

## TRANSPORTATION ENGINEERING AND PLANNING

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### Summary

Transportation engineering and planning are concerned with the movement of people and goods by means of highways, rail, air, water, and information technology. Presently, urban and inter-modal means of transportation are high development priorities. Transportation has played a crucial role historically in connecting countries and continents, however, promoting economic and social integration of the various regions of the world. All forms of transportation influence our lives and raise environmental, health, and safety issues. Transportation is intimately interwoven with the daily lives of individuals and organizations in our society: it is easy to overlook its significance until it fails in some way.

The aim of this article is to provide readers with diverse sources of information and knowledge about transportation engineering and planning, to help ensure that informed actions compatible with sustainable world development are taken in this sphere in the future. It begins with a historical analysis of transportation development, since an understanding of how transportation technologies developed is a prerequisite for understanding issues involved in transportation systems, and for developing sound policy analysis. Next, the article analyzes transportation problems, discusses the state of public policy addressing those problems, considers the causes and effects of changes in demand for mobility as the socio-economic environment changes, and then deals with the fundamental question of whether transport can indeed be a “sustainable” activity.

Transportation problems are framed within three broad categories: problems that affect transportation; transportation service problems; and problems caused by transportation.

Within these categories a wide range of issues is considered. These include increase in demand for transportation, due to increase in population and income, transport land-use implications, the impacts of transportation pricing policy, peak-hour demand, congestion, air pollution, safety, energy, and equity issues.

## **1. Introduction**

### **1.1. Transportation in Our Daily Lives**

Humans are one of several species capable of transporting goods and migrating from one location to another. A major distinguishing feature of humans, however, is that they are capable of modifying natural forces in order to devise new and innovative mechanical means to achieve greater mobility. Transportation engineering and planning are concerned with the movement of people and goods by means of highways, rail, air, water, and information technology. While today there is much emphasis on urban and inter-modal means of transportation, systems connecting countries and continents and promoting the development of economical and social integration of the various regions of the world are equally important.

The development of transportation saw great human efforts to amplify the mobility of people and goods, overcoming distances and time, and has a long history. It has advanced from the use of human-powered vehicles, such as canoes and bicycles, to automobiles and aircraft. Now transportation also takes place digitally through the medium of bits, instead of—or as well as—atoms. For example, millions of people read the news on computer screens delivered by bits, instead of reading newspapers delivered as atoms. The growth of human ability to transport large quantities of goods and people over long distances at high speeds, in comfort and in safety, is both a measure of technological progress and an indication of the development of society.

The majority of nations have adopted the mixed economic system, in which some goods and services are produced privately and some are produced publicly. Private institutions, such as households and entrepreneurs, produce and consume goods and services in pursuit of their parochial interests, whereas the public sector seeks to address broader public interests. The result is that the decision-making processes regarding transportation lie in both the private and public sectors in a world representing a mixed economic system. The public sector constructs new transportation systems, improves their capacities, and regulates services and prices; the private sector chooses locations of production, modes of transportation, and routes of shipment.

A common theme in these joint decision-making processes is the need to improve the quality of human life, by adopting and conforming to better environmental standards and new technology. Automobile makers use technology to develop automated vehicles or “smart” buses that will use “intelligent” highways. Location-based services (LBS), one of the new emerging technologies, will soon provide travelers using cell phones or personal digital assistants (PDAs) with real-time, route guidance assistance to the cheapest local gasoline station, for example.

The growth of transportation facilities has led to global concerns about the ability of road transport, despite continuing technological innovations, to provide key network links while managing traffic congestion and pollution, particularly in urban areas. Public sector organizations seek solutions through various policy tools, including taxation and innovative financing to improve highway infrastructure. The use of tolls for public transportation networks, such as highways, also provides financing and helps reduce congestion and pollution.

