

CHAPTER 1 - INTRODUCTION

NEED FOR HIGHWAY PLANNING MODELS

Highways serve national and public needs by providing transportation links which reduce the cost of moving people and goods. This reduction in transportation costs encourages the use of highways, stimulates economic growth and the development of natural resources. New or better roads and expansion of rural road systems are needed for accessing these untapped reserves. Because resources are always limited and many groups compete for them, objective procedures are needed to establish warrants for the allocation of such resources.

In the highway transportation sector, there is direct competition for funds to 1) reduce traffic congestion in cities, 2) improve road links connecting major population areas and 3) create an effective rural road system. An objective economic analysis procedure is needed to assist administrators in determining an investment policy which will optimize the use of such funds. These procedures can be quantified in planning models.

Recent experiences have shown that objective planning models can be designed to effectively help in the economic-engineering analysis of project alternatives for a given link or for the road network of a country or region. This project is concerned with such models for primarily rural roads.

FUNCTIONS PERFORMED BY A HIGHWAY COST MODEL

A planning model is a tool which is designed to assist administrators in making decisions. As such it augments professional judgement in the establishment of policy, but never replaces it.

A highway model can simulate real world relationships between highway construction and maintenance standards, vehicle user costs and the condition of a given designed highway in a known environment. Alternate policies for design standards and maintenance quality can be examined and blended to minimize

total transportation cost for a specific project. A model can also be used to examine a variety of maintenance strategies for a fixed design standard or the implications of different designs holding maintenance constant or even eliminating it. In general, a planning model predicts construction, maintenance and user costs. Ideally, it should quantify user impact in terms of safety, comfort and convenience. However, these latter indexes are difficult to quantify in cost terms.

BACKGROUND

The use of economic analysis for highway project planning has received limited acceptance historically. Most highway projects have been based on travel demand, engineering judgement as to standards and the assumption that a road would be maintained during its life in its as-built condition.

Technical papers on vehicle running costs started appearing in the early 20's in the United States, but until the AASHTO Red Book (Road User Benefit Analysis for Highway Improvements) (Ref. 1) was published in 1952, little use was made of economic analysis for planning highways. Even then, only selected highway agencies used economic analysis and that primarily to determine least costs between alternate routes. In Brazil, GEIPOT was responsible for the introduction of economic analysis of highway projects in 1966.

The AASHTO Red Book was updated in 1960 and subsequent publications by Winfrey, de Weille, Lock and Delaney, et al, Bonney and Stevens, Curry and Anderson, and Claffey (Ref. 2-7) were directed toward improving the analysis procedures and developing current empirical data to support these analyses. This information came into wider use, but still was used primarily for comparing or selecting between alternate routes.

The need to establish quantitative warrants for actually building roads was finally recognized in the early 60's by the World Bank and other groups in the United States, United Kingdom, Australia and France. Use of the existing economic procedures, particularly for low volume roads were considered

inadequate. Further, there was little primary empirical data and most of it was out of date. Furthermore, the applicability of such information in Brazil was not known.

EXISTING MODELS

In 1968 the World Bank initiated a research contract with a group at MIT to develop a rational analysis of economic consequences of alternative design, construction and maintenance policies for low-volume roads (Ref. 8). The conceptual framework developed included models for road deterioration. Further, attempts were made to relate road conditions to the cost and benefits derived from the road. The MIT model was based on information available from existing literature. Therefore, the hypothesized 1) patterns of deterioration for different road types, 2) design standards, 3) surface conditions and 4) road user costs could not be verified with empirical data. However, the study did show that a model could be used to optimize total highway transportation cost.

The highway cost model developed at MIT includes modules to compute construction, maintenance and road user costs as a function of road design, condition and maintenance policy. Although operational, it has limited use as developed, because its empirical base is inadequate.

Because the MIT model was deficient in the sound empirical relationship needed to predict reliable cost, the Transportation and Road Research Laboratory, in cooperation with the IBRD, undertook field studies to develop empirical data in Kenya (Refs. 9-12) These studies were designed to measure the road deterioration process of low volume roads and to establish road user costs on the road as they deteriorated. The results were used to produce a model directly with data collected in the field. The Kenya study was to establish a set of relationships between vehicle operating costs, vehicle type, physical operating conditions and operator characteristics. Both experimental investigation into vehicle speeds and fuel consumption and a user survey on vehicle operating costs were used to develop the data.

A second part of the study was concerned with the character of the road, in particular, how a given road design performed in a particular environment when subjected to a given traffic loading. The impact of different maintenance policies also was addressed in this portion of the study.

The models generated by the Kenya study established many empirical relationships which need to be verified under broader conditions. Further, the transferability of the Kenya results to other countries and regions having different conditions needs to be established. Finally, only limited attention and data were developed for certain user cost elements, such as depreciation, and only a limited range of extreme conditions of road roughness and geometry were investigated. However, the model will aid decision making for project selection based on minimizing the sum of construction, maintenance and road user costs over the "life" of the alternative road designs examined.

