PRELIMINARY EVALUATION FOR ROAD NETWORK IMPROVEMENT ALTERNATIVES IN LESS DEVELOPED COUNTRIES

by

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ABSTRACT

An approach is developed to provide the decision makers in a Less Development Country with a tool for selecting an investment program and operating policy best suited to its development criteria and the existing Economic and political conditions. Using the Highway Cost Model, which provides a detailed, accurate framework for assessing the costs and benefits associated with the operation and development of links in a low volume highway network, it generates and presents the consequences of potential investment alternatives in a concise form, based on the input of Highway Cost Model link strategies. The choice and relative timing of these link strategies may vary within bounds, and patterns of network strategies, which do not satisfy the investment constraints are eliminated. For those remaining, year by year benefits may be determined considering the users' consumer surplus, maintenance and construction costs. The net present value is computed for these network strategies, and used to rank them.

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CHAPTER ONE

INTRODUCTION

1.1 Objectives for Planning a Transport Network

The planning of a transport network is fundamental, not only for the transport of goods and people, but for the country's economy as well. As stated by the Harvard Transport Research Program (1):" any change in the Country's transportation network has obvious repercussions throughout the entire economy". The goal of transport network planning is to achieve balanced and sustained economic growth. In numerous developing and less developed countries, the expected impact for transportation investment is so significant that the investments on network improvements have accounted for over 25 percent of the total public investments (2).

Planning of transport network improvement is usually undertaken in a hierarchical fashion. Regional economic goals are identified, then transport needs. Projects or sets of projects may be identified to satisfy these needs and then strategies consisting of their implementation sequences in specific years are generated. Project improvements to the network are then made following a chosen strategy, and projects designed in more detail.

The objectives of the transport network planning are the economic growth of the country and the improvement of the existing social conditions (i.e. education, way of life). These are accomplished with the increase of mobility throughout the country, resulting from the improvement of the transport network's level of service. These objectives are:

i. To decrease the transport costs and travel time between the production and consumption centers;

ii. To create access roads to remote areas or potential production centers;

iii. To enable the free movements of men and material resources all over the country.

iv. Finally, since all improvements must be accomplished by allocating resources (material, manpower, capital) to projects, improvements should be undertaken so as to attain the most effective consumption of resources.

In achieving the above objectives, carefull planning of links improvement is of great importance including their engineering and design characteristics and the choices among alternatives.

The output of transport planning are: (1) The proposal of the improvements and their consequences, (2) which links it is worth improving, when and by which strategy. (3) What are the resulting benefits and the costs, (4) Appraisal of the proposed alternative in comparison with others.

Lansing (3) has summarized these objectives even more broadly by writing:

"Among these goals (of economic policy) are economic efficiency, economic growth, a high level of employment and freedom from pronounced cyclical flunctuations, and a degree of equity in the distribution of the products of economic activity which avoids the juxtaposition of extreme poverty and extreme wealth. Transportation (network) planning is directly involved in the attainment of these objectives".

1.2. Planning process

The transport network planning process consists of the following phases: (1) Definition of objectives, (2) Generation of alternatives for the accomplishment of the objectives, (3) Feasibility of the alternatives and/or screening, (4) Network analysis, (5) Determination of impacts, (6) Evaluation of alternatives, (7) Choice and (8) Implementation (The whole process is represented in figure 1.1).

The definition of objectives is undertaken by the government as part of a proposed Development Plan for the country. They must contribute to the attainment of the broad objective "economic and social development".

The generation of alternatives is done by a transportation planner. He considers all the possible alternatives, that might accomplish the objectives. During the generation, two broad classes of variables are recognized:

(i) options related to transportation itself, and (ii) activity system options .

Transportation options are those items that can be controlled directly by the analyst or the agency for which he works. They are the decision variables, which range from such broad items as alternative technologies and modes to specific items such as vehicle types, links (to be improved), type of improvement (at this point either detailed engineering studies about each improvement strategy or models that simulate the activities of construction and maintenance as needed).
Activity system variables are the social, political and economic variables

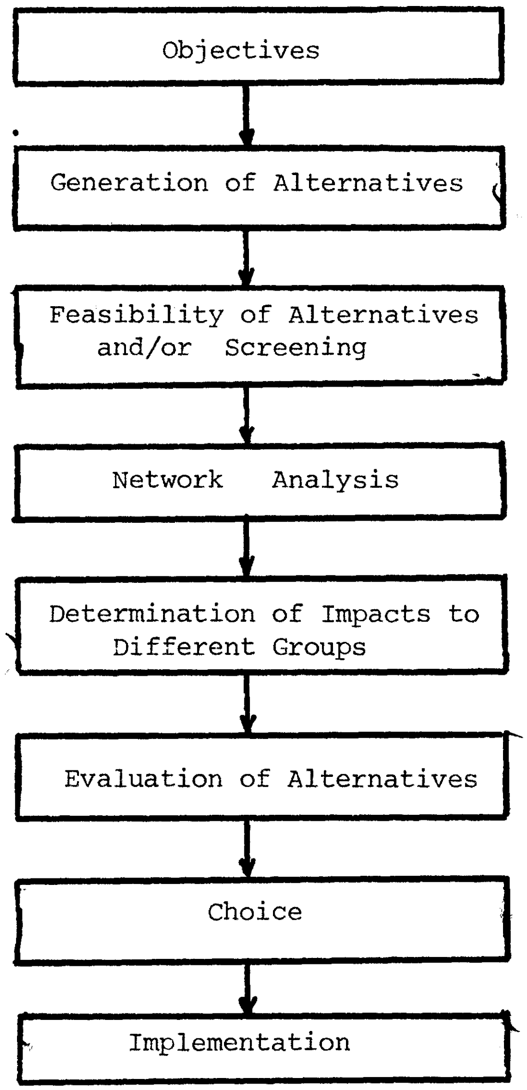


Figure 1.1.

Transport Network Planning Process

which determine the demand for the transportation options. They include variables such as spatial patterns of population, economic activity, agricultural and industrial policy and the like, all of which can influence in one way or another the demand for transport services. In most instances these options are taken as major exogenously specified factors, non-maniputable in the direct sense.

The feasibility of each alternative will be examined in the next phase: To be feasible, all the constraints introduced by the analyst must be verified. (Only the feasible alternatives will be considered in the next phases). For each feasible alternative, the analysis of the resulting transport network is done. The analysis may be performed by simulation of all network activities or using direct mathematical procedures. With the analysis, the impacts of each alternative to different groups (users of transport network, producers, consumers, government) will be found. Then, the evaluation of the alternatives will be done.

The next phase is the choice: The alternative that contributes more to the accomplishment of the set objectives is chosen as the one to be implemented. In some cases, the analyst through the screening process may eliminate some alternatives without a detailed evaluation. This will make the task of evaluation easier and faster. The screening is based on criteria set by the analyst and derived from the objectives.

The final phase is the implementation of the best alternative on a proposed time schedule.

1.3. Role of an evaluation model

The role of an evaluation model is to develop the impacts of alternative plans and compare and rank them with each other and the do-nothing alternative. Most of the evaluation models introduce formulae which enable the analyst to compare the different and often irregular, series of benefits and costs that are associated with alternative plans.

The evaluation model can be compared with other types of network programming tools (e.g. screening): It can rank plans by productivity, by returns, and the like, it enables the analyst to consider numerous alternatives, it gives him a more accurate picture of the impact of each alternative and it takes into consideration the goals and objectives directly and realistically in the evaluation.

Thus, the evaluation model broadens the horizons of the transportation planner during the process of planning transport network improvements.

CHAPTER TWO

BACKGROUND

2.1 Evaluation measures and objectives

Several measures for evaluating the consequences of the implementation of an alternative may be identify. The consequences may be measurable in monetary terms (costs, users savings) or non-monetary terms (level of service, environmental impacts). Most studies are concerned only with monetary impacts, using economic or financial cost-benefit analysis exclusively.

The benefits of transport network improvements (or planning in other sectors of the country's economy), will result from a reduction in the consumption of resources. It will impact the economy by altering the interactions between resources, production and transport in such a way as to improve (or deteriorate) the welfare of inhabitants. If an evaluation measure is based on economic analysis, it seeks that alternative which consumes the minimum resources while providing significant economic growth. A number of planning models have been developed which employ the economic analysis in the evaluation of alternative plans. Among them are the Harvard-Brookings Macroeconomic model for evaluation of network alternatives in Colombia (4) and Taborga's work with the Chilean Transport Network (5). (Explained in § 2.2.2). If financial analysis is employed, this would imply that the value of a plan is specified independent of any detailed study about how it may alter the economy, and focuses instead in the investments' consumption of resources; its purpose is to determine the best way to allocate resources to projects of presumed known value. That is, it is primarily concerned with budget constraints, and not with the economic relationships, which determine an investment's impacts.

The evaluation measures may be classified into four types of analysis according to their objectives. (Based on a classification system introduced by R. de Neufuille and D. Marks (6)).

i. Type I: Standard Benefits Cost Analysis

This is the simplest case. The future costs and benefits are discounted to a common point in time (usually the present) and compared. Several criteria exist to the comparison: (1) Benefit-cost criterion, computing the ratio of the present value of all benefits to the present value of all costs, (2) the internal rate of return criterion, that is the discount rate at which the net present value of the benefits equals to the net present value of the costs, (2) net present value criterion, that is the difference between the present value of all benefits and present value of all costs. The underlying assumptions are:

(i) the value of a benefit or cost, increases linearly with the amount of benefits or costs at any time.

(ii) As long as values are linear in the amount of benefits, uncertainty can be introduced with the use of expected values.

(iii) Money is taken to be the measure of all things. If it is not feasible or practical to qualify a benefit or cost, such as an aesthetic one, it does not get considered.

(iv) All parties interesting in the investment must agree upon a single criterion of evaluation. This assumption is reasonable so long as groups accept that it is meaningful to measure all benefits and costs,

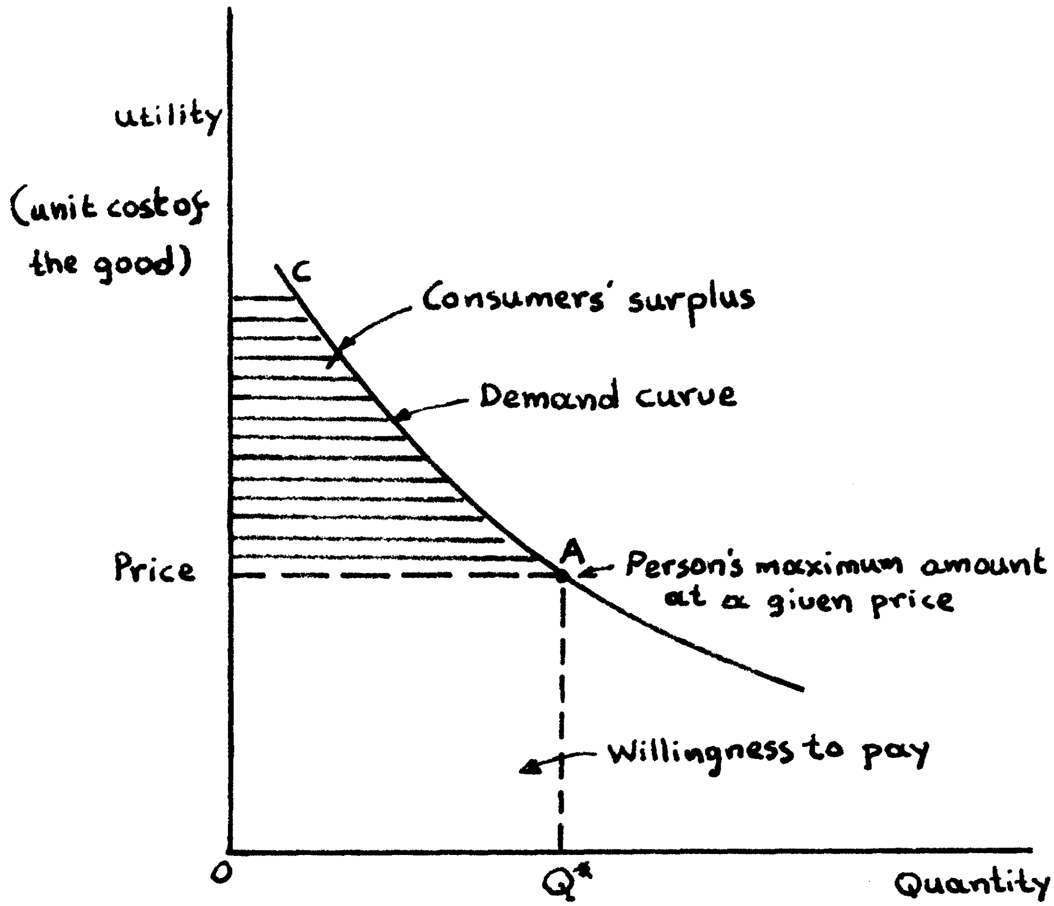


Figure 2.1: Consumer's Surplus

such as loss of life on a common basis and with the same weight on each kind of benefit and cost.