## **1.2. Purpose and Organization of the Article**

The purpose of this article, in parallel with the goal of EOLSS as a whole, is to provide readers with a source of information and knowledge about transportation engineering and planning, in order to better understand the needs of sustainable world development. Section 2 considers the historical development of transportation, and is based heavily on William Garrison's "Historical transportation development," in EOLSS on-line, 2002, and on the three articles within this section. In Section 3, transportation systems are described and analyzed; in Section 4, issues related to mobility and societal changes. Discussion of sustainable transport and mobility follows in Section 5.

## **2. Historical Development of Transportation**

### **2.1. Life Cycles of Transportation Modes**

Since an understanding of how transportation technologies developed is a prerequisite for understanding issues involved in transportation systems and sound policy analysis, this chapter begins with a historical analysis of transportation development. Four articles in EOLSS on-line are devoted to the analysis of historical transportation developments. Garrison describes technological transportation innovations and policy evolution ("Historical transportation development"), and technological changes and their influence on transportation developments ("Technological changes and transportation development"). Thompson analyzes transportation developments and their implications for institutional changes ("Transportation development and institutional changes"), followed by Nolan describing historical perspectives of transporting freight ("History of goods transportation").

In every civilization there has been trade, human interaction, and transport. Expanding trade and political power have exerted pressure for faster, more economical, and larger-capacity forms of transportation, which have been enabled as new technologies in transportation emerged. As long as the new mode is faster, better, and cheaper, it has overtaken the existing mode. From the first trials of a new mode, there is often a period of 20–30 years of "innovation," during which the predominant form of the new technology emerges by trial and error. Once the new mode's technological and economic advantages are clear, incremental improvements become the pattern, accompanied by input substitution until the stage called "growth-to-maturity" is reached. When a new technology emerges, the predominant one that has preceded it enters the stage termed "decline." This has been a consistent pattern throughout the history of transportation. The necessary conditions for a new mode of transportation to become dominant are technological superiority and economical viability.

Several technically superior modes of transportation have never become popular dominant modes. These include group rapid transit (GRT) systems, sometimes called personal rapid transit (PRT) systems, of the kind operating in Morgantown, W. Virginia, and the monorail systems seen in several amusement parks. Despite their technical qualities they are expensive to construct and operate, and therefore cannot compete with existing modes.

The following chronology lists some notable events in transportation development.

- 1555: The Highways Act in England resulted in the election of surveyors to plan and supervise road works.
- 1765: The Duke of Bridgewater's 7½ mile (12 km) canal, from coal mines on his estate at Worsley to Manchester, England, opened.
- 1780s: Rotary power obtained from steam engines.
- 1816: Steamboat applications in Sweden, on the Hudson River in the US, and in cross channel services linking England and France.
- 1825: The Stockton and Darlington Railway opened. Twenty-five miles (40 km) long and connecting coalfields, it is regarded as the world's first railway/railroad, although steam powered locomotives hauling cars on iron rails, or strips on wood beams, had already operated for some decades.
- 1835: The Great Western Railway was organized, with I. K. Brunel as the chief engineer and a major promoter.
- 1837: The SS *Great Western*, designed by Brunel, entered service, steaming from Britain to New York in nineteen days.
- 1840: Frank Hillis operated a steam-powered vehicle between London and Hastings and maintained a speed of 25 mph (40 kmh) for 125 miles (200 km).
- 1870: A street cable car in London, using a natural fiber and then wire rope, commenced operation. A subway under the River Thames used cable power, as did an elevated line along 5th Avenue in New York.
- 1870: E. W. von Siemens demonstrated an electric railway in Berlin.
- 1872: The Great Epizootic in the U.S. killed many horses, especially in urban areas where the respiratory disease spread quickly.
- 1873: A. S. Hallidie opened a cable car line in San Francisco.
- 1880: Thomas Edison explored battery power, compressed air, and chemical generation of electricity.
- 1886: Karl Benz developed a three-wheel car powered by an internal combustion engine, and G. Daimler and W. Maybach a four-wheel car.
- 1887: America's first electric vehicle was built by William Morrison.
- 1888: Frank J. Sprague built electric streetcar systems.
- 1896: The Panhard et Levassor company placed the automobile engine in the front of the vehicle.
- 1899: Congress appropriated funds to the Army Corps of Engineers to build at Los Angeles what became, by the 1930s, the world's largest artificial harbor. The first stage of the project was completed in 1912.
- 1900: There were about 5,000 miles (8,000 km) of streetcar lines in the US, carrying about 4 billion transit trips in 1900. The total number of cars in Europe reached about 10,000.

