CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

One of the precursors of the Highway Costs Model (MICR) was the *Road Analysis Model (RAM)*. The RAM was conceived by Louis Y. Pouliquen to be utilized by the World Bank as an instrument for economic evaluation of highway projects. A preliminary version of the RAM was concluded in 1969 and, after being applied in the evaluation of more than 20 projects, the model was reworked by Pedro N. Taborga, of the Department of Transportation and Urban Projects of the World Bank. The new version not only improved the numerical calculations and the results, but also incorporated the experience gained in the applications of the model, together with a number of suggestions offered by its early users.

The RAM focused on the advantages of a new highway project in relation to an already existent project, both designed for the same area. Basically, the model determined the traffic that would be transferred to the planned road, together with the benefits that would be generated by this traffic. Utilizing the project investment costs supplied by the user, the model calculated the internal rate of return on the investment in question, the optimum year for the investment, and its current net value, based on a given annual rate of discount.

The major functions of the RAM were as follows:

- to effect all the calculations associated with the economic evaluation of projects;
- to permit easy and direct communication between the user and the computer;
- to make it possible to obtain reports on the results selected by the user;
- to present a cost-benefit summary compatible with the *CBPACK (Cost Benefit Package)* program, so as to permit analysis of risk;
- to permit additions to the model with minimum efforts in terms of programming.

The characteristics of the RAM which differentiated it from the other models were its modularity and its capacity to permit a dialogue between the user and the computer during evaluations.

In the course of 1969, the Massachusetts Institute of Technology (MIT), with the sponsorship of the World Bank, initiated the development of a model to be used in the economic evaluation of invest-

ments in roads with low traffic volumes, and more specifically in the evaluation of construction projects and alternative maintenance standards. Directed by Fred Moavenzadeh, the program was concluded in 1971 and resulted in an integrated structure which related the costs of highway construction, maintenance and utilization involving construction projects and alternative maintenance standards proposed by the user.

Phase 1 of the World Bank/MIT Study was dominated by this part of the task, and produced the *Highway Cost Model* (HCM). This model differed from the others by including real correlations of road deterioration, a phenomenon presented in terms of the costs and benefits of the road in question, permitting the user to specify a number of maintenance policies. However, the most important conclusion of the study was that existing empirical data were insufficient to confirm the interrelationships among the characteristics of the construction project, the quality of the road surface and the operating costs of the vehicles utilizing it. These results encouraged the World Bank to enter into an agreement with the British Transport and Road Research Laboratory (TRRL) in order to correct this deficiency and develop the interrelationships deemed necessary.

The TRRL set up a team in Kenya to produce a model based on real data collected in the field. The locality was considered to be adequate for the research, since the government of Kenya had demonstrated considerable interest in it, and the TRRL possessed vast experience in that country - a fact that would facilitate the planning and execution of the field work. The team began working in April 1971, with the specific objective of measuring the characteristics of deterioration of some roads and the operating costs of the vehicles that used them. The studies included:

- measurements of speed and fuel consumption of different types of vehicles on roads possessing varying design standards and surface qualities;
- survey inventory of some transportation companies and gathering information on their fleets, in order to permit estimation of tire consumption, maintenance expenditures and depreciation costs; and
- measurements of the riding surface deterioration of gravel roads and of roads with surface treatment, with differing traffic conditions and maintenance policies.

The work was completed in 1974 and a computational model, the *Road Transport Investment Model* (RTIM), was produced in 1975. This model calculated the total cost of a road and predicted surface condi-

tions and traffic volume over time. With information on the surface conditions in a given period of analysis, the RTIM estimated the costs of vehicle operation and maintenance for each year. All costs were discounted to the base year and added together to obtain the total cost. However, the RTIM had the following limitations:

a) Data from Kenya

The great majority of the interrelationships were obtained during the field work in Kenya. To utilize the model in different localities, it would be necessary to examine the available data to ensure that they would not be used in extrapolations, in order to ensure application of the model within the intervals determined by the Kenya study.

For example, if only flexible paved roads were studied, it would never be possible to apply the model to a rigid road. Similarly, if roads possessing good to excellent surface conditions were the only ones studied, it would be unwarranted to apply the model to highly deterioration roads;

b) Study of Networks

The RTIM made simulations and cost calculations in relation to links. Therefore, it was not possible to use it to study a highway network, unless the network could be broken down into various links and the effects of each link added together to reflect the effects of the network as a whole; and

c) Prediction of Traffic Growth

The RTIM demanded that the user supply the rates and periods of traffic growth, and also estimate the volume of additional traffic (induced or generated traffic) which would utilize the road as a consequence of the improvement made.

Later on, MIT, sponsored by the Agency for International Development (AID), established four objectives specifically related to the RTIM:

- to develop an updated version of the model, incorporating the results obtained in the extensive field work carried out by the TRRL;
- to corroborate the model, utilizing it in the evaluation of investments in recently concluded projects;
- to ensure use of the model as a normal practice by the highway authority of some developing country; and
- to expand the model to include the effects of a highway network.

