Energy and environmental issues in transport

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The paper discusses the environmental impact of transport, particularly that of road transport. It reviews current conditions in India, standards prevalent elsewhere and discusses measures that could be taken to reduce environmental damage by road transport.

TRANSPORT is essential for economic and human development. Technology, defined as the application of scientific knowledge to the solution of practical problems, has enabled the quality of life to be enhanced significantly, especially in the last century. This includes transport developments. However, there is another side to this – the effect on the environment of the planet. There is a concern that human activities stemming from a relentless pursuit of material well being would cause irreversible damage to the environment. The prospects for sustainable development on a planet with finite resources and a fragile environment have to be explored, implying a sensible utilization by humans of the resources of planet earth. Here we consider the issues pertaining to transport and the environment and the related questions of energy and transport, in such broader context.

Sustainable development

Sustainability in the long term means neither stagnation with no improvement in the lives of the poor nor escalating 'consumerism'. The key concept is the achievement of a quality of life (for all) and the state of the biosphere that is not purchased at the expense of the future. It means inter-generational and intra-generational equity. It also means survival of a measure of human diversity and of the organisms with which we share the planet and the ecological communities they form.

This has to be achieved by a set of interlinked transitions – technological, economic, social, ideological and institutional. Finite natural resources have to be properly costed and charged. Inter and intra-generational equity implies attention to needs but without 'greed'. A move towards more moderate levels of resource use/consumption is necessary. A change from a short term and parochial view to a broader, long term global perspective is needed. This applies to all sectors, including transport.

General environmental aspects – Transport projects

When transport infrastructure projects are formulated, a full environmental assessment study should be made, covering the impact both during construction and operation in the long term. The environmental effects of transport differ by mode. Non-motorized transport is largely environmentally benign.

The environmental effect of rail transport is mainly related to the direct and indirect use of coal (for generating electricity) and the use of diesel oil in diesel locomotives. Rail-generated noise can have intense local impact.

Inland waterway transport is fuel efficient and has relatively little environmental impact.

The operational discharging of oil during marine transport has some impact on the marine environment, but major damage occurs from tanker accidents. Shipping can contribute to pollution in ecologically-sensitive coastal waters.

Aviation causes local air and noise pollution at ground level, and gaseous emissions (including carbon dioxide, etc.) in the troposphere that can deplete the ozone layer.

When a road is constructed to some natural resource or to connect two areas for economic activity, the impact of the road and the subsequent induced development on forests, ecological habitats, and other sensitive areas need serious consideration. Adequate measures should be taken to mitigate the environmental effects, including issues of resettlement. At the micro level, during construction, etc. sensitive areas should be avoided. Measures to avert soil erosion are also necessary. The long-term effects should be carefully assessed, to avoid problems later. This is sometimes difficult – an example being the unanticipated scale of migration in a Brazilian development programme[1].

Vehicle emissions

The transport sector accounts for a large proportion (half or more) of the petroleum used in many countries. Air pollution caused by emissions from motorized vehicles is a serious environmental issue (see Table 1 on US data for passenger vehicles). The principal emissions from motorized road vehicles equipped with spark-ignition gasoline engines are:

Table 1. Air pollution from passenger vehicles

Transport mode	Carbon dioxide (pounds/pass km)	Organic compounds (g/pass km)	Carbon monoxide (g/pass km)	Nitrogen oxides (g/pass km)	Sulphur dioxide (g/pass km)
Truck (gasoline)					
Single occupancy	1.55	3.20	27.46	2.05	0.23
Average occupancy car	0.81	1.68	14.45	1.08	0.12
Car					
Single occupancy	1.12	2.57	20.36	1.61	0.14
Average occupancy	0.68	1.51	11.98	0.95	0.08
Vehicle ride share					
3 person car pool	0.37	0.86	6.79	0.54	0.05
4 person car pool	0.28	0.64	5.09	0.40	0.03
Bus (diesel)					
Transit	0.39	0.25	1.21	1.82	n/a
Rail					
Amtrak/intercity					
Diesel	0.43	1.12	0.6	0.9	0.51
Electric	0.26	–	0.05	1.1	2.07
Commuter (diesel)	0.53	1.04	1.44	4.10	0.63
Transit (electric)	0.37	–	0.06	1.48	2.89
Aircraft	0.57	0.5	0.52	1.08	0.08
Bicycle	0	0	0	0	0

Source: *Environmental Almanac*, World Resources Institute, 1992, p. 70.

