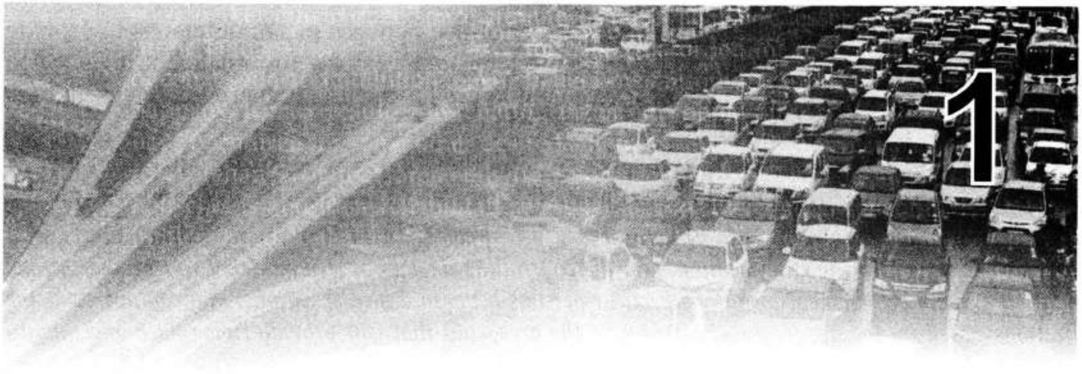


Introduction to Transportation

1.0 PREAMBLE

Transportation can be defined as an act, process or instance of moving, conveying or transferring an object or a person from one place to another using suitable source of energy. Going to office from home is an act of moving a person, whereas, taking raw material from a manufacturer or retailer to the construction site is the act of moving an object. There is a certain process involved in moving coal from storage area to furnaces in power plants or moving persons to higher altitudes using cables and suspended cabins. These are examples of conveying man or material between two distant places when normal movement becomes impossible or quite difficult. Similarly, any instance of moving the object or the person from one to another type of mode of travel, say for example, from train to bus at an intermediate stoppage, is a classic example of transferring the object or the person.

All these movements are either guided by scientific laws or are restricted by physical features of the geography of the area in which that movement takes place. Whatsoever is the type of the movement, a source of energy is always required to execute that movement. This source of energy may be derived either from a mechanical device or by converting potential energy to kinetic energy or from human or animal energy. Movements using an IC engine, sliding along a slope and walking or moving in an animal drawn cart are examples of such uses of energy, respectively. It means transportation involves an application of science and mathematics by which the properties of matter and the sources of energy in nature are made useful to move man and material from one place to another. The frictions caused by the physical features of the geographical area had spurred technological inventions and innovations that can help in overcoming those frictions so as to achieve the desired objectives of moving man and materials. The frictions caused by rivers and mountains are overcome using bridge and tunnel technologies, respectively. Along with movement, the safety of the item being moved needs to be ensured. This may be in terms of provision of safe storage along the route; availability of supporting mechanism from below to maintain movement at a predefined level; and placement of a controlling system that facilitate movement without collisions, theft and damage. Efficiency is another important aspect related to the movement or transportation. Any movement should be performed within a stipulated time so that the time and quality utility can be attached to that movement. Similarly, the movement should be performed between places of interest to provide place utility. At the same time, any system or mechanism developed, formulated or invented to achieve the above objectives should be convenient to use for the user. Otherwise, the usefulness of the transportation system will be lost.

At this point, it is worthwhile to note a definition that can comprise all the points of considerations as discussed before to delineate the breadth of transportation engineering.

Transportation engineering can be defined as a useful combination of physical facilities, objects and devices moving/operating in a medium, and the controlling devices or systems, that can provide a safe, efficient and convenient movement of objects or persons between desired locations; that can overcome the frictions posed by the geographical features of the area; and that can provide time, place and quality utility to the one which is moved using that combination.

There are certain terms used in this definition. These terms signify certain functions that are inherent in any movement. Physical facilities provide guidance and support to the objects that are moved in a medium using those facilities. They also point towards the connectivity and accessibility available between the places of interest. The objects are devices moving in a medium basically indicate towards the mobility imparted to the objects or persons who wished to be moved between places using the connectivity available through physical facilities. The controlling devices ensure the safe and efficient movement, and attach utility to that movement.

1.1 FIELDS OF TRANSPORTATION ENGINEERING

Transportation engineering is a combination of different fields, which are unified by the use of the scientific methods and certain basic fundamentals. Primarily, field of transportation can be broadly classified as:

i. Transportation economists
ii. Transportation lawyers
iii. Transportation engineers
iv. Transportation planners and
v. Other transportation professionals.

Transportation economists, lawyers and planners are out of scope of this book, and hence are simply defined to give an idea of the transportation domain in which they work.

Transportation economists generally deal with the economics related to transportation projects, project finances and budgeting, economic viability and feasibility of the projects.

Transportation lawyers deal with the legal issues involved in the planning and construction of transportation facilities, their operation and maintenance. They need to examine and study the legalities involved in the implementation of proposed rules and regulations and have to study in advance the legal possibilities which can stop or delay the implementation of transportation projects.

Transportation planners make estimates of future requirements to improve the existing facilities, plan new facilities, transit systems, re-route the traffic, make rearrangements within the system, take policy implementation decisions, etc. They may work as:

- Consulting firms
- System planners
- Large scale engineering design analysts
- State/Provincial highway/Railway planners
- Regional planners
- System operation planners

- Traffic planners
- System operators
- System optimization analyst/managers
- System regulators
- System maintenance schedulers, etc.

A transportation engineer remains involved with works that are related to transportation. The various fields in which a transportation engineer works are:

- Highway and airfield pavements
- Bridge design
- Design of canals, docks, railways, port facility, intermodal terminal facility, etc.
- Mechanical designs of vehicles, design and working of engines, aeronautics, marine vessels, naval architects, etc.
- Communication, safety (control of flow), etc.

Transportation engineering, therefore, is an extremely broad field encompassing different kinds of professional activity. Broadly, from transportation perspective it can be classified as:

- Transportation system engineers or system planners
  - Mainly working in the area of design and planning of complete transportation system for a region, and includes different modes, technologies, and their interrelationships.
- Transportation system component engineers
  - Mainly work on the design of components and procedures of their use.

The divisions of transportation engineering field is shown in Fig. 1.1.

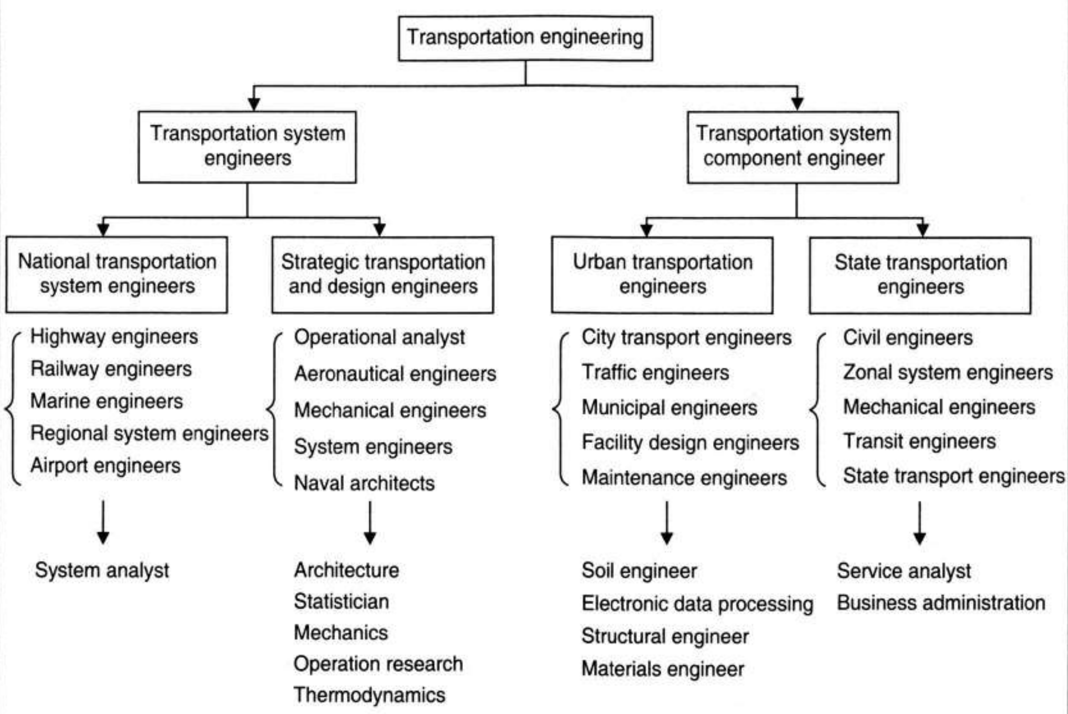


Fig. 1.1: Fields of transportation engineering

There are large number of specialists working in different fields who assist in the planning, design and implementation of transportation facilities. A short list of such application specialities is given below:

- Highway engineering
- Freight transportation
- Marine transportation
- Transportation management
- Traffic engineering
- Urban transportation planning
- Developing country transportation planning
- Rail transport
- Port development and planning
- Airport planning
- Trucking
- Transportation regulations
- Transportation engineering
- Transportation and economic development
- Transportation economics
- National transportation policy
- Transportation environmental analysis and others.

Similar to above, there are methodological specialities who work in the area of forecasting and projection of demands. Such specialities are:

- Demand analysis
- Transportation system performance and evaluation
- Policy analysis and implementation
- Urban planning and development management
- System analysis methods
- Environmental impacts
- Economics
- Activity system analysis and others.

The scope of transportation engineering is out of geographical boundaries and may relate to either urban or rural areas; developed or developing areas, nations and so on. At the same time, it is not limited in its scope. It may relate to:

- Types of movements
- Different modes of transportation
- Technological frontiers
- Development of technology, etc.

In a developing society, a transportation system engineer works closely with policy makers, economists and sociologists. In urban settings they have to work closely with city planners (for the development of land with different uses like place to live, work etc.) and traffic police (for controlling the flows). The role of transport system component engineer comes after the initial role of transportation system planner. The designs of the components should be widely acceptable and should not be individualized. Transportation engineers, not only have to play their role in government or public sector but also in private sector, e.g. truck lines, airlines, inland and ocean water transportation, container companies.

1.2 ROLES OF TRANSPORTATION

Transportation plays different roles in the society, like:

- Economic role
- Social role
- Political role, and
- Environment role.

These are discussed in detail in the following successive sections.

1.2.1 Economic Role of Transport

This can be further discussed under following headings:

- Place, time and quality utility
- Destination choice
- Long v/s short distance movement
- Location of an activity
- Extent of freight transport.

Place, time and quality utility of goods

One of the main objectives of transportation is to attach utility to the movement of objects or persons. This may be in terms of place utility, time utility or quality utility.

Place utility means a commodity having good chances of consumption at a place other than the place of production. It is decided based on the inter-relation of cost at the place of manufacturing, cost at the place of consumption and paying willingness of buyer. Cost at the place of consumption is taken as a function of threshold transport cost (i.e. fixed charges of loading a vehicle, billing, documentation, etc.) and product of unit charge of transport and distance between production and consumption places. This is shown in Fig. 1.2.

