UNIT – III (18MAG43C)

Transport Policy and Planning – Urban transportation: growth and problem – transport and environmental degradation - Alternative to transport system in mega cities of India - Flow Models – Network Structure – Gravity Model.

Transport Policy and Planning: *Transport policy tries to make decisions concerning the allocation of transport resources while transport planning is their effective implementation.*

1. Policy and Planning:

The terms "policy" and "planning" are used very loosely and are frequently interchangeable. However, substituting one for the other is misleading. Policy and planning represent separate parts of an overall process of intervention. There are circumstances where policy may be developed without any direct planning implications, and planning is frequently undertaken outside any direct policy context. However, precise definitions are not forthcoming, and the following are suggested:

Transport policy deals with developing a set of constructs and propositions that are established to achieve specific objectives relating to social, economic, and environmental conditions, and the functioning and performance of the transport system.

Transport planning deals with the preparation and implementation of actions designed to address specific problems.

The goal of transport policy is to make effective decisions concerning the allocation of transport resources, including the management and regulation of existing transportation activities. Governments also often perceive that it is their role to manage transport systems due to the essential public service they provide in addition to impose a regulatory framework.Yet, many transport systems, such as maritime and air transportation, are privately owned with firms servicing international markets that able to set their own policy. However, there are substantial geographical variations in ownership with the United States having a history of private involvement while ***Europe, China, India, and Japan*** have more relied on public ownership and operations. The standard rule is that the public sector usually provides transport infrastructure and the regulatory framework while the private sector assumes the provision and operations of many modes and terminals.

Public policy is the means by which governments attempt to reconcile social, political, economic, and environmental goals and aspirations with reality. These goals and expectations change as the society evolves, and thus a feature of policy is its changing form and character. Policy tends to be dynamic and evolutionary.

A major distinction between planning and policy is that the latter has a much stronger relation with legislation. Policies are frequently, though not exclusively, incorporated into laws and other legal instruments that serve as a framework for developing planning interventions.

Planning does not necessarily involve legislative action and is more focused on the means of achieving a particular goal, often within the existing regulatory framework.

2. The Relevance of Transport Policy

Transport policies arise because of the importance of transport in virtually every aspect of economic, social, and political activities of nation-states. Transport is taken by governments of all inclination, from those that are interventionalist to the most liberal, as a vital factor in economic development. Transport is seen as a key mechanism in promoting, developing, and shaping the national economy. Transport frequently is an issue in national security. Policies are developed to establish sovereignty or to ensure control over national space and borders. The Interstate Highway Act of 1956, which provided the United States with its network of expressways, was formulated on the grounds of national security. Security was at the heart of the more recent impositions regarding passengers or freight clearance taking place at the port of departure in addition to conventional clearance occurring at the port of entry.

Transport policy has been developed to prevent or control the inherent monopolistic tendency of many transport modes. Unrestrained competition commonly leads to market dominance by a company, thereby achieving (close to) monopoly power. Such dominance brings into question many issues affecting the public interest such as access (smaller actors prevented to access infrastructure), availability (smaller markets being less serviced, or services being discontinued) and price (the monopolist being able to charge high prices).

In recent years, four trends had significant consequences over the context in which the transport policy takes place:

Globalization increased interactions at the international level, both for freight and passengers. This led to the emergence of large actors managing a portfolio of modes and infrastructures across international jurisdictions and therefore dealing with a variety of transport policies and regulations. Deregulation and privatization have been ongoing in many transport markets. This enabled the transfer of ownership and operation of many transport modes to the private sector and favored the entry of new actors. This was particularly the case of the airline industry. A broader focus of policies, particularly considering intermodalism and multimodalism, as well as logistics.

A move towards social and political issues behind transport projects as opposed to technical and engineering issues. The policy process is becoming more responsive towards public concerns over issues such as environmental externalities and social equity. However, this has also been linked with additional costs, delays, and controversy of many large transportation projects.

3. Policy Instruments

Governments have a large number of instruments at their disposal to carry out transport policy. Some are direct, such as public ownership, but the majority are indirect, such as safety standards. The most common are:

A vital instrument concerns public ownership. The direct control by the state of transportation infrastructure, modes, or terminals is widespread. Most common is the provision by public agencies of transport infrastructure such as roads, ports, airports, and canals. Public ownership also extends to include the operation of transport modes such as airlines, railways, ferries, and urban transit by public agencies.

Subsidies represent an important instrument used to pursue policy goals. Many transport modes and services are capital intensive, and thus policies seeking to promote services or infrastructure that the private sector is unwilling or unable to provide may be made commercially viable with the aid of subsidies. Private railroad companies in the Nineteenth Century received large land grants and cash payments from governments anxious to promote rail services. In the United States, the Jones Act, which seeks to protect and sustain a US-flagged merchant fleet, subsidizes ship construction in US shipyards. Indirect subsidies were offered to the air carriers of many countries in the early years of commercial aviation through the awarding of mail contracts. Dredging of ship channels and the provision of other marine services such as pilotage and navigation aids are subsidies to facilitate shipping. Most public transit systems are subsidized to provide mobility since full cost recovery would make fares unaffordable to the poorer segments of the population. Both public ownership and subsidies represent instruments that require the financial involvement of governments. Revenue generation is becoming an increasingly important instrument in transport policy.

4. Policy Development

Public policies reflect the interests of decision-makers and their approaches to solving transport problems. These interests and approaches are both place-specific (they apply to a particular area of jurisdiction) and time-specific (they are established to reflect the conditions of transport and the intended solutions at a point in time). Policies are dynamic. They change and evolve as circumstances change, and as new problems are recognized. The dynamic nature of policymaking is reflected in the way the policy instruments have been employed over the years. In the 19th Century, when many of the modern transport systems were being developed, the prevailing political economy was one of laissez-faire, in which it was believed that the private sector should be the provider of transport services and infrastructure. Historical examples of private transport provision include:

Turnpikes. The first British modern roads in the 18th century were the outcome of private trusts aiming a deriving income from tolls on roads they built and maintained. It was likely the first massive private involvement in transport infrastructure provision.
Canals. Many of the earliest canals were built with private capital. One of the first canals that helped spark the Industrial Revolution in Britain was the Bridgewater Canal.
Urban transit. In most North American cities, public transit was operated by private firms. The earliest examples were horsecars that followed rail lines laid out on city streets. With electrification at the end of the 19th century, the horsecars were converted to streetcars, and the network was greatly expanded. In the 20th century, busses were introduced by private companies operating on very extensive route systems.

This situation was not entirely without public policy involvement, however. The massive subsidies that were granted to North American railroads are an example of state intervention. In the early 20th century, the overprovision of rail lines (rail manias), competition between carriers, and market failures led to a crisis in many parts of the transport industry, particularly after 1918. This led to a growing degree of government involvement in the transport industry, both to offset market failures, jurisdictional conflicts and to ensure that services could be maintained for the sake of the "public good":

Government-owned railroads still exist in France, Germany, Italy, and Spain, but the tracks have been separated from the traction and rail service operations and have been opened to new service providers. In Latin America, most of the state-owned transport sector has been deregulated. While the former centrally planned states have had to make the furthest adjustments to a more open market economy, several, such as China, have opened large sections of the transport industry to joint ventures with foreign private enterprises. In China, many new highways and most of the major ports have been developed with private capital. Thus, at the beginning of the 21st Century, transportation is under less direct government economic control worldwide than at any period over the last 100 years.

5. Changing Nature of Policy Interventions

The trends in transport policy in recent decades have been towards liberalization and privatization. This has not necessarily weakened the role of governments and their interventions over transportation. Controls over monopoly power are still in place, and even in the most liberal of economies, there is still strong evidence of public policy intervention:

Ownership of ports and airports. Terminals continue to be largely under State or municipal ownership, but concession agreements to private operators are common.

Highway provision, upgrade, and maintenance remain one of the most significant and enduring commitments of public funds.

Urban transit systems remain dominantly publicly owned and operated. Intercity transport is mostly private, which brings the question about if urban transportation would gain to be privatized.

Mergers and acquisitions between large private or public entities in the transport sector are commonly subject to regulatory approval.

Government policy orientations have changed, however. Governments are beginning to exert greater control over environmental and security concerns, issues that are replacing former preoccupations with economic matters. For instance, because of biofuel policies aiming at ethanol production using corn, the unintended consequence was a surge of global food prices as more agricultural land was devoted to energy production instead of food production. Sustainability and the environment are becoming a significant issue for government intervention. Coastal zone legislation has made it increasingly difficult for ports to develop new sites. Air quality is a significant factor influencing the allocation of US federal funds for urban transport

infrastructure. In Europe, environmental issues are having an even greater influence on transport policy. The EU Commission is promoting rail and short sea shipping as alternatives to road freight transport. Projects are assessed based on CO2 reduction. All transportation projects are subject to extensive environmental assessments, which may lead to delays and even a rejection of proposals, despite strong economic justification. As a major source of atmospheric pollution and environmental degradation, the transportation industry can anticipate further government environmental policy interventions.

Safety has always been a policy issue. Legislation imposing speed limits, mandating seat belts, and other measures have sought to make travel safer. These continue to proliferate. However, it is the area of security that the most recent set of policy initiatives have been drawn. Screening of people and freight has become a major concern since 9/11. Both the US government and such international organizations as the International Maritime Organization (IMO) and the International Civil Aviation Authority (ICAO) have instituted new measures that impact operations and represent additional costs to the transport industry.

6. Logistics Policies

To better adapt to the growing complexity of the transportation system, there has been an emerging shift in transportation policy towards a set of logistics policies. They cover a wider range of activities, such as transportation modes and terminals, warehousing, and manufacturing. The emerging preponderance of logistics is challenging the scale (integrating global, regional, and local considerations) and scope (across modes) of transport policy, which needs to be expanded into a more comprehensive framework. However, this expansion must consider specific policy challenges:

Cross-sectorial issues. Logistics brings within the realm of policy several actors outside the transport sector that policymakers are not well prepared to deal with. For instance, supply chain management involves transportation, distribution, and manufacturing aspects, which are conventionally considered as separate sectors. Thus, the cross-sectorial characteristics of logistics require new information and knowledge to support public policy.
Cross-jurisdictional issues. Logistics brings complex relationships and linkages across several functional (such as modes) and geographical jurisdictions. Standard transport policy is commonly articulated around modes that are viewed as independent and subject to well-defined jurisdictions (e.g. specific ministries). The cross-jurisdiction characteristics of logistics require new realms of engagement and intervention of public policy.

Transnational actors. Many actors supporting logistics have a strong transnational presence, operating in several countries and regions of the world. This is particularly the case for 3/4PLs, which are highly globalized entities. These actors often have more leverage than the public authorities they interact with, particularly when it involves setting concessions. The transnational character of logistics requires the consideration of trade and transactions as a policy issue. Considering these challenges, logistics and public policy can interact over three main pillars, each offering a realm of potential intervention; actors (who controls and manage logistical activities?), operations (what are the logistical activities being performed?), and outcomes (how the logistics performance meet the criteria of the industry?). Each pillar

underlines to what extent its components are effectively meeting national goals or the requirements of the industry. Are customs procedures effective? Is there enough capacity at terminals and connectors to meet existing and anticipated needs? Is the workforce sufficient and adequately trained to meet the need of the industry? Is the public sector able to manage effectively its regulations?

Shortcomings over any of these issues should be investigated and trigger appropriate policy response. A common observation is that logistics policy should avoid directly dealing with operational issues since these aspects should ideally be addressed by the private sector. Public policy should remain an enabler and support for logistics activities, not a provider of logistics services unless these services are substantially inadequate. Logistics policies fill an essential gap in coordinating the development of transport infrastructure and the economic activities that generate commercial and trade flows. They are mainly articulated around:

- Improving trade facilitation through the simplification, harmonization, and standardization of trade procedures and the setting of free zones.
- Improving the global interface of logistics with gateways, corridors, and hinterland accessibility strategies.
- Providing a land base for logistics infrastructures and activities with the setting of logistics zones and inland ports.
- Developing human resources in logistics by expanding labor and logistical services skills.
- Supporting digitalization such as freight portals (single windows) and port community systems.
- Developing sustainable niche logistics activities with infrastructures and services promoting unique comparative advantages, including green logistics strategies.
- Improving last-mile logistics with city logistics. Many final deliveries are taking place in a congested context with difficulties to access the final destination, including parking.

