

Chapter 1

Introduction to transportation Engineering

Overview

What is transportation?

- Transportation is all about moving goods and people from one place to another
- It is also Safe, efficient, reliable, and sustainable movement of persons and goods over time and space

What is Transportation engineering?

- Transportation engineering is a type of civil engineering which focuses on the infrastructure of transportation: all the elements which support the movement of goods and people. Transportation engineers design runways, build bridges, layout roads and plan docking facilities. They look at traffic patterns, determine when new transport facilities are needed and come up with better ways to get from point A to point B.
- Also Application of technology and scientific principles to the planning, functional design, operation, and management of facilities for any mode of transportation in order to provide for the safe, rapid, comfortable, convenient, economical, and environmentally compatible movement of people and goods

Mobility is a basic human need. From the times immemorial, everyone travels either for food or leisure. A closely associated need is the transport of raw materials to a manufacturing unit or finished goods for consumption. Transportation fulfils these basic needs of humanity. Transportation plays a major role in the development of the human civilization. For instance, one could easily observe the strong correlation between the evolution of human settlement and the proximity of transport facilities. Also, there is a strong correlation between the quality of transport facilities and standard of living, because of which society places a great expectation from transportation facilities. In other words, the solution to transportation problems must be analytically based, economically sound, socially credible, environmentally sensitive, and practically acceptable and sustainable. Alternatively, the transportation solution should be safe, rapid, comfortable, convenient, economical, and eco friendly for both men and material.

The characteristics of transportation system

The characteristics of transportation system that makes it diverse and complex are listed below:

1. **Multi-modal:** Covering all modes of transport; air, land, and sea for both passenger and freight.
2. **Multi-sector:** Encompassing the problems and viewpoints of government, private industry, and public.
3. **Multi-problem:** Ranging across a spectrum of issues that includes national and international policy, planning of regional system, the location and design of specific facilities, carrier management issues, regulatory, institutional and financial policies
4. **Multi-objective:** Aiming at national and regional economic development, urban development, environment quality, and social quality, as well as service to users and financial and economic feasibility.
5. **Multi-disciplinary:** Drawing on the theories and methods of engineering, economics, operations research, political science, psychology, other natural, and social sciences, management and law.

The context in which transportation system is studied is also very diverse and are mentioned below:

1. **Planning range:** Urban transportation planning, producing long range plans for 5-25 years for multimodal transportation systems in urban areas as well as short range programs of action for less than five years.
2. **Passenger transport:** Regional passenger transportation, dealing with inter-city passenger transport by air, rail, and highway and possible with new modes.
3. **Freight transport:** Routing and management, choice of different modes of rail and truck.
4. **International transport:** Issues such as containerization, inter-modal co-ordination

Therefore as we understand from above Transportation engineering is a very diverse and multidisciplinary field, which deals with the planning, design, operation and maintenance of transportation systems. Good transportation is that which provides safe, rapid, comfortable, convenient, economical, and environmentally compatible movement of both goods and people. This profession carries a distinct societal responsibility. Transportation planners and engineers recognize the fact that transportation systems constitute a potent force in shaping the course of regional development. Planning and development of transportation facilities generally raises living standards and enhances the aggregate of community values.

Generally a transportation system has three elements these are

- **Infrastructure:** which includes Road, canal, rail, air Transfer points Supporting elements (signs, signals, safety)
- **Vehicles:** which includes Planes, trains, autos, buses, ships, trucks
- **Operators/Content :** which includes Drivers, pilots, freight, passengers

History of transportation engineering

Long before cars, snowmobiles and airplanes, humans had migrated to all over the Earth powered almost exclusively by their feet. Eventually, people got tired of walking around and carrying everything they needed on their backs. They started to use domesticated animals to carry goods. They also built machines and devices, like sleds and travois, to help them carry more. In some parts of the world, they began using the wheel and axle to build carts and carriages. As people travelled back and forth, establishing trading routes, well-used paths became more and more permanent. These paths became the first roads. As time went on, people started to maintain the roads and look at ways in which they could be made easier to travel, these people were the first transportation engineers.

