Man is dependent upon his physical environment for the satisfaction of his basic wants. Yet in the course of his efforts to master the environment man has brought about such radical changes that concerns have been raised about environmental quality. In the beginning, man's economic activities, being limited in scale and intensity, impinged very little upon an environment largely unexplored. One could indeed conceive the notion of earth as having an infinite capacity. Since then, the realisation has dawned that the planet is finite and its resources are limited.

As the human population grew and greater demands began to be made on the environment, concerns were expressed from time to time on issues such as deforestation, soil erosion, water pollution, and deterioration of air quality in the towns. However, it was not until the advent of industrialisation that the quality of the environment became a significant issue. One could clearly see how the environment was being adversely affected through directly productive activities made possible by impressive technological change. The growth in industrial activity was accompanied by very rapid growth in human population. The world population, estimated at 500 million in 1650, became twice that number in 1850, and has more than quadrupled since then.

The twentieth century has seen both widespread environmental concerns and serious efforts to repair environmental damage. Mass production has impacted seriously on basic natural resources – air, land and water. Non-renewable resources such as coal and oil have been depleted to such levels that the prospect of their extinction in the twenty-first century looms large. Serious problems of the rupture of the ozone layer and global warming, along with the prospect of climate change, are now at the forefront of international discussion. Urbanisation and the emergence of mega-cities have brought into focus the problem of pollution resulting from transport. In the city, transport often ranks first in terms of impact on air pollution. Concern now centres not only on the adverse effects of man's directly productive activities but also on the widespread environmental changes resulting from the building and operation of such infrastructure as transport networks. Questions have been raised about the potential of transport to create or aggravate environmental problems caused in other sectors. The adverse external effects of transport also include the depletion of scarce energy resources, congestion and accidents. These negative externalities are not
captured in the transactions of the market for transport services. Since the market fails to promote a social optimum, it is relevant to inquire how these externalities can be mitigated through policy initiatives such as the promotion of one mode of transport at the expense of another. A comparison between the two important modes of transport—road and rail—in terms of their external effects is thus an important area of policy research.

The present thesis aims to determine the factors behind the present trends of rail and road traffic in India as well as to examine and monetise the relative social impacts of the two modes, with a view to making policy recommendations for correcting identified market failures. In this chapter, we shall review the nature of man's impact on the environment and his efforts to improve environmental quality, with particular reference to the Asia-Pacific region and India. This will be followed by a description of the impact of transport on the environment. Finally, the problem to be analysed in the thesis will be stated, along with the methodology of analysis and the plan of the study.

Environment Impact of Human Activity

The damage and disruption caused by man to his environment may be classified under the following heads (Brandon, 1995).

Land degradation

Land, the most valuable natural resource, is under serious threat of deterioration because of constant human pressure and exploitation beyond its capacity. While a large number of natural factors such as land and wind erosion contribute to the degradation of land, the nature of land-use is an important, if not the deciding, factor in the determination of land quality. Land-use patterns are subject to continuous changes, which are due to the interplay of various socio-economic, political and technological pressures. The impacts of transport-related activity upon land include diversion of land for infrastructure construction, extraction of road-building materials, and dereliction of obsolete facilities. In the Asia-Pacific region, the trend suggests that in response to the increasing pressure of population growth, urbanisation and development of transport infrastructure, the acreage of forests and woodlands has declined, with land being diverted for agriculture and urban uses.
Arable land in the region is already being over-utilised and any further expansion of such land must take place in marginal areas, leading to further land degradation.

In the Asia-Pacific region, India has the highest percentage of degraded land in the total land area (53%). About 163 million hectares of land have some degree of degradation. A survey carried out for only agricultural land indicates that 83.4 million hectares of agricultural land are degraded, with 35% being slightly degraded, 31% moderately degraded, and 34% severely degraded (UN/ADB, 1995).

Water erosion of land in India is accelerating because of activities such as destruction of natural vegetation for fuel, timber and forage, and cultivation on steep slopes. 69 million hectares of land are estimated to be extremely eroded by water and 106 million hectares severely eroded. Wind erosion of land is exacerbated by human activity such as overgrazing, burning and felling of trees. In India, the estimated area affected by wind erosion varies between 17 million hectares and 39 million hectares. Erosion of land due to wind is most common in the arid regions, covering 31.7 million hectares. The problem across India is aggravated by increased use of tractors for ploughing of cultivated fields.

Mismanaged irrigated lands contribute to soil salinity. Water-logging occurs in long-irrigated areas, where watertables have risen to within 1.5 metres of the surface. According to a government report of 1990, an area of 8.53 million hectares is waterlogged in India; other sources put the figure as high as 10 million hectares. Although precise data is lacking, much of the rangeland in India is threatened by overgrazing and over-harvesting of the natural vegetation (UN/ADB, 1995).

The primary on-site costs associated with soil degradation are reduced yields (at constant input levels), and/or the downgrading of that land to crops of lesser net value. Off-site costs include siltation of drainage canals, irrigation canals and reservoirs, besides changes in the hydrology of watersheds. The estimated productivity losses due to land degradation (based exclusively on reduced yields) fall between 4% and 6.3% per year, which represents an annual foregone production of $1.5 to $2.4 billion. The estimated losses are more or less evenly divided between the dry and humid regions.

The last few years have seen considerable initiatives at the global, regional and national levels to combat the problems of land degradation in the Asia-Pacific
region. At the regional and subregional levels, agencies are involved in collecting data, imparting training, carrying out specific case evaluations, and formulating action plans to combat land degradation. At the national level, technologies for the amelioration of degraded land resources have been applied in the field to control water and wind erosion, manage watersheds, rehabilitate waterlogged and salinated lands, and improve soil fertility (Brandon, 1995).

