Program 1

Introduction to Transportation Engineering

Transportation is ordinarily defined as means of conveyance or travel from one place to another, or, it is a public conveyance of passengers or goods especially as a commercial enterprise. The importance of transportation in world development is multidimensional. For example, one of the basic functions of transportation is to link residence with employment and producers of goods with their users. From a wider viewpoint, transportation facilities provide the options for work, shopping, and recreation, and give access to health, education, and other amenities. Nearly every day, items in the news remind us of transportation's vital role in our economy and its significant relationship to our quality of life. Mobility is important to the whole community. An exploration of the realm of transportation, with emphasis on key aspects of its engineering and its close relationship to our social and economic lives is focused in this course, which is likely to be helpful to lead to transportation engineering (Figure 1.1)solutions in the real world.

Figure 1.1 Transportation Engineering

Transportation engineering is the application of the principles of engineering, planning, analysis, and design to the disciplines comprising transportation: its vehicles, its physical infrastructure, safety in travel, environmental impacts, and energy usage. Transportation engineering involves the "hard" physical sciences, as the engineer evaluates pavements, geometric design, vehicle design, environmental effects, and the like. It involves thorough analyses of the impact on transportation design and operations from a variety of soft or social sciences, such as human behavior, welfare economics, urban planning, and political science. The competent transportation engineer must be capable of integrating the factors found in both the "hard" and the "soft" sciences when searching for the best solution to a given transportation problem.

Transportation is much more than people making trips. The movement of goods is a critical part of local, regional, and national economies. As goods move from origin to destination, transfer points can be rail yards, truck terminals, warehouses, or distribution centers. Line-haul goods movement will be by rail, truck, water, pipeline, or some combination of these modes. Again, properly designed and operated facilities are essential to an efficient transportation system. If a transportation facility or service is overdesigned, the result may be a waste of resources. If it is underdesigned, bottlenecks

that cause delays, lost productivity, or unsafe conditions may arise.

Transportation engineering involves working with the public, with industry, with citizens' groups, with elected officials, and with employees of the agencies of local, state, and federal governments. It involves facing real problems that usually require engineering judgment. It is the county engineer, the city traffic engineer, or the state DOT (department of transport) engineer who will be asked to propose solutions for citizens and local officials to grapple with in public forums.

As commonly used, however, the term transportation engineering refers to a subspecialty of civil engineering. Since the main purpose of this book is to discuss the practice of transportation engineering, such topics as vehicle design will be ignored, even though they are extremely important applications of engineering to the transportation system. At the same time, the transportation field practiced by civil engineers is inherently multidisciplinary, overlapping such diverse fields as economics, psychology, geography, city planning, public administration, political science, industrial engineering, and electrical engineering. In addition, major theoretical contributions to transportation engineering have been made by people with backgrounds in physics and mathematics.

This breadth of interaction with other disciplines stems from the fact that the scope of transportation engineering is determined more by society need to provide an adequate transportation system than by the backgrounds of its practitioners. Thus it involves synthesis of several different intellectual perspectives and scientific knowledge bases to solve perceived technical, economic, social, and environmental problems. Among the civil engineering specialties, it is similar in this respect to environmental engineering, but differs from hydraulic engineering or structural engineering, which are more closely tied to particular bodies of scientific knowledge.

This range of material presents a challenge, especially in an introductory course.

Any such course needs to serve at least three purposes:

(1) To provide general information about the practice of transportation engineering for readers, mostly students, who will practice other civil engineering specialties.

(2) To prepare students who will practice in transportation related jobs immediately upon graduation.

(3) To provide the necessary background for students who wish to pursue graduate studies in transportation engineering.

The material presented in this book is dealt with lots of matters. For instance, it is organized in terms of the different transportation modes such as land (highways), rail, water, air and pipe, etc., and some focus exclusively on one of these modes, usually highways. In contrast, the approach here is to organize the material in terms of the different types of design and analysis that transportation engineers engage in, for instance, geometric design of facilities, traffic analysis, analysis and design of traffic control systems, transportation demand analysis, or transportation planning, and to discuss these in terms of basic concepts and techniques that often can be applied in a wide variety of situations to different transportation modes. The objective in presenting the material in this way is not only to emphasize the many similarities among the transportation modes but (more importantly) to help students experience the intellectual power and efficiency that can result from being able to apply abstract concepts and techniques to a range of concrete situations. At the same time, most of us

learn abstract ideas best by first being exposed to concrete examples. Consequently, the approach that will be followed is to introduce basic concepts and techniques by means of examples. Students are expected to understand that these examples are applications of basic principles that can be used in many other situations; and students should strive to understand the principles and imagine their full range of application, rather than merely memorizing the solution to specific problems.