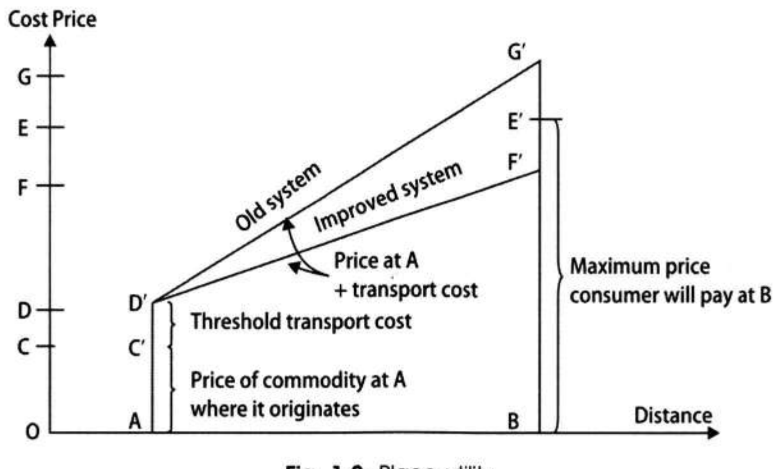


Fig. 1.2: Place utility

In Fig. 1.2, place 'A' is the production centre and place 'B' is the consumption centre. 'OC' denotes the cost of production of the commodity at place 'A' and 'CD' is the threshold cost, as defined before. Therefore, 'OD' is the total cost at the place of manufacturing. In the old transport system, the cost of transportation is 'DG'. This makes the total cost of the commodity at place 'B' equal to 'OG', which is more than the willing price 'OE' consumer may pay at place

'B'. With high transport cost, there will not be any buyer at place B. When system improves the transport cost reduces and is equal to 'DF', thus bringing the total cost of the commodity at place 'B' equal to 'OF'. This is less than the willing price the consumer may pay for the commodity at place 'B'. Therefore, the commodity will be consumed at the place 'B', thus giving it a place utility. The difference in the total cost and the willing price, i.e. 'EF' can be interpreted in different ways. This may allow the increase in the price of the commodity at place 'A' by an amount equal to F'E' (manufacturer's view point) and still the commodity will be purchased at the place 'B'. This may also provide surplus money to the user equivalent to 'EF' that can be used for the purchase of another commodity, which could not be purchased before due to shortage of money available in hand or it may be used to purchase more quantity of the same commodity, may be for stocking or satisfying the actual needs, which were left unsatisfied before. The decision regarding use of excess money in hand will depend upon the users' or consumer's viewpoint.

If the price of commodity is greater than 'OE' at the place of consumption, then the value of commodity at the place 'A' would become zero as there will be no consumer for that commodity at place 'B'.

Mathematically:

Cost of transport (P) = Fixed cost + variable cost

Fixed cost = cost of manufacturing + threshold cost

$$= OC + CD = \alpha$$

Fixed cost is not dependent on the distance between place of manufacture and place of consumption.

$$\text{Variable cost} = \text{Unit operating cost} \times \text{distance moved}$$

$$= \beta \times d$$

The unit operating cost will be dependent upon the cost of fuel, wears caused during operation, cost of lubricants, and wages paid to the operators.

Therefore, the cost of transportation will be written as:

$$P = \alpha + \beta \times d$$

Here the ratio '/' is dependent upon the weight or volume of the commodity that is moved through the system.

Time utility: The transportation of goods must be completed within a certain time period in order for the goods to have time value. Many of the commodities have value if they are delivered to the place of consumption well within time. Once that time is over, the value of the that commodity may drop drastically. Best examples for the time utility are transportation of raw materials to the place of consumption. There are manufacturing processes, which operates using stage production units that are located at different places. The output of the one stage production unit is an input to the next production unit in line. Any delay in the transportation of the raw material from first unit to the next will stop the production at the next unit in line.

Quality utility: While transporting the goods, their essential qualities should not be diminished or lost. For example: perishable items require special environmental conditions like controlled temperature, pressure or humidity during transport to reduce their natural deterioration. Such items will lose their utility if delivered under deteriorated condition. Sometimes, processed material is transported instead of the raw material, which reduces the weight of the commodity, thus making transportation in bulk possible and easy. Damage to goods during shipment or loading or unloading is another point having economic implications. This may need special packing requirements or use of a specific type of vehicle and is dependent on the condition of the pathway.

Destination choice and transport cost

Destination choice also plays an important role in arriving at transportation cost of materials. The destinations, which are nearby or are connected with other places having continuous movement of traffic between them, will cost less in transportation than those destinations, which are in a remote area or are not having traffic on regular basis or are less likely to be reached. This will increase the cost of transport between such places. The taxes to be paid at the time of crossing the boundaries between states or nations also become a part of the threshold cost.

Further, there are fixed charges for certain minimum weight of the cargo to be moved. With the increase in the weight of the cargo to be shipped, the total cost of transport will not increase proportionately. It will be a loss to the shipper if the shipment is falling below the threshold limit of weight to be transported. In such cases, the cost to be paid by the shipper may be reduced by sharing the space in vehicle with other shippers. Maximum cargo that can be shipped is defined by the vehicle cargo holding capacity. Similarly, maximum weight to be shipped is defined based on the characteristics of the supporting system of the vehicle.

Sometimes, special schemes are implemented to generate revenues and to provide some benefit to the shippers. Golden card scheme allowing extra load above the restricted value is one such scheme. In this scheme the shipper pays extra money for getting golden card and is allowed to ship load more than the restricted load that can be transported using a type of a vehicle.

Use of different transport technology

Technological innovations have resulted in large number of transport technologies. Different technologies are suitable for movement in different distance bands or for movement in varying terrain conditions. Technologies like turbo, jets, rockets, etc. can be used only for travel to long distances say across continents, whereas, technologies based on animal power or human power can be used only for short distance travels. Use of technology can also reduce the time of travel between two distant locations. The distance which were used to be covered in days using runners or animals in old good period can now be covered in some hours only. There is also a difference in the total tonnage hauled between places in the modern times. In good old days, it was possible only by employing a large numbers of labourers or animals to deliver large quantities, but today even a single movement of train can do the same work with higher efficiency and less number of persons employed for the same. This has become more resource efficient. As per one study, the cost per ton-mile has decreased from human back-horse-cart-truck-rail system. This indicates the change from slow movement to faster movement, from smaller loads to bigger loads, from small distances to large distances, and from energy consuming to energy efficient modes of transportation.

Long-distance v/s short-distance traffic

There is a compositional change in the movements categorized by distance travelled. Two distinct movements are person movements and freight movements. Large number of person movements can be categorized either in short distance movements or in medium distance movements. Short distance movements are mostly carried out using personal vehicles or public transport facilities available in the area. Medium distance movements are made possible using public transport like bus or train. Few person movements are observed for long and very long distances, which are generally covered using air transportation facilities. Even if such facilities are not available at the point of start of journey, they are reached by using other modes of transportation. Freight movement is the one, which has economic considerations. Large amount of freight is moved from one part of the nation to another part, may be due to location of place of manufacturing and consumptions. Not necessarily, these can be hauled directly to the desired places using a single transportation technology. At times, it requires a mix of technologies, working in coordination with each other, to complete the movement. The shift of freight may be between different types of modes within a system or between different systems.

One example for such a requirement may be the commodities transported via sea routes to other nations. Once these commodities reach the harbor or port of a nation, they are unloaded and transferred to transport modes like trucks and railways for further distribution in different parts of the nation.

Changes in location of an activity

The provision of transportation facilities in an area(s) may cause a change in the activity pattern of that area. Lets us look at an economic scenario. Certain commodity is manufactured at one place and is supplied to another place where it is consumed. After certain period of time another manufacturer sets up a manufacturing unit to produce the same commodity at a distance farther away compared to distance at which the first unit is from place of consumption. Owning to either reduced cost of production or reduced cost of transportation or relaxations in taxes by the government, the second unit supplies the same commodity at lower price than the first unit. This will cause a shift in the consumption pattern of that commodity, the one produced by second unit being consumed more than that of first unit. Depending upon the price difference, this will make a change in the activity pattern, sooner or later. The first unit may get closed down, if improvements to bring down the price of the commodity are not taken or are not made competitive to those offered by second unit. One drastic change, as an after effect, will be the change in the employment pattern in that area.

Figure 1.3 presents a similar activity scenario. Place 'A' is the place of manufacturing a commodity that is consumed at place 'B'. The cost of production at place 'A' is 'AC'. The total cost of production is 'AD', which includes threshold cost 'C'D'. The cost of transportation between place 'A' and 'B' is 'D'E', thus bringing the price cost at place 'B' to 'OE'. Say, this is less than the price cost that a consumer can afford at place 'B' and hence, is consumed. After certain time period, a new manufacturing unit is set at place 'K' to produce the same commodity. Its distance from the place of consumption, i.e. 'KB' is greater than that of first unit, i.e.

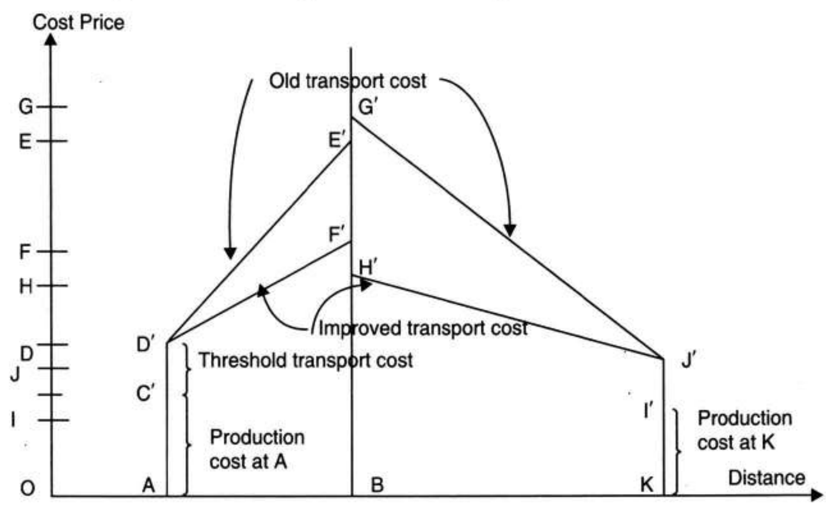


Fig. 1.3: Effect of location of an activity

'AB'. The cost of production at location 'K' is lower than that at 'A'. The threshold cost being same at both the locations, the total cost of production at place 'K' comes to be lower than that at place 'A'. Due to longer distance for supply, the price cost of commodity produced at place 'K' comes out to be higher (OG) than that from place 'A' (OE) and hence, will not be consumed at place 'B'. After some time a new transportation technology is introduced, which brings down the transportation cost between the places, but the reduction in transportation cost is higher between places 'K' and 'B', as compared to between places 'B' and 'A'. This brings the reduction in price cost of the commodity at place 'B', the new value being 'OF' for commodity produced at place 'A' and 'OH' for that produced at place 'K'. As OF > OH, commodity produced at place 'K' will be consumed more than that produced at place 'A'. This transportation improvement may even cause stopping of the production at place 'A'. This change will affect the pattern of production and the pattern of settlement, and the shipment will change accordingly. The change may cause localization or concentration of developmental activities and loss of employment at other places. Therefore, the balancing of economic activities between places is required.

With the changed economic scenario certain income effects may be visualized:

- Saving of money while same living standard is maintained
- More purchase of same commodity
- Spending of saved money on some other commodity
- May cause reduction in time spent on working also

Some more examples depicting the effects of the transportation infrastructure improvements are:

- Constructions of bypass may increase the cost of land available on both the sides of the road; and may induce ribbon development, unauthorized constructions, etc.
- Construction of flyover may reduce delays to crossing traffic, reduce operating cost and travel time, but may cause loss to market activities, which were flourishing on the sides of the road before the construction of the flyover due to coming within ramp areas.

Extent of freight transport

It helps in increasing the range of goods available for consumption, thus improving upon the living standard of the users. Cost of extraction versus transportation, e.g. oil, decides whether a commodity can be consumed at a place away from the place of extraction, or the price of the commodity or its quality. The opportunities of freight transportation may induce the shift in the location of production, employment, etc.

1.2.2 Social Role of Transport

This can be further discussed under following headings:

- Formation of settlements
- Size and pattern of settlements
- Ease of travel
- Long distance travel

Formation of settlements

Formation of settlement helped the end of nomadic life. It made the transportation of food and fuel possible, as well as the storage of food for emergencies. The saving in time that was spent in searching food and shelter during nomadic period, due to better transportation resulted in giving time to other activities. Most of the initial settlements were located near water bodies, especially flowing water, because of ease of transportation. This caused the development of terminal facilities near such trans-shipment points and warehousing facilities to store the material either to be transported through water route or received at that terminal from other locations. Human being could devote more time to professions or activities like farming, cattle rearing, manufacturing, etc. Higher level of interaction started between such settlements, bringing cultural and temporal changes in societies. Availability of material not available at a place otherwise due to transportation routes improved the style of living. Increasing level of technological up gradations and development of transportation systems has lowered the travel times causing horizontal swelling of cities.

