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TITLE: Transport and Environmental Management

SUMMARY: The objective of this paper is to highlight the environmental impacts associated with the provision of transport services necessary for the movement of passengers and goods. The management of the transport sector requires trade-offs to be made between three major goals of transport management - growth, equity and environmental sustainability. To place the discussion on ways of reducing the environmental impacts of transport activity in context, we review international trends in emissions of the major noxious air pollutants, and then take a close look at policy instruments which might contribute to reducing the impact that transport services have on the quality of the environment.

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Introduction

The community views transport in the modern era with mixed feelings. It provides the technological means to facilitate movement of passengers and goods, but it also is at the centre of the growing concern about environmental degradation in the form of air pollution, global warming, noise, and safety. Combined with traffic congestion in major conurbations - at the ports, at the airports, and on the roads, the transport sector has been cited as a major contributor to the ills of twentieth century society. Roads in particular, which provide the infrastructure for moving cars and trucks, have come under increasing criticism on environmental grounds. The question has been raised whether they are the servant of technology rather than whether they offer a positive opportunity to mould the environment.

Transport systems provide the mechanistic infrastructure used to facilitate movement; they also have a broader and socially valuable role in contributing to the economic, social and environmental fabric of civilisation. What would a nation look like and how would it function in the absence of streets and roads, airports and ports? Transport systems today are key elements in the global economic system, components in a society's amenity infrastructure, and settings of mounting economic environmental and social challenge.

The emphasis on outcomes (eg accessibility, clean air, safety) rather than means (eg cars, buses, trains, trucks, planes, ships) is more important today than ever before, since the traditional transport mode emphasis fails to accommodate institutionally the widening set of ways of 'moving' information and people's contributions to a nation's activity. Setting constraints on particular forms of transport to achieve desirable outcomes must be evaluated within the broader set of ways to satisfy opportunities offered by 'high tech' and 'high touch' industries in contrast to a priori beliefs being imposed that only improvements in particular modes of transport will 'solve' the ills of society.

Community concern and trade-offs

Many of the environmental problems that are both real and sensitive community issues, stem from the use of transport infrastructure by passenger and freight vehicles. Automobiles, aeroplanes and trucks are major sources of local pollutants, such as lead, carbon monoxide and noise. Traffic congestion exacerbates these problems, and also imposes direct economic and health costs on users and non-users in the form of wasted time and money, stress, and other illnesses. Transport systems also make a significant contribution to global warming through emissions of carbon dioxide and other greenhouse gases.

As the observed level of wealth in society increases and the demand for transport use increases, society faces real and special challenges to contain and reverse the trends in the wide range of negative impacts of greater mobility. Communities are not expressing blanket concern about transport per se; rather they are concerned about specific issues (principally freeways, toll roads, and the location of seaports and airports) and about the 'failure' of government to do something about the harmful outcomes from these specific investments. Governments however have the difficult trade-off between what they know are appropriate actions to help stem the desire for mobility (especially by a range of pricing instruments); and yet politically they lack the will to execute such policies. The emphasis on physical incentives/disincentives to achieve change relative to financial opportunities continues to be a major constraint on containing the environmental costs of transport systems.

Despite the concerns about adverse environmental effects, it cannot be overlooked that there are however many positive features of transport. The challenge is to manage the benefits of transportation better so that the broad set of environmental impacts are reduced to acceptable levels while ensuring acceptable outcomes in terms of economic performance and equity. Civic pride embellished in the design of transport systems must be given a centre stage in the deliberations.

Emphasis of the paper

Transportation must be evaluated within a broad set of transport management goals — growth, equity and environment, paying attention to the impact of incentive and disincentive based policy instruments with respect to topical evaluative criteria such air quality, traffic noise, traffic congestion, global warming, and accidents. The paper emphasises key environmental issues by concentrating on four performance criteria linked with the environment: *air pollution, global warming, energy consumption, and traffic congestion;* however we recognise the importance of water pollution with a case study in the maritime sector. Additional case studies on urban passenger transport and airports emphasise greenhouse gas emissions and air quality.

A major objective is to *illustrate* the debate through a set of reasoned arguments based on better/best practice information, transmitted in a readable form. Historical and contemporary evidence can assist provided it has been properly interpreted. If readers reconsider their own knowledge base and interpretations of the debate on the role of transportation to a nation, then the paper has achieved its purpose. The distinction between rationality and advocacy often is cited as a distinguishing attribute of alternative views on the role of transportation; however rational debate needs advocates.

Opportunities for Environmental Management - An Integrating Framework for Planning Transport Systems

We know a great deal about the nations of the next 35 years because they are essentially the nations of the present. Much of what we see and are likely to see in the future is driven by inherited geography, topography, and climate; and by the highly specialised economic and political functions that they have acquired. Transport facilities are intertwined with the culture and character of nations. In addition however the utilitarian role must be fulfilled. Aesthetically pleasing designs of transport systems are as much of a challenge to a diversifying culture which is also seeking solutions to its ever-growing desires for better accessibility, lifestyle and environmental sustainability.

The urban area is a major focus of environmental management and it illustrates the potential to pursue environmental management through and integrating framework. Typical of many recent empirical simulations studies, Roy *et al*. (1995) simulated the relationships between urban residential density, job decentralisation and transport energy consumption when new housing is added as outward urban expansion or infill (redevelopment) within an existing urban area. They find for large Australia cities that strong infill can produce energy savings in commuting of over 17% compared with the best sprawl scenarios, so long as the infill policies are accompanied by significant improvements to the level of service in public transport. However, the degree of infill required would take many years to occur, especially given that much of the housing stock has been constructed during the last 40 years and is generally in good condition. Furthermore, the energy advantage (which is also a greenhouse advantage given that greenhouse gas emission changes are almost directly proportional to energy consumed) of infill shrinks to 2-3% when workplace location choice occurs in the nearest sub-centre.

Roy et al (1995) conclude that transport demand management policies and matching jobs to disperse sub-centres in residential areas will have a greater impact in the next 10-20 years in reducing greenhouse gases than will infill policies (which could take anywhere from 40 to 100 years to have a noticeable impact). They also suggest that if these sub-centres contain ancillary services, as well as public transport stops and other public transport nodes such as stops for circumferential express buses, market forces will automatically increase housing densities in areas surrounding these sub-centres, yielding natural equilibrium levels of infill without the need for intrusive land-use control. This is the basis of the urban village idea. Studies in Adelaide have shown that urban housing consolidation and infill does not result in significant increases in population density; its role has been, at best, to arrest the trend towards lower population density in the inner suburban areas.

The opportunity for transit corridor retrofit is also real. Travel densities which support public transport can be produced from low density residential activity provided we allow for a wider range of more flexible forms of public transport such as hail-n-ride bus services using both mini-buses and conventional sized buses. Limiting public transport to very rigid traditional forms of transport such as rail and scheduled route bus services is not helping the rejuvenation potential of public transport as an environmentally appealing alternative to the automobile.

Other considerations affecting location choice and thus commuting times such as high job turnover, high residential relocation costs, and employment heterogeneity in multi-worker households have been suggested by Small and Song (1992) as reasons why households seek accessibility to an array of possible future jobs rather than just to their current employment. Wachs *et al*. (1993) track the differences over 6 years between home and work location among 30,000 employees of a large health care provider in Southern California. They found that work trip length had in general not grown over the six years, but the growth of the workforce had contributed more to the growth in local traffic congestion than had a lengthening of the work trip over time. This implies that the strategies for reducing vehicle kilometres should reconsider the predominant interest in commuting activity and give more emphasis to non-commuting travel as vehicle kilometres increase.

Securing higher residential densities regardless of distance from the core of an urban area appears on balance to reduce automobile kilometres travelled, but only if accompanied by travel pricing policies designed to make the car less attractive and complementary improvements in public transport. The increase in density near rail stations and bus routes provided it is combined with road pricing has been recognised for many years — the constraint is the political will to implement serious road pricing. Increasingly urban and regional simulation studies are finding that a comparison between dispersed-growth and contained-growth scenarios finds no clear winning scenario in terms of emissions. Concentration of travel in the centres leaves the peripheral areas less congested and therefore people travel farther in these areas.

