CHAPTER 3
CONSIDERATIONS REGARDING
THE MODEL

3.1 INTRODUCTION

As was stated in Chapter 2, the MICR calculates the total cost of a highway by aggregating the shares relative to road construction cost, maintenance cost and utilization cost.

The construction cost is provided by the user, since the Model does not calculate the quantities of materials and services that would be consumed in the implementation of a proposed project, and does not aid the user in the initial choice of favorable alignments.

The maintenance cost is calculated by the Model through the survey of the quantities of materials consumed in each of the maintenance operations, which are later multiplied by the unit costs provided by the user. The execution of most of the maintenance operations can be specified by the user in a programmed or conditioned manner. The programmed maintenance consists of the execution of the operation at certain time intervals. The conditioned maintenance consists of the execution of the operation when the road surface reaches a certain level of wear considered critical by the user. On paved surfaces, this level is determined by the roughness and by the cracked area, while for unpaved surfaces it is determined only by roughness.

Finally, the MICR calculates the cost of utilization of the highway, by adding together vehicle operating costs and travel time costs. These costs depend principally on the condition of the road surface (represented in the Model by roughness), and by the indices of vertical and horizontal geometry.

The indices of geometry are utilized only in the equations which estimate the average speed and fuel consumption of the vehicles. By affecting speeds, they have an indirect influence on travel time costs and on the calculation of vehicle utilization, which reflect the number of kilometers covered by each type of vehicle in one year.

The equations of speed and fuel consumption that are built into the MICR have their origin in the *aggregation* of the equations of the Model of Time and Fuel Consumption (MTC), described in Volume 9 of this report.

Aside from this, the equations that estimate utilization costs were developed on the basis of the performance of a fleet of ve-

hicles supposedly representative of all Brazilian vehicles. This res-
tricts the application of the Model to situations which involve vehi-
cles with characteristics that are at least similar to the types of ve-
hicles studied, and subjects the Model to the risk of obsolescence as
a consequence of future developments in the mechanical characteristics
of the vehicles. For more detailed information, see Appendix I, Chap-
ter 2, item 2.8.

3.2   FUNDAMENTAL VARIABLES

From item 3.1, it can be seen that some of numerous variables
utilized by the MICR were considered to be more representative than
others by the procedures of statistical analysis (i.e., as being those
which better explained the interrelationships of the areas researched).
These are the fundamental variables and are given as follows, in order
of their increasing importance to the Model: the index of horizontal
geometry, the index of vertical geometry, and surface roughness.

3.2.1   Index of Horizontal Geometry

The index used to represent the horizontal geometry of the
roads is based exclusively on the central angles of the curves, and is
determined in the following manner:

$$ADC = \frac{\sum\limits_{i=1}^{n} AC_i}{\ell}$$

Where:

ADC = index of horizontal geometry, in degrees per kilometer
(average degrees of curvature);

AC_i = central angle of the i-th horizontal curve, in degrees;

ℓ = total length of the section under analysis, in kilo-
meters.

As it was conceived, the ADC utilized by the MICR does not
seem to discriminate the horizontal geometry of a road in a totally sa-
tisfactory manner. However, it was also found that the horizontal geo-
metry of a road has only a moderate influence on the fuel consumption

results and on the majority of the operating cost components.

3.2.2   *Index of Vertical Geometry*

The index of vertical geometry adopted by the PICR for use in the Model was developed on the basis of the TRRL studies. In the Kenya research, two indices were utilized in an attempt to represent the vertical geometry of a road: *Rise* and *Fall* (See Report 764 of the TRRL - *Road Transport Investment Model - RTIM*). Through the utilization of these two indices, interrelationships considered unsatisfactory by the specialists were found. Therefore, the PICR sought to define a single index that would include *Rise* and *Fall*. This new index, designated *Rise plus Fall,* is defined in the following manner:

$$RPF = \frac{\sum\limits_{i=1}^{n} |g_i| \cdot \ell_i}{100 \sum\limits_{i=1}^{n} \ell_i / 1000}$$

Where:

RPF = *Rise plus Fall,* or index of vertical geometry, in meters per kilometer;

$|g_i|$ = absolute value of i-th grade, in % (5=5%);

ℓ_i = length of i-th grade, in meters.

Figure 3.1 presents three different vertical profiles joining points A and B, located at a distance of 10 km from one another. On calculating the RPF in the manner defined above, one obtains the same value (24 m/km) for the three situations. This indicates that the RPF is unable to fully discriminate a given vertical geometry and, for this reason, it does not have the weight or influence that was expected in the equations which estimate vehicle speed and fuel consumption.