**Deforestation**

The forests and woodlands in the Asia-Pacific region occupy approximately 662 million hectares, about 70% of the world's total. India has 70.6 million hectares of forest, comprising about 23% of the total land area. Of the total forest area, a little more than half has a crown density above 40% while the remainder consists of degraded and unproductive forests.

Forests provide a wide range of economic and environmental services: (a) direct use values relating to consumption (timber, firewood and a wide range of plant and animal non-timber products); (b) direct use values not relating to consumption (recreation or ecotourism); (c) local indirect use values (watershed protection, soil retention); (d) global indirect use values (carbon sequestration functions); and (e) option values (habitat for biodiversity and source of supply for future gene pools).

The Food and Agriculture Organisation (FAO) estimates India's rate of deforestation at 0.6% per annum between 1981 and 1990, implying a loss of 3.4 million hectares over the decade. The deforested area consists of 15% tropical rain forest, 64% dry deciduous forest and 11% hill and montane forest (the remaining 10% covering other types of forest). As a result of rapid increase in plantations, the total forest area in India is increasing even while areas of natural forest cover are decreasing (Brandon, 1995).

Gaps in supply and demand exist for forest commodities. In India, the supply of industrial wood in 1992 was 24.6 million cubic metres, while the demand projected for 2000 was 42.12 million cubic metres. The supply of pulp and paper falls much short of requirements. The problem is aggravated by demand from new uses such as the production of packing cases for transport of fruit and other items. It is estimated that packing cases for apples grown in one acre of an orchard require wood from 10 acres of forests.
In the "user cost" approach to forestry valuation, only the commercial timber that is depleted by deforestation is usually valued, while the other economic losses resulting from deforestation are ignored. Nevertheless, the range of estimates for the annualised replacement cost of India's deforestation over the period 1980-90 is $183-244 million. Deforestation-related losses are largely irreversible over a ten-year period. The full discounted value of the ten-year losses range from $1.4 billion to $1.9 billion, using a 5% discount rate. These costs will grow higher over time, with continued deforestation and the absence of an adequate maintenance of existing forest areas. The transport sector itself can cause extensive depletion of forest resources, such as when roadways or rail beds are constructed through thick forest land.

Plans and programmes have been formulated not only to check excessive deforestation but also to augment the forest area. In India, a National Forest Policy has been in place, laying great emphasis on bringing at least one-third of the country's land area under forest cover. By 1995, the adoption of the Forest Conservation Act of 1980 had reduced the annual diversion rate of forest land to non-forestry purposes from 150,000 hectares to 16,000 hectares. Recent developments include the adoption of a participatory forest management approach and an increased thrust towards natural regeneration (Brandon, 1995).

**Water pollution**

Fresh water is a natural resource vital to the survival of all living beings. The sources of fresh water – river basins, groundwater reserves, lakes and man made reservoirs – are both limited and increasingly under pressure to meet heightening domestic needs as well as demands from agriculture and industry. Over-exploitation or misuse leads to environmental degradation, resource depletion, pollution of water bodies and increased risks to human health. Transport operations lead to the pollution of water bodies in a number of ways: the pollution of surface and groundwater by surface run-off, the discharge of oil spills, the modification of water tables, etc.

In India, contamination of water supply in both rural and urban areas poses significant problems with almost the surface water (except in the mountainous areas) being unfit for human consumption. Water pollution has three major sources:
domestic wastewater, industrial wastewater and agricultural run-off. Water pollution from domestic and human wastewater is the cause of many severe water-bone diseases. Data of the World Bank and the World Health Organisation (WHO) shows that about 21% of all communicable diseases (11.5% of all diseases) are water-related.

Estimates of morbidity and mortality due to water pollution can be aggregated into a single health impact measure called DALYs (disability adjusted life years). About 30.5 million such DALYs are lost each year in India because of poor water quality, sanitation and hygiene. Of the total, diarrheal diseases account for 28 million DALYs. If the statistical value of one DALY is equal to the annual average productivity of an Indian worker, then the medium estimate of the value of one DALY turns out to be $330 (assuming a constant statistical value of life across all ages).

Urban water supply systems in India are subject to supply shortfalls because of urban growth, higher per capita demand resulting from rising income, excess demand due to under-pricing or low collection rates, and pollution that limits existing supplies. Further urban water supply projects would cost 2 to 3 times more than current projects because of the need to pump water over longer distances, use additional treatment and/or invest in water transfer schemes. Pollution creates a need for more expansive and expensive water supply schemes and is one of the components of the rising costs of water supply. Since public investments in municipal and industrial water supplies in developing countries constitute 5-6% of total public investment, even a small cost factor associated with environmental degradation is likely to be significant. Besides, with the high rate of urbanisation taking place in India, these costs are rising very rapidly.

To date the main aim of water policies has been to meet the growing needs for supply while reducing capital investment and protecting the quality of water. Over the past several decades, governments in the Asia-Pacific region have been embarking on ambitious water quality enhancement, water conservation and water resource development programmes. In India, the Government initiated the Ganga Action Plan in 1985, following a systematic survey of pollution sources. The treatment of wastes from a limited number of industrial complexes that pollute the river was included in the Plan. The fact that it has not had the desired effect underscores the difficulty of making efforts in this area.
At the international and regional levels, efforts are underway to improve water resource management. The role of international and regional organisations in water resources management has been extensive and diverse. Most water supply and sewerage projects have assisted urban communities, but projects in countries such as India have also concentrated on rural areas.

**Biodiversity**

Biodiversity is an index of the condition of the biological resources upon which large segments of the population rely for their food, medicines and a wide range of useful products. A decline in biodiversity entails the loss of species or genes from an ecosystem and also signifies the loss of a potential food or other resource to man.