1.1 Transportation and People's Life

Considering your furniture, your clothes, the food you eat, and everything else you use as part of your life, there is very little among those things that did not at some point undergo movement by at least one freight carrier.

Good transportation provides for the safe, rapid, comfortable, convenient, economical, and environmentally compatible movement of people and goods. The field of transportation can be compared to a mansion with several stories, many chambers, and scores of connections. We would like to take the reader on a short tour of this mansion just to acquaint him or her with some of its characteristics. One of the prerequisites for accompanying us on this trip is to have an open mind. Almost everyone will have had several years of personal experience as a user of the transportation system, such as a car driver, a bus passenger, an elevator user, a frequent flyer, or just a sidewalk user. Naturally, almost every person will tend to acquire his or her own personal viewpoint. No two persons can expect to come to the same conclusion about a problem confronting transportation even though they are each known to be highly objective and rational. Try as hard as you can to approach the field of transportation and its myriad problems with an open mind, free of presumptions and prejudice. Like food, shelter, clothing，and security, transportation is an integral part of human culture. Movement in a broad sense offers both inherent joy and pleasure as well as pain, suffering, and frustration. These factors will assume even greater importance in the years ahead.

Everybody is involved with transportation in so great a variety of ways that a mere listing of these ways would take us by surprise. Ultimately, all human beings are interacting over distance and time, and this interaction in itself creates involvement. Transportation has an increasingly close relationship to various social, economic, and political affairs. The role of transportation in the day-to-day life of human beings can be appreciated in various aspects.

1.2 Transportation Engineering

Because transportation is one of the major functional systems of society, it presents numerous issues and challenges. Transportation engineering will appeal to those who are attracted to public service and to opportunities to wrestle with challenging social problems and

contribute to their solutions.

1.2.1 The Field of Transportation Engineering

The desires of people to move and their need for goods create the demand for transportation. People's preferences in terms of time, money, comfort, and convenience prescribe the mode of transportation used, provided of course that such a mode is available to the user. Transportation engineering is a multidisciplinary field drawing on more established disciplines to provide its basic framework, such as economics, geography, and statistics.

1.2.2 Definition of Transportation Engineering

An appropriate point of departure for any discussion of transportation systems is a set of definitions. What is a transportation system? What are the various types of transportation systems? And how do they interact with their environment? After responding to these questions, this essay will briefly examine the role, effects, and control of transportation systems in the economic, social, and physical systems.

The Institute of Transportation Engineers (1987) defines transportation engineering as the application of technological 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. Traffic engineering, a branch of transportation engineering, is described as that phase of transportation engineering which deals with planning, geometric design, and traffic operations of roads, streets, and highways, their networks, terminals, abutting lands, and relationships with other modes of transportation.

The textbook definition of a transportation system or mode is a system for moving persons or goods consisting of three components:

(1) The vehicle (equipment) is what moves objects or traffic (people, goods). The vehicle consists of a container and some type of motive power, either onboard or elsewhere.

(2) The guideway is what the vehicles move along. The guideway consists of links and nodes that together form a network. A sequence of links is called a route. A terminal is a node where traffic is transferred from one vehicle to another.

(3) The operations plan is the set of procedures by which traffic and vehicles are moved over the guideway, including schedules or timetables, crew assignments, and control systems.

As with any general definition, various authors use somewhat different terms and divide the system in various ways. The definition given here is recommended for its simplicity.

Transportation systems, either existing or envisaged for the future, can be classified according to these components and their relations to the larger economic, social, and physical systems in which

they occur. Guideways often reside on or within Earth's surface and are therefore described as surface or ground transportation systems. Examples are highways and railways. Some systems, however, have their guideways in the air or on the water. In this case, their principal facilities are ports, either airports or harbors. Of course, a canal is also a guideway consisting of water held in a channel.

Vehicles operating over these guideways may be similarly classified. Automobiles and trucks operate on highways; locomotives and various types of railroad cars operate on railways; and airplanes and ships operate in the air and water. Operations plans provide the timetables, crew schedules, control systems, and protocols that enable these vehicles to operate safely and efficiently.

