CHAPTER 2
OBJECTIVES AND PRINCIPAL
CHARACTERISTICS OF THE MICR

2.1   OBJECTIVES

As was previously stated, the Highway Costs Model (MICR) resulted from the incorporation of the equations which describe the interrelationships found by the PICR in Brazil into the structure of the HDM (October 1979 version), in place of the correlations found in Kenya by the TRRL.

The Model calculates the total costs (construction costs maintenance costs + utilization costs) of two or more roads or road alternatives, and simulates the surface conditions and traffic volumes of each one of them, during a specific period of analysis defined by the user, which can extend for as long as 30 years. Based on knowledge of road conditions, the Model estimates its maintenance costs and the operating costs of the vehicles that utilize the road, for each year of the specified analysis period. All of these costs are discounted to the base year (the Model permits the utilization of as many as five different rates of discount), and then added together to produce the total costs of each one of the highway alternatives analyzed.

The MICR has the major objective of verifying the technical-economic feasibility of one or more improvements applied to one or more existing roads. Thus, the MICR basically simulates and compares the costs of a given basic alternative with the costs of one or more alternatives for improvement which serve the same geographical area. The basic alternative consists of an existing road, with known traffic level and a maintenance policy whose characteristics are described by the user.

The improvement alternatives normally include a construction project that requires an appropriate maintenance policy. Usually, there occurs an increase in traffic as a consequence of improving road conditions. Other sets of costs and benefits may also appear as a consequence of these more favorable conditions.

Aside from economic feasibility, the MICR can also supply the following results:

- costs and quantities of materials required by highway maintenance policies;
- vehicle operating costs incurred by users of these roads;
- average speed and fuel consumption of the different vehicle classes; and

a thorough follow-up of the simulation, which is carried out
on different highway segments to learn about the traffic
and its growth, the road conditions (deterioration) and
the effects of maintenance operations on deterioration.

These results permit the use of the MICR for other objectives,
such as:

- testing different maintenance policies for the purpose of
  selecting the one most suited to the road segments studied;
  and
- to verify how the alterations in the composition of traffic
  affect road deterioration, thus aiding in the establishment
  of norms to govern the setting of highway taxes.

It should be emphasized, however, that the Model cannot serve
these two purposes directly. To attain then, the user needs to make a
number of successive tests or, in other words, to use the Model several
times to meet the needs of each case.

2.2   GENERAL CHARACTERISTICS

The criteria used by the MICR to characterize a road and de-
fine alternatives are as follows:

   i) the road is initially divided into links (each link repre-
      sents a homogeneous segment as to traffic);
  ii) the link can be divided into as many as ten sections and
      should contain at least one section (each section repre-
      sents a homogeneous segment in terms of physical charac-
      teristics: vertical geometry, horizontal geometry, rough-
      ness, suface type, rainfall, road width, deflection and
      structural number of the pavement, subgrade, CBR, etc.);
 iii) the association of a traffic set and a maintenance policy
      to a *link* constitutes a *link alternative,* which can be
      called a *basic alternative;*
  iv) when one desires to study the feasibility of improving a
      link, it is necessary to associate a construction project
      to this link, and, should it be the case, a set of other
      costs and benefits resulting from this improvement. The
      traffic set is normally changed by adding to the previous-
      ly existing traffic, the traffic increment due to the im-
      provement. The maintenance policy is also expected to
      change, in order to better fit the road conditions after
      completion of the proposed project. This new association
      constitutes another link alternative, which can be called
      an *improvement alternative.* Various improvement alterna-
      tives can be created, through combinations involving pro-
      ject, traffic, maintenance and other costs and benefits,
      so that they can be compared one by one with the basic al-
      ternative;

v) various *link alternatives* can be brought together to form a *group alternative*. In this way, one can have a basic group alternative and various *group alternatives*, the latter involving improvements. The comparison among these are carried out in the same way as among *link alternatives*; and

vi) a set of *group alternatives* forms a *group* and characterizes a highway system. It is important to note that comparisons can only be made among *group alternatives* that pertain to the same *group* or highway system.

