CHAPTER 2
METHODS, INSTRUMENTS AND BASIC DATA

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2.1 METHODS

To gain knowledge of the total cost of highway transportation, broken down into its major items (costs of highway construction, maintenance and utilization), one must be familiar with the Brazilian highway environment, its organization, practices and standards of highway construction and maintenance, as well as the organization and practices of the users of these roads.

As mentioned in the previous chapter, the most complex tasks are those of identifying and quantifying the costs of highway maintenance and utilization, with the objective of correlating maintenance expenditures with the quality of the road surface, as well as the costs of vehicle operation with the characteristics of the road (geometry and surface quality).

During the period extending from July 1975 to December 1981, the great effort expended in this research project was concentrated on obtaining information, gathering data and performing experiments, with the aim of determining the costs of highway maintenance and vehicle operation on selected segments of the highway network.

Since the PICR was, from various points of view, a pioneering task, it was necessary to develop specific methods of work, test them and adapt them and, only after all this, begin the systematic work of collecting data and information both on the selected road sections and on the costs incurred by selected users.

In the light of the material impossibility of researching the entire highway network, as well as the population of users, the solution arrived at was that of establishing, by consensus among the technicians, those factors of greatest relevance which would include the totality of the highway universe. These factors were combined into factorial matrices, composed of cells resulting from the conjugation of two or more factors.

The data and information obtained are divided into three basic categories:

a) Data and information supplied by highway authorities and by highway users,

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b) Tests and physical measurements, and
c) Experiments with all the factors under control.

Fundamentally, the first group contains the information gathered from the highway authorities with respect to the highway network under their jurisdiction (geometric, geological and geotechnical characteristics of the pavement structures, traffic and its composition, maintenance practices). Also included in this group is the information obtained from highway users on the costs of the various items which make up the operating cost (fuel, lubricants, parts and mechanic labor, tires, operating labor, type of operation and load, travel time, etc.).

The physical measurements consisted of identifying and determining the speeds of the highway users, weighing the vehicles and determining the physical characteristics of the materials which compose the road structures, such as texture, roughness, granulometry, *in-situ* resistance, etc.

In the category of experiments, one should mention the measurements of fuel consumption as a function of roadway characteristics (geometry and roughness), and the laboratory tests, the latter carried out with to obtain better knowledge of the physical characteristics of the highways under study.

The specific methods utilized by the different groups responsible for the gathering of data and information are described in detail in Chapters 3, 4 and 5 of Volume 2 of this report, while the conclusions are presented in Volumes 5, 6 and 7.

2.2 *INSTRUMENTS*

The scientific and measuring instruments available to the PICR were of good quality and considered to be the best on the market at the time work began.

Conventional equipment widely used in highway engineering was utilized, together with technically sophisticated instruments used for the first time in Brazil. This equipment is described

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in volume 3 of this report, together with information on its operation, the special care to be taken in utilization, major operating defects, and the minimum team required for maintenance.

Special mention should be made of the following equipment and instruments utilized for the first time in Brazil:

1) *Mays-Ride-Meter* (or Maysmeter) - a rather simple instrument which detects the vertical movement of the differential of a vehicle (rigid axle) in relation to the body, as the vehicle moves over the highway. After covering a specific unit of distance, these movements are added together and transformed into statistics corresponding to the surface quality of the road segment in question. Though this is a relatively simple measurement, it is influenced by a number of factors, such as tire pressure, state of the vehicle suspension system, speed of movement, etc. However, this low-cost, relatively simple equipment made it possible to obtain data on roughness at the same speed of circulation as that of highway users.

2) *GMR Profilometer* - also known as the Surface Dynamics Profilometer is a technically sophisticated instrument used basically for calibrating the simpler measuring instruments (Maysmeters). This consists of a utility van in which complex electronic equipment has been installed, and which receives, analyzes and computes the movements of a pair of sensor wheels in contact with the highway, producing a recording of an analogical profile on magnetic tape. This profile can be adequately analyzed and simulated within the vehicle, generating statistics that are interpreted as the roughness of the road surface, with which the measurements generated by the Maysmeters are correlated.

The Profilometer was not widely used, since it could not circulate at speeds above 32 km/h (20 miles/h) and thus interfered with the normal flow of traffic, besides presenting complex maintenance problems.

3) *Resilient Modulus* - this is a test which consists of measuring the deformities introduced into a test body through the application of a small weight at regular time intervals. In short, it is the practical application of Prof. Lobo Carneiro test, also known as the *Brazilian method*. During the PICR, this test was for the

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first time systematically and intensively carried out in Brazil.