The objective of this type of measure is to maximize the monetary profits (benefits minus costs) over the time horizon.

ii. Type II: Consumer's Surplus

It recognizes the non-linearity of the values in terms of benefits and costs. The real value of any benefit is known as its utility, and the utility function describes the real value of the benefits. The non-linearity of the utility function, which contradicts the first assumption on which the standard benefit-cost is based, is a pervasive phenomenon. As a general rule, both individuals and the public have a diminishing marginal utility for benefits. As it appears in figure 2.1, someone would be likely to demand more of a good until, at the margin, was equal to its costs. This would occur at Q* in the figure. It follows that someone's utility or value for less than Q* of a good is greater than its price. The sum of the utilities over all quantities used will result in the willingness to pay for the good. The difference between the willingness to pay and what actually has been paid to a certain price is the consumer's surplus. This type of analysis attempts to incorporate consumer's surplus into the measurement of benefits. It employs the benefit-cost analysis to accomplish its objective, the maximization of profits. Basically, it recognizes that benefits often have a real value much greater than their price.

iii. Type III: Decision Analysis

This approach includes procedures to quantify any individual's own utility over risk, usually nonlinear functions. Unlike the utility functions over quantity, however, the utility functions over risk are not expressed in terms of common units, such as money, which different groups might be willing to pay for any specified number of goods.

The process of decision analysis consists of the following steps: (i) all possible sequences of decisions and their consequences are laid out. This is represented as a decision tree, since there can be several choices at any stage and since each choice may branch into several consequences. (ii) All possible outcomes are indicated together with the a priori probability of occurrence. (iii) The utility function of the decision maker is assessed and the utility or real value of each outcome is calculated. Finally, (iv) the optimal choice at each choice at each stage, and thus the optimal sequence of choices, is calculated on the basis of maximizing the expected value of utility.

The objective of the Decision Analysis is to find the optimal sequence of choices of alternatives over time aimed at maximizing the expected value of utility, since uncertainty is incorporated.

Pecknold (7) employ Decision analysis measuring all consequences in monetary terms, as profits or losses.

iv. Type IV. Multiattribute Analysis

This approach attempts to account for the non-linear, nonadditive nature of any individual or group's utility function over several attributes. Once the multiattribute utility function is encoded, it can be used in the evaluation just like a utility function of type I.

Therefore the objectives are the same as of type I.

v. Type V: Multiobjective Evaluation Analysis

So far we have had only one objective. This analysis attempts to lay out explicitly the preferences of the different groups concerned with a project for the set of possible consequences. In this way, it intends to allow the analyst to estimate those choices which are preferable to the several groups, according to their objectives and how these differences might be resolved. It does not define the best alternative, but rather leaves the selection to judgement.

It is important to note that the existing procedures of multiobjective evaluation do not propose clear, analytic methods for determining the preferences of any group. The most cogent descriptions of the theory and proposed practice have been presented under the auspices of the United States Water Resource Council. It has not yet been applied to transport network planning. However, it would be interesting, if it could be applied, since transport network planning implementation affects several groups: the users of the network, the producers and consumers of goods, industry and the government itself.

2.2. State of the art

2.2.1. Link evaluation models

These models deal with the evaluation of the several alternatives for link improvements. It is assumed that (1) the alternatives are mutually exclusive, (2) any improvement of one or more links in the network does not affect the others and (3) the budget allocated to each link-for its improvement- is fixed; thus, links to be improved are not competing for the same funds.

Wohl and Martin (8) deal with the evaluation of link improvements taking into account present and future impacts of the improvement. Tarplay and Drake (9), Thygeson (10) and Marglin (11), all develope fairly simple evaluation models, incorporating the timing (the improvements to be done in stages, and may be postponed for one or more years). They showed that substantial benefits can be achieved with the appropriate timing. Winfrey (12) is concerned with the optimal staging of an improvement (namely an expansion of a 2-lane highway to a 4-lane one, given that some increased capacity is needed now), and not when the improvement should start. Thus, he ignores the impacts of delaying the starting time and the supply-demand dependencies. Cole (13) develops a model with a probabilistic demand structure but, once the sequences of improvements is decided it would remain unchanged over the economic life of the link, no matter what changes in demand might occur. Howard and Nemhauser (14) introduce dynamic programming for the evaluation of alternative link improvements considering supply-demand dependencies in a fairly theoretical work. Other models simulate the activities which take place on the link during a development and operating time horizon, considering construction, maintenance and vehicle operation. The Highway Cost Model (15) and, the Project Analyzer of the Harvard Brookings Transport Model (16) are such models, calculating economic consequences with a sequential simulation of events over time for the evaluation.

The main characteristics of the above mentioned models are the following:

(1) demand is exogenuously given and independent of the alternative selected,

(2) link capacity is merely additive; to meet increasing demands, we need only to widen the link to carry the new volume,

(3) costs are very simple in structure: fixed and variable ones, with the only exception the ones simulated by the HCM,

(4) the problem is one of minimizing total costs only, and simple techniques are used to produce the optimal sequence of the improvements.

2.2.2. Network Evaluation Models

The network evaluation models can be divided into four categories (expanding Pecknold's (7) classification) which become progressively more complex:

(1) capital budgeting models

(2) Network flow models

(3) Stochastic Models

(4) Activity growth models.

The latter are the most complex, introducing the constraints of long-run supply-demand dependencies in addition to normally using a complicated network flow simulation procedure. Surprisingly enough, little work has been done on the use of such models. The reason is their complexity. The most significant studies which employ macroeconomic model in conjunction with a transport model are Taborga ([5]) work with the optimal transportation policy in Chile, the Northeast Corridor Study (NEC) (17) and the Harvard Brookings study on Colombia (4).

2.2.2.1. Capital budgeting models

Capital budgeting models generally assume all benefits are exogenously specified, single valued and independent of the sequence chosen. They incorporate the combinatorial mathematics to select the best sequence of improvement activities subject to capital (budget) constraints. Marglin (11) deals with the network problem in finding the optimal strategy of network improvement, although, he deals with dependencies caused by budget constraints only. The optimal strategy is one that allocates the budget among the links in such way as to maximize the sum of the net present values of the alternative and the net present value of slack, subject to the condition that the sum of alternative outlays in each period not exceed the period's budget. Weingartner (18) uses mathematical programming to solve the capital budgeting problem. Consad (19) proposes several models to find the optimal sequence of improvements of a transport network, still in terms of abstract projects (i.e. projects, although intended to be transport projects, are represented solely by a set of costs and benefits). One of the proposed models for the Northeast corridor project was a quadratic programming model, which can handle project dependent costs and benefits quite easily.

Mori (20) uses dynamic programming for the selection of these link improvement strategies to produce the optimal network improvement alternative subject to capital budget constraints. The optimal alternative is the one that maximizes the benefits (B_i) from all link improvements in each period, for P periods.

maximize
$$Z = \sum_{i=1}^{P} \sum_{j=L}^{N} g_{ij}(x_{ij}) = \sum_{i=1}^{P} B_i$$

s.t.
$$X_i \geq \sum_{j} (x_{ij})$$

where:

x_{ij}: the amount allocated for each link j in period i

X_i : the budget available in period i

$g_{ij}(x_{ij})$: the benefits of each link (j) improvement

N: number of improved links.

The technique permits: (i) Examination of many stages for each link alternative proposed as an addition to the road network, however, this technique can handle only two or three stages; (ii) analysis over multiple time periods; (iii) inclusion of budget limitations; and (4) consideration of situations where system costs, and benefits change over time.

Meyer and Straszheim (21) present a fairly concise and clear treatment of the dual problem of the capital budgeting primal problem, the shadow prices and internal (vs. external) opportunity costs of the alternatives.

2.2.2.2. Network flow models

The network flow models are an extension of the capital budgeting models. The cost and benefits are not exogenously specified, fixed quantities, but depend on some prediction mechanism. In some cases, it can be internal (as in linear flow models) and in others, it is a completely separate model. They all deal with a deterministic and fixed demand structure. They have been generally limited to linear flow models, however. Additionally, they usually ignore the dependancy of supply- demand. Recently, developments in branch and bound techniques have placed fewer constraints on the form of the flow model. Hershdorfer (22) applied a branch and bound algorithm- developed by Land and Doig- to the single period, link addition problem developing a linear programming flow model to determine the measure of effectiveness of network changes. He sets up a general network with nodes i=1,2,...,N and directed arcs. Demands are specified between groups of origin-destination pairs. Each "commodity" may be the flow from a single origin to several destinations or from several origins to one destination. There are the flow constraints and capacity constraints for existing links and additional ones. The objective function searches for the minimum additional construction necessary to reduce travel costs.

Roberts (23), at the same time, although independently, was using the same branch and bound algorithm coupled with heuristic backward stepping, time-sequencing algorithm for the multiperiod problem.

Bergendahl (24), in a similar approach to Roberts, used a linear programming flow pattern of any improvement plan at each period, but employed dynamic programming to search for the optimal sequence of improvements in time. Roberts in Meyer and Straszheim (21) developed a model which minimize the sum of costs for both constructing link additions and operating vehicles over the entire system, subject to the following constraints: (i) all supplies and demands of each commodity type must be met by flow over the network, in which the sum of flows into each node must equal to flows out; (2) if a link is not built, then there can be no flow over it; (3) the amount of funds committed to building new links must not exceed the available budget; and (4) the partial construction or improvement of a link is not permitted. He comesup with the optimal improvements and their timing. It is assumed that the network in any given stage n is a subset of the network which will exist at the next stage n+1. Therefore a dynamic programming approach was introduced. However, there is a shortcomming in the approach : traffic patterns in the last planning period are the only ones that affect the selection of the highly important final or Nth-stage plan. Today's volumes merely determine which links of this final plan to build early. There is, therefore, an element of commitment to the Nth-stage plan, once it is determined. Morlok (25) has proposed a dynamic programming procedure to define the optimal timing and strategies in the Northeast corridor context, ignoring the network effects of multiple and overlapping paths.