Size and pattern of settlement

Size of settlement is governed by population and per capita requirement. It should be able to sustain the population residing therein. If the distance of supply to a point is doubled then due to circular area of influence, the area of land supporting the settlement gets quadrupled. This is known as 'Lardner's law of Squares'. If the distance related transportation cost is reduced then area of possible production for the city increases. The law is depicted in Fig. 1.4.

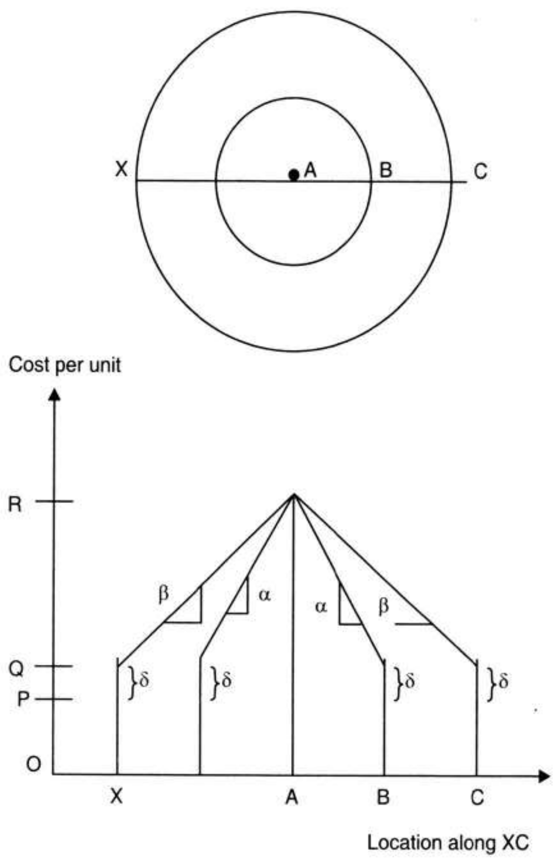


Fig. 1.4: Location and size effect of the city

Where, OR = Affordable cost at 'A'

OP = Production cost of commodity

δ = Threshold cost

α = Unit rate of transportation, defining the extent of settlement, i.e. AB

β = Unit rate of settlement after improvement (< α)

Technological developments have reduced the transportation costs in recent years. But the availability and affordability of motorized modes has induced the sprawling of cities. The effect of reduction in the unit transportation cost is the increase in the size of the city within affordable prices. Figure 1.4 shows that under the constraint of affordable price at location 'A' and the existing unit cost of transportation 'α' the city can expand upto location 'B'. But with the transportation improvements, the unit cost of transportation reduces to 'β', thereby increasing the distance that can be traveled within the money available to the user. Hence, the city now can expand to location 'C'.

Another effect is the increase in spendable money that will be available with the household, if no shifting to outer locations takes place. This will result in taking up those activities that could not be taken up before due to unavailability of money. The high population growth has been observed at the two extremes, i.e. high incoming groups and low-income groups. If the size of the household is big, then it may affect the spending power of the households belonging to low-income groups, especially on transport.

In the initial periods of formation of settlements, the central area acts as a core area of activities. Most of the activities remain concentrated in a small area termed as CBD (Central Business District). Dense settlement takes place near CBD area thus increasing the value of land in that area. Similar settlement patterns can be observed along the through routes that connect CBD with other locations in a city. Therefore, the land value increases along the transport networks (ribbon developments, linear developments, etc) also, thus creating higher densities near the facilities. With time, the central areas or areas near the transport facilities become congested not fit to live in due to less air circulation and increasing pollutions, and cause outer flux of population to open areas. This becomes possible again because of lower transportation costs due to improved transportation systems.

The city size has its effect on the development of activity centers also. Single central core causes the concentration of activities, resulting in large number of trips made to that area. This causes congestion, pollution and delays. In its place, the development of number of small activity centers throughout the city can cater to the needs of local areas, thus reducing the need to travel long distances within city, as well as, to a specific location like CBD. The major activity centers may cater to specialized needs and can act as employment hubs.

Dispersal of activities and related developments away from transit routes due to availability of access modes also creates its effect on the settlement patterns. The size of the population and spatial form of urban areas are matters of social choice, with technology limiting the range of choices but not specifying them.

The size of the city and the settlement pattern also affects the personal movement. This needs to be studied with respect to the trade-off between travel time and travel cost. The accessibility and affordability is to be maintained along with mobility. The use of walk mode reduces the extent of the city to around 5 km, so that any location is reachable within half an hour. Animal drawn vehicles or trams increase the extent of the cities to around 13 km. Mostly these are affordable to the masses. The automobile dependence with the technological innovations has increased the city size to around 45 km.

Ease of travel

The technology has helped in easing out the travel burden and has brought about the following changes in the society, settlement and travel patterns-

- Choice of place of residence with respect to the place of work
- Depletion of population from older areas/central areas, causing change in population density pattern
- Dispersal of business and activities in a city or outside the city, like relocation of major businesses namely, wholesale fruit markets, transport providers, etc.
- Increase in traffic congestion due to increase in per capita trips and increase in automobile ownership
- Dangerous levels of noise and air pollution, creating problem of dispersal of pollutants and health problems
- Improvement in accessibility and connectivity along with mobility
- Extreme reliance on automobile causing
  - Disparity in travel opportunities among population groups
  - Automobile oriented development
  - Overlooking of the needs of disabled, elderly and children
- Requirement of certain level of income to use new form of transport, like travel in air-conditioned services
- Use of vehicle, as a symbol of status in the society rather than as a need of travel, reducing social interactions and creating barriers among masses

Long-distance travel

The technological improvements have made it feasible to travel long distances within shorter time periods. The various effects of long-distance travel can be listed as follows:

- Vacation, weekend trip over long distances become possible for masses using affordable modes, for example travel to resorts or amusement parks, nearby hill stations, etc.
- Improvement in level of understanding due to mixing or coming in contact of persons from different cultures, traditions, etc.
- Availability of industrial products at long distances bringing changes and improvements in patterns of living
- Faster travel has increased business trips over long distances within same time period bringing in economic revolution
- Improvement in rural economy and living due to better connectivity, bringing them out of isolation and at times inducing migration to urban areas.

1.2.3 Political Role of Transport

The following aspects need to be discussed:

- Rule of an area
- Political choices in transport
- Financing of transport

Rule of an Area

Transportation has enabled governance of vast area feasible and easy. In ancient period, passing on of the information about the unrest or the problems faced by the people of an empire used to take many days. It was done either by employing runners, or by using drummers located at audible distances passing-on coded information or sending a person on a horse back. Similarly, sending assistance to affected areas from central seat of governance used to take many days. The problems were acute in the case of boarder areas having strategic importance and facing continuous threats from invaders. The day to day policing of an area have also become possible due to availability of good transportation networks and means of trans-portation. Various political aspects that can be taken care of by transportation are:

- Passing of information related to good governance of an area to all parts of the region or nation governed by a government
- Meeting out the needs of the area and providing assistance to the masses during emergencies
- Use of communication technology to pass-on the information at a faster rate to make possible the equitable governance of different areas, like central or state government decisions, gazette notifications, information on internal or external security of areas, etc.
- Smooth functioning of a representative form of government, as there is no requirement for the government to send a representative physically to get the orders or directions from the higher leadership and wait till the representative returns with the required details.
- Strategic requirements, like movement of defense personal and machinery to the locations which are otherwise inaccessible, like Siachin Glacier; maintaining a continuous supply of required material for their sustenance; providing connectivity to remote but strategically important areas, etc.
- Policing of internal areas, ensuring day to day safety of residents

Political choices in transport

The choice of nation's transport system is necessarily a political one. Some examples of communication in the ancient times as pointed before are through drums, horses, messengers, Pony Express system, etc. In the later period, road networks were developed by Romans for the movement of troops in their administered area. The ancient civilizations used maritime intercity transport system as is clear from their location of settlement. Various types of movements of persons and goods require provision of systems that can satisfy the needs of intra-town, intra-urban, intercity, rural-urban movements. Mobility hierarchy has been provided to provide connectivity between different parts of the country after getting approval from governing political wings. One such example is of Rural Highways, having hierarchical system comprising Expressways, National highways, State highways, Major District roads and Rural roads. Recent examples of political choices are construction of roads under Pradhan Mantri Gram Sadak Yojna (PMGSY), North-south and East-west freight transportation corridors, Golden quadrilateral, rail links upto higher altitudes and strategic locations like Udhampur and Srinagar, year round ferry service in Ganga river between Allahabad and Howrah, etc.

Similarly, mobility hierarchy can be discussed for urban areas. It includes freeways, arterial roads, sub-arterial roads, collector streets and local streets. The decision of providing a private owned vehicle network or a public transport network in a city is also dependent on political choices. Certain examples of such choices are metro or suburban rail (MR) or light rail transit (LRT) systems, Sky bus system, Bus Rapid Transit (BRT) system, construction of flyovers, etc.

Financing of transport

Financing of transport system is one of the biggest tasks. Mostly it is the responsibility of the central government but the priorities changes with the change in the government. Local bodies have to be provided with sufficient technical knowhow so as to maintain roads and facilities falling under their jurisdictions. One recent example of such initiative is National Rural Employment Guarantee Assurance (NREGA) scheme of central government which envisages the passing of technical knowhow related to road construction, maintenance and quality assurance to local persons through training. Policies need to be implemented wherein the user pays for the provision of facilities and their maintenance, like Road pricing, Tolls, etc, so that the money collected is utilized efficiently in maintaining the old facilities or for providing new ones. Private participation, e.g. BOT, etc. and Public-Private-Participation (PPP) are some such schemes to pool resources for transport infrastructure development. Fixing of priorities and phasing of activities are done so that works can be taken up within available resources. Economic viability of transportation projects should also be analyzed before the provision of facilities.

1.2.4 Environmental Role of Transport

The following aspects need to be discussed:

- Pollution
- Energy consumption
- Land and aesthetics
- Safety

Pollution

Transportation sector is the main polluting sector. Almost seventy percent of the pollution is due to this sector. This may be of any type like air pollution, water pollution, noise pollution, waste, land pollution, etc. The pollution can be defined as unwanted by-product, which deteriorates environment and causes health hazards. The contamination of air from transportation sector usually takes place due to internal/external combustion engines, burning of fossil fuels, etc. One study has observed that a large number of police personals in Bangkok deputed at the roadside to control traffic are affected with respiratory diseases. The pollution level on the road has been found equivalent to smoking of many cigarettes in a day. The gravity of air pollution is associated with the natural dispersal of pollutants or use of cutting-edge technology to reduce concentration of pollutants. These may help in maintaining environmental quality. This is also dependent upon type of urban development, wind velocity and its direction, and the rate of dispersal of pollutants. This process is time dependent. Certain emission control devices are available that can be installed on the vehicles to reduce the harmful emissions. New technology vehicles come with energy efficiency norms and thus affect the environment at reduced level. The fuels are modified, e.g. premium oil and lubricants, Xtra mile oil, etc. that are supposed to improve engine efficiency and reduce pollution. The search for alternate fuels is on, some examples being hybrid fuels, hydrogen fuel, battery operated engines, etc. Some of such vehicles are already under design testing phase, as well as in operation.

Another pollution caused by transportation is noise pollution. Noise is defined as an unwanted sound. It causes physical and psychological effects like deafness, sleep disturbances, startles, loss of concentration, etc. There are noise-sensitive areas like areas with hospitals and schools, where noise control should be implemented. Noise abatement techniques are in use, whereby the noise can be tackled either at the source of the noise itself or by interrupting the path of the transmission of noise disturbances. Some examples are noise barriers, use of acoustic material, etc.