The anthropological invariance view of travel behaviour is very appealing. When combined with the residential density effect (and pricing of automobile use) we begin to see niche opportunities for public transport — train ***and*** *bus — throughout the urban area.*

Emerging directions

Out of a heritage evolves current trends and speculations as to which ones are likely to dominate the patterns of national evolution over the next 35 years and beyond. Projecting with insight and wisdom into the far future is risky business indeed — history has shown all too often the errors of prediction. The suggestions that some appealing infill policies will require 40 — 100 years to have a noticeable impact may disappoint some and encourage others to reject the ability of public transport (as a beneficiary of infill) to assist the process of desirable change — maybe the 'solution' is to redefine the period of time in the future that the current generation should be responsible for and see the next 100 years as a candidate. Questions on the agenda of the 1990's such as global warming, local air pollution, energy consumption levels, 'sprawling' cities and loss of amenity may well be handled best by technologies which some people currently criticise, some even regard them even as inimical to society, such as automobiles and roads, in favour of technologies such as railways which have been described by some road advocates as:

'... a technology belonging to the nineteenth century [which] are about as efficient when compared to roads as waterways and canals ..... are when compared to railways. But they enjoy a special place in the affections of many otherwise sensible individuals'. (Ross Swan, Editorial in World Highways, April 1995,7).

Two major international trends related to the performance criteria of interest need to be set out. The ***first trend*** is the continuing rise in demand for transport services. Reductions in trade barriers and the globalisation of business have led to record levels of international trade and the pace of this growth is unlikely to abate in the next two decades. This generates increasing flows of goods and business people and coupled with a booming business in international tourism, shipping operators, seaports, airlines and airports are planning for expansion. However, we draw particular attention to the trends in ownership and usage of automobiles.

For example, between 1970-71 and 1989-90, total passenger vehicle registrations in Australia grew by an average of 3.5% per annum (a low of 1.25% in 1985-86 and a high of 5.6% in 1972-73), equivalent to 0.39 vehicles per head in 1970-71 and 0.44 vehicles per head in 1988-89. This trend is likely to continue until automobile ownership levels off when it approaches 0.6-0.8 personal vehicle per adult, as is occurring in the USA. The increase in ownership by females is most noticeable. Europe is witnessing a similar trend. Korea has witnessed a 25% annual increase in car ownership since 1982, growing from 1 million to 8 million vehicles in a population in 1995 of 70 million people. In the last 10 years, the number of passenger vehicles in China has increased by an average of 15% per annum (and rising to as high as 30% per annum in developed coastal regions). There are currently 9.93 million cars and 30 million Chinese people licensed to drive a car. As many societies approach a value of 0.8 vehicles per head (assuming 20% non-adults), it is likely that per-capita use will also level off given the strong evidence that distance travelled per passenger vehicle has shown remarkably little variability over time. The growth in recent years in the leasing of automobiles in the rental car industry to a growing market of short-term visitors to cities together with the growing use of taxis adds further automobile traffic to the system.

Since 1971, average annual kilometres per passenger vehicle in many countries have varied between 10,000 and 16,000. Total time spent travelling per person also has shown remarkable regularities across countries and time periods (confirming the presence of a constant travel time budget). As improvements in transport infrastructure and service levels occur, households and firms relocate to take advantage of other benefits of location while preserving the mean and variance of travel times throughout the urban area (Marchetti 1992). Any future improvements in road infrastructure which increase average speeds tend to increase annual distance travelled without affecting travel times in any noticeable way.

The ***second trend*** is the very noticeable reduction in total noxious air-pollutant emissions in the western world but a worrisome prospects for increases in greenhouse gas emissions and for all emissions in emerging economies

Stringent new requirements for emissions of hydrocarbons, carbon monoxide, and nitrogen oxides from new automobiles (and trucks) have been introduced in many countries. Energy consumption per vehicle kilometre travelled is declining in western economies although increases in the growth of automobiles and total vehicle kilometres results in a net increase averaging 3.36% per annum. Thus the absolute reductions in emissions are even more impressive when we see the growth in vehicle use. The benefit of emission control legislation is evident. Disturbingly, however, efforts in countries such as Australia and the USA amount to very little internationally when we see the positive trend worldwide for carbon monoxide and hydrocarbon emissions disappearing in about 10 years time due to the projected growth in countries where emission controls are minimal (Table 1).

Table 1: Global Trends in Motor Vehicle Emissions

Carbon Monoxide (tons/year)				
Year	**Car**	**Light Trucks**	**Motorcycles**	**Heavy Trucks**
1990	223,357,376	1,260,248	8,168,139	7,793,019
1995	217,043,366	1,410,969	9,209,773	8,301,436
2000	183,131,401	1,623,464	10,464,134	9,374,474
2010	97,559,141	2,077,267	14,166,965	12,214,989

Hydrocarbons (tons/year)				
	Car	**Light Trucks**	**Motorcycles**	**Heavy Trucks**
1990	30,025,462	506,570	5,568,461	1,818,987
1995	26,309,692	529,987	6,387,750	1,830,407
2000	23,314,293	607,874	7,075,987	2,038,046
2010	22,084,536	798,924	8,227,297	2,637,515

Nitrogen Oxides (ton/year)				
	Car	**Light Trucks**	**Motorcycles**	**Heavy Trucks**
1990	11,049,831	1,995,856	481,970	14,654,156
1995	10,651,242	2,205,343	550,760	13,459,297
2000	8,387,873	2,517,257	619,217	15,054,203
2010	5,996,606	3,113,332	782,274	18,752,930

Carbon Dioxide (tons/year)				
	Car	**Light Trucks**	**Motorcycles**	**Heavy Trucks**
1990	2,140,563,394	648,810,244	115,235,655	1,095,306,335
1995	2,326,778,635	714,188,146	131,007,340	1,272,857,434
2000	2,287,475,047	764,561,988	147,578,254	1,468,158,497
2010	2,588,738,693	802,074,961	190,301,058	1,934,317,592

Source: Walsh (1993)

Notes: PM-10 = particulate matter, CO2 = carbon dioxide, CO = carbon monoxide, VOCs = volatile organic compounds, NOx = nitrogen oxides. USA = all highway vehic*les, Australia* = *passenger cars*. *Sources:* USA = National Air Quality and Emissions Trend Report 1993, Office of Air Quality Planning and Standards, EPA, October 1994. Australia — Greenhouse Gas Emissions from Australian Transport, BTCE Report 88.

This contrasts with the continuing increase in greenhouse gas emissions, primarily CO_2. More than three-quarters of the carbon dioxide emitted from all transport sources in Australia and the USA comes from automobile and truck fuel (Table 2). Changes in CO_2 emissions is highly correlated with changes in automobile fuel efficiency and vehicle use, strongly hinting at the major benefits available from improvements in the fuel efficiency of automobiles and reduction in vehicle use. Dobes (1995) has compared greenhouse gas emissions in Australia in 1900 and the year 2000 and concludes that

'Within the limits of long-term historical comparisons and availability of data, it may be concluded that use of the internal combustion engine itself has not contributed disproportionately to greenhouse gas emissions in the transport sector. The equally qualified corollary is that an economy of size similar to that of today would not have generated a

significantly lower quantity of greenhouse gases had the motor car not replaced animals and steam from 1900' (Dobes, 1995, page 19).

The automobile is the dominating form of motorised transport in terms of the major emissions. For example in Australia (Table 2a) we see that 78.9% of all carbon dioxide, 93.3% of all carbon monoxide ('smog), 65% of nitrogen oxides and 90.3% of NMVOC's in the transport sector is produced by cars and trucks. Importantly, less than one-quarter of all carbon dioxide emitted derives from the transport sector compared to nearly three-quarters of carbon monoxide. In OECD Europe (OECD 1991), in 1991 the estimate of transport's share of nitrogen oxide, carbon monoxide and carbon dioxide is 60% (49-76% across countries), 78% (71-86%) and 21% respectively. Similar findings for carbon monoxide and nitrogen oxide exist in the USA (Table 2b) although the VOC contributions are much higher as a percentage of all sources of VOC.

