SAVING CARBON BY IMPROVING URBAN TRANSPORTATION AND VICE VERSA: THE INTERACTION OF TRANSPORT POLICY AND CO_2 EMISSIONS

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Abstract:

This article reviews quantitative and qualitative trends in urban transportation and environment, focusing on developing countries. Reviewing recent efforts to look at transportation, the article adopts a definition of "sustainable transportation" that includes economic and environmental sustainability as well as equity as key criteria. It is argued that governance sustainability is also important if policies and technologies are to reduce the main externalities from urban transport. An important identity is introduced to relate emissions to traffic, modal share, fuel use, and fuel characteristics, from which it is argued that transport policies must confront all of these components of the identity if emissions are to be reduced significantly. Focusing on why urban areas in developing countries have become the most polluted and congested cities in the world, the article notes addresses major barriers to serious transport sector reform that would address these ills. The pessimistic tone is lifted by citing recent examples of policies and technologies that have permitted some regions in Latin America and Asia to begin to turn the corner. It is concluded that strong actions by cities, backed by national government formulation of equipment and fuel standards and supported by private sector initiatives are all needed – together with political will – to reverse the unsustainable trends in urban transport in the largest urban areas today.

The Transport Conundrum

Transportation brings people and goods to people, returning enormous benefits to economies (Braudel)[1]. But transportation also brings significant undesirable side effects or externalities, particularly in urban areas and on the global environment via CO_2 emissions. While its undesirable side effects have long been recognised, state efforts to tackle the transport problem have been limited because of its inherent complexity and

[1] Braudel, F. "The Wheels of Commerce". In: *Civilization and Capitalism*, 15th - 18th Century. Vol. 2, Berkeley, CA: University of California Press. 1992.

the costs, disruptions and long lead times involved – all of which have militated against politicians initiating substantive interventions.[2]
Nevertheless, society's benign neglect of the transport dilemma cannot be allowed to continue as transportation externalities – safety, air and other pollution, carbon emissions, congestion and noise, sprawl, and other side effects - are creeping pervasively into the daily lives of ever more millions of people each year. The situation is becoming problematic in developing countries, which are experiencing rapid growth in motorised transport. In China and India growth rates in automobile and two-wheeler ownership often exceeded 10%/year in recent years. There is evidence everywhere one looks in Third World cities of transport's negative impact on local populations, (particularly the poor) and the local environment, as well as of the way pollution and congestion act as a brake on local, national and regional economic growth.[3] At the same time, experience shows that the longer the pervasive creep of transport externalities is left unaddressed, the harder it becomes to halt and then reverse this process through policy interventions.[4]

The size of these transportation externalities is surprising. The World Bank estimates that air pollution and traffic congestion lead to enormous losses in health, time, and ultimately economic growth (3). These problems are visible today in virtually every sizeable city in the Developing world. A rising number of programmes at the national, Local, and multinational (i.e. World Bank) level have taken aim at these problems. There are some successes, such as the phase out of leaded fuel in most developing countries. Yet smogs and particulate fogs as well as grid-locked traffic remain the rule in most places, in part because the growth in vehicle use is often faster than the reduction in emissions per kilometre driven.

Perhaps the costliest externality of all in the very long term, however, is not visible locally but arises from the absolute size and relentless rise in the sector's share of total CO_2 emissions. These grew from 19.3% to 22.7% in the 1990s and are forecast to expand over the next two decades to 26% of total emissions (or 4.73 Gtonnes) – some 43% higher than the 1997 level. As a consequence of this, the need to take urgent, effective and concerted action to tackle the energy-environment-transport conundrum is now shooting rapidly up the environmental agenda of the international community.[5] While few Developing Countries are expected to impose significant policy changes on transportation only for CO_2 emissions, many seek to exploit the hidden links between improvements in the transport system and local pollution and carbon emission restraint.[6]

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[2] The Dutch government repeatedly backed away from ambitious plans for intercity road pricing; the government of Stockholm, which had worked out a detailed transportation package in the early 1990s, saw its work fall through because of political differences

[3] The World Bank has threaded environment, economy, and equity into their important book, *Sustainable Transport: Priorities for Policy Reform*. Washington, DC, The World Bank. 1996. More recently it commenced a major effort in its "Urban Transport Review", http://wbln0018.worldbank.org/transport/utsr.nsf)

[4] A recent World Bank/IEA hosted Roundtable (http://www.back-to-work.com/clearingtheair.html documented this phenomena in New Delhi and Mexico City – where policies designed to address years of neglect of the transport challenge either had the opposite effect (leading to increases in traffic and emissions) or took so long to implement that any benefit was overwhelmed by problems elsewhere. valuable years were lost. This is a subtle but terribly important reason why urgent action is needed - once the problems (and failed solutions) get out of hand, trends are even harder to break.

[5] **IEA, 2000. World Energy Outlook**. Indeed, the IEA presents a case of intervention for OECD countries in which the growth in emissions from transport is brought to near zero after 2010.

[6] This is the principal recommendation of Schipper, Marie, and Gorham 2000, **Flexing the Link between Carbon Emissions and Transportation** (World Bank). See also *www.iea.org/flexing.html*. A more

And few countries are keeping score on the changes within the transportation system that underling growing emissions of all kinds.

The conundrum is this: Transport, which makes cities viable, threatens their viability today. Transport, which allows cities to grow outward spatially, threatens to break down in the spatial dimension. But changes to the patterns of transport require cities to impose profound changes in the rules for location (i.e., land-use planning), as well as the costs of moving around. These changes might be acceptable, but their results will not be seen for many years, which means those implementing the policies could see their work reversed if the population becomes impatient. Thus little political action is undertaken, and the cities' transportation systems get worse.

Awareness is rising of the need for action

Rising volumes of air pollution and traffic congestion have gained the attention of authorities in virtually every major city of the world. Growing recognition that "something needs to be done" about transport is at last being translated into action of a sort. Notable, but least effective, are the rising tide of pronouncements by politicians, under pressure from their constituents to tackle the chaos on the roads and its side effects.[7] In some cases, words are being replaced by action and recently, a small number of new policies and programmes.

National and International Transport Policy Reform Positions

The EU issued its green paper on transportation in 1995,[8] followed by a similar study of transport pricing by the European Council for Ministers of Transport in 1998.[9] The U.S. National Research Council's Transportation Research Board released its own assessment of "Transport for a Sustainable Environment.[10] What each recognised that certain key externalities – safety, air pollution, congestion, noise, etc. --- represented enormous costs to society. These costs were borne not just by drivers but by non-drivers, particularly pedestrians and cyclists. The studies recognise that reducing the problems are represents both challenges to technology and to behaviour, both that of individuals and governance, i.e., collective behaviour. What many see as "unsustainable" is the growth in transportation activity – vehicle acquisition and use – that proceeds much more rapidly without internalisation of costs or tough regulations to stem some of the worst problems.

complete version is available as Schipper and Lilliu-Marie, 1999. *Transportation and CO2 Emissions: Flexing the Link – a Path for the World Bank*. Paper No. 69. Washington: World Bank Environment Division.

[7] Former Vice President Al Gore made many statements about urban sprawl, for example during the 2000 Presidential Campaign in the US.

[8] CEC (Commission of the European Communities), 1995a. *Towards Fair and Efficient Pricing in Transport – Policy Options for Internalising the External Costs of Transport in the European Union*, Green Paper COM(95) 691 final, Brussels, Belgium.

[9] ECMT, 1998. *Efficient Transport for Europe: Policies for Internalisation of External Costs*. Paris, France: OECD

[10] NRC (National Research Council, National Academy of Sciences), 1997. *Transportation for a Sustainable Environment. Report of the Transportation Research Board* (in press). Washington, DC.

The IEA studied the way certain member countries have approached the CO_2 problem[11]. Four of the five European countries studied had begun to strengthen price signals, either through fuel taxes or other forms of taxation that favoured cleaner fuels and vehicles and in one way or another discouraged vehicle use. The initiatives in Europe echo the thoughts of the World Bank.

All of the aforementioned studies recognised the importance pricing and of regulations. While no one argues that pricing alone will achieve all of the goals of clean transport, most agree that few private actors (i.e., vehicle and fuel companies, private vehicle users) will change technologies or behaviour without both price signals and regulation. But it is widely recognised that charging for use of the transport infrastructure and for the externalities imposed on others is politically difficult.

The problems are now recognised in the Developing World. Even before the World Bank's "Sustainable Transport" in 1996 broadened the topic to embrace most of the developing world, local and international studies of Mexico City, Santiago, Beijing, and other large metropolises recognised the real costs of both air pollution and congestion on health and human activity, and pointed to the rapidity with which the pollution from transportation often become dominant over that from stationary sources. The World Bank is now reviewing its entire urban transport strategy, with a great deal of attention paid to environment.[12] A forthcoming Pew Climate Centre review led by Prof. D. Sperling of the Univ. of California, Davis, organised thoughtful reviews by local experts from Delhi, Shanghai, Capetown, and Santiago[13]. The IEA is completing a study of advanced bus systems for more than a half-dozen of the world's largest cities.[14] These works points to solutions, but also shows the challenges to technology, individual behaviour, and governance that any solution brings. Thus there is much happening on the urban transport front.

A Broader Perspective: "Sustainable Transportation"

This topic became popular after the Brundtland Commission report of 1987. Not surprisingly, it has been addressed in many of the aforementioned transport studies and dozens more, as can be seen by searching the web on "Sustainable Transport". In an early definition, "Sustainable transport means users and beneficiaries paying their full costs, including those imposed on the future" (Schipper, Sperling and Deakin 1996)[15]. Yet making transport sustainable – however defined – is no simple matter.

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[11] IEA, 2000. *The Road from Kyoto: Current Co2 and Transport Policies in the IEA*. Paris: Int'l Energy Agency.
[12] World Bank, 2001. "Urban Transport Review". (http://www.worldbank.org/html/fpd/transport/ut_over.htm).
[13] Ranjan Bose, Daniel Sperling, Mark Deluchi, Lorien Redmond, Lee Schipper, and Geetam Tiwari, Transportation in Developing Countries: *Greenhouse Gas Scenarios for Delhi, India*. Pew Center on Global Climate Change, Washington, DC, 2001. Hongchang Zhou, Deborah Salon, Daniel Sperling, and Mark Delucchi,
Transportation in Developing Countries: Greenhouse Gas Scenarios for Shanghai, China. Pew Center on Global Climate Change, Washington, DC, 2001.
[14] Fulton, L and Schipper. L., 2001. Making Urban Transit Systems Sustainable Around the World: Getting Many Birds with One Bus?" Presented at "Cities of Tomorrow", Gothenburg, Sweden, Aug. 23/24, 2001.
[15] Presented at the OECD Workshop on Sustainable Transport, Vancouver BC, Canada, and published by the OECD, Paris.
See http://www.ecoplan.org/vancouvr/enhome.htm

The reasons for the difficulties can be seen in the World Bank's description of sustainablity with three characteristics:

- Economic and Financial Sustainability. "To be economically and financially sustainable, transport must be cost-effective and continuously responsive to changing demands".
- Environmental Sustainability: "Transport has significant effects on the environment that should be addressed explicitly in the design of programs (*and systems in general [our addition]).* Making better use of readily available and cost-effective technology is necessary, but not in itself sufficient. More strategic action is also required in the form of better-directed planning of land use and stricter management o demand, including the use of pollution and congestion charges to correct the relative prices of private and public transport."
- Social Sustainability, i.e. equity. "Transport Strategies can be designed to provide the poor with better physical access to employment, education, and health services."

The problem with these otherwise lofty ideals is that they lead to conflicts in the sphere we would call "governance sustainability". Few local or national governments can impose the regulations and pricing and land-use controls which, taken together, might provide a balanced and equitable set of underpinnings. Bus operators barely make money, often only by skirting safety rules, speeding, and ignoring environmental safeguards to cut costs further. Thus there are immediate apparent losers – private vehicle owners and transit riders who face higher costs or more inconvenience– and apparent losers in the longer term – transport operators, vehicle and fuel manufacturers, all of whom must adjust their business practices.