One important source of disturbance or land uses along the side of a facility is vibration induced due to the movement of vehicles on that facility. The transmission of vibrations from railway networks or rapid transit lines causes disturbances to certain activities that require concentration. The effect of vibrations can be reduced by the use of dampeners or by relocating the transit routes or by developing thick vegetation between the source and the affected.

Pollution of water due to transportation is generally associated with the inland water transportation routes or distance sea routes. This is mostly caused due to the release of oil, accidently or intentionally, and wastes into the sea and water bodies or because of accidental spills from tankers This has deteriorating effect on the marine life and on quality of water.

Pollution of ground happens due to the discharge of waste onto ground, or dumping loose cargo or time-barred products on vast lands. This makes the land as good as barren with no productive value. The metal deposits and fluid discharges at the time of breaking or processing of such waste render the land further unusable.

Energy consumption

One of the negative effects of transportation is the consumption of energy in different forms. Fuel consumption in the transportation sector is one of the concerns because of the cost of fuel, which is to be imported from the oil rich nations and the depleting nature of that fossil fuel. This causes the outward flow of money, putting pressure on foreign exchange reserves and makes the nations dependent on others. If the comparison is made between different types of travel modes and travel systems then it becomes clear that the consumption of material during vehicle manufacture and operation of motorized vehicles is much higher than those of non-motorized nature. This is another burden on nation's limited resources.

Another point of concern is the loss of energy during movement through the congested networks due to delays and forced stops. Many studies have estimated such losses generally in terms of the loss of productive man-hours. These are found to be much larger in size, at times amounting to some percent of nation's GDP. The distribution of resources should be done equitably without being biased towards certain class of system users. One example of unequitable allocation of resources is the provision of high class facilities for small proportion of car users in developing countries. This is again mostly done at the expense of facilities for mass transport systems or non-motorized modes.

Land and aesthetics

The way in which the transportation system is designed and implemented in a city defines whether it is going to have good effect or a bad effect on the society and the environment. As far as norms are concerned, the land area required for the circulation purpose should ideally be as high as 25 to 30 percent, whereas, it is around 13 percent in India. Such circulation networks should be continuous and wide as far as possible. This will reduce the expenses on wear and tear of vehicles, improve fuel efficiency, reduce polluting emissions, reduce delays and loss of productive time and disperse emissions at a faster rate. This will certainly improve the aesthetics of the network also.

Another aspect to look at is the transportation hierarchy of networks systems. Freeways, arterials, interchanges, etc. may come out to be good or bad depending upon their designs and the ultimate satisfaction of the desired goals. As far as possible, the crossing traffic should be separated out at different levels. The designs should also be user friendly, with no confusion at all while making any maneuver. This will improve the movements, reduce the delays caused due to confusing states and reduce the hazardous situations on the road. A proper or improper design of the system may also induce changes in the residential and business patterns. One such example already discussed is that of the loss of business to the shops located at the sides of the road due to the construction of flyover at that road.

The change in the value of land and its use with the provision of transportation network is another effect of transportation. The change in the value of land may render the area highly desirable or undesirable. Certain examples to this effect are the construction of bypass, CBD areas, etc. Due to congestion a person may like to move out from the CBD area. If this trend persists then one may find an increase in the land value at the outskirts of the city, being most sought after due to open space and more area available in lesser amount initially, and reduction in the land value in the CBD area for being discarded for residential activity due to high level of congestion and pollution. Such changes may also bring in the displacement of facilities. If this happens, it may result in the eating up of additional land available, which otherwise would have been used for some other desired activities, like agriculture. It also has implications related to sustenance of that area. Big transportation projects may also result in displacement of households and their rehabilitation. As far as possible, a good rehabilitation scheme should be implemented so that least legal proceedings get initiated.

The transportation infrastructure can also be used as a structure of tourist attraction. It all depends upon its designing and maintaining the aesthetics. Certain examples are already there, like Howrah bridge, Ram Jhula and Laxman Jhula (swing) at Rishikesh, Sydney harbor link, Worli-Bandra and Worli-Nariman Point sea-links under development in Mumbai, etc.

Safety

One of the disturbing effects of transport is the loss of life and injury to transport users. A large number of accidents are reported involving different types of vehicles. Similarly, a large numbers of in-vehicle and out-of-vehicle users get affected due to accidents. Special mention may be made of the accidents involving freight transport. There is a need to improve the system on different accounts like,

- Periodic inspection of transport vehicle and equipment, e.g. rail and air transport
- Issuing license to operators (for vehicle and route, both) after proper examination of their capabilities
- Use of technological improvements in designs and operations, e.g. expressways, use of instrumental aids, etc.
- Implementing safety measures, in general and specific to conduits
- Stringent measures before issuing driving license to drivers
- Higher enforcement of rules and regulations
- Introducing rapid accident prevention and curing system on highways and urban roads.

1.3 INTEGRATING AND COORDINATING ROLE OF TRANSPORTATION

Transportation has an integrating and coordinating function at all the three steps of economy, i.e. production, distribution and consumption. These are shown in Fig. 1.5.

The process of production requires raw material that is made available through transportation networks and varied means of transportation. The mobility of manpower needed for controlling the manufacturing processes at the plant or for the distribution of produce and manufactured goods becomes feasible only through the transportation means and networks. Availability of items at the place of consumption is again controlled through transportation systems. Apart from these, transportation plays an important role in the governance of an area, in the movement of defense personal and equipment to the border areas, in speedier communication between distant places (apart from information technology) and in generating revenues from use of transportation infrastructure projects. Similarly, markets get directly connected to the production places and consumption places. It also plays its role in the energy sector. Consumption of fuel and other forms of energy is one such aspect. High consumption of fossil fuel and burden placed due to its import has brought forth the need to search alternate fuels that are sustainable, available easily and cheap.

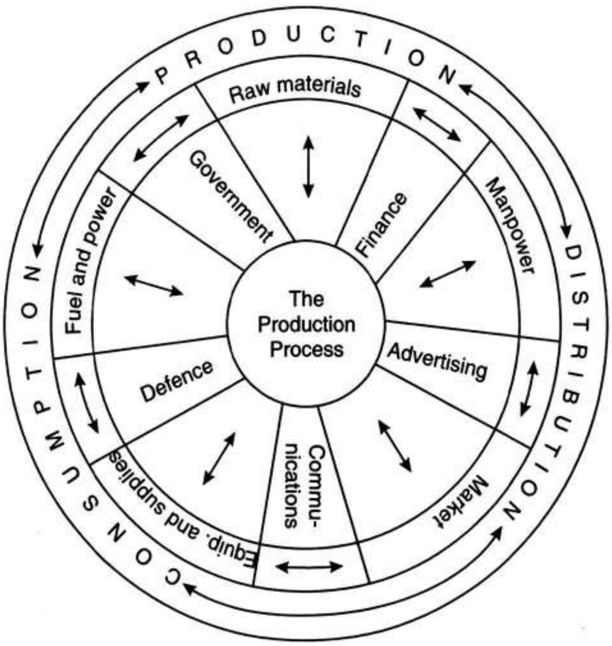


Fig. 1.5: Economic role of transportation

1.4 TRANSPORTATION TECHNOLOGIES

A good numbers of transportation modes are available throughout the world. Each is suitable for different travel distances. They can be categorized based on either the supporting medium, technology used for propulsion and the ownership. At times, certain transportation modes are fitted with technologies that make the use of different supporting medium feasible. A detailed classification chart is given in Fig. 1.6. The major transportation technologies are defined in successive paragraphs below.

1.4.1 Prepared Surface-based Technology

The prepared surface-based technology uses a surface that is prepared to take loads of the vehicles that are expected to move above it. The surface is usually prepared to specifications such that it has sufficient strength to support the vehicle movements without failure. There can be two types of technologies involved in such a system. They are:

- Rail-based technology
- Steel-rimmed or pneumatic wheel-based technology

Rail-based technology

Rail-based technology can be defined as a combination of flanged wheel with a rail. The rail may be either conventionally rigid or flexible. Rails provide lateral guidance and support from the bottom. The mobility is achieved from the engine mounted on a carrier. A good number of modes or systems constitute this category. They are intercity railways, rapid transits, street cars (light rail systems), some designs of monorails, automobile carriers, and tracked air cushioned vehicles (TACVs). The rolling guidance is achieved through the rail and flange combination. This technology has single degree of freedom.

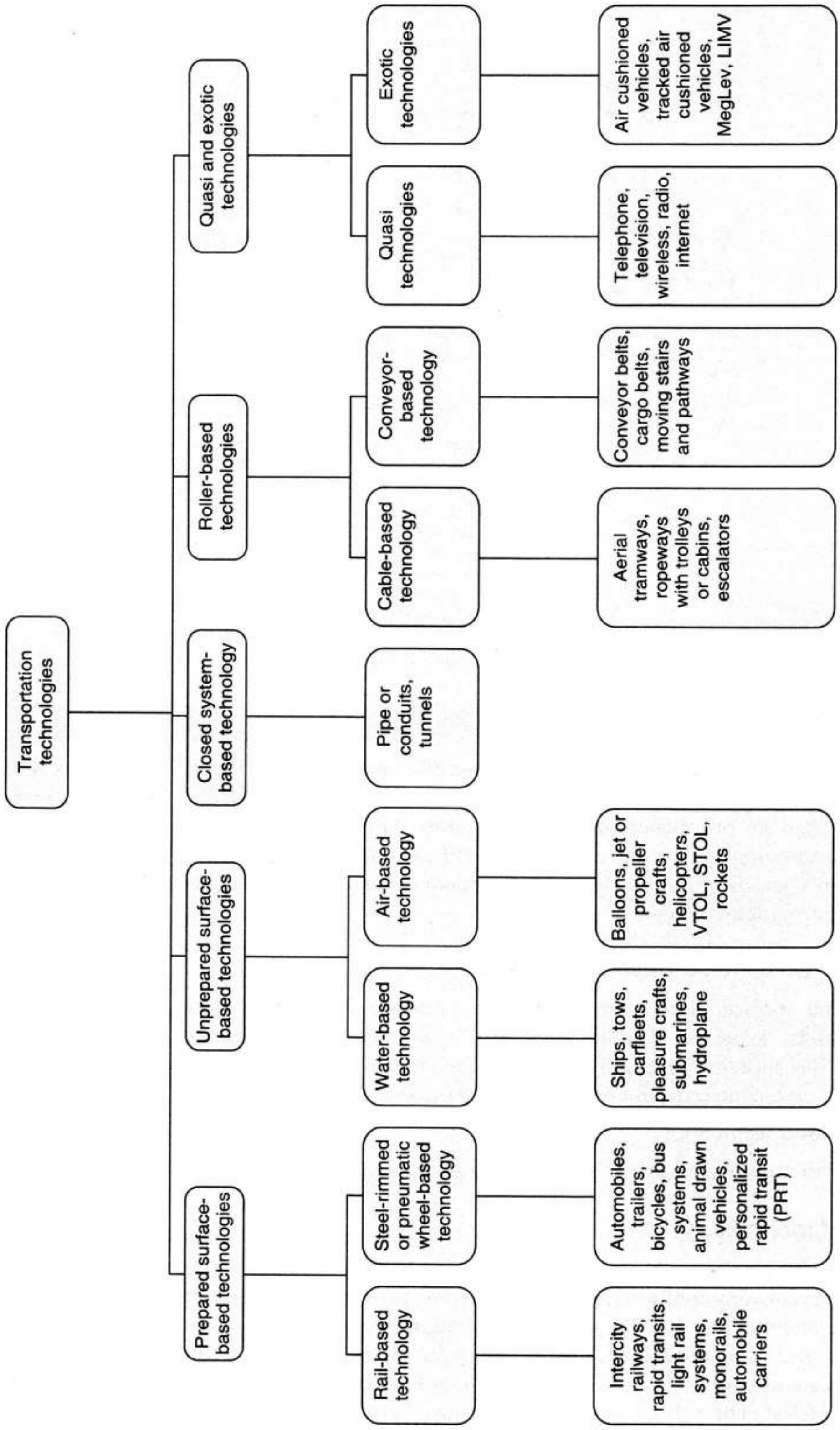


Fig. 1.6: Classification of transport technologies

Steel-rimmed or pneumatic wheel-based technology

The steel-rimmed or pneumatic wheel-based technology uses a flexible or a rigid supporting surface, which is prepared for a smooth and safe movement of steel rimmed or pneumatic wheel vehicles. Examples in this category are automobiles, trucks, buses, tractor-trailers, bicycles, motor bikes, bus systems, animal drawn vehicles, and some of the personalized rapid transit (PRT) people carriers. Mobility in this technology is achieved through the propulsive unit mounted on a vehicle base. The steering system of the vehicle provides maneuverability to the vehicle. This technology has double degree of freedom.