Most factors currently threatening biodiversity are the results of man's activities. These can be grouped as immediate and underlying causes. The direct causes of biodiversity loss are habitat loss, unsustainable use of biological resources, environmental pollution and conflict in governmental policies. The underlying causes of biodiversity loss are international trade, population growth, poverty and the introduction of exotic species. Transport operations can be a contributory factor to loss of biodiversity when, for example, the construction of infrastructure involves the partition or destruction of neighbourhoods, farmland and wildlife habitats.

The countries of the Asia-Pacific region have undertaken numerous steps to protect biodiversity through in-situ and ex-situ conservation. In-situ conservation includes the demarcation of protected areas and the promotion of conservation in non-protected areas. Ex-situ conservation includes the establishment of botanical gardens, zoological parks, and gene banks.

In order to promote both these types of conservation, countries in the Asia-Pacific region are also making efforts to strengthen their institutional capacities for the management of biodiversity. In India, the main responsibility for conservation lies with state or provincial authorities. Although the central government strongly supports conservation, the commitment and level of activity towards that end in many states is poor or lacklustre.
At the international level, a number of agreements have been adopted for the conservation of biodiversity. Among the most important are the Convention on Illegal Trade in Endangered Species (CITES), 1973; the Convention on Wetlands of International Importance, especially as Waterfowl Habitat, 1971; the Convention concerning the Protection of World Cultural and Natural Heritage, 1973; and the Convention on Conservation of Migratory Species of Wild Animals, 1979. The principal development in biodiversity conservation has been the framing of the Convention on Conservation of Biological Diversity in 1992 at the UN Conference for Environment and Development (UNCED) in Rio de Janeiro. A number of other international initiatives have been undertaken to conserve and promote biodiversity. International and regional organizations have assisted in natural-level analyses of biodiversity for the assessment of existing protected area systems and the identification of additional areas needing protection.

Air pollution

Increased human activities accompanied by rapid industrial expansion, rising energy consumption and deforestation have been putting immense pressure on the earth’s atmosphere in recent years, especially in the urban environment. New evidence on the accelerated degradation of the earth’s protective ozone layer demonstrates that air pollution can also have global effects with serious implications. Predictions of global climate change and sea-level rise through the greenhouse effect bring into focus the most threatening aspects of the cumulative effects of air pollution.

(i) Urban air pollution

The rapid growth of cities, together with industry and transport, has resulted in an equally rapid increase in urban air pollution. The use of poor quality fuel (e.g. coal with high sulphur content and leaded gasoline), inefficient methods of energy production and use, poor condition of automobiles and roads, traffic congestion and inappropriate mining methods in developing countries are major causes of increasing airborne emissions of sulphur dioxide (SO₂), oxides of nitrogen (NOX), carbon dioxide (CO₂), suspended particulate matter (SPM), lead (Pb), carbon monoxide (CO) and ozone.

India has 23 cities of over one million people and ambient air pollution levels exceed WHO standards in many of them. The transport sector is a very significant contributor to urban air quality: in a city like Delhi, road transport is responsible for
60% of the total urban pollution. Urban air pollution is worsening because of upward trends in power consumption, industrialisation, vehicle ownership and use, and refuse burning. Six of the ten largest cities – Ahmedabad, Mumbai, Kolkata, Delhi, Kanpur and Nagpur – have severe air pollution problems, with annual average levels of SPM at least three times as high as the WHO standard. Nationwide, over 90% of the monitoring stations for which annual mean concentrations are reported by the Central Pollution Control Board (CPCB) show particulate concentrations exceeding 75 micrograms per cubic metre, the midpoint of the WHO recommended range.

In contrast, annual average concentrations of SO₂ and NO₂ (nitrogen dioxide) in India are low in relation to typical ambient standards. However, the level of SO₂ emissions is significant since coal is the dominant fuel and approximately 200 million tonnes are consumed per year. Although Indian coal is generally low in sulphur content (around 0.5%), inefficient use causes higher emission per unit. Based on the amount of coal production, sulphur content figures and per unit emission, India’s annual SO₂ emission is estimated at three to four million tonnes.

The relative contribution of motor vehicles, industry and domestic sources to air pollution, especially to particulate pollution, are not well studied in India. Some estimates have been made of the relative contributions to PM₁₀ pollution for Mumbai. (PM₁₀ consists of particles less than 10 microns in diameter, which more easily penetrate the lungs and are therefore more relevant than total particulate matter for human health). Refuse burning and vehicle exhaust contribute more than 50% to total PM₁₀ pollution in the city (Brandon, 1995).

(ii) Ozone depletion, greenhouse gases and climate change

An important aspect of air pollution is stratospheric ozone depletion. The ozone layer is being depleted by man-made chemicals such as chlorofluorocarbons (CFCs). Bromine compounds and halons also play a large role in the thinning of the ozone layer. About one-quarter of all CFCs are used in cooling applications, the remainder being used in the production of foam, plastics and aerosols. In the Asia-Pacific region, approximately 100,000 tonnes of these chemicals are used each year, about 25% of the world’s total. Japan is the world’s second largest producer and consumer, following the United States. China and India produce or consume significant amount of CFCs, though in smaller quantities (UN/ADB, 1995).
Ozone-depleting substances have caused a rupture in the ozone layer over the Antarctic, where a hole has been observed every year since 1989. Ozone depletion has a number of adverse consequences for human health and agriculture. These include increased rates of skin cancer and eye cataracts, weakening of the immune system, damage to crops, reductions of primary producers (plankton) in the ocean, and increased air pollution. In the context of the transport sector, it may be mentioned that emissions of such gases as nitrogen oxides from airliners lead to ozone depletion effects at higher altitudes.