In IEA countries unsustainable element of governance appears in many forms:

- Continual changes in the rules of the California Zero Emissions Vehicle rules (for better or worse), as the State of California was recently sued by General Motors Corporation;
- Challenges to European governments over fuel taxation in the fall of 2000 as a falling Euro and rising prices of crude oil stimulated truckers to demonstrate for lower road taxes, particularly environmental ones;
- Powerful resistance in the U.S. to proposed new rules for low-sulphur diesel fuel, even as political pressures are forcing many large bus authorities to switch to CNG-fuelled buses;
- Softening in many key areas of the original plans of European nations to deal with CO_2 in transportation, between the early conceptions of policies in the beginnings of the 1990s to what was on the books by 2000 (IEA 2000[11]);
- The abrupt reversal by President George W. Bush of the United States' "commitment" to restraining carbon emissions.

The same problems plague the developing world in many more critical ways. If one works the first sustainability principal through economically healthy transport, one finds that transport operators, whether public or private, will fight higher costs imposed by the second principal, environmental sustainability. With fares for public transit barely covering costs, few operators want to improve their vehicles or fuels and risk not covering the incremental costs. And manufacturers of vehicles for individual personal or freight transport fight regulations on pollution or safety for the same reason: higher first costs threaten sales. In a few IEA countries, these problems are mitigated by differential taxation, such as lowering the acquisition or yearly fees on vehicles that are very low emission or low fuel users. But these countries already charge wealthy users high enough taxes to have room for such adjustments. By contrast, raising diesel taxes in India in 1998 and 1999 was met with wide-spread protest. Indeed, few developing countries even passed on the full force of crude oil price hikes in 2000. Some of the countries that are major oil producers sell road fuels at less than world market prices. Raising fuel prices to pay for cleaning up the fuel is difficult.

Transportation is complicated by the third principal, social equity. The new Metro in Calcutta, like many others, is too expensive to be used by the poor, and it is heavily subsidised (World Bank 1996; World Bank 2001). Studies of Delhi, India, point to the negative social impact of higher bus fares --- very poor are shut out of motorised transport, while middle class users often switch to polluting scooters, increasing pollution and congestion. The same concern is raised in Latin America when aim is taken at semi-legal paratransit (mini buses and vans): those riders would revert to cars or have no other way of getting around except with long walks to the trunk lines of "normal", i.e., poorly operated and inefficient public transit. Matching people to jobs and free time in an affordable way is what equity strives at, yet the spatial distribution of habitat, workplace, and play is confounding. Indeed, non-motorised transport, which requires public infrastructure (pathways, sidewalks, safe storage of cycles) does not have the support of any "operators", hence is rarely treated in an even handed way. We suspect the reasons for these difficulties are lack of political will – governance – and a lack of both public and private resources to adapt to new boundary conditions – social and economic sustainability.

Why do people move around so much? Many studies point to the pivotal role of land use: "If people could just live near work (our reading, 'want to live or can afford to live near work') then transport distances would be reduced". Unfortunately, very few communities have solved the land use regulation problem because doing so would destabilise governance. Robert Cervero, in "The Transit Metropolis", reviews the relatively modest successes of a number of cities around the world.[16] The two notable highlights, Singapore in Asia[17] and Curitiba in Brazil[18], are justly held up as models for transportation planning, yet neither has been replicated elsewhere. Other cities he cites – Zuerich, Ottawa, -- each made progress combining both good public transportation and land use rules, but both are still overwhelmingly dominated by cars for most trips. But do residents of those cities really own fewer cars and travel less in them then residents of other cities. In short, what is the quantitative bottom line from experience in these regions, in terms of modal share, total travel, total pollution, and total fuel use?

There is one final element of this conundrum that makes action difficult, In its most narrow form, sustainability means not leaving unpaid cost for future generations to pay. The US NRC study identified only a limited number of externalities as truly intergenerational in this sense: CO_2 and disruption of natural habitat. To this may be

[16] Cervero, R., 1998. The Transit Metropolis. Washington, DC: Island Press.
[17] Ang, B. W., and Tan, K. C. 2001. Why Singapore's land transportation energy consumption is relatively low. *Natural Resources Forum* 25 (2) 2001
[18] Rabinowitch, J., and Leitman, J. 1993. *Environmental Innovation and Management in Curitiba, Brasil*. Washington DC:UNCP/UNCHS World Bank Urban Management Programme, Working Paper #1.

added the long-term damages to human health and ecosystems of pollution. Additionally, one could argue that the fixed infrastructure laid down in any era is very difficult to change short of war and natural catastrophe. And rarely after such events do planners pause to ask how to improve the infrastructure just destroyed. In short, decisions and actions whose consequences are largely irreversible are closely related to effects that are unsustainable.

Now add the arrow of time. Economic growth usually means more cars and more transport activity in an irreversible spiral: How many metropolises find it impossible to restrict car use or impose land-use controls once cars are widespread, in contrast to Curitiba and Singapore, which acted relatively early on[19]. Normally, it is impossible to move homes, jobs, i.e. buildings, and roads and guide-ways overnight to a new configuration that would reduce travel; moving them piecemeal takes decades, during which other forces are likely to intervene to sideswipe the plan, although the reverse – building suburbs connected by superhighways – has managed to transform most cities in N. America and Europe in two or three decades. While few oppose reducing congestion now (”getting the other guy off the road”) or pollution (”get rid of his black smoke”), real action still faces the classic commons problem, where the collective benefits are not felt by the individual who has to make the investment to reduce the pollution or incur the cost of not driving. And few individuals behave in a way that reflects concern for problems that face their descendants. Hence some elements of the transport conundrum echo face the usual problem of the commons or the lack of real concern for damages that accrue to the future. Politicians can make some inroads against the first set of concerns, but it is more difficult to convince individuals to make sacrifices on behalf of others not yet born.

The Framework for Developing Responses: AS IF Keeping Score on Transport Developments Mattered[20]

In order to develop sensible, sustainable plans and policies in transport, it is first necessary to understand where one stands and where one is heading. This issue -- keeping score on transportation and environment -- is not simply one of counting accurately (bottom-up statistics). It also rests on untangling the components of changes over time and across the population and the vehicles they use (top-down decomposition). It is vital to both allocating political credit for success and for fixing blame and fixing the problem when a policy or technology does not yield the intended benefits.

[19] There is an interesting counter example in Stockholm, Sweden. “Slussen” the elaborate set of ramps that is one of only two connections between Northern Stockholm, Gamla Stan (the old town) and Soedermalm (the southern part of Stockholm) was built in 1936 when Sweden still used the left side of the road for driving. The authorities at the time realised that the had to build a symmetrical set of ramps or forever face the spectre of huge costs should they decide to switch to right-hand drive, which they did in 1967. By contrast, did the authorities of Los Angeles think about reversibility when they removed the “Key System” trolley lines, or did the authorities of Paris worry when they took away the rail that originally went around Paris? Instead both cities had to re-invest billions of dollars decades later to try to reverse some of the impacts of these decisions, much of which went to rebuilding parallel structures!

[20] This discussion is taken from Schipper, L. and Fulton, L. 2001, “Driving a Bargain? Using Indicators to Keep Score on the Transport-Environment-Greenhouse Gas Linkages”. Presented at the 75th Annual Transpiration Research Board, Meeting, Washington, January 2001. Washington, DC: Transportation Research Board, National Research Council.

The IEA has developed the ASIF equation, expanding an idea of Ehrlich and Holdren[21] to cover transport impacts in a more general (and thus complete) way (Schipper and Lilliu 1999; Schipper and Fulton 2001):

$$G = A * S_i * I_i * F_{i,j} \qquad (1)$$

where G is the emission of any pollutant summed over sources (modes) *i;* A is total travel activity, in passenger kilometers (or ton-km for freight), across all modes. S converts from total passenger (or freight) travel to vehicle travel by mode. I is the energy intensity of each mode (in fuel/passenger or tonne-km), and is related to the inverse of the actual efficiency of the vehicle, but it also depends on vehicle weight, power, and of course driver behaviour and traffic. F is the fuel type *j* in mode *i.*

What matters for transport and environment is that each of these components be exposed to transport policies as well as feedback from other components. Not all components respond the same to a given stimulus, say a fuel tax increase or a kilometre road-use fee. And not all actors, i.e., vehicle operators, travelers, or shippers, will respond to the same stimuli in the same way, either. Each component (and not simply those related to fuel) affects emissions, too. For example, congestion drives up emissions; so does short trips in motor vehicles taken with cold engines. If some car trips are replaced by less energy-intensive modes or non-motorised transport, the savings are more than proportional to the km not taken by car.

The key purpose of the ASIF identity is to show policy makers how the components of transport and emissions fit together, and make sure that the potential –and actual – impacts of their actions on each component are noted. Modes are linked, too: safe cycle storage encourages cycling to collective transit nodes (bike and ride); measures to give buses or cycles priority lanes often take road or parking space from cars, which discourages car use etc. ASIF helps remind analysts of some of these linkages. In the end ASIF is only an identity, but it has a powerful effect identifying underlying factors and rates of change.

Where Can Interventions Take Place? Where Should they Take Place?

The ASIF framework affords a way of linking policy and technologies to particular problems that are associated with any of the ASIF components or their interactions. The following matrix was proposed by Schipper and Lilliu-Marie (1999). Shown below is the part for passenger transportation as it relates to carbon emissions, but very similar matrices could be drawn for other pollutants or for freight transportation.

A key interaction to guard against is a rebound effect, by which changes in one term of ASIF lead to changes in the opposite sense in another term. The most common of these, increased car usage with lower fuel costs (or indeed increased usage of any mode if costs fall), is small in high-income countries but can be very important in lower income countries.[22] Perhaps the most perverse of these effects can arise when an alternative

[21] Ehrlich, Paul R., and Holdren, John P., 1971. Impact of population growth, *Science*, vol. 171, pp. 1212-1217, 26 March.
[22] See the entire issue of *Energy Policy* (vol. 28, July 2000), which addresses the Rebound effect.

"clean" fuel is available at substantially lower variable costs than the traditional fuel, for example, LPG or CNG for cars and taxis or even diesel in place of gasoline. Indeed, it has been strongly suggested that the low price of diesel fuel stimulates more fuel use from the resulting extra driving than is saved because diesel cars use roughly 10% energy / km on the road than gasoline cars.[23]

Table 1: Interaction Matrix:
Which Policies Affect Which Components of Travel Related Emissions?
(source: Schipper and Lilliu- Marie 1999)

Component/ Option	**A** (Activity)	**S**(Modal Share)	**I** (veh. Intensity, characteristics, load factor)	**F** (Fuel Mix)
Vehicle Fuel Economy Technology	None except through small rebound in driving caused by lower fuel costs	Slightly encourage modes with lower running costs	All	Affected by fuel (e.g. diesel has lower fuel intensity)
Overall Fuel Taxation	Slight restraint, elasticity low	Favors modes with low fuel intensities	Encourages improvement in all comps.	Neutral
Carbon Taxation	Slight restraint`	Favors low carbon modes	Same as above	Favors lower carbon fuels
Km Pricing (including congestion pricing, etc.)	Significant restraint. Depends on extent, costs, time of day, etc.	Favors modes with small footprints per passenger (i.e., bus, rail)	Little effect unless permits small vehicles selectively	Little effect unless cleaner fuels exempt
Fuel Quality Improvements	Small impact if fuel prices rise	Small impact away from most fuel intensive modes, but potentially important when affecting fuels used in vehicles used by lower income people such as buses or two-wheelers	Usually small improvement in engine performance.	Can improve the attractiveness of otherwise "dirty" fuels (e.g., diesel or gasoline) over alternative fuels (natural gas or alcohol).
Alternative Fuels: development, pricing	Little effect unless price of fuel forced up	Little unless "clean fuel " modes given priority	Little, unless clean fuel more efficient	Potentially large (subsidies, taxes on dirty fuels)
Transit Development	Increases activity among low income, distance for all	Encourages its own use if supported by policies	Could take some hi-occupancy car	Could be developed to use nat. gas, electricity
Non-Motorized Transport Initiatives	Increases among those w low activity	Reduce other shares, but could take some passengers from collective modes	None except where short, fuel-intensive car trips are replaced	None
Land use Planning	Supposedly would reduce total activity	Could increase transit share	Little	Little

Equally important is to think about the stakeholders who are concerned about possible initiatives. Their relative strengths vary from region to region, and their responses may vary too. The ability to balance these stakeholders and develop strong policies is the key element of governance required for dealing with transport problems. This is shown by the "Governance Matrix" of Table 2, also from Schipper and Marie 1999.

[23] Schipper, L., Fulton, L, and Marie, C., 2001. Diesels in Europe: Analysis of Characteristics, Usage Patterns, Energy Savings and CO_2 Emission Implications. *Jour. Trans. Econ. Policy* (in press).