1.4.2 Unprepared Surface-based Technology

The unprepared surface-based technology does not require a physical supporting system that keeps the vehicle in position during its movement. The support is derived from the medium in which a vehicle moves. The exclusion of physical supporting system makes these technologies more hazard-prone. Two of such technologies mostly in use are:

- Water-based technology
- Air-based technology

Water-based technology

Water-based technologies are those technologies, which use water as a medium for the movement of vehicles. The vehicles derive support from the fluid characteristics of the water to remain in position. Such characteristics are buoyant force, draft and block coefficient. Similarly, certain vehicular characteristics like metacentric height, angle of heel and tilt, etc. also act towards the stability of the vehicle. These vehicles consist of engine on board for their mobility. Such technologies are, in general, free from grade resistances. Water bodies used for movement may be channels, rivers, lakes, sea and oceans. Some of the examples of vehicle types using water-based technology are ships, tows, carfleets, pleasure crafts, etc. Technological advancements have made it possible for the vehicles to move through the medium, such as in the case of submarines, or to use two different mediums such as by hydroplanes. These vehicles have two to three degree of freedom.

Air-based technology

Air-based technology uses air space at a height more than the nominal height above the ground for the movement of specially designed vehicles. These vehicles are aerodynamic in design and uses on-board engine to produce propulsive power or thrust for their forward motion. The support is derived from the medium in the form of lifts and drags using components installed on the wings, whereas, the stability along the three axes is achieved using components installed at the tail and wings of the airplane. The long chord of the wing defines the load carrying capacity of the airplane. The air-based technology has three degree of freedom. Examples falling under this technology are balloons, jet or propeller crafts, helicopters, vertical take-off and landing crafts (VTOL), Short take-off and landing crafts (STOL), rockets, etc. These vehicles are able in negotiating any gradients.

1.4.3 Closed System-based Technology

The closed system-based technology allows movement through enclosed surfaces built artificially. The movement is through conduits. Such technology can be used for both, passenger and freight movements. If designed and constructed in rightful manner, it provides a safe and protected passage for their movement. These technologies are mostly used to traverse certain topographical sections, which are otherwise difficult to traverse. Tunnel is an example for passenger movement through such sections. The bed below provides support for the movement and enclosed sides provide guidance for movement. Pipes are the example of transportation of freight. Liquid is used to support the freight as a floating substance and pumping pressure or gravity is used as a propulsion medium. So it provides safe containment, as well as, a roadway. Some of the examples of freight transportation are gas, heat, sewage, petroleum products, etc.

1.4.4 Roller Supported Technology

Roller supported technology is utilized to transport both, the passengers and the freight. Mostly, it is used for freight transportation. Use for passenger transportation is purely for recreational or pleasure trips. Examples of such movements are roller skates. Two such technologies generally in use are,

- Cable-based technology
- Conveyor-based technology

Cable-based technology

Cable-based technology is used primarily for moving products of mines or relatively short distances over a terrain that is too rough for the economical construction and operation of other technologies of transport. These are based on moving suspended cars on cables tightened or slackened at either of the two ends. Rollers are used for such movements. There are specialized designs like aerial tramways, ropeways, trolleys, cabins, etc. that are used to transport passengers or freight over rough terrain.

Conveyor-based technology

Conveyor-based technology is in use again mostly for moving cargo or freight over short distances but for gentle gradients. In this technology, flat conveyors with projected sides are moved using motorized rollers at its bottom. These systems are mostly in use for transporting granular particles of bulks, and therefore, cannot be operated at steep gradients. Such examples are transporting coal in power plants to turbines, mine products to ground levels, etc. In the case of passenger transportation, exclusive applications using conveyor principle are cargo belts at air terminals, escalators or moving stairs, moving pathways, etc.

1.4.5 Quasi and Exotic technologies

Transportation substitutes or alternatives are defined as quasi transport technologies. These technologies reduce the need of moving between places with the desired intention. Some of such technologies are telephone, television, transmission by wire or radio, etc.

Exotic technologies are mostly those technologies that are basically design concepts under pilot testing phases, or the tested concepts that are ready for use. These technologies have found limited implementation due to the cost involved in it. Mostly, they are in use for limited distances on trial basis. Some of the examples of such technologies are air cushioned vehicles (ACV), tracked air cushioned vehicles (TACV), linear introduction motor vehicle (LIMV), magnetic levitation system (MEGLEV), very high speed rail-based systems, etc.

1.5 COMPARISON OF MAJOR TECHNOLOGIES

A comparison of major transportation technologies is given in Table 1.1.

Table 1.1: Comparison of major technologies

S.No	Factor	*Prepared Surface Technology*		*Unprepared Surface Technology*	
		Rail-based	*Pneumatic wheel-based*	*Water-based*	*Air-based*
01	Distance coverage	Moderate to long	Small to moderate	long	Moderate to long
02	Speed of movement	Medium	Low to medium	Low	High
03	Hauling capacity	High	Low	High	Medium
04	Type of traffic handled	Freight and passengers	Freight and passengers	Freight and passengers	Passengers and freight
05	Choice of modes	Limited	Varied	Few	Few
06	Fuel consumption (as ratio w.r.t. railway)	1.0	4.0	5.2	25.0
07	Accidents: Numbers Intensity	 Less Medium	 Large Low	 Less High	 Less High
08	Degree of freedom	One	Two	Two to three	Three
09	Unit of transport	Assemblage	Single or with trailer	single	single
10	Flexibility: Route flexibility Operational flexibility	 Limited Limited	 High High	 Nil Limited	 Limited Nil
11	Dependability	Good to excellent	Fair to good	Fair	Fair
12	Gradients traversed	Steeper	Gentle	Nil	Steepest
13	Noise range	70-80 dBA	70-85 dBA	55-68 dBA	75-95 dBA
14	Storage requirements	Manageable	High and unmanageable	Not an issue	Limited and available
15	Guidance system	Rail-flange guidance	Lateral wheel guidance	Electronic guidance	Electronic guidance
16	Support systems	Combination of rail, sleepers and ballast, superelevation design, suspension system of vehicle	Pavement crust thickness, superelevation design, suspension system of vehicle	Buoyancy, depth of channel, draft and block coefficient	Lift, burble angle, long chord of wings
17	Stability of vehicle	Derailment, overturning	Skidding or slipping, overturning	Metacentric height, size and velocity of wave	Stability w.r.t. lateral, longitudinal and vertical axis

(*Contd.*)

Table 1.1: Comparison of major technologies (*Contd.*)

S.No	Factor	Prepared Surface Technology		Unprepared Surface Technology	
		Rail-based	Pneumatic wheel-based	Water-based	Air-based
18	Resistances	Due to track profile, and starting and acceleration, Train, and Wind resistances	Air, Rolling, Grade, Curvature, Transmission loss resistance	Skin friction, Streamline, Eddy-current, Wave and Air resistance	Drag resistance, Wing area, Angle of attack
19	Accessibility	Upto medium	High	Limited	Low
20	Cost of:				
	Physical Features	Moderate	Moderate	Nil	Nil
	Maintenance	Moderate	Moderate	High	High
	Terminals	Moderate	Low	High	High

1.6 COMPONENTS OF TRANSPORTATION SYSTEM

The various components of a system are:

1. **Object:** Object can be defined as any item that can be moved in the system using system characteristics. It may be a passenger or freight.
2. **Path:** Path is defined as a location in space along which the object flows or moves.
3. **Vehicle:** Vehicle is the one, which gives the object mobility on a particular type of path employed, and which can be propelled on that path. It may also serve to protect the object from damage.
4. **Container:** It is the device into or onto which the objects to be transferred are placed in order to facilitate the movement. It does not itself posses either mobility or the capability of propelling itself on the path or both. It protects the object and facilitates loading and unloading.
5. **Way-Link:** Way links are the paths in which the flow is constrained to follow a particular route, as in the case of a railway track, highway, pipes, aircrafts, etc.
6. **Way Intersections:** Flows of two or more links can be merged together at intersections, and a single flow can be separated to follow two or more distinct paths at intersections.
7. **Terminal:** Terminals are the points through which traffic is transferred from one vehicle or container to another within the system or between different systems. These are the facilities which accept the objects to be moved into the system or get them out of the system at the end of the journey. It also facilitates the storage of the vehicle when not in use.
8. **Operations Plan:** It is essential that the terminals be operated in a manner that the traffic flowing through them can be accommodated, that vehicles are available to accept the traffic, that the traffic is routed via the proper links and the intersections through the system to the final destination of the traffic. Therefore, it can be defined as a set of the procedures by which the co-ordination of these activities is achieved. The main objective of these procedures remains the safe and efficient movement of the objects.

9. **Maintenance of subsystem:** It is a system, which is primarily treated as a function of cost and management associated with each of the physical components identified earlier. This helps in maintaining the system so that all the components can work together in a coordinated way.
10. **Information and Control subsystem:** It is similarly treated in the context of components and operations where they apply. These provide the safety measures not only for an individual component but also for whole of the system. These may take any shape like devices, information, rules and regulations, design guidelines, etc.

The interrelationship of all the above components is shown in the flow chart given in Fig. 1.7 below. The components related to major transport systems are given in Table 1.2.

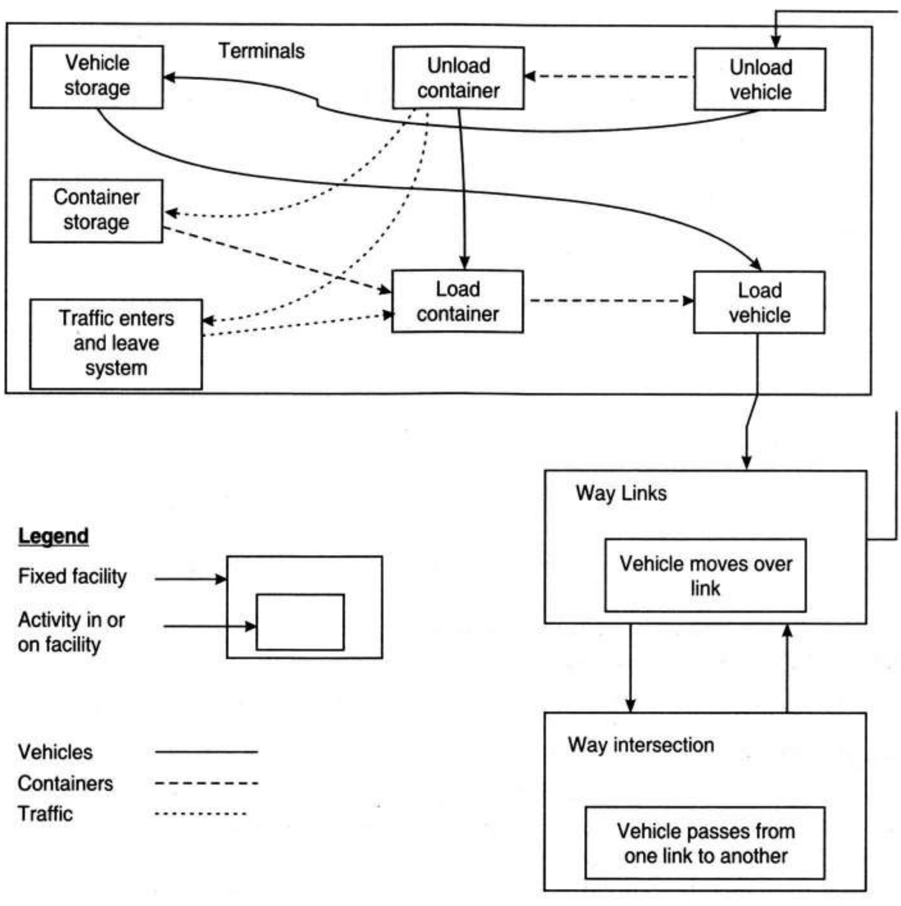


Fig. 1.7: Interrelationship between components of a transportation system

1.7 TRANSPORTATION COORDINATION

An ideal transportation system is the one which facilitates the movement of an object between consigner's door and consignee's door in a single haul. But it is quite difficult to have such a system. Sometimes, such an ideal mode cannot be realized. Each of the transport mode or a system possesses certain inherent technical and economic advantages and disadvantages. For example, a good bus raid transport (BRT) system can be designed and operated in a city. But it is not possible to connect each and every house with its network. Therefore, a person has to walk to a bus stand to get into BRT system. In such cases, the inherent advantages of a system can best be realized or disadvantages overcome, only if two or more of the transport systems are combined together to provide a joint or coordinated transport service. Another example can be the provision of feeder services to main traffic corridors like urban railways or BRTs.