- 1903: First powered flight in France, using airships. Orville Wright made a short sustained, controlled airplane flight in North Carolina.
- 1907: Robert Fulton introduced the Albany–New York steamboat service on the Hudson River.
- 1908: The first Model T automobile was built by Henry Ford.
- 1910: The total number of cars in Europe reached about 200,000.
- 1914: The Panama Canal opened, diverting a large share of non-perishable transcontinental freight traffic from all-rail movement to rail–water–rail movement.
- 1915: The USA established the National Advisory Committee for Aeronautics.
- 1925: Bus services began to replace streetcars.
- 1930: In the USA alone, transit trips rose to about 17 billion, and the average urban dweller was making about 120 trips per year by transit of all sorts.
- 1964: The Japanese National Railroad opened new high-speed rail infrastructure between Tokyo and Osaka, known as the Shinkansen.
- 1975: The first Group Rapid Transit (GRT) line, sometime called Personal Rapid Transit (PRT), opened in Morgantown, W. Virginia.
- 1981: France began operating a new high-speed train called TGV, between Paris and Lyon in 1981.
- 1991: ITS America was mandated by the US Congress to co-ordinate the development and deployment of intelligent transportation systems in the United States.
- 1997: The automated highway systems (AHS) were demonstrated for the public for the first time in San Diego, 7–10 August.
- 2001: Limited transportation location-based services (LBS) are offered in Japan, Korea, and a few European countries.

## 2.2. Transportation and Economic Activities

Cities in the world have tended to develop where water and roads intersect. These intersections were natural sites for production activities, markets, warehouses and other infrastructure connected with transportation of raw materials. Shipbuilding and other industries followed. In earlier days, wet docks and canals were built to accommodate ships and increase the range of sites available for port activities (see “Water transport systems and port developments,” EOLSS on-line, 2002). Railroads (“Railroad transportation”) and highways (“Highways and private modes of transportation”) then followed. These interfaces between land and water transport modes became focal points for economic activities, attracting workers who eventually formed city populations. Central business districts (CBDs) formed around railroad stations. Suburban centers were formed where interstate highways met. In addition to their industrial and commercial roles, cities became centers of learning, arts, ideas, innovation, imagination, and culture.

Urbanization accelerated during the decades in which rail, maritime, and highway transport modes developed. By 1900, more than half of the population of Great Britain resided in urban areas; by the 1920s, about half the US population was urban. By the year 2000, about 47 percent of the world population lived in urban areas. Currently, there are over twenty world cities with populations over 10 million, referred to as

“megacities;” the majority lie in developing countries. Urbanization patterns differ nation to nation, as do protocols for classification of urban versus rural populations.

Air transport modes connect cities in the world. While the American flag carriers dominate air transportation, the United States, United Kingdom, and Japan have major presences both in airfreight and air passenger traffic. Airports, found in all world cities, also have a new role in the world economic market. Once considered public utilities providing services of national importance, governments gradually tended to privatize them during the 1990s. The privatization of airports does have potential benefits by allowing them to engage actively in the hotel and retail businesses. (For discussion of the economic role of airports and their design issues, see “Airport design and development,” EOLSS on-line, 2002.)

Deregulation of aviation markets in the US has led to widespread use of cost-saving “hub-and-spoke” networks, which channel passengers through a hub location. Density and capacity utilization is increased when passengers in different markets are carried on the same aircraft. (For analysis of the economic impacts of deregulation in other continents see “Network developments in aviation,” EOLSS on-line, 2002.)