Climate change and sea-level rise are two very important consequences of man’s impact on the earth’s atmosphere. Human-induced climate change takes place through the greenhouse effect, a process whereby some atmospheric gases allow the energy in solar light to pass through the atmosphere but prevent some of the heat generated on the ground from radiating back to space.

Greenhouse gases (GHGs) are emitted through a number of human activities: energy production and use (including the use of energy by transport modes), land-use changes (notable deforestation), livestock raising and disposal of livestock wastes, production and use of CFCs, cement production, disposal of human sewage and municipal solid wastes, fertilizer use, and rice cultivation. CO₂ is one of the important GHGs contributing to global warming. The amount of atmospheric CO₂ has grown by nearly 30% since the dawn of the pre-industrial era (c. 1750). The transport sector contributes significantly to emissions of GHGs and discharge of CFCs, and is hence implicated in global warming.

Although knowledge of the effects of GHG emissions on the earth’s climate has increased significantly over the last two decades, there is much that remains uncertain primarily on account of the difficulty of modelling terrestrial biotic process. Similarly, measurements of net sea-level rise due to increases in global temperatures is made more difficult by ocean currents, winds and tides, besides natural changes in land and atmosphere. Nevertheless, it is certain that the mean global temperature has gone up by 0.3°C to 0.6°C since the beginning of the twentieth century and the sea-level has risen between 10 cm and 25 cm over the same period. In the course of the twenty-first century, the mean global temperature is set to rise by 2°C and the sea-level by 50 cm approximately.
Some of the physical and biological impacts of climate change are: changes in temperatures, changes in the amount and timing of precipitation, changes in plant growth rates, disastrous flooding of some island states, changes in forest cover, changes in the distribution, and changes in ocean temperature. In the case of sea-level rise, the most obvious regional (as well as global) impact is inundation of coastal lands by the higher water level of the oceans. Estimates of the extent of inundation by a one-metre sea-level rise in the region include 23,000 sq. km of land in Bangladesh, 126,000 sq. km of land in China, and significant losses of land in many other countries.

The socio-economic impacts of climate change and sea-level rise will be particularly strong in the Asia-Pacific region, which has a high percentage of the world's most densely populated coastlines as well as eight of the world's largest coastal cities. The issues connected with these impacts are: the need for resettlement, the loss of marine productivity, reduced employment for dislocated populations, increased exposure of populations to natural catastrophes, inland agricultural productivity losses, the enhancement of agricultural output due to increased atmospheric CO₂ (offsetting the declines of productivity), the need for new capital investments to maintain water supplies, loss of property through inundation, disruption in shipping traffic due to increased sea-level, adverse impacts on tourism, and adverse impacts on the storage, transport, treatment and disposal of toxic, municipal and other wastes.

Assuming a one-metre sea-level rise for India, an ADB study has worked out the economic costs of such a rise at almost Rs 185,000 crore (UN/ADB, 1995).

(iii) *Health impacts of air pollution in India*

Making use of 1991-92 data, a World Bank study obtained results for air pollution health impacts (from particulate matter, sulphur dioxide, lead and nitrogen dioxide) in 36 Indian cities where pollution levels exceed WHO guidelines (Brandon, 1995). We shall review this study in detail in the next chapter dealing with the literature on the externalities of transport. Particulate matter and sulphur dioxide are found to be responsible for over 95% of the health damages. The remaining 5% is contributed by the impact of high lead levels in a few Indian cities such as Mumbai, Kolkata and Delhi. Significant decreases in premature deaths, hospital admissions and minor sicknesses would follow from a reduction in urban pollution levels to WHO annual average standards. Premature deaths would reduce by over 40,000, hospital
admissions by over 19.5 million and minor sicknesses by over 1 billion. The economic loss resulting from these premature deaths is estimated at between $400 million and $1600 million, while the estimate of the social cost of the hospital admissions, emergency room visits, restricted activity days and minor sicknesses is $350–490 million per year.

**Transport and Environment**

Transport operations are a significant source of many atmospheric pollutants and a serious cause of noise nuisance, besides having an adverse impact on human safety. As far as air pollution is concerned, it is estimated that in the OECD states, transport contributes 48% of the total nitrogen oxide (NOX) emission, 75% of the carbon monoxide (CO) emission and 40% of the hydrocarbon (HC) emission (Button, 1993). Transport infrastructure may be visually intrusive and its construction after involves destruction of habitats and other negative effects. The environmental impact of transport ranges from local effects (concerning those living close to the area of transport operations), through trans-boundary influences (e.g. emissions from transport in one country contributing to acid rain in another country), and finally to global effects (e.g., global warming due to the emission of greenhouse gases such as carbon dioxide).

While there is no agreement on the precision of the methods used in the valuation of externalities or the results given by such methods, there is general agreement that transport-related negative environmental externalities impose considerable, economic costs on society. The estimated total external cost of road transport as a percentage of GDP in OECD countries is as follows:

- Noise - 0.10%;
- Pollution - 0.40%;
- Accidents - 2%; and
- Time loss - 6.8%.

The cost of noise pollution from other transport modes is 0.01% of GDP while the cost due to loss of time is 1.7% (Button and Rietveld, 1999). Transport in developing countries is estimated to account for about 4% of global emissions of carbon dioxide (Button, 1993 a). Estimates suggest that they contribute about 30% of
global emission of three harmful toxic pollutants – i.e. carbon monoxide, nitrogen oxide and hydrocarbon and a greater proportion of lead and diesel particulates on account of the low quality of fuel used, old engines and a higher share of diesel vehicles. Transport is generally less safe in low-income countries; it has been estimated that costs imposed by traffic accidents run between 1% and 2% of GNP in developing countries.