Governments are facing the challenge of coordinating logistics policies since the governance structure of many organizations focuses on specific infrastructure, modes, and locations. This can require the setting of new governance structures with a focus on logistics or the development of a consortium regrouping the key stakeholders.

Urban transportation

Transportation management is a major part of urban planning and development. Urban areas worldwide are rapidly expanding and so is the urban population. Urban planning majorly impacts how much a city supports business growth, and of which transportation management has a key role to play. City transportation influences per capita expenditure and revenues to a large extent and thus a country’s GDP. If examples are to be drawn from my home country, Mumbai owes much of its business capital status to a well-laid out public transportation management. And Bangalore is known for its inability of city planning to cope with a sudden and prolific growth of IT establishments. Typical man-hours spent in traffic in a day, traffic hazards and the pollution levels, following which the livability depend on traffic modes and sizes in the city; additionally the pride value of a city and the country lies with traffic behavior along with other factors.

Urban travel demand has been continuously growing in both developed and developing countries. Overall population growth and increasing urbanization have led to rapid growth of large cities, which are crippled by the sudden rise in travel demand. The supply of transport infrastructure and services, by comparison, has lagged far behind demand. Land prices and rental rates also escalate in city centers, which force establishments and housing to move to the city peripherals and thus further increasing everyday commuting. Certain developed countries have been quite successful in keeping traffic demands in checks. Some policies also appear as unfriendly towards private vehicle ownership/usage:

1. Some developed countries do not attempt to decongest city centers. High rise buildings are allowed in every part of the city, so that establishments and residential properties are available within city limits. This is in sharp contrast to the Indian scenario. In India, a typical (Floor space index) FSI of 1.5 is imposed in cities, as against other Asian countries that allow an FSI of 5 to 15.

2. A high premium is imposed on owning and using private vehicles within city centers, in terms of congestion charges. This may include vehicle registration, excise duty, oil duty, toll prices, parking levies and also charges based on carbon emissions, such as in London.

3. High fuel prices, high ownership and maintenance prices of private vehicles, combined with buyer-unfriendly automobile industry discourage private vehicle ownerships.

4. Several cities provide totally free public transport. Hasselt (Belgium) had free public transportation until recently. A zero-fare public transport has been recently implemented in Estonian capital Tallin since January 2013. An efficient feeder network and proper integration of multi-modal traffic encourage public transport utilization.

Many of the above are a distant reality in developing countries, where unorganized sector of public transport, such as auto rickshaws, tumtums, non-motorized cycle rickshaws, shared private vehicles, chartered travel also vie in the business. However it is predicted that by the mid-century Asia and Africa will peak in urbanization with 54% of Asia and 20% of Africa living in urban areas and a no less of 70% worldwide. The table below is extracted from a UN report which gives an insight into future urban population growth and thus can be a proportional estimate of urban traffic demand.

- *Existing problems in urban transportation planning and management are many. A few from the Indian transport sector are listed below.*

  - Billions of man hours are lost in a “stuck in traffic” excuse. As an example, in two decades between 1981 to 2001, the population of six major metropolises in India increased by about 1.9 times, whereas the number of motor vehicles went up by over 7.75 times during the same period.

  - The cost of travel has increased considerably, especially for the economically lower class. Non-motorized modes such as cycling and walking have become

non-existent or extremely risky, since there is no right of way for these modes. Lower rents and land prices led to extended city peripheries that increase travel distances, thereby forbidding non-motorized modes.

- Number of road accidents has increased from 160,000 in 1981 to 390,000 in 2001; of which fatalities increased from 28,400 to 80,000.

- Increased use of private vehicles and lack of strict and periodic emission checks and control have led to increased carbon emissions and noise pollution. This results inunhealthy air quality and thus public health impairment.

- Road infrastructure is of poor quality and hence already diminishing non-renewable petroleum resources are exhausted in a staggering manner.

- Vehicle insurance, maintenance, operational and acquisition costs for the millionsof licensed drivers who own millions of vehicles have escalated.

- Parking space/lot congestion is ubiquitous everywhere.

Urban transportation trends

Urban travel demand has to be understood from the context of differentiated urban growth. To some extent, capacity increase is possible by slight modifications with little or no investments such as signaling changes, widening of roads and extricating encroachments. But what works for one city may not work for the other, though some valuable lessons can be learned. Despite investments in road infrastructure, land use and transport planning and development, several cities face problems of heavy influx, congestion, traffic accidents, and air and noise pollution. Hence a unified approach to integrate multi-modes of traffic and efficient feeder network must be adopted, in addition to inculcating public discipline. Recent trend in many cities in India and the rest of the World is heavy investments into railways. Several metro, light rail transit (LRT) and monorail projects have been initiated, which is strategically a new approach to urban transportation management. Railways for urban transportation management generate public attention and interest for the following reasons:

1. Railways are a mass transit system and hence it is more efficient than roadways in meeting higher land based traffic capacity demands.

2. Railways are highly capital intensive when compared to other modes. So project planning has to be immaculate and has to be exercised with utmost caution. Any time loss leads to inconveniencing existing public facilities and cost appreciation.

3. Railway transportation requires a very long time planning and takes years to design, develop, build infrastructure and execute. And the route has to be planned in such a way that it caters to clearing bottlenecks while simultaneously causing minimum impacts to existing structures.

4. If there is one, urban railway transportation should be the best possible public-private partnership. Huge funding requirements necessitate Government investments and high technology and rapid execution necessitate private involvement.

5. A multitude of planning, engineering, operations and management activities are required in urban railway transportation. Hence a consortium of planners, engineers, infrastructure developers, suppliers, maintenance and management gurus team up in each project. There are only a hand-countable number of players in each domain and they provide transportation solutions to all regions across the continents. This sort of consortium operations is a radical shift from a "Multi-national" company (which everyone is used to these days) mode, to a "Cross-national" or an "Intra-national" or a genuine "Inter-national" focus. Certainly opportunities to learn from different cultural settings proliferate and hence a quality excellence is hoped for.

6. All such projects are highly resource and time sensitive, by and large managed with huge (Government) public funding. There could also be impending legal complications; in-spite, private players are expected to deliver on time with strict conformance to quality specifications, as every project is a major business opportunity for the private players.

7. It is been a long time that we witness large scale engineering and technological projects that directly impact the general public; other than in real estate, which is miniscule compared to transportation investments. It is happening right away, not only in India, but all over the world.

8. One might also not expect huge infrastructural investments during a recession period. But a major number of public transportation projects kicked off during the peak downturn years of 2007-09. Clearly it is an indication of a global strategic shift to energy conservation and to saving depleting oil reserves for the future.

In India, several initiatives on land use management and road transport planning are underway in many cities. Numerous railways based urban transportation projects are also being planned and executed. Three railway technologies for urban transportation are most popularly implemented all over the world. They are metro railways, light rail transit (LRT) systems and monorail; each has distinct features and capabilities.

Few major metro projects in India that are in various stages of progress are Delhi metro, Chennai Metro, Kolkata Metro, Mumbai Metro, Bangalore Metro, Jaipur Metro, Kochi Metro, Hyderabad Metro, Gurgaon Metro and Navi Mumbai Metro, Ahmedabad &Gandhinagar, Bhopal,Chandigarh, Indore, Kanpur, Lucknow, Ludhiana, Nagpur, Patna, Pune, Surat and Guwahati. LRT systems are underway in Bangalore Light Rail Transit (LRT), Kolkata and New Delhi. Monorails are proposed or being constructed in Chennai, Bangalore, Delhi, Indore, Kolkata, Kozhikode, Navi Mumbai, Patna, Pune, Thiruvananthapuram, Madurai, Tiruchirappalli and Coimbatore.

Worldwide 139 metro projects and 162 light rail transit projects are underway, with the highest number of projects in Europe, followed by Asia, Americas, Australasia and Africa. One of the highly successful urban transportation systems is TransMilenio Project in Bogota, Columbia, with a bus rapid transit system, bicycle paths, improved pedestrian facilities, and significant

restrictions on private car use. The results are impressive reductions in air pollution, roadway congestion, and traffic accidents.In general, public transportation is not meant for generating revenues; fares are usually fixed in such a way that just the operational expenses are met. But Dubai Metro and Delhi Metro seemed to have turned the tables, by generating profits over and above the operational expenses. Hence across the continents, one may not be alone in being (momentarily) inconvenienced by the metro construction in Indian cities or some of the constructional mishaps. It is finally hoped for a better class of transport services with less everyday congestion in the cities we live and thereby save the oil reserves.

The line between developed and developing nations may not be thin. But social awareness towards ethical behavior and public discipline - individually and collectively helps a lot. Apart from social values that one may attach with one's city or country, there is also much to contribute at a professional level. Opportunities abound, as strategists, planners, engineers, traffic modelers, software developers, marketing, legal and finance professionals have a big stake in such ventures, not only in India, but in the rest of the world. One has to acquire the right qualifications and skills to take up the field.

Growth and problem transport and environmental degradation:

1. The Issue of Transport and the Environment

The issue of transportation and the environment is paradoxical since transportation conveys substantial socioeconomic benefits, but at the same time, transportation is impacting environmental systems. From one side, transportation activities support increasing mobility demands for passengers and freight, while on the other, transport activities are associated with environmental impacts. Further, environmental conditions impact transportation systems in terms of operating conditions and infrastructure requirements such as construction and maintenance (see Transportation and Space for a review of these constraints).

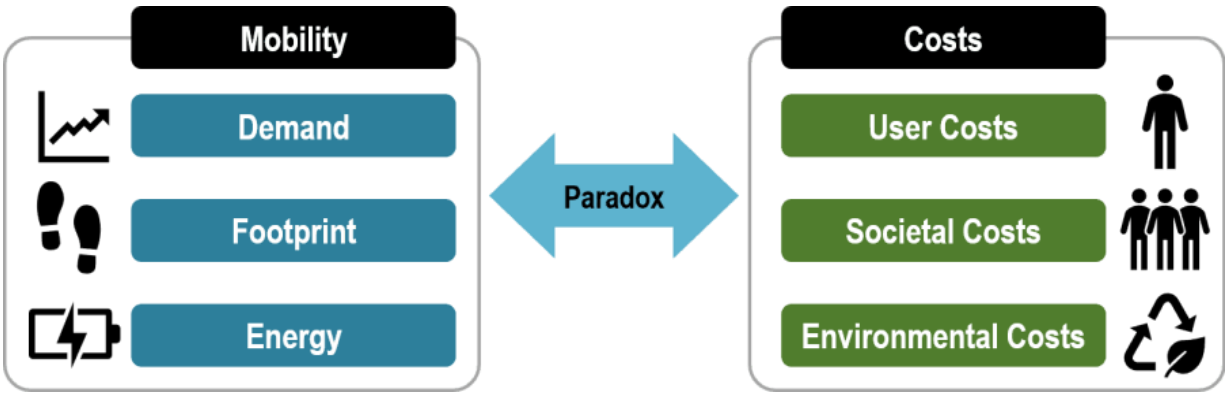
The growth of passenger and freight mobility has expanded the role of transportation as a source of emission of pollutants and their multiple impacts on the environment. These impacts fall within three categories:

- **Direct impacts.** The immediate consequence of transport activities on the environment where the cause and effect relationship are generally clear and well understood. For instance, noise and carbon monoxide emissions are known to have direct harmful effects.
- **Indirect impacts.** The secondary (or tertiary) effects of transport activities on environmental systems. They are often of a higher consequence than direct impacts, but the involved relationships are often misunderstood and more challenging to establish. For instance, particulates, which are mostly the outcome of incomplete combustion in an internal combustion engine, are indirectly linked with respiratory and cardiovascular problems since they contribute, among other factors, to such conditions.
- **Cumulative impacts**. The additive, multiplicative or synergetic consequences of transport activities. They consider the varied effects of direct and indirect impacts on an ecosystem, which are often unpredictable. Climate change, with complex causes and consequences, is the cumulative impact of several natural and anthropogenic factors, in

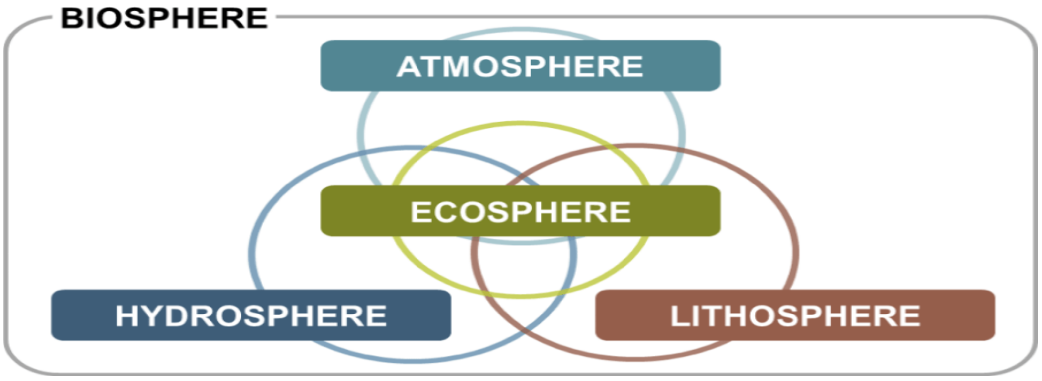
which transportation plays a role. The share of transportation in global CO2 emissions is increasing. 22% of global CO2 emissions are attributed to the transport sector, with this share is around 25% for advanced economies such as the United States.