The Model functions at the level of *link alternatives* and the simulation is carried out annually for each section of the *link*. Consequently, for each year of the analysis period, the costs of construction, maintenance and vehicle operation are estimated for the *link alternative* studied. Hence, for each *link alternative* the costs of the highway are structured on an annual basis, either during its existence or during the analysis period. This is illustrated in Figure 2.1, which contains a description of the operations carried out for the survey of the highway costs involving a given *link alternative*. The costs of a *group alternative* are estimated by adding together the costs of its corresponding *link alternatives*.

In each application of the Model, as many as 100 alternatives, including both *link alternatives* and *group alternatives*, can be simulated. In the specification of these alternatives, one can define up to 20 *links*, 50 construction projects, 8 maintenance policies, 20 traffic sets and 20 sets of other costs and benefits.

The MICR also permits comparisons between pairs of *link alternatives* and between pairs of *group alternatives*, provided the total number of comparisons does not exceed 50 in each application. For each comparison made, the Model supplies:

- the flows of estimated economic costs and benefits for the entire analysis period, for each component of the total cost or benefit;

- the total economic costs or benefits discounted to the base year, through the use of up to five rates of discount specified by the user;

- the cost/benefit ratios (totals) and present net values, using the same rates of discount;

- the benefits of the first year, considering all of the non discounted costs and benefits; and

- the internal rate of return.

All the above results refer to the improvement alternative in relation to the basic alternative.
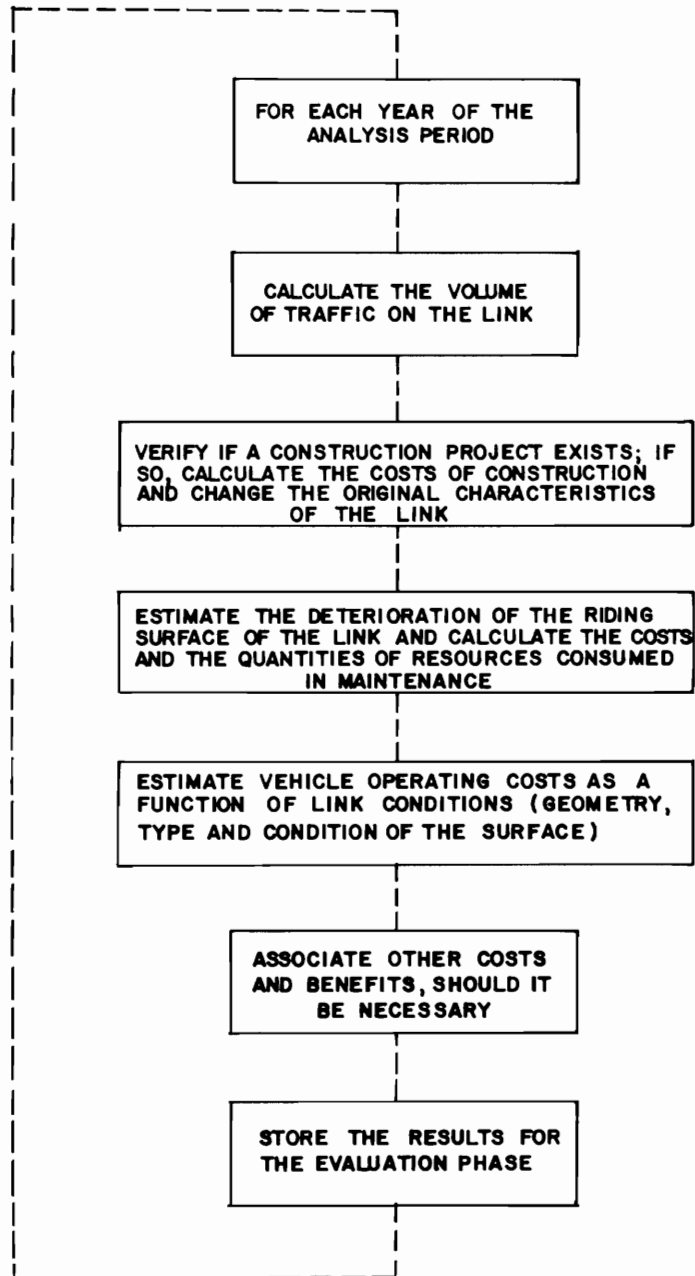
Figure 2.1 - SIMULATION OF A LINK ALTERNATIVE.