The strong interrelationship and the interaction between transportation and the rest of the society especially in a rapidly changing world is significant to a transportation planner. Among them four critical dimensions of change in transportation system can be identified; which form the background to develop a right perspective.

1. **Change in the demand:** When the population, income, and land-use pattern changes, the pattern of demand changes; both in the amount and spatial distribution of that demand.
2. **Changes in the technology:** As an example, earlier, only two alternatives (bus transit and rail transit) were considered for urban transportation. But, now new systems like ITS, LRT, MRTS, etc over a variety of alternatives.
3. **Change in operational policy:** Variety of policy options designed to improve the efficiency, such as incentive for car-pooling, bus fare, road tolls etc.
4. **Change in values of the public:** Earlier all beneficiaries of a system was monolithically considered as users. Now, not one system can be beneficial to all, instead one must identify the target groups like rich, poor, young, work trip, leisure etc.

Major disciplines of transportation

Transportation engineering can be broadly consisting of the four major parts:

1. Transportation Planning
2. Geometric Design
3. Pavement Design
4. Traffic Engineering

Transportation planning

Transportation planning essentially involves the development of a transport model which will accurately represent both the current as well as future transportation system.

Geometric design

Geometric design deals with physical proportioning of other transportation facilities, in contrast with the structural design of the facilities. The topics include the cross-sectional features, horizontal alignment, vertical alignment and intersections. Although there are several modes of travel like road, rail, air, etc.. the underlying principles are common to a great extent. Therefore emphasis will be normally given for the geometric design of roads.

Pavement analysis and design

Pavement design deals with the structural design of roads, both (bituminous and concrete), commonly known as (flexible pavements and rigid pavements) respectively. It deals with the design of paving materials, determination of the layer thickness, and construction and maintenance procedures. The design mainly covers structural aspects, functional aspects, drainage. Structural design ensures the pavement has enough strength to withstand the impact of loads, functional design emphasizes on the riding quality, and the drainage design protects the pavement from damage due to water infiltration.

Traffic engineering

Traffic engineering covers a broad range of engineering applications with a focus on the safety of the public, the efficient use of transportation resources, and the mobility of people and goods. Traffic engineering involves a variety of engineering and management skills, including design, operation, and system optimization. In order to address the above requirement, the traffic engineer must first understand the traffic flow behavior and characteristics by extensive collection of traffic flow data and analysis. Based on this analysis, traffic flow is controlled so that the transport infrastructure is used optimally as well as with good service quality. In short, the role of traffic engineer is to protect the environment while

providing mobility, to preserve scarce resources while assuring economic activity, and to assure safety and security to people and vehicles, through both acceptable practices and high-tech communications.

Other important disciplines

In addition to the four major disciplines of transportation, there are several other important disciplines that are being evolved in the past few decades. Although it is difficult to categorize them into separate well defined disciplines because of the significant overlap, it may be worth the effort to highlight the importance given by the transportation community. They can be enumerated as below:

1. *Public transportation*: Public transportation or mass transportation deals with study of the transportation system that meets the travel need of several people by sharing a vehicle. Generally this focuses on the urban travel by bus and rail transit. The major topics include characteristics of various modes; planning, management and operations; and policies for promoting public transportation.
2. *Financial and economic analysis*: Transportation facilities require large capital investments. Therefore it is imperative that whoever invests money should get the returns. When government invests in transportation, its objective is not often monetary returns; but social benefits. The economic analysis of transportation project tries to quantify the economic benefit which includes saving in travel time, fuel consumption, etc. This will help the planner in evaluating various projects and to optimally allocate funds. On the contrary, private sector investments require monetary profits from the projects. Financial evaluation tries to quantify the return from a project.
3. *Environmental impact assessment* : The depletion of fossil fuels and the degradation of the environment has been a severe concern of the planners in the past few decades. Transportation; in spite of its benefits to the society is a major contributor to the above concern. The environmental impact assessment attempts in quantifying the environmental impacts and tries to evolve strategies for the mitigation and reduction of the impact due to both construction and operation. The primary impacts are fuel consumption, air pollution, and noise pollution.
4. *Accident analysis and reduction*: One of the silent killers of humanity is transportation. Several statistics evaluates that more people are killed due to transportation than great wars and natural disasters. This discipline of transportation looks at the causes of

accidents, from the perspective of human, road, and vehicle and formulate plans for the reduction.