Other ways to categorize modes are also useful. One categorization differentiates between public and private. For example, freight railroads in the United States are generally owned and operated by private organizations, but in many countries they are publicly owned and operated. Passenger railroads generally consist of publicly owned vehicles and operations plans, but may operate over private railways. Airline services are provided by privately owned airplanes operating between publicly owned and operated airports under the control of a public air traffic control system.

Urban transit systems are increasingly public in their guideways, vehicles, and operations plans. This mode illustrates another dichotomy of modes: urban vs. interregional. Some transit modes only serve one urban region; others connect many urban regions into an interregional system. An example is an urban bus system vs. an interregional bus network.

Each transportation system operates within a larger economic, social, and physical environment, as noted above. Accordingly, each system generates certain external effects, or externalities, on its environment. Among these are emissions, noise, and damage to property and persons, both those using the system and those adjacent to it. Emissions, largely from vehicles, degrade the air, water, and soil through their exhaust and spills of hazardous materials. Noise from vehicle operations impact society within hearing distance. Passengers and bystanders are injured or killed when crashes occur, and accidents also damage or destroy goods and property.

1.2.3 The Practice of Transportation Engineering

Transportation engineering involves a diversity of basic activities performed by such specialists as policymakers, managers, planners, engineers, and evaluators. Several fringe and developing modes have not been identified. Whereas airways, conveyors, highways, pipelines, railways, and waterways are comparatively commonplace, we need to explain the modes as roundly as possible. When two or more modes are combined to provide utility and service to the public, the combination is known as a multimodal system. Exotic systems are those modes that are not yet being used commercially but that have been tested in a pilot project. Air-cushioned magnetically levitated vehicles fall into this category. Transportation substitutes such as the telephone (as used widely in teleconferencing) and facsimile transmission of documents by wire and radio can be considered as quasi-transport.

1.2.4 The Nature of Transportation Engineering

Transportation engineering is a multidisciplinary area of study and a comparatively new profession that has acquired theoretical underpinnings, methodological tools, and a vast area of public and private involvement. The profession carries a distinct societal responsibility. A wide comprehensive training in transportation is therefore the desirable goal of all transportation education. Because of the multidisciplinary content of transportation engineering, it is understandable that concepts drawn from the fields of economics, geography, operations research, regional planning, sociology, psychology, probability, and statistics, together with the customary analytical tools of engineering, are all used in training transportation engineers and planners.

Figure 1.2 illustrates, in a general way, the interdisciplinary breadth and the depth of involvement of transportation engineering. Most specialization in transportation engineering occurs at the graduate level; undergraduates receive an overall general view of the elements of transportation engineering. The upper-left part of this figure traditionally represents the "soft" side of transportation engineering, and the lower-right side, representing pavement design, bridge engineering, and drainage, may be looked on as the "hard" side of transportation. However，there is no definite demarcation between the two.

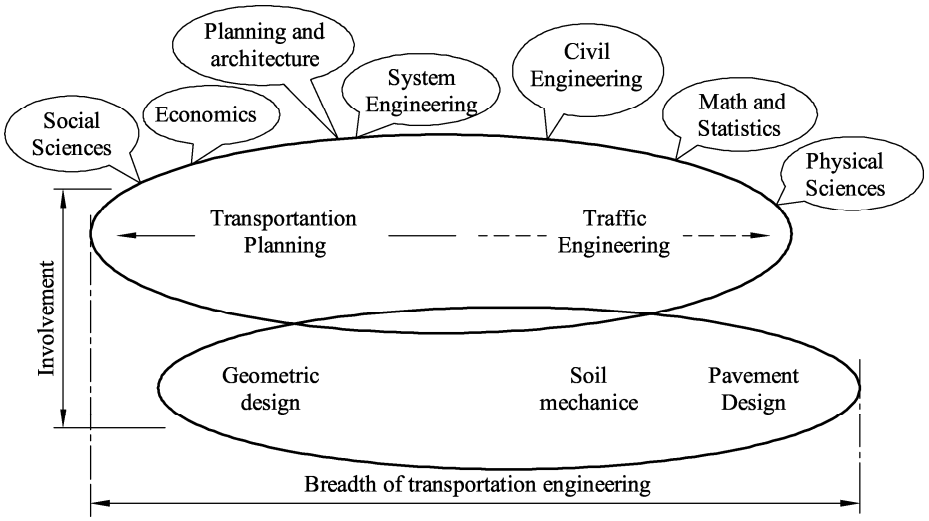

Figure 1.2 Interdisciplinary breadth and depth of transportation engineering

1.2.5 Civil Engineering Involvement in Transportation

Transportation engineering is the application of scientific principles to the planning, design, operation, and management of transportation systems. The term is more commonly used, however, to refer to a subspecialty of civil engineering, which includes both physical civil engineering related to transportation facilities and systems engineering related to the planning and operation of the transportation system.