Transport coordination, in this way, can bring in faster and more dependable services and at the same time may economize the transportation. This will be beneficial for both, the passengers as well as to shippers.

Table 1.2: Components of major transportation systems

Component type	*Rail-based*	*Pneumatic wheel-based*	*Water-based*	*Air-based*	*Closed system*
Traffic	Freight and passenger	Passenger and freight	Freight and passenger	Passenger and frieght	Fluid and semi-solids
Terminal	Shipper and consignee docks, railway stations	Bus station	Port or harbor	Airport	Tanks
Container	Closed or open Box	Closed or open Box	Cabin, deck	Cabin	Conduit
Vehicle	Separate IC engine or electric traction	On-board IC engines	Turbines on a lower deck	Jet engines or propellers on wings or below fuselage	Liquid and pumps
Way link	Rail Track	Carriageway	Water strip	Air lane	Pipe or conduit
Way intersection	Turnout	Road junction	Strip junction	Air lane junction	Pipe junction
Operations plan	Schedule	Schedule	Schedule	Schedule	Batching

1.7.1 Factors Promoting Coordination

The factors that are supposed to promote transport coordination are briefly discussed below.

Extension of service

Most of the transport technologies do not provide service from door-to-door. The air services are located at the periphery of the city or at some distance from the city due to its operation requirements. If no feeder and distribution service is provided to and from the airport then it cannot be used by anybody. Similarly, urban rail services or bus services provided in the city ply on a predefined route. To improve their ridership, they require connecting services to bring or take back home the potential passengers. The flexibility of truck services is utilized by railways to extend their services to the door of shipper. In all these examples, it is clear that a combination of different services can help in expanding the area of the influence of a major service. Another example of extension of service can be the provision of separate platforms for meter gauge and broad gauge rail services at the same terminal, thus extending the service of railways in low traffic areas.

Economy

The coordination of services between transport modes or within a transport system can bring in financial economy or land use economy. Sometimes, it is possible to provide a single terminal facility that operates two or more systems together or consist of facilities that are common between different transport systems. This type of coordination can make financial economy feasible. Example for such coordination may be operating railway system and road transport system from the same terminal. The platforms for trains and buses can be provided on the two opposite sides of the terminal building and all administrative units, utilities and facilities can be located within the terminal building. Similarly, it is possible to use same land area for different types of services or systems. It reduces the cost of acquisition of costly land, thus economizing the provision of a service. There can be many examples in this case also, the most seen being the joint use of bridge by railways and road-vehicles at two levels, or road bridge with a pipeline fitted on a side of the road, thus reducing the need of constructing a separate pier for pipeline.

Convenience

The transport coordination facilitates the concentration of objects at one place through a major transportation system and the dispersal of the same using another transportation system. The bulk shipment carriers like railways and waterways accumulate large quantities of freight at a single place may be in the form of stock piles, tanks, warehouses, and the same is distributed to different places of consumption in small lots using road transporters like truckers. The same is true for farm products or dairy products. A simple example of news paper can also be looked in. It is dispatched in bulks from printing press using big automobiles to distant places and is later distributed to the readers by vendors moving on bicycles. In terms of passenger movement, the example of providing railway and road-based system at one place makes it convenient for those passengers who do not have railway services in their area but do have bus services. So they feel themselves free from the stresses of shifting luggage to long distances before getting another forward service.

Speed of transfer

Speed of travel do matter in long distance travel, may be inter-city or inter-country or inter-continent. It is difficult to use the same mode for all travel distances with the same travel efficiency. The coordination helps in achieving the speed efficiency. In case of certain perishable objects, the speed of movement becomes a major factor even if the travel distances are not too long. To get to speedier service, one needs to use another service. For example, to use air service one has to use own travel mode or public mode available to access it.

1.7.2 Limitations of Coordination

Transport coordination should be exercised only when it makes a real contribution to the overall economy and efficiency of movement. Merging of two distinct facilities or two facilities under use by different systems but located at acceptable distance from each other makes no contribution to either efficiency or economy. While planning new facilities, the provision of different transport systems at one location should be emphasized. Coordination should also be examined and properly planned from the viewpoint of frequent interchanges, rehandling of equipment and loading and unloading of equipment. Each handling or interchange increases the possibility of loss or damage to the objects to be transported. Therefore, interchange facilities should be designed based on minimum requirement of handling of the objects and equipment and need of reverse movements.

1.7.3 Types of Transport Coordination

Transport coordination, as discussed before, can be carried out between different systems of transportation, i.e. inter-system coordination, or between different players within the system, i.e. intra-system coordination. The various forms of transport coordination are discussed in brief in the following paragraphs.

Joint use of a terminal

Terminals are used jointly both for inter-system coordination and intra-system coordination. In most of the metro or metropolitan cities, terminal railway stations host facilities for both inter-city travel and intra-city travel. One such example can be of Mumbai Central Railway station, which hosts platforms for inter-city trains as well as for intra-city (Suburban Railway) local trains. This is a good example of intra-system coordination. Another example of intra-system coordination is of bus stations provided in most of the big cities. They provide bus services that ply between big cities, may be non-stop or with limited stops and at the same time also provide services that provide connectivity to interior location of that area, thus making it feasible to move between interior areas to big cities located at long distances. An example of inter-system coordination can be of ferry terminals that are generally accessed through pneumatic wheeled vehicles. So it is a combination of water transport and land transport by road. The same is with railway stations, airports, etc. There are examples wherein union depot is provided for rail, bus and air transport for lake and river transport.

Such coordination is advantageous as it improves convenience, transfer, land-use economy, and allows provision of better facilities for passengers or freight, which otherwise could not be provided due to fund shortages. The coordination helps in reducing the number of services required and frequency of individual shipper, saving of mileages, and avoids the duplication of facilities thus saving resources. But such constructions require large piece of land often at central locations of a city that may consume good proportion of money resources and may cause congestion on roads around the terminal especially during rush hours. Many of the facilities will remain unused and unproductive during lean periods. The individual carriers may also find it disadvantageous as they lose their identity and economic advantage once enjoyed from an individual location over other carriers, and have to spend big amount on spaces used for their operation and administration. It also makes it difficult to apportion user costs and charges among different transport systems using that terminal.

Coordination of schedules

Most of the transport systems or carriers operate with fixed schedules. These schedules are mostly well publicized or published for wider circulation. It is, therefore, possible to rearrange the schedules of different carriers or transport systems or carriers within a transport system for their mutual benefits. Arranging of the schedules of one carrier to connect with the schedules of another carrier can improve upon the ridership of both the carriers. The requisite to such an operation is to have either a common terminal for two different systems or a feeder or bridge line service for a major carrier. Some of the examples of such a coordination can be provision of platforms for long distance trains and local trains at the same terminal; the matching of schedules of two trains reaching a junction station from two different directions and moving forward as a link train; and provision of bus feeder services and distribution services according to the departure and arrival of trains at a railway station. At times, the commuters themselves fix the schedule of their movements according to the schedules of main mode to be taken for long distance commuting.

The coordination of schedules makes the movement of objects or passengers feasible between locations not connected directly. It relieves them of mental and physical stresses of reaching unconnected locations. The intermediate connectivity improves the turnover of the operators. It helps the commuters in reaching distant places in minimum possible time. But, such coordination has its disadvantages also. A commuter has to move within time frame. One has to catch a feeder bus service at a pre-specified time to get the main service say a train. In case of a link train, if one train gets late in its running then other train has to wait for it. This causes unnecessary delay to the passengers of the first train. Variable schedules of feeder and distributor services have to be formed to adjust the flow on main corridors or with main carriers.

Interchange of equipment

The coordination with interchange of equipment involves the movement of the equipment and the content carried in it freely between two different carriers. Such interchanges save rehandling costs and loss of time in transferring freight. Disadvantages of this coordination includes the difficulties of getting the equipment returned, maintenance required for foreign or off-line equipment, determination and collection of user costs and empty return of equipment causing loss of revenue.

The concept of containerization fits in the above definition of coordination. Containers may be simple boxes that are set on truck bodies, or on flat cars, or in gondola cars, or in ship's holds or on demountable truck bodies or chassis for land movement. The standard containers can be hauled by largest aircrafts only, if air transfer is required. Smaller units that fit the curves of a fuselage are already in use. Individual freight items loaded in the container need not be rehandled from the time that container is closed and sealed by the shipper until the seal is broken by the consignee.

Joint use of right-of-way

Provision of transport systems on dedicated but separate right-of-way has caused shifting of productive land to these facilities, the loss of other productive activities and an increase in the cost of providing these facilities. Due to these reasons, the possibility in the joint use of right-of-way started receiving adequate attention during the last decade or so. In such coordination, two or more than two transport systems use the same right-of-way for their operation. The combinations may involve only passenger movements or freight movements or a mix of the two. There are many examples to define such coordination. At many places, especially over big rivers, bridges are constructed with double decks or more, with each deck being dedicated to one system of transportation. It may be rail at one level, road-based vehicles at next level and another level for peddlers and pedestrians. Another example is of using the same deck of the bridge for the movement of vehicles, as well as, to provide support to pipelines. Sometimes, they are provided below ground level either under footpaths or central medians. But in such cases, the pipelines should be buried deep enough to avoid breakage and disastrous fire in the event of an accident. Many a times, the central median of expressways, freeways or superhighways is used as a right-of-way for railways or rapid transit systems, or for pipelines or systems like skybus.

Such coordinated provisions help in reducing the cost of construction of the facilities, optimal use of land space occupied, and possibility of providing interchange facilities on route and eliminates the monotony of movement when covering longer distances. The major problem with this system lies in the maintenance schedules of individual transport systems, which may cause hindrance to the other transport systems, and may disrupt the operations during events of hazardous nature.

Piggy-back system

This term is used to describe a type of coordination that has come into common use, especially on railways and road-based systems. This is also known as 'trailer-on-flat car' (TOFC) service system. Five systems are generally recognized under this category. They are,

- Vehicles of common highway carriers are hauled by railways. In this system the shipper deals with highway carrier who then deals with the railways.
- Only trailers owned by railways are carried by railways.
- Anyone's trailer is carried by railways
- An intermediate or forwarding agency or broker secures the freight, loads it onto its trailer and onto its own flat car and turn it over to the railways to haul.
- First plan with joint railway and highway rates for haul with provision of highway carriers.

This coordination provides door-to-door service. Much of the expenses and nuisance of highway haul, like traffic congestion, personal problems, traffic rule violations, accident hazards, delays, restrictions on weight and size, limitations on vehicle size, etc. either get avoided or are markedly reduced in nature. Though such a coordination relieves the shipper from the stresses of managing the haul, there are always chances of a breakup between partners, i.e. railways and highway operators that can stop the system from working.