The effects of transport on the environment are complex. These extend from the normal use of transport to the implications of both vehicle and infrastructure construction. For example, road building disrupts the natural environment and requires large quantities of stone, aggregate and bitumen, the extraction of which generate their own negative environmental effects. The construction of rolling stock necessitates the use of steel in large amounts and has particular implications for the environment. Air pollution is a serious consequence of transport operations, especially with regard to surface transport. Simple effects of such pollution cover both the short and long term, and are due to the concerned pollutants before their chemical transformation in the atmosphere. Indirect effects take place after a mixture of pollutants has been subjected to atmospheric transformation. In this regard, the most serious problem concerns photochemical oxidants formed by chain reaction between unsaturated hydrocarbon and other reactive organic compounds, nitrogen oxides and oxygen in the presence of sunlight.

Different modes of transport affect the environment in different ways. The environmental problems concerning each mode have their own particular characteristics. The problems surrounding surface transport are different from those related to maritime and air transport. The main problem of maritime transport centres on the potential spillage of oil and other toxic material from ships, leading to on drive pollution and shoreline damage. The negative effects of air transport are primarily noise and accident. Surface transport (road and rail) causes a variety of environmental impacts which differ with respect to type of vehicle, geographical area, traction energy, public or private transport, etc. In the table below, we present selected environmental effects of the principal transport modes.

Many of the environmental costs of transport are not internalised. Hence of the benefits of transport service are often not so great as they appear. We now discuss some of the principal environmental costs of transport systems with special reference to India (UN/ADB, 1995 and Button, 1993a).
### Table 1.1
Selected Environmental Effects of Principal Transport Modes

<table>
<thead>
<tr>
<th></th>
<th>Marine and Inland Water Transport</th>
<th>Rail Transport</th>
<th>Road Transport</th>
<th>Air Transport</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air</strong></td>
<td>Air pollution in populated areas, global pollution from thermal generating stations for electric traction</td>
<td>Air pollution (CO, HC, NOX, Particulare &amp; fuel additives such as lead), global pollution (CO2, CFCs)</td>
<td>Air pollution, greenhouse &amp; ozone depletion effects at higher altitudes due to NOX emissions</td>
<td></td>
</tr>
<tr>
<td><strong>Water Resources</strong></td>
<td>Discharge of ballast water, oil spills, etc. of modification water systems during port construction &amp; canal cutting and dredging</td>
<td>Pollution of surface and ground water by surface run-off; modification of water system by road building</td>
<td>Modification of water tables, river courses and field drainage in airport construction</td>
<td></td>
</tr>
<tr>
<td><strong>Land Resources</strong></td>
<td>Land taken for infrastructures; dereliction of obsolete port facilities &amp; canals</td>
<td>Land taken for right-of-way and terminals; dereliction of obsolete facilities</td>
<td>Land taken for infrastructures; extraction of road building materials</td>
<td></td>
</tr>
<tr>
<td><strong>Solid Waste</strong></td>
<td>Vessels and craft withdrawn from service</td>
<td>Abandoned lines, equipment and rolling stock</td>
<td>Abandoned spoil tips and rubble from road withdrawn from service; waste oil</td>
<td></td>
</tr>
<tr>
<td><strong>Noise</strong></td>
<td>Noise &amp; vibration around terminals and railway lines</td>
<td>Noise and vibration from cars, motorcycles &amp; lorries in cities &amp; along main roads</td>
<td>Noise around airports</td>
<td></td>
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<tr>
<td><strong>Risk of Accidents</strong></td>
<td>Bulk transport of fuels and hazardous substances</td>
<td>Derailment or collision of freight trains carrying hazardous substances</td>
<td>Deaths, injuries &amp; property damage due to road accidents; risk in the transport of hazardous substances; risk of structural failure in old or worn road facilities</td>
<td></td>
</tr>
<tr>
<td><strong>Other Impacts</strong></td>
<td>Partition or destruction of neighbourhoods, farmland and wildlife habitats</td>
<td>Partition or destruction of neighbourhoods, farmland and wildlife habitats; congestion</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: UN/ADB (1995), 'State of the Environment in Asia and the Pacific'

(a) **Effects on Natural Resources**

The consumption of forest, agricultural and urban land by transport infrastructure causes stress on already scarce land resources. The inevitable loss of precious land is accompanied by the possibility of soil erosion and adverse impact on water tables, river courses, field drainage, flora and fauna. Evidence suggests that due consideration is not given in the construction of transport infrastructure to the adverse effects of the removal of topsoil and nutrients on fragile ecosystems. In
addition, the obstruction and restriction of the free flow of streams and rivers resulting from such construction have serious environmental and ecological consequences. Landslides and soil instability result from both soil cutting and filling in the process of building roads, rail lines, etc., besides deforestation to clear land.

The manufacturing of transport vehicles involves energy and mineral consumption, emission of pollutants, and generation of waste. A study in Japan shows that for an average-sized passenger car weighing 1 tonne, having 12 km per litre fuel efficiency, and with a life-span of 100,000 km, the amount of carbon discharged on account of fuel consumption over the lifetime of the car is expected to be around 5.3 tonnes, of which 86.6% is due to locomotion, 8.7% material processing and 4.7% assembling.

The transport sector is a major consumer of fossil fuel reserves, which are becoming increasingly scarce and on which various sectors make competing demands. The share of the transport sector in the total domestic energy consumption in the developing countries is quite significant, being as high as 39% and 33% respectively for such countries as Thailand and Malaysia in 1997 (from data compiled by the International Energy Agency and reported in World Resources Institute, 2000). In India, the share was around 12% in 1997. The share of transport fuel consumption (motor spirit and high-speed diesel consumption) in the total consumption of petroleum products was nearly 50% in 1998-99 (GOI/Ministry of Petroleum and Natural Gas, 2000-01). In the same year, the transport sector in India consumed about 32 million tonnes of high-speed diesel oil, which was 87% of the total domestic consumption of this fuel. Besides the main petroleum fuels like gasoline, diesel and jet fuels, the share of coal, which is the most polluting fuel, is significant in both China and India when account is taken of the fact that electricity for tractive power in transport is largely generated in thermal power stations using coal as heat input. The replacement of conventional fossil fuel by electricity in railways in India is therefore not necessarily a beneficial trend.