Table 2: The Governance Matrix:
Who Cares about Each Policy?
(source: Schipper and Liliu- Marie 1999)

Actor/ Option	Nat/Local Govt.	Vehicle Makers	Consumers, taxi drivers, etc,	Stakeholders and Lobbies
Vehicle Fuel Economy	Local: No influence except through procurement. Nat influence through fuel prices, standards, taxes	Hold the technologies	Choose vehicles and how to drive them.	Mainly Car industry opposing regulations to encourage or mandate. Less opposition to taxation
Fuel Taxation	Set by national or state governments	Mixed position; accept if alternative to regulation, but often defend status quo, especially through their industry associations.	Oppose!	Opposed in past by many groups
Registration, yearly, or Special Fees	Set by national or local governments	Oppose when aimed at new vehicles	Oppose	Opposed: by principal transport industries (e.g., airlines opposed landing fees, etc.)
Km Pricing (including congestion pricing, etc.)	Local and national favor for different reasons	Few have thought through what significantly lower utilization/year would mean for sales and planning!	Would oppose unless congestion benefits clear	Probably opposed, particularly by truckers and other transport professionals
Cleaner Fuels	Set Standards	Usually accept because of beneficial impacts on vehicles	Mixed, depending on costs	Often opposed by national oil companies and refiners, or transporters who have to pay the extra costs
Alternative Fuels: development, pricing	R&D, testing, pricing, introduction into market	Mixed reaction. Could favor	Suspicious unless price differential	Lobbies for fuels develop quickly
Transit Development	Crucial for planning, financing, running (?)	Some taking proactive stand (Volvo)	Urban interested; suburban not	All sides of issue
Land use Planning	Local Gov. implements, but can be based on national laws	No view	Take both sides	Usually real-estate interest, property owners organize to oppose

The table suggests that there are important groups who would be opposed to fiscal or regulatory measures. Vehicle manufacturers are not opposed to improved fuel economy *per se*, but, because of fears about market acceptance, are reluctant to commit themselves or their products to significant improvements. The challenge for analyst is to anticipate political opposition, economic difficulties, and other unforeseen problems and incorporate them into sensitivity analysis to gauge the real costs of any development.

For developing countries, an additional political issue arises if a policy encourages use of a technology or product that must be imported. Conversely, the fact that some vehicle technologies are poor or old and outmoded in some countries may have more to do with trade and industrial policies than with any problems of local technical competence. India, where older models of British and Japanese cars were produced for many years, even decades, comes to mind immediately, as do the former Soviet bloc countries. Whether such policies are simply protectionist or a result of perception that newer technologies are too expensive, they cannot be put aside easily to make way for progress. Thus the Table suggests many profound positions that must be understood on a local level and met squarely in the political sphere, i.e., with political sustainability.

What is in the Way?

There are many kinds of factors in the way that run deeper than the problems indicated in the previous Table. Addressing them will take a long term commitment to fuse transportation issues with progress on other social fronts, i.e., improving all four of the elements of transport sustainability.

Serious inadequacies in the existing analytical and advisory policy-making infrastructure.

Lack of good data is of course no excuse for inaction, but it is a good reason to move carefully. But recent experience in many of the worst cities of the world revealed amazing inadequacies of even the most elementary data:

- The number of vehicles in use by type and fuel is not known in many countries. In India, for example vehicles are counted once, when they are first registered, but not through any yearly fees or census;
- Distances driven are also generally not known, nor is the total traffic by vehicle type.
- Hence, there are almost no real figures on fuel economy of each vehicle;
- Non Motorised Transport (and some informal transport, such as jitneys) is rarely counted accurately, and often significantly underestimated;
- Emissions tests are rare, so emissions inventories are from simulations or norms, not from real measurements that reflect fuel quality, traffic, driver behaviour, and ageing of vehicles;

These uncertainties may seem academic, yet the quantities that are uncertain form the basis for the ASIF breakdown. Without such information, authorities cannot discern good news from bad. Not knowing existing pollution per km or total km, one cannot evaluate the benefits of an improvement in pollution/km or a reduction in km very well. Lacking direct tests, it is impossible to say how much pollution a CNG bus or a combination of filter and low sulphur diesel will emit relative to the present base line. Worse, one cannot take credit for "reductions from what would have been" since there is no real base line. In some cities, notably Mexico City, traffic and travel surveys have improved knowledge greatly, but dynamic monitoring efforts are only just getting started in the Ministry of Environment.[24] A similar effort has been underway in Sao

[24] Comision Ambental Metropolitana, 1996. *Inventario de Emisiones a la Atmospfere en la ZMVN*. Mexico City: CAM. And Secretaria de Medio Ambiente, Recursos Naturales y Pesa y Secretaria de Salud:

Paulo (OD surveys) under the Secretariat dos Transportes Metropolitano.

There are, of course, established centres of expertise and sources of information within academia/public interest groups, government agencies and the private sector (consultants, companies, etc.) capable of providing the sort of information and expert input that will be needed by policymakers trying to design and implement cost-effective transport interventions.[25] But a careful look at this institutional and information infrastructure reveals some serious shortcomings in the depth and coverage of existing information and data bases relating to the key aspects of the problem, such as vehicles in use, vehicle usage, fuel economy, and emissions of most kinds:

- The actual components of "ASIF" belong to different authorities or constituencies. For example, estimates of vehicle km are done by road authorities, estimates of mobility are done by transport ministries, estimates of total emissions are made by the air quality authorities, and estimates of emissions/km usually made by the environmental testing authority or a local university. Fuel deliveries are usually recorded by energy or fiscal authorities. Getting all of these levels (and in many cases regions) of authority to sit down and work out numbers is difficult almost anywhere.

- In the explanatory power of "models" used by analysts, policy makers and investors to understand the situation and devise optimal strategies where little is really known about the present situation, e.g., data on vehicle use, fuel economy etc as key input data.

- In the issue coverage and expertise of existing institutions – particularly among those operating in the public interest and servicing developing countries where human and financial resources for developing baselines and monitoring the impacts of policies and technologies have been almost non-existent.

- In the lack of strong advocacy for non-motorised transport, since it does not represent any particular economic or political interests other than a large share of the poor;

- In the fact that since multi-laterals and donors assess problems and design solutions via individual "projects", they are missing huge opportunities for significant synergies, as transport externalities must be addressed from a systemic perspective as they have national, regional and urban dimensions, are shaped by cross-cutting drivers and have impacts well beyond transport *per se*[26].

The net result is a very limited information pool, inadequate understanding and scattered institutional capacity to support the sort of significant multi-national

Programa para Mejorar la Calidad del Aire en el Valle de Mexico 1995-2000. Mexico City: Departamento del Distrito Federal and Gobierno del Estado de Mexico.

[25] Norway's Institute for Transport Economics, Sweden's "SIKA", India's Transportation Research & Injury Prevention Programme, Indian Institute of Technology in Delhi, the Indonesian NGO Pelangi, the Federal University of Rio de Janeiro's COPPE all have important programmes in transport policy related to environment.

[26] To some extent the *Global Overlays* now being produced by the World Bank have begun to develop ways of recognizing environmental benefits beyond either those of any given project or beyond those accruing only to the local environment.

interventions, aimed at both technology and in the policy sphere, that are now recognised as necessary to have a real impact on the transport challenge. This means authorities are poorly informed and unable to obtain relatively fresh information on what is going wrong…or what is going right!

Lack of Detailed Understanding of Local Policy Context Undermines Effective Intervention by International Bodies

The problems these "infrastructural" shortcomings pose for the transport policy-making process are compounded and greatly exacerbated by another feature of the current situation that is by far the most serious of all the weaknesses in current approaches to assessing the transport problem and devising solutions. Even when a solution appears to be solely technological, one size rarely fits all. For elementary improvements in vehicle technology, this is appropriate. But each region has its peculiarities that affect both technology and governance.

Basically, below the national level, - in virtually all developing countries and many OECD countries - very little timely, systematic analysis of transport trends is being carried out.[27] As a result, the information available is too aggregated or broad to generate the insights and understanding necessary to design optimal, second or even third-best policies.[28] Each of the foregoing examples showed why what might seem like best practices can not be applied easily.

Some regional public authorities, donor agencies and well-meaning NGOs responded to the transport "crisis" with actual and proposed standards, taxes, regulations and an array of one-off, ad hoc interventions designed with little reference to reality of the local underlying cause-effect relationship of the transport externalities and system problems they are trying to address. The "forced" conversion of buses to CNG or ethanol under political pressures in many cities, and Mexico's "Hoy no Circulan" are two good examples. To be sure, these interventions may have some measure of success. But they may also prove to be an expensive waste of time and public money that allow the real problems to increase as they "creep" further and further into the warp and weave of the lives and livelihoods of everyone living in or close to urban areas. One important source of waste is not poor advice per se but the inability of authorities to follow the impacts of their interventions and discern success from failure in time to make corrective changes, in time to avoid great losses.

Even worse, the overall result of these interventions may be profound changes in the transportation system, generated via the wrong market signals being sent out, that are decidedly sub-optimal from a resource allocation, economic development and

[27] Even in Curitiba, Brazil, the city with the most far reaching bus system in the world, it is virtually impossible to measure the overall balance of car use, fuel use, and emissions in the city, and thus impossible to give a bottom-line fuel and emissions balance for the city. (Source *MS Thesis,* R. Marston de Texiera, Univ of Sao Paulo, 1998).

[28] Most analyses in fact hearken back to data provided by the IEA. That raises the spectre of circularities, since the IEA is stretched to the limit to analyze a limited set of internationally collected aggregate data on energy use and CO_2 emissions; the present "Energy Indicators" effort, is still in its infancy vis. a vis. collecting data from IEA Member countries and, equally important, getting member countries and major private and international interests as well to look closely at trends. And the IEA has only now begun to approach China, India, Russia, etc. to get their basic data in order.

environmental protection perspective but whose efficacy cannot be assessed until its too late to take corrective action. Yet given the enormous lead times required to change transport trends and the enormous costs (environmental and economic) involved and at risk, authorities can ill afford long-term mistakes caused by inability to measure and see where the system is going. The good news is that Mexico City recovered from “Hoy no Circulan”, Los Angeles and Mexico City concluded their ethanol bus programmes and moved on, and other cities learned lessons in designing their own behavioural strategies, or simply avoided the widest pitfalls and loopholes

Thus to a large degree, characteristics of technology performance, behaviour and lifestyles and in the impact of national or local policies and corporate or local, non-governmental initiatives to affect transportation are simply too poorly known to draw lessons, spot winning technologies, correct undesirable trends, or reinforce successful initiatives. For policymakers and donor agencies, this means it is almost impossible to design optimal interventions or to measure the added value of an intervention - while trends need to build up for a decade or longer before they emerge in a well-understood way, by which time it is often too late to change policies or change technologies except at very large cost.

<u>Political Difficulties: Divided Markets and Divided Responsibilities</u>:

One of the paramount problems of governance in transportation is that of divided responsibilities. Consider these examples of sensitive local situations where either markets (i.e., economic competition) or responsibilities (political competition) are divided:

- The role of “paratransit” is a sensitive issue in many large cities, because in the transport market, paratransit is both a competitor and a complement to organised public transit.

  In most third-world cities, informal transportation (or paratransit) co-exists with formally organised municipal buses, trams, and metros in a relationship that may not be totally sanctioned by the authorities. In Mexico City, around 30 000 “collectivos” (mini-buses and vans, akin to jitneys in the US and similarly around the world) have managed to garner about 30% of all trips in that region, mostly at the cost of regular bus and metro riders, but probably absorbing some car trips as well. Politically the collectivos are “tolerated”, yet represent a chaotic, uninsured and sometimes unsafe mode of transport that nevertheless delivers a much desired service. Unquestionably the drivers are a strong political force. In Brazil, the equivalent modes have been brought into the system in some cities, tolerated in others yet officially hated in most. Given this tension, little effort has been made to clean up the vehicles or organise the routes to fit with bus and metro systems. Indeed, the appropriate vehicles are virtually unavailable as new vehicles in Mexico City today, making the existing aging fleet old and polluting. (the Collectivos consume more gasoline than the buses from the two public companies consume diesel!). Any transport solution must fit this kind of local circumstance squarely into the picture. But at present the antagonism between all parties makes exploiting synergies impossible.

- Fierce competition between collective and individual modes has arisen in many cities, always as a function of peculiar local conditions.