Ferry system

This type of coordination can be defined as the movement of especially highway vehicles by car floats or ferries across the lakes and channels. The water carrier provides a container service, whereby the container, equivalent to highway trailer without a vehicle is transferred to and from the ship to the highway for land movement and vice versa. This type of coordination provides connectivity between places across water bodies when no other type of connectivity is provided. The main problem remains about the size of the ferry fitting the size of the vehicle that is to be ferried across the water body. Further, the system becomes unoperational during high tides, floods, cyclones, etc.

1.8 POPULATION AND MOTOR VEHICLES GROWTH

The population of India is increasing continuously at a high rate. At present, the total population of India is only second to that of China and at the present rate of population increase it is slated to surpass the population of China in next 25 to 30 years. The population statistics of India are given in Table 1.3.

Table 1.3: Population history

Year	*Total Population*	*Decadal Growth*
1950	357,000,000	—
1960	443,000,000	24.09%
1970	553,000,000	24.83%
1980	684,000,000	23.69%
1990	838,141,000	22.53%
2000	1,004,591,054	19.86%
2005	1,095,054,669	—
2007	1,129,866,154	12.47%*

*With respect to 2000 population

The population growth of the country has seen the decreasing trend continuously since 1960. The decadal growth rate has decreased by 4.23% in the last 50 years. During the current decade it is increasing at a rate of around 1.7% annually. The population demographics by age show an increasing trend in the age group of 15-34 years and for age group 65 years and above. It indicates that the life expectancy is increasing in the country. The total population of the country is expected to reach 1300 million by the year 2020. The statistics are given in Fig. 1.8. The increasing size of the population will obviously put more pressure on the transportation infrastructure. Heavy investment will be needed to overcome the expected shortage of transportation needs.

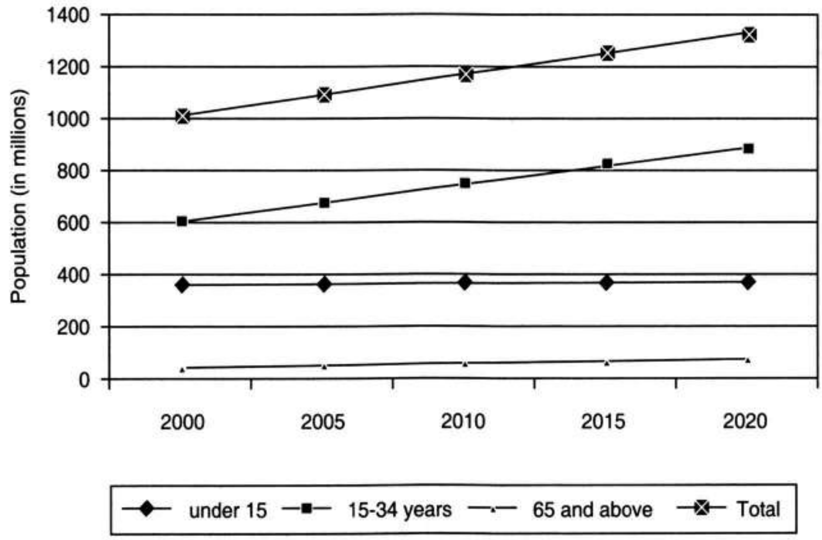


Fig. 1.8: Population projection for India

Another influencing factor affecting transportation is the number of vehicles that get added every year. The data of registered motor vehicles for the country is given in Table 1.4. The population of motor vehicles has increased 237 times between 1951 and 2004. Compared to this, the increase in population between 1950 and 2005 is 206.7%. Starting from 1976 and till 1991, for each successive five year period the rise has been almost 100 percent. Next higher increase in vehicle registration has been observed between 1991 and 1996, and 2002-2003. This high increase in vehicle registration has its effect on the travel needs of private vehicle owners, as well as, on the needs on public transit users.

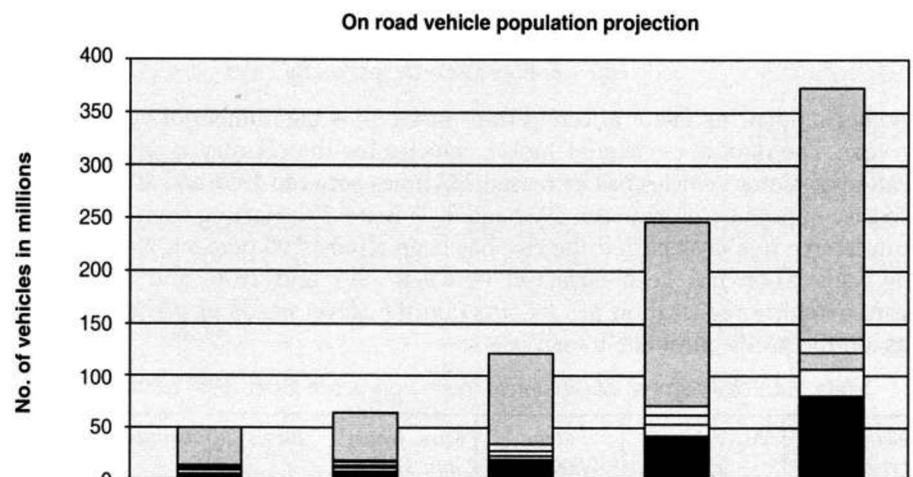
Table 1.4: Total number of registered motor vehicles in India, 1951-2004, in thousands

Year (As on 31st March)	*All Vehicles*	*Two Wheelers*	*Cars, Jeeps and Taxis*	*Buses*	*Goods Vehicles*	*Others*
1	2	3	4	5	6	7
1951	306	27	159	34	82	4
1956	426	41	203	47	119	16
1961	665	88	310	57	168	42
1966	1099	226	456	73	259	85

(Contd.)

Table 1.4: Total number of registered motor vehicles in India, 1951-2004, in thousands (*Contd.*)

Year (As on 31st March)	*All Vehicles*	*Two Wheelers*	*Cars, Jeeps and Taxis*	*Buses*	*Goods Vehicles*	*Others*
1	2	3	4	5	6	7
1971	1865	576	682	94	343	170
1976	2700	1057	779	115	351	398
1981	5391	2618	1160	162	554	897
1986	10577	6245	1780	227	863	1462
1991	21374	14200	2954	331	1356	2533
1996	33786	23252	4204	449	2031	3850
1997	37332	25729	4672	484	2343	4104
1998	41368	28642	5138	538	2536	4514
1999	44875	31328	5556	540	2554	4897
2000	48857	34118	6143	562	2715	5319
2001	54991	38556	7058	634	2948	5795
2002	58924	41581	7613	635	2974	6121
2003	67007	47519	8599	721	3492	6676
2004	72718	51922	9451	768	3479	6828



	2005	2008	2015	2025	2035
2-W	35.8	46.1	87.7	174.1	236.4
3-W	2.3	3	5.3	8.8	13.1
HCV	2.4	2.9	4.6	9.1	16.2
LCV	2.4	3.2	5.7	12.5	26.9
CAR, SUV	6.2	8.8	1.8	41.6	80.1

Fig. 1.9: Projection of vehicle population for India

The vehicle population projection estimates are shown in Fig. 1.9. The estimates indicate exponential rise after 2008. This rise is quite high in the motorized two-wheeler segment and is picking big strides in car or SUV segment. The vehicle population is expected to reach 175 million by the year 2020. The vehicle ownership is expected to rise to 0.131 from 0.045 between 2005 and 2020.

1.9 GROWTH OF HIGHWAYS IN INDIA

A look at the budget outlay for transportation during five year plans indicates a decrease in the total share with the change of plans since 1951. The first three plans saw almost one-fifth of the total outlay spent on transportation. After that it has been observed to be fluctuating between 16 and 12%. Even from the committed outlay, a major share has gone to railways. The expenditure on roads has been 6.7% during the first five year plan and that has reduced to 3% during eighth plan. The budget outlay for transportation sector as a whole and road transport in specific is given in Table 1.5 for the period between 1951 and 1997. Table 1.6 gives the outlay for the ninth and tenth plan upto 2005.

Table 1.5: Budget outlay for transportation sector during five year plans (Rs. in crores)

Five Year Plan	*Outlay for Transportation sector*	*Outlay for Road Transport*	*Outlay for Roads*
First Plan, 1951-1956	434	12	135
Second Plan, 1956-1961	1100	18	224
Third Plan, 1961-1966	1983	27	440
Fourth Plan, 1969-1974	2522	128	862
Fifth Plan, 1974-1979	5543	503	1701
Sixth Plan, 1980-1985	13962	1276	3807
Seventh Plan, 1985-1990	29457	2151	6335
Eighth Plan, 1992-1997	56142	3850	13210

Table No. 1.6: Outlay (Centre and States) for road transport sector during IX plan and X Plan (Rs. in crores)

YEAR	*Outlay*			*Revised Outlay*		
	Centre	*States*	*Total*	*Centre*	*States*	*Total*
1	*2*	*3*	*4*	*5*	*6*	*7*
IX Plan (1997-2002)	60.00	7355.26	7415.26	42.78	5026.15	5068.93
X Plan (2002-07)	210.00	9206.90	9416.90	...	...	...
2002-03	30.00	2209.49	2239.49	29.75	1837.20	1866.95
2003-04	40.00	1361.32	1401.32	35.48	1577.47	1612.95
2004-05	44.00	1498.50	1542.50	35.48	1299.11	1334.59

Source: Planning Commission, Govt. of India.

For the financial year 2006-07, the actual expenditure of the Department of Road Transport and Highways has been 22807.86 crore (Appropriation Accounts 2006-07).

India, having one of the largest road networks of 3.314 million km, consists of Rural roads and Highways namely National Highways, Expressways, State Highways, Major District Roads, Other District Roads and Village Roads with following length distribution (MOSRT&H Annual Report 2007-08):

National Highways/Expressways	66754 km
State Highways	128000 km
Major and other District Roads	470000 km
Rural Roads	2650000 km

The road network formed by the above categorized roads is assisted by the roads that are constructed and maintained by different authorities like Zila Parishads, Panchayat Samities or Village Panchayats, Urban authorities like Municipalties, and specific agencies like Port trusts, Forest departments, Irrigation department, Electric supply department, etc. Roads under national schemes like Pradhan Mantri Gram Sadak Yojna (PMGSY), Jawahar Rojgar Yojna (JRY), National Rural Employment Guarantee Scheme (NREG), etc. are providing connectivity at the grass root level, as well as, generating employment in rural areas. Road network figures of upto March 31, 2002 are given in Table 1.7.

Table 1.7: Total and surfaced road length by categories in India as on 31st March (kms)

India/Category	*Total/ Surfaced*	*1998*	*1999*	*2000*	*2001(P)*	*2002(P)*
1	*2*	*3*	*4*	*5*	*6*	*7*
A. HIGHWAYS	T	1822874	1888261	1953843	1967005	1981409
	S	1079020	1124064	1146232	1166209	1175353
a - PWD Roads	T	826515	859851	915487	925838	921248
	S	714803	748288	784056	798057	796910
(i) National Highway	T	38517	49585	52010	57737	58112
	S	38354	49368	51952	57679	58006
(ii) State Highway	T	136489	137950	132797	132100	137711
	S	134304	135679	130592	129862	135546
(iii) Other PWD Roads	T*	651509	672316	730680	736001	725425
	S*	542145	563241	601512	610516	603358
b-Panchayat Raj Roads	T	996359	1028410	103856	1041167	1060161
	S	364217	375776	362176	368152	378443
(i) Zilla Parishad Roads	T	451574	456666	483137	487604	499462
	S	247959	250995	272899	275786	283832
(ii) Village Panchayat Roads	T	445353	425486	408524	406150	412595
	S	84374	69485	53705	55675	57338
(iii) CD/Panchayat Samiti Roads	T	99432	146258	146695	147413	148104
	S	31884	55296	35572	36691	37273

(Contd.)