Another interesting approach to find the optimal time-staged sequence of improvements is to solve the combinatorial problem using the discrete optimization technique of branch and bound programming. Ochoa and Silva (26) apply a branch and bound algorithm and a branch backtrack algorithm to the network improvement (single period) problem, using a traditional assignment model as a flow prediction mechanism.

Also, there are a number of heuristic approaches for the network improvements, which concentrate mainly on the link addition or capacity expansion, only in one period, using a simulation model. Barbier (27), Stairs (28), Spenser (29) and Bhatt (30), all propose ways to select improvement plans for testing in a simulation model, which corresponds to a form of direct search procedure. Allman (31), Fisco (32) and others have developed simulation models mainly serving the needs of the railroad in North America.

Carter and Stowers (33) develop a model to find the optimal allocation of funds for network improvements. A general transportation network is specified with n nodes and m arcs with arbitrarily chosen directions. Associated with each arc is a capacity $b_{ij} \geq 0$ and a travel cost $c_{ij} \geq 0$. Each distinct flow or "commodity" is defined as the flow from a single source with supply r_k to various destinations. The non-linear relation between link volumes and construction costs is handled by means of a piecewise approximation- one **constant** user cost is associated with relatively free flow conditions and another constant user cost is charged to all vehicles volumes above a critical "practical capacity". This is easily incorporated into the model by representing each link by two "artificial links", with respectively low and high user costs.

The low cost link will have a capacity equal to the "practical capacity" of the link. The other higher cost link will have a capacity equal to the difference between the possible and practical capacity of the actual link. The optimization algorithm will load the low cost branch first and if its capacity is exceeded the high cost branch will then be loaded. In this way an actual link with nonlinear travel costs will be simulated. The introduced objective function aims at minimizing the sum of transport costs and cost of improvements, keeping them within the budget limits. The program developed can use a standard linear programming procedure for its solution, but for a relatively large network this might overcome the computer capacity.

Quandt (34) has developed a model having as objective the minimization of user costs. This model is based upon the classic Hitchock-Koopmans transportation network problem: There are N sources and M destinations and all sources are initially connected to all destinations. Each source has a fixed supply k_i and each destination a fixed requirement R_j. He equals the total supplies with the total requirements. Also, he introduces as constraints, the total outflow from source i to be less or equal to its supply k_i and the total inflow to destination j to be greater or equal to its requirement R_j. The objective function aims to minimize the total transport costs, provided that the cost of improvements does not exceed the available budget. He associates with each link ij the decision variable k_{ij}, the amount of capacity to be added. This variable is continuous and a small positive increase in its value may well correspond to the widening of a road or the installation of a better signal system; a large value of k_{ij} may well be indicative of the need for provision of an additional link. Though k_{ij} will be restricted to values greater than or equal to zero, links may be taken entirely out of the network or added if their initial capacities b_{ij} are set to zero. Therefore the total traffic flow on the link must be less or equal to the sum of the initial capacity and the capacity to be added.

2.2.2.3 Stochastic Models

Pecknold's (7) work is the most important in this area. He recognizes that improvements are usually implemented as a series of staged sequential improvements to a fairly extensive existing system and that there is substantial uncertainty over the future demands. He has developed a basic stochastic time-staying model, which is capable of handling supply-demand interdependencies, network connectedness, budget constraints and system dependencies on the type of improvements. The use of a descriptive non-analytic simulation model for transport flows, which recognizes both uncertainty and the multi-stage nature of investment alternatives results in an extensive multi-stage decision tree of extreme dimensions. He introduces approximating procedures, called pruning rules and terminal evaluation functions to heuristically reduce the computations and make application of his sequential decision model feasible for large networks.

2.2.3. Traffic assignment approaches

Numerous approaches have been developed for the assignment of the traffic on the links of the network. Here we will mention the ones more relevant to our work.

Beckman (35) considers a transport network consisting of N nodes and directed arcs, with a single type of homogenous traffic flowing on it. He solves the problem using an algorithm which:

(1) starts with an initial demand $D_{\ell,k}$, on each origin-destination pair ℓ,k and the flows x_{ij} over the links ij;

(2) computes the travel costs or time c_{ij} associated with using the link and the flow x_{ij}:

$$c_{ij} = a+b \cdot x_{ij} \quad \text{where: } a,b \text{ constants.}$$

(3) finds out the minimum path for each origin-destination piar ℓ,k with the help of the expression:

$$c^{*}_{\ell,k} = \text{min-path} \sum_{ij} c_{ij}$$

which gives the minimum travel time between ℓ,k,

(4) now, a new demand is generated:

$$D'_{\ell,k} = f-gc^{*}_{\ell,k} \quad , \quad \text{where: } f,g \text{ are constants}$$

(5) a weight sum of the new and the old demand is generated:

$$a \cdot D'_{\ell,k} + (1-a)D_{\ell,k} \quad , \text{ where } 0 \quad a \quad 1$$

(6) the assignment of the flows on the links is done through the imposed conservation conditions:

$$\sum_{j=1}^{N} x_{ij}-x_{ji} = \begin{cases} D_{\ell,k}: & \text{(at origin)} \\ -D_{\ell,k}: & \text{(at destination)} \\ 0 & \text{(elsewhere)} \end{cases}$$

(7) the same calculations are repeated,

(8) the flows between each 0-D pair will oscillate within a. $D'_{\ell,k}$ and if a is progressively decreased during the iterations, convergence will be satisfactory.

Manheim and Martin (36) propose an algorithm, which requires as inputs: interzonal transfers, network description, volume- delay characteristics and a specification giving a volume increment and a generation rate characteristic. The algorithm works in five basic phases:

(i) The random selection of a zone pair,

(ii) The determination of the minimum time path between the zone pair,

(iii) The use of a generation rate characteristic to determine the potential volume to be assigned between the zone pair,

(iv) The addition of a small increment of the potential volume to the minimum path,

(v) The use of volume- delay characteristic to update the travel times of the links in the minimum path due to the increase in volume.

The produced output consist of link volumes out travel times, interzonal potential volumes. Isard (37) develops a model handling aggregatively the shipment of commodities between regions; shipments are considered to be direct between origins and destinations; rerouting and transhipment possibilities as well as capacity constraints on the links are not considered. The model defines the shipment of commodities is such a way as to maximize the regional income subject to the conservation rule of supply and demand.

Tomlin (38) develops a model defining the flows over the links according to the minimum costs of transport. A network is specified with nodes 1,2,...,N and directed arcs 1,2,...,M. Associated with each arc is a capacity $b_{ij} \geq 0$ and an average user cost c_{ij}. The objective function is the one minimizing the overall user costs:

minimize

$$Z = \sum_{k=1}^{q} c_k \cdot x_k,$$

where:

c_k: the vector of the transport costs of the k^{th} commodity over each link.

x_k: the flow vector forthe k^{th} commodity over each link.

The introduced constraint is the one of flow conservation at node i:

$$\sum_{j=1}^{N} x_{ij}^{k} - x_{ji}^{k} = \begin{cases} r_k & \text{(origin)} \\ -r_k & \text{(destination)} \\ 0 & \text{(elsewhere)} \end{cases}$$

The arc-node formulation leads to a basis of large size. The program can be handled by means of the decomposition principle developed by Dantzig (39).

2.3. Conclusions

After reviewing a number of models, we can conclude the following:

- The evaluation of alternative network improvements and the choice of the optimal one is a problem which is complex in theory and depends largley on whose point of view we are concerned with;

- the problem has been approached from a variety of different perspectives, each emphasizing a certain commitment to a profession, to a mode, or a philosophy which emphasizes some aspects and largely ignores others;
- a number of computational techniques have been used to solve the problem, not recognizing the non-linear status of the problem, or introducing assumptions to transform the non-linearity to linearity;
- none of these techniques or algorithms can be used satisfactorially in all of these basic problems of transport investment planning.

Furthermore, reviewing the models with the perspective of being applied in a less developed country we may find some that are inappropriate for couple of reasons:

- They are too sophisticated, thus they need large computer facilities (usually unavailable in a less developed country) to be implemented,
- the data requirements are such that it is impossible to meet them with the available resources and facilities in a LDC. (most of the data does not even exist, thus making those models which are highly sensitive to accurate data obsolete).

Summing up our conclusions for the type of evaluation model needed for the improvements of the transport network in a LDC we may recommend: a model which is easily applied, straightforward, with few data requirements. Finally, it must be able to serve in the best possible way the needs of a LDC for better transport.

CHAPTER THREE

THE APPROACH: PROBLEMS FACED AND THEIR SOLUTIONS

3.1. The approach

3.1.1. Definitions

Before describing the approach itself, the definition of the words, expressions and concepts employed should be done. A transport network is composed of links and nodes. It is assumed that all economic activity takes place within nodes, cities or villages, rather than being continuously distributed over space and that transport is confined to links, routes between these nodes. A point where two or more links join must also be a node, even if not a point of economic activity. Each commodity is produced at one or more supply nodes. Demands for these commodities exist at other nodes within the network. Commodities are shipped from supply nodes (origin) to demand nodes (destination) over the links of the network. Similarly, people are moving from the origin node for the destination node over the links. A transport network is composed by links of several modal types: highway, rail, waterway and air. In this study only the case of the highway mode is considered.

Network improvements denote the construction of new links, the upgrading or widening of parts of others, or better maintenance for the road surface, aimed at lowering the vehicle operating costs. Network improvements are executed according to a proposed plan called a network improvement strategy. Network improvement strategy, or network strategy (N.S), is composed of one improvement strategy for one or more links- the link improvement strategy, which is a time sequence of projects or changes on the link, is chosen from among alternatives. It is obvious that the number of network strategies possibly considered depends on the number of links to be improved and the number of tentative link improvement strategies. With the timing of a link strategy left as a variable, one network strategy may be identical to another except for the time when one link strategy is implemented.

A link improvement strategy, or link strategy (L.S.), may denote one or more of the following: (i) the timing of the construction projects for a new link, staged or not; (ii) the maintenance of policy to be followed overtime; (iii) the time-sequence of the upgrading (e.g. the year that an earth road will be improved to a gravel one, and, possibly, to a paved road) to part or all of the link; (iv) the time-sequence of widening the road or adding a new lane; or (v) no improvement at all. It should be pointed out a link strategy is a sequence of activities with a fixed relative timing. The entire sequence may be shifted in time.

3.1.2. Overview of the logic

The approach, advanced here, generates alternatives network strategies from proposed link strategies, simulates the network performance over the time horizon for each feasible network strategy, and finally, evaluates it.

The consequences of a network strategy are evaluated as follows: First, the alternative is checked to see whether it satisfies the imposed constraints on budget, foreign exchange and skilled labor. Then, during the simulation of the network, the annual costs and benefits are computed.

The cost are those associated with construction and maintenance activities. The benefits are defined as the difference between the price a user is willing to pay or was paying before the implementation of an incremental cost change due to a change in transport cost and the price actually paid. To estimate the transport cost for each trip from its origin to its destination, the routes of the vehicles must be determined and the cost of time and congestion added to the operating costs. The evaluation of the alternative is based on the net present values of these incremental costs and benefits produced by the simulation for each alternative when compared to a base network solution. The approach proposes as the optimal network strategy for implementation the one with the highest net present value. The figure 3.1 shows the several steps of the approach.