- Carbon monoxide (CO), oxides of nitrogen, unburned hydrocarbon in the exhaust.
- Suspended particulate matter (SPM) – this can be considerable, particularly from two-stroke engines.
- Lead aerosol emissions from combustion of leaded gasoline are significant. This is particularly injurious to children and is said to affect their mental development and the neurological system.
- Additional hydrocarbon emissions due to evaporation, etc.

The most significant emissions from diesel-fueled vehicles are:

- Suspended particulate matter (SPM)
- Oxides of nitrogen (especially heavy duty vehicles)
- Sulphur dioxide
- Carbon monoxide and hydrocarbons, though to a much lesser extent than those for comparable gasoline engines.

Emission of carbon dioxide, implicated in possible global warming, occurs with both diesel and gasoline-fueled vehicles. Two-stroke gasoline engines, used in two wheelers and three wheelers, predominantly in Asia and Europe are a special case. Hydrocarbon emissions from such vehicles are high because a significant part of the air–fuel mixture escapes unburned into the exhaust (almost 20–25% of the fuel used is lost this way). Particulate emissions from two-strokes are also high[2]. Hydrocarbon emissions from a single two-stroke motorcycle can exceed those from three uncontrolled passenger cars and particulate emissions can exceed those from a heavy duty diesel truck. This is relevant in the Indian context as the increasing numbers of two wheelers and three wheelers now constitute nearly 80% of the registered vehicles (Table 2) and many of them use two-stroke engines, and account for 45% of total gasoline consumption.

Table 2. India: Number of registered vehicles (in thousands)

End March	1991	1993	1994*
Buses	333	382	390
Goods vehicles	1,411	1,740	1,791
Cars, jeeps and taxies	3,013	3,326	3,446
Two wheelers	14,047	17,191	17,936
Others#	2,506	2,775	2,901
Total	21,310	25,415	26,464

*Estimated
#Figures include tractors, trailers, three wheelers (both passenger and goods vehicles) and other miscellaneous vehicles.
Source: Tata Services – *Statistical Outline of India* 1995–96.

Factors affecting vehicle emissions

Several factors affect vehicle emissions:
- Vehicle characteristics such as size, age, engine type and technology,
- Engine mechanical condition and adequacy of maintenance,
- Emission control equipment condition,
- Fuel properties and quality
- Operating characteristics – altitude, temperature, humidity and driving patterns, traffic speed, congestion.

Motor vehicle emissions are highly variable. Apart from differences among vehicles, differences in operating conditions can cause emission from a vehicle to change by more than 100%. A consistent and replicable test procedure has to be prescribed for emission regulations or incentive systems to be enforceable.

Health impact of vehicle emissions

Public health studies have shown that air pollution, particularly in urban areas, is associated with higher incidence of respiratory ailments – chronic bronchitis, breathing difficulties, etc. The report of a study conducted in 1995–96 (ref. 3) in Chembur (a northeastern suburb of Mumbai) correlates high frequencies of cough/breathlessness and asthma with air pollution in two traffic-congested sites. The impact on children is often more severe.

The situation in the big cities of India, where the vehicle population is increasing and traffic congestion exists in many areas, deserves particular attention. Data from the Mumbai Municipal Corporation indicates an increase in the daily pollutant emissions from transport vehicles in Mumbai from 399 tonnes in 1978 to 1538 tonnes in 1993. Some other studies show different figures, but still large increases. (This shows the need for proper monitoring and measurements using agreed methodologies.) The daily pollutant emissions in Delhi are placed at 1300 tonnes[4]. Measures to reduce such air pollution by vehicles are therefore obviously needed. This also applies to big cities in other countries – e.g. Bangkok. It is necessary to focus attention on pollutants causing local and regional impact.

Technical options to mitigate air pollution by vehicles

Technical options are now available (and are being continuously improved) to control/mitigate air pollution caused by vehicles. These options are:

(a) Vehicle technology improvements
(b) Fuel options for controlling emissions
(c) Alternative technologies

Vehicle technology improvements

For gasoline-fueled automobiles, improvements are:

- Engine modifications
- Use of three-way catalysts and electronic engine control systems
- Lean burn techniques combined with oxidation catalytic converters (at costs of the order of US $650–800 per car[2]) that can achieve big reductions in pollutants and a 10 to 15% reduction in fuel consumption.

For diesel-fueled vehicles emissions can be greatly reduced from uncontrolled levels through engine design changes, improved fuel injection systems, turbocharging, and charge air cooling. These changes improve fuel economy significantly but increase engine costs. Using low sulphur fuel and an oxidation catalytic converter one can further reduce particulate matter and hydrocarbon emissions. These technical options imply only modest increases in costs.