4) *Scale for Weighing in Motion* - this consists basically of transducers installed in the road surface. When they come under the pressure of vehicle wheels, the devices emit a signal which, after being interpreted by adequate electronic equipment, gives the weight of each wheel of the vehicle. As supplementary equipment, two *loops* are also installed in the roadway to detect the circulating speed and the length of the vehicle. This equipment proved to be of little use, due to the virtually constant defects which appeared in its electronic components. The description of this equipment and recommendations as to its operation and maintenance are described in Volume 3 of this report.

2.3 BASIC DATA

The data, information and measurements obtained during the PICR constitutes a highly valuable file, which can be used in the future to improve highway planning techniques.

The three groups responsible for the gathering of data labored intensively from July 1975 to December 1981. The work of collecting data on vehicle performance in relation to acceleration and deceleration is being concluded in 1982. Observations and measurements of the deterioration of selected test sections should continue for the next several years, so as to improve and enrich the files and the performance models of the roads.

The group responsible for the collection of data on user costs systematically obtained data on the different components of total operating cost, in the form of monthly information supplied by the users themselves. When this information did not exist, systems adapted to the characteristics of the companies were installed, and data were gathered on the following items:

- fuel consumption;
- consumption of lubricants;
- tire consumption;
- spare parts;
- maintenance labor;

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- operating time;
- operating crew; and
- depreciation.

In addition to these data from the major survey, information was also collected on the following items:

- age of the vehicles;
- load, freight, passengers transported;
- travel time;
- number of stops, loading and unloading;
- speed of the vehicles; and
- vehicle specifications.

With respect to the routes used by the vehicles for which cost data were collected, a survey of the following characteristics was made:

- type of surface;
- roughness of the surface;
- vertical geometry;
- horizontal geometry;
- width of the riding surface;
- use of the soil in the region; and
- traffic.

For logistical reasons, the area covered by the study was initially restricted to the Federal District and the states of Goiás and Minas Gerais. However, in order to widen the scope of the factorial matrix of the study, it was necessary to extend data gathering to the states of Mato Grosso, Mato Grosso do Sul, São Paulo, Espírito Santo and Rio Grande do Sul.

The description of the methods and techniques utilized in the gathering of data are found in Chapter 3 of Volume 2. Volume 5 of this report contains the conclusions, parameters and equations obtained.

The group responsible for the collection of data on vehicle performance on the highways was organized with the objective of identifying the operation patterns of the highway users, measuring the speed of circulation of the different classes of vehicles, and

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relating it to road characteristics (horizontal and vertical geometry and surface quality).

After these observations, the operation was simulated in vehicles equipped with adequate instruments, and fuel consumption was measured with all factors under control.

The carrying out of these tests made it possible to create performance models for the different types of vehicle in the national fleet, including automobiles, utilities, light, medium and heavy trucks, as well as intercity buses. The equations resulting from the analysis of the data generated a family of equations capable of predicting the operating speed and the fuel consumption of the vehicles as a function of the geometric characteristics of the highway and the quality of the riding surface.

The methods and techniques utilized by the group are described in Chapter 4 of Volume 2 of this report, while the result of the statistical analysis of the data collected is found in Volume 6 of this report.

After an intensive search, the group responsible for the study of road performance and maintenance identified those highway sections with characteristics that fitted the cells of the general matrix of the experiment. Pavement deterioration was observed on these sections, and the effect of maintenance operations was measured.

To evaluate the effect of maintenance on the highway, the selected test sections were divided into two subsections: one received no maintenance, while the other received the routine maintenance, normally practiced by the highway authorities.

In selected sections of badly deteriorated highways, experimental sections were constructed on which different maintenance techniques were applied, ranging from slurry sealing to varying thicknesses of asphaltic concrete (4 to 12 cm). The performance of these sections is still under observation.

Probe holes were drilled in the selected test sections for the purpose of extracting materials from the different pavement

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layers, and determining the CBR *in situ*. The material withdrawn from these holes was later tested at the soil laboratory to determine such physical characteristics as granulometry, limits, CBR. Test samples of the surface material were also withdrawn, while undeformed samples were extracted from the subgrade with the use of Shelby tubes.

In addition to the characterization of the pavement structures of these sections, information was also gathered on the climate and traffic (its composition and weight). A systematic survey of the pavement condition was also carried out. This was done through measuring the areas of cracks, potholes and patches; measuring deflection with the Benkelman beam; and measuring riding surface roughness.

The methods and techniques utilized by the group are described in Chapter 5 of Volume 2 of this report, while the results of the statistical analysis of the data (represented by equations and models of pavement performance and deterioration) are presented in Volume 7.

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