# CHAPTER 1
# INTRODUCTION

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## 1.1 *OBJECTIVES*

The Research on the Interrelationships of Highway Costs (PICR) has the objective of determining functional relationships between the three components of the total cost of highway transportation (construction, maintenance and utilization), by gathering and analyzing empirical data on highway designs, pavement deterioration and maintenance, as well as on the costs of vehicle operation. One of the basic activities of the research was to measure vehicle speeds and their fuel consumption. These experiments are carried out to relate a vehicle speed and fuel consumption with highway geometry, type of surfacing and roughness of the road surface.

A very large and complex series of experiments would be necessary if reliable empirical relationships were to be developed among these variables under non-free flow conditions. In spite of the fact that the traffic flow can be controlled to a certain extent by means of selected samples, it is doubtful that the entire inference space could be covered, since it would not be possible to control the directional division and composition of traffic. In addition, there seems to be no cost-efficient manner of elaborating a speed profile for every vehicle, under conditions of traffic congestion, for estimating fuel consumption. This is due to the fact that vehicle speeds are influenced in various ways by interactions with other vehicles in the traffic flow.

The enhanced speed and capacity of modern digital computers have made it possible to employ simulation techniques that describe the behavior of each of the vehicles as they are driven along a highway section. Therefore, it would seem that a traffic flow simulation model, with variables, parameters and constants calibrated based on a limited number of field observations, would be the most cost-efficient way of determining relationships between operating speed and fuel consumption, on the one hand, and the physical variables of the highway, on the other, under non-free flow conditions.

This Report describes the development of a traffic-flow simulation model on two-lane highways. By estimating operating speed and fuel consumption, the Model makes it possible to determine the aforementioned relationships.

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The MST (Model for Simulating Traffic) is a traffic simulation model for two-lane highways. The simulation process consists of: (1) determining the moment of arrival of the vehicle at the beginning of the highway section under study; (2) generating the vehicle class, as car, bus, truck, etc.; (3) generating the speed performance of the binomial vehicle-driver within the class; (4) predicting this performance along the highway section, on the basis of preestablished rules; and (5) sampling the desired traffic-flow data, analyzing them and reporting the results (Bilich, 1981).

## 1.2 *PREVIOUS STUDIES*

This section presents a critical review of previous studies of the phenomenon of non-free traffic flow. It has the threefold purpose of identifying the factors which affect traffic and how they act, describing the various attempts to model the phenomenon of non-free traffic flow, and presenting some of the applications of these models to the analysis of alternative traffic policies.

### 1.2.1 *Factors Influencing Traffic*

The first to investigate the problem of overtaking on two-lane highways were Farben *et alii* (1967). They elaborated a research program with the purpose of developing one or more systems (radar, for example) that would make it possible to reduce problems related to a driver's imprecise perception of speed and distance of the vehicle approaching in the opposite lane, a phenomenon which normally leads to dangerous and even fatal consequences.

To determine the headways (time intervals between vehicles in a traffic flow) that would permit a pedestrian to cross a street, or a driver to safely cross a transversal street, Miller (1971) made a comparative study of nine of the various available methods.

McGee *et alii* (1978) carried out a study with respect to visibility distance or, in other words, the distance at which drivers are able to detect a potential danger or threat, in a disordered highway environment, come to a decision as to how to resolve the problem

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and put this decision into effect, safely and efficiently. This research sought to relate the concept of visibility distance to specific types of highways, speed limits, traffic levels, geometric characteristics and driver skills.

St. John and Kobett (1978) emphasized the modelling, simulation and interpretation of the traffic flows on a two-lane highway, where there was a large variety of vehicles duly represented. Among other factors, the method adopted included a representation of the acceleration capacity of the vehicles, the utilization of this capacity by drivers, driver behavior and estimates of the frequency of each type of vehicle in the traffic flow. They also sought to obtain information on how larger vehicles influenced the level of service and the safety enjoyed by other highway users.