For two-stroke gasoline engines used in two/three wheelers, emissions can be reduced by adopting advanced two-stroke design incorporating timed fuel injection and crankcase lubrication or switching to a four-stroke design. This would reduce hydrocarbon and particulate emission by about 90%, at a cost of about US $60 to 80 (ref. 2) per vehicle. This would also reduce fuel consumption by about 30% and thus be economical. Additional emission reductions are possible with improved four-stroke engine design and calibration and through the use of catalytic converters. Catalytic converters are used in two-stroke motorcycles in Taiwan and in mopeds in Austria and Switzerland. Adoption of such technical solutions in India would be extremely beneficial to reduce pollution and also save fuel.

Fuel options for controlling emissions

Pollutant emissions can be reduced by 10 to 30% through cost-effective fuel modifications. This has major advantages – they can take effect quickly, can be targeted geographically or seasonally, and are easier to enforce since fuel refining and distribution are highly centralized.

Major efforts have been made worldwide to remove lead from gasoline, both to reduce lead emissions and to facilitate the use of vehicle emission control technologies such as catalytic converters. Possible further changes to reduce emissions include reduced volatility, increased oxygen content, reduced aromatics and more widespread use of detergent additives.

Conventional diesel fuel can be improved by reducing the sulphur and aromatic content and by using detergent additives.

The substitution of gasoline and diesel by cleaner burning fuels has received attention in the last decade. The more important alternatives used are natural gas (generally compressed natural gas – CNG), liquefied petroleum gas (LPG), methanol, ethanol and gasohol, and biodiesel. CNG is playing a significant role as motor fuel in Argentina, Italy, Canada, New Zealand, Russia and the USA. There are over a million vehicles using CNG worldwide, of which half are in Argentina and Italy. CNG vehicles emit significantly less CO, oxides of nitrogen, etc. LPG now powers an estimated four million vehicles in several countries, notably Australia, Canada, Italy, Japan, Korea, the Netherlands, New Zealand and USA. LPG has many of the same emission characteristics as natural gas. Methanol has also been tried out in USA. Ethanol and gasohol (ethanol blended with gasoline in proportions up to 22%) have been extensively used in Brazil. They emit less CO and oxides of nitrogen, but have high unburnt ethanol (a catalytic converter can control this).

Hydrogen has the potential to be the cleanest-burning motor fuel. Research and development work on hydrogen powered vehicles is progressing in several countries including Canada, Germany, Japan and USA. A prototype 60 passenger bus has been put into service in Vancouver, Canada.

Alternative technologies

It was recently reported that Mercedes Benz of Germany has come out with a fuel cell powered car[5], called the New Electric Car (NECAR). Fuel cell technology converts chemical energy to electricity. NECAR is said to have a range of 250 km before recharging and attains speeds up to 100 km per hour. Other electric cars have also been built and they are less complex than gasoline vehicles, have no emissions and are clean. However the problem so far has been the range of a practical electric vehicle and the necessity for devising adequate battery charging systems. Even so, the current range is over 100 km at reasonable speeds for urban use, and such cars are being tried out in California[6]. It has been reported recently that an electric car with a range of 80 km and top speed of 65 km for urban use is proposed to be commercially manufactured in India[7]. 'Solar cars' have appeared since mid 1980s and are powered from the sun. (In 1989, the Sunraycer[8], a 400 pound automobile averaged 66 km per hour to win a 3004 km race in Australia.)

Hybrid vehicles (electric vehicle that uses two or more power sources, one of which is a battery pack) have also been developed. Technological improvements described above and cost reductions could, in future, provide workable alternatives to polluting fossil fuel-based vehicles.

Road safety

Road safety is another important element of environmental assessment and is a major concern in many developing countries. Use of seat belts, enforcement of speed limits, and traffic management measures have been helpful in industrialized countries. The situation in developing countries where there is a mix of road vehicles is somewhat different. Better road geometry, signals, crossings, more 'education' in the use of roads, driver training, separation of automobiles and other traffic and traffic management measures may be needed. The measures adopted should be based on local data, analysis and co-ordination amongst the agencies involved.

Mitigating the effects of emissions – non-technical measures

To mitigate the effect of emissions by transport vehicles, the following non-technical measures can be adopted:

- Optimize demand, and improve efficiency of transport.
- Induce the adoption of technical options that reduce or eliminate emissions.
- Some personal travel can be avoided by using advances in telecom technology – for example email, videoconferencing, internet, etc. besides telephones and fax. Provision of 'information centres' in suitable areas can reduce some of the travel.