Table 2. Estimated Emission Levels by Transport Mode and Transport Proportion of Total Emissions, 1992-93. NMVOC = non-methane volatile organic compounds

a. Australia. Source: BTCE Report 88, 1995 ('000 tonnes)

Trace gas	Road	Rail	Air	Sea	Total Transport	Total emissions energy use	Transport as a % of total emissions
Carbon dioxide	53815	1602	8618	4132	68167	288353	23.6
Carbon monoxide	3073	14	80	124	3291	4470	73.6
Nitrogen oxides	307	40	33	91	473	1276	37.1
NMVOC's	402	3	3	38	445	628	70.9

b. USA. Source: Davis, 1995 (millions of short tons)

Trace gas	Road	Rail	Air	Other off highway	Sea	Total Transport	Transport as a % of total emissions
Carbon dioxide	311.3	9.1 (est.)	54.3	in road	21.5 (est.)	396.2	31.8
Carbon monoxide	59.99	0.12	1.02	12.88	0.06	75.26	77.4
Nitrogen oxides	7.44	0.95	0.15	2.04	0.18	10.42	44.5
NMVOC's	6.09	0.04	0.20	1.91	0.04	8.30	35.6
PM-10	0.20	0.05	0.05	0.27	0.03	0.59	1.3
Sulfur dioxide	0.44	0.07	0.01	0	0.2	0.72	3.3

If we take a closer look at the growth in cars, light-duty trucks (LDT's), heavy-duty trucks (HDT's) and motorcycles (MC's) throughout the world (Table 3) as a good indicator of the potential increase in air pollutants without efforts to curb such growth, (the last type of road vehicle being dominating in many fast developing economies), some interesting results emerge. Economies in the rapidly industrialising Asian-Pacific have annual vehicle growth rates at least 50% higher than the USA and Europe, signalling the challenges the world faces with containing the growth of the automobile and the truck. The CO2 emissions per capita for selected countries (Table 4) show the much higher rates for wealthier nations and signal the direction that the emerging economies will be heading without appropriate actions to stem the massive increases in carbon dioxide. Most emerging and relatively poorer economies currently exhibit rates per capita less than 1 tonne in contrast to an average of 3.34 for OECD countries. The challenges facing these countries to reduce emissions are huge; and hopefully will benefit from the evidence on policy instruments implemented in the mature economies such as emissions controls on automobiles and trucks. The Australian evidence (Figure 2) is very encouraging.

Table 3. Annual road vehicle growth rates

	USA	EC	EFTA	EE	OECD Pacific	RICA	RICB	ROW
1989-95								
Cars	1.5	2.5	2.0	3.0	4.0	7.0	7.0	3.5
LDT	2.0	2.5	2.0	3.0	4.0	7.0	7.0	3.5
MC	0.0	0.0	0.0	3.0	-1.0	7.0	7.0	3.5
HDT	2.0	2.5	2.5	3.5	3.0	5.0	5.0	3.5
1995-00								
Cars	1.5	2.5	2.0	3.5	3.0	6.0	6.0	2.5
LDT	2.0	2.5	2.0	3.5	3.0	6.0	6.0	2.5
MC	0.0	0.0	0.0	3.0	-1.0	5.0	5.0	3.5
HDT	2.0	2.5	2.5	3.5	2.5	4.0	4.0	3.5
2000-10								
Cars	1.5	2.0	2.0	3.5	2.0	5.0	5.0	3.0
LDT	1.5	2.0	2.0	3.0	2.0	5.0	5.0	3.0
MC	0.0	0.0	0.0	2.0	0.0	5.0	5.0	3.0
HDT	2.0	2.5	2.0	3.0	2.0	4.0	4.0	3.5

Source: Walsh (1993). EC = European Community, EFTA = European Free Trade Association, EE = Eastern Europe and the republics of the former USSR, OECD Pacific = OECD countries of the Pacific including Japan, Australia and New Zealand, RICA =rapidly industrialising countries that have take steps to introduce state-of-the-art pollution control on cars (Brazil, Chile, Hong Kong, Mexico, Singapore, South Korea and Taiwan), RICB = rapidly industrialising countries with minimal pollution control programs (Indonesia, Malaysia, Philippines, Thailand), ROW= rest of the world including much of Africa, Asia and Latin America.

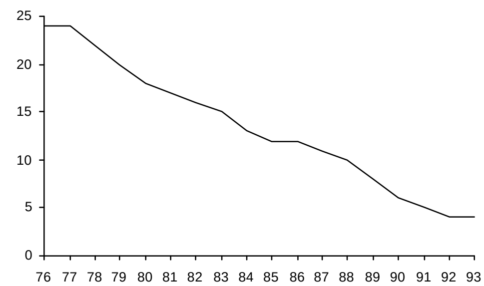
Table 4. Carbon Dioxide Emissions for Selected Countries, 1990

Country	Population (millions)	Emissions (m tonnes)	Transport Emissions per capita (tonnes)	Contribution of transport to emissions (%)
Australia	17.1	288.4	3.87	23.2
Belgium	10.0	122.1	3.64	29.7
Bulgaria	8.8	81.5	1.34	14.5
Canada	26.5	452.7	5.46	32.0
Denmark	5.1	55.5	2.92	27.0
Finland	5.0	60.6	3.01	24.8
France	56.4	350.5	2.07	33.3
Hungary	10.6	75.2	0.99	13.8
India	850	563	0.08	11.7
Indonesia	178	118.2	0.17	26.0
Italy	57.7	371.8	1.76	27.3
Japan	124	1074.7	1.73	19.9
New Zealand	3.4	26.2	3.02	39.3
Philippines	61.5	38.4	0.22	35.2
Poland	38.2	473.5	0.91	7.3
Sweden	8.6	56.3	2.84	43.2
Switzerland	6.7	45.9	2.52	36.8
Turkey	56.1	182.5	0.39	11.8
United Kingdom	57.4	564	2.10	21.4
United States	250	5224	6.11	29.2

OECD	839	10,300	3.34	27.2
World	5,292	22,700	0.83ß	19.3

Source: BTCE (1995)

a)



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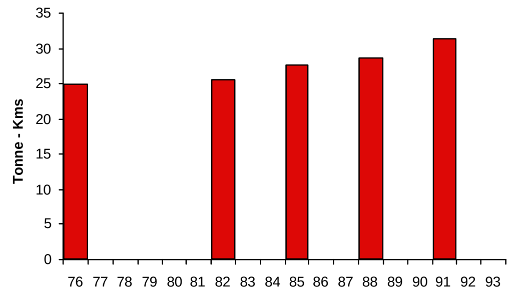

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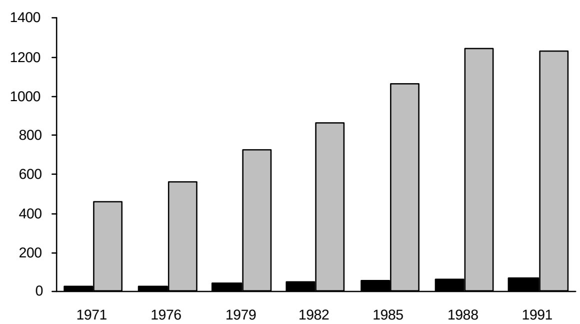

Source: Australasian Transport News (1994)

Figure 2: a) Truck emissions: nitrous oxides (gm/kWh) b) Truck fuel efficiency (tonne kms per litre c) Improvements in truck productivity (thousands of tonne kms per yr per vehicle

Managing the environmental effects of transport

The impacts of automobiles and trucks on air quality, on peace and quiet, on scenic value and on the ecology concern many in the community. An extreme view is that these modes impose a net cost to society and a very small minority of people go so far as to say that as to be willing to reverse the longstanding and pronounced shift toward personal mobility represented by automobile ownership. However, there is little if any economic analysis that could support draconian measures to reduce the use of automobiles and trucks sufficient in order to 'solve' environmental problems (Small 1991). The desired responses would either have to be a switch to public transport and/or a reduction in travel. If we observe that only 8% of all urban passenger movements are by public transport in Australia, a very small switch away from the automobile of say 1 percentage point is a 10 percent increase in public transport patronage.

The degree of change for public transport systems would require substantial adjustment even with negligible reductions in car use.

Fortunately there are plentiful alternatives — technological and behavioural — that could greatly reduce the problems without having much effect on overall mobility. For example, the evidence that a small fraction of the cars is causing a disproportionately high fraction of air emissions suggests that a greater effort to improve the inspection and maintenance of the highly sophisticated pollution control devices on cars and trucks would probably greatly reduce this particular environmental impact. This may not satisfy the proponents of alternative means of movement such as public transport, yet it is clearly resolving their concern about a major adverse environmental impact of the automobile. The challenge for reducing greenhouse gas emissions remains however, although a recent study undertaken by the Institute of Transport Studies (unpublished) supports increasing controls on automobile technology, combined with pricing from the set of possibilities (increased fuel excise, carbon tax, congestion pricing, and parking pricing) and the promotion of alternative work practices.