(b) Effects on urban air quality

The unceasing growth in motor vehicles means a greater discharge of polluting emissions into the environment. Although every mode of transport causes some form of air pollution, the operation of road vehicles is the most deleterious source of such pollution. Railways and maritime transport are not in general associated with serious problems of air pollution since their pollution loads are
spread over wide areas. Road vehicle movement is usually confined to urban centres, which are already densely crowded and congested. In addition, the nature of the vehicles in use and the quality of fuel contribute further to the intensity and severity of pollution.

The burning of fossil fuels in combustion engines results in the emission of a multitude of pollutants such as carbon monoxide, lead, oxides of nitrogen, sulphur dioxide, hydrocarbons, photochemical oxidants responsible for the production of ozone, suspended particulate matter and other toxic substances as well as carbon dioxide and methane. Table 1.2 summarises the health effects of major pollutants from motorised engines.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Health Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>Affects circulatory, reproductive, nervous and kidney systems; suspected of</td>
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<tr>
<td></td>
<td>causing hyperactivity and lowered learning ability in children; hazardous</td>
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<tr>
<td></td>
<td>even after exposure ends. (Lead is injected through the lungs and</td>
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<tr>
<td></td>
<td>gastrointestinal tract)</td>
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<tr>
<td>Particulate matter</td>
<td>Irritates mucous membranes and may initiate a variety of respiratory</td>
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<td></td>
<td>diseases; fine particle may cause lung cancer and exacerbate morbidity and</td>
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<tr>
<td></td>
<td>mortality from respiratory dysfunctions. A strong correlation exists between</td>
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<td></td>
<td>suspended particulates and infant mortality in urban areas. Suspended</td>
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<tr>
<td></td>
<td>particulates have the ability to adhere to carcinogens emitted by motor</td>
</tr>
<tr>
<td></td>
<td>vehicles</td>
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<tr>
<td>Carbon monoxide</td>
<td>Interferes with absorption of oxygen by haemoglobin (red blood cells);</td>
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<tr>
<td></td>
<td>impairs perception and thinking, slows reflexes, causes drowsiness, brings</td>
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<td></td>
<td>on angina, and can cause unconsciousness and death; it affects fetal growth</td>
</tr>
<tr>
<td></td>
<td>in pregnant women and tissue development of young children. It has a</td>
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<td></td>
<td>synergistic action with other pollutants to promote morbidity in people with</td>
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<tr>
<td></td>
<td>respiratory or circulatory problems; it is associated with reduced worker</td>
</tr>
<tr>
<td></td>
<td>productivity and general discomfort</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>A harsh irritant; exacerbates asthma, bronchitis and emphysema; causes</td>
</tr>
<tr>
<td></td>
<td>coughing and impaired lung functions</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>Can increase susceptibility to viral infections such as influenza; irritate</td>
</tr>
<tr>
<td></td>
<td>the lungs and cause oedema, bronchitis and pneumonia; and results in</td>
</tr>
<tr>
<td></td>
<td>increased sensitivity to dust and pollen in asthmatics. Most serious health</td>
</tr>
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<td></td>
<td>effects are in combination with other air pollutants.</td>
</tr>
<tr>
<td>Hydrocarbons</td>
<td>Low molecular weight compounds cause unpleasant effects such as eye</td>
</tr>
<tr>
<td></td>
<td>irritation, coughing and sneezing, drowsiness and symptoms akin to</td>
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<tr>
<td></td>
<td>drunkenness; heavy molecular weight compounds may have carcinogenic or</td>
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<tr>
<td></td>
<td>mutagenic effects. Some hydrocarbons have a close affinity for diesel</td>
</tr>
<tr>
<td></td>
<td>particulates and may contribute to lung disease.</td>
</tr>
<tr>
<td>Ozone precursors (hydrocarbons</td>
<td>Irritates mucous membranes of respiratory system causing coughing,</td>
</tr>
<tr>
<td>and nitrogen oxides)</td>
<td>choking and impaired lung function; causes eye irritation, headaches and</td>
</tr>
<tr>
<td></td>
<td>physical discomfort; reduces resistance to colds and pneumonia; can</td>
</tr>
<tr>
<td></td>
<td>aggravate chronic heart disease, asthma, bronchitis, and emphysema.</td>
</tr>
<tr>
<td>Toxic substances</td>
<td>Suspected of causing cancer, reproductive problems, and birth defects.</td>
</tr>
<tr>
<td></td>
<td>Benzene and asbestos are known carcinogens linked to leukaemia and lung</td>
</tr>
<tr>
<td></td>
<td>cancer; aldehydes and ketones irritate the eye, cause short-term respiratory</td>
</tr>
<tr>
<td></td>
<td>and skin irritation and may be carcinogenic</td>
</tr>
</tbody>
</table>

Source: UN/ADB (1995), 'State of the Environment in Asia and the Pacific'
High lead concentrations in urban centres are primarily the result of vehicles using gasoline with lead content. Lead is emitted along with exhaust gases and contaminates the atmosphere causing potential health risks. Hydrocarbons released by motor vehicles such as benzene are human carcinogens. Emissions of nitrogen oxides irritate the lungs and aggravate conditions such as asthma. Additionally, they inhibit crop growth and contribute to acid rain. The combination of hydrocarbons and nitrogen oxides in the presence of sunlight forms ozone, a key ingredient of urban smog and a danger to both human health and local vegetation. Particulate matter, heavily emitted by diesel-driven vehicles, impairs respiration and visibility and act as a vector for airborne carcinogens into the lungs. Sulphur dioxide seriously affects human respiration, besides causing acid rain. Carbon monoxide, lead and hydrocarbons are mostly emitted by gasoline engines, while particulate matter and sulphur dioxide are emitted by diesel engines, and nitrogen oxides by both types of engines.