Table 1.7: Total and surfaced road length by categories in India as on 31st March (kms) (*Contd.*)

India/Category	*Total/ Surfaced*	*1998*	*1999*	*2000*	*2001(P)*	*2002(P)*
1	*2*	*3*	*4*	*5*	*6*	*7*
B. URBAN ROADS	T	236055	237866	248408	252001	250122
	S	178877	180558	188325	191797	190102
(i) Municipal Roads	T	212635	214475	224983	228607	226706
	S	157458	159169	166936	170437	168719
(ii) MES Roads	T	11921	11883	11941	11905	11918
	S	11763	11725	11806	11770	11783
(iii) Railway Roads	T	10282	10282	10322	10319	10325
	S	8464	8464	8505	8504	8510
(iv) Major Port Roads	T	832	841	680	687	689
	S	810	818	666	673	675
(v) Minor Port Roads	T	385	385	482	483	484
	S	382	382	412	413	415
C. PROJECT ROADS	T	269427	270523	213827	223665	225116
	S	50523	50758	56041	56541	55034
(i) Forest Department	T	161954	162508	119701	129205	130346
	S	9662	9666	13317	13456	13916
(ii) Irrigation Department	T	73803	74017	61247	61475	61627
	S	19145	19051	21382	21637	19496
(iii) Electricity Department	T	4583	4657	4349	4356	4369
	S	3978	4049	3960	3961	3984
(iv) Sugar Cane Authority	T	22741	22972	23121	23240	23319
	S	12062	12293	12373	12491	12570
(v) Coal Mines Authority	T	3909	3923	2955	2928	2985
	S	3478	3493	2797	2771	2819
(vi) Steel Authority	T	2437	2446	2454	2461	2470
	S	2198	2206	2212	2225	2249
D. RURAL ROADS (PMGSY)**	T	—	—	—	3996	26697
	S	—	—	—	—	—
INDIA	T	2328356	2396650	2416078	2446667	2483344

(*Contd.*)

Table 1.7: Total and surfaced road length by categories in India as on 31st March (kms) (*Contd.*)

India/Category	*Total/ Surfaced*	*1998*	*1999*	*2000*	*2001(P)*	*2002(P)*
1	*2*	*3*	*4*	*5*	*6*	
		(3228356)#	(3296650)#	(3316078)#	(3346667)#	(3383344)#
	S	1308420	1355380	1390598	1414547	1420489
		(1491622)#	(1538582)#	(1573800)#	(1597749)#	(1603691)#

(P) Provisional.

Includes rural roads constructed under Jawahar Rojgar Yojna as on 31.3.1996.

* Reconciled figures for the years 1998 and 1999.

The increase in the road lengths since 1951 has been substantial even though still not upto the mark. Table 1.8 gives the total road length during different years.

Table 1.8: Growth of roads during different years

Year	*Total road length (km)*
1951	3,99,943
1961	7,08,122
1971	9,17,880
1981	14,85,421
1991	20,16,594
2001	33,46,667

Different types of road works were taken up during the tenth plan. These included widening works, from single lane to two lane or from two lane to four lane system, strengthening of roads, construction of bridges and railway over-bridges (ROBs) and bypasses, improvement of junctions or shoulders, etc. The outlay of different works during the tenth plan is given in Table 1.9.

Table 1.9: Details of achievement of physical targets during the tenth plan period (upto Dec. 2006) (km or No)

Sl. No.	*Name of Scheme/ project/programme*	*Unit*	*2006-07*				*Total %age of Achievement during the 2006-07*
			*Overall Target during the 2006-07**	*Target*	*Achieve-ment*	*Shortfall and reasons therefore*	
1	Widening to 2-lanes	km.	1157.00	705.81	708.62	Land Acquisition ROB Clearance, Environment and Forest	100.39
2	Widening to 4-lane	km.	1323.00#	559.35	334.71		59.84
3	Strengthening	km.	534.00	357.40	655.87		183.51
4	Improvement of Riding Quality	km.	2087.00	1323.97	1006.13		75.99
5	Construction of Bypasses	No.	11	7	1	Clearance, Law and Order Problems, etc.	14.28

(*Contd.*)

Table 1.9: Details of achievement of physical targets during the tenth plan period (upto Dec. 2006) (km or No) (*Contd.*)

Sl. No.	*Name of Scheme/ project/programme*	*Unit*	*Overall Target during the 2006-07**	*2006-07 Target*	*Achievement*	*Shortfall and reasons therefore*	*Total %age of Achievement during the 2006-07*
6	Major Bridges	No.					
7	Minor Bridges	No.	144	84	55		65.47
8	ROB/RUB No.	No.					
9	Others (Paved Shoulders, Junctions Improvement, Road Safety, Toll Plaza, etc.)	-	Nil	Nil	Nil		Nil

Note: * Includes the Annual Targets for State PWDs, NHAI and BRO

Includes 2.5 km. length of widening to 8-lane in Delhi.

1.9.1 Growth of National Highways

The development of national highways was considered as main artery of the road networks. Major surge was experienced during fourth plan, ninth plan and tenth plan. The growth of the national highways during different five year plans is given in Table 1.10.

Table 1.10: Addition to NH length during different plan periods

Plan/Period	*NH Length (km)*
As on 01.04.1947	21378
Pre Plan period (1947-51)	22193
First Plan (1951-56)	22193
Second Plan (1956-61)	23707
Third Plan (1961-66)	23886
Interim Plan (1966-69)	23938
Fourth Plan (1969-74)	28757
Fifth Plan (1974-79)	28977
Interim Period (1979-80)	29023
Sixth Plan (1980-85)	31980
Seventh Plan (1985-90)	33612
Interim Period (1990-92)	33689
Eighth Plan (1992-97)	34298
Ninth Plan (1997-2002)	58112
Tenth Plan (2002-2007)	67120
Eleventh Plan (2007-2012)	67284 – 530 denotified = 66754

The National Highways have been classified depending upon the carriageway width of the highway. Generally, a lane has a width of 3.75 meters in case of a single lane and 3.5 meters per lane in case of multilane National Highways. The percentage of National Highways in terms of width is as under:

Single Lane/Intermediate lane 18350 km (27%)

Double lane 39079 km (59%)
Four Lane/Six lane/Eight Lane 9325 km (14%)

Still large proportion of national highway length is either single lane or intermediate lane wide. This is below the standard norms of national highways, according to which it should be double lane wide. This is going to be the emphasis in the eleventh and twelfth five year plan.

The Government of India has constituted National Highway Development Project (NHDP) to oversee the construction, maintenance and upgradation of national highways in the country. Some of the projects with high significance to infrastructure development namely Golden Quadrilateral, North-south and East-west corridors for movement of freight, addition of lanes to the existing system, efficient movement through the removal of bottlenecks by constructing bypasses, etc. have been taken up under NHDP. These works are taken up in phased manner. The lengths to be constructed, the targets achieved and the final date of completion (expected) are given in Table 1.11.

Table 1.11: Overall status of different phases of NHDP as on February 2008

Phase	*Total Length (in km)*	*Length Completed in km*	*Likely date of Completion*
I GQ, EW-NS corridors, Port connectivity and others	7,498	7035	97% of GQ will be completed by Mar - 08
II 4/6-laning North South-East West Corridor, Others	6,647	1123	Dec - 2009
III Upgradation, 4/6-laning	12,109	330	Dec - 2013
IV 2-laning with paved shoulders	20,000	-	Dec - 2015 (as per financing plan)
V 6-laning of GQ and High density corridor	6,500	NIL	Dec - 2012
VI Expressways	1000	NIL	Dec - 2015
VII Ring Roads, Bypasses and flyovers and other structures	700 km of ring roads/bypass + flyovers, etc.	NIL	Dec - 2014

The road length density of national highways in different states and union territories with respect to the area of the state or union territory and with respect to the population (census 2001) are given in Appendix 'A'. Similarly, the list of various national highways, by their number, route and length between terminating locations, categorized by states and union territories are given in Appendix 'B'.

1.10 TRANSPORTATION ADMINISTRATION IN INDIA

The hierarchical structure of administrative setup in India related to transportation sector is given in Fig. 1.10.

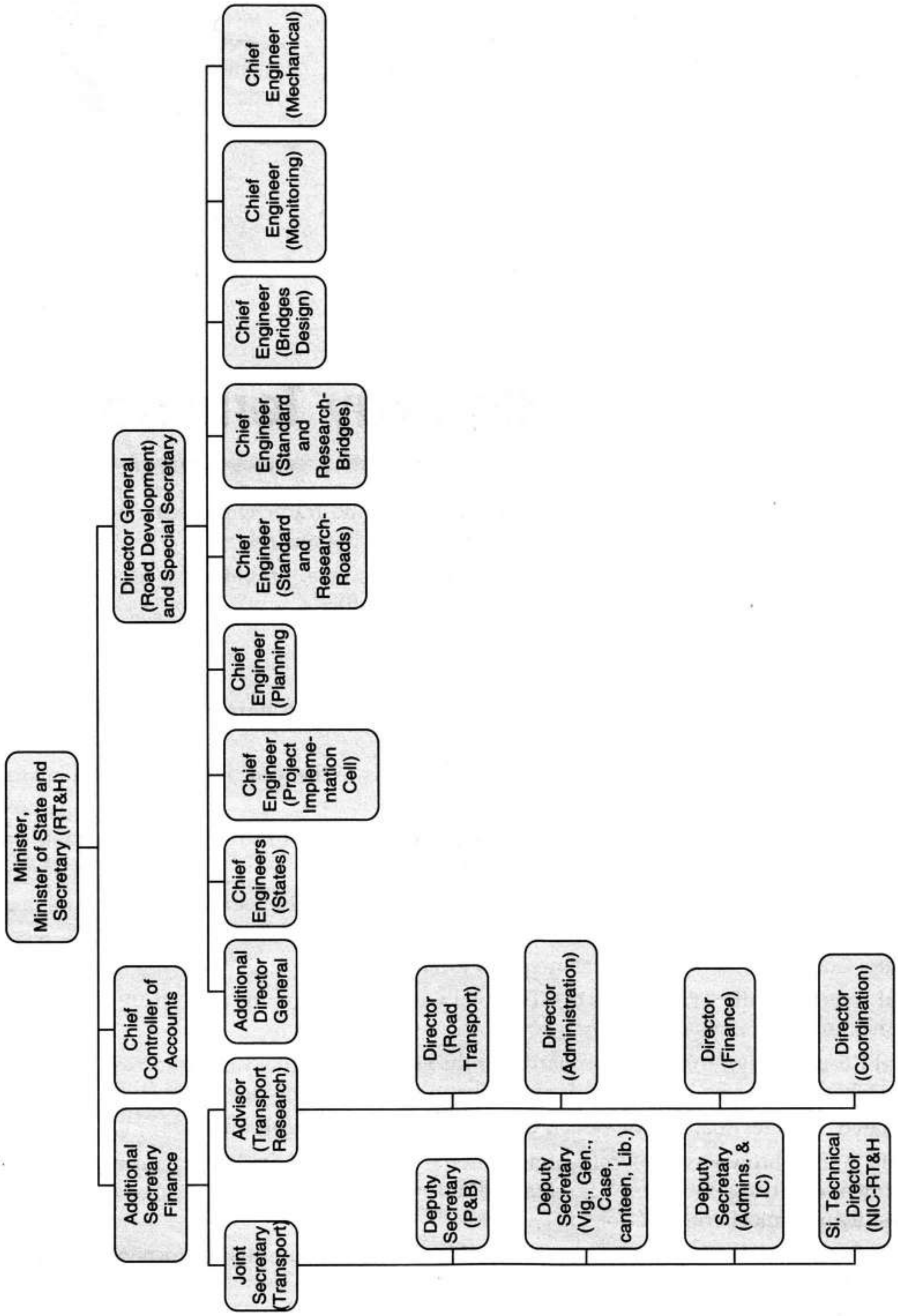


Fig. 1.10: Administrative setup of highway administration at center in India