In the comparisons among alternatives, the Model user can specify as many as five sensitivity studies. These studies attribute parameters which multiply some or all the components of the total cost of one or of the two alternatives that are being compared. In this way, the user can check the influence of an increase or a decrease in the costs (construction, maintenance, operation, travel time and other costs) on the result of the economic feasibility study, observing that the internal rates of return, the net present values, the benefits of the first year and the benefit/cost ratios were changed.

The MICR requires the following input information:

- characteristics of the existing links;
- specifications of the proposed projects;
- specifications of the maintenance policies and unit costs;
- characteristics and unit costs of the vehicles;
- descriptions of the traffic sets;
- specifications of the sets of other costs and benefits;
- specifications of link alternatives;
- specifications of group alternatives;
- specifications of required output reports;
- specifications of sensitivity studies and of comparisons among alternatives; and
- specifications for control of execution.

More detailed information on the necessary inputs is found in Appendix I, *MICR User's Manual*, Chapter 3 (bound separately in a limited edition).

The output reports supplied by the MICR are as follows:

- a series of reports that arrange and describe in detail all the information submitted as input;
- flows of economic costs for each of the alternatives;
- flows of financial costs for each of the alternatives;
- flows of economic costs and benefits referring to each of the comparisons between pairs of alternatives;
- summary of economic comparisons among the alternatives;
- summary of the total maintenance cost (economic and financial), by link alternative or by group alternative, which can include the entire period of analysis;
- annual maintenance costs by link alternative or group alternative;
- annual situation of the traffic and operating costs of the vehicles, by link alternative; and
- annual situation of road conditions, by link alternative.

More detailed information on the outputs supplied can be found in Appendix I, *MICR User's Manual*, Chapter 4, where the complete application of the Model is exemplified.

2.3   *OPERATING CHARACTERISTICS*

Basically, the operation of the MICR is divided into three distinct phases. The first phase, or *input phase*, is characterized by the reading and consistency of all the data supplied by the user.

The second phase, called the *simulation phase*, includes all the simulations and cost estimates executed by the Model, involving construction projects, traffic, and road deterioration, maintenance and utilization.

The third phase is the *output phase* or *economic evaluation phase*. It includes all the calculations related to the economic comparisons among alternatives, as well as providing all results.

2.3.1   *Input Phase*

This phase examines all the input data to verify the existence of possible errors of format, numerical errors and internal inconsistencies.

Tests are carried out to verify the type and content of the information. The first test verifies whether the data supplied is in integers or fractions, depending on the case. The test of content verifies if the information supplied is within an acceptable interval, when numerical, or if the information represents a valid code, when alphabetical. Aside from this, other tests are made to check if the information is consistent or, in other words, if contradictions exist among different bits of information.

Two types of errors can occur during this phase. The first is called "fatal", and when it occurs, an explanatory message is issued and the execution of the two following phases (simulation and output) is halted. Consequently, execution is terminated after completion of the input phase.

The second type is the so-called "non-fatal" error. In this case, a warning message is issued, but there is no interruption in execution after completion of this phase.

After verification of the data, the user is issued several reports which conveniently arrange all of the information supplied by him. These reports are called *input reports* or *echo prints*. By consulting them the user can gain a good overview of the situation he intends to analyze.

2.3.2   *Simulation Phase*

All the simulations required of the Model are executed in this phase. Each of the *link alternatives* specified by the user is accompanied during the entire period of analysis. The construction project, deterioration, maintenance, traffic, operation of the vehicle fleet and the association of other costs and benefits are all controlled.