In cities of developed, newly industrialised and rapidly developing countries, where the density of private passenger vehicles mostly operated with gasoline is rapidly growing, gasoline-based pollutants are dominant. On the other hand, in cities of developing countries, the most common form of air pollution is suspended particulate matter and sulphur dioxide emitted mainly by poorly maintained diesel vehicles. In most of the major cities of the developing world, road transport accounts for a major share of air pollution load; in Delhi, the figure is around 60%. The amounts of pollutant discharge (in tonnes/year) in Delhi in 2000-01 were estimated to be as follows: carbon monoxide, 286.33 tonnes; hydrocarbons, 116.39 tonnes; lead, 0.17 tonne; nitrogen oxides, 25.70 tonnes; sulphur dioxide, 3.63 tonnes; and suspended particulate matter, 0.58 tonne (UN/ADB, 1995).

(c) **Effects on the global environment**

Emissions from motor engines have their impact not just on the local environment and economies, but also on the global ecosystem. In 1995 motor vehicles accounted for 14% of world emissions of carbon dioxide – the primary greenhouse gas implicated in global warming. Nitrogen oxides and hydrocarbons act together to form ozone, also a greenhouse gas. The presence of carbon monoxide, a significant motor vehicle emission, can lead to a longer lifetime and a higher ambient concentration of methane, another greenhouse gas. Finally, chlorofluorocarbons leaked from air-conditioners used in transport are not only greenhouse gases, but also the main cause of atmospheric ozone depletion.
Increasing attention has been focused on environmental pollution due to civil aviation, especially high altitude air pollution. Significant amounts of carbon dioxide, water vapour, nitrogen oxide, and sulphur dioxide are produced in the burning of aviation fuel. Apart from contributing significantly to stratospheric ozone depletion, it has been estimated that the emissions of nitrogen oxides from air traffic are likely to raise tropospheric-level ozone and are responsible for 8% of the global warming potential of greenhouse gases.

(e) **Effects on coastal and marine environments**

Port and harbour projects have impacts on sensitive coastal ecosystems. Their construction significantly affects hydrology and surface water quality in the coastal zones. Developing countries are rapidly expanding their port capacities and undertaking dredging operations for the maintenance of the existing port facilities. These activities can be expected to create a host of impacts on the coastal environments of these countries. Shipping is a major contributor to the pollution of the open seas. Surveys of oil spills and tar balls on the oceans indicate concentrations occurring along the routes of heaviest tanker traffic. In addition to petroleum and refined oil products, hazardous cargoes transported by sea include sulphur, fertilisers, petro-chemicals, caustic soda, acids, pesticides, and weed killers, all of which pose serious threats to the marine environment as a result of shipwrecks and collisions. It is estimated that globally around 3.2 million tonnes of oil reach the sea annually as a result of human activity, of which 47% comes from marine transportation. When large tanker spills take place on or near the coast, the resulting extensive oil slicks destroy sea birds and marine mammals and cause immense damage to shell fisheries and coastal amenities. Tar is deposited along the west coast of India at a rate of 1000 tonnes a year. The frequency of shipping accidents causing large-scale oil spill is increasing along major shipping routes, especially in Asia.

(f) **Disposal of wastes**

Transportation creates problems related to the disposal of wastes from a variety of sources. Though not a major issue in terms of magnitude in developing countries, this can have serious implications especially in view of the increasing practice of replacing traditional metals in manufacturing of vehicles with composite materials. A 10% plastic content is common in cars, while some estimates suggest a figure of 25%. The large variety of chemicals involved in the production of composite...
materials makes their recycling impossible, leaving large-scale polluting incineration as the only means of disposal. Air conditioning is now becoming increasingly standard equipment; chlorofluorocarbons in air conditioners are released when vehicles are destroyed. The waste-managing capabilities of most developing countries are inadequate in handling the complexities involved in the disposal of a vehicle. Abandoned infrastructure facilities such as rail lines and obsolete ports, though partly recyclable, generate solid wastes, besides affecting the aesthetics of local environments. Airports and harbours often have inadequate waste reception and treatment capacities and this, together with poor environmental monitoring and management, contributes to the waste disposal problem.

**Issues in Environmental Economics and Transport Policy**

Environmental economics is concerned with the study of economic activity in relation to the natural environment. Its objectives are, among other things, to understand the precise impact of environmental change and valuation of economic resources and to analyse schemes for environmental welfare through the regulation of economic activity while keeping in view various conflicting objectives. Among the various issues that are dealt with in environmental economics are the following: market failure in the presence of public bads and externalities, property rights, Pigouvian taxes, the regulation of pollution, emission fees and marketable permits, environmental regulation and its economy-wide effects, the demand for environmental benefits, and surrogate markets for environmental valuation (Kolstad, 2000). Environmental economics is especially relevant to the transport sector because of the fact that the prices of services in transport markets do not reflect the peculiar and specific externalities of each mode of transport. A social optimum does not hold and there is a classic case of market failure. For example, the road user is often not charged for the infrastructure that he makes use of, nor for the congestion, pollution, noise and accidents that he causes. The rail user may be discouraged from using rail services for certain commodities, where higher rates are used to cross-subsidise passenger traffic even though greater use of rail freight would promote environmental and social welfare. In the presence of market failure, the principles of environmental economics suggest a number of ways in which the social optimum might be brought about. These policy instruments are broadly of two kinds: command-and-control and market-based.
Command-and-control involves the imposition by the government on a firm or sector of specific requirements in order to reduce the impact of such negative externalities as pollution. Specific pollution-control equipment requirements may be specified for power plants. Or an emission limit may be imposed for particular types of plants and particular pollutants. An example is the US standards for new automobiles, which require every new car to emit no more than a specified amount of carbon monoxide per mile driven through the installation of a specific technology. All new cars are further required to have a specifically designed system for capturing vapour that might escape from the gasoline tank during refuelling (Kolstad, 2000). Command-and-control measures have the advantage of greater flexibility in the regulation of complex environmental processes and greater certainty as to how much of negative externalities will remain. On the other side, such measures involve restricted choice for the polluter as to the means of achieving an environmental target and are often more costly since marginal costs are not equalized among several different polluters.

