buses. In practice, TRL field surveys revealed little difference, and research using multiple regression analysis to allow for factors such as station spacing, suggests that the inherent difference between busways and LRT is not statistically significant.

Table 4: Approximate estimated commercial speed for selected systems.

	Bus in CBD mixed traffic	*Busway transit*	*Tram*	*LRT*	*Metro*
Commercial Speed km/h.	*10*	*18-26*	*12-16*	*19-29*	*29-36*

3.4 COMFORT AND CONVENIENCE

There is little doubt that travelling in a modern LRT on a newly-constructed track is one of the most comfortable forms of land transport. Even the elderly E. European trams provide a service which is considered comfortable by a large proportion of users surveyed by TRL, with the Technical University of Budapest, and the Czech research institute USMD. Buses, in general traffic, are less comfortable, though segregation can improve both passenger comfort and vehicle wear and tear.

Many passenger surveys have shown that walking and waiting time is an important consideration. In this respect the bus scores more highly, as it can use ordinary suburban roads, and thus provide a door-to-door service before joining the busway. Metros are often planned on the assumption that passengers will use feeder buses to reach stations. In practice, passengers dislike interchange, and prefer to use the same vehicle for the entire journey. Through-ticketing, as found in many E. European cities, provides a positive incentive to make an interchange, but is not always easy to implement.

4 BENEFITS FOR THE CITY

In addition to the considerations for passengers, there can be benefits to a city of pursuing a policy that includes some form of mass transit.

4.1 CITY STRUCTURE

The essence of a city centre is that it is the most accessible point from both within and without the city. This superior accessibility is important for many activities, and in

particular for those central functions that serve a wide area and/or need a wide labour market: head offices, central government offices and legal institutions, financial institutions, media firms, theatres, department stores, etc. and all the supporting organisations (catering, hotels, etc.) that exist to serve these central functions. Mass transit can be used to sustain these vital functions.

It is often said that the implementation of a metro can boost the confidence of a city, and thus encourage property development. In the USA many non-users consider a visible above-ground LRT a symbol of civic improvement equal to more expensive, but hidden, underground systems (TGM, 1990). The flexibility that is the hallmark of busway transit can be a disadvantage. Property developers will be reluctant to invest in land benefiting from an adjacent transport facility if they think this can be removed at the whim of future politicians.

Recent evidence casts doubt upon the magnitude of the development catalyst effect. In 'Can Rail Save the City? ' Hall and Hass Klau (1985) concluded 'transport improvements by themselves can never achieve anything; they merely facilitate urban change'. Simpson, 1990 reached a similar conclusion after studying metro and LRT systems in Europe and N: America. He stated that "if there is interest in developing in the locality, urban railways usually attract development: if there is no interest, urban railways will not create any".

4.2 ENERGY AND ENVIRONMENT

Energy and environmental issues have, rightly, become of increasing importance in recent years. The level of environmental impact of a mass transit system will depend upon the mode chosen. Two main vehicle types are used for mass transit; buses which are usually powered with diesel engines; and rail vehicles, which, for urban services, are normally electric-powered. Table 5.

Electric vehicles have a major advantage in that the energy used for their propulsion is generated remotely. There are therefore no **local** emissions - though this does not mean (as sometimes inferred) that they have zero pollution. In the Czech republic, electricity for transport is generated using brown coal, which is responsible for some of the worst pollution in Europe. Buses, if poorly maintained, can be a highly visible source of emissions. This is frequently given as a reason for pursuing a rail-based system (though it is rarely used as a justification for improving existing buses).

In considering pollution, a better indication (if data were available) would be to look at the total life impact of a system. This would consider everything; from emissions during construction phase, for example, through to the impacts of tunnelling on groundwater.

Table 5: Approximate estimated emission levels for selected systems

Emissions (mg per passenger- km)	*Motor car*	*Bus*	*LRT*	*Metro*
SOx	*34[a]-54[f]*	*40[a]-251[b]*	*0[c]-279[c]*	*0[c]-173[c]*
NOx	*430[d]-2480[a]*	*232[b]-960[d]*	*0[a]-74[c]*	*23[c]-46[c]*
Hydrocarbons	*430[d]-2423[f]*	*60[e]-160[a]*	*0[c]-6[d]*	*0[c]-1[c]*

Figures based on the following sources:
[a]ETSU, 1994, [b]Walsh, 1989, [c]Reno & Bixby, 1985, [d]APTA, 1989, [e]Sinha et al, 1989 and DTp, 1989
[f]BC Transit, 1990.

The main polluter is, undoubtedly, the private vehicle. East Europe is attracting West Europe's cast off second-hand cars, which, with the two-stroke cars still in service, are among the most environmentally unfriendly vehicles in Europe. Any improvement in mass transit that can attract people from their cars, or more realistically, slows the growth in car use, will result in environmental improvements, whatever the mass transit type.