The complexities of the impacts have led to much **controversy** in environmental policy, the role of transportation, and mitigation strategies. This is made even more complex by the fact that priorities between environmental and economic considerations shift in time, which can have an impact on public policy. The transportation sector is often subsidized, especially through the construction and maintenance of road infrastructure, which tends to be free of access. Sometimes, public stakes in transport modes, terminals, and infrastructure can be at odds with environmental issues. If the owner and the regulator are the same (different branches of the government), then there is a risk that regulations will not be effectively complied to.

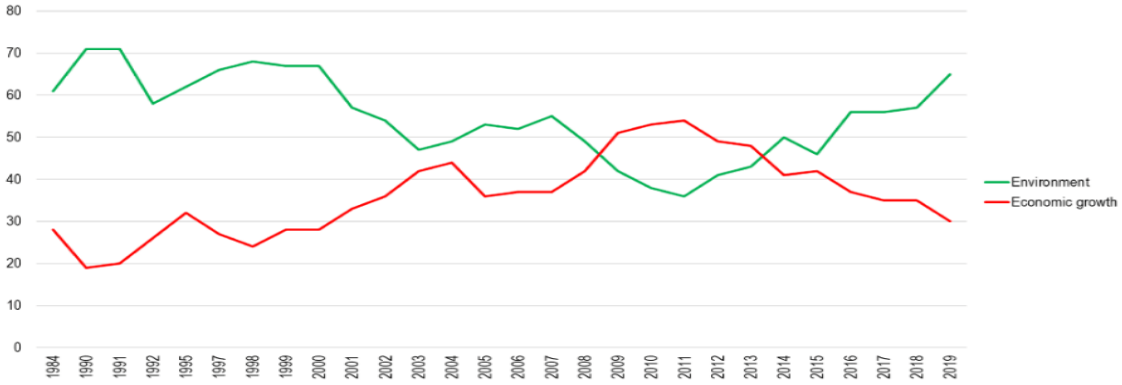
Total costs incurred by transportation activities, notably environmental damage, are generally not fully assumed by the users. The lack of consideration of the **real costs of transportation** could explain several environmental problems. Yet, a complex hierarchy of costs is involved, ranging from internal (mostly operations), compliance (abiding by regulations), contingent (risk of an event such as a spill) to external (assumed by the society). For instance, external costs account on average for more than 30% of the estimated automobile ownership and operating costs. If environmental costs are not included in this appraisal, the usage of the car is consequently subsidized by society, and costs accumulate as environmental pollution. This requires due consideration as the number of vehicles, especially automobiles, is steadily increasing.



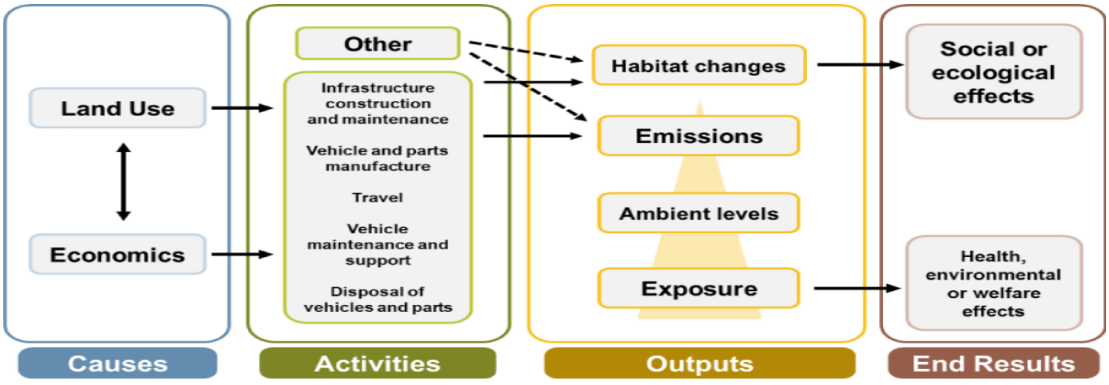
The Paradox of Mobility and its Costs



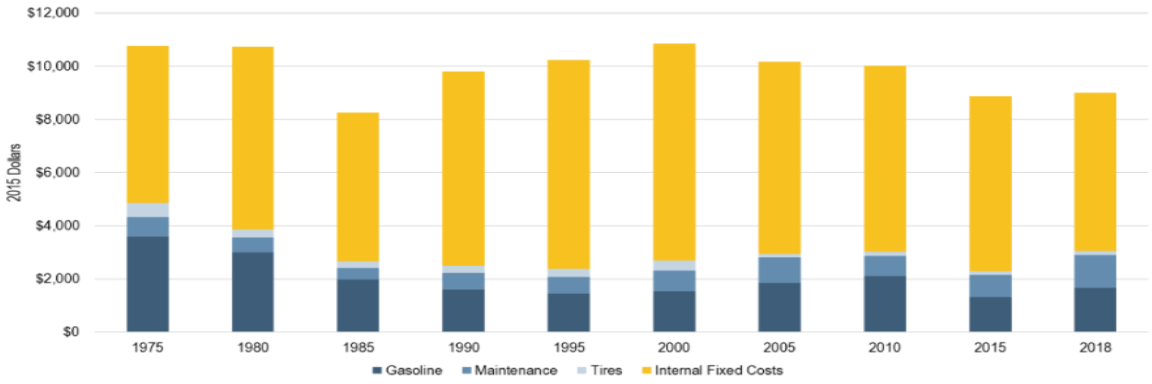
The Environmental System



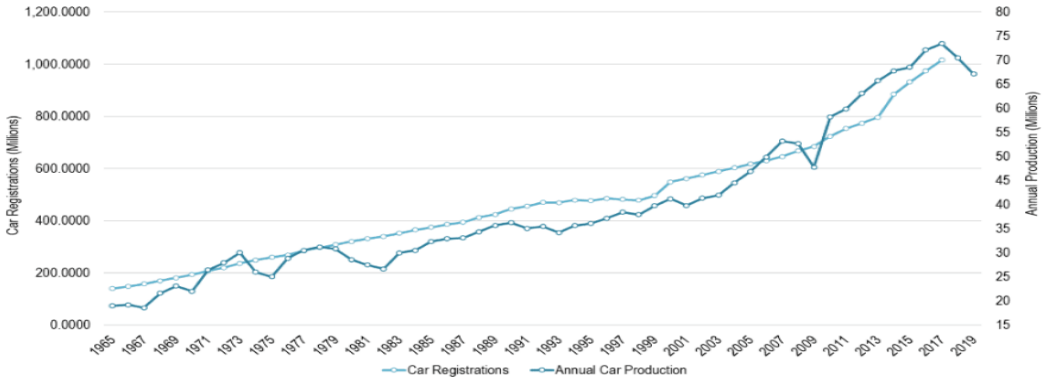
Public Preferences for Priority between the Economy and the Environment, 1984-2019



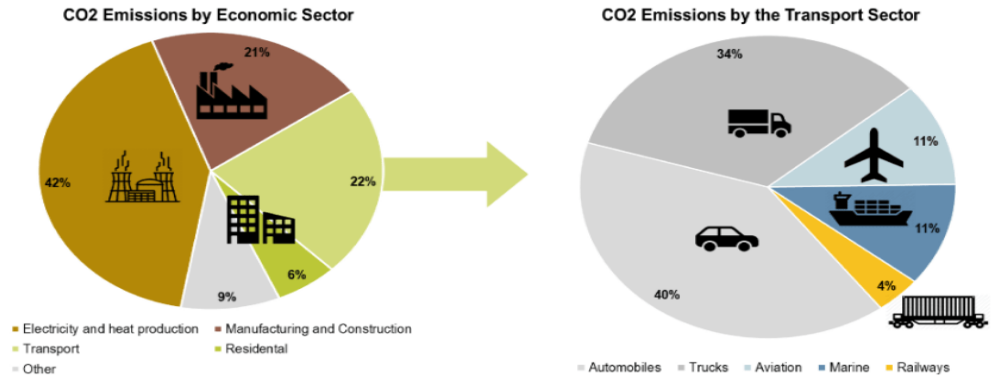
Environmental Dimensions of Transportation



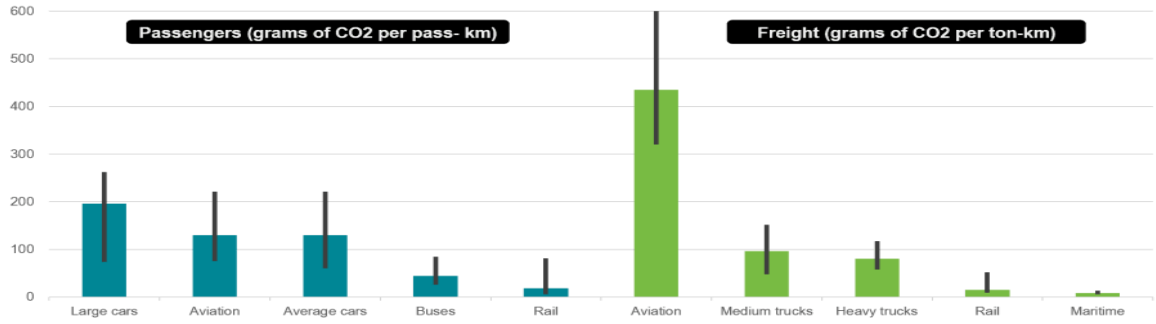
Average Cost of Owning and Operating an Automobile, 1975-2018



World Automobile Production and Fleet, 1965-2018



Global Greenhouse Gas Emissions by the Transportation Sector



Average CO2 Emissions by Passenger and Freight Transport Mode

2. The Transport – Environment Link

The relationships between transport and the environment are **multidimensional**. Some aspects are unknown, and some new findings may lead to changes in environmental policies. Historically, transportation was associated with very few negative environmental impacts because of the modes used and the low mobility levels. For instance, the construction of large navies composed of sailships was responsible for a level of deforestation in Western Europe and North America from the 16th to the 19th centuries. Urbanization in the 19th century and the reliance on horses created problems concerning the disposal of manure. Further, industrialization and the development of steam engines lead to pollution (e.g. soot) near ports and rail yards. Still, these issues remained marginal and localized. .

From an operational perspective, the Clean Air Act of 1970 set clear air quality standards and expectations for both stationary (e.g. a power plant) and mobile (e.g. an automobile) sources of air pollutants. For transportation, it immediately set emissions standards for a list of acknowledged pollutants such as carbon dioxide, volatile organic compounds, and nitrogen oxide. The outcome was a rapid decline in air pollutant emissions by the transportation sector through better engine technology. The Clean Water Act of 1977 provided a similar regulatory environment concerning water pollution and the ability to build infrastructures over wetlands.