5. *Intelligent transport system:* With advent to computers, communication, and vehicle technology, it is possible in these days to operate transportation system much effectively with significant reduction in the adverse impacts of transportation. Intelligent transportation system offers better mobility, efficiency, and safety with the help of the state-of-the-art-technology.

In addition disciplines specific to various modes are also common. This includes railway engineering, port and harbor engineering, and airport engineering.

Factors in Transportation Development

Transportation develops because of several and frequently overlapping factors. From the many, the following are important:

Economic Factors

Almost all transport development is economic in origin. The chief preoccupation of the first human was the procurement of food, shelter and sometimes clothing. As they become more highly developed their needs increased, often beyond what their local economy could supply. Means of transporting goods from distant places had to be devised, adding to the costs of the goods thereby secured. The need for transporting individuals over wider areas also arose. Increasing transportation productivity and lower unit costs have occurred over the years as the system of transportation becomes more highly developed and complex.

Geographical Factor

Geography is closely related to economics. The geographical location of natural resources determines the transport routes that gives access to those resources and create economic utility, that is, time and place utility, by taking them from a location where they have little values to processing and consuming areas where their values is vastly increased.

Political Polices

Political polices frequently play a deciding role in transport development. Basically is in a way to form integrated political system and control.

Military

The military might of a nation is primarily intended to support its political polices and to provide for national defense. Consequently, often it has direct influence on transport development.

Technological Factor

Progress in direct and supporting technologies has played an obvious role in transportation, for instance introduction of new economical transportation mode to the exist system calls for the development of transportation

Competition

The competitive urges have given a powerful impetus to transport development. Railroads compete with railroad also with trucks, barges, pipelines and airlines. Airlines have counted heavily on speed but have also been forced to greater safety and dependability to meet ground transport competition. No less real is the competition between products and industries tributary to transport. Bituminous material competes with concrete as the road surface. Diesel won steam but may face competition with electricity.

Urbanization

The rapid growth of urban areas by an even more rapidly expanding population is a phenomenon that cannot be overlooked among transport development factors. Accessibility to land and the intensity of land use are closely related to transport availability.

Role of transportation in society

Transportation is a non separable part of any society. It exhibits a very close relation to the style of life, the range and location of activities and the goods and services which will be available for consumption. Advances in transportation has made possible changes in the way of living and the way in which societies are organized and therefore have a great influence in the development of civilizations. This topic conveys an understanding of the importance of transportation in the modern society by presenting selected characteristics of existing transportation systems, their use and relationships to other human activities.

Transportation is responsible for the development of civilizations from very old times by meeting travel requirement of people and transport requirement of goods. Such movement has changed the way people live and travel. In developed and developing nations, a large fraction of people travel daily for work, shopping and social reasons. But transport also consumes a lot of resources like time, fuel, materials and land.

Economic role of transportation

Economics involves production, distribution and consumption of goods and services. People depend upon the natural resources to satisfy the needs of life but due to non uniform surface of earth and due to difference in local resources, there is a lot of difference in standard of living in

different societies. So there is an immense requirement of transport of resources from one particular society to other. These resources can range from material things to knowledge and skills like movement of doctors and technicians to the places where there is need of them. Without the ability to transport manufactured goods, raw materials, and technical know-how, a country is simply unable to maximize the comparative advantage it may have in the form of natural or human resources.

Goods have little values unless given utility, that is, the capacity for being useful and satisfying wants. Transportation contributes two kinds of utilities: place and time utility, economic terms that simply mean having goods where they are wanted when they are needed, essential functions that can also be applied to the movement of people. An example is given to evaluate the relationship between place, time and cost of a particular commodity. If a commodity is produced at point A and wanted by people of another community at any point B distant x from A, then the price of the commodity is dependent on the distance between two centers and the system of transportation between two points. With improved system the commodity will be made less costly at B.