3.2. Constraints on the feasibility of an alternative

The constraints imposed to each network strategy are of three types: 1) those related to the costs of improvements, 2) those related to the timing of each strategy and 3) those economic weightings associated with each strategy which determine its importance in the economic improvement of the country. The feasibility of a network improvement strategy is based on whether it satisfies constraints introduced to prune the generated network strategies. An annual budget is allocated for highway construction and maintenance,and distributed among the regions of the country. Each network strategy may not have costs of construction and maintenance activities for each region higher than the

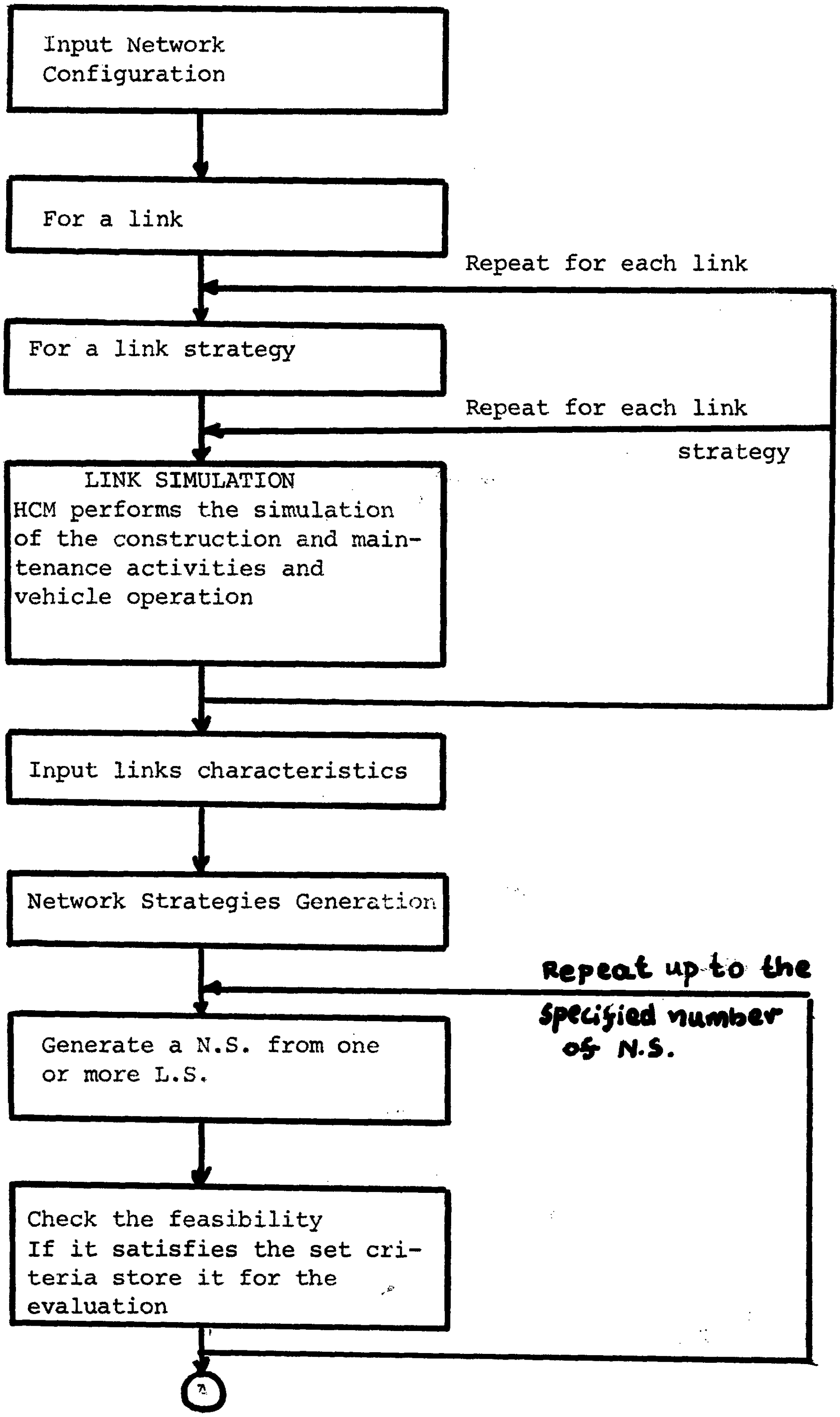


Figure 3.1.: Flow Diagram of the Approach

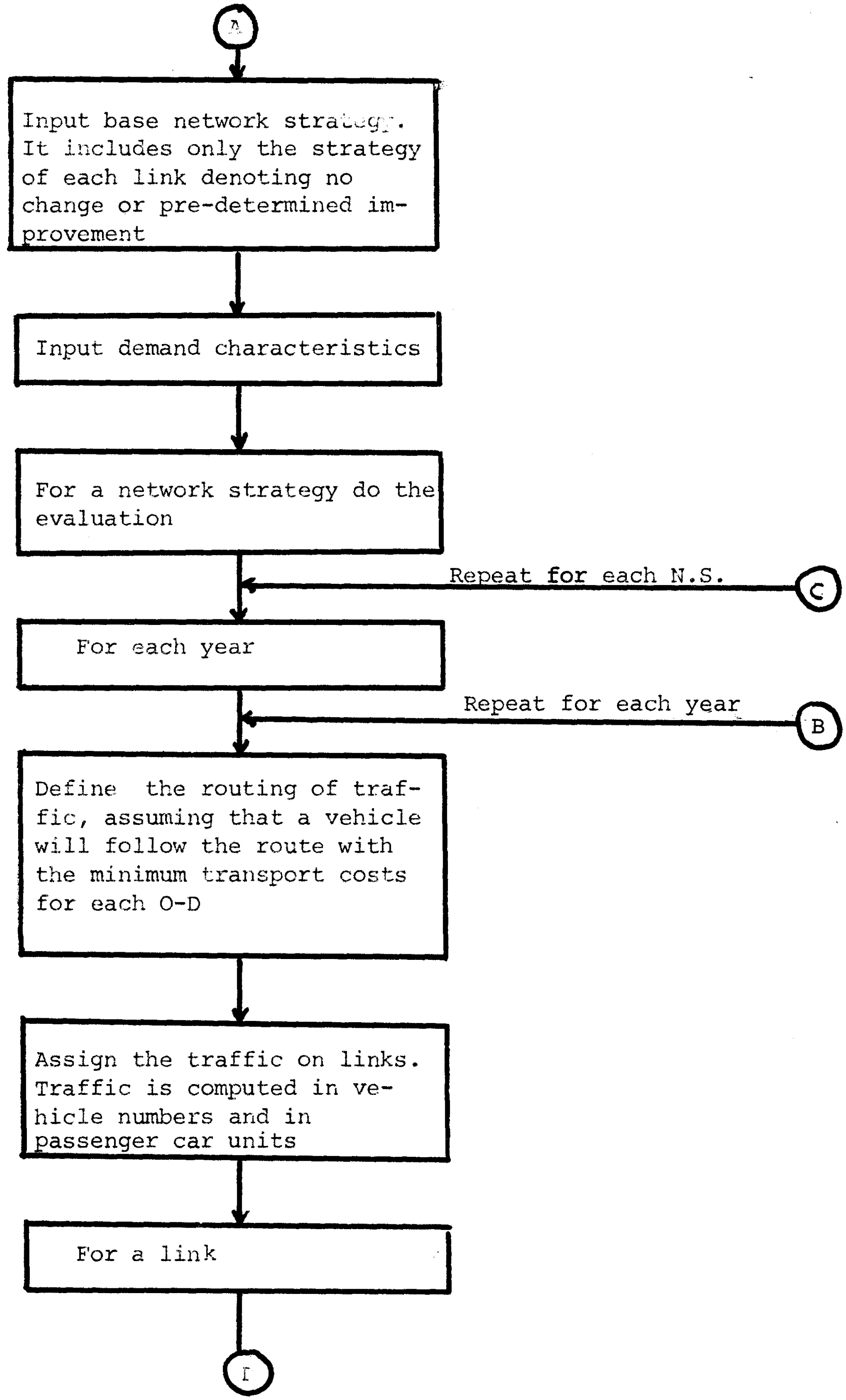


Figure 3.1.: (continued) Flow Diagram of the Approach

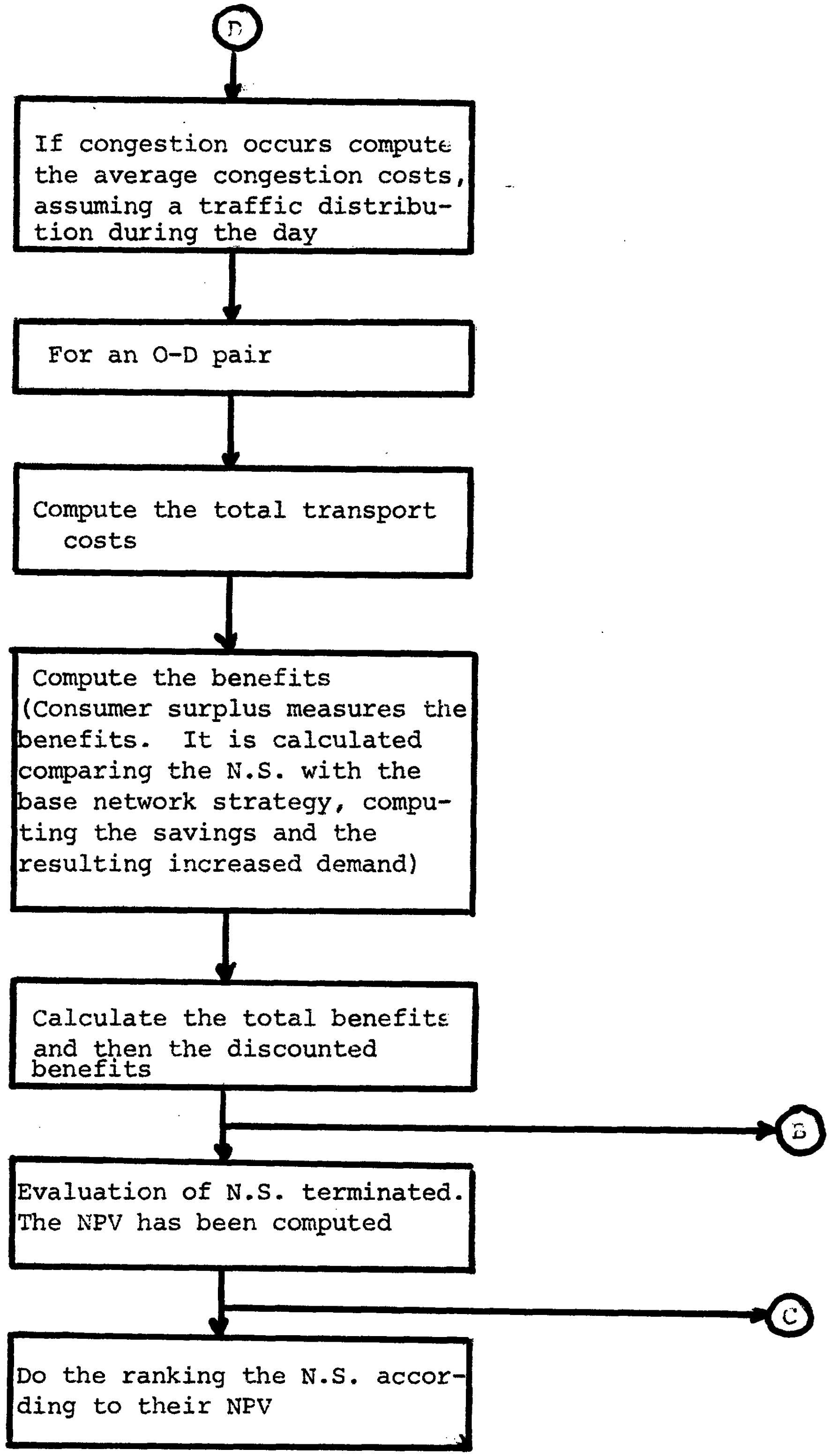


Figure 3.1 (continued) Flow Diagram of the Approach

annual regional budget.

