TRANSPORTATION SYSTEMS

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Contents

Summary

Although transportation systems are pervasive to modern society, people tend to take them for granted until something goes wrong. Airlines are known to fail as economic enterprises, public systems encounter deficits, excessive crashes occur on highways, and spacecraft are sometimes lost. Understanding transportation systems in terms of their technological and economic complexity, and their important impacts on society, is a large and fascinating field of study. This article, and the individual articles that it summarizes, seek to capture the excitement of these systems at an introductory level, and encourage further reading and study.

1. Definitions

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

(a) 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.

(b) 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.

(c) 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.

The articles within this topic may be neatly described in terms of these definitions. The first three articles concern systems with a strong urban orientation. *Highways and Private Modes of Transportation* describes highways and related private modes of transportation, including not only automobiles and trucks, but also pedestrians, bicycles, and motorcycles. The emphasis is on the guideways and vehicles comprising the highway/vehicle mode. *Public Transportation Modes* comprehensively examines public transportation systems in an urban setting, providing a detailed classification of vehicle types and the guideways on which they operate. Because operations plans are so important to this system, sections are also devoted to the scheduling of transit services. *Paratransit Systems* considers another type of transit mode, describing paratransit as all forms of passenger transit that operate on schedules and follow routes determined by the demands of individual passengers, hence the name *demand-responsive transit*. Not surprisingly, the emphasis in this article is on the operations plan component of this system.

The next four articles examine modes that are primarily interregional in nature. *Water Transport Systems and Port Developments* addresses water transportation systems and ports, primarily as a freight transportation mode. Naturally, vessel technology as well as management systems is covered. *Railroad Transportation* provides a comprehensive treatment of the railroad mode, organized largely according to the above guideway-vehicle-operations plan definition. While the emphasis is on freight transportation, there are also sections on high-speed railroad passenger service. *Network Developments in Aviation* examines recent developments in aviation networks and their underlying economic mechanisms. Deregulation of international airline markets is a primary thrust of this article, as well as the interplay of airlines and airport operations. *Airport Design and Development* covers the aviation sector from the airport development viewpoint. The emphasis on engineering design and operations in this article nicely complements the economic perspective in *Network Developments in Aviation*.

The final three articles of this topic examine issues of travel demand and safety. *Urban Travel* considers the multimodal transportation system serving large urban regions from the viewpoint of travel choices in the context of congestion and excess demand. This approach complements the supply orientation of the first three articles, and emphasizes the role of the equilibrium between demand and generalized travel costs. *Inter-Regional Transportation* surveys the broad topic of interregional transportation from both the supply (technology) and demand points of view. The emphasis on developing regions complements the earlier articles on interregional modes, which are written more from a developed region perspective. Finally, *Safety of Transportion* treats the question of transportation safety primarily from an American highway perspective.

2. Roles and Effects of Transportation Systems

As documented in the ten articles in this topic, transportation systems have pervasive and extensive effects on the economic and social systems that they serve. Although it is common to describe the use of transportation services as a derived demand, the way in which transportation modes are provided has an enormous effect on society itself. The initial effect of the introduction of a new transportation mode or service is generally to reduce travel or shipment times and costs, whether the mode or service is an existing technology or a new technological development. But this is only the first step in the "two-step dance" (see also *Historical Transportation Development*). The second step occurs when "innovative folk think of ways to do new things using the newly created services: entirely new market niches are uncovered, or old ones significantly expanded and remolded." As a result, mobility may be increased, and spatial interaction and trade expand. Finally, opportunities for economic and social integration may occur. The history of technology development in transportation is replete with examples of the effects of such innovations, many of which are described in this topic and in *Historical Transportation Development*.

Despite their positive effects, transportation systems also can, and often do, have large negative effects on the economic and social systems they serve. One of the most pervasive effects is that of traffic congestion in all levels and types of transportation services. Congestion of transportation systems occurs when the demand or use of the system brought forth at the given generalized cost (time, money, risks, etc.) is excessive compared with the system's capacity or the supply of services available. Congestion is effectively the wasted time and expense of using an inadequately supplied transportation service. However, congestion also serves to bring the system's use into balance with its available capacity.