In urban areas especially, transportation provides the connecting link between dwelling-units to their corresponding activities.

Social role of transportation

Transportation has always played an important role in influencing the formation of urban societies. Although other facilities like availability of food and water, played a major role, the contribution of transportation can be seen clearly from the formation, size and pattern, and the development of societies, especially urban centers.

Formation of settlements: From the beginning of civilization, the man is living in settlements which existed near banks of major river junctions, a port, or an intersection of trade routes.

Size and Pattern of Settlement: the initial settlements were relatively small developments but with due course of time, they grew in population and developed into big cities and major trade centers. The size of settlements is not only limited by the size of the area by which the settlement can obtain food and other necessities, but also by considerations of personal travels especially the journey to and from work. The increased speed of transport and reduction in the cost of transport has resulted in variety of spatial patterns.

Growth of Urban Centers: When the cities grow beyond normal walking distance, then transportation technology plays a role in the formation of the city. For example, many cities in

the plains developed as a circular city with radial routes, where as the cities beside a river developed linearly. The development of automobiles and other factors like increase in personal income, and construction of paved road network, the settlements were transformed into urban centers of intense travel activity.

Environmental role of transportation

The negative effects of transportation are more dominating than its useful aspects as far as transportation is concerned. There are numerous categories into which the environmental effects have been categorized. They are explained in the following sections.

Safety

Growth of transportation has a very unfortunate impact on the society in terms of accidents. Worldwide death and injuries from road accidents have reached epidemic proportions. Present indications are that about half a million killed and about 15 million injured on the road accidents annually. Increased variation in the speeds and vehicle density resulted in a high exposure to accidents. Accidents result in loss of life and permanent disability, injury, and damage to property. Accidents also causes numerous non-quantifiable impacts like loss of time, grief to the near ones of the victim, and inconvenience to the public. The loss of life and damage from natural disasters, industrial accidents, or epidemic often receive significant attention from both government and public. This is because their occurrence is concentrated but sparse. On the other hand, accidents from transport sector are widespread and occurs with high frequency.

Air Pollution

All transport modes consume energy and the most common source of energy is from the burning of fossil fuels like coal, petrol, diesel, etc. The relation between air pollution and respiratory disease has been demonstrated by various studies and the detrimental effects on the planet earth are widely recognized recently. The combustion of the fuels releases several contaminants into the atmosphere, including carbon monoxide, hydrocarbons, oxides of nitrogen, and other particulate matter. Hydrocarbons are the result of incomplete combustion of fuels. Particulate matters are minute solid or liquid particles that are suspended in the atmosphere. They include aerosols, smoke, and dust particles. These air pollutants once emitted into the atmosphere, undergo mixing and disperse into the surroundings.

Noise pollution

Sound is acoustical energy released into atmosphere by vibrating or moving bodies where as noise is unwanted sound produced. Transportation is a major contributor of noise pollution, especially in urban areas. Noise is generated during both construction and operation. During construction, operation of large equipments causes considerable noise to the neighborhood. During the operation, noise is generated by the engine and exhaust systems of vehicle, aerodynamic friction, and the interaction between the vehicle and the support system (road-tire, rail-wheel). Extended exposure to excessive sound has been shown to produce physical and psychological damage. Further, because of its annoyance and disturbance, noise adds to mental stress and fatigue.

Energy consumption

The spectacular growths in industrial and economic growth during the past century have been closely related to an abundant supply of inexpensive energy from fossil fuels. Transportation sector is unbelievably to consume more than half of the petroleum products. The impact of the shortage of fuel was experienced during major wars when strict rationing was imposed in many countries. The impact of this had cascading effects on many factors of society, especially in the price escalation of essential commodities. However, this has few positive impacts; a shift to public transport system, a search for energy efficient engines, and alternate fuels. During the time of fuel shortage, people shifted to cheaper public transport system. Policy makers and planners thereafter gave much emphasis to the public transit which consumes less energy per person. The second impact was in the development of fuel-efficient engines and devices and operational and maintenance practices. A fast depleting fossil fuel has accelerated the search for energy efficient and environment friendly alternate energy source. The research is active in the development of bio-fuels, hydrogen fuels and solar energy.