A more optimum use of transport modes (including multimodal) could mitigate the environmental effects.

Energy efficiency in transport

Inland waterway transport of bulk freight is very energy efficient and should be used where appropriate. But aspects like maintenance of waterways and other infrastructure issues may limit its use. Coastal shipping (which also can be energy efficient) is another option that should be explored and used to advantage. A view is often expressed that rail has generally better fuel efficiency than road and this should be exploited. In the discussion of the fuel efficiency of modes, it is the fuel used in 'operations' that are generally referred to (the energy used in the construction and maintenance of facilities and equipment, though relevant, is usually not considered in the absence of reliable figures). Even here, comparisons are often made on the basis of 'average' figures that can be misleading, as fuel/energy consumption is influenced by a number of factors including the nature and type of service provided. The commodity, the consignment size, the load factors, capacity utilization, the type of vehicle used and speed, the nature of service all make a difference. It would be more appropriate to make a comparison on a case by case basis for similar services performed. Comparisons on a mere per ton-km or per pass-km basis mask the great differences in the mix of services they perform. In the case of passenger traffic also, the number of passengers to be carried at one time, the frequency/time interval, the distance, speed, etc. all matter. The fuel efficiency of buses can be equal to or better than that of rail under certain circumstances. A Japanese study concluded that in local service on a rail line carrying less than 4,000 persons per km a day, a bus service would be more fuel efficient than a rail service using diesel rail cars.

Further, energy is not the only resource used by transport services. The costs of all the resources consumed and the overall costs to the user (not just transport costs) are more important. Prices reflecting true costs would promote economic efficiency by providing the right signals for decision making. Each mode would then get optimally utilized.

Mitigating pollution – inducing adoption of technical measures

Regulation and pricing are two important measures to induce adoption of technical options that reduce pollution.

Regulatory measures/setting standards

An important measure taken in most countries is to set standards for vehicle emissions and enforce them by requiring emission testing, and monitoring this. The test procedures are also prescribed. The standards prescribed in India (Table 3), effective from April 1996 are closer to the European Union standards than the tougher US standards (California in USA has still tougher standards). The standards initially prescribed can and should be gradually tightened, as has been done in USA (Table 4).

Setting standards for fuel efficiency of new cars and the fleet is another important measure. This has been implemented in USA, resulting in an improvement in the fuel efficiency of new cars, averaging 29 miles to the gallon[6]. However, experts believe that there is still great scope for more fuel-efficient cars. Ten manufacturers are reported to have built and tested safe, low-pollution prototype cars that get 67 to 120 miles per gallon[6]. Unfortunately there is little manufacture of such ultra efficient cars.

Pricing measures

Prices reflecting true costs provide the right signals to users. For this purpose, environmental costs and the 'resource costs' of natural resources used should be included. This reform should be gradually introduced.

Estimating the environmental costs of vehicle pollution has been difficult and controversial. Estimates vary widely or have large ranges even in the same country, as some recent studies in USA and Europe have shown[9].

Appropriate fuel pricing is important as low fuel prices promote use of more vehicles than necessary. The price of petrol/diesel should cover the resource cost, an element that internalizes the environmental effects, and an element that serves as a proxy road-user charge. An additional element to cover as proxy congestion costs may be appropriate in some cases. Considered in this light the prices charged in USA (where gasoline is priced at about US $1.25 per US gallon) is extremely low. Some scientists[6] consider that crude oil selling for US $20 per barrel should really cost $80. The Union of Concerned Scientists estimates the 'external' costs as $2.53 per gallon of fuel. (Yet it seems very difficult to change the very low US prices.) The gasoline prices in Europe and Japan are higher at about US $ 3 to 4 per US gallon[10]. A recent study shows that existing fuel prices in Europe would be between 40 and 70% of the levels necessary to internalize the environment externalities[1]. (Even this calculation excludes the resource costs mentioned earlier.) Prices can be raised to adequate levels by making small increases over a prolonged period.

To provide incentives for the use of cleaner fuels (including use of lead-free petrol), differential taxation and pricing should be used. This should be accompanied by other measures. One example is a 'feebate' system under which a fee is levied for cars that have an efficiency below a specified level and a rebate for those above that level. This would promote choice of more efficient cars and was considered in California some years ago.