  In Delhi (and other Indian Cities) the most important mode of motorised transport is the two-wheeled scooter, most of which have dirty two-stroke engines. They compete directly with buses for much of the mobile middle-class. Because they are so numerous they are a significant source of air pollution and congestion, in fact they consume as much as 66% of all gasoline in metropolitan areas! Although most manufacturers are switching to clean, four-stroke engines (and even CNG for the three-wheeled taxis), these vehicles will remain a huge source of air pollution for many years. If bus fares are raised to permit acquisition of modern, comfortable vehicles with improved motors and clean fuel, one result could be further erosion of the bus market and a worsening of both air pollution and traffic. Yet if bus fares do not rise, bus operators (public, contract, and private) will stick with old, polluting vehicles based on ancient designs putting bus bodies on truck chassis.

- Divided Responsibilities

  In some important regions, political parties divided authorities. In both Sao Paulo and Mexico City, the Mayor is of a different party than the national or state government. This tends to impede progress. Divided responsibilities separate those pushing technologies from those who use them. Indeed, new technology may be the least important component of the solution unless its acquisition and use is carefully adapted to these kinds of local conditions. In Brazil, for example, there are enormous potential gains to be made by improving bus technologies. But the owners of buses are rarely the operators. Whether owned by contractors to large cities (as in Sao Paulo), or by speculators, buses are resold after only a few years in service to the original purchaser. Most make their ways from larger to smaller cities. Hence few original purchasers are interested in expensive buses that they may not be able to resell. In El Salvador, virtually all buses were purchased used, primarily from the United States. And in both countries, small private operators dominate the bus business, few of whom can afford to buy more expensive, modern buses. While technologies to both improve fuel economy and drastically cut emissions in buses in both countries seem attractive, the present organization of the bus market presents a formidable barrier, even in the cities of Brazil with the most advanced systems, like Curitiba.

  Divided Responsibilities arise where transport crosses geographical or administrative borders often undermines technological and behavioural solutions. New York City Metropolitan Transit Authority operates one of the most important bus systems in the world. With long north-south streets on Manhattan and wide boulevards in Brooklyn and Queens, it would seem a logical place for dedicated bus lanes. Yet MTA cannot easily develop bus paths, as it is technically a State entity, while the City of New York controls the streets. This kind of divided responsibility plagues other cities, too, such as Delhi, Sao Paulo, and Mexico, where two or more regional or even national authorities have to agree on a strategy because vehicles and people cross borders constantly. Experts in all three cities say authorities rarely do agree.

Firsts Costs: High and Divided.

Money is a barrier to almost all social investments. The problem is particularly acute for transportation because the payoff to the public sector are so long-term. Thus even modest costs will be seen as high costs because the apparent payoff is so slow to realise. This is a classic problem for metro systems, which are extremely expensive but over decades could transform transport patterns profoundly. But as with most investments involving externalities, the payoffs to private investment are usually negligible. As previously noted, private bus and van owners and operators are usually small businesses or individual operators with little capital. Users of private vehicles – cars and two-wheelers – buy what is available, so if national governments have not required clean engines and clean fuels, the results will be pollution. Since the free infrastructure must be shared by public and private vehicle users, travellers and freight, there is rarely a simple or politically acceptable way of charging for road use, which further drains away potential funds that could be useful for infrastructure investments (including bus-ways), electronic road-pricing schemes, signal timing, or other investments that could reduce traffic.

The Good News: Policies and Technologies are being developed

Lest this review appear unduly pessimistic, it is only aimed at being realistic. Recognising barriers and failures is as important as crowning successes, as lessons learned all around help guide future actions. Indeed, we noted that actions are being taking in key areas. Removing lead from gasoline, lowering the sulphur content of fuels, raising vehicle pollution controls, imposing some controls in traffic, and working through the governance process to bring transport operators as well as private citizens and NGOs, fuel companies and vehicle producers into a dialogue has been underway. In parallel is a larger array of smaller projects and collaborative initiatives among stakeholders emanating from multi-lateral agencies, private donors, NGOs and the private sector and all targeting transport's environmental and economic externalities[29]

Compared to the scale of the problem, these moves are very limited. Some even backfired! But they are at least indicative that the public, politicians, the policy-making system and even major private sector players are beginning at last to engage seriously with the transport dilemma and starting to look for answers. This upward trend in demand for action emanating from the public and the public sector can only accelerate in the future.

> Mexico City's "hoy no circulan" was a policy that dictated that a car could not be driven one day per week, the day depending on the last number of the license plate. Newer cars with modern clean exhaust systems were exempt. The World Bank's study[30] showed that the policy appeared to stimulate a significant uptake of used cars with license plates covering the "fifth day" in Mexico city, by those

[29] Including the World Business Council for Sustainable Development Industry Collaboration on Transportation, the World Bank's "Clean Air Initiative" with local governments in Latin America and Asia, the W. Alton Jones Foundation Clean Bus project involving the IEA and local and national governments in Asia and L. America, plans for dedicated bus-ways in El Salvador and Bangalore, India, etc).

[30] Eskeland, G.S. and T. Feyzioglu, *Rationing can backfire, The Day "Without a Car" in Mexico City*, The World Bank, Policy Research Department, Public Economics Division, December 1995.

who could afford them. This led to more driving and fuel use, not less, since more cars were available.

Low Sulphur Diesel in Europe and the US. Pioneered in Sweden ("City diesel"), very low sulphur diesel has been appearing increasingly in bus fleets in Paris, London, and more recently in US Cities. The City of New York's Metropolitan Transit Authority soon will have switched all of its diesel fuel to very low sulphur diesel, and also embarked on an ambitious environmental program that has mean acquisition of several hundred compressed natural gas (CNG) buses, plans for an equal number of diesel hybrid electric buses (with significant savings of fuel and emissions) and addition of particulate filters to its diesel buses.

CNG Buses have become popular in many cities in Europe and the US. In the developing world, cities like Delhi and Jakarta have begun to convert to them, as have many cities in China. The conversion of all public buses to CNG before April 1, 2001 in New Delhi, India, has been ordered by the Indian Supreme Court, but as of May 2001, only a few hundred have been converted. When buses were ordered off the streets on April 2, some of the few that did appear were attacked and burnt by angry riders. But a useful side effect of this order is the wave of conversions of three and four-wheeled taxis, the former from gasoline, the latter from either gasoline or diesel, to natural gas. The Three-wheeled, two stroke taxis were a source of horrendous pollution; the natural gas vehicles are no doubt burning more cleanly than those that were replaced. The real issue the Indian authorities have finally confronted is the difficulty of making choices and carrying them out in ways that meet all four tests of sustainability.[31]

The City of Bogota, Columbia, which declared car-free Sundays, introduced its Millenia 2000 bus-way, reported to carry now several hundred thousand people per day. It has also upgraded its cycle paths significantly, introducing an important complement to NMT.
(http://www.terra.com.co/proyectos/transmilenio/index.htm)

A Voluntary Agreement on CO_2 Emissions from New Cars, in Europe was adopted by the manufacturers and EU, with Japanese and Korean importers agreeing to go along. The agreement targets a 25% reduction in sales-weighted new car emissions by 2008. A similar agreement was reached in Japan in late 1998. Data from the manufacturers and ECMT show that through 1999/2000, these test emissions are headed downward.[32]

Honda Motor Co. pledged to phase out two stroke motors for its two-wheelers (scooters, mopeds), and the industry in India is slowly doing the same thing. A series of inspection and maintenance clinics is being developed in India to improve the running and reduce pollution from the millions of existing vehicles.

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[31] Bose, R., K. and Nesamani, N.K. 2001. Urban Transport, Energy and Environment. A case Study of delhi. Delhi: Tata Energy Research Institute.
[32] ECMT, 2001. *Monitoring of CO_2 Emissions From New Cars*: Paris: OECD

Thus there have been some important actions that pry open the future with policies and with technologies. Most of these actions are being watched closely, but not all produce cleaner air and other results that are unambiguous beyond the uncertainties of measurement. This creates problems for governance: how to take proper credit (or dole out blame) for results of initiatives?

Longer term efforts are being made. Sao Paulo is developing its long range plan, "PITU",[33] and Mexico City is commencing --- once again --- on a long-range vision. Bangalore India has laid out a long-term strategy for bus-ways currently awaiting international funding of the first stage, and Jakarta is developing a Master Plan of its own. Many other cities in Latin America besides Curitiba sport important new busways. Even Los Angeles, stung by the huge costs and low-ridership of its Metro and light rail lines, implemented a traffic signal synchronization scheme along two of its major bus corridors with measurable results – higher bus speeds, more passengers, and likely less fuel consumption and pollution as well. All of these achievements came about because authorities at different levels and in different regions – as well as in different parts of the same authority – began to work together to build sustainable governance for transportation.

At the same time, a number of very bold and important experiments are underway to test both technologies and behaviour, both individual and governance. RATP, the Paris transportation company, is running buses on low-sulphur diesel, natural gas, LPG, and even electric batteries, as are many other cities[34]. The World Bank, the Global Environmental Facility, and UNDP are fostering experiments with advanced buses powered by fuel cells and diesel hybrid engines. Toyota and Honda are selling limited numbers of hybrid automobiles with very low emissions and low fuel consumption, and many companies have announced limited numbers of fuel-cell cars for sale by 2003. Cycle paths are being extended in Paris and other European cities, as well as in Shanghai and other cities in Asia and Latin America. Even Bangkok is trying, with its people mover. And the World Business Council for Sustainable Development has convened a large and far-reaching study of Sustainable Mobility, funded by fuel and transportation companies, that is engaging much of the Third World in local dialogues to diagnose the problems before imposing "solut9ions". The first decade of the new millennium should be filled with experiments and signals about what works, and what does not, providing valuable insights into what might contribute in the longer term to the four pillars of sustainable transport.

The Way Forward A New Paradigm for Transport Planning and Implementation[35]

What is the way forward? City authorities must take the lead:

- **Cities must take a long-range, systematic approach, including strengthening transport system governance.** Any urban transport initiative plan must be part of a systematic or comprehensive plan in order to succeed. The plan must include a long-

[33] Governao do Estado de Sao Paulo, 1999, Plano Integrado de Transportes Urbanos para 2020. Sao Paulo:Secretaria de Estadodos Transportes Metropolitanos.
[34] RATP, 2000. Bilan des Experiments des Bus Ecologiques. (Results of Experiments with Ecological Busses). Paris: RATP.
[35] This discussion follows Fulton and Schipper (2002, in press, Transportation Research Board).

range vision of where both the region and its transportation system is headed, and how that direction might be changed. Issues of governance and transport system management (including regulation and licensing of operators) are as important as technical issues. The various policies affecting transport must be harmonized so that they work together, for example to encourage use of mass transit and discourage single-occupant car travel. Improving integration of transport and land-use planning is also very important. Improvements in single or isolated elements of a transit system or transport plan rarely have strong effects, while the systematic approach allows synergies to strengthen the system and improve transportation.

- **Focusing only on technology without paying attention to other aspects of transportation represents a narrow approach.** Technologies gain strength in the battle against pollution and congestion as other systems that reinforce them are also strengthened. As long as competing, "dirtier" modes pay a "correct" share of their external costs – however difficult that is to determine – then the incentive to use improved technologies will be highest. And technologies must be used properly and maintained, not simply installed. This requires good management and monitoring of pollution from vehicles. People are adept at exploiting the weaknesses – and strengths --of technological systems. Policies must erase incentives for people to drive, pollute, and congest more, even if actual emissions from vehicles are reduced by technology.

- **Focusing on behavior and management without careful attention to technology is an equally narrow approach.** Policies and management strategies must be in tune with technological innovation and technologies that support the policy goals, and recognize technologies (including automobiles!) as part of the landscape. Rapidly evolving transport technology can speed up traffic and reduce pollution, yet charge each user for road space during congested times. GPS systems could make paratransit – small busses and vans – easily available to those who need them without creating endless swarms of hovering vans that mark many airports.

- **National Governments Must Help**. Fuel and vehicle standards need to be set firmly by national governments. Although local variations may be necessary, both fuels and vehicles are manufactured and traded within and between countries. The scale of production is usually too large to be adjusted to each locality. If the U.S. and California are any guide, authorities are willing to move to the most stringent levels of quality if they meet demands of a large market (i.e., California), rather than fragment into too many individual markets. And only national governments can negotiate standards with large multinational corporations and other countries.