Since transportation services, such as highway systems, do not always have an active supplier, so the interplay of use and available capacity may not be described well by the classical demand-supply model of microeconomics. Instead, the supply may be fixed for the present, and pricing mechanisms may be absent. Some economists and others advocate that pricing should be invoked in such situations to dampen demand. However, pricing of transportation services impacts various socioeconomic groups and travel and shipment purposes differently. Therefore invoking transportation pricing may not manage demand in the way that advocates believe.

Likewise, increasing the supply of transportation services, such as building more road capacity, may be counterproductive because households and firms may simply have an incentive to increase use of the service. Providing alternative services, which may be suited to serve large-scale demand efficiently, may be a better solution. For example, if road congestion to a common destination is pervasive, the solution may be to improve the quality of public transit service available, rather than increasing the road capacity. Such solutions may also need to be accompanied by disincentives for the use of private cars.

Excessive atmospheric emissions and use of nonrenewable resources (for example petroleum) often accompany traffic congestion. These issues are complex, and therefore require careful investigation and analysis from both demand and supply points of view. Understanding both the performance and the cost of the alternative technological solutions, and forecasting their future use, is essential for wise and effective decisions.

3. Planning and Control of Future Systems

In attempting to take a long run, global perspective of transportation systems development, one is struck not only by how much has been accomplished in the twentieth century, but also by differences in transportation development among various world regions. When visiting large, rapidly developing regions, such as China and Russia, one wonders whether they will avoid the transportation development mistakes of regions that were principal innovators, such as the United States, Western Europe, and Japan. If so, what knowledge and resources will they require, and how should they go about obtaining it? Knowledge development generally occurs through research by institutions of higher education and professional experts. Acquiring resources for transportation development requires an estimate of future benefits and costs, which themselves require the best available forecasts of use levels and costs of system implementation and operation.

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Biographical Sketch

Dr. David Boyce is Adjunct Professor, Department of Civil and Environmental Engineering, Northwestern University, Evanston, Illinois, and Professor Emeritus of Transportation and Regional Science, Department of Civil and Materials Engineering, University of Illinois at Chicago. During 40 years of research and teaching, Professor Boyce has addressed key methodological issues related to metropolitan transportation and land use planning. His early monograph, Metropolitan Plan Making, critically examined the experience with the land use and travel forecasting models during the 1960s. Recognizing that these methods lacked an adequate scientific basis, he has since devoted himself to the formulation and solution of urban travel and land use forecasting models as constrained optimization problems and related constructs, which synthesize elements of network analysis and modeling, stochastic discrete choice theory, and entropy-based methods.
Through this research, he concluded that the conventional travel forecasting paradigm, widely known as the four-step travel forecasting procedure, may now be seen to be a counter-productive concept. By focusing research on individual elements of daily travel decisions, mainly represented as having fixed travel times and costs, the conventional point of view obscures the overall equilibria and interdependence of travel choices. To offer an alternative perspective, Professor Boyce has rigorously formulated, implemented, estimated, and validated large-scale, integrated models of travel behavior. This ongoing research offers an alternative both to the conventional viewpoint and to newer initiatives that lack a rigorous scientific foundation. He has also extended this integrative approach to the study of regional economies, interregional commodity flows, and freight transportation systems.
In addition to this primary research theme, from 1986 to 1996, Professor Boyce was an early innovator of in-vehicle dynamic route guidance systems, a principal element of the emerging field of Intelligent Transportation Systems. This research culminated in his leading a multi-university team that performed development and evaluation tasks for the ADVANCE Project, a large-scale field test of a prototype route guidance system, in conjunction with Motorola, Inc., and federal and state transportation departments. In

this role he also conducted theoretical and modeling studies of the performance of route guidance systems on urban road networks.

During his career, Professor Boyce has served as a faculty member at the University of Pennsylvania (1966–1977), the University of Illinois at Urbana-Champaign (1977–1988), and the University of Illinois at Chicago (1988–2003) and Northwestern University (2003-2006). From 1988 to 1996, he also served as Director of the Urban Transportation Center at the University of Illinois at Chicago. Professor Boyce received the BS in civil engineering from Northwestern University in 1961, and the PhD in regional science from the University of Pennsylvania in 1965. He also received the Master of City Planning degree from the University of Pennsylvania. He is a Registered Professional Engineer in the State of Ohio. He has published 180 books, book chapters, journal articles, and reports during the past 40 years.