Figure 2.1 (already presented) shows the sequence of the operations that are executed in the simulation phase of a given *link alternative*.

2.3.2.1   *Traffic*

For each year of the analysis period, the Model calculates the volume of traffic and the number of equivalent standard axles passing over the *link*. The number of equivalent axles is used only to determine the deterioration of paved sections. On unpaved sections, this is done by using the average daily traffic.

The MICR classifies the traffic as *normal traffic* and *generated traffic*. *Normal traffic* is the volume of traffic that originally existed on a *link*. *Generated traffic* is the volume of traffic that is induced or diverted to the *link*, as a consequence of the improvements made on it. According to these definitions, the generated traffic can only be associated to an *improvement alternative*.

Normal and generated traffic are specified by the user in "sets". The manner of specifying the traffic sets is explained in detail in Appendix I of this volume, *MICR User's Manual*, Chapter 3 (bound separately in a limited edition).

Only one normal traffic set is permitted for each *link alter-native,* although various generated traffic sets can be specified.

2.3.2.2   *Construction Projects*

The costs of construction are allocated to the *link* on an annual basis, in financial and economic terms and in foreign currency, during the entire construction period.

After conclusion of construction, the original characteristics of the links are modified according to the project specifications, and the generated traffic sets and sets of other costs and benefits are associated to the link. The following improvements can be specified:

- new construction;
- overlay of road surface;
- reconstruction of the pavement, without altering its geometric conditions;
- widening of the section;
- widening of the section and pavement reconstruction; and
- change in alignment.

The specifications of the construction projects are explained in Appendix I, Chapter 3.

2.3.2.3   *Deterioration and Maintenance*

The simulations of highway deterioration and maintenance play an important function in the interrelationships of highway costs. The deterioration of the highway is the result of the original pavement project, the type of materials, the volume and composition of traffic, and the specified maintenance policy.

For each year of the analysis period, the Model estimates traffic-caused deterioration of the road surface. Once road conditions are known, the Model calculates the quantities of maintenance services required, updates the conditions of the road after these services have been executed, and applies the unit costs to determine the total maintenance costs for that year, corresponding to the *link alternative* being simulated.

The following operations can be specified in the design of a maintenance policy for paved roads:

- temporary patches;
- permanent patches;
- slurry sealing;
- surface treatment;
- overlay with asphaltic concrete; and
- routine maintenance.

The execution of any one of the maintenance operations for paved roads is always considered by the Model as occurring at the end of each year of the analysis.

The computational procedure that involves the simulation of the deterioration and the maintenance of a paved road for each year of the analysis period can be summarized in the following steps:

1) calculation of the annual increase in road surface deterioration, as a function of pavement strength, surface conditions and traffic at the start of the current year;

2) addition of the increase calculated in (1) to the deterioration found at the beginning of the year, to obtain the deterioration of the road at the end of the year;

3) calculation of the costs and quantities of resources consumed in maintenance, by operation, based on the specified standards and surface conditions of the road at the end of the year;

4) calculation of the conditions of deterioration at the beginning of the next year of analysis, based on the conditions at the end of the current year and on the maintenance operations executed during the course of the same year; and

5) calculation and storage of the average values of deterioration in the current year, to be utilized later in the calculation of vehicle operating costs.

The following operations can be specified in the design of a maintenance policy for unpaved roads:

- road blading in the dry season;
- road blading in the rainy season;
- localized regravelling;
- regravelling along the entire course of the road; and
- routine maintenance.

The deterioration of unpaved roads is measured basically in terms of gravel loss and surface roughness.

In Appendix I, MICR *User's Manual*, Chapter 2, item 2.6.10, the statistical equations that simulate and describe the development of roughness on unpaved roads are presented.

Routine maintenance operations, on both paved and unpaved roads, include drainage, control of vegetation, maintenance of shoulders, signs and signals, safety installations and other items that are not entirely simulated by the Model. The Model may consider the cost of these operations, but does not estimate their effects on pavement quality.