Historically, the primary involvement of civil engineers in transportation has been in the provision of physical facilities and the devising of operating strategies for them. Consequently, most civil engineers working in the transportation field are employed by facility-oriented organizations. In addition, civil engineers have been employed by railways, which provide their own physical facilities, and urban transit operators, where the connection to civil engineering has been through both transportation planning activities and the design of operating strategies.

Most civil engineering activity related to the provision of physical facilities is what might be called physical civil engineering. This includes the design, construction, and maintenance of fixed transportation facilities and involves the full spectrum of civil engineering specialties. A major highway project, for instance, will involve not only the sizing and geometric design of the roadway, which is normally thought of as a part of transportation engineering, but also the design and construction of：bridges and other structures, which requires structural engineering; drainage design, which requires hydraulic and hydrologic engineering; consideration of earthwork compaction and slope stability, which requires geotechnical engineering; construction management; and surveying. Similar complexity and breadth of civil engineering involvement characterize other major transportation projects, such as the construction of airports or urban rail rapid transit systems.

Most civil engineering activity related to planning and operation of the transportation system, on the other hand, is what might be called systems engineering. This involves transportation planning, including the analysis of transportation demand; the analysis of system capacity and operating characteristics; and the design of traffic control and operating strategies. The design of traffic control and operating strategies includes highway traffic engineering and operational design (that is, design of operating strategies) of freight and mass transit systems.

1.3 Overview of Transportation Systems Characteristics

Transportation is typically systematic engineering. A system is a set of interrelated parts, called components that perform a number of functions in order to achieve common goals. It is also, as ex-plained at Longman Dictionary of Contemporary English, a group of related parts which work together forming a whole.

The transportation system is organized around society’s need to provide an adequate service and involves broad interaction with many other disciplines. The transportation system itself is one of the major functional systems of society, and is an essential feature of peopled lives, especially in wealthy societies. The goals of the transportation system are primarily economic; the most important constraints it faces are environmental. The transportation system itself may be analyzed in functional terms or in terms of modes of transportation.

The physical plant of most transportation systems consists of four basic elements:

(1) Links: the roadways or tracks connecting two or more points. Pipes, beltways, sea-lanes, and airways can also be considered as links.

(2) Vehicles: the means of moving people and goods from one node to another along a link. Motorcars, buses, ships, airplanes, belts, and cables are examples.

(3) Terminals: the nodes where travel and shipment begins or ends. Parking garages, off-street parking lots, loading docks, bus stops, airports, and bus terminals are examples.

(4) Management and labor: the people, who construct, operate, manage, and maintain the links, vehicles, and terminals.

These four elements interact with human beings, as users or nonusers of the system, and also with the environment. The behavior of the physical, human, and environmental subsystems is highly complex because it involves interaction of people as drivers, riders, and non-riders, using vehicles of differing character and performance on links with diverse vehicle characteristics in a myriad of environmental conditions.

Transportation systems can be evaluated in terms of three basic attributes:

1. Ubiquity

The amount of accessibility to the system, directness of routing between access points, and the system's flexibility to handle a variety of traffic conditions. Highways are very ubiquitous compared to railroads, the latter having limited ubiquity as a result of their large investments and inflexibility. However, within the highway mode, freeways are far less ubiquitous than local roads and streets.

2. Mobility

The quantity of travel that can be handled. The capacity of a system to handle traffic and speed are two variables connected with mobility. Here again, a freeway has high mobility, whereas a local road has low mobility. Water transport may have comparatively low speed, but the capacity per vehicle is high. On the other hand, a rail system could possibly have high speed and high capacity.

3. Efficiency

The relationship between the cost of transportation and the productivity of the system. Direct costs of a system are composed of capital and operating costs, and indirect costs comprise adverse impacts and unquantifiable costs, such as safety. Each mode is efficient in some aspects and inefficient in others.

Relation between aspects of transportation and their effects on people is shown in Table 1.1.

Table 1.1 Relation between aspects of transportation and their effects on people

Human behavior Environmental aspects	Activities	Locomotion	Social Interaction	Feelings	perception
Spatial organization		X	X		
Circulation and movements	X	X	X		
Communication	X	X	X		