Brach *et alii* (1978) describe a research project, conducted by *Planning Environment International*, to develop a model that would make it possible to determine fuel consumption and pollutant emissions as a function of vehicle speed and highway geometry.

Kadiyali *et alii* (1981) describe the preliminary results of a user cost study obtained in India. The study has the objective of determining the factors which cause both rolling and air resistance for the vehicles used in that country. These factors are needed as input data for the Swedish Model VTI, now being adapted to the conditions in India.

### 1.2.2 *Traffic Simulation*

Gerlough (1956) suggests two methods of simulating traffic flow. The first is a physical representation in which each vehicle is represented by a binary, and the highway by a group of memory cells. Some rules are set down to regulate vehicle movement. The second method is that of memorandum, whereby each simulated vehicle carries a file containing all of the physical information regarding itself, such as location coordinates, speed, spacing between vehicles and travel time. These files are periodically updated. The second method is generally the most widely employed since it requires less computer time than

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the first.

Janoff and Cassel (1970), of the Franklin Institute Research Laboratories, developed a traffic-flow model which simulates the movement of vehicles on a two-lane highway. Highway configuration includes zones in which overtaking is prohibited, restrictions as to visibility distance, and grades of each traffic lane, at any point along the simulated highway. Vehicle speeds and headways are generated according to the volume-speed and volume-headway relations in the *Highway Capacity Manual* (Highway Research Board, 1965). Using as inputs the traffic and highway data, the model simulates the traffic movement according to the conditions involving a particular vehicle. The output data of the model can be summarized in any time interval of the period of time simulated.

Heimbach *et alii* (1974) modified the simulation model of the Franklin Institute. They present the NCSU model, which is used to investigate the configuration of the non-overtaking zone with respect to the volumes of traffic on two-lane highways. This model incorporates two subroutines, designated "Truck-On-Grade" and "Car Exit", and a main routine called "Speed-Headway".

Boal (1974) formulates a traffic-simulation model for two-lane highways in which the highway is considered as straight and level. The model has the capacity to simulate overtaking moves.

Marwah (1976) developed stochastic models of daily and monthly traffic, based on five highways in Kampur (India), which were used for traffic predictions.

Gynnerstedt *et alii* (1977) describe a traffic simulation model for two- lane highways with traffic in both directions. The model assumes that, though limited by road geometry, speed limits or the presence of other vehicles, each vehicle travels at the basic speed desired by the driver. They also describe the effect of these factors and how they are combined.

Gravem (1979) presents a traffic simulation model based on a two-way highway network. The model considers such elements as horizontal and vertical road profile, auxiliary lanes, visibility, vehi-

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cle performance and driver characteristics. The model is applicable to the evaluation of proposed or already existing highway network projects, as well as to the evaluation of the influence of changes in geometry, regulations, flow conditions and vehicle/driver characteristics on traffic operations, safety and fuel consumption.

Gipps (1981) describes a simulation model designed to predict the response of a vehicle, within the traffic flow, to the behavior of the vehicle immediately ahead. The parameters used correspond to the obvious characteristics of driver behavior.

### 1.2.3 *Applications of Traffic Simulation*

Traffic simulation models have a wide variety of potential applications. Some of the applications effected with existent models are described below.

Cassel *et alii* (1970) carried out studies with the aim of making it possible to develop systems (radar, for example) that would aid drivers in perceiving more accurately the distance and speed of the vehicle in the opposite lane.

Both *et alii* (1980) describe a two year research project which investigated alternative projects involving the construction of a third lane on positive grades, on two-way highways. This study also included the development of a minimodel of simulation with the purpose of evaluating the effect of this additional lane.

Gynnerstedt and Troutbeck (1981) describe the process of data gathering and the changes that should be introduced into the traffic simulation model of the Swedish Institute of Highway Research (VTI) by the Central Road Research Institute (CRRI) in India, so that the model could be used to predict travel time and the number of overtakings.

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