

## Chapter 9

# Modelling the Route Choice: The Role of Volume–Delay Functions in Transport Planning

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### ABSTRACT

*The issue of route choice is a key factor for the freight transport performance. Congestion at roads encourages hauliers to change routes to minimize the delays and keep lead times in a reliable range. In the context of transport planning, the route choice problem can be assessed by modelling the travel times needed to reach a destination through the different routes in a road network. Is in this point where the volume-delay functions become relevant. A Volume-Delay Function (VDF) is a mathematical representation of the increase of the travel time as more and more vehicles utilize the routes, causing congestion on the road networks. The related literature and practitioners report on the use of some known functional forms, as the BPR function, the Conical volume-delay function or the Akcelik's function, which are widely utilized in flow's assignment modelling in transport planning. A successful application of VDFs requires a proper fitting of the function's parameters. In a classical focus these parameters can be deduced from speed-flow surveys carried out at the routes or links of interest; these surveys generally require time money and personnel. As an alternative to this classical focus, particularly when facing scarcity of resources, this work carries out a mathematical analysis of the VDF functional forms, as well with an interpretation of their parameters in relation to road's operation. The results of these analyses clarifies the meaning of the functional forms for the VDFs and their parameters, and suggest other ways to assess those parameters which may be more practical for the purpose of modelling the choice of route in freight transport. Some considerations to put into practice this in Mexico are discussed at the end of this work.*

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## **1. INTRODUCTION**

In any surface transportation system, a reasonable forecast of vehicle flows on the diverse routes available to connect origins and destinations is of interest for transport planners, road users and hauliers moving freight. For transport planners, these forecasts guide the design of control policies for traffic and reduction of impacts like congestion, accidents and environmental damage. For users and hauliers, forecasts give insight on congestion conditions, travel times and the alternative routes, in order to plan logistics issues.

Forecasts of vehicle flows are based on mathematical assignment models, which determine the expected vehicle volumes on each route in a transport network, once the network topology, an origin-destination matrix and the volume-delay functions on the network links are known.

A volume-delay function (VDF) is a mathematical function whose independent variable is the vehicle volume on a network's link, or alternatively the percentage of link's capacity that is used by traffic, and gives as response the expected time needed to cross that link.

The formulation of a VDF aims to represent the delay suffered by trips as a consequence of the growing number of vehicles on the road. Thus, VDFs are usually proposed looking for some common desired characteristics as: being continuous functions, monotonically increasing and bounded on their domain, and having derivatives at least of the first and second order. The latter is convenient for modelling marginal costs or when dealing with optimizing algorithms based on gradient methods. The role of the VDFs in the assignment model is to estimate the effect that occupancy of the road by vehicles has on the trip times. Based on this estimation, the assignment model uses route choice criteria to optimize a desired objective (e.g. time or cost) and calculates the vehicle flow split on the available routes.

In practice, modelling of route choice usually is done in reference to the equilibrium concepts proposed by J.G. Wardrop around the 1950s. These two equilibrium concepts are: user's equilibrium (UE) and system's Equilibrium (SE).

User's equilibrium occurs on a road network when users choose the more convenient route to reach their destinations freely on a self-interest basis. When the network begins to be occupied, early users choose usually the shortest routes to their destinations. As more users enter into the roads, the congestion effects motivate some users to change route in order to improve their travel times. These changes happen without any agreement among users, and finally they reach an equilibrium point where travel time on any used route is the same, so nobody gets improvement by changing route.

System's equilibrium appears on a road network when users choose their routes in such a way that the total time of their trips, or also the average trip time on all used routes is a minimum. This equilibrium does not happen spontaneously, and in general it is not easy that users agree among them to produce this effect. That is why results from a SE model have a normative focus, in the sense that the forecasted flows are those desirable from the planner's viewpoint, so in order this really happen the network has to be controlled, e.g. by fostering circulation on certain routes or inhibiting it on another parts of the network.

An additional criterion used in practice is the so called "All-or-Nothing". This criterion does not consider congestion effects on the network, and assumes that costs (times) are fixed on the routes; it is useful for networks having low traffic levels or with operating conditions very well controlled, as is the case of railroad networks.

Several functional forms for VDFs are found in the assignment modelling literature. Probably the most commonly used is that proposed by the US Bureau of Public Roads, known as BPR function; other typical formulations used in practice are the Conical function and Akcelik's function. These functions are usually available in transportation planning software packages like TransCAD from Caliper Corporation

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