Apogee Research (1994) has reviewed the literature on transport control measures (TCM's) to identify their effectiveness in reducing regional emissions. They conclude that pricing has the strongest impact on reducing emissions of mobile sources, with land use planning, telecommuting and compressed work weeks having high potential, although the evidence on the latter is currently speculative. TCM's such as high-occupancy vehicle (HOV) lanes, incident management, employer trip reduction, transit improvements, signal timing, area-wide ridesharing, park and ride parking facilities, bicycle/pedestrian facilities and buy-back of older cars have a very weak impact on mobile source emissions. Many of these poorly performing TCM's have been recognised for some time as being cosmetic in impact and not suitable surrogates for real impacting policies. The recent increase in off-street quality parking at key suburban rail stations has encouraged switching of modal access from bus to car, with negligible impact on linehaul modal switching. Buy-back of older vehicles, a policy being promoted by some governments, forces purchase of younger vehicles. These vehicles are more fuel efficient, cleaner and have lower operating costs, tending to encourage increases in vehicle kilometres in line with the idea of a constant expenditure budget of transport (approximately 16% of gross expenditure when automobile capital is included).

Cambridge Systematics (1994) evaluated the effects of a large number of land use and TDM strategies on commuting behaviour in the Los Angeles Metropolitan Area. These strategies were classified as financial incentives (which included transit subsidy, employee parking subsidy, carpool/vanpool subsidy), flexible work schedules (including flexible work hours, telecommuting program, compressed work week program), and assistance programs (including employer-based matching programs, guaranteed ride home). They concluded that if the aim is to reduce the drive-alone modal share then:

'A successful travel demand management strategy should be built around a core of financial incentives, regardless of the land use and urban design characteristics of a particular site' (Cambridge Systematics 1994, 4-1).

A recent assessment of the health costs of road vehicle emissions in Australia suggests that the air quality of Australian cities tends to be relatively unpolluted compared with cities in the United States and Europe; and that there is currently no evidence that fine particles are above safe levels. Air quality monitoring data based on sites around Australia demonstrate that concentrations of most air pollutants are now at 'acceptable levels', for which the evidence indicates no health risk. The pollutants No_x, CO and SO_2 do not currently, and are not expected within the foreseeable future, to exceed acceptable levels. Atmospheric lead levels have been excessive, but with the reduction in use of leaded fuel, future atmospheric lead concentrations for Melbourne are estimated to remain below the existing acceptable level of 1.5 ug/m^3 as well as the proposed tighter level of 1.0 ug/m^3. Ozone at levels above the current one-hour standard of 0.12 ppm which is the threshold for definite health risk, occurred in Sydney and Melbourne an average of 3 days over the period 1989-1993. In Victoria this rose to 17 days when ozone exceeded the 0.08 ppm one-hour standard (the range of uncertain health risk). Recent evidence in the USA reported at a Conference on the full social costs and benefits of transport suggest that within 10 km of road, the nitrogen oxides 'eat' the ozone and hence eliminate a major health risk attributable to automobile use. The chemical with the greatest potential risk is PM10, referred to as 'road dust' or 'fugitive dust', There is however great uncertainty as to its real health risk (McCubbin and Deluchi 1995) and the extent to which the contribution by the automobile is confounded by wind erosion, salt spray, power plants and other sources that produce particulates (even the common house dust).

Road Traffic congestion and pricing - a missing building block

Traffic congestion is not a new phenomenon. Julius Caesar in 45 BC declared the centre of Rome off limits between 6 am and 4 pm to all vehicles except those of officials, priests, high-ranking citizens and visitors (Dobes 1995, 1).

Road traffic congestion, more than any other single item, provides a daily reminder to all of the inefficiencies in the current transport system. Traffic congestion adds almost billions of dollars to road travel costs. Calls for improved public transport are a common response; calls for congestion pricing are rare (although increasingly being heard), and calls for discouraging road construction as a contribution to reducing traffic congestion through encouraging the use of public transport and assisting the move towards a more compact urban area are on the increase. It is true that urban mobility in many cities throughout the world is being ‘strangled’ by the large amounts of time unnecessarily wasted in traffic jams, draining the urban economy. It has also been said that 'congestion is the sign of a healthy urban economy — what is lacking however is the presence of organised congestion' . Congestion pricing does not eliminate congestion - rather it ensures that the level is the outcome of efficient prices. The supply-side response of more roads is not an efficient or sensible ‘solution’ in the presence of distortionary pricing which is way out of line with the full set of externalities which arise from the effects of such pricing. This does not preclude the development of strategic road links built for reasons other than congestion mitigation, such as links to major transport hubs like seaports and airports.

We must continue to make the case for appropriate charges (as distinct from taxes) which reflect the real cost of resources consumed in travel. Congestion pricing is arguably the only policy that will make a noticeable difference in peak congestion levels in the world’s most congested cities. Other policies can create real and substantial benefits (see below), but cannot do much to reduce the most severe congestion. There is so much latent demand for car travel at peak periods and during the shoulder periods that whatever capacity we can feasibly expect to build, or that can be freed up by enticing a few drivers off the road, will quickly become filled by people who are now being deterred only be congestion itself. This is a well documented empirical reality known as the ‘fundamental law of traffic congestion’ (Downs, 1962, 1992).

Neutze (1995) in commenting on the relationship between roads and urban patterns says:

‘ I believe that if you correctly price roads, you will increase the extent to which the investment will cause movement of employment to the outer parts of cities. If you price them correctly, the areas where the price will be high will be in the inner urban areas because that is where the road costs and land costs are high. Land is scarce, therefore it is expensive to provide roads just as to provide buildings in those areas. That will discourage the use of roads in urban areas and that is one of the reasons why, even with optimal investment, you will have and should have high levels of congestion in places where land prices are high’.

Implementation of congestion pricing involves recognition of the following issues:

- congestion pricing would cause some motorists to change their behaviour
- congestion pricing would result in a net benefit to society
- congestion pricing is technically feasible
- institutional issues are complex but can be resolved
- all income groups can come out ahead given an appropriate distribution of revenues
- some motorists will lose
- congestion pricing would reduce air pollution and save energy
- the political feasibility of congestion pricing is uncertain
- evaluation of early projects is crucial
- an incremental approach is appropriate

Efficient pricing however is a necessary but not sufficient condition for a socially desirable outcome. There must be a role for other policy instruments such as physical planning. The limits to pricing as a planning tool are vividly illustrated in a UK House of Commons Transport Committee hearing in which the expert witness, Goodwin (1995) said:

‘ ....there is the intriguing test of intuitive common sense. It is noticeable that there are some transport policies that nobody suggests should be determined by 'willingness-to-pay'. An example is the division of road space between vehicles and pedestrians. It would be possible to say that the relative width of sidewalk and carriageway should be determined by the amounts that pedestrians and vehicles are willing to contribute, or even more specifically that pedestrian-actuated traffic signals should require the insertion of a coin. The logic in one sense is similar to that of road pricing, but it does not command serous consideration. Nor does there exist (as far as I know) an underground of hard-line road prices biding their time until the moment is right to implement pedestrian charging with push-chair supplements and a penalty for elderly slow walker’

Efficient pricing signals and physical planning ordinances should be viewed as being as much potential complements as they are potential substitutes. The “dark green” end of the environmental spectrum has tended to treat physical planning (constraints) as an alternative, at least partially, to “failed” pricing. Pricing however differs from physical planning in one important aspect — it provides money. Under the new realism banner, eloquently documented by Goodwin et al. (1991), it is argued that the huge revenue sums raised from any change in road user prices should in part at least be allocated in a way which is consistent with the preferences of both society and transport users.

Allowing for both economic reasoning and political reality, the 'rule of three' is actively promoted in a number of countries. The road space initially released by congestion pricing can be used as follows: one-third reclaimed for environmental improvement, including pedestrian and non-transport uses, one-third used for extra traffic for which the reduction in congestion would be important. For example, use the revenue to favour buses, delivery trucks, emergency vehicles and disabled travellers. A final one-third would have the effect of reducing congestion delays for all remaining traffic. To maintain this benefit will require a combination of pricing and non-pricing instruments to offset the tendency for traffic growth to eliminate the achieved speed increase.

Urban Public transport

Opportunities to make better use of public transport exist in all urban areas. Some of these opportunities however involve a choice between bus-based and rail-based systems and a recognition that rail systems have the inherent advantage of a dedicated track, while bus systems offer greater flexibility and lower cost.