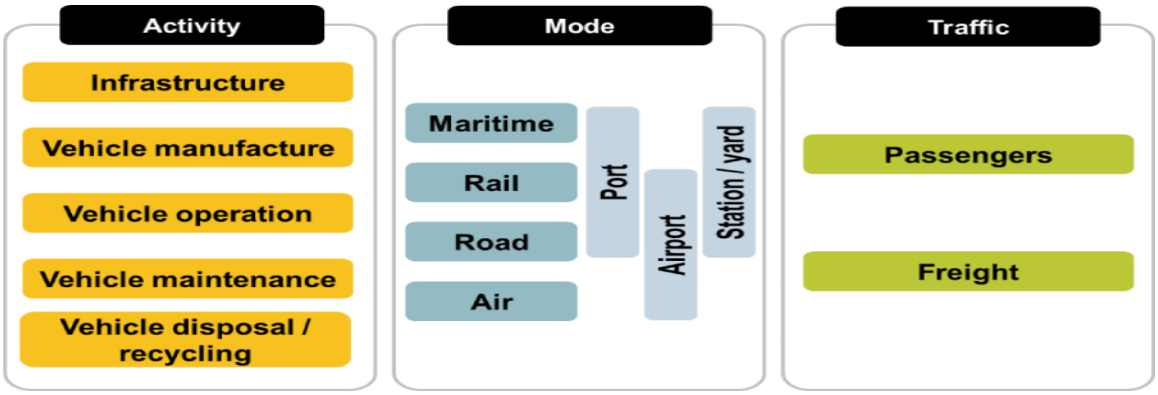
The main factors considered in the physical environment are geographical location, topography, geological structure, climate, hydrology, soil, natural vegetation, and animal life.

The environmental dimensions of transportation are related to the **causes**, the activities, the **outputs,** and the **results** of transport systems. Establishing linkages between environmental dimensions is a difficult undertaking. For instance, to what extent carbon dioxide emissions are linked to land use patterns? Furthermore, transportation is embedded in environmental cycles, notably over the carbon cycle where carbon flows from one element of the biosphere, like the atmosphere, to another like the ecosphere, where it can be accumulated (permanently or temporarily) or passed on. The relationships between transport and the environment are also complicated by two observations:

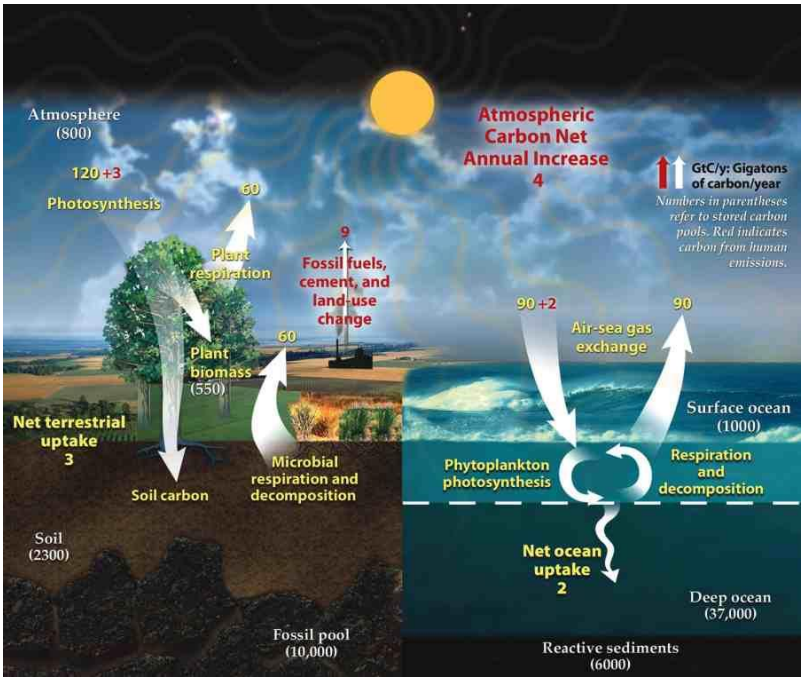
- **Level of contribution**. Transport activities contribute among other anthropogenic and natural causes, **directly, indirectly, and cumulatively to environmental problems**. In some cases, they may be a dominant factor, while in others, their role is marginal and challenging to establish.
- **Scale of impact**. Transport activities contribute at different geographical scales to environmental problems, ranging from local (noise and CO emissions) to global (climate change), not forgetting continental / national/regional problems (smog and acid rain).

Establishing environmental policies for transportation thus must take account of the **level of contribution** and the **geographical scale**, otherwise, some policies may just move the problems elsewhere and have unintended consequences. A noted example is environmental policies in advanced economies inciting the relocation of some activities with high environmental externalities (e.g. steel making) in developing economies. This transfers the problem from one location to another. Still, such as transfer usually involves new equipment and technologies that are usually having a lower environmental impact. Even if an administrative division (municipality, county, state) has adequate environmental enforcement policies, the geographical scale of an environmental impact (notably air pollutants) goes beyond established jurisdictions. This has become salient in the disposal of waste such as electronic goods that are transferred to developing economies with lower environmental regulations to be disposed of or recycled.

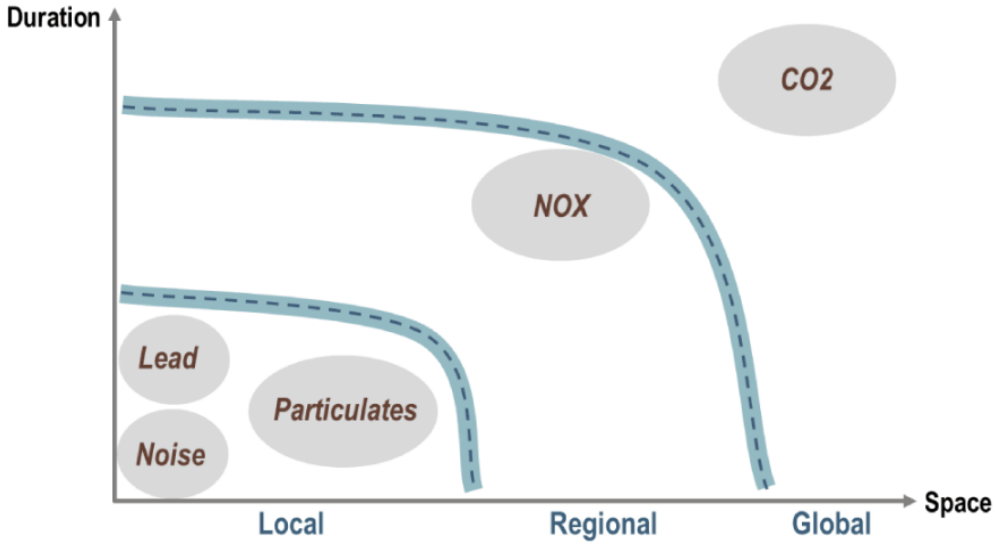
The structure of the transport network, the modes used, and traffic levels are the main factors of the environmental impact of transportation. Networks influence the spatial distribution of emissions (e.g. centralized versus diffuse networks), while modes relate to the nature of the emissions and the traffic to the intensity of these emissions. In addition to these environmental impacts, economic and industrial processes sustaining the transport system must be considered. These include the extraction and production of fuels, vehicles and construction materials, some of which are very energy-intensive (e.g. aluminum), and the disposal of vehicles, parts as well as the provision of infrastructure. They all have a life cycle timing their production, utilization, and disposal. Thus, the evaluation of the link between transport and the environment without the consideration of **cycles in the environment and in the product life** alike is likely to convey a limited overview of the situation and may even lead to incorrect appraisal, policies and mitigation strategies.



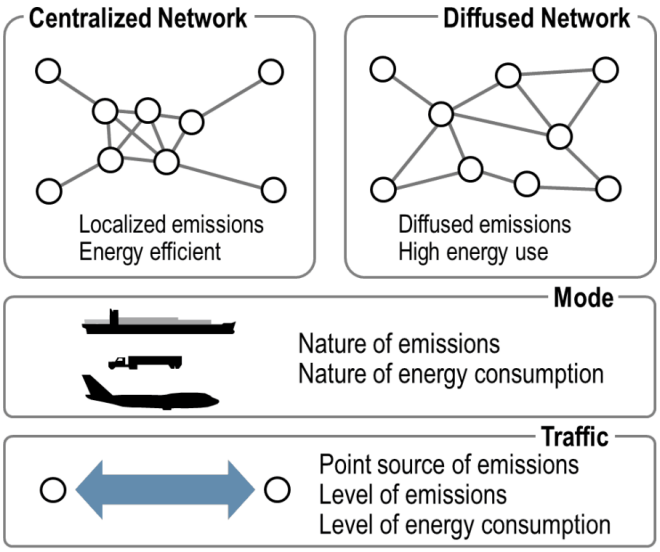
Transportation Activities Affecting the Environment



Transportation and the Carbon Cycle



Spatial and Durational Environmental Effects of Selected Environmental Externalities



Transportation Systems and the Environment

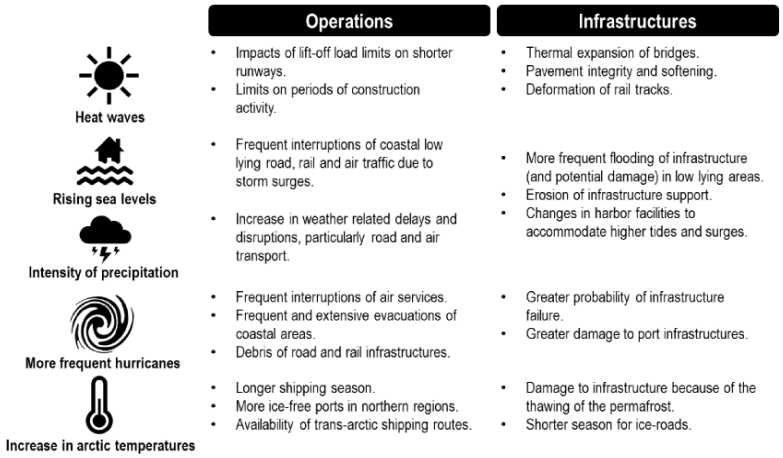
3. Environmental Dimensions

Transportation activities support increasing mobility demands for passengers and freight, notably in urban areas. But transport activities have resulted in growing levels of motorization and congestion. As a result, the transportation sector is becoming **increasingly linked to environmental problems**.

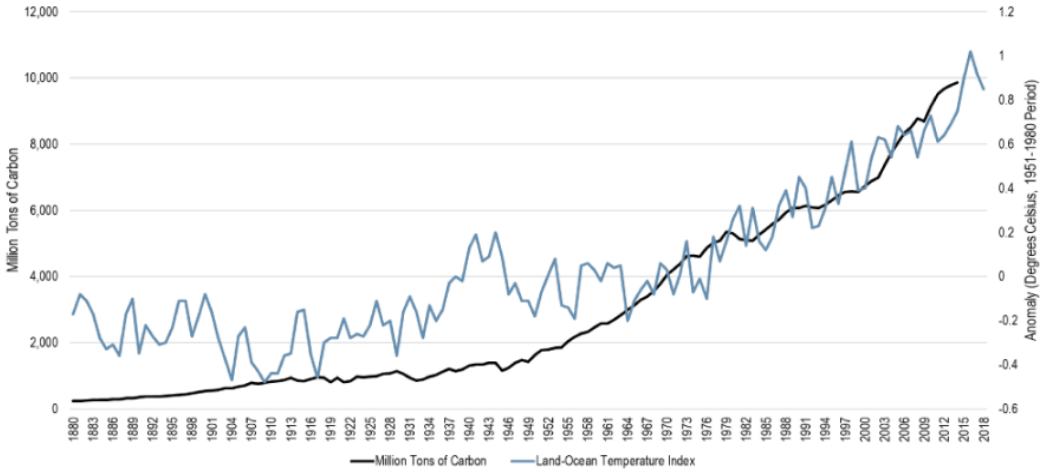
a. Climate change: The greenhouse effect is a fundamental component of the regulation of the global climate and is a naturally occurring process that involves partially retaining heat in the earth's atmosphere. These include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and halocarbons, gases that accumulate in the atmosphere long enough to reach a homogeneous composition across the world. Thus, irrespective of the location, their concentration is similar. The quantity of conventional greenhouse gases released into the atmosphere has increased substantially since the industrial revolution and particularly over the last 25 years. The respective impacts of greenhouse gases are further complicated by differences in their atmospheric lifetime (or residence time), which is the time they spend in the atmosphere before decaying or being absorbed by biological or chemical processes. For CO2, it can range between 5 and 200 years, while it is about 12 years for methane and 114 years for N2O. For halocarbons, such as Chlorofluorocarbons, it is at least 45 years.