Two other constraints are closely related to the economic conditions: Most of the money available for initial construction comes from abroad either as direct aid in foreign exchange or low interest, long term loans. The balance of payments usually constraints the growth of the country; therefore the available money for purchases of machinery, materials, etc. is limited to the aid or loan money or to specific allocations to the transport sector as a whole. Therefore the model allows foreign exchange allocations in each region to be constraint. Similarly, there is often a scarcity in skilled labor. This may be a deterant to development or imply the use of labor instead of capital intensive techniques, the latter using mostly skilled labor. It may be specified as a regional constraint.

3.3 The Costs

3.3.1. The cost of construction and maintenance activities

An improvement may be any continuation of upgrading or construction of part or all of a link. The costs are those resulting from the construction or upgrading that occur during the improvement phase as well as those associated with the maintenance of the link.

The cost may be specified exogenously or computed by the Highway Cost Model (HCM) after simulation of the activities of improvement. Construction costs may be computed directly and accurately by the HCM; maintenance costs can only be approximated because they vary with the traffic on the link, which is not known until the entire network is simulated. Maintenance costs are computed for an approximate expected volume. Although fairly insensitive to volume, these costs could be adjusted if the volume turns to be significantly different.

The cost of construction and maintenance activities may be distinguished as financial and economic costs, the economic costs being those obtained by deducting from the financial costs the percentage resulting from indirect taxes and import duties. This is an estimate of the "cost of the improvement" to the country's economy net of the payments of taxes. It is this cost that is used to measure national objectives. The financial costs, perceived by the user, as the costs that influence his behavior. Budgets are stated in these terms. Similarly, budget constraints may also be stated in terms of other critical resources, such as foreign exchange and skilled labor, since their allocation to other sectors of the economy than in the transport sector, could influence the country's economic growth.

3.3.2. Vehicle operating costs

Since the model will be integrated with the HCM, it adopts some of its characteristics and constraints. One of these is that, seven vehicles types may be handled. They are usually designated as: passenger car, bus, pick-up truck, 5-ton truck, 10-ton truck and two types of tractor-trailers.

Vehicle operating costs are dependent on the design and the surface as well as on the traffic volume on the road. The operating costs resulting from the road conditions can be exogeneously specified or computed by the HCM through the simulation process. The costs due to the introduced monetary value of the travel time are computed by the evaluation model. The vehicle operating costs are computed as both financial and economic costs. Economic costs are these derived from fuel and lubricants consumption, tires usage, vehicle depreciation and interest on capital, maintenance and repairs and wages (in the case of trucks and busses). The financial costs are the economic costs plus the costs of insurance and taxes. The financial costs are used to determine the routing of the traffic between Origin and Destination (O-D) and changes in demand due to operating costs, and the economic costs used to compute the benefits resulting from the improvement.

3.4. Definition of demand and the generated traffic

The traffic on the network originates from the supply nodes, its destination being the demand nodes. The demand is given by O-D pairs (origin-destination nodes). A supply (origin) node represents a production region, where one or many crops are produced, a mine, a place where animals are raised, or a city or industrial area, where manufactured goods are produced, ready to be consumed locally or shipped to other places. A demand (destination) node represents a city, a town or a village where the goods are consumed.

The annual based demand is a function of the population and its growth rate, the average income and its increase, the price of the commodity etc. The changes in transport costs will shift the demand up or down due to price elasticity. The number of vehicles moving on the links of the network is based on such demand of the commodities between each O-D pair.

The model handles seven different vehicles types, each with different capacities. It is assumed that for one O-D pair, one vehicle type carries one commodity type or at least ones with similar handling and transporting characteristics. Thus, the model limits the number of substantially different commodities which can be transport between each O-D pair to five, not including passengers. Demand can be measured in two ways: in number of vehicles per day (according to vehicle type) for each O-D pair; or in tons per day. (From the volume of commodities in the vehicle capacities and the load factors, the number of vehicles for each O-D pair is easily computed). Each vehicle type will follow that sequence of links which connect the O-D pair and minimize its total operating costs. As the network characteristics change, so may be the routing.

3.5. Impacts of the Improvement on Demands and Traffic

Any change in the operating characteristics of a link in the network will affect the distribution of traffic on the links. Changes may induce greater demands, divert traffic from other links, or create congestion on the link due to the traffic increase.

The demand of commodities and passengers between origin and destination pairs is influenced by changes in the transport costs. This sensitivity to demand is denoted as the price elasticity. Price elasticity is the percentage change in demand that results when the transport costs have changed by one percent. Elasticity may vary from O-D (inelastic demand, i.e. no change in demand) to values as high as 0.1 to

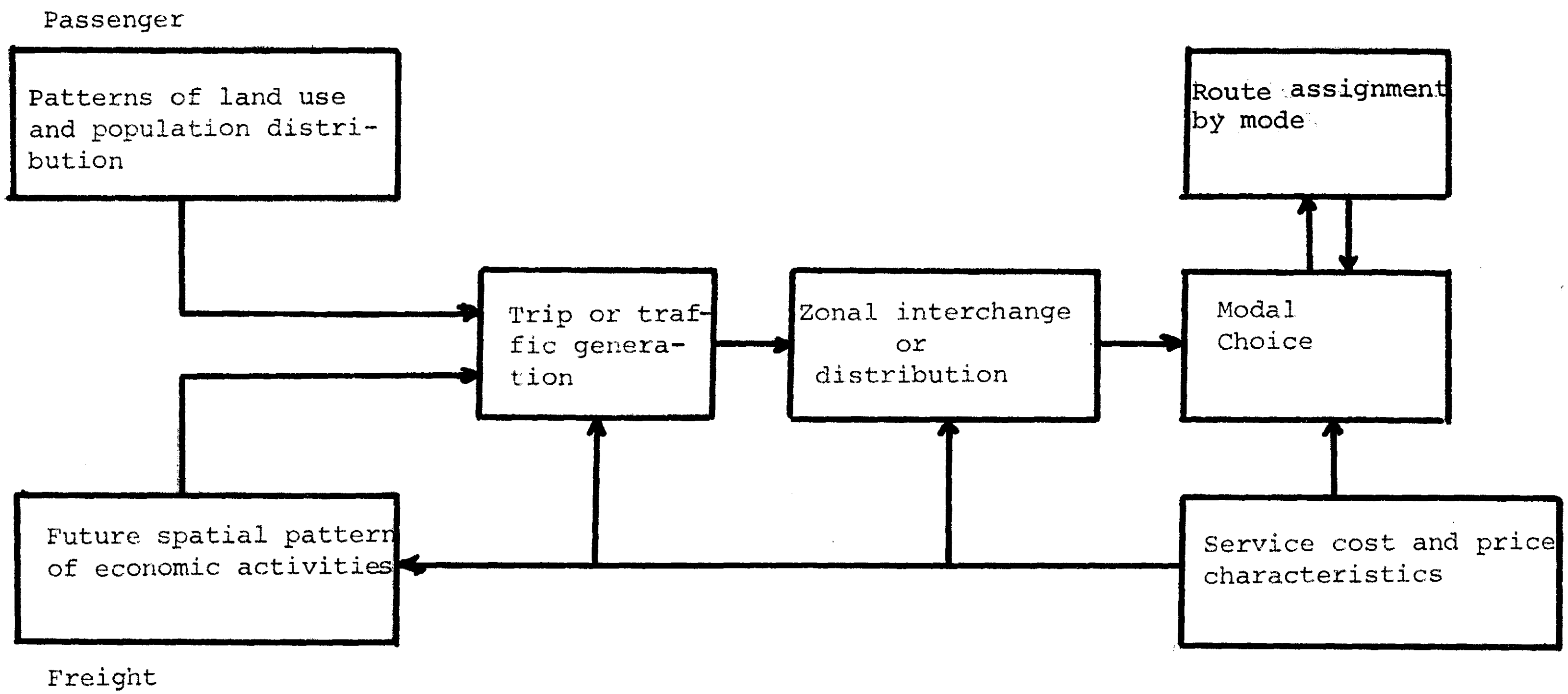


Figure 3.2.: Schematic model for forecasting passenger and freight transportation demand

o.4 (elastic demand).

Several approaches have been developed to estimate the demands of the O-D pairs. Their general scheme is protrayed in the flow chart in figure 3.2 It begins with land use or spatial location characteristics, derive trip demands and trip destinations and then follo this with an assignment or allocation of these trips to a network. When the demand is elastic any change in the transport costs, resulting from the route assignment, will change the demand.

Route assignment provides specific estimates of demand placed on various links in a network summed from the individual O-D demands. Since there may be a number of alternatives paths that can be used for connecting the O-D pairs, the assignment selects the least costly route. These costs vary with travel time, which varies with link (not O-D) volume. If links capacities were infinite, and the travel time therefore did not vary, the assignment would be relatively simple. However, as flows on a transportation network change, the cost-performance characteristics on the network also change. Real world users adapt their behavior to local capacity shortages. If a shorter, faster route becomes congested (and thereby slower), users will shift to a less congested and formerly slower alternative route. The result is a complex equilibrating process of travel demands, travel speeds and link volumes. There are numerous solution approaches and assumptions introduced to solve such problem. For LDC's, where alternatives are fewer, we will assume away this problem by assuming that congestion costs do not alter the routing, determined ignoring congestion.

3.6 The Assignment of Traffic on the Links

The assignment of traffic follows the assumption that each vehicle will travel the sequence of links that connect the O-D pair and minimize its total operating costs. No reassignment of the traffic on the links is considered for changes in transport costs due to the increased travel times caused by congestion. This limitation is not considered to be significant since most links in LDC's are uncongested and usually there is only one reasonably feasible route connecting most O-D pairs, which the vehicles must follow regardless of congestion. Congestion, however, it it exists, is considered by computing the costs resulting from the time value of the commodities and the passengers.

Initially the assignment is done for the first year of the simulation. It is then repeated during the time horizon if any change occurs in the network (identified by changes in user costs in any link) or if specified by the analyst.

3.6.1. The Routing Algorithm

Numerous algorithms have been developed which search a sequence of links to find minimum cost routes.

The Algorithm developed by Floyd (40), which can treat efficiently a general network and multiple O-D pairs, ahs been applied.

The Floyd procedure builds optional paths (routes) by inserting nodes, when appropriate into more direct paths. The algorithm starts with a NXN matrix C of transport costs, and N matrices are constructed sequentially, where N is the number of nodes. The K^{th} such matrix can be interpreted as giving the minimum transport costs of all possible routes between all node pairs (i j), where only routes with intermediate nodes belonging to the set of nodes 1 through k are allowed. The (k + 1)st matrix is constructed from the K^{th} using the formula:

$$C_{ij}^{(k+1)} = \min \left(C_{ij}^{(k)},\ C_{i,k+1}^{(k)} + C_{k+1,j}^{(k)}\right),\ C_{ij}^{(o)} = c_{ij} \qquad (3\text{-}1)$$

Here, K, which is initially zero, is incremented by 1 after i and j have ranged over the values 1,...,n; and K=N-1 at termination. If two nodes are not connected directly by a link, the assigned transport costs for this link is a large number. Also a time matrix T is introduced being the same as, C, but with travel times on the links as its elements. The label matrix has as elements in the initial stage the nodes denoting the beginning of each link; i.e. the element aij is i, if i is the beginning node of link ij. Note that all matrices have elements defined by node pairs, not by O-D pairs.