Other impacts

Transportation directly or indirectly affects many other areas of society and few of them are listed below: Increased travel requirement also require additional land for transport facilities. A good transportation system takes considerable amount of land from the society.

Aesthetics of a region is also affected by transportation. Road networks in quite country side are visual intrusion. Similarly, the transportation facilities like fly-overs are again visual intrusion in urban context.

The social life and social pattern of a community is severely affected after the introduction of some transportation facilities. Construction of new transportation facilities often requires substantial relocation of residents and employment opportunities.

Modes of Transportation

Transport modes are the means by which people and freight achieve mobility. They fall into one of three basic types, depending on over what surface they travel – land (road, rail and pipelines), water (shipping), and air. Each mode is characterized by a set of technical, operational and commercial characteristics.

Road transportation

Road infrastructures are large consumers of space with the lowest level of physical constraints among transportation modes. However, physiographical constraints are significant in road construction with substantial additional costs to overcome features such as rivers or rugged terrain. Road transportation has an average operational flexibility as vehicles can serve several purposes but are rarely able to move outside roads. Road transport systems have high maintenance costs, both for the vehicles and infrastructures. They are mainly linked to light industries where rapid movements of freight in small batches are the norm. Yet, with containerization, road transportation has become a crucial link in freight distribution.

Rail transportation

Railways are composed of traced paths on which are bound vehicles. They have an average level of physical constraints linked to the types of locomotives and a low gradient is required, particularly for freight. Heavy industries are traditionally linked with rail transport systems, although containerization has improved the flexibility of rail transportation by linking it with road and maritime modes. Rail is by far the land transportation mode offering the highest capacity with a 23,000 tons fully loaded coal unit train being the heaviest load ever carried.

Pipelines

Pipeline routes are practically unlimited as they can be laid on land or under water. The longest gas pipeline links Alberta to Sarnia (Canada), which is 2,911 km in length. The longest oil pipeline is the Transiberian, extending over 9,344 km from the Russian arctic oilfields in eastern Siberia to Western Europe. Physical constraints are low and include the landscape and pergelisol in arctic or subarctic environments. Pipeline construction costs vary according to the diameter and increase proportionally with the distance and with the viscosity of fluids (from gas, low viscosity, to oil, high viscosity).

Maritime transportation

Because of the physical properties of water conferring buoyancy and limited friction, maritime transportation is the most effective mode to move large quantities of cargo over long distances. Main maritime routes are composed of oceans, coasts, seas, lakes, rivers and channels. However, due to the location of economic activities maritime circulation takes place on specific parts of the maritime space, particularly over the North Atlantic and the North Pacific. The construction of channels, locks and dredging are attempts to facilitate maritime circulation by reducing discontinuity. Comprehensive inland waterway systems include Western Europe, the Volga / Don system, St. Lawrence / Great Lakes system, the Mississippi and its tributaries, the Amazon, the Panama / Paraguay and the interior of China. Maritime transportation has high terminal costs, since port infrastructures are among the most expensive to build, maintain and improve. High inventory costs also characterize maritime transportation. More than any other mode, maritime transportation is linked to heavy industries, such as steel and petrochemical facilities adjacent to port sites.

Air transportation

Air routes are practically unlimited, but they are denser over the North Atlantic, inside North America and Europe and over the North Pacific. Air transport constraints are multidimensional and include the site (a commercial plane needs about 3,300 meters of runway for landing and take off), the climate, fog and aerial currents. Air activities are linked to the tertiary and quaternary sectors, notably finance and tourism, which lean on the long distance mobility of people. More recently, air transportation has been accommodating growing quantities of high value freight and is playing a growing role in global logistics.

Intermodal transportation

Concerns a variety of modes used in combination so that the respective advantages of each mode are better exploited. Although intermodal transportation applies for passenger movements, such as the usage of the different, but interconnected modes of a public transit system, it is over freight transportation that the most significant impacts have been observed. Containerization has been a powerful vector of intermodal integration, enabling maritime and land transportation modes to more effectively interconnect.