The activities of the transport industry release several million tons of greenhouse gases each year into the atmosphere, accounting between 25 and 30% of all greenhouse gas emissions. There is an ongoing debate about to what extent these emissions are linked with climate change, but the debate relates more to the extent of these impacts than their nature. Some gases, particularly nitrogen oxide, also participate in depleting the stratospheric ozone (O3) layer, which naturally screens the earth's surface from ultraviolet radiation. The rise in air traffic, in addition to its emissions, has increased the number of contrails, which are mainly ice crystals formed from condensation around planes flying at high altitudes. They can contribute to climate

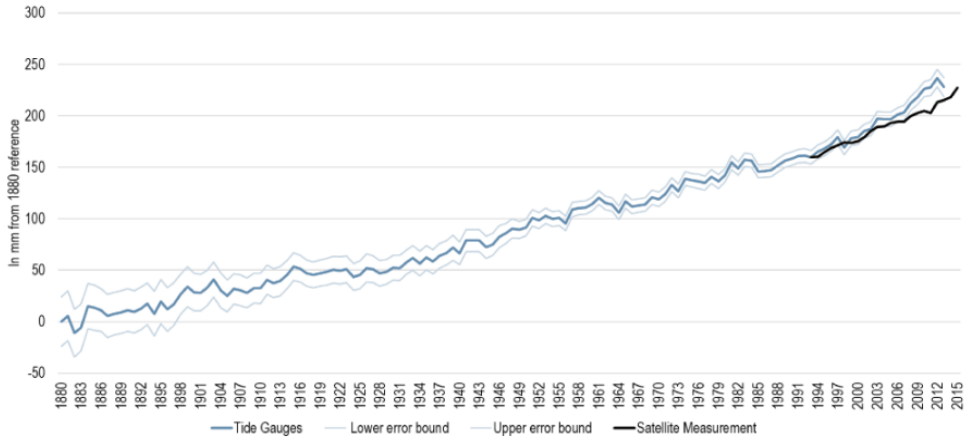
change in a paradoxical fashion as, on the one hand, they can trap heat, and on the other, they are also reflecting solar radiation. In addition to being a contributor to climate change, transportation is also impacted by it, particularly over infrastructure (e.g. more floods due to rising sea levels) and operations (harsher operating conditions).



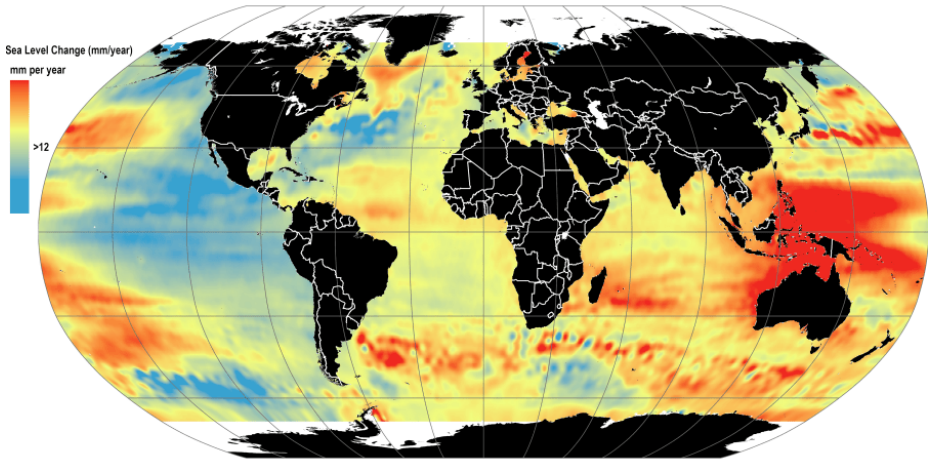
Climate Change and its Potential Impacts on Transportation



Average Global Temperature and World Carbon Emissions From Fossil Fuel Burning, 1880-2018



Global Mean Sea Level Change, 1880-2015



Remotely Sensed Sea Level Change, 1992-2012

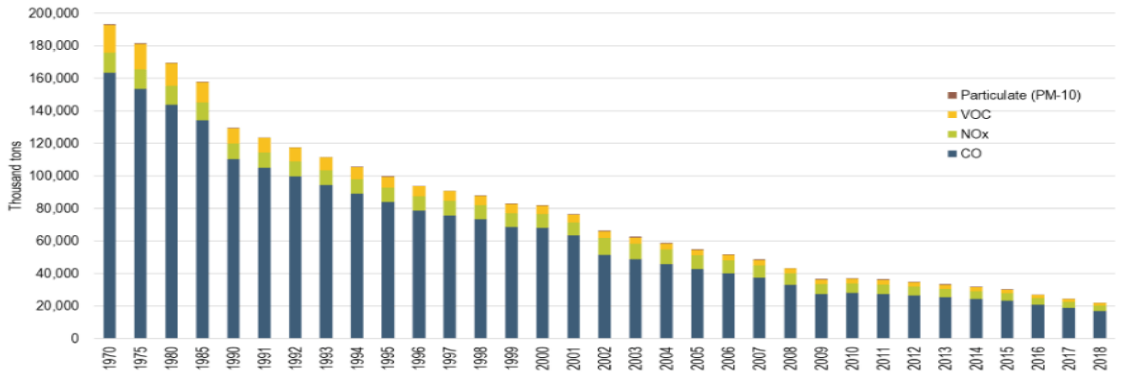
b. Air quality: Highway vehicles, marine engines, locomotives, and aircraft are the sources of pollution in the form of gas and particulate matter emissions. They affect air quality and cause damage to human health. The most common include lead (Pb), carbon monoxide (CO), nitrogen oxides (NOx), silicon tetrafluoride (SF6), benzene and volatile components (BTX), heavy metals (zinc, chrome, copper, and cadmium) and particulate matters (ash, dust). Lead emissions have declined substantially in the last decades as its use as an anti-knock agent for gasoline was banned in most of the world from the 1980s. Only a few countries, such as Myanmar, Iraq, and North Korea are still using leaded fuel. The main factors behind this ban were that tetraethyl lead (the form used as a fuel additive) was associated with neurotoxic effects on human beings and that it impaired catalytic converters.

Toxic air pollutants are associated with cancer, cardiovascular, respiratory, and neurological diseases. Carbon monoxide (CO), when inhaled, reduces the availability of oxygen in the circulatory system and can be extremely harmful and even deadly at specific concentrations. Nitrogen dioxide (NO2) emissions from transportation sources reduce lung function, affect the respiratory immune defense system, and increases the risk of respiratory

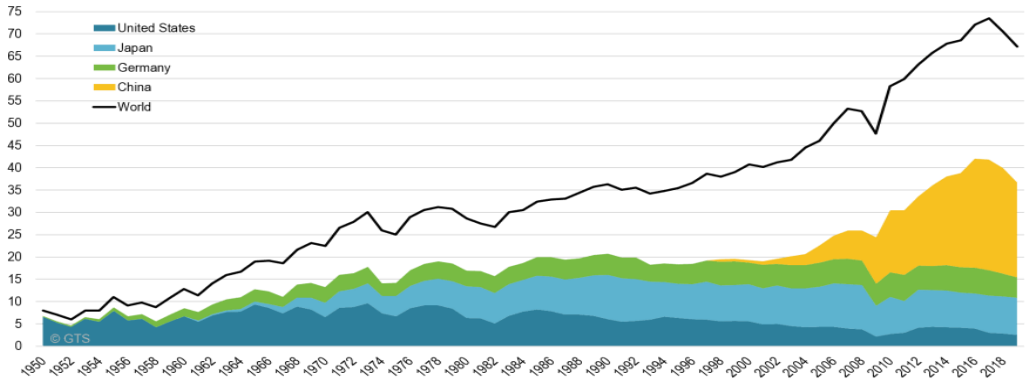
problems. The emissions of sulfur dioxide (SO2) and nitrogen oxides (NOx) in the atmosphere form various acidic compounds that, when mixed in cloud water, creates acid rain. Acid precipitation has detrimental effects on the built environment, reduces agricultural crop yields, and causes forest decline.

Air quality issues have been comprehensively addressed in advanced economies, with substantial declines in the emissions of a wide range of pollutants. In developing economies, rapid motorization has shifted the concern to the large cities of China and India among those the most impacted by the deterioration of air quality.

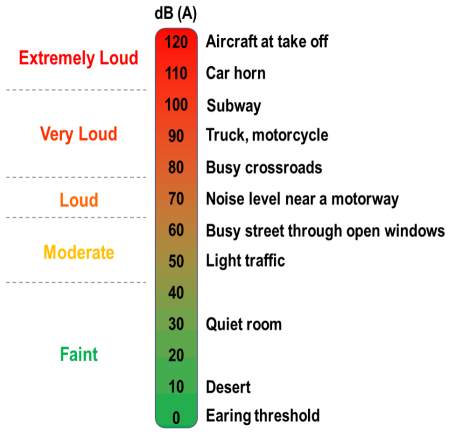
c. Noise: Noise represents the general effect of **irregular and chaotic sounds** on people as well as animal life. Basically, noise is an undesirable sound. The acoustic measure of the intensity of noise is expressed in decibel (dB) with a scale ranging from 1 dB to 120 dB. Long term exposure to noise levels above 75 decibels severely hampers hearing and affects human physical and psychological well-being. Noise emanating from the movement of transport vehicles and the operations of ports, airports, and railyards affects human health through an increase in the risk of cardiovascular diseases. Ambient noise is a frequent result of road transportation in urban areas, which is the cumulative outcome of all the noise generated by vehicles (ranging from 45 to 65 dB), impairs the quality of life and property values. Falling land values nearby acute noise sources such as airports are often noted since buyers are less willing to bid on properties in areas of elevated noise levels. Many noise regulations impose mitigation if noise reaches a defined level, such as sound walls and other soundproofing techniques.



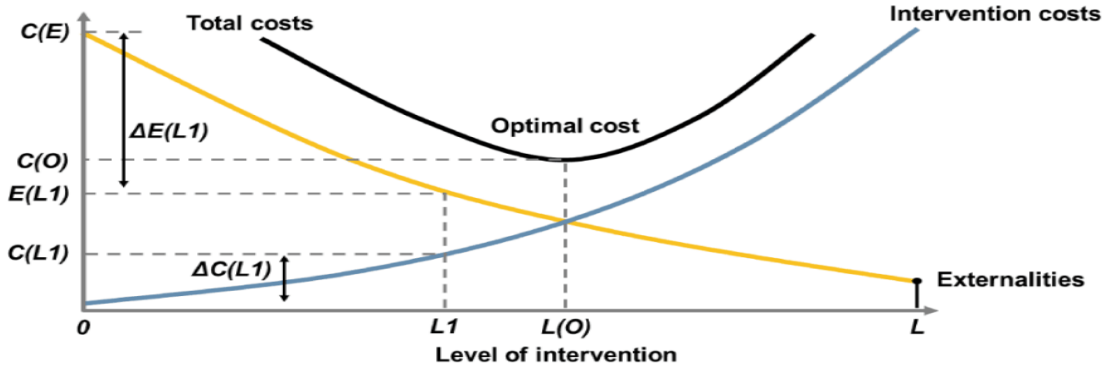
Estimated Air Pollutants Emitted by Highway Transportation in the United States, 1970-2018



Automobile Production, Selected Countries, 1950-2018



Noise Levels from Different Sources



The Concept of Externalities

d. Water quality: Transport activities have an impact on hydrological conditions and water quality. Fuel, chemicals, and other hazardous particulates discarded from aircraft, cars, trucks, and trains or port and airport terminal operations can contaminate hydrographic systems.

Because demand for maritime shipping has increased, marine transport emissions represent the most important segment of water quality impact of the transportation sector. The

main effects of marine transport operations on water quality predominantly arise from dredging, waste, ballast waters, and oil spills. Dredging is the process of deepening harbor channels by removing sediments from the bed of a body of water. Dredging is essential to create and maintain sufficient water depth for shipping operations and port accessibility. Dredging activities have a two-fold negative impact on the marine environment.