3.2.3   *Roughness*

Among the fundamental variables, the roughness index has the greatest influence on the MICR equations. For this reason, it was chosen to be the principal measure of road surface condition. Roughness thus has a decisive influence on vehicle operating costs.
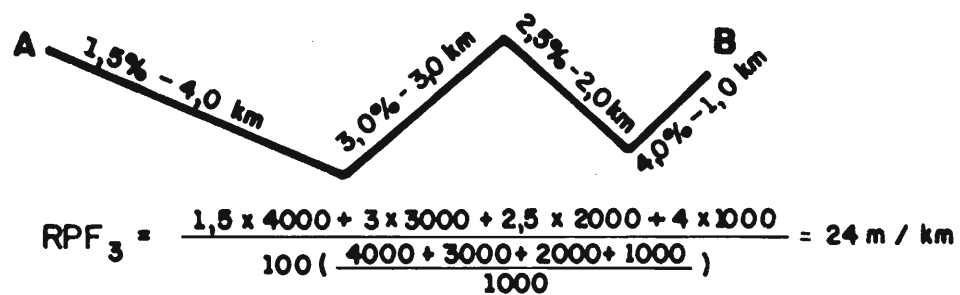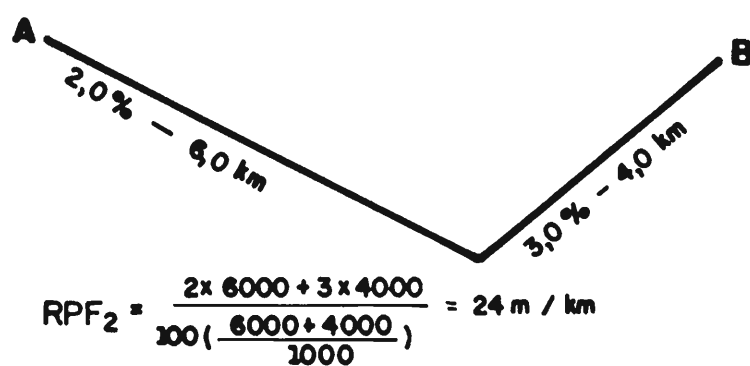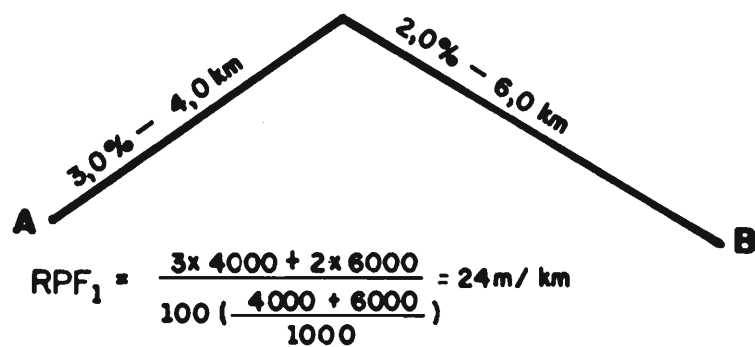
$$RPF_1 = \frac{3 \times 4000 + 2 \times 6000}{100 \left(\frac{4000 + 6000}{1000}\right)} = 24 \, m/km$$

$$RPF_2 = \frac{2 \times 6000 + 3 \times 4000}{100 \left(\frac{6000 + 4000}{1000}\right)} = 24 \, m/km$$

$$RPF_3 = \frac{1,5 \times 4000 + 3 \times 3000 + 2,5 \times 2000 + 4 \times 1000}{100 \left(\frac{4000 + 3000 + 2000 + 1000}{1000}\right)} = 24 \, m/km$$

Figura 3.1 - CALCULATION OF RISE PLUS FALL FOR DIFFERENT VERTICAL PROFILES.

A study of the validity of the roughness data was carried out by a team composed of PICR researchers. In October 1981, this team produced a conclusive report, explaining the problems relative to conception and measurement involving those data (Alckmin, *et al.*) The study indicates that the roughness measurements are subject to a number of factors that diminish their precision.

In some of the tests carried out, the MICR proved to be extremely sensitive to roughness variations. Consequently, the roughness variable as now present in the MICR equations has an effect on the predicted cost that is much greater than should be expected.

3.3   SUGGESTIONS AND CONCLUSIONS

A careful study of the other basic data on pavement conditions could make a favorable contribution to the development of new equations that would minimize or perhaps even exclude the effects of roughness, exchanging the roughness measure for the effects of cracks, potholes and patches. If feasible, this procedures would considerably improve the equations for operating cost, thus making the Model's estimates for paved roads much more trustworthy.

As for the geometry indices, a study has been started to develop new indices based on the physical characteristics of the roads. If these indices prove to be trustworthy, they could be used to discriminate more precisely the horizontal and vertical geometry of the highway.

Once a good geometric representation of the highways is obtained, it will become possible to improve considerably the Model's estimates of speed, fuel consumption, vehicle utilization and travel time costs.

In conclusion, it can be perceived that, in the light of the present state of the MICR, it would be premature to recommend the model for general use by Brazilian highway planners. However, when employed by duly trained technicians, it can supply indications for the evaluation of the impacts of specific highway construction and maintenance policies.

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