Measures in urban areas

To mitigate the problems of acute pollution in urban areas, several measures can be taken:

Table 3. India – Emission standards and regulations

The Union government is responsible for making emission regulations with respect to motor vehicles. These are prescribed under section 115 of the Central Motor Vehicles Rules, 1989. The currently prescribed standards are indicated below:

A. From 1 March 1990, all vehicles have to comply with the following standards:

(a) Idling CO (carbon monoxide) emissions not to exceed 3% by volume in the case of four-wheeled petrol-driven vehicles
(b) Idling CO emission limit for all two and three-wheeled petrol-driven vehicles not to exceed 4.5% by volume.
(c) Smoke density for all diesel driven-vehicles as follows:

Method of test	Maximum	Smoke	Density
	Light absorption coefficient l/m	Bosch units	Hartridge units
1. Vehicles other than agricultural tractors Full load at 60 to 70% of max. engine rated rpm	3.25	5.2	75
or free acceleration	2.45		65
2. Agricultural tractors 80% load corresponding to max. power developed in PTO performance tests	3.25	5.2	75

B. From 1 April 1996 Type Approval Tests and Conformity of Production (COP) tests and standards are prescribed for diesel-driven and petrol-driven vehicles. These are as follows:

MASS Emission Standard for Diesel Vehicles Type approval tests

Vehicle category	HC* (g/kWh)	CO* (g/kWh)	NO* (g/kWh)	Smoke
Medium and heavy over 3.5 ton /GVW	2.4	11.2	14.4	***
Light diesel up to 3.5 ton/GVW	2.4	11.2	14.4	***
or reference mass	CO**	HC + NO_x**		
R(kg)		g/km	g/km	
$R < 1020$		5	2	
$1020 < R < 1250$		5.7	2.2	
$1250 < R < 1470$		6.4	2.5	
$1470 < R < 1700$		7	2.7	
$1700 < R < 1930$		7.7	2.9	
$1930 < R < 2150$		8.2	3.5	
$R > 2150$		9	4	

Note:
*The test cycle is as per 13 mode cycle on dynamometer.
**The test should be as per Indian driving cycle with cold start.
***The emission of visible pollutants (smoke) shall not exceed the limit value to smoke density. When expressed as light absorption coefficient, values prescribed for various nominal flows when tested as constant speeds over full load.
COP standards
10% relaxation in the standards for HC, CO and NO_x
10% relaxation in the standards for CO and combined CO + NO_x

Mass Emission Standard for petrol-driven vehicles
Approval test

(i) Passenger cars

Cubic capacity (cubic cm)	CO (g/km)	HC + NO_x (g/km)
< 1400	8.68	3
1400 and < 2000	11.2	3.84
> 2000	12.4	4.36

Notes:
1. The tests will be as per Indian driving cycle with warm start. However, with effect from 1 April 1998, the test will be as per Indian driving cycle with cold start.
2. There should be no crankcase emission.
3. Evaporative emission should not be more than 2.0 g per test.
4. COP standards: 20% relaxation in the standards for CO and combined HC + NO_x.

(ii) Three wheelers (for all categories)
CO g/km 6.75
HC + NO_x g/km 5.40

(iii) Two wheelers (for all categories)
CO g/km 4.50
HC + NO_x g/km 3.60

Note: In the case of both (ii) and (iii) above the notes 1 and 4 given under (i) Passenger cars also apply.

C. The rules also prescribe that after the expiry of a period of one year from the date on which the motor vehicle was first registered, every vehicle should carry a 'Pollution under control' certificate issued by an agency authorized for this purpose by the state government. This validity of the certificate should be for six months or any lesser period as may be specified by the state government.

Source: Central Motor Vehicle Rules, 1989; Amendment rules, 1996 published in the *Gazette of India Extraordinary*, Pt. II, Section 3(i) dated 29 March 1996.

(i) Integration of land use planning/urban structure with transport (also among modes).
(ii) Reducing traffic demand by non-traffic measures – e.g. staggering of hours of work, flexible hours of work, reducing the need for citizens to visit government/local offices by suitable procedural changes.
(iii) Taking measures for reducing congestion:

(a) Traffic management measures[10,11] – segregation of traffic, one-way streets, improvements in public transport, bus only lanes, incentives for high occupancy vehicles, creation of vehicle-free areas and promotion of non-motorized transport.
(b) Restraint/Quantity-based measures.
– Area traffic bans based on certain types of license plates – tried in Mexico, Athens and Santiago.

– Singapore has restricted the number of vehicles by auctioning a predetermined number of licenses for purchase of new vehicles.