- **The Private Sector Must be Involved.** Vehicles and fuels are made largely by the private sector. Indeed, some publicly owned fuel companies are among the most notorious for the slowest responses to environmental clean-up demands. Bringing in the private sector to develop, produce, and sell the technologies needed for clean transport is a key step towards sustainable transport. Getting these actors to move ahead on their own with enthusiasm, however, is not so easy.

- **Political Sustainablity Must be Developed.** Regardless of the present attractiveness of policies or technologies, a path must be developed that is relatively robust to changes in the political winds for the party governing a city, or indeed acceptable to more than one party should there be divided political responsibilities. The private sector will not act with full strength if it believes that rules will be changed once the next politicians take over.

Strategic Questions and Issues to Consider

This paper is based on several presumptions that are worth emphasising as the basis for future discussions.

- Do the four elements of sustainable transport (economy, environment, equity, and governance) fit together? How well a match must there be among efforts addressed at all these elements for real progress to occur?
- How well do the components of **ASIF** need to be known and monitored for success with technologies and policies?
- How do technologies, short-term behavioural change, economic forces, and urban planning fit together to affect the ASIF components?
- How can governance be harnessed to provide better solutions to tomorrow's problems? That is, how do public (i.e., local and national government, international organisations, lenders, and NGOs) and private-sector roles blend for sustainable transportation?
- What is the best mode for intervention: technological experiments or policy trials?
- Is the proposed Programme too ambitious, or too limited? Are there serious omissions?

Closing Thoughts: Optimistic or Pessimistic View?

Problems of traffic, transport, and pollution have emerged very rapidly in the cities of developing countries, even as plenty of examples of "what to avoid" could have informed urban policy makers what to do. One reason why so many cities may have sped ahead beyond an optimal point is the true lack of quantitative measures, e.g., the components of the **ASIF** notation. Authorities simply may have missed the danger signs. Another is the incentive to continue the process of individual motorization and let that lead to new forms of cities, rather than let city development lead to appropriate transport.

The good news, however, is that authorities are reacting at an earlier stage of development outside of the developed countries than was the case in those countries themselves. Consider that e. Europe introduced lead-free gasoline in the 1990s, a time when their per capita GDP lay not far from where it was in the U.S. when authorities were putting lead <u>in</u> gasoline. Euro-4 fuel (and engines to match) is not far away from major countries of L. America and Asia at per capita incomes around those at which the debate over automobile air pollution first began in Southern California. And the lags between introduction of technology in wealthy countries and first appearance in developing countries is getting shorter. In short, clean air technologies are being developed with an eye to world markets, rather than just a few countries with strong regulations. And at this writing, fuel economy agreements in Europe and the likelihood of policy initiatives in the U.S. make that element of carbon emissions once again within reach of being tamed. In short, technology is not standing still, it is getting both less costly and better.

Two enormous barriers stand in the way. The first is the political will (in both Developed and Developing countries) to change rules and/or prices to make cleaner and more fuel (or carbon-saving) technologies move faster through development and into every vehicle on the road. These developments can reduce the importance of the **IF** terms in the **ASIF** equation remarkably over as little as 20 years, i.e., one generation of vehicles. Thus the technological problems of un-sustainable transport probably can be solved.

The second barrier is the political will to deal with the **AS** components of the equation. No matter how clean, enormous flows of traffic and ever expanding cities will always themselves cause problems to present generations, while leaving even worse problems to future generations. In developed countries, this may mean less motion, but not necessarily less access to people, goods, and services. In the developing countries this must mean more access to the same ends, without the endless chase to be like Americans, Europeans, or Japanese. What is working so hard against the developed countries is generations of habits built up around individual motorised transport; what is pressing hard against the developed countries is the huge and rapidly growing scale of the challenge, exacerbated by swollen urban population and inadequate infrastructure to deal even with last years' problems. But the developing countries are wealthy and innovative, so that deep cuts will work their way slowly but surely through the problem; the developing countries are growing and changing so rapidly that even modest cuts in some forms of emissions rapidly become the norm as vehicles are replaced, and citizens can grow into new patterns of mobility and access before they get mired in the old ones.

Annex

MAKING URBAN TRANSIT SYSTEMS SUSTAINABLE AROUND THE WORLD: GETTING MANY BIRDS WITH ONE BUS?

Urban Public Transport in Developing Countries: Potential and Problems

Transportation is a backbone of growth in developing economies. But transportation has become a major source of environmental problems as well, as its share of energy consumption and greenhouse gas emissions has grown. Problems are exacerbated by vehicle travel levels that are rapidly outstripping the capabilities of existing infrastructure systems, leading to traffic congestion and even more fuel use and air pollution than would otherwise occur. The problems are particularly acute in the developing world's largest cities. Swollen populations and high densities of vehicles of all types mean major congestion, slow travel speeds, higher exposure to polluted air, and very high rates of morbidity and mortality from traffic accidents (World Bank 1996). At the same time, growing incomes lead to mode choices that add to these problems: traditional non-motorized forms of transportation, such as walking and bicycling, give way to motorized transport, first busses, but as incomes grow, increasingly cars and in Asia in particular, two-wheelers. Cities appear to be strangling in their own prosperity and in the problems of the success of transportation, and that strangling in turn threatens future health and prosperity. Ironically, then, transportation, which brings people to people in cities (as Braudel put it), also threatens to strangle cities. The future of many cities therefore lies in the future of their transportation systems. This paper discusses the potential role of bus transportation in reducing that threat.

In many developing country cities, a large share of all urban passenger transportation activity is borne by busses, largely because of their low cost per trip. Indeed, In most OECD countries in Europe, busses carried as much as half of all traffic in urban areas until the 1950s and 1960s, when they were displaced in part by metros, but increasingly by private cars as well. Thus in most cities at or above middle income status (e.g., Mexico City, Bangkok) busses and other forms of collective transport are losing shares of trips and travel to individual modes. This evolution is spreading rapidly to most of the large cities of the developing world, with two- and three-wheelers more prominent than cars in many Asian cities. Whether this kind of evolution will continue in the developing world will depend on many factors, particularly incomes, the price of automobiles, the way cities grow, and the health of the existing bus systems.

A few cities have been different. In Curitiba, Brazil, a large scale bus-system that grew over three decades with the city continues to carry a large share of all traffic, as citizens of that relatively wealthy city simply use their cars less than do other Brazilians of similar income and situation. But in many other cities in Latin America and Asia, busses, while still the backbone of urban transportation, are seen increasingly as inefficient and as major sources of pollution, noise, and road hazards. Even in some poorer cities, such as Delhi, bus ridership has declined significantly in recent years.

Given the inherently economical (and space-efficient) nature of bus travel, strong efforts to keep bus travel viable and increase its share of trips is warranted, and is beginning to occur. City authorities around the world have started to ask for viable, clean and affordable urban bus transit systems that will maintain or even increase their share of mobility even as incomes grow and cities expand. And this appears to be feasible, if bus systems are reformed and modernized.

Bus systems come in many scales (Cervero 1998; Dunleavey, 1999 Merielles 2000). In Curitiba, Brazil, busways (bus rapid transit, or BRT) form the main element of the transport system, carrying nearly 50% of all daily motorized trips with high average bus speeds (Rabinowich and Leitman 1993). The integration of the trunk lines (with double-articulated busses) with the rapid lines and others through special stations is well known and part of the reason the system works so well. In Sao Paulo, busways play a less prominent role overall, but key routes are integrated with the Metro, other bus lines, and mini-vans (Government of the State of Sao Paulo 1999). In Ottawa, Canada, the highly successful BRT, consisting of three main routes, is linked to rail and soon to light rail, with park-and-ride stations at the fringes of the city as well (Ontario Municipal Board 1999). What makes these systems work is their speed and reliability. In Los Angeles, a recent initiative is based on a signal synchronization system along a 40km corridor (Wilshire-Whittier). New stations were built for these “Rapidbusses”, with clocks indicating the approach of the next bus. While there are no dedicated lanes, this approach has succeeded in raising average speed 15%, attracting passengers, and even lowering fuel use/km slightly, relative to other busses in the same region of Los Angeles (Department of Transportation 2001). None of these measures to improve busses were undertaken in a vacuum; all were part of wider, long-term urban transit strategies.

Bus systems are but one of those that can be called “mass transit” (World Bank 2001; Halcrow-Fox 2000): Bus systems have the disadvantages of taking road space and causing local air pollution. But they have the advantages of flexibility, and even more important, very low cost (in $ invested/passenger of capacity or passengers carried per year), compared with Metros or even light rail systems. And systems can be built quickly. To be sure, a good metro can carry an enormous number of passengers along a corridor quickly, but it appears that this then frees road space for...more cars! Certainly there is room in most transport plans for contributions from more than one system, but our project focused primarily on busses.

The potential for revitalizing bus systems is hampered by a number of factors. At the top of the list is the manner in which bus systems are managed and the way individual bus routes and buses themselves are regulated. Serious problems in the manner in which bus systems are regulated and managed plays a major role in preventing buses from producing significant revenues; this in term represents a major hurdle in the viability of improving the technology and operation of buses themselves. Although the manner in which bus services are organized, managed, and licensed varies considerably from city to city, a number of problems are commonplace. A second major issue is that buses are too often stuck in traffic. The sustainability of bus systems is dependant on bus speeds both from the point of view of providing a service that encourages ridership and from the point of view of raising revenues – slow bus speeds reduce the total kilometers, and therefore passenger loadings, that a bus can achieve each day.

As a result of the lack of revenues available to pay for better buses, many cities are dominated by older, poorly maintained busses with little or no pollution control; they are typically outmoded vehicles often converted from truck frames or bought used from developed countries. Budgets available for upgrading these busses or replacing them, or even replacing worn parts, are often tiny. Further, poor fuel quality – usually very high sulfur diesel fuel - combined with poor engines means most busses in the developing world are major sources of particular matter and NOx emissions, and therefore of ozone (smog) as well. Busses are often seen as a major part of the problem, not part of the solution.

A few cities have managed to restrain significantly the negative transport impacts of development through the effective use of mass transit systems, i.e., metros, trams and busses. Such cities are usually (but not always) less congested, less noisy, and less polluted than most others, and arguably provide better access and mobility to their residents. Current success stories can provide models for other cities in the future. As bus systems tend to offer the most cost-effective approach to providing mass transit, the International Energy Agency in Paris (IEA) believes that promoting development of carefully planned bus systems can assist in promoting a sustainable transport future around the globe. This kind of future could reduce the threat from congestion and pollution now challenging the largest cities of the world.

Background on the IEA Project

To meet this challenge, the IEA is undertaking a one-year study to examine technological and system-oriented options to provide clean and efficient public transit in large developing cities around the world. The project is working directly with leading authorities in cities in Asia and Latin America. The project is focused both on bus transit and the system and environment in which buses operate. Areas for potential improvements include: adoption of advanced technology and alternative fuel buses, improved bus transit operations and regulation, and physical improvements to systems, such as dedicated bus lanes. The advanced bus technologies that we consider include fuel cell and hybrid-electric propulsion systems, compressed natural gas powered and other alternative fuels, and clean diesel technologies.

Key elements of the IEA project include 1) a review of technologies for buses and fuels 2) analysis of the transport systems and policies of selected cities; 3) review of recent experience in selected North American and European cities. One goal of the project is to explore the paths that lead to "clean bus" strategies; another is to measure the various benefits, such as reductions in local pollution and congestion, as well as more global benefits, such as lower fuel imports and lower emissions of carbon from fuels. These multiple benefits give rise to the title of this paper. The purposes of the clean bus strategy itself, improving urban transportation and cutting pollution, have enormous local benefits that dwarf the value of

As part of this effort, we compiled data and carried out analysis in several areas:

- The current state of, and trends in, transportation, emissions, and energy use in major developing cities around the world.

- The current role of bus transit systems, problems that cities are having with these systems, and potential avenues for improvements.
- Air pollution, CO_2 and energy related concerns in cities and how these match up with the strengths and weaknesses of different bus technologies and fuels.
- Costs of various technical options v. their benefits, and relative to what cities currently pay for different aspects of their bus systems.
- Potential pathways for the introduction of advanced technologies – such as fuel cells and hybrid-electric propulsion systems – using bus systems as an early area of market penetration.