Table 6 shows typical levels of energy consumption per place provided. If data were available, a better indicator would be consumption per place used. This would favour a system that is flexible enough to match supply to demand, and thus keep occupancy levels high (eg buses). Given that the figures for buses are for operation in normal traffic, the reduction in stops and starts afforded by segregation would improve the position of buses still further.

Table 6: Approximate estimated energy consumption of selected systems[f].

	Private car (urban)	*Urban buses*	*Metros*	*Trams/LRT*	*Trolley-buses*
Energy consumption per passenger km (MJ).	*4.2-5.7*	*0.6-1.6*	*1.3-1.6*	*1.6-1.9*	*1.9-2.3*

[f]based on Beauvais & Pillet, 1981

LRT and trolleybuses require an overhead catenary. Because of the weight of the cable, roadside poles must be substantial, and can be a potential road safety problem and an aesthetic distraction. Buses are normally noisier than LRT, but some tramways in E Europe have high levels of track noise. The rails are laid on slabs in what is sometimes called the Hungarian construction method. When water washes out the sand supporting these slabs, an acoustically resonant cavity is formed.

Transport-related accidents are an obvious source of concern. The influence of accidents on the choice of mass transit mode, however, appears not to be a significant one. One possible reason for this is that reliable data is difficult to obtain. All modes are susceptible

to some form of accident, whether this is due to falls from metro platforms, or pedestrian injuries from bus or trams. Once again, the greatest influence on road safety is likely to be the ability of good public transport to attract people from the less safe private modes such as car and ,especially, two-wheelers.

5 INTANGIBLES

The choice of a mass transit system is made according to many factors. These can be divided into two main categories; the first of these include 'practical' issues, such as transport planning and engineering, while the second category includes institutional and 'political' issues. Political effects, for example 'civic pride' appear to play a major part in influencing choice. These may be beneficial or damaging. Mostly they will be difficult to quantify objectively, especially in financial terms. In some cases, they may be not just unquantifiable, but intangible. Some attempt can be made to classify the main factors under the two headings of rationality and democracy (Levin, 1981).

5.1 RATIONALITY

A rational decision regarding investment would be based upon sensible, reliable information. There are many examples of different reasons why this has *not* been so (although unfortunately they are rarely documented). Almost every system has its own peculiar factors which have influenced implementation. Some of these have been shown, with the passage of time, to have been fortuitous: others have resulted in financial and economic hardship.

In Prague, the city's underground metro was built during the 'Cold War', and following the Soviet invasion of the city. Consequently, tunnels and stations are very deep to be suitable for bomb shelters. Unfortunately, this makes the distance to be covered by escalator very long which has implication for travel time and for energy usage.

Many cities in transition have difficulty in ensuring institutional cooperation, and this can influence decisions. Institutional problems have contributed to several metro projects running over-budget. Implementation of busways requires the active cooperation of the highway authority, the licensing authorities, the police and bus operators, which many cities find impossible.

Civic pride appears to have a major influence on decision making policies. Rail systems in particular obviously have a very special place in the hearts of the men in control of the World's cities. A new metro can be a powerful symbol of a city's status, disproportionate to its function as a people mover. Comparisons might be drawn with Medieval cathedrals, whose size and grandeur far exceed the requirements of a meeting place for worship.

The problem arises for a city when this pride is misplaced. As the report by Fouracre et al (1990) shows, several cities in the World have suffered financial hardship because of introducing metro systems which still carry fewer passengers than a similar busway. Conversely, it might be argued that in Singapore (and in Manchester) the decision to go for a metro, rather than a potentially more cost-effective busway, did help to modernise the cities' image.

5.2 DEMOCRACY AND EQUITY

If one accepts that the sign of a good society is one on which decisions are taken for the benefit of the maximum number of people, then the benefits of public investment should be evenly distributed. In this respect, any public transport system should score highly, as it can bring widespread benefits. The problem occurs when the extremely large amounts of money involved are not spent wisely.

There are many pressures on political leaders, not least in countries in transition, to choose a particular mass transit option. The status or image benefits that a modern transit system can bring to a city appear to have a significant part to play in the decision making process. Furthermore, in some societies where "commissions" and informal payments can add around 10 percent to a project cost, the attractions of a billion-dollar metro are obvious. The political desire to 'do something' to build a city's image, bolster support, or to reward past favours may also influence the choice of system. This favours prestige projects such as modern rail systems, even when these might not be the best practical or cost-effective solution.

6 DISCUSSION

The transport problems of East and Central Europe are by no means over. Democratically elected city governments, at a time when their budgets are being cut, find themselves responsible for public transport systems heavily reliant on subsidies. Conversely, private spending on cars is growing rapidly. It is clear that decisions regarding mass transit investment in the new Europe will be difficult to predict, and will not necessarily depend upon the outcome of financial and economic evaluations.

Whilst new civic leaders receive aid-funded advice on a balanced transport approach, pressures will come from the car lobby on the on hand, and the suppliers of modern mass transit on the other. Western suppliers of all types of equipment have seen the combination of transition and aid-funding as an important market opportunity.