The total cost per kilometer and per year should be provided in order to represent the resources consumed by routine maintenance operations. Since the equations that estimate deterioration were developed on the basis of the supposition of adequate drainage conditions, the user should provide at least the drainage cost.

All of the equations that simulate road deterioration and maintenance are presented in Appendix I, Chapter 2.

2.3.2.4 *Vehicle Operation*

In each year of the analysis period, vehicle operating costs are estimated as a function of the geometric characteristics of the road, type of surface, volume and composition of traffic and surface conditions in the current year. These costs are obtained by multiplying the quantities of resources consumed in vehicle operation, such as fuel and tires, by their respective unit costs.

In the Model, the costs referring to the vehicles are classified under *operating costs* and *travel time costs*. The operating costs take in vehicle maintenance and operation and include fuel, tires, spare parts and labor, depreciation, interest, overhead and crew costs. The travel time costs are the value of the time of the passengers and the cargo in transit.

The MICR allows the user to provide the unit costs in financial and economic terms. Some items can also be provided in terms of foreign currency.

The financial costs represent the costs incurred by transportation operators in order to maintain and operate the vehicles. The economic costs represent the actual costs for the national economy

which result from vehicle ownership and operation, where adjustments
are made to compensate for distortions in market prices caused by the
existence of taxes, exchange restrictions, labor laws, etc. The costs
presented in foreign currency can represent financial costs or economic
costs, depending on the situation.

It is important to observe that the concepts of financial and
economic costs, presented above, are only for illustrative purposes. There-
fore, the adoption of these concepts is not essential. When the user
has different areas of interest, he can provide the units costs of the
vehicles in a manner coherent with them.

Assuming a directional symmetry of the traffic, the Model
calculates the resources consumed per kilometer, for five vehicle clas-
ses:

- automobiles;
- utilities;
- buses;
- medium trucks; and
- heavy trucks.

Appendix I presents all the characteristics of the vehicles
considered in the Model, together with all the statistical equations
which estimate the costs.

2.3.2.5 Other Costs and Benefits

For each year of the analysis period, the Model checks if the
user specified any other cost or benefit which should be associated with
the link alternative that is being simulated. The user specifies the
other costs and benefits in "sets". The reason for the existence of
these sets of other costs and benefits is to allow the user to consider
costs and benefits other than those simulated by the Model, which occur
as a consequence of the improvement effected on the link. Therefore,
it can be seen that the specification of a set of other costs and bene-
fits only makes sense if it is associated with an improvement alternative.
In Appendix I, an explanation is provided as to how these specifica-
tions can be made.

2.3.3   Output Phase

This third and final phase of the MICR executes the economic analysis for each link alternative and for each comparison between pairs of alternatives. A number of reports are produced, some of which are generated automatically, while others are generated only when requested by the user.

In the MICR, the procedures required for effecting the economic analyses of the alternatives may be summarized in the following steps:

1) for each link alternative, the Model establishes the annual cost flow, in financial and economic terms and in foreign currency. These cost flows involve investments in construction projects, resources consumed in maintenance, vehicle operation, time of passenger and cargo permanence in transit, and also other costs that may be provided by the user;

2) the annual cost flows established in (1) are added together for each group alternative;

3) for each comparison among pairs of alternatives, the annual cost and benefit flows are calculated for the improvement alternative in relation to the basic alternative. These flows include construction costs, maintenance costs, benefits from the operation and travel time of the vehicles, other benefits, total economic benefits and total costs in foreign currency;

4) the cost and benefit flows calculated in (3) are added together for each comparison between group alternatives;

5) for each pair of link alternatives compared, the Model calculates the current net values and the benefit/cost ratio for five different rates of discount supplied by the user; the rate of return; and the benefits of the first year;

6) step (5) is repeated for each comparison between group alternatives; and

7) steps (5) and (6) are repeated for each sensitivity study specified by the user.

2.4   COMPUTATIONAL CHARACTERISTICS

The major characteristics of the computational program of the MICR are described in a separate document containing information on the computational program (currently available only in Portuguese).