THE MODULE CONCEPT

For the highway cost model to be an effective decision tool it must be capable of making rapid investigations of many alternate geometric standards, pavement designs and maintenance strategies. To do this economically, the model must be designed for use with a computer. Further, the simulation routines and iterative nature of the analysis process is not practical outside of a computer environment.

The highway cost model will consist of a number of separate sub-systems or modules which are structured to interact with one another through instructions from a main program. These modules can include the following:

- 1) Main program module
- 2) Input module
- 3) Construction quantities module
- 4) Road deterioration module
- 5) Maintenance module
- 6) Vehicle performance module
- 7) Cost module
- 8) Output module

Input Module

In general, the following parameters will be input to the highway planning cost model although some might be generated in the program to facilitate the use of the model in very general situations or for sensitivity testing of various module elements of the model.

- a) Environment
 - Terrain
 - Traffic
 - Weather
 - Geological Conditions
- b) Design
 - Pavement
 - Speed
 - Geometry
- c) Unit Costs
 - Construction
 - Maintenance
 - Road User
- d) Maintenance
 - Policy
 - Technology

Construction Quantities Module

For given environmental and design constraints, the construction quantities required to produce the road project will be determined. Further, this module will calculate quantities for stage constructions projects.

Road Deterioration Module

Each year of the analysis, a road in a given condition state is subjected to traffic and the natural environment. It involves to a second condition state, depending in part on maintenance inputs. This module will predict these roadway conditions in terms of roughness, rut depth, cracking and other quantifiable measures of the condition of the road.

Maintenance Module

Each year of the analysis, the road is in a given condition state. Depending on maintenance policy inputs, the condition is translated into maintenance workload. This, in turn,

is converted to maintenance quantities using maintenance activity standards which describe the labor, equipment and material requirements for the workload.

Vehicle Performance Module

Each year of the analysis, vehicle operation is simulated on a road having 1) given geometric characteristics, 2) surface qualities related to the road condition state, and 3) within a traffic stream of predicted volume and composition. This simulation process yields quantities of vehicle consumption, i.e., fuel, oil, tires, etc.

Cost Module

Unit cost inputs to the module are applied to quantities of construction, maintenance and vehicle user consumption to produce total annual highway costs. This cost is appropriately discounted and accumulated over the analysis period being studied.

Output Module

The principal output of the module is a total transportation cost value for a given design standard and maintenance strategy. Any interim costs for major or minor elements of the system also can be generated by the program. However, default output will be limited to that information needed to permit an overall assessment of the analysis. When details in any area of the analysis are desired, they will be required to be requested by the user.

A system flow diagram for the highway cost model developed by MIT for the World Bank is shown in Figure 1.

The highway cost model will be developed to accommodate a wide range of users, including both governmental and financial agencies. Further, it will be structured to permit analysis at various study levels. This includes pre-feasibility, feasibility and actual project appraisals. To permit this maximum interface with users for a variety of purposes, the input requirements can be varied widely. The inclusion of extensive default routines to generate needed