Besides, various types of garbage containing metals and plastic are not easily biodegradable. They can persist on the sea surface for long periods of time and can be a severe impediment to maritime navigation in inland waterways and at sea and affecting as well as berthing operations. Ballast waters are required to control a ship's stability and draft and to modify their center of gravity in relation to cargo carried and the variance in weight distribution. Ballast waters acquired in a region may contain invasive aquatic species that, when discharged in another region may thrive in a new marine environment and disrupt the natural marine ecosystem. Invasive species have resulted in significant changes in nearshore ecosystems, especially in coastal lagoons and inlets. Major oil spills from oil cargo vessel accidents are one of the most severe problems of pollution from maritime transport activities.

e. Soil quality: The environmental impact of transportation on soil quality particularly concerns soil erosion and soil contamination. Coastal transport facilities such as ports have significant impacts on soil erosion. Shipping activities are modifying the scale and scope of wave actions leading to damage in confined channels such as river banks. Highway construction or lessening surface grades for port and airport developments have led to an important loss of fertile land. Soil contamination can occur through the use of toxic materials by the transport industry. Fuel and oil spills from motor vehicles are washed on roadsides and enter the soil. Chemicals used for the preservation of wooden railroad ties may enter the soil. Hazardous materials and heavy metals have been found in areas contiguous to railroads, ports, and airports.

f. Biodiversity: Transportation also influences biodiversity. The need for construction materials and the development of land-based transportation has led to deforestation. Many transport routes have required draining land, thus reducing wetland areas and driving-out water plant species. The need to maintain road and rail right-of-way or to stabilize slope along transport facilities has resulted in restricting the growth of certain plants or has produced changes in plants with the introduction of new species. Many animal species are becoming endangered as a result of changes in their natural habitats and reduction of ranges due to the fragmentation of their habitat by transportation infrastructures.

g. Land take: Transportation facilities have an impact on the urban landscape. The development of port and airport infrastructure is a significant feature of the urban and peri-urban built environment. Social and economic cohesion can be severed when new transport facilities such as elevated train and highway structures cut across an existing urban community. Arteries or transport terminals can define urban borders and produce segregation. Major transport facilities can affect the quality of urban life by creating physical barriers, increasing noise levels, generating odors, reducing urban aesthetic,s and affecting the built heritage. The expansion of logistics activities has also been an indirect factor of land take in suburban and periurban areas.

4. Environmental Externalities: Externalities are an economic concept that refers to the activities of a group that has **consequences**, positive or negative, intended or unintended, on

other groups. These consequences, particularly if they are negative, are **not fully assumed by those causing them**. Therefore, the impacts are externalized. A common example of a **positive externality** concerns technology since it obviously benefits the innovative firm but also the whole economy through various productivity improvements or improved convenience. **Negative externalities** are highly relevant over environmental issues since many of the negative consequences of pollution are assumed by the whole society.

The environmental externalities of transportation include the consideration of physical measures of environmental damage and the evaluation of involved costs for society. The main fallacy underlined by externalities is that the costs attributed to a few sources (e.g. users of cars) must be burdened by many (users and non-users alike). Knowing the sources of environmental externalities is a relatively easy undertaking. At the same time, the evaluation of damage and other costs has not yet reached comparative standards among governmental and non-governmental agencies. The challenge resides over three issues:

- **Relationships**. The nature and extent of the relationships between transport and the environment must be considered. This is particularly complex as most environmental relationships tend to be indirect and cumulative.
- **Quantification**. Relationships must be quantified, and their value to environmental externalities should be appraised. This is highly challenging as only general figures subject to debate can be assessed. Therefore, the quantification of economic, social, and environmental costs subject to much contention. Inaccurate assessments can lead to the exaggeration or underestimation of environmental externalities and improper policies and regulations.
- **Mitigation**. The level and extent of corrective actions that can be taken to alleviate environmental externalities linked to transportation, usually in a manner where those contributing bear the responsibility of their activities. Given the two above points, attempts at regulation, particularly if they involve a comprehensive framework (multinational and multisector), have not reached a significant consensus. Alternatively, a consensus may be reached about the nature of an environmental externality, but not about its mitigation.

The costs of environmental externalities can be considered from **economic**, **social,** and **environmental dimensions**. The basic types of transportation externalities attributed to the environment fall within air pollution, water pollution, noise, and hazardous materials. **Establishing and quantifying environmental externalities** is a complex undertaking. Quantification is at its preliminary stage, and many have used this argument to differ the application of several environmental policies by lobbying governments. For instance, in the 1970s it took time to accumulate enough evidence to demonstrate the impacts of sulfur emissions, mainly originating from coal power plants, on rain acidification, and implement mitigation strategies (scrubbers, shift to natural gas). In the 1980s the impacts of chlorofluorocarbons and hydrochlorofluorocarbons on atmospheric ozone led to a series of regulations (e.g. Montreal Protocol of 1987) banning their use in the manufacturing of aerosols and refrigerants. Additionally, the wider the geographical scale, the more complex the environmental problem becomes since it involves **cross-jurisdictional issues**. Recent attempts to reach a consensus about climate change, such as the Paris Agreement of 2016, have underlined

the complexity of multilateral environmental agreements over a complex issue that cannot be effectively quantified. Parties simply make general non-binding commitments

The **sources/emitters of pollutants rarely bear the consequences of their impacts**. This has several implications. First, when specific sources are concerned, like road transportation, users only take account of the direct costs of modal ownership like a car (vehicle, fuel, insurance, etc.). Ownership is often the only entry and utilization cost for several transportation modes. Society generally assumes the role of providing and maintaining infrastructure and other indirect costs like damage to structures and infrastructure, losses in productivity, cleanup, health services, and damage to ecosystems. Second, the geographic separation between sources and recipients is often acute. Acid rains and climate change are prominent examples. On a local level, a community may be affected by noise levels well over its contribution (notably near major highways), while another (e.g. suburbs) may be affected in a very marginal way and still significantly contributes to noise elsewhere during commuting.

There is a tendency towards a shift from **direct to indirect consequences for environmental externalities**, as of total costs involved. For instance, the absolute levels of air pollutant emissions have considerably dropped in developed economies. The problem of source reduction by vehicles was addressed because it was a straightforward cause of air pollutant emissions. This has tended to displace problems elsewhere and developed new types of externalities. Thus, the relative share of air pollution impacts is lessening, but not the number of vehicles, investment in infrastructure, or noise levels, which have their own externalities. Reductions in the relative importance of one type of externality redirect the focus on other types that were less addressed, but probably as important in the overall impacts of transport over the environment.

Transfers and additions of costs are prevalent attributes of environmental externalities. Trying to lessen economic costs will either lessen or worsen social and environmental costs, depending on the externality. In the context of limited resources, the distribution of economic, social, and environmental costs takes an important role as to what type of damage is acceptable and in what proportions. It is clear from past strategies that several economic costs have been minimized, notably for producers and users, while social and environmental consequences were disregarded. This practice no longer applicable since the society is less willing to bear the costs and consequences of externalities for various reasons (public awareness, quality of life considerations, high health costs, etc.).

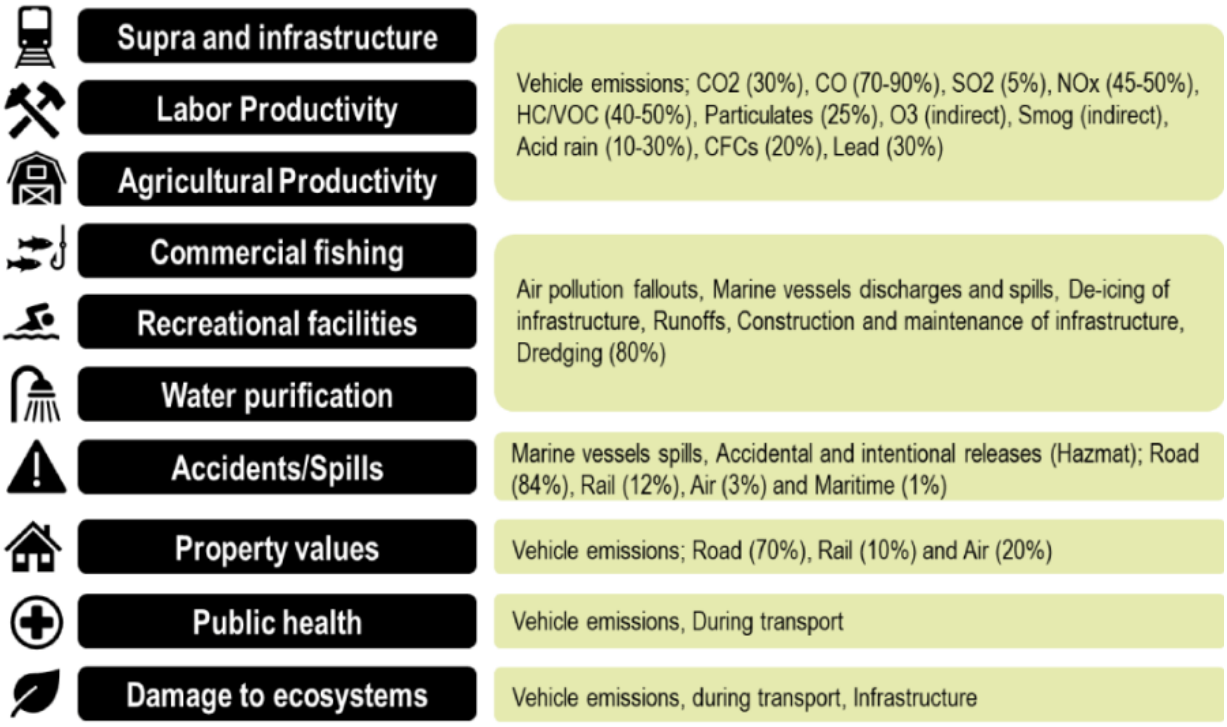
5. Assessing Environmental Externalities: Air pollution is the most important source of environmental externalities for transportation, mainly because the atmosphere enables a fast and widespread diffusion of pollutants. Although the nature of air pollutants is clearly identified, the scale and scope of how they influence the biosphere are subject to controversy. On the positive side, emissions of the most harmful air pollutants, such as Carbon Monoxide and Volatile Organic Compounds, have declined despite substantial growth in the number of vehicles, which is indicative of the increasing levels of environmental compliance of vehicles. Carbon Dioxide emissions have increased proportionally with the growth of transportation usage.

As all externalities, costs are very difficult to evaluate because several consequences are not understood, the problems could be at another scale or highly correlated with others, and value (monetary or other) cannot be conclusively attributed. Two major groups of factors are contributing to air pollution, notably in urban areas.

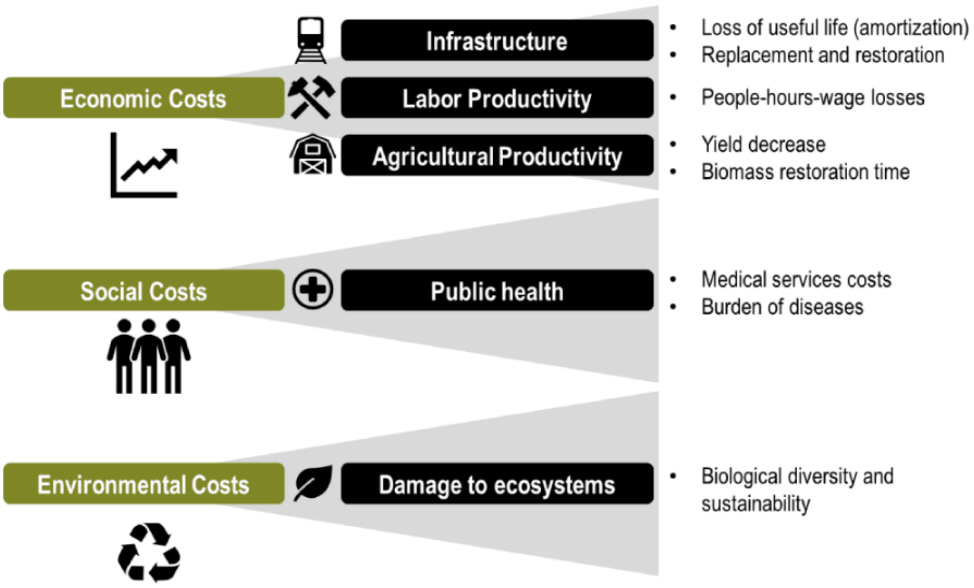
- **Structural factors** are inherently linked to the **size** and **level of consumption** of an economy. Factors such as income and education tend to be proportional to emissions.
- **Behavioral factors** are linked to individualism, consumerism, and transportation preferences. Because of convenience and its symbolism, the car is systematically the preferred mode of transportation, even when other modes are available.

From a general perspective, the costs of air pollution associated with transportation can be grouped within **economic**, **social,** and **environmental** costs. Externalities related to water pollution are almost all indirect consequences. It is thus difficult to evaluate and to appraise the specific contribution of transportation over various environmental issues, which explains that problems tend to be addressed on a modal basis.