The algorithm proceeds as follows: It pivotes on every node of the network, i.e. it obliges all traffic between O-D pairs to pass through this pivot-note for each O-D pair, it compares the resulting transport costs with the previous ones and saves the leasts ones as the transport costs of the O-D pair under consideration.

If the traffic has to pass through the pivot node, the algorithm updates the label matrix and the time matrix as well. The pivoting had ended, for each O-D pair the cost matrix C would come up with the minimum transport costs the time matrix T with the resulting travel time and the label matrix L with the previous node of any node, both nodes defining a link of the minimum costs route.

Finally, the set of links of which the route is made up may be found.

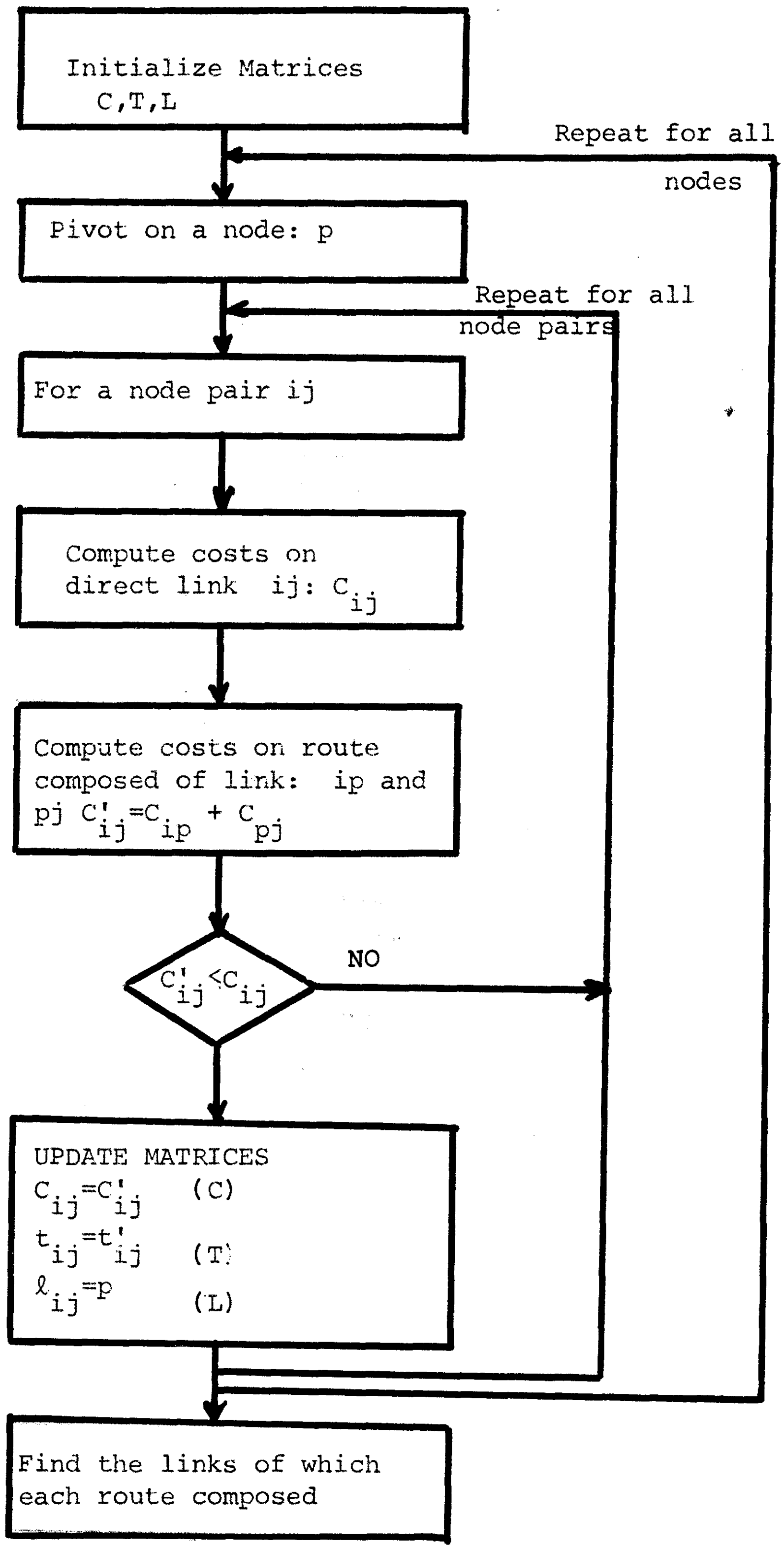


Figure 3.3.: Minimum Cost Route Algorithm

The steps of the algorithm are shown in figure 3.3. An example of the algorithm application is presented in Appendix 1 of this chapter.

Using the routing so determined, the transport costs by O-D pair may be computed. To the total operating costs found by the algorithm, we add the costs associated with the time lost in travelling, determined without taking in to consideration any costs resulting from possible congestion.

3.6.2. Congestion

If congestion occurs during anytime period, it will cause vehicles to lower their speeds, thus increase the travel times and transport cost. If the average traffic volumes on a link are given on a daily basis, which is usually the case, we must translate them to a distribution of volume levels, but on an hourly basis to determine whether congestion will occur or not. If one sampled the hourly volumes at many points in time, the result would be a distribution of hourly volume levels for the whole day. If speeds are determined at each volume level and the resultant ravel times weighted by the number of vehicles traveling at that volume level, the estimate of "average" conditions is much improved. The distribution of hourly volumes varies for different types of roads. In general, heavily traveled roads tend to have distributions in which the "peak volume" is skewed towards the higher volume levels, while the distributions of volumes on less traveled roads are heavily skewed toward very low volume levels. Roberts (16), introduced a probability mass function, which is analogous to the one resulting from the "binomial distribution". There are 4 Bernouilli trials, the sucess Y_k being whether the hourly volume will fall in the k^{th} volume level. Therefore, he measures the probability of each hourly volume level to be the same as the hourly volume on the link-which is unknown, the volume given on a daily basis. Thus without knowing the hourly volumes on a link, he comes up with an approximation of them, sufficient to help solving the congestion problem. His approach has been applied, as described belows.

3.6.2.1. Measuring the Traffic in Passenger Car units (PCU)

The traffic on the links is given in numbers of vehicles by vehicle type (cars, busses, trucks). A common unit of measure for traffic is needed in order to represent it. This is taken as one passenger car, all other vehicles are represented by passenger car units (CU). Factors are introduced for each vehicle type for this transformation.

The Highway Capacity Manual (41) considers a truck or a bus displacing several passenger cars in the flow on the road. The number of passenger cars that each truck or bus represents under specific conditions is termed the "passenger car equivalent" (PCE) for those conditions. Note that the passenger car units (PCU) for a truck is equal to its PCE. (Passenger Car Equivalents) In level terrain where trucks can maintain speeds that equal or approach the speed of passenger cars, it has been found that the average truck is equivalent, in a capacity sense, to between 2 and 3 passengers cars on 2-lane highways depending on the level of service. These values are appropriate for most downgrades as well. On upgrades, the passenger car equivalent of trucks may vary widely, depending on steepness and length of grade and number of lanes. For approximate analyses of operations on a given road, section it may be sufficient to apply an overall approximate equivalency factor to the road as a whole.

According to Highway Capacity Manual, for the case of two-lane roads, the difference, between truck speeds and passenger car speeds on grades, is what causes trucks to reduce the traffic volume carried by a road at any given level of service. The greater the speed difference, the greater is the reduction in any given volume, with corresponding increase in the passenger car units. Roberts (26) developed a formula to compute the PCE, for each vehicle type.

$$PCE\ (IV) = \frac{ROC \times SPEED\ (1) - SPEED\ (IV)}{10} + 2, \quad (3\text{-}2)$$

Where:

IV: the vehicle type

SPEED (1), SPEED (IV): the speeds of passenger car and vehicle type IV respectively (in km/hr)

ROC: is the increase in PCE for each kilometer per hour difference in speed

Roberts computes ROC taking into account factors such as the number of lanes (LANES), the type of surface (SURF), and the sight distance, using the rise and fall, in m/100m, (RFF) as a surrogate: Thus:

$$ROC = \frac{SURF \times RFF}{LANES-1} \quad (3\text{-}3)$$

and for the case of a two-lane road, it turns out to be:

$$ROC = SURF \times RFF \quad (3\text{-}4)$$

For the surface types, Roberts uses indices from 1 to 3; 1 being paved or surface treated road, 2 being gravel and 3 being earth road.

Considering only the surface type and the rise and fall of the road, this does not take into account the impact of the design standards of the road. Since, the other important factors in the road design standards are, besides the surface type and the sight distance, the horizontal alignment and the width of the road, it would be appropriate the introduce these as factors to determine the ROC. This is done with a road design index, RDI, taking values from 1 to 3, combining the roads surface type, the road width and the horizontal alignment. Since all these factors may be reflected in the design speed of the road, the RDI may be calculated if the design speed of the road is known. In our approach a formula is developed according to which RDI equals to 1, when the design speed is 100km/hr and to 3 if it is 25km/hr. Other values may be found through interpolation or applying the developed formula:

$$RDI = 3.67 - 0.027 \times V \qquad (3\text{-}5)$$

where:

V: the design speed of the road.

and,thus:

$$ROC = RDI \times RFF = (3.67 - 0.027 \times V) \times RFF \qquad (3\text{-}6)$$

Thus the RFF and the design speed of the road or the RDI must be inputs. In case that RDI is given, the design speed may be computed applying the equation:

$$V = 137.5 - 37.5 \times RDI \qquad (3\text{-}7)$$

Thus, using the above approach the traffic (ADT) is measured in PCU/day. Given is also the capacity of the road (CAP) in PCU/hr both directions. Assuming the movement will take place only 16 hours per day the daily capacity of the road is computed:

$$DCAP= 16 \times CAP \qquad (3-8)$$

3.6.2.2. Determining the Congestion Speeds

The ratio of the daily traffic volume and the road daily capacity

$$VOLCAP=\frac{ADT}{DCAP} \qquad (3-9)$$

may be used as a measure of congestion. According to Roberts (16), if VOLCAP turns out to be less than 0.1, no congestion is likely to occur in any hour of the day. Otherwise the variable RVOL is computed as a function of VOLCAP:

$$RVOL= 1.25 \times (VOLCAP- 0.10) \qquad (3-10)$$

Where, RVOL represents the probability in the Bernoulli trials of and hourly volume level to be equal to the hourly volume on the link. It is assumed that the probability is the same for all volume levels. The proposed probability mass function will be applied for 4 Bernoulli trials. The levels of hourly volumes are 5, represented by VOL (IP) (IP taking values from 1 to 5).

Each volume level is defined as a percentage of the hourly capacity of the road (CAP). Thus:

$$\begin{aligned} VOL\ (1) &= 0.10 \times CAP \\ VOL\ (2) &= 0.30 \times CAP \\ VOL\ (3) &= 0.50 \times CAP \\ VOL\ (4) &= 0.70 \times CAP \\ VOL\ (5) &= 0.90 \times CAP \end{aligned} \qquad (3\text{-}11)$$

The proposed probability mass function of the hourly volume level IP to be equal to the actual hourly volume on the link is given by:

$$VOL(IP) = \binom{4}{x} RVOL^{x} \cdot (1-RVOL)^{4-x} \qquad (3\text{-}12)$$

where:

X= IP-1, the index numbers for the hourly volute levels, as used in the probability mass function.