The issue of the pace of motorization needs serious consideration.

(c) Congestion pricing: area licensing, electronic road pricing, etc.

Long term future scenario

Two important concerns affect transport in the long term. One relates to the issue of possible global warming and the other to the need for minimizing fossil fuel usage.

Global warming

Emissions of greenhouse gases by fossil fuel burning (as in vehicles) are thought to contribute to global warming. There is also a global 'convention' on climate change. The hype about this is not matched by actions needed to avert the threat. Some aspects merit serious consideration, especially by developing countries.

First, the scientific evidence for global warming due to human interventions that result in emissions of 'greenhouse gases' into the atmosphere is not conclusive. Many scientists still question the hypothesis. These gases are also produced in nature in huge quantities – by action of termites, rice fields, cows and other ruminants. Climate is affected by many complex factors and the link between atmospheric concentration of the gases and the degree of climate change, especially amongst different regions is poorly understood. The 'climate models' used to make predictions have serious limitations.

Second, the rationale for the convention was a recommendation by the inter-governmental panel on climate change for an *immediate* reduction in the emission of gases due to human intervention by over 60%. The industrialized countries, which are responsible for 80% of the accumulations and 75% of current emissions, have taken little action and emissions have increased. Studies including recent ones have shown that they can make drastic reductions with small investments. Yet they seem to be shifting the onus on to developing countries using a funding mechanism (Global Environment Facility, GEF) under which their actions are not questioned. There are now moves to 'negotiate' (really impose) limits using the argument of 'high future growth' from developing countries. As the emissions from developing countries are a *fraction* of that from the industrialized countries, any actions taken by them can only mean marginal changes in accumulations and the predicted climate changes cannot be avoided – this requires *drastic reductions by industrialized countries.*

Table 4. Progression of US exhaust emission standards for light duty gasoline-fueled vehicles (grams per mile)

Model year	Carbon monoxide	Hydrocarbons	Nitrogen oxides
Pre 1968 (uncontrolled)	90.0	15.0	6.2
1970	34.0	4.1	–
1972	28.0	3.0	–
1973–74	28.0	3.0	3.1
1977	15.0	1.5	3.1
1980	15.0	1.5	2.0
1981	7.0	0.41	2.0
1994–96 (tier I)	3.4 (4.2)	0.25* (0.31)	0.4 (0.6)
2004 (tier 2)#	1.7 (1.7)	0.125*(0.125)	0.2 (0.2)

–Not applicable

Note: Standards are applicable over the 'useful life' of the vehicle, which is defined as 50,000 miles or five years for automobiles. The durability of the emission control device must be demonstrated over this distance within allowed deterioration factors. Figures in parentheses apply to a useful life of 100,000 miles, or ten years beyond the first 50,000 miles.

*Non-methane hydrocarbons.

#The US Environmental Protection Agency (EPA) could delay implementation of tier 2 standards until 2006.

In addition to exhaust emission standards, US regulations address many other emission-related issues, including control over evaporative emissions, emissions durability requirements, emissions warranty, in-use surveillance of emissions performance, and recall of vehicles found not to be in compliance. Regulations that require on-board diagnostic systems that detect and identify malfunctioning emission systems or equipment are also being implemented.

Source: Faiz, A., Weaver, C. S. and Walsh, M., in *Air Pollution from Motor Vehicles*, The World Bank, Washington DC, 1996, p. 3.

An equitable basis would be a common per capita emission level (sort of living right of an individual) pegged to, say, present population levels and charging a pollution tax to be paid by countries with emissions above such levels – the polluter pays principle – to be used for the common good. The funding mechanism of GEF, involving donors who are not questioned and recipients who are, could be modified. Developing countries need to take this matter seriously only when industrialized countries take effective steps.

Minimizing fossil fuel usage

The concern for minimizing fossil fuels usage stems from the finite nature of these resources and the non-sustainability of their continued high usage (intergenerational equity demands this). Sustained attention is needed to find appropriate alternatives and accelerate the pace of their development.

Summary

Environmental issues in transport need consideration in the wider context of sustainable development. Environmental assessment of projects and adoption of measures to mitigate the effects are necessary. All modes of transport use fossil fuels and cause emissions. A major concern is air pollution caused by road vehicle emissions, road being the dominant mode. Technical options at reasonable cost are now available to greatly reduce these emissions, which are known to have adverse health consequences, especially in urban congested areas. Non-technical measures are also necessary. Alternative fuels and alternative technologies are evolving – these should be fostered to minimize fossil fuel usage in the long term.

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