Roads are used by public transport; indeed they are arguably the most flexible form of infrastructure in accommodating mass public transport, and are capable of assisting public transport in adapting to changing levels of traffic density for relatively low cost. To be specific, buses can be interacted with roads in a low density mode (ie buses mixing with all other traffic); as demand for public transport increases buses can be given dedicated road space (possibly in the interim mixing with high occupancy automobiles and taxis). As traffic densities increase even more, buses can take on the characteristic of linked vehicles (which are called trains) and operate over sections of the infrastructure under a single control unit. The provision of opportunities to expand the role of buses and bus systems (or bus-trains) is greatly enhanced where freeway-level infrastructure is in place, since it is most likely to provide the required alignment essential for public transport to accommodate changing traffic densities. There must however be a cultural change within the planning community in recognising the important role of road infrastructure in public transport provision and to promote such capacity specialisation in the future. Mixing buses and cars however in high-occupancy vehicle (HOV) lanes is not a marketable strategy no matter how sensible it may be on other criteria. One would like to imagine in a world of institutional reform centred on outcomes that modal-planning is replaced with outcome-planning which allows for freeways to become busways and then railways at very high levels of traffic density.

This ability to efficiently and effectively accommodate flexible densities is not a trait of fixed-track rail systems simply because the latter cannot be used for other forms of transport (eg cars and trucks). A common track as offered by a road is the most efficient form of infrastructure technology for accommodating changing traffic densities. Combined with efficient pricing it will ensure that it is efficiently utilised and will not succumb to the indivisibility constraint of rail track.

To illustrate the value of bus systems with dedicated road infrastructure for the linehaul component of service, the Adelaide O-Bahn should be re-visited. Chapman (1992) undertook a post implementation social cost-benefit analysis of the economic impact of the O-Bahn system in Adelaide. Chapman concludes by saying that ".... Adelaide's O-Bahn Busway ... has been one of the relatively few public transport projects that can be considered to have in any way contributed to the economic welfare of the community. It has been extremely popular with commuters, initial ridership projections having been exceeded. Some very large travel time savings have been provided, and commuters clearly appreciate the combination of limited stops, high capacity, smooth ride and congestion free travel offered by a dedicated right-of-way, and the high frequency, flexibility and through service into suburban areas offered by a conventional bus system". Furthermore, Chapman says that "... in a city of Adelaide's size and urban density it has proven to be a much more effective and economic public transport service than conventional heavy or light rail systems. It was constructed at approximately half the cost of a comparable rail-based system and is one of the few public transport systems in this era of automobile dependency that has been able to attract (and retain) passengers" (page 99). Taking the general transit patronage decline and population growth in the corridor into account, the net overall impact of the Busway is a patronage level approximately 53% higher on a daily basis than otherwise would exist.

Managing the Environment Means Paying One's Transport Way

A number of studies throughout Europe, Canada and the USA have consistently shown that transport users generally do not pay enough user taxes and charges to cover their external costs. In a review of 5 major studies, Gomez-Ibanez (1995) concludes that public transport users do not pay their way largely because the fares they pay are not sufficient to cover the capital and operating costs, not because they generate significant amounts of pollution and other social costs. For automobile users, by contrast, government capital and operating expenses constitute only about 20% of total external costs. Among the external costs, parking accounts for about 20%, air pollution about 20%, accidents about 20% and energy security about 20%. These figures are approximations, but they do highlight where the externalities exist. Some of the international evidence is summarised in Table 5. It should be interpreted with great caution since our knowledge of costing many of the items is both immature and often subject to huge variations caused by the context in which transport services are provided. The higher estimates in the range for the USA are for urban peak trips. The Australian evidence for the automobile suggest that there is overpayment for automobile use, which might be queried for urban congestion contexts. The message is simple — there is much scope for correcting the (under) pricing of externalities via a mix of pricing and technological change to eliminates/reduce such external impacts. There is also a need for much more research into identifying the variation and sources of variation in each of the unit cost items.

Table 5: Estimates of external costs and subsidies for typical urban passenger trips

cents/passenger km (cents US, 1994)	**Germany Car**	**Germany Train**	**Aust Car**	**Aust Bus**	**Aust Train**	**USA Car**	**USA Bus**	**USA Train**
Government:								
Capital			1.64 (*)	10.5 (*)	13.9 (*)	0.25 -1.4	0.18-4.4	8.75
Operating and maintenance						0.0-2.2	27-33	19.0
Other govt (police, fire etc)						0.18-1.1	0.07-0.16	0.06
Subtotal			1.64	10.5	13.9	0.4-4.7	27.1-37.2	27.6
Societal:								
Congestion			2.8	.01	0.0	0.25-9.7	2.3	0.0
Air pollution	2.4	0.38	2.0	2.4	2.2	0.6-4.7	1-2.8	0.9-3.2
Noise pollution	0.24	0.06	0.9	0.2	1.0	0.06-0.5	0.03-0.3	0.13
Water pollution			0.1	0	0	0.06-7.5	0.06	
Solid waste						0..13	0.0	
Accidents	1.7	0.18	1.7	0.1	0	.88-2.1	.43-1.4	.38
Energy			0.8	0.1	0	0..44-3.2	0.56-1.8	0.25-.8
Parking			0.5	0	0	0.5-6.8		
Other						0.008-5.2	0.25	
Subtotal	4.25	.59	8.8	2.81	3.2	2.8-12	4.66-8.88	1.69-4.4
User payments:			16 (**)	8 (**)	7 (**)			
Fares, tolls						0.0	8.8-11.9	8.8
Taxes and charges	2.1					.4	0.0	0.0
Subtotal	2.2		16	8	7	0..44-1.3	8.8-11.9	8.8
Net Subsidy	*2.13*		*-5.56*	*4.81*	*10.1*	*2.8-14.5*	*23-34.1*	*41-23*

Source: Gomez-Ibanez (1995). Germany and Spain data are from the European Federation for Transport and the Environment; the USA data are from the World Resources Institute, the National Defence Council and Todd Litman (an independent Consultant). Australian Data is sourced from Austroads (1994a). (*) = sum of capital, operating and maintenance costs. (**) includes operations, ownership and fares.

Placing Transport in a Policy Context

The community should rightfully raise questions about suitable policy instruments and strategies designed to produce outcomes reflecting the goals of transport management which have high levels of positive impact in terms of the performance criteria which define success. There are many policy instruments available; too many to explicitly identify. What is useful is a tabular summary (Table 6) of the degree of impact of a select set of potential instruments in terms of the performance criteria selected as measures of success.

These policy instruments are representative of the broad types of actions worthy of consideration. The directional indication of impact reflects what we believe will be the likely degree of influence of a policy within a range of application which we believe might be introduced given realistic constraints such as politically feasibility and widespread community support. There is almost certainly to be disagreement on the impact because of the complex system-wide interaction, but that is accepted — the primary objective is to encourage debate.

Table 6. Summary of potential impact of policy instruments (within likely achievable range and likely behavioural responses over next 40 years)

Degree of impact on measure of success **blank = no or negligible effect, ? = unsure**	**Air Pollution**	**Global warming**	**Energy consumed**	**Traffic congestion**
Congestion pricing (Mix of Charges and Taxes)	+++	++	+++	+++
Increase Parking charges (CBD, regional centres)	+++	++	++	+++
Parking rationing/restrictions in CBD	++	+	+	++
Toll road charges (selective major routes)	+	?	?	+
Restrictive automobile access to CBD	++	++	++	++
Reduce sales tax on new autos — skew/eliminate	+?	+?	+?	
Increase vehicle registration charges (by age, weight, fuel)	+	+	+	
Limits on Company car provision and use	?	?	?	?
Limit maximum age of vehicles	+	+	+	
Carbon tax (linked to alternative fuels)	+++	+++	+++	+
Fuel excise by fuel type: increase/exemptions	+++	+++	+++	+
Tradeable permits	+	+	+	
Fee-based compulsory emissions checks	+++	++	++	
Price rebates/discounts on alt. fuelled vehs (end use impacts only)	+++	+++	+++	?
Govt purchase and scrap high emitters	++	+	+	
Alternative fuels — electric vehicles (end use impacts only)	+++	++	++	?
Alternative fuels — LPG , CNG, diesohol (end use impacts only)	++	++	++	?
Automobile engine/transmission technology improvements — conventional fuels	++++	++++	++++	
Automobile vehicle design (weight, drag)	++++	++++	++++	
Intelligent Transport Systems	?	?	?	++
Urban form and density (physical planning, dwelling mix):				
Legislative actions (zoning etc.)	+?	?	?	+
Compact cities with regional nodes	?	?	?	+
Work-Related Incentive Strategies:				
Ride sharing and employer incentives	+	+	+	
Telecommuting	+++	+++	+++	+++
Compressed work week (time use)	++	++	++	+++
Non-motorised options — bicycle, walk	+	+	+	
New public transport — light rail	+?	+?	+?	
New public transport — bus priority systems	++	++	++	
Public transport — park-n-ride/kiss-n-ride	?	?	?	?
Existing public transport — reduce fares				
Existing public transport — increase levels of service	+	+	+	+