The f(IP) is represented in figure (3-4)

The resulting frequency distribution f(IP), is used to determine the equivalent number of vehicles VEHNO (IP), travelling at each volume level, (IP), according to the following equation:

$$VEHNO\ (IP) = \frac{2^{*}\ IP-1}{10} \ {}^{*}f(IP)^{*}DCAP \qquad (3\text{-}13)$$

The speeds of vehicles traveling in each volume level can now be determined by the relationship (a simplified linear version of the volume-speed curves so frequent in the literature):

$$VEL = V^{*}\ \left(1-\frac{VOL\ (IP)}{CAP}\right) \qquad (3\text{-}14)$$

where: V is design speed of the road.

3.6.2.3. Costs of Congestion

Having defined the VEL for each vehicle type IV, the weighted additional travel time is computed by the equation for each type IV:

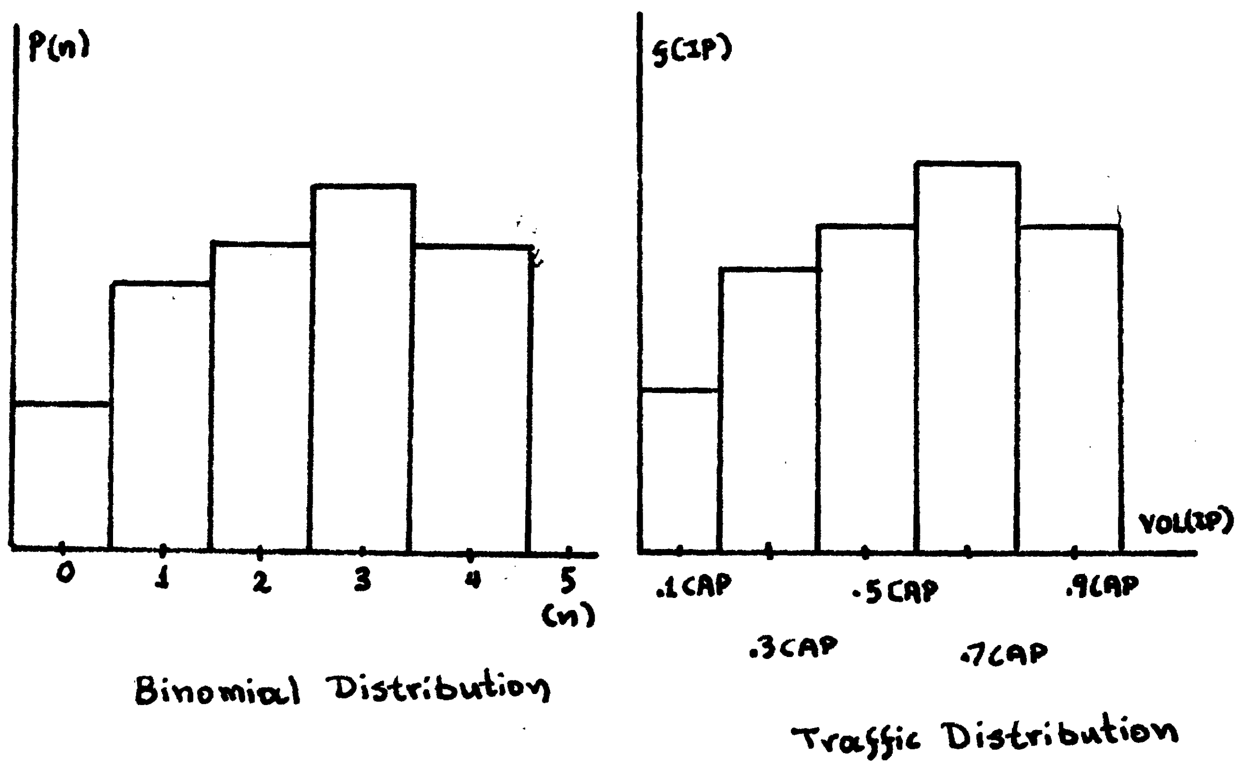


Figure 3.4: Comparison of Artificial Traffic Distribution and Binomial Distribution

$$AAT(IV) = \frac{\sum_{IP=1}^{5} \left((AT\ (IP) * VEHNO\ (IP) \right)}{ADT} \qquad (3\text{-}15)$$

where:

AAT (IV)= weighted additional travel time of vehicle type IV

AT (IP)= the additional travel time of vehicle type IV, if it was in volume level IP, given by the equation: (T being the travel time on the link without congestion):

$$AT\ (IP) = \frac{V\text{-}VEL\ (IP)}{V} * T \qquad (3\text{-}16)$$

TRAF (IV)= number of vehicles of type IV

ADT = average daily traffic in PCU/day

VEHNO (IP): equivalent daily volume of level IP, in PCU/day

The additional travel time is multiplied by the value of the time, to give the costs of congestion for each vehicle type.

An example of the approach is presented in Appendix 2 of this chapter.

3.7. Benefits resulting from the Improvement

Using total transport costs for the vehicle movement form origin to destination, the benefits attributable to changes in the network can be defined. They are computed by comparing the transport costs of each O-D pair after the improvement and before. The benefits are the savings, in transports costs, accruing to the network users underneath the demand curve. If the demand curve is unavailable an approximation that can be made is given by the equation:

$$BEN = \Delta\Theta \cdot T^{o} + 0.5 \cdot \Delta\Theta \cdot \Delta T \qquad (3\text{-}17)$$

where:

$\Delta\Theta \cdot T^o$: benefits to normal traffic (T^o), after unit transport cost reduction,

$0.5 \cdot \Delta\Theta \cdot \Delta T$: benefits from the induced traffic (ΔT); after the unit transport cost reduction, $\Delta\theta$

This equation is another expression of the "consumer surplus" resulting from the improvement. The induced traffic, ΔT, is the difference between the traffic before the improvement (T^o) and the traffic after (T').

$$\Delta T = T' - T^o \qquad (3\text{-}18)$$

and thus equation 3-17 will be transformed to:

$$BEN = 0.5 * (T' + T^o) * \Delta\Theta \qquad (3\text{-}17a)$$

the familiar form of the "consumer surplus". The increase in O-D traffic will result if the demand is elastic with respect to ransport costs. Thus, if ELA is the elasticity of demand with respect to costs and Θ^o, Θ', the transport costs before and after the improvement:

$$T' = T^o \cdot \left(\frac{\theta'}{\theta^o}\right)^{-ELA} \qquad (3\text{-}19)$$

This is resulting from the definition of the demand function:

$$T_1 = A \cdot \Theta_1^{-ELA} \qquad (3\text{-}20)$$

where:

T_1 : the traffic (demand) at unit transport cost

Θ_1: the unit transport costs

ELA: elasticity of demand with respect to costs (positive)

A: a constant

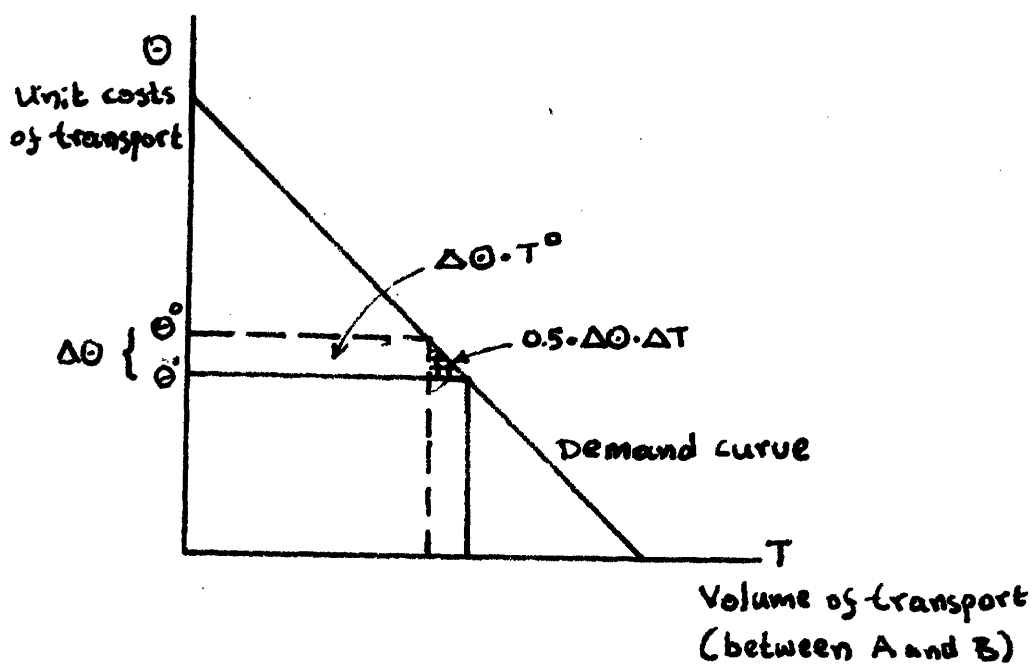


Figure 3.5: Transport Demand Function

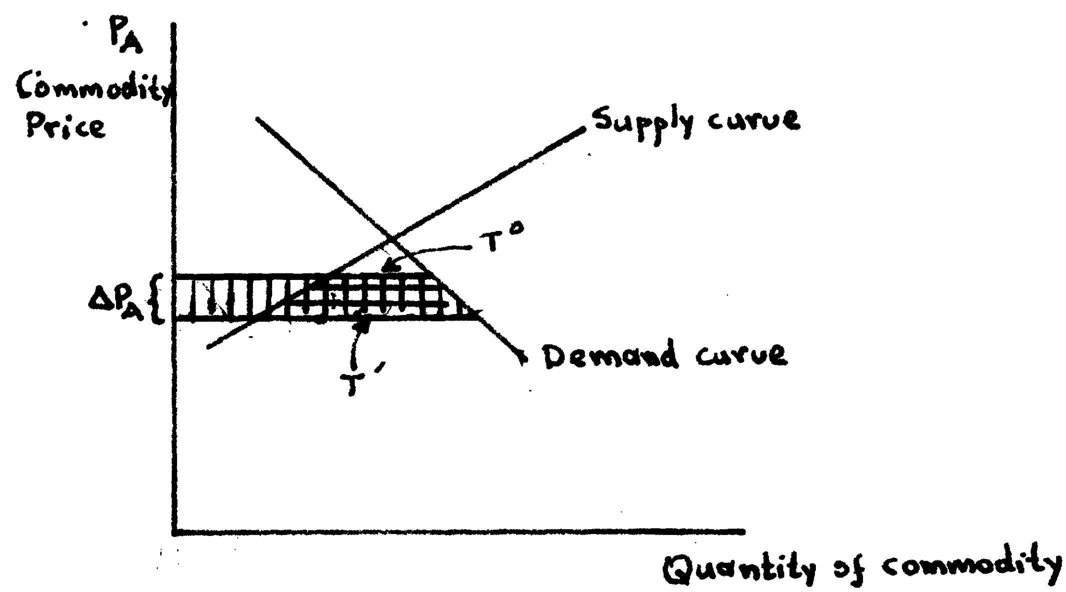


Figure 3.6: The Market for a Transported Commodity in node A (consumption)