### **3. Transportation Problems**

#### **3.1. Characteristics of Transportation**

While one cannot imagine a world without transportation systems, there are many problems associated with transportation, some of them severe. Transportation problems are not new. In fact, cities in Europe and the US were already very congested in the early nineteenth century when horse-drawn omnibuses, streetcars, and automobiles were competing with each other for road space, resulting in congestion. Transportation problems can be classified under three broad categories: problems that affect transportation; transportation service problems; and problems caused by transportation.

Before analyzing transportation problems in depth, it is important to understand the unique characteristics of transportation. One of these is that demand for transportation is driven by a need to achieve some other final purpose(s). We use cars, buses, subways, and taxis to go to work, for example. We drive a car to shop, take our children to schools, and drive for leisure. The one possible activity in which driving is truly an end in itself is when we take lessons to obtain a driver’s license. Economists term the demand for transportation as “derived demand.”

Another characteristic is that the public and private sectors interact in transportation activities. Public sector bodies construct and own most rights of way, with responsibility for improving capacity, and for regulating services and prices. Travelers, on the other hand, exercise their own preferences when selecting modes, routes, time, and day of travel. Therefore, transportation is a typical activity in a mixed economic system, where public and private sectors make interactive and joint decisions in the market. If transportation infrastructure was totally owned and operated by the private sector, we could end up paying many different tolls, as we drive every day from home to office on streets that are owned by different individuals.

Congestion, another unique characteristic of transportation, has always been an issue. This is caused by the life cycle of individual transportation modes. If a single mode is to remain dominant, it must be faster, better, and cheaper than other modes; this results in more users and thus in congestion. If the system does not remain faster, better, and cheaper, another improved mode becomes dominant by attracting more users. In turn, this becomes dominant and congested, and thus the cycle repeats itself.

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### **Biographical Sketch**

**Dr Kim** began his education in architectural engineering in his native South Korea and completed graduate study in planning at Princeton University, where he received his Ph.D. in 1976. He completed two years' graduate study in Urban Design in Austria, and worked in Germany, South Korea, Indonesia, Sweden, Kenya, the People's Republic of China, Saudi Arabia, and the United States. In 1979–80 he served as project director of the National Comprehensive Transportation Study of Korea, sponsored by the World Bank. He also directed the Optimal Transport Sector Development Project in Indonesia in 1990–1. He served as the director of the Office of Overseas University Collaboration, University of Illinois at Urbana-Champaign, and was the University of Illinois liaison officer to the Midwest Universities Consortium for International Activities, Inc. (MUCIA). He was an advisor to Governor Thompson of Illinois on international affairs, a Fulbright scholar to Germany, senior Fulbright scholar to Korea, a member of the Geography and Regional Science Advisory Panel, National Science Foundation (NSF), and chair of the National Advisory Committee for GIS Implementation of Korea.

He is editor of an international journal, *The Annals of Regional Science*, the head of delegates from Korea for Technical Committee for GIS Standardization (TC 211) of the International Organization for

Standards (ISO), project leader for international standard for Multimodal Tracking and Navigation of LBS System, and an advisor to the Arriyadh Development Authority (ADA) in Saudi Arabia since 1994.

Dr Kim teaches courses in transportation, GIS, and the application of the social sciences to urban and regional planning. Recent research funded by the National Science Foundation focused on models that attempt to show the impact of transportation on urban form and structure, and evaluate the economic impacts of transportation interruptions by unscheduled events. Other research projects include development of efficient, real time traffic data using personal communication systems (PCSs), travel time forecasting using real time traffic data, episodic and seasonal controls for transportation for improving air quality, and GIS standards.

Dr Kim has published seven books dealing with urban systems analysis, regional systems analysis, expert systems applications to urban planning, expert systems in environmental planning, environmental programming evaluation, and spatial planning in Indonesia. In addition, he has published twenty book chapters, forty-six journal articles, and thirty-six professional articles.

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