Case Study: Urban Passenger Transport Policies and Impact on CO2 changes in Perth, West Australia, 1993-2003

Using a model system of the household sector developed for Perth, West Australia, we have evaluated the impact that four policy instruments might have over the period 1993-2003 in respect of carbon dioxide emissions and total end user cost. To understand how we identify the impact of a policy instrument, consider a fuel tax increase. The imposition of an increase in the tax on automobile fuel, via its impact on unit operating cost (c/vkm) has an immediate and direct influence on (i) the use of each vehicle for particular trips such as the commuter trip (i.e. mode choice, which includes both a switch to public transport and vehicle-substitution from within the household's vehicle park), (ii) a change in the timing of the commuter journey to reduce the increased costs associated with traffic congestion, and hence (iii) a change in the overall and non-commuting use of each automobile available to a household. It also directly affects the household's choice of types of automobiles from the set of conventional fuel, electric and alternative-fuel vehicles (the last two vehicle fuel types introduced in any year, under a reasonable expectation of availability). The indirect impacts include a change in residential location via the change in modal and spatial accessibility to work opportunities, and a change in the number of vehicles in a household (given the increased operating costs). Changes in residential location may further affect the total use of each automobile, as well as the mix of urban (commuting and non-commuting) and non-urban kilometres. The adjustment in commuter travel may also affect non-commuting car use if a vehicle previously used for commuting is released for use by another non-working member of the household. Some adjustment in the loss rate of automobiles will also occur.

The adjustments in vehicle, travel and location choices at the household level translate at the aggregate level into a new set of equilibrium levels for traffic congestion (broadly measured by the ratio of travel time to distance travelled), residential densities, total kilometres of travel by automobiles and various forms of public transport, fuel consumed and greenhouse gas emissions. Table 7 summarises the 4 illustrative policy instrument changes to be evaluated *separately*. All changes commence in 1996. The cost items are calculated in constant dollars ($93), but are converted into present values at a real discount rate of 8% per annum for all dollar-based.

Table 7. Illustrative Policy Instrument Evaluative Strategies

Policy Instrument	Acronym For Table 8	Units	Range of Assessment
Sales tax on new automobiles	Stax	% of wholesale price	10, 20, 30
Increase in fuel excise on fossil fuels	fex	cents/litre	60, 80, 100
Change in fuel efficiency (litres/100km)	Feff	% decrease	- 5, - 15, - 25
Existing public transport fares	PT fares	% change	- 25, -15, +20

* The conversion of a carbon tax from cents/kg to cents/litre is as follows: for petrol = 5,10,15,20 and 25 cents/kg is equivalent to 3.1, 6.3, 9.2, 12.3, and 15.4 cents per litre in $94 assuming a retail price of 70 cents a litre. The equivalent diesel prices are 3.7, 7.3, 11.0, 14.7 and 18.5 cent per litre.

Table 8. The illustrative impact of Various Policy Instruments in Perth, West Australia, on CO2 and End user cost, 1993-2003

FEx c/litre	Fex CO2 %change	TEUCpv $ pa	Stax %	CO2 %change	TEUCpv
60	-5.46	758m	10	3.94	-310m
80	-14	1.37bn	20	3.69	33m
100	-21.6	1.82bn	30	3.52	387m
FEff %	**CO2 %change**	**TEUCpv**	**PT fares**	**CO2 %change**	**TEUCpv**
5	2.66	-100m	25% inc	4.1	115m
15	.41	-310m	25% dec	3.45	-140m
25	-5.45	-540m	50% dec	3.06	-340m

Within the ranges evaluated, improvements in vehicle fuel efficiency have the greatest impact on reducing CO_2, as well as reducing the cost to the end user. In contrast a fuel excise also reduces CO_2 but has the effect of increasing the cost to the end user. The sales tax policy has been evaluated at 10%, a level lower than the current 20% for the majority of new passenger vehicles (excluding luxury vehicles) as well as at a higher level (30%). We see that CO_2 improves relative to the 'do nothing' effect in each year up to 2003, but it does not better the 1993 level. The cost to the end user decreases for the lower sales tax, but increases at a disproportionately higher rate for the larger sales tax. A public transport fare decrease of 50% has a small but noticeable impact on changes in CO_2, decreasing it by 3.06%, while reducing total end user cost by $340m (in $93). There is a consequent 2.65% reduction in the car's modal share for commuting and a reduction in total vkm of less than 1 percent overall.

In evaluating these policies one has to consider some of the broader implications. For example, the fuel efficiency policy adds traffic to the road system by encouraging an increase in vehicle kilometres travelled. While this may be attractive for individuals with latent travel demand, it nevertheless may be undesirable from an environmental point of view. Possibly a congestion charge might accompany this policy.

Emissions from Commercial Aircraft - A Challenge in International Management

> *Somewhere on earth, every second of every day and night, 45 commercial aircraft commence their takeoff runs. ... There are freeways in the sky, and crowding them are machines with un-equalled rates of converting kerosene into persistent pollutants.* Thomas (1996)

The focus of this Paper so far has been on the management of transport in an urban context but there are significant challenges in other parts of the transport system. For example, the growth in international airline traffic has been spectacular, particularly since the introduction of wide-bodied aircraft into commercial airline fleets since the 1970's and as competition and productivity improvements have kept the real cost of airline travel falling. The combination of low fares and higher incomes has resulted in a world airline market in 1994 equivalent to one billion passengers a year travelling an average of 2,049 kilometres (McDonnell Douglas 1995). In terms of the triad of growth, equity and environment objectives, it is necessary to question whether there has been an undue emphasis on the growth dimension. However, this has to be put into perspective. By far the greatest amount of travel is undertaken using some surface transport mode and aircraft account for no more than 3 percent of all Co_2 emissions and probably less than this for No_x emissions according to the Intergovernmental Panel on Climate Change (a part of the World Meteorological Organisation) see Table 2. Nevertheless, commercial aviation gives rise to problematic issues of management. There is scope to improve air quality at the local airport level, but problems of aircraft emissions in the upper atmosphere and the issues of aircraft design require a multilateral approach to management and policy. The example of aviation illustrates some challenges of a different kind to those discussed previously.

At the regional level, the issue of air quality can be traced directly to particular airports. However, large airports are located near major urban populations and their contribution to total emissions is very minor. For example emissions from aircraft fell below 5 percent of the region's total beyond a distance of 3 kilometres from Schiphol Airport (Amsterdam). Once moving beyond the airport boundary, aircraft movements make only a small impact on total emissions (Kinhill 1991a). At the airport, of course, aircraft generate the largest share of all types of emissions in taking off and landing, during taxiing, during maintenance, and in refuelling. However, an airport is the hub of a considerable amount of activity with arriving and departing passengers, with cargo movements, and with a sizeable workforce. All of this results in additional emissions from motor vehicles. Other contributions to emissions can arise if aircraft dump fuel in flight and when fire safety training exercises are conducted.

Collectively, the airport-related emissions include hydrocarbons, nitrogen oxides, carbon monoxide, suspended particulate matter, sulphur dioxide, ozone and lead. The problem of devising policy responses at the regional level is to identify management measures that will result in changes in the behaviour of airlines, maintenance operations, and individuals as they travel to and from the airport. Taking the passengers first, it needs to be understood that airport planners need to be concerned with issues of ground transport access. A consequence of planning major airports without provision for public transport systems is a reliance on the motor vehicle. The contribution of this vehicular traffic to total airport-related emissions of carbon monoxide and NO_x is non-trivial. Also, there is scope for the airport operator and the urban planner to influence this component of the emissions. Policy responses range from the construction of heavy or light rail access, improved bus services, increases in parking charges for motor vehicles, and other traffic calming measures in the region of the airport.

On the airport itself, it is possible to take actions that can achieve results. For instance, ancillary vehicles that operate on the airport itself can be converted to alternative sources of energy that emit fewer emissions. Also, power can be supplied by terminal operators to parked aircraft to maintain air conditioning and services. Aircraft engines are designed to be at their most efficient when cruising; taxiing is the least efficient phase of a flight and it goes without saying that airport operators can play a role in the reduction of hydrocarbons, carbon monoxide and nitrogen oxides emitted on their premises. For example, it has been found that the construction of a parallel runway (rather than to have runways crossing) can reduce taxiing and queuing time (Transport Canada 1990).

