URBAN TRAVEL

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Summary

Congestion levels of urban transportation systems are widely regarded as unacceptable, especially in the popular press. In fact, congestion is the result of a complex process in which urban residents make choices pertaining to where, how and when to travel, as well as where to live and work. This article examines what determines these choices, and how planners and engineers attempt to predict them. When considered in this way, one begins to realize that urban travel is a complex system equilibrium, and that congestion simply represents one way to describe it. From this viewpoint, congestion may be regarded as a property of the system, and a measure of its vitality. High levels of congestion may indicate the strong vitality of a region, as well as inadequate investment and poor system management. The challenge facing policy makers is to understand the difference and make wise choices concerning the future of such systems.

1. Introduction

Each year for the past 18 years, the Texas Transportation Institute has issued its Urban Mobility Report documenting the growth of congestion on major roads in the 68 largest urban areas of the United States. The overt message of the report is that congestion is growing and that the causes are complex. The total estimate of congestion costs for the United States for 1999, measured in time and money, are impressively large: US$78 billion, the imputed value of 4.5 billion hours of delay and 6.8 billion gallons (25 billion liters) of excess fuel consumed. Restated on a per person per day basis, however, the costs and time seem more reasonable, even though the range for large vs. small urban areas is quite broad. The reason for referring to this annual study at the outset of this article on urban travel is to motivate the reader by asking whether society faces a problem, or even a crisis, in this regard.

The approach to answering this question is to examine the nature of the system that produces traffic congestion and to try to begin to understand its properties. A short answer is that urban traffic is a system in equilibrium or tending towards an equilibrium state. The vitality of that state is an issue of substantial importance to the well-being of each urban area and the larger region in which it is located.

Urban travel, as viewed by individual travelers, consists of a set of choices related to the route, mode, destination, timing, and frequency of travel. Some of these choices are closely related to the location of the traveler's place of residence, work, and other daily activities. If one considers that the choices of each individual are interacting with the choices of many others, then the enormous complexity of this system begins to become apparent.

The task of this article is to begin to explore this complexity in a descriptive manner. The emphasis of the article is on the choices made by individuals, also known as the demand for travel. Since the supply of urban transportation systems has been ably described in chapters *Highways and Private Modes of Transportation*, *Public Transportation Modes,* and *Paratransit Systems*, these aspects are not repeated here. Other views of the complexity of travel choices and use of urban transportation systems in book-length formats have been offered by Downs, Pucher and Lefevre, and Gerondeau, among others.

2. Travel Choices in Large Urban Areas

In the course of daily activities, urban dwellers make many choices about when, where, and how to travel. Some of these choices are considered on every trip and others only periodically. In this section, the nature and assumptions underlying these choices are examined, first in isolation and then in combination. Emphasis is placed on how the choices of each individual interact with others.

2.1. Route Choice

The discussion begins with route choice because it is a choice that is often made for every trip based on current travel conditions. Making one's choice of route requires a *destination* and a *mode* of travel, and a location from which the journey begins, the trip *origin*. Deciding upon a definite route requires an objective. Typical objectives for route choice include minimizing travel time, travel distance, travel cost, or some combination of these. One must also consider what the traveler actually knows about these times and costs. In the case of transit and nonmotorized travel, considerable information (timetables and fares) is available, presuming the system is reasonably reliable. In the case of an automobile operating over congested urban roads, much less information may be at hand, since incidents and daily variations in travel may cause conditions to fluctuate. The development of traveler information systems is improving the situation, however. Even so, through their accumulated experience, auto travelers seem to acquire a sense of which routes are best for their journeys. Bovy and Stern have explored this topic in great depth.

Given these assumptions, what can be said about the resulting travel pattern? Around 1950, a British traffic engineer, John Wardrop, proposed a simple principle of route choice that has become known as Wardrop's First Principle: "The journey times on all the routes actually used are equal, and less than those which would be experienced by a single vehicle on an unused route." Implicitly, Wardrop was referring to travel from one origin to one destination during a certain period of the day, such as the morning or evening commuting period when flows are large but relatively stable. If travel times and costs increase with roadway flows, and given a fixed origin–destination pattern of flows during a certain period of the day, Wardrop's First Principle corresponds to a rigorous mathematical representation of equilibrium roadway flows, as originally shown by Martin Beckmann. Moreover, these roadway flows are unique and have certain stability properties; however, the route flows are not unique, since flows on alternate routes can be exchanged without altering the total roadway flows. The equilibrium roadway flows can be found precisely for very large road systems with a reasonable computing effort.

In this auto route-choice situation, the choices of travelers are highly interdependent through the congestion occurring on the system of roads. Each traveler's route choice adds some small amount to the travel time experienced by every other traveler on shared roadways. Since these effects occur throughout the day, their severity depends on the total flows on the roadways, which in turn vary throughout the day.

Route choices over transit systems depend on scheduled services with fixed timetables and fares, at least in the near term. In many situations, only one scheduled transit service is available for a given trip, often with a walking segment to and from the bus stop or train station at each end of the trip. In cases where multiple transit services are available, the choice of route may depend on the scheduled time and the frequency of service of the competing services. The actual choice of which scheduled service to use may depend on which one arrives first at the transit stop.

2.2. Mode Choice

For the purpose of this discussion, mode choices may be categorized as (a) automobile, including shared riding and taxi, (b) transit, including paratransit, and (c) nonmotorized (walking, bicycling, etc.). Choice of mode of travel may be regarded as an extension of choice of route, in which the vehicle type is one dimension of the choice. A complicating factor, however, is whether an automobile is available to the traveler, either as a driver or passenger.

Given the available modes, the travel times and monetary costs of the alternatives can be compared, and the best alternative can be selected. For any given traveler, or class (group) of travelers with similar tastes and importance attributed to the time spent in traveling, a weighted sum of travel time, travel cost, fare, and other modal attributes, including benefits, can be determined for each mode. Assuming travelers minimize these *generalized costs* (maximize their *generalized benefits*), the choice of mode, and route, can be determined by choosing the lowest cost alternative.

Since modal attributes tend to be somewhat more subjective than route attributes, a stochastic model is often employed in predicting mode choices. The most common approach is to assume that the perceived generalized cost of travel includes a perception error distributed according to certain exponential probability distribution. In this event, the proportion of travelers choosing each mode is given by the multinomial logit function based on the observed generalized travel cost. In a detailed analysis or forecast, separate models are required for each class of traveler. The mathematical formulation of the auto route-choice problem can be extended to include transit choice and mode choice in such a way that the auto travel costs over the road network are determined as the result of an equilibrium solution that jointly determines mode choice and route choice.

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Biographical Sketch

Dr. **David Boyce** is Professor of Transportation and Regional Science in the Department of Civil and Materials Engineering at the University of Illinois at Chicago.

During 35 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 (1988–2002). 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 over 150 books, book chapters, journal articles, and reports during the past 35 years.