The TRL research has found little to justify the high demand for rail-based mass transit. Whilst there can be no doubts over its comfort, and the prestige that it can confer on a city, there are serious doubts over its cost and even its performance. Conversely, the busway offers unrivalled performance and value for money. It has unsurpassed flexibility

in that it can be built only where necessary, and as funds become available. Operation costs are minimal. Some Brazilian cities, such as Sao Paulo and Curitiba have also shown that is possible to provide a busway that has a good, modern image. There are likely to be many opportunities for busways to make a valuable contribution to the re-generation of the great cities of E. and Central Europe. If necessary, they can be seen as pre-cursers of new rail schemes or extensions to existing ones. Whether they can be used as replacements for existing rail schemes will require examination on a case-by-case basis.

More important than the choice of mass transit system, however, will be the policies towards the private car. The main priority must be to stem the growth of private transport use (although as Karlicky has said (1992) private vehicle *ownership*, as distinct from *use*, can be encouraged).

An important pre-requisite for the successful implementation of any infrastructure will be institutions capable of steering a true path through the decision making process. In this case, transport aid must be well focused. One architectural advisor to the Czech President Vaclav Havel said ;

> ".....If I could spend the development money Prague is receiving, such as that from the Prince Charles Heritage Fund, I would use it to build a modern, intelligent, creative, city council. Both our town, and our historic buildings would benefit." *Miroslav Masak, (in Kennedy, 1993)*

7 CONCLUSIONS

When the research evidence is examined, the "best buy" would therefore appear to be the Busway. No other option comes close to it in price or flexibility, and its environmental impact, though not outstanding, is acceptable.

The fact that recent experience has seen a strong and growing demand for metros and LRT suggests that the influence of intangible factors is as strong, if not more so, than the technical evidence presented here.

The real competition should be between public and private transport. An ideal policy would involve widespread ownership but restricted use of private transport. An ideal decision making process would allow consideration of the benefits of comfort and image from the rail options, while screening out projects that would cause severe financial hardship.

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REFERENCES

ALLPORT R J and J M THOMSON, 1990. Study of mass rapid transit in developing countries; TRRL Contractor Report 188. Crowthorne : Transport Research Laboratory.
AMERICAN PUBLIC TRANSIT ASSOCIATION, 1989. Mass transit - The clean air alternative. Washington, D.C.
ARMSTRONG-WRIGHT A, 1986. Urban transit systems: Guidelines for examining options. World Bank Technical Paper No 52. Washington DC: World Bank.
ARMSTRONG-WRIGHT A, 1993. Public Transport in Third World Cities. TRL State of the Art Review /10. HMSO, London.
B.C. Transit, 1990. Transport and the Environment. Prepared by Transvision Consultants Ltd, Vancouver.
BEAUVAIS, J-M and PILLET, J P, 1981. Transport et energies: Nouveaux enjeux. ENETRANS. Paris, April 1981.
DEPARTMENT OF TRANSPORT, 1989. Transport Statistics; Great Britain 1971-1981. London ,H.M.S.O.
E.T.S.U., 1994 Energy and environmental implications of light rail systems. A THERMIE Programme Action. Harwell, U.K.
FOURACRE P R, R J ALLPORT and J M THOMSON, 1990. The performance and impact of rail mass transit in developing countries. TRRL Research Report 278. Crowthorne: Transport Research Laboratory.
GARDNER G, PR CORNWELL AND JA CRACKNELL, The Performance of Busway Transit in Developing Cities, TRRL Research Report No. RR329, Transport and Road Research Laboratory, Crowthorne, UK 1991.
GARDNER G, RUTTER JC and F KUHN, The performance and potential of light rail transit in developing cities. TRL Project Report No. PR69, Transport Research Laboratory, Crowthorne, UK 1994.
KARLICKY P, 1991. Czech transport. PTRC Summer Annual Conference. Salford University, PTRC.
KENNEDY, L. Prague Heritage. Broadcast for BBC Television, June 1993.
RENO A T AND BIXBY R H, 1985. Characteristics of urban transport systems. Urban Mass Transportation Administration (U.M.T.A.). Washington, D.C.
SIMPSON B J (1990) Urban Rail Transit: Costs and Funding. TRRL Contractor Report No. CR160. Transport Research Laboratory Crowthorne.
T.E.S.T. (1991) Wrong Side of the Tracks? Impacts of Road and Rail Transport on the Environment: a basis for discussion.
TGM (1990) Light Rail Transit - A proven alternative. Transit Gloria Mundi Video. USA.
VUCHIC V R, 1981. Urban public transportation systems and technology. New Jersey: Prentice-Hall Inc..
WALSH, M P, 1989, Motor vehicle emissions in Mexico: A Strategy for Progress. World Bank, Washington, D.C.
WINPENNY, JT. Values for the Environment. A guide to economic appraisal. HMSO, London. 1991