It is during the take-off and climb-out that an aircraft generates most of its nitrogen oxides. Airport managers might take the view that there is little scope for them to exert influence on the airlines, or for the airlines even, to reduce this impact. The take-off phase leads us to consider the more difficult issue about emissions once aircraft are en route. As aircraft climb through the troposphere, that part of the atmosphere that extends up to 9 kilometres from the earth’s surface, the evidence is that their emissions contribute to ozone production. Turboprop aircraft stay in this region, but jet aircraft tend to cruise in the tropopause, the next layer of atmosphere up to 15 kilometres above the surface (depending on the geography and season). Some jet aircraft do reach into the stratosphere, but this is the operating domain of supersonic aircraft.

More research is needed into the effects of emissions, but it does appear that pollutants stay longer in the upper atmosphere. Nitrogen oxides released in the upper atmosphere are said to have 30 times more impact on global warming than similar emissions at ground level. In the upper atmosphere, the emissions result in the depletion of ozone; one estimate is that aviation contributes more than 10 percent of global greenhouse gas warming (Thomas 1996).

Airframe manufacturers and engine producers are conscious of the fragile financial state of the world’s airlines and there are ways being tested to reduce fuel consumption with consequent beneficial effects on emissions. For example, aerodynamics can be improved through advanced wing design, through weight reduction, and through attention to materials used in the “skin” of aircraft. Newer jet turbine engines, according to Airbus Industries, will halve the nitrogen oxide emissions of an aircraft by the year 2010. Though there are gains to be made in engine technology, a basic problem has been that an engine designed for maximum fuel efficiency also produces high amounts of No_x. Another approach is to connect jet turbines to propellers to achieve greater fuel efficiency at lower altitudes. On-board sensors and instrument landing systems remove some of the concerns about flying at lower altitudes in prop-jet aircraft in poor weather conditions. Airlines can choose not to fly their jets in the stratosphere, but to do this they have to sacrifice some fuel efficiency. A more immediate benefit results when larger aircraft replace smaller aircraft and when airlines operate with higher load factors. Also, there remains scope to reduce the distances flown by commercial aircraft, particularly on international routes.

The International Civil Aviation Organization (ICAO) has recognised the need for the airline industry to take action and it has issued limits for emissions of smoke, unburned hydrocarbons, carbon dioxide, and nitrogen oxides. Some countries have acted on these guidelines, but Sweden, Denmark and Norway have imposed a carbon tax on airlines flying within their territories based on the amount of fuel consumed, and it is possible that other governments will adopt similar measures in the future. This provides airlines with an added incentive to reduce fuel consumption, but it is possible the imposition of a tax on fuel usage could result in an increase in nitrogen oxides, particularly in the upper atmosphere where they are more problematic.

Too little, however, is known about the extent of the problems and about the efficacy of some of the “solutions”. ICAO’s 15-member Committee on Aviation Environmental Protection was reported to have decided in its December, 1995 meeting that it should recommend reductions in nitrogen oxide emissions by 16 percent (*Airline Business*, March 1996). This would be achieved by requiring modifications in new engines from 2000 and for modifications to engines in current use by 2008. Meanwhile, there are numerous studies in progress to gain a better understanding about the levels of emissions and about the effects of those emissions. The Mozaic project, for example, involves five Airbus A340's carrying out measurements during flights to study concentrations of ozone and water vapour. A Swissair Boeing 747 is measuring nitrogen oxides in the troposphere in another study.

In dealing with emissions from commercial aircraft, we have seen that there are some initiatives that can be taken by the managers of local airports, but the design of aircraft and their operation in the upper atmosphere requires a response at a different level. Individual airlines, or individual nations for that matter, can achieve a considerable amount of success simply through better management of the air transport system. Higher load factors, improved navigation to achieve shortest path flights and the use of the most efficient aircraft for the transport task all can make significant contributions to the reduction of emissions. Airframe manufacturers and engine manufacturers are responding to the challenges as well, but multilateral agreement on appropriate environmental management of commercial aviation is difficult to reach. The international airline industry has been experiencing very difficult financial times and those close to the industry are reluctant to impose requirements that will add to costs. Debate within ICAO is occurring, but a recent industry analyst was led to make the statement that:

> *Airlines can argue quite rightly that they have played a large role in reducing aircraft noise and emissions and contributing to a cleaner, greener earth. But their reluctance to take the next step could result in harsh measures being imposed by those with less knowledge of the industry than an organisation like ICAO.* (*Airline Business*, March 1996, page 29)

Oil Pollution in Straits of Malacca - the Impact of Shipping

The last section of this paper deals with the management of the marine environment and focuses on the difficulty of management in the absence of universally enforceable regulatory regimes. In effect, of course, this means that policies and strategies formulated to meet equity goals have little chance of success.

In the early 1990s 1.4 billion tons of oil were moved globally by more than 3,000 tankers over an average distance of 4,700 nautical miles. The threat of spills has been of concern for some time but major tanker accidents such as the grounding of the *Torrey Canyon* in 1967 and the *Argo Merchant* in 1976 which broke up, releasing 23,000 tonnes of oil into the sea, focussed global attention on the problem of how to preserve the marine environment. More recently, three shipping collisions in the Straits of Malacca - the *Royal Pacific* and *Tefu 51*, the *Nagasaki Spirit* and *Ocean Blessing* and *Maersk Navigator* and the *Sanko Harbour* resulting in major oil spills and the loss of life focused the problem to a regional level and led to a call by the littoral states - Malaysia, Indonesia and Singapore - for more stringent marine pollution control measures.

All spills are serious but particular problems are created when they occur in an international and relatively narrow waterway such as the Straits of Malacca These Straits separate the Indonesian island of Sumatra from Peninsula Malaysia and Singapore and is the main sea link between the Indian Ocean, South China Sea and the Pacific Ocean (Figure 3). It is a funnel shaped waterway varying in width from 3 to 300 miles. The depth of the Strait is highly variable making it dangerous for navigation - in the Philip Channel alone there are 37 areas where the depth is less than 23m - the minimum draught for a 250,000 dwt tanker. Further hazards including rocks, dangerous reefs and cross currents as well as wrecks in reported approximate positions and a seabed of hard rock and granite make groundings very dangerous (Mochtar 1994:12).

The Straits of Malacca are one of the world's most heavily used waterways - up to 400 vessels transit each day, 40 percent of which are predominantly foreign owned oil carriers. The dangers from pollution have increased with economic development in East Asia which required increasing volumes of crude oil. Japan's oil consumption alone increased by 20 percent annually after the late 1960s and its annual crude oil imports by the early 1980s had reached 600 million tons - the bulk of this passing through the Straits. Moreover, ships passing through the Straits now are larger and there are more of them; and the number of accidents has increased with congestion as has the severity of spills with vessel size. During the period 1977-1993 there were 71 shipping casualties in the Straits, 17 percent involving tankers. This is a relatively small number of casualties, given high traffic densities, but it only takes one or two serious tanker accidents to cause very serious damage in an ecologically vulnerable area (Gold 1994:5).

The risk of pollution in the Straits is not new and has always existed in a waterway which, because of physical characteristics, is difficult to navigate. This concern intensified over the last decade or so for a number of reasons. Firstly, the increased use of the Strait, which is the major shipping link between the Middle East and East Asia, and the increased size of the vessels with the emergence of the supertanker. Secondly, there are problems associated with an ageing fleet - age of a vessel has been identified as a major factor in ship loss. As a ship ages a general deterioration in condition occurs, stresses build up which attack the structural soundness of the vessel - a particularly significant factor in large bulk carriers. Serious maritime casualties involving older bulk carriers have revealed the vulnerability of such ships to breaking up, rapid sinking when ruptured or to be engulfed in flames (Raja Malik and Bin Raja 1993:6). The third reason is of an economic nature and the growing practice of flagging out. The high cost of shipping has led to the transfer of ships from traditional flag states to Flag of Convenience (FOC) and second registries. FOC states offer tax and investment incentives but frequently have a less stringent approach to ship inspections and many FOC vessels fail to comply with agreed international standards.