During this study the following cities were visited or consulted for discussions with officials, academics, vehicle manufacturers, bus operators, fuel companies, NGOs, and others with a direct stake in urban transport:

- In Latin America: Buenos Aires, Argentina; Curitiba, Rio de Janeiro, Porto Alegre, and Sao Paulo, Brazil; Mexico City.
- In Asia: Dhaka, Bangladesh; Shanghai, China; Bangalore and New Delhi, India; Jakarta, Jogjokarta and Surabaya, Indonesia; Manila, Philippines; Singapore; Bangkok, Thailand.
- In IEA Countries: Ottawa and Vancouver, Canada; Paris, France; London, UK Chicago, Los Angeles and NY City, US.

This paper will review the key findings of the project thus far, in expectation that more detailed publications that will follow. Although the project focused nominally on bus systems, we were drawn to the broader issues of transport activity and emissions in each region, as we review next.

ASIF: The Basic Tool for Analysis and Thought.[36]

In order to develop sensible, sustainable plans and policies in transport, it is first necessary to understand where one stands and where one is heading. This issue -- keeping score on transportation and environment -- is not simply one of counting accurately (bottom-up statistics). It also rests on untangling the components of changes in underlying transport activity, fuel mix, and overall emissions over time and across the population and the vehicles they use (top-down decomposition). This approach is similar to those used for estimating the contribution of traffic and transport to pollution (CITEPA 2000). Such a decomposition is vital for measuring progress in taming the major problems related to traffic volume and emissions, particularly in city where the overall growth in vehicle numbers and use swamps other effects. The same approach is useful both for allocating political credit for success and for fixing blame and fixing the problem when a policy or technology does not yield the intended benefits.

For these reasons, the IEA developed the **ASIF** equation to cover transport impacts in a more general (and thus complete) way (Schipper, Marie-Lilliu, Gorham 2000; Schipper and Fulton 2001):

$$\mathbf{G = A * S_{\mathit{i}} * I_{\mathit{i}} * F_{\mathit{i,j}}} \qquad \mathbf{(1)}$$

[36] This discussion is taken Schipper and Fulton 2001.

where **G** is the emission of any pollutant summed over sources (modes) *i;* **A** is total travel activity, in passenger kilometers (or ton-km for freight), across all modes. **S** converts from total passenger (or freight) travel to vehicle travel by mode. **I** is the energy intensity of each mode (in fuel/passenger or tonne-km), and is related to the inverse of the actual efficiency of the vehicle, but it also depends on vehicle weight, power, and of course driver behavior and traffic. F is the fuel type *j* in mode *i*. Figure 1 schematically illustrates this relationship and introduces other factors that affect the basic ASIF parameters.

[INSERT FIGURE 1 HERE]

What matters for transport and environment is that each of these components be exposed to transport policies as well as feedback from other components. Increasing load factors in busses both reduces fuel use/passenger-km and (if the passengers came from cars), induces an overall modal shift towards less fuel intensive modes. Of course, not all components respond the same to a given stimulus, say a fuel tax increase or a kilometer road-use fee. And not all actors, i.e., vehicle operators, travelers, or shippers, will respond to the same stimuli in the same way, either. Each component (and not simply those related to fuel) affects emissions, too. For example, congestion drives up emissions; so does short trips in motor vehicles taken with cold engines. If some car trips are replaced by less energy-intensive modes or non-motorized transport, the savings are more than proportional to the km not taken by car.

The key purpose of the ASIF identity is to show policy makers how the components of transport and emissions fit together, and make sure that the potential –and actual – impacts of their actions on each component are noted. Modes are linked, too: safe cycle storage encourages cycling to collective transit nodes (bike and ride); measures to give buses or cycles priority lanes often take road or parking space from cars, which discourages car use etc. ASIF helps remind analysts of some of these linkages. In the end ASIF is only an identity, but it has a powerful effect identifying underlying factors and rates of change.

A Tale of Two Cities: Bangalore and Mexico City

The examples below (Figures. 2 and 3) are taken from Mexico City and Bangalore. They show the contribution of different motorized modes to traffic, travel, and several kinds of air pollution. By putting these into an ASIF matrix, however, unlikely combinations of estimates are easily identified if they give unrealistically high distances /year (say 200 000 km/car/year), far too much fuel consumed, or very high or low specific emissions coefficients when vehicle activity is compared with estimates of total emissions. Certainly there are many uncertainties, particularly distances each vehicle move in a year and even local fuel sales. But as a first order estimate of key parameters of traffic, transport, and pollution, the figures and the estimates behind them are very useful.[37]

[37] Non-motorised transport (walking, cycling, rickshaw) is important in Bangalore, probably accounting for an additional 25% of trips and 10% of distance travelled, if studies of Delhi are indicative (RITES 1994). The same modes are probably less important in Mexico both because of higher incomes and because of real concerns about safety from cars that suppress cycling.

[INSERT FIGURE 2 HERE]

[INSERT FIGURE 3 HERE]

There are interesting similarities in these cities. Paratransit exists in both Mexico City and Bangalore: small vans and buses (called "colectivos"), and for similarly for Bangalore (Maxicabs). In Mexico City, these have gained a larger share of total travel than either cars or the Metro since the early 1990s, drawing both from the Metro and from large busses, whose numbers have plummeted since the late 1980s. This means that even "public" transportation in Mexico has spread into vehicles with smaller loads, with consequences for congestion. Most of those using *colectivos* used to ride the Metro or large buses, as can be seen by examining how modal shares in Mexico have changed since the mid 1980s (Zegras et al. 2000). By contrast, the Maxicabs have not yet taken off in Bangalore, possibly because three-wheelers (or auto-rickshaws) offer some of nearly door-to-door service that colectivos give in Mexico. But another reason is that this form of transport tends to be more expensive than large, city-controlled busses.

Note air pollution and overall traffic is dominated by private vehicles, automobiles in Mexico City, two- and three-wheelers in Bangalore. But there are important differences. If busses and the colectivos are counted together, their share of 40% of traffic is much less than the corresponding share in Bangalore, 60%. Private vehicle ownership is much higher in Mexico than in Bangalore, and this is what accounts for most of the difference. But average income is much higher in Mexico than in Bangalore. Given the clear link between income and car ownership/use (Schipper, Marie-Lilliu and Lewis-Davies 2001), it is not surprising that Mexico City has a higher share of car travel. Normalizing by approximate populations (6.0 million for Bangalore, 13 million for Mexico City) gives approximately 6700 pass-km/year traveled in Bangalore and about 10 000 in Mexico City; the figures for car/two wheeler are 700 and 2300 pass-km/year respectively. This increase of more than a factor of 4 illustrates how automobile ownership and use rises sharply with incomes, again, at the expense of the collective share of travel. But the high level of bus travel in Bangalore is surprising, and may reflect long work-trips into the city of those actually residing out side of Bangalore.

These ASIF representations have clear implications. First, automobiles (for Mexico City), and two/three wheelers (for Bangalore), that is, individual transportation, dominates traffic and air pollution from passenger transportation. Implicitly, pollution per passenger-km is much higher from individual modes than from busses. Indeed, busses are responsible for far less pollution than are other modes. While from buses are important, those arising from trucks are far more important for Mexico City. Other cities in Latin America (Rio de Janeiro, Sao Paulo, Buenos Aires) face the domination of the automobile illustrated by Mexico City, while those of lower-income Asia (Delhi, Dhaka) resemble Bangalore, with the domination of two wheelers. Higher income cities in Asia (Bangkok, Jakarta) begin to show the increased influence of cars. In every case, large busses have only a modest share of overall pollution. Thus while cleaning up buses is important for reducing air pollution, getting riders out of cars or two-wheelers and on to busses could have a far greater impact on both air pollution and congestion as well.

This rough comparison is meant neither to absolve nor implicate busses in any part of the pollution picture. Rather, it illustrates the importance of using ASIF to see the context in all four dimensions – total mobility, mode (or vehicle type), vehicle technology and fuel. But the clear implication is that busses have lower emissions/passenger-km than individual modes, by a wide margin. Thus strategies that shift traffic from individual motorized modes to busses should lower pollution, unless these result in significant increases in distances traveled. Tracking all of the "data" shown in these tables, as well as the specific emissions coefficients (g/km, etc.) is an important task for moving resources to technologies and policies that will bring the greatest reductions in congestion and pollution from a baseline.

Actions Promoting Busses to Reduce Impacts of Transportation

The key question for cities is what to do to improve their transport systems, and how buses fit in? Without an overall concept and goal that deals with each component of ASIF, it is hard to know what combination of new or even radical technologies, system-oriented measures, pricing reforms, financing, general transport policies, and other factors would both improve mobility and lower the total costs to society of transportation (including hidden costs referred to above)?

Clearly there are many ways that busses can help the overall situation, as suggested by Figure 1 and the data used to construct Figs 2 and 3:

- Reducing pollution from busses themselves, both by reducing fuel use/veh-km (**E**) or pass-km (the components of **I**) and by reducing pollution per km using cleaner fuels and better engines (the **F** for busses), or by reducing impacts from both terms through smoother traffic (**OR**);
- Increasing bus load factors (**L**);
- Increasing the bus share of overall travel (**S**), principally by making bus travel faster, bus service more frequent, and busses cleaner, quieter, and more comfortable.

The last two steps are crucial and are often overlooked by those focusing only on tailpipes of busses as sources of pollution. First, busses only account for a small part of overall traffic congestion and pollution. Their greatest contribution to reducing pollution and congestion could well be in getting cars and two-wheelers off the street. But clean busses stuck in otherwise polluting traffic will not attract new riders, even if fares are artificially low.[38] But the key to attracting more riders is to speeding up the busses and integrating them better with other modes of transportation.

Key Areas of Attention for Improving Bus Systems

The recent success of Bogota's "Transmileneo" system (SIDA 2001), as well as steady progress in a number of cities in developing and developed countries suggest busses can

[38] Indeed, simply putting busses on the street while ignoring measures that discourage using other modes is clearly insufficient, as the experience with US cities from 1970 to 2000 shows. During that period of heavy subsidies for urban transit system, the average load factors of city busses fell, and their average energy intensities soared to over those of cars (on average) or even air travel (Davis 2000). The reason was that little else was done to stem individual car use or the flight of increasing numbers of households to the suburbs.

play a key role in providing clean access in cities while improving transportation and air quality overall. In discussions with officials in all the cities in Table 1, as well as Vancouver, Chicago, Los Angeles, New York, and Paris, as well as with most of the major bus manufacturers in the world, certain themes emerged almost universally when we asked the question "What would it take to increase the usage of busses while decreasing their contribution to congestion and air pollution"? The answers resemble those to broader questions about reducing overall impacts of transportation and making transport more sustainable (World Bank 1996):

- **Cities must take a long-range, systematic approach, including strengthening transit system governance.** Any urban transit bus development plan must be part of a systematic or comprehensive plan in order to succeed. The plan must include a long-range vision of where both the region and its transportation system is headed, and how that direction might be changed. Issues of governance and transport system management (including regulation and licensing of bus companies) are as important as technical issues. The various policies affecting transport must be harmonized so that they work together, for example to encourage use of mass transit and discourage single-occupant car travel. Improving integration of transport and land-use planning is also very important. Improvements in single or isolated elements of a transit system or transport plan rarely have strong effects, while the systematic approach allows synergies to strengthen the system and improve transportation. Focusing only on clean buses (some US Cities) or only on busways and high ridership (Bangalore, Sao Paulo) or ignore the role of other modes, including informal transport, in feeding major bus routes (Mexico City) may satisfy the goal of the individual focus but fail to improve the overall system and the environment as well.

- **Focusing only on busses without paying attention to other aspects of transportation represents a narrow approach.** Bus systems gain strength as other systems that reinforce them are also strengthened and competing systems with greater negative impacts on transport and environment, i.e., cars and two or three-wheelers are "weakened". As long as competing modes pay a smaller share of their external costs than do buses, those modes continue to hold the advantage that propels them ahead of busses in popularity in so many cities.

- **Each additional bus provides large benefits.** Regardless of whether a bus is "clean" or " dirty", if it is reasonably full it is displacing anywhere from 10 to 40 other motorized vehicles (including 2-wheelers as well as cars; in some cities the primary displacement is of 2-wheelers). The fuel savings, CO2 reductions, and pollutant reductions of such displacements are relatively large – our preliminary analysis suggest that they can be much larger than the potential benefits of making a fuel or technology upgrade to the bus itself. Thus getting buses on the road, and getting riders onto buses (mainly by offering a service that riders want) is the best strategy for providing efficient, sustainable transportation systems.