Market-based policy instruments involve economic incentives which give more choice to the firm. They fall into three main categories: emission fees, marketable emission permits, and liability rules. A classic example of an emission fee is the Pigouvian fee, which is a charge per unit of pollutant generated, set equal to the marginal damage of pollution, at the efficient level of pollution generation. Marketable emission permits involve the government selling or giving away permits to pollute, which may be traded among polluting firms. Liability rules involve holding polluters liable for any damage they may cause; these are particularly useful for regulating risky activities that lead to occasional accidents (Kolstad, 2000). Such market-based instruments help to keep the costs of control of adverse externalities low and also to promote innovation.

The present thesis studies the environmental impacts of the rail and road modes of transport, and within the road mode, the impacts of different road vehicles. Apart from the physical impact of externalities in the form of emissions of noxious pollutants, it estimates the monetary damage of negative externalities. The thesis works out the true social costs of the alternative modes of transport and concludes by recommending appropriate policy measures to correct the impact of negative externalities and bring about a social optimum.
The Problems and Objectives of the Current Study

Our overview of the environmental effects of transport shows that these are varied and complex, while differing from mode to mode. In this context, studies carried out abroad (to be reviewed in Chapter 2) have found that the rail mode enjoys a superiority over the road mode in terms of lower adverse environmental and social impact. The share of rail in total traffic has generally been on the decline all over the world, including India. In the light of the environmental and social cost advantages which the rail mode is said to hold over the road mode, such a fall in its share of total transport output implies a serious challenge for any policy aiming at sustainable transport, which may be defined as one that seeks to use resources for transport services in such a manner as to maximise the social benefits of transport for both the current and future generations.

The current study is concerned with the issue of rail and road competition in India and the relative impact on the social costs of the two modes of transport. The problems under consideration are the following:

(i) why, in India, the modal share of rail in relation to that of road is diminishing for both passenger and goods traffic;
(ii) to determine the ranking of the two modes in terms of the social impact of transport; and
(iii) whether the current trend of modal shares of the two modes is in accordance with the above ranking.

The thesis may be broadly divided into two parts, the first being an econometric analysis of the factors determining modal split between rail and road in India, and the second being concerned with the estimation of the financial and social costs of the rail and road modes of transport. In the current study, the social cost of transport includes financial costs, on the one hand, and external costs such as the cost of health damage due to air pollution and the cost of accidents, on the other.

The objectives of the study may then be stated as follows: (i) to identify the factors responsible for the current modal split between rail and road in India in respect of both passenger and freight traffic; (ii) to rank the social impact of the two modes in terms of their external and social costs and determine the modal mix with
the least socially adverse impact; and (iii) to arrive at definite policy conclusions regarding sustainable transport policy in the country.

Methodology

To fulfil these objectives, the thesis makes use of data from a sample of eight sections in the country where the rail and road modes are in competition. Data on traffic flows in these sections has been obtained from the road transport ministry and the specific railway zones. In order to explain the trend of modal shares in India, we construct for every section a time-series of rail and road passenger and freight traffic, and such explanatory variables as the cost difference or the cost ratio between the two modes. The user costs for the rail mode are worked out by using information on passenger and freight earnings by the zonal railways, while in the case of the road mode, vehicle costs per kilometre are worked out on the selected road sections both for passenger and freight movement. The information is pooled to make a panel data set on which appropriate econometric estimation procedures may be carried out. Chapter 4 sets out in detail the methodology, problems and results of this exercise.

The estimation of the environmental and social impact of rail and road in India again makes use of the data on the eight sample sections. Equivalent volumes of passenger and freight traffic are worked out on each of these sections for both the modes. The implications of inter-modal shifts of these volumes are studied in terms of changes in overall energy consumption and air pollution from the transport sector, as well as variations in financial, health damage and accident costs due to transport activities. These costs of transport are worked out by using information from a number of sources and making appropriate adjustments. The procedure is described in detail in the succeeding chapters. The issue of market failure is found to be crucial in the context of the transport sector. Accordingly, we take up this issue eventually and look at appropriate policy initiatives to promote social welfare.

Plan of the Thesis

Having reviewed the general nature of environmental problems and the special-environmental impacts of transport, we shall in the next chapter (chapter 2) review the literature on transport and its external costs with particular reference to rail and road. Chapter 3 will review the trend of modal shares of these two modes in India. Chapter 4 will deal with the econometric analysis of this trend in modal shares.
In chapter 5, after describing the methodology and database for the estimation of the environmental and social impacts of transport, we deal with the relative position of road and rail in respect of energy consumption and air pollution. The financial costs of transport operations are discussed in chapter 6, while the external costs of transport (health and accidents costs) are dealt with in chapter 7. Finally, in chapter 8 we summarize the results of the study and set out the conclusions while discussing transport policy in the context of rail and road competition.