During 37 years of academic research and teaching, Professor David 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 devoted himself to the formulation and solution of urban travel and location forecasting models as constrained optimization problems and related constructs, which synthesize elements of transportation network analysis and modeling, discrete choice theory and entropy-based methods. Through this research, he concluded that the conventional travel forecasting paradigm, widely known as the Sequential Procedure, may be counter-productive. By focusing research on individual elements of daily travel decisions, often 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 some newer initiatives, which also lack a rigorous scientific foundation.

Website: http://www.civil.northwestern.edu/trans1/boyce.htm

Abstract

David Boyce
One of the first mathematical models of a physical network interacting with human behavior was the model of road traffic equilibria with variable flow (demand) formulated by Martin Beckmann and colleagues in 1954. Beckmann applied the recently-proved theorem of Kuhn and Tucker to incorporate an assumption and two hypotheses concerning road traffic into a single mathematical formulation. The model considers a road network consisting of nodes and links. Associated with each directional link is a function relating its travel time, or generalized travel cost, to its flow. Subsequently, more general formulations were investigated based on variational inequality, nonlinear complementarity and fixed point theory. Beckmann’s formulation and its descendents considered traffic flows over a relatively long period of time, during which network conditions may be regarded as constant. The peak commuting period in the morning or evening is a typical example. Such models are static, and the flows departing from and arriving at nodes are constant over the time period. Models that consider shorter periods of time, and for which the departure and arrival rates are variables, are dynamic. These models seek to represent the effect of changing network conditions during a longer time period, including accidents and other incidents disrupting flow.

Although Beckmann did not propose an algorithm for solving his formulation, in the 1970s researchers began to solve large-scale traffic equilibria. Until recently, these solutions were rather approximate, and did not reveal the structure of the solution, especially with regard to the number and pattern of equilibrium routes. In 2003, Bar-Gera and Boyce proposed an algorithm that reveals this structure for the first time.
Subsequently, they began to explore the properties of this solution for large-scale implementations, such as for the Chicago region. The initial results of these explorations for the Chicago region are unexpected and may be regarded as quite remarkable, if not actually amazing. One result examines the relation between the number of routes between a pair of zones, and the frequency with which this number occurs in the network. They observe that the number of routes increases greatly as the level of congestion increases.

The paper seeks to introduce traffic network equilibrium models to scholars from a broad range of backgrounds, mainly focusing on static models of urban road traffic. Findings on the solution properties of static models for a large network for three congestion levels are presented. A discussion of the applicability of the findings to other types of networks, such as electrical power and supply chain networks, concludes the paper.