- **Transit system improvements go hand-in-hand with bus technology improvements.** In order for bus companies to justify the expense of advanced technology (or even EURO-II compliant) new buses, these buses must earn considerably higher revenues than do the current buses. Revenues can be increased three ways: fuller buses (carrying more passengers per kilometer), faster buses (more kilometers per day), and higher fares. The first of these requires system improvements and policies that promote transit (like fuel pricing). The second can benefit both from system improvements (such as dedicated bus lanes) and from better buses (newer technologies with better engines can help improve acceleration and average speeds). The third, higher fares, can be justified once actions taken on both the system side and bus side sufficiently improve the quality of the bus experience for riders. This includes faster travel, safer and more comfortable rides, greater reliability and predictability. Thus improvements to the "system" side of the equation help pave the way to better buses, and vice versa. It will be very difficult to sustainably implement a "more expensive" bus without system improvements.

The institutional, financial, and governance aspects of bus systems must be strengthened.

- **Improving Bus System Regulation and Licensing** In many developing cities, most buses are run by independent bus companies. In some cities private companies have grown up to fill vacuums created by the inability of public bus systems to provide adequate service. There are often many independent bus provides, often quite small, surviving on a day-to-day basis. These companies are not able to make major investments in buses or bus systems.

- **Strengthening the Finances.** Bus fares are often too low (especially when combined with inefficient systems) for drivers and operators to recover the costs of new, large, buses that provide reasonable levels of service. For example, medium size buses (seating 24-40 people) in SE Asia typically cost $20,000 - $30,000, and are built by local manufacturers that sometimes build new bus bodies onto recycled truck chassis. In order to recover costs on a western style 80 passenger capacity bus, costing $150,000 or more, revenues would need to increase by 2-3 fold, taking into account a doubling of passenger loading capacity of these buses. Increased revenues could come from a combination of four changes: fare increases, increased load factors, increased average travel speeds and daily travel distances, and other revenues sources such as advertising.

Bus systems themselves can be improved greatly:

- **Increasing bus speeds is a high priority.** The opportunity to increase bus travel speeds and thus move more people farther each day is probably the most important improvement that can be made to many bus systems, since it increases both revenues and the overall efficiency of the system. It can contribute to raising revenues two ways – one, buy simply allowing the bus to run the length of the route more often per day, and second, by improving the level of service and attracting more riders to the system. Raising fares, in contrast, may have the opposite effect on the level of ridership. However, there is strong evidence that wealthier individuals are willing to pay considerably extra for "premium" levels of bus service, such as the guarantee of a seat, air conditioning, and reliable service. Even the poorest of cities (e.g. Dhaka) has a large population of middle class residents capable of affording premium service. Dhaka in fact has a premium service (featuring air conditioning and guaranteeing a seat) on two routes with fares several times that of regular buses.

- **Development of demonstration “Bus Rapid Transit” (BRT) corridors appears to be an important step.** In many developing cities the task of modernizing bus systems and increasing ridership is daunting. Part of the problem is knowing where to begin and what to do. Pilot or demonstration projects that focus on a single bus corridor help deal with both of these issues. They allow testing and fine-tuning a different approach to delivering bus services, and create the “seed” that can later grow into a fully established system of bus rapid transit routes. Demonstration projects typically include dedicated bus lanes, improved infrastructure such as bus stops and terminals, and (often very importantly) a new system of regulating and licensing bus services on the route. They can also offer a showcase for advanced technology (or just new, modern) buses.

- **Fully Developing BRT Systems should be a goal.** The concept of bus travel that begins to look and feel like rail travel, and that provides comparable or even superior service to rail (not to mention compared to other modes) is a new one but is catching on fast in cities around the world, particularly Latin America. It is epitomized by the system in Curitiba, Brazil, which is characterized by a network of roadways that are dedicated for bus travel and that operate large (articulated and bi-articulated) buses capable of carrying over 200 riders at a time. By giving over lanes and entire corridors to buses, bus travel becomes increasingly attractive relative to other modes (notably 2 and 4 wheel private vehicles as well as unregulated minibuses). By adding features such as bus priority at traffic signals (holding or advancing the green light to speed bus journeys), buses can become the premium form of urban travel, rather than a last resort.

On the technology side there are also important steps:

- **Incorporating Advanced Bus System Technologies.** A key to developing successful bus systems is to make bus travel attractive. While obvious, this has been achieved in very few places. However, there are a number of recent innovations that may allow systems all over the world to quickly improve. Dedicated bus lanes give buses important speed advantages over other traffic modes. But other technologies, such as global positioning systems (GPS) to track bus position and relay this information to travelers in real time, and advanced signalisation systems that give buses an “early green” or “long green” at intersections, are near commercial and hold the promise for major near term benefits in cities all over the world. This may be a case where technology “leapfrogging” makes good sense.

- **Advanced Propulsion and Fuel Technologies are there, but expensive.**. The most advanced propulsion technologies (fuel cell busses, even hybrids) are too expensive today for most developing countries. But a variety of strategies to clean up fuels including compressed natural gas, very low-sulfur diesel fuel, exhaust gas after-treatment, and better maintenance could reduce emissions significantly in the coming years, as the prices of the more advanced technologies fall. Busses produced in LDCs that meet EURO-4 emissions standards together with cleaner fuels and in some cases retrofitted pollution controls (or diesel-emulsions) are probably within the financial reach of major cities in Asia and Latin America.

Whether the ultimate choice is CNG or low-sulfur diesel, however, the costs are not zero, but the benefits are great when these first steps are taken.

- **Decisions regarding clean and alternative fuels (such as ULSD, CNG, LPG or DME) must take into account energy supply, cost and infrastructure considerations.** For good reasons, decisions regarding alternative fuels often get made on the basis of energy, rather than strictly environmental, considerations. Important aspects in any city are the national availability and supply of different fuels, local fuel distribution infrastructure, and relative fuel prices. Even in pursuing a path toward cleaner diesel buses, a major question is the availability and cost of ultra-low sulfur diesel (ULSD) fuel from domestic refineries or imported. In recommending any clean or alternative fuels initiative, the IEA must be sensitive to these considerations. It will also be important for cities to determine whether they want to embark now down a particular path toward "next generation" buses, such as fuel cells (see last bullet below) which may require a CNG or other alternative fuel or feedstock.

- **Field Tests of Options is Imperative.** Perhaps the greatest need today is field testing of buses and fuels. Using antiquated emissions models from one city (with one kind of fuel specification) to simulate emissions in another is unsatisfactory. Ignoring local fuel and road conditions, driver training and behavior, real passenger loads, etc. leads to results that have little resemblance to real emissions or measures of durability. Given the wide uncertainty in system costs noted above, it is important to pin down the system benefits. This is particularly true where the challengers are either very low sulfur diesel fuel or CNG.

Promising Outlook

There are some promising developments, particularly in three areas. First, demands for cleaner fuels in Japan, North America, and Europe have provoked oil companies into making cleaner diesel fuel, and effort that could be replicated in developing countries. Second, bus manufacturers have been developing new bus designs that are both much cleaner and efficient than even ten years ago. Even relatively low-tech diesel buses can now be outfitted with catalytic particulate traps that may be affordable in cities around the world. In addition, demonstration versions of inherently cleaner and more efficient propulsion systems, such as diesel/electric hybrids and fuel cell systems, are now being tested in IEA Countries and in a few developing countries, such as Brazil.

The World Bank's Clean Air Initiative (http://www.worldbank.org/wbi/cleanair/)- and Urban Transport Review (http://wbln0018.worldbank.org/transport/utsr.nsf) and many local studies and activities we found have identified technical, infrastructure, and policy options for cities. The foremost goals emerging from these efforts are cleaning up exhaust from existing fleets of vehicles (through vehicle retrofits and fuel-oriented measures) and taming the very disorderly traffic through system enhancements. But it seems clear that longer-term goals must include managing travel demand and mode choice, and encouraging the use of space-efficient as well as fuel-efficient (and low-emitting) vehicles.

Perhaps most important, developing cities themselves have begun to take significant actions to draw the line on emissions and traffic congestion. Both through well-publicized collaboratives among national and local stake-holders (such as the World Bank's Clean Air Initiative) and in less publicized efforts to adopt clean fuels and engines, city leaders have begun to implement promising programs to fight the difficult transportation problems. A wide recognition has arisen that the problems are multifaceted and need co-ordinated solutions, including technical aspects (engines, fuels, vehicle designs), system aspects (improvements in transit owner-operator and financial structures, licensing reform, route system development, scheduling, route infrastructure, and urban planning,) and political (co-ordination of government agency efforts, overcoming resistance to change from entrenched stakeholders such as bus operators, vehicle producers, fuel providers, etc.).

Two important examples of action can be found in India and Latin America. These illustrate the differences inherent a short run fix vs. a long-range vision. In Delhi, the Indian Supreme Court announced in 2000 that all diesel busses must be converted to natural gas by 1 April 2001. By June of 2001 less than 1000 CNG busses were running in Delhi, and little measurement of results is available. Controversy over the real long-run benefits of this switch to CNG is high, although near-term benefits include massive switching of three-wheelers from dirty two-stroke gasoline motors and some diesel taxies to CNG (Bose and Nesamami 2001). Other countries in Asia (China, Indonesia, Bangladesh) are moving in this direction as well in a more concerted way. However, the outlook for cleaner diesel fuel is also bright (ECMT 2000; Walsh and Shah 1997). It is clearly very difficult to make rapid technological changes to bus fleets, but cleaning up fuels, perhaps with additives, might prove effective. Bangalore, India, is close to adopting a long-range bus corridor strategy that will use modern busses and eventually stretch to well over 100 Km, of which the overwhelming majority will be bus-only lanes on existing streets (SIDA 2000). Surabaya, Indonesia is also considering a similar system (Fjellstrom 2001).

In Latin America, bus systems receive great attention. In Curitiba, the present bus system is the result of a very long-term approach to urban and human development that yielded an excellent bus system almost as a side benefit. Presently Volvo Corp. (one of the forces behind both the busways concept itself and an important producer of busses there since 1974), is re-examining Curitiba with an eye to upgrading the system, which is only marginally profitable for its operators despite its apparent success with riders and international observers.

This development in Curitiba occurs at the same time that many other cities in Brazil America (e.g. Sao Paulo and Porto Alegre). But other cities in Latin America are in the process of implementing different types of "bus rapid transit" (BRT), i.e. dedicated busway systems onto existing large city transport patterns. The first step of Bogota's "Transmilenio" has apparently attracted several hundred thousand riders per day at very low overall costs. Quito, Ecuador has developed a corridor, and now Mexico City is beginning the same development. And in North America, where Ottawa has developed a very successful system of multiple corridor routes and Pittsburgh a smaller system with one route. Los Angeles recently implemented a relatively simple traffic signal synchronization program for one of its main corridors that has both reduced bus travel times and attracted new riders, as well as reduced fuel consumption relative to buses not operating on the corridor. While these "retrofit" projects may not be as easy as the slow, long-term developments of Curitiba, they indicate that governments are beginning to consider modest expenditures on busses and bus systems to help clear the air in novel ways.

This good news is not limited to system improvements. While a number of cities (Chicago, Vancouver) have tested early fuel cell busses from Ballard and Xcellsis (Xcellsis 2000), a much more ambitious program has been announced for nearly a dozen European cities. New generations of limited numbers of fuel cell busses are appearing, some of which will be tested in major cities of the Developing world (UNDP-GEF 2000).. New York is satisfied with its own diesel hybrid tests and has ordered several hundred of these busses (Dana Lowell, NYMTA, priv. Comm. 2001). New York has switched to low sulfur fuel for all its busses, as has Paris and many other European cities. Paris is also testing Aquizol, a mix of diesel fuel and water that shows remarkably fewer particulate emissions than ordinary diesel fuel (RATP 2000), and a competing product, Lubrizol, is on the market (Lubrizol 2000). On the manufacturer side, Volvo is testing a natural gas turbine hybrid, busses running on DME, and a variety of active filters to reduce pollution and particulates from all fuels (P. Danielsson, Volvo Bus, 2001 Priv communication). Other bus companies are engaged in similar activities. Thus there are many technological initiatives that will help clean the air.

What Research is Needed?