A plethora of international conventions exists pertaining to laws of the sea and marine pollution though many of them are either outdated or difficult to implement. The traditional formulation of the International Law of the Sea stipulated that ships had freedom to sail the oceans. The 1958 Convention on the Territorial Sea and Contiguous Zone formalised this tradition which meant that a vessel could proceed with "innocent passage" so long as it did not threaten the peace, order and safety of coastal states (Mochtar 1994). Although this tradition remains the basis of the law of the sea at present, it is questionable whether it is appropriate. The marine environment is now a valuable source of wealth in terms of food and of raw materials, not only a transport lane, and it can be validly argued that a passage that leads to its destruction is no longer "innocent".

International regulatory regimes exist dealing specifically with the prevention of pollution and clearly defines the responsibilities of each party. Under the 1982 UN Convention of the Law of the Sea (UNCLOS), for example, 'vessels transiting international straits must comply with generally accepted international regulations, procedures and practices for safety at sea and for the prevention of marine pollution' (Gold 1994:12). This rule was designed to protect coastal states without imposing unreasonable burdens on passing vessels, but how compliance is enforced is anything but straightforward. UNCLOS does provide enforcement powers to protect the marine environment but the procedure is complex and, in the context of transiting vessels, impracticable - a claim can be brought through diplomatic channels for a breach of treaty obligations but its success depends solely on the willingness of the flag state for enforcement (Gold 1994:5). Coastal or boarder states do not, under UNCLOS, have the right to suspend passage.

The enforcement of international conventions in the Straits of Malacca brings with it a particular set of problems and difficulties. Firstly, there is the dispute on whether the Straits are, in fact, "international". Both Malaysia and Indonesia have argued that the Straits lie within their respective territorial waters and are, therefore, national. This has been rejected by users and the issue has never been resolved - the Straits remain formally "international" as defined by UNCLOS (Gold 1994:3).

Not only do difficulties exist because Conventions are not uniformly adhered to, or because agreement on definitions cannot be reached, but a further problem is caused by the compensation regime that exists and this can impede restoration. When spills do occur access to immediate assistance is vital in minimising the environmental damage but delays in receiving compensation payments are common for a number of reasons. Firstly, a polluter must be identified. In the case of major disasters where ships break up and major spills occur, this is not a problem. But the majority of spills (84 percent) are less then 7 tonnes and may not be readily detected (White 1994:2). In the absence of an offender, against whom can a claim be lodged? Secondly, there are a number of categories for compensation and this, in itself, may be contentious. Among the more straightforward reasons for compensation claims are those for clean up measures or property damage directly occurring from a spill such as contamination of fishing gear, boats, and pleasure crafts. It also includes economic loss associated with property damage, such as fishermen prevented from carrying out their occupation because of damage to boats or due to oil on the surface of the sea. One of the more contentious areas in compensation claims, however, relates to environmental damage. The marine environment has a value to society beyond that which it confers on those who depend upon it for their livelihood. The issue that creates controversy is when compensation is sought for damage to natural resources which are neither commercially exploited nor used in an economic sense.

Solutions at a regional level may also be difficult to enforce although instances of unilateral imposition of transit restrictions do exist. The Italian Government, following a collision between two tankers in the Strait of Messina in 1985, issued a decree that merchant ships must navigate on the right side of the traffic separation line; pilotage is compulsory for merchant ships over 15,000 dwt, or for ships over 6,000 dwt if they carry oil of other substances which are harmful for the marine environment; and navigation in the Strait is prohibited for all oil carrying tankers exceeding 50,000 dwt (Scovazzi 1994:21).

The imposition of the "Grandfather Clause" and the restriction on aged vessels, has been a further strategy aimed at the prevention of spills. The age of a ship has been identified as a major factor in ship losses and the imposition of the 'Grandfather Clause' has been considered an effective means of minimising spills in territorial waters elsewhere. The United States, for example, has effectively banned tankers exceeding 15 years of age from operating in its waters and the European Parliament passed a resolution urging authorities in the Community to ban oil tankers more than 15 years old from using Member State ports. Fully laden oil tankers have been discouraged from using the Strait of Bonifacio altogether (Scovazzi 1994:22).

Management Strategies for the Straits of Malacca: A Case Study

Implementing effective management strategies in the Straits of Malacca has not been without its problems. Being an international waterway passage cannot be prevented; flag restrictions cannot be imposed (Scovazzi 1994) nor have attempts to implement numerous other strategies been successful. The imposition of the Grandfather Clause,for example, while enhancing safety and reducing the risk of pollution would have serious repercussions on domestic transport, particularly the coastal trades, if implemented. Both Indonesia and Malaysia are oil exporting countries and this restriction would also affect local vessels. There also remains the legal implication - can the Grandfather Clause be enforced legally by the littoral states? Where these strategies have been successfully implemented - in the USA and the European Community - it has been imposed in territorial waters and in ports, both instances where the coastal and port states can legally restrict passage.

Other strategies have been proposed but rejected either due to user opposition or because agreement could not be reached among the littoral states. Levying a toll on all ships passing through the Straits was considered, for example. This would provide funds which could be used to improve the safety of navigation and to combat pollution and was rejected by users on the basis that the Straits are international waterways and in that case how then could a charge be legitimately levied and by whom?

Proposals to restrict tanker size, as occurred in the Strait of Messina, has also been difficult to implement. While some Japanese users agreed to abide by a 200,000 dwt restriction, limitations based on size or deadweight were rejected by the majority of users for a number of reasons. Firstly it was considered discriminatory and unfair to westbound tankers, generally returning in ballast, or to tankers travelling to the east not fully loaded. Secondly, modern methods of design indicate that tonnage measurement may be less relevant to size and for limitation purposes an Under Water Clearance (UWC) would be more appropriate. As a result an UWC of 3.5 meters has been recommended and adopted as an alternative criterion for size limitation.

Rerouting strategies through the Straits of Lombok and Makassar have also been considered. These have economic implications, however, and have been opposed by users on that basis as a detour through the Straits of Lombok and Makassar adds approximately 1600 nautical miles and an additional 2 days to the voyage at an added cost. In addition, Singapore opposed the rerouting strategy from the outset as it would by-pass the port of Singapore altogether. It can be argued that rerouting is not a long term solution in any event but a displacement of the problem - a shifting of potential polluters from the Straits of Malacca to the Straits of Lombok and Makassar.

Compulsory pilotage through the narrower and more difficult passages has not been considered an appropriate solution and was also rejected on the basis that over 90 percent of marine casualties were caused by groundings due to poor seamanship, and not to physical characteristics of the Straits (Mochtar 1994:30).

An effective means of controlling maritime casualties in the Straits has been the introduction in the early 1980s of a routing scheme -Traffic Separation Scheme (TSS). Raja Malik (1993) points out that, since its introduction, there is no record of shipping casualties within the Scheme. Unfortunately, the Scheme covers only the northern part of the Straits and accidents have continued to occur in those areas outside the Scheme. It is now proposed to extend the Scheme but this will require concurrence not only among the littoral states but also among users. Undoubtedly, the intended changes will be scrutinised, especially by east Asian countries, to ensure that any impediment of passage is strictly in accordance with international law. The extension of the TSS will mean that ship masters will no longer be free to exercise the option of drawing their own courses. This puts the additional onus on the littoral states to ensure safe navigation. They will have the responsibility of ensuring that ships are able to position themselves with reasonable ease, that the route is safe from navigational hazards, unobstructed and with ample manoeuvring width. This calls for additional navigational aids, verification of chartered depths, hydrographic surveys, marking and removal of wrecks, establishment of monitoring and communication capability to issue navigational warnings. While this undoubtedly will make the Straits safer, it is costly and the question is who will pay for this. Again, safety and equity are mutually exclusive conditions.

Clearly, effective solutions require regional consensus. But it is not a regional or national problem only. The management and protection of the marine environment is of global concern and requires, therefore, implementable international solutions.

Concluding comments

Transport in the modern era has provided the technological means to facilitate the movement of passengers and goods. While effective transport systems have become indispensable they have been developed frequently in isolation of environmental protection to the extent that transport has been cited as a major contributor to the ills of twentieth century society.

Central to the issue is the growing concern about environmental degradation in the form of air, noise and marine pollution, traffic congestion and global warming.

While governments are developing policies to combat some of the problems, in many instances it is a matter of 'too little too late'. In addition, many issues transcend national boundaries and require an international, rather than a national, approach. Effective environmental management in the future demands adequate resources and an integrated global approach if attempts to reverse some of the ills are to be successful. In an increasingly global environment international strategies will require equity across nations: where this responsibility is not shared, outcomes must remain sub-optimal.

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