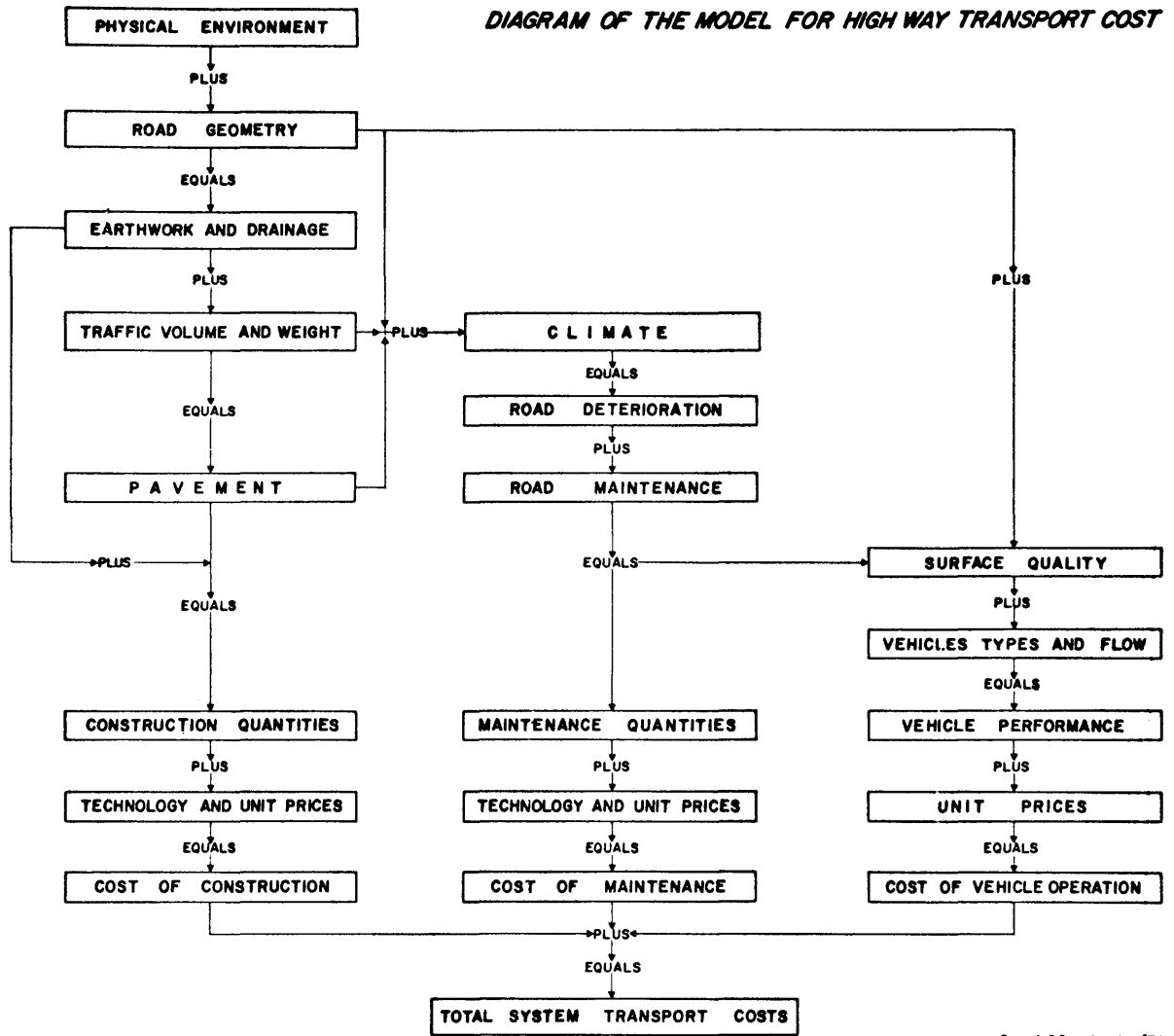


Figure 1 Flow Chart for Highway Cost Model Developed in the MIT Study (Ref 8)

data when it is not otherwise readily available will maximize the ease with which the program can be run.

The model also should permit users to modify when needed many of the relationships defined within the model. This relaxing of manipulative rigidities can be accommodated through optional input parameters requiring definitive action on the part of the user.

The model must be structured so that it is readily updatable, otherwise it will quickly become obsolete. This is accommodated in part by the modular structure envisioned for the model. It also is important that quantities of materials and user consumption rather than costs be the predicted output of the relationships established. Using a unit costing concept facilitates this approach. Finally, in structuring the actual program, the empirical relationships used in predicting the various quantities and user consumption will be clearly delineated and labeled.

ELEMENTS REQUIRING MAJOR ATTENTION

Prior to the Kenya study, no research had been directed towards understanding the relationships between maintenance policies, roadway conditions and total highway and user costs. Considerable study still is required in this area.

More verification between experimental results relating user costs to roadway geometrics and conditions are needed. This is particularly true related to tirewear, vehicle maintenance and depreciation. Also, user relationships need to embrace a wider range of vehicle classes than was used in the Kenya study.

Additionally, the effect of vehicle congestion on vehicle speed should be accommodated in the model.

BRAZILIAN MODEL REQUIREMENTS

The majority of the Brazilian road transport network involves rural highways with less than 5,000 average daily traffic.

Although new roads are needed to open underdeveloped

areas in Brazil, major investment decisions involving the maintenance and the existing system will also need to be made in the future. Reliable quantitative planning tools to make these decisions are non-existent. For this reason the Brazilian Government has undertaken with two of its major transport planning agencies research directed towards the development of interrelationships between the cost of construction, maintenance and utilization of the highways. This interest is based on a need to have an objective highway planning tool for use in Brazil, and also on the reluctance to use relationships developed for areas unlike Brazil and therefore of questionable validity here.

The wide range of traffic, climate and geography encompassed by the road network in Brazil needs to be covered in the study. The scope of these conditions for the country is shown in Appendix 1.2.

Secondary Model Requirements

Recent rises in world petroleum prices and the dependency of Brazil on oil imports (only about 1/3 produced locally) has created critical problems in the balance of payments with deep reflection on the economy and in the transport industry. To cope with the problem the government is taking several steps in a general fuel-saving policy outlined in several government documents.

The main objectives of the research are related to highway planning. However, the data collected during research can provide primary input to evaluate many of the steps tried for saving fuel.

The research team is not committed to undertake economic studies that will lead to recommendations to the government on the fuel-saving policies. Nevertheless the output of the research can be part of the input needed to answer related questions.

1. What would be savings in fuel if the limit of speeds in all federal and state highways were reduced to the optimum level for fuel saving of the average traffic need?
2. How much expenses could be justified to enforce the reduced speed?