In June 1976, an agreement was signed among the World Bank, MIT and the TRRL, with the objective of producing a single model that would combine the HCM and the RTIM, while avoiding the imperfections of both. Another version then came into being, designated the *Road Investment Analysis Model* (RIAM), which utilized the structure developed during Phase 1 of the Study and incorporated the results of the research carried out by the TRRL in Kenya, together with the results of other technical studies in the area of highway engineering carried out since 1970.

The equations which estimated the costs of highway utilization were based on the Kenya results, and included only vehicles in free traffic conditions, without forecasting the effects of congestion, and reflected only those types of vehicles that are representative of the western region of Africa.

The equations which correlated the effects of highway deterioration and maintenance were based on tests carried out by the American Association of State Highway Officials (AASHO), as well as on the results of the Kenya research. The application of these equations was restricted to surfaces of asphaltic concrete and bituminous treatment, with a stabilized cement base, and subject to limited conditions of traffic and maintenance. The equations of deterioration of unpaved roads were based on the results of the TRRL, and included only well-maintained gravel roads.

The World Bank acquired some experience testing the RIAM in a number of evaluations of Bank projects, and later decided to modify and expand the model. The Bank designated the modified RIAM as the *Highway Design and Maintenance Standards Model* (HDM). A second version of the HDM was produced in October 1979 and still another in April 1981.

1.2 THE RESEARCH AND THE ICR MODEL

In January 1975, the Brazilian Government and the United Nations Development Programme (UNDP) signed an agreement to carry out a highway research project in Brazil. The Brazilian Government made the Ministry of Transportation responsible for the project and assigned its execution to the Brazilian Transportation Planning Company (GEIPOT).

The UNDP designated the World Bank as its executive organ and the Texas Research and Development Foundation (TRDF) was contracted to organize a team of foreign technicians to participate in the research, and to select and purchase the equipment of foreign origin required by the project. The participation of the TRDF lasted until December 1979.

The major objectives of this project were: (1) to interrelate the costs of highway construction, maintenance and utilization, with the use of genuinely Brazilian parameters; (2) to develop methods and models with the aim of minimizing the costs of transportation on paved and unpaved Brazilian roads, with low levels of traffic; and (3) to aid Brazilian highway technicians in their technical-economic feasibility studies.

This project, which was designated the *Research on the Interrelationships Between Costs of Highway Construction, Maintenance and Utilization (PICR)*, carried out its studies through the following three basic work groups:

a) User Costs Survey Group

The object of this group consisted of the costs incurred by users as a result of the operation of their vehicles on non-urban roads (vehicle operating costs). The group's objective was to identify the relations among the various components of vehicle operating costs, and the variables associated to road design and maintenance, such as surface roughness and vertical and horizontal geometry. Only situations characterized by low and medium traffic volumes were considered in the study;

b) Traffic Experiments Group

The primary objective of the traffic surveys and experiments was to generate a data basis to develop mathematical functions for use in a user-costs simulation model, in order to evaluate speed, travel time and fuel consumption of different classes of vehicles operating on intercity highways. The most important experiments were the following:

- survey of free speeds on positive and negative grades;
- survey of free speeds on curves; and
- measurement of fuel consumption at steady-state speed.

c) Pavement-Deterioration Studies Group

The specific objectives of the pavement and maintenance studies were:

- to determine the deterioration of paved roads in terms of roughness, rut depth, cracks and potholes, as a function of maintenance, pavement structure, geometry and traffic, in climatic conditions typical of Brazil;
- to determine the deterioration of unpaved roads in terms of roughness, rut depth, loss of gravel and loose matter as a function of maintenance, geometry, traffic and material characteristics; and
- to obtain information on maintenance techniques, productivity and unit costs, for the calculation of maintenance costs.

One of the products of the PICR was a model to be used in the economic evaluation of highway investments, designated the *Highway Costs Model (MICR)*. The MICR is the result of incorporating the equations obtained by the PICR study into the structure of the October 1979 version of the HDM.

It was obviously necessary to modify the structure of the HDM somewhat, since the equations developed by the PICR included variables that were different from those originally found in the HDM, which resulted from the TRRL research in Kenya. A number of modifications were also made to correct errors of logic, since the task involved the utilization of a structure that had not been totally checked (this was the case of the October 1979 version which, for this same reason, gave rise to another version in April 1981). Aside from these, other alterations were made in the HDM, as a result of implementing the following procedures:

- simulation of some maintenance operations on paved roads that were different from those originally found in the HDM, such as temporary patching and slurry sealing;
- correction of the calculations of the benefits of the first year; and
- inclusion of the calculations of the cost/benefit relations.