The large number of local initiatives now underway has raised interest in general evaluation of the position of urban mobility in Developing country cities, and in specific evaluations of potentially promising technology and system-wide options. Some of the general research that is needed in individual cities includes:

- Analysis of present travel patterns and mode choices, and how improved provision of public transit could affect these dynamics.
- Analysis of existing forecasts of growth, land use development, vehicle ownership, and future travel patterns to assess the likely situation and emerging issues in a region in ten or twenty years.
- Analysis of private consumption expenditures for various modes of transport, housing, and other expenses that are clearly connected to the size, shape, and health of a city and its transportation patterns.
- Assessment of the characteristics of fuels currently used for urban transportation, including analysis of the future possible improvements in fuel quality and the costs and benefits of making such improvements.
- Assessment of the current state of vehicle technology and evaluation of new technology options in order to understand what options are feasible and appropriate to improve vehicles and reduce local emissions and fuel consumption. This includes testing of in-use emissions (e.g. NOx, particulates, CO2) of new and existing vehicles, and the effects of traffic conditions on these emissions. (This can vary considerably by city.)
- Assessment of the local transportation services industry, i.e., the public and private vehicle operators, their interests and willingness to undertake substantial vehicle improvements or be subject to significant changes in transportation policies and fuel pricing or taxation.

- The roles of local and international vehicle companies and fuel providers, and how their interests can be aligned with furthering the ends of developing clean, sustainable urban transport.
- Assessment of how the international community can effectively works with local authorities to develop and implement specific projects as well as long-term sustainable transportation plans.
- Evaluation of the already existing (and relatively few) experiments with new technologies and clean fuels, such as advanced bus technologies and Curitiba-style systems (including additional assessment of Curitiba itself).
- More study of non-technical factors, such as system financing, regulatory and institutional considerations, etc., that must be addressed to successfully move a city or region to an advanced transportation system; in particular the approach to licensing bus systems needs to be reformed in many cities.

This list is of such a scope that no single analytical project could hope to fully cover it. It indicates the wide range of types of research that must be carried out in individual cities (and for comparative purposes across cities), and any individual project can only realistically cover a few of these items in perhaps one or several cities.

The current IEA initiative attempts to provide a unifying framework to addressing these issues, and provide a roadmap for cities to act in concert. By identifying similar problems, and common solutions, we hope to gain momentum towards re-invigorating the role of buses and their contribution to solving transport problems world-wide. And from a broader IEA perspective, the changes in both policies and technologies that the problems of urban transportation will without a doubt provoke will have profound impacts on future oil markets.

What Could These Developments Mean for the City of the Future?

Judging by the level of traffic and pollution in Curitiba, Brazil, we can surmise that good bus systems will have several important impacts on growing cities. First, private vehicle traffic will be lower than otherwise. This will occur as long as other policies are enacted – road user charges, parking fees, fuel taxes, etc.— so that the perceived and real costs of using private vehicles in the densest parts of the city are not lowered by the reduction in traffic. In other words, reducing the number of users of individual vehicles will not have a major impact on traffic as long as other potential users of individual vehicles spring to replace those who took the bus (or other mass transit system). With fewer individual vehicles in the densest areas, more space is available for pedestrian-oriented developed. If this development is coordinated with bus traffic, which is the case in Curitiba, than even more use of busses is encouraged because there are more places to go most effectively by bus. But this is simply careful land-use planning, the kind of strategy that underlay the developments in Curitiba over forty years.

As long as this condition is met, then overall congestion and pollution will fall from what it would have been. Indeed, the pollution and traffic levels in Curitiba are perceived to be so low – incorrectly in our opinion – that authorities there do little careful monitoring of pollution from traffic or of traffic and personal travel itself. We believe that vigilance is necessary to monitor the health of the transportation system, measured in volume and pollution as well as in economic terms. By contrast the level of pollution and car use in restrictive Singapore is monitored much more carefully (Ang

2000). Authorities are ready to change the car-ownership and car use fees as necessary to control growth in traffic. While Curitiba has nowhere near the congestion of Singapore, things could worsen rapidly, as has been shown for all the larger cities of Latin America.

Is this an idealized picture of what a good bus system could do for a city? Perhaps, but increasingly authorities are placing their limited resources behind BRT as a necessary element in their cities' transportation futures: Bangalore, Surabaya, and most recently Mexico City have promulgated real plans to start one route as part of larger BRT systems. Ottawa is adding a light-rail link between two BRT lines, so important are the latter to the cities traffic. The US Federal Transit Administration has organized a consortium of cities to implement bus corridors of one sort or another. So this idealized picture may be a worthy goal, even if it may never be wholly realized in each city.

What is clear, however, is that many elements must be present for a BRT system to succeed in enlivening a city threatened by death by traffic choking. Following developments carefully in all the cities with major bus systems using the **ASIF** matrix as the analytical basis and a careful mix of policies and technologies to improve all the components may be the surest way to insure that many birds are captured from one bus.

FIGURE 1 The ASIF equation in two dimensions (CO_2 case)
FIGURE 2 Traffic, Travel, and Emissions Shares for Mexico City 1998
FIGURE 3 Traffic, Travel, and Emissions Shares for Bangalore, India, 2000

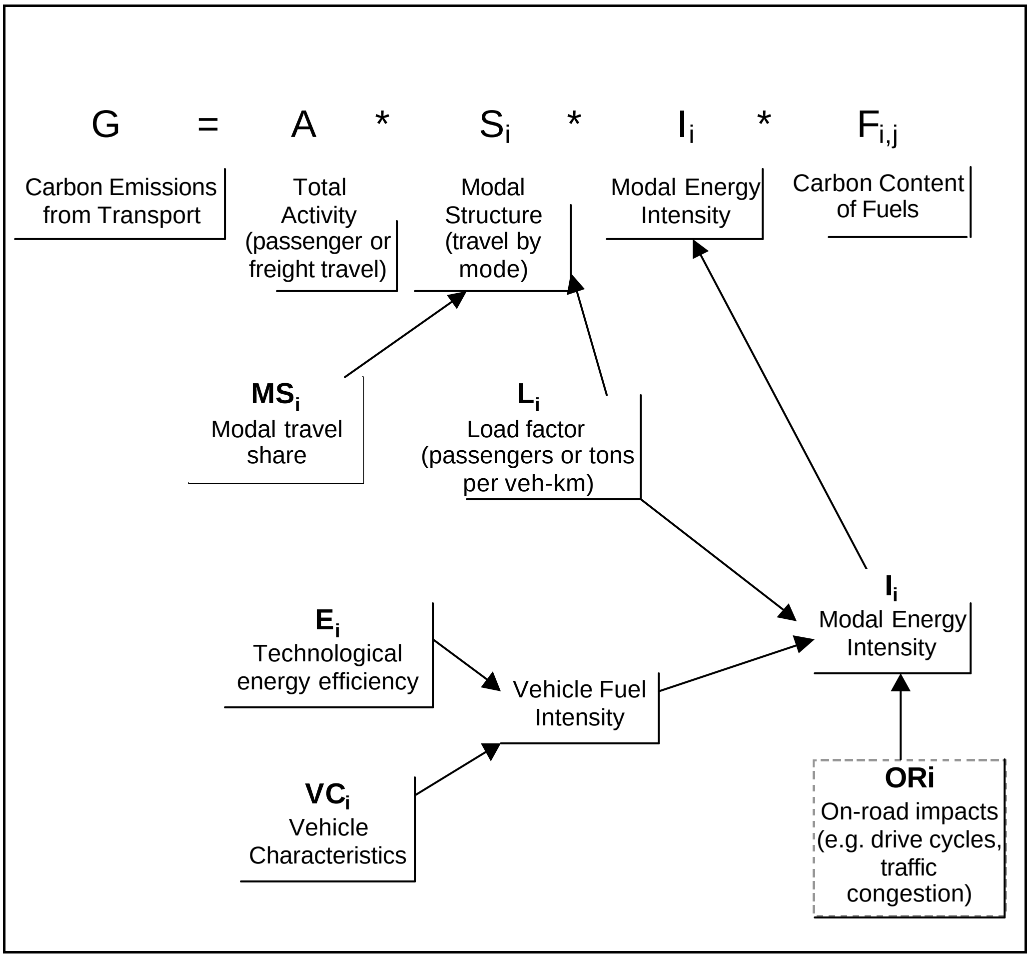
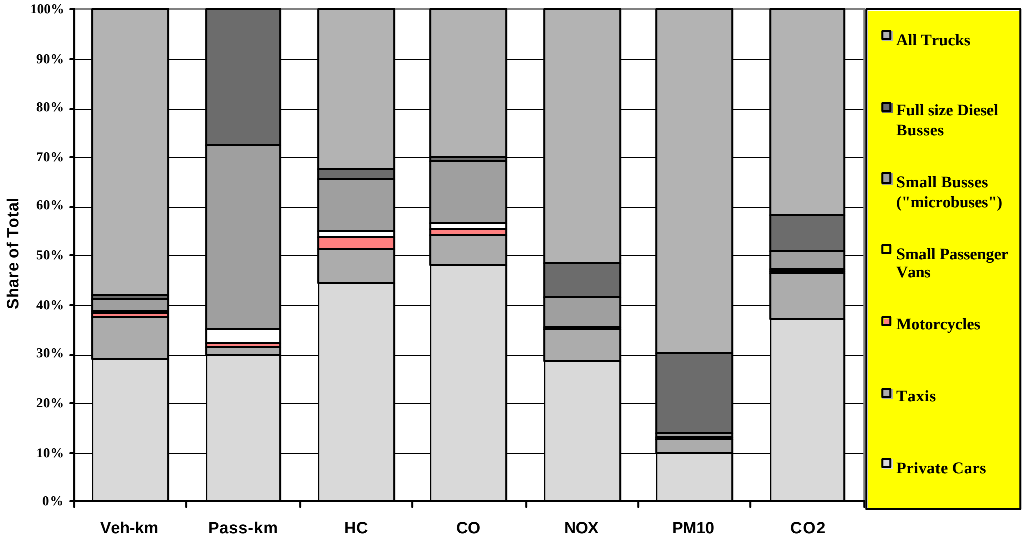
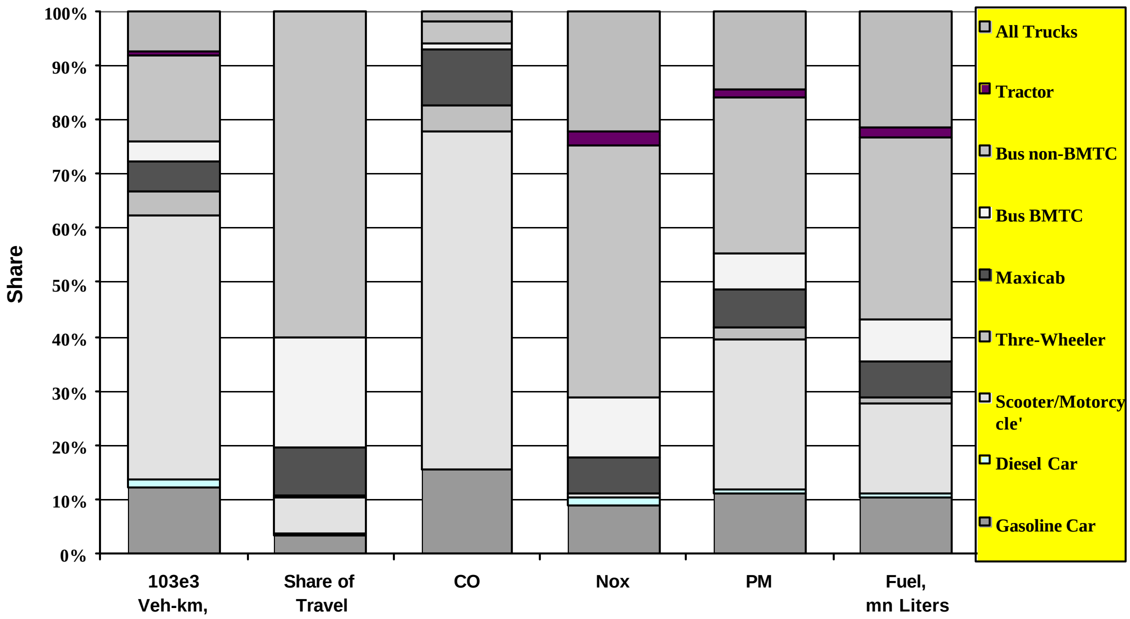


FIGURE 1 THE ASIF EQUATION IN TWO DIMENSIONS (CO_2 CASE)



Source: Mexico City Min of Environment; GEMIS Model.

FIGURE 2 Traffic, Travel, and Emissions Shares for Mexico City 1998



Source: Estimates from SIDA Report on Bangalore, Dec. 2000.

FIGURE 3 Traffic, Travel, and Emissions Shares for Bangalore, India, 2000

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