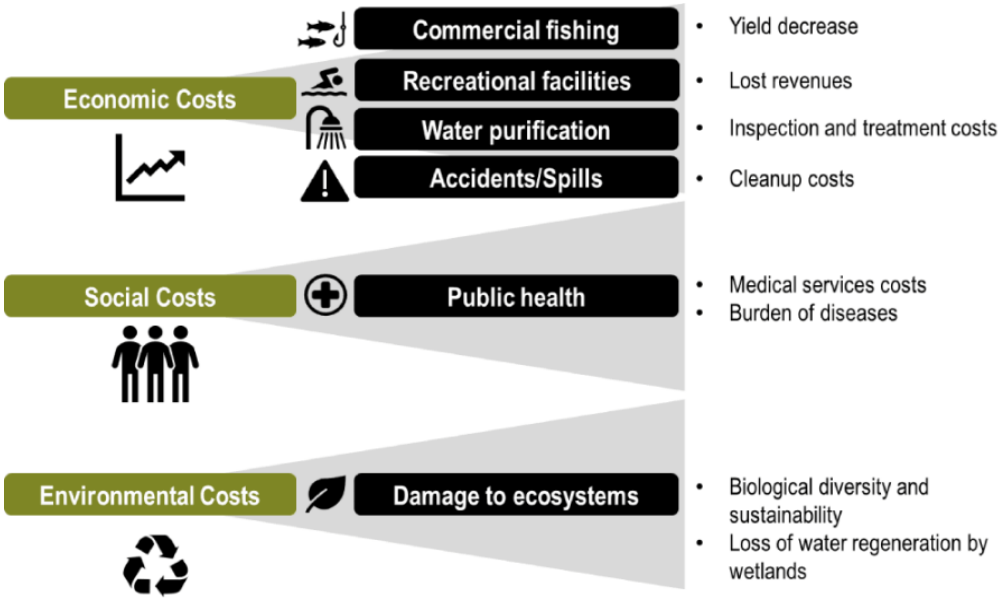
Noise emissions can be represented as **point** (a vehicle), **line** (a highway) and **surface** (ambient noise generated by a set of streets) sources. Noise pollution is only present as **vibrations**. For instance, for a road vehicle, vibrations are created through the internal combustion engine, moving parts (transmission), and friction on the surface over which a transport mode operates. The impacts of noise are strictly local, as vibrations are quickly attenuated by the distance and the nature of the landscape (trees, hills, etc.).



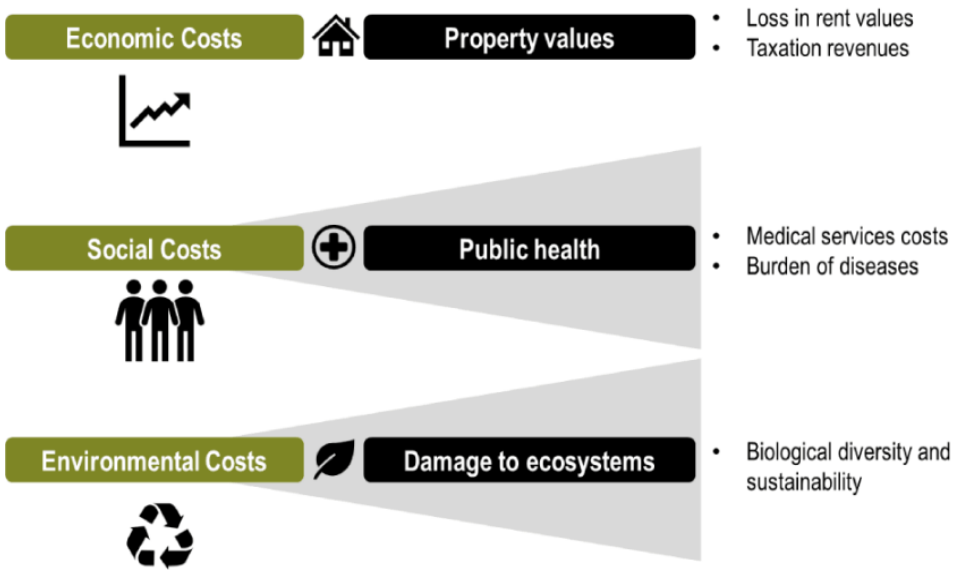
Environmental Externalities of Transportation



Externalities of Air Pollution



Externalities of Water Pollution



Externalities of Noise Pollution

A hazardous material is a substance capable of posing an **unreasonable risk** to health, safety, and property when transported in commerce. Considering the large amounts of freight being shipped through transport systems, hazardous materials have become a concern. Several hazardous materials (hazmat) releases are spectacular events, notably when it involves a supertanker or a train convoy. However, we must consider that maritime transportation only accounts for 0.1% of the total number of hazmat accidents in the United States, although the volume of hazmat released is higher. Other transportation modes are thus important sources of hazmat release in the environment, even if they mostly **involve small quantities**. Minimal information is available on the nature and consequences of hazmats released during transportation, except for safety regulations. The effects of hazmat release are always punctual but intense. The nature of the effect is related to the type of accident and the hazmat involved. It can range from a small-scale accident where limited quantities of hazmat are spilled, to notable accidents requiring prompt intervention and evacuation of local residents.

Thus, transportation has a wide array of environmental externalities, some of which can be reasonably assessed while others are mostly speculative, but often taken as facts by environmentalist groups. Externalities are also occurring at different geographical scales, and some may even overlap over several scales. The bottom line is that better transport practices, such as fuel-efficient vehicles, that reduce environmental externalities are likely to have positive economic, social, and environmental consequences. While the public sector is incited the address the environmental impacts of transportation through policies and regulations, the private sector deals with compliance and tries to innovate. This iterative process is complex, but the environmental aspects of transportation have been addressed more comprehensively. It remains to be seen about which strategy is the most beneficial as in all environmental matters much subjectivity and often ideology prevails.

Alternative to transport system in mega cities of India:

India's urban population is growing at an average rate of around 3 percent per annum. It has almost doubled during the period between 1981 and 2001 from 160 million to 285 million. The average rate of growth of the urban population is not expected to change significantly during the next twenty years. Assuming a decadal increase of around 37%, India's urban population is expected to be around 540 million during 2021. In terms of percentage of total population, the urban population has gone up from 17% in 1951 to 29% in 2001 and is expected to increase up to around 37% by the year 2021 (Figure 2). Consequently, the number and size of cities have also increased considerably.

During the 1990s, 68 million people joined the ranks of urban dwellers – which implies a slower decadal growth of 31 percent when compared to the growth of 36 percent during the 1980s. Although urbanization has slowed down in India during the 1990s, the number of metropolitan cities – those with a million plus population – has increased over this period. From 23 in 1991, the number of metropolitan cities rose to 35 according to the Census of India, 2001. India's metropolises grew rapidly during the 1990s with Surat registering the fastest growth of 85.1 percent followed by Faridabad (70.8 percent), Nashik (58.8 percent), Patna (55.3 percent), Jaipur (53.1 percent), Delhi (51.9 percent), Pune (50.6 percent), and Indore (47.8 percent) (2). The overall decadal growth rate of the 35 metropolises worked out to be around 34 percent, which is higher than urban India's growth of 31 percent. India's big cities now account for a larger share of total urban population – a trend that has been observed since Independence. In 2001, the share of metropolitan cities was 37.8 percent, up from 32.5 percent in 1991 and 26.4 percent in 1981.

The pattern of urbanization has many distinguishing characteristics. There is a great variation across states. The range is from around 8% for Himachal Pradesh to around 35% for Maharashtra (3). Many factors contribute to this variation. Transport is one of them. It is interesting to note that the level of economic development is higher in those states where the urbanization level is high indicating a positive correlation between urbanization and economic development. The distribution of urban population by city size widely varies and is skewed towards larger cities. One specific feature of India's urbanization is the increasing metropolitanization, that is, growth in the number and size of cities with a million plus population. The trends indicate the continued urbanization and metropolitaniztion in the years to come.

Current urban transport scenario in India:

On average, during peak hours in Mumbai, the actual occupancy in a suburban train is in excess of 4000 passengers, which have maximum desirable capacity of 2600 passengers (5). Most of the Indian cities have more or less similar traffic congestion. Estimates for the metropolitan cities show that approximately 80 million trips will need to be catered to per day, whereas only 37 million trips are being provided by the available rail and bus mass transport facilities (6). Furthermore, according to a World Bank study (4), for every extra one million people in a developing city an extra 3.5 to 4 million public transport trips per day are generated. Considering the population growth in most Indian cities, the urban transport infrastructure thus

needs to be increased manifold in the decade or so, if the gap in the demand and supply has to be eliminated.

Vehicular growth:

According to Motor Transport Statistics (7), the annual rate of growth of motor vehicles in India was around 11 percent during the last decade (see also Figure 3). In 1987 there were 12.6 million vehicles. 10 years later, in 1997, this number had increased threefold to 37.2 million. Vehicle population is estimated to be over 50 million by 2001. The basic problem is not the number of vehicles in the country but their over-concentration in a few selected cities, particularly in metropolitan cities. If one compares the vehicle as well as car ownership rate across countries, India fares poorly vis-à-vis even most developing countries. India, where more than 15% of the world's human population lives, constitutes just 5% of the world's motor vehicle population. As far as cars are concerned, its share is even less than 1%.

Travel demand:

The level of urban travel demand in India is increasing substantially over the years. Three factors contribute to this. The first is the increase in population. The urbanization process has indicated that the population size of an urban area doubles in about two decades. The second factor is the mobility rate, that is, the average number of trips per person per day. The mobility rate in urban India is continuously increasing over the years. For example, in Delhi, the average number of trips per person per day has increased from 0.49 during 1969 to 1.10 during 2001. The trip rates for Mumbai, Kolkata, Chennai, Hyderabad, Bangalore, Ahmedabad, and Pune are 1.26, 1.26, 1.22, 1.05, 1.20, 1.57, and 1.48 respectively (8). The third factor contributing to travel demand is the increase in trip length due to an increase in the physical expansion of the city. For example, the average trip length in Delhi has increased from 5.4 km in 1969 to about 13.5 km in 2001 (8). The average trip length on Delhi Transport Corporation (DTC) buses has increased from 6.4 km in 1972 to nearly 18.0 km at present. Currently, it is estimated that the average trip length of four mega cities varies from 12.7 to 13.5 km. There is also a change in the pattern of trip distribution; more and more trips are being made in urban areas for work, followed by education. For example, more than 60% of the total trips in Mumbai are meant for work and around 31% for education (8).

Existing transport infrastructure:

The area occupied by roads and streets in Class – I cities in India is only 16.1 percent of the total developed area while the corresponding figure for the USA is 28.19 percent. Figure 5 presents the allocation of urban space for transportation in selected city centers. It is interesting to note that even in Mumbai, the commercial capital of India, the percentage of space used for transportation is far less when viewed in comparison to its counterparts in the developed world. In general, the road space in Indian cities is grossly insufficient. To make the situation worse, most of the major roads and junctions in Indian cities are heavily encroached upon by parked vehicles, roadside hawkers, and pavement dwellers. As a consequence of these factors, the already deficient space for the movement of vehicles is further reduced.

The present urban rail services in India are extremely limited. Only three cities i.e., Mumbai, Kolkata, and Chennai are served by suburban rail systems. The rail services in these three main cities together carry more than 7 million trips per day. Interestingly, the Mumbai Suburban Rail

System alone carries about 5.5 million trips per day. Delhi with a population of about 12.7 million is the only mega city in India, which does not have an urban rail system. It is hoped that the Delhi Metro which is under construction will adequately integrate with other modes and help in better circulation. A few other cities also have limited suburban rail systems but these hardly meet any urban transport demand.

Road safety in India:

Many developing countries including India have serious road accident problems. Fatality rates are quite high in comparison with developed countries. While in Europe and North America the situation is generally improving, many developing countries face a worsening situation. A large number of deaths in the developing world are due to road accidents. Apart from the humanitarian aspects of the problem, road accidents cost countries of the developing world at least one percent of their Gross National Product (GNP) each year – sums they can ill-afford to lose (11).

The nature of the problem in developing countries is in many ways different from that in the industrialized world. The proportion of commercial and public service vehicles involved in road accidents is often much greater. Pedestrians and cyclists are often the most vulnerable. Given the fact that the poorest of the poor in urban India cannot even afford to use public transport, they resort to cycling or walking. Since cyclists and pedestrians are the prime victims of road accidents, there must be a serious attempt to either make public transport available to them through targeted subsidization or to make the road safer to cycle and walk.

Energy consumption in the transport sector:

In general, energy consumed in the urban transport sector are petroleum products, mainly gasoline and High Speed Diesel (HSD). The energy consumption in urban transport largely depends on the modal split as well as the speed of the vehicle. On average, energy consumption per pass.-km is the least by bus and the highest by car among different modes of road-based passenger transport. Estimated energy consumption in urban India during 1994 is presented in Table 10. One can see that buses, which carry around 50% of motorized urban passenger traffic, consume far less energy as compared to cars, jeeps, and two-wheelers, which carry around 40% of this traffic. On average, a car consumes nearly six times more energy than an average bus, while two-wheelers consume about 2.5 times and three-wheelers 4.7 times more energy. In terms of fuel cost per pass.-km, a two-wheeler is 6.8 times, a three-wheeler 7.0 times, and a car is 11.8 times costlier than a bus.

Flow Models – Network Structure and Gravity Model.

Flow Models

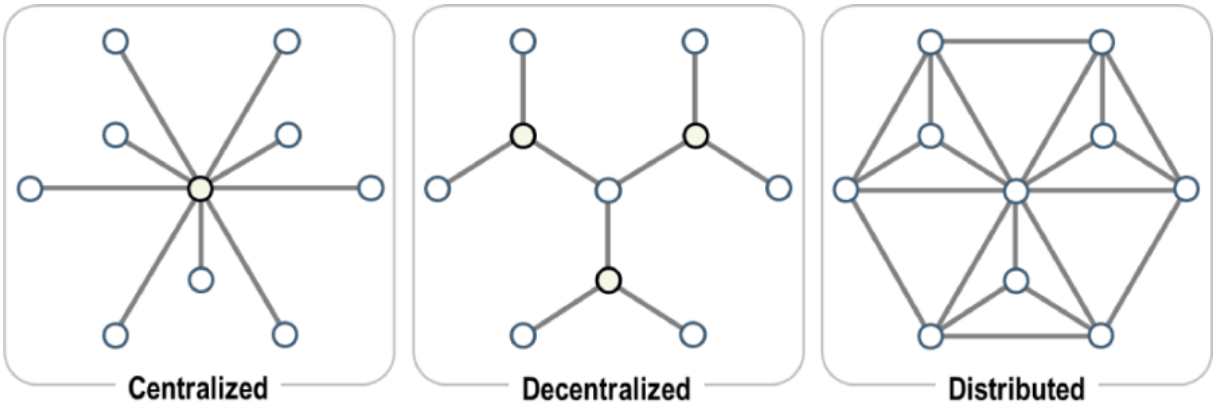
Flow analysis is the core of many well-recognized technologies for the evaluation and improvement of transport systems, including the analytical methods and simulation software packages for transport system planning and design, traffic control, traffic safety analysis, and demand management. Urban and regional transport systems belong to a highly complex sector that involves the intricate activities of millions of commuters each day, which makes it highly

challenging to accurately analyze and predict the flows. Herein, these flows also cover the dynamics in different subsystems, including the urban road networks and public transport systems; thus how to reasonably address the interactions and correlations between these subsystems is still a difficult and prevailing problem in the transport engineering and science area. In addition, new emerging sharing mobilities (such as ride-sharing, car sharing, and bike sharing) have provided new dimensions to travelers for the trip choices, which have introduced new challenges to the studies of transport system flows. To this end, this special issue aims to address the cutting-edge ideas, knowledge, methodologies, techniques, and practices in the broad areas of transport system flow analysis. There were 70 papers submitted to this special issue, 20 of which were accepted for publication. As the guest editors of this special issue, we would like to summarize the accepted papers as follows. "Analysis on Port and Maritime Transport System Researches" by L. Chen et al.

A two-component finite mixture of logistic regression model is applied to analyze the vehicle trajectory data collected on a highway segment and discovered two major merging behaviors of drivers: risk-rejecting and risk-taking. "Characterizing Critical Transition State for Network Fundamental Diagram" by **R. Hong et al.**

A stochastic traffic flow model is designed, and a shockwave speed based stochastic fundamental diagram is studied for a road segment between two signalized intersections for capturing the density-flow data scattering. The distribution of shockwave speeds is obtained by the variational Bayesian learning method from the field data. "The Impact of Aggressive Driving Behavior on Driver-Injury Severity at Highway-Rail Grade Crossings Accidents" by **C. Ma et al.**

Network Structure:



Source: Adapted from U. Blum and L. Dudley (2001) Report of the 109 round table on transport economics, Transport and Economic Development, European Conference of Transport Ministers.

Transportation networks are designed to offer a level of service which is related to their structure. Conceptually, three basic network structures can be designed to link the same locations:

- **Centralized**. One center has high accessibility and thus represents the dominant element of the network and the spatial structure it supports. This is the common characteristic of hub and spoke networks.

- **Decentralized**. Although the center is still the point of highest accessibility, the network is structured so that sub-centers have also significant levels of accessibility.
- **Distributed**. No center has a level of accessibility significantly different from the others, which implies a high connectivity levels and redundancy.

Gravity Model:

The gravity model is the most common formulation of the spatial interaction method. It is named as such because it uses a similar formulation than Newton's law of gravity. Gravity like representations have been applied in a wide variety of contexts, such as migration, commodity flows, traffic flows, commuting, and evaluating boundaries between market areas. Accordingly, the attraction between two objects is **proportional to their mass and inversely proportional to their respective distance**. Consequently, the general formulation of spatial interactions can be adapted to reflect this basic assumption to form the **elementary formulation** of the gravity model:

$$T_{ij} = k \frac{P_i P_j}{d_{ij}}$$

- *Pi* and *Pj* : Importance of the location of origin and the location of destination.
- *dij* : Distance between the location of origin and the location of destination.
- *k* is a proportionality constant related to the rate of the event. For instance, if the same system of spatial interactions is considered, the value of *k* will be higher if interactions were considered for a year compared to the value of *k* for one week.

Thus, spatial interactions between locations *i* and *j* are proportional to their respective importance divided by their distance. The gravity model can be extended to include several calibration parameters:

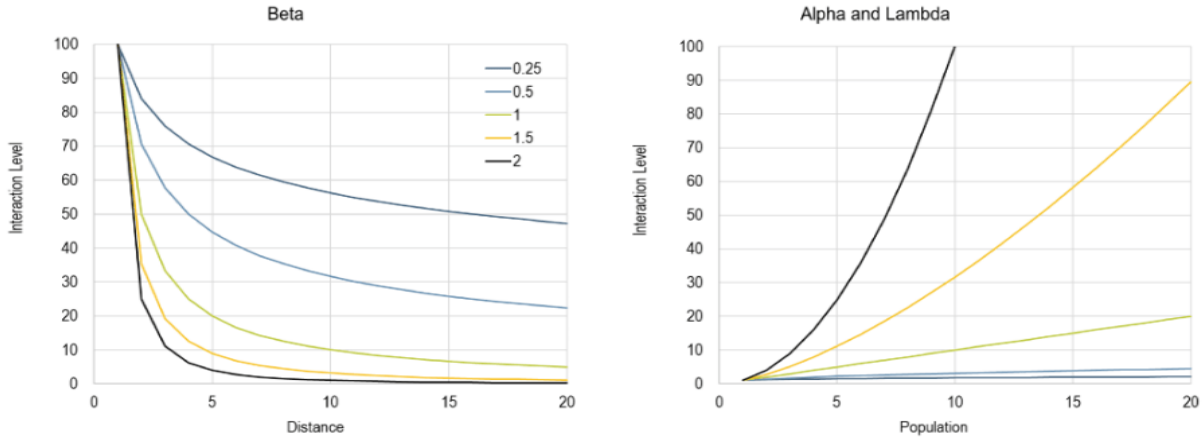
$$T_{ij} = k \frac{P_i^{\lambda} P_j^{\alpha}}{d_{ij}^{\beta}}$$

- *P*, *d* and k refer to the variables previously discussed.
- β (beta): A parameter of transport friction related to the efficiency of the transport system between two locations. This friction is rarely linear as the further the movement the greater the friction of distance. For instance, two locations serviced by a highway will have a lower beta index than if they were serviced by a regular road.
- λ (lambda) : Potential to generate movements (emissivity). For movements of people, lambda is often related to an overall level of welfare. For instance, it is logical to infer that for retailing flows, a location having higher income levels will generate more movements (customers).

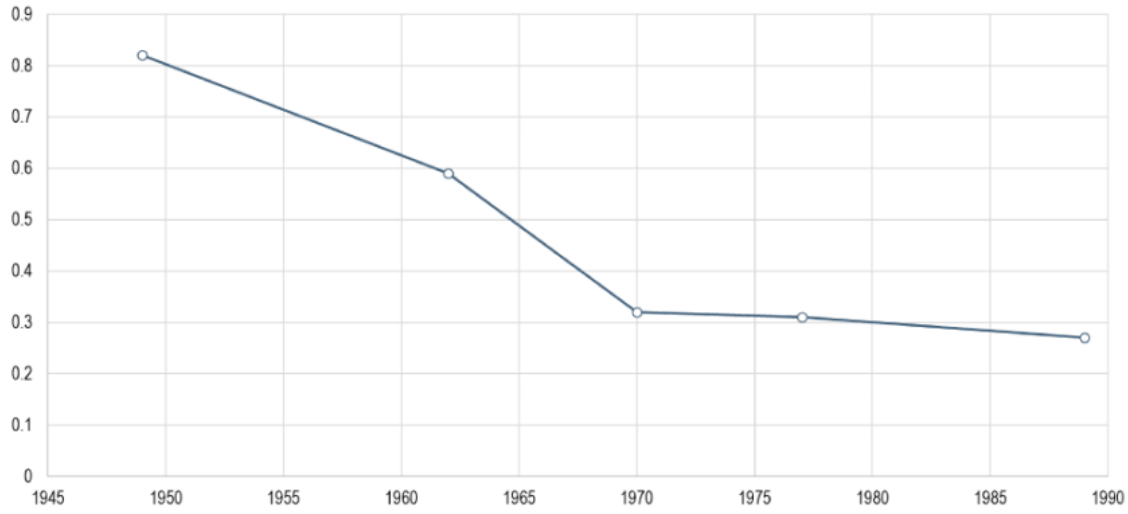
- α (alpha) : Potential to attract movements (attractiveness). Related to the nature of economic activities at the destination. For instance, a center having important commercial activities will attract more movements.

A significant challenge related to the usage of spatial interaction models, notably the gravity model, is related to their **calibration**. Calibration consists of finding the value of each parameter of the model (constants and exponents) to ensure that the estimated results are similar to the observed flows, that those results can be replicated and that changing the parameters would generate valid results. If it is not the case, the model is of limited use as it predicts or explains little. It is impossible to know if the process of calibration is accurate without **comparing estimated results with empirical evidence**. Consistent calibration enables the model to be more rigorous and adaptable to other contexts.

In the two formulations of the gravity model that have been introduced, the simple formulation offers good flexibility for calibration since four parameters can be modified. Altering the value of beta, alpha and lambda will influence the estimated spatial interactions. Furthermore, the value of the parameters can change in time due to factors such as technological innovations, new transport infrastructure, and economic development. For instance, improvements in transport efficiency generally have the consequence of reducing the value of the beta exponent (friction of distance). Economic development is likely to influence the values of alpha and lambda, reflecting growth in mobility.



Effects of beta, alpha and lambda on Spatial Interactions



Chicago's beta Values for Air Transportation, 1949-1989

Calibration can also be considered for different O/D matrices according to age, income, gender, type of merchandise and modal choice. A part of the scientific research in transport and regional planning aims at finding accurate parameters for spatial interaction models. This is generally a costly and time-consuming process, but a very useful one. Once a spatial interaction model has been validated for a city or a region, it can then be used for simulation and prediction purposes, such as how many additional flows would be generated if the population increased or if better transport infrastructures (lower friction of distance) were provided.

Outside the gravity model, there are other models that can be used to measure spatial interactions. **Destination choice models** are considered an extension of the gravity model that is gaining popularity since they provide a more extensive range of factors explaining the assignment of spatial interactions. While the gravity model assumes that flows are generated as a function of attributes of the origin and destination pondered by impedance functions, the destination choice model allows for additional behavioral attributes to mobility, including income, walkability, the availability of parking and psychological barriers. The main goal is to explain flows that the standard gravity model does not capture well.

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