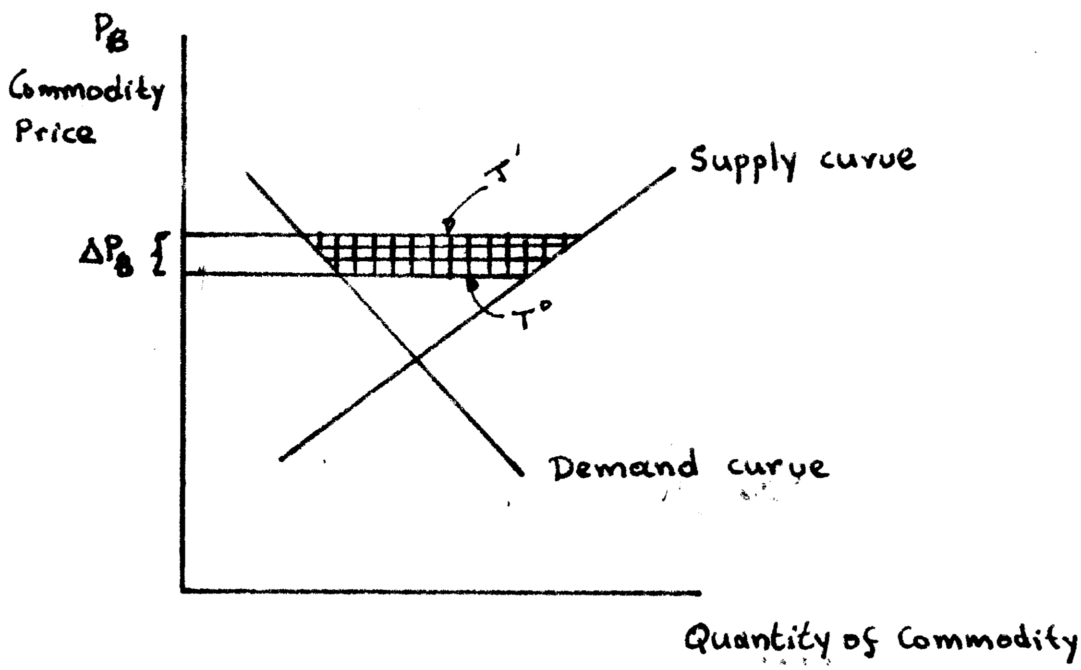


Figure 3.7: The Market for a Transport Commodity in node B (production)

Figure 3.5 represents the benefits by the shaded area.
It will be proved that these benefits are equal to the benefits accruing to the consumers and producers of the transported commodites, considering an one commodity transport between two regions (represented by the O-D pair), with no other transport made to share the transport. Another assumption is the indifference with respect to benefit distributions between the two regions and between producers and consumers. Furthermore, it is assumed that the commodity is produced in region B and consumed in region A.

The two regions are connected by a single road and due to the assumed abscence of competitive transport, all the volume of the commodity has to use the road-therefore the transport costs are common for each alternative improvement strategy of the road. The equilibrium between supply and demand (see figures 3.6, 3.7) before any improvement sets the per unit price of commodity in A equal to the per unit cost of production in B plus the unit transport costs (which in this case is assumed to be invariant with respect to the volume of transport measured in units of commodity). Similarly, the equilibrium between A and B equal the difference between the per unit price of the commodity in region A and the per unit cost of production of the commodity in region B. (Again the transport costs are assumed to be invariant).

Thus,

$$\Theta = P_A - P_B \qquad (3\text{-}21)$$

Where:

Θ: the unit transport costs between A and B

P_A: unit price of commodity in A

P_B: unit cost of production of commodity in B

Denoting by (^{o}) the case before the improvement, and by ($'$) the case after the improvement, we have:

$$\Theta^o = P_A - P_A^o$$

$$\Theta' = P_A - P_B \qquad (3\text{-}22)$$

The change in unit price of commodity is A due to the improvement is:

$$\Delta P_A = P_A - P_A^o \qquad (3\text{-}23a)$$

since P_A^o a greater than P_A' (price reduction after the improvement), ΔP_A is negative.

The change of the unit costs of commodity in B is:

$$\Delta P_B = P_B - P_B^o \qquad (3\text{-}23b)$$

Since P_B' greater than P_B^o (cost increase), ΔP_B is positive.

Then change in unit costs of transport are:

$$\Delta\Theta = \Theta^o - \Theta' \qquad (3\text{-}24)$$

since Θ' less than Θ^o (trnasport cost reduction), $\Delta\Theta$ is positive. Substituting the Θ' and Θ^o in the equation 3-24 from equations 3-22 the outcome is: $\Delta\Theta = \Delta P_B - \Delta P_A$ (3-25)

To prove that equation 3-17 gives the benefits to the consumers and producers of the two regions, figures 3.6 and 3.7 are required as reference. The price of commodity in an A falls but the cost in B rised when the transport costs fall. At the same time the volume of traffic increases from T^{o} to T'. The increase equals the excess demand in A plus the excess supply in B. In region A, the consumers surplus $\left[\frac{T^{o}+T'}{2}\cdot\Delta P_A\right]$ is offset by the producers losses $\left[-\Delta P_A\cdot(T^{o}+T')\right]$ Therefore the benefits of region A (shown in the shaded area of Figure 3.6) are:

$$BEN_A = -\Delta P_A\cdot\frac{T^{o}+T'}{2} \qquad (3\text{-}26)$$

Similarly, in region B, a part of the producers surplus $\left[\Delta P_B(T^{o}+T')\right]$ is offset by the consumers losses $\left[-\Delta P_B\cdot\frac{T^{o}+T'}{2}\right]$ Therefore the benefits of region B (shown in the shaded area of Fig. 3.7) are:

$$BEN_B = \Delta P_B\cdot\frac{T^{o}+T'}{2} \qquad (3\text{-}27)$$

The toal benefits for both regions are:

$$BEN = 0.5\cdot\Delta\Theta\cdot(T^{o}+T') \qquad (3\text{-}28)$$

which is the same expression as in the one in 3-17.

These are the benefits observed when we improve a route connecting two regions. What about constructing a new road that will connect two regions, previously unconnected? It is obvious that before the construction no demand of the commodity was existed. However, a potential demand would be up to a maximum of T^{o} units of commodity; where $T^{o} = A\cdot(\theta^{o})^{-ELA}$

θ^{o} being the difference between the price of commodity in region A (consuming region) and the cost of production in region B (producing region). That is: $\Theta^{o} = P_A^{o} - P_B^{o}$ (3-21a)

The new road will reduce the transport costs to and the new prices will be P_A' and P_B' as a result the new volume would be $T' = A\cdot(\theta')^{-ELA}$ and the benefits will be measured as previously.

3.8 Evaluation Criterion

Using the costs and benefits computed for every alternative improvement strategy, they must be ranked as the next step is the evaluation process. There are four principal economic evaluation criteria: annual costs, benefit cost ratio, rate of return, and net present value. It must be stressed that each of these techniques has associated with it, in one way or another, an interest rate and a period of analysis, or time horizon. The net present value criterion has been introduced to the model as the evaluation criterion. With this method, present and future costs and benefits are discounted to the present and summed and the difference between the two sums in computed. Strategies having a net present value less than zero is unacceptable and that strategy with the highest net present value will be most desirable, when chossing among mutually exclusive alternatives. The reasons why the net present value is chosen as criterion instead of another, due: (i) the NPV method will always give single valued results; (ii) allows inflation costs to be considered as a component of the discount rate; (iii) provides good relative ranking among alternatives with similar cash flows. It requires, however, a reasonable choice of a discount rate, being the critical issue of the evaluation.

APPENDIX 1: Example about Assignment

The following example will illustrate the effectiveness and the simplicity of the minimum cost route algorithm (3.6.1). In the figure 3.8 a network is represented with the associated vehicle operating costs on the links (it is assumed vehicle type 1) and travel times. We construct the matrices C, T, L, as follows for the different itterations.

C

	1	2	3	4	5
1	-	4.5	10^7	12.0	7.0
2	4.5	-	8.0	10^7	10^7
3	10^7	8.0	-	5.0	10^7
4	12.0	10^7	5.0	-	5.0
5	7.0	10^7	10^7	5.0	-

T

	1	2	3	4	5
1	-	20	10^7	60	30
2	20	-	40	10^7	10^7
3	10^7	40	-	25	10^7
4	60	10^7	25	-	25
5	30	10^7	10^7	25	-

L

	1	2	3	4	5
1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5

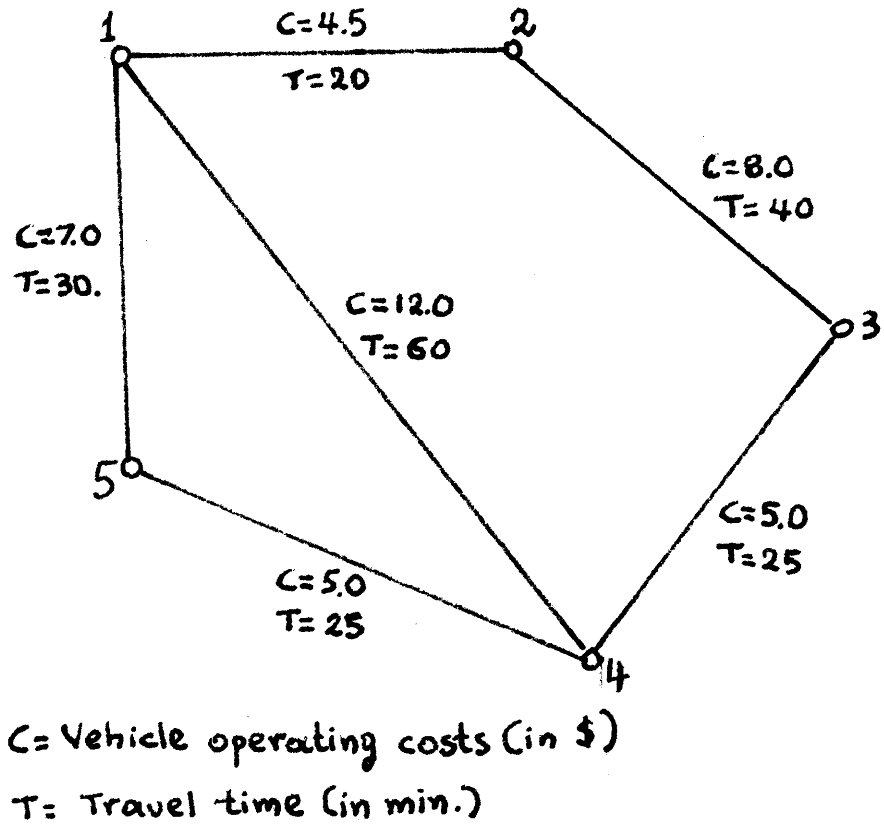


Figure 3.8: The Network of Roads

1st iteration: Pivot on node 1

C

	1	2	3	4	5
1	-	4.5	10^7	12	7
2	4.5	-	8.0	16.5	11.5
3	10^7	8.0	-	5.0	10^7
4	12.	16.5	5.0	-	5.0
5	7.0	11.5	10^7	5.0	-

T

	1	2	3	4	5
1	-	20	10^7	60	30
2	20	-	40	80	50
3	10^7	40	-	25	10^7
4	60	80	25	-	25
5	30	50	10^7	25	-

L

	1	2	3	4	5
1	1	1	1	1	1
2	2	2	2	1	1
3	3	3	3	3	3
4	4	1	4	4	4
5	5	1	5	5	5

2nd iteration: Pivot on node 2

C

	1	2	3	4	5
1	-	4.5	125	12.0	7.0
2	4.5	-	8.0	16.5	11.5
3	12.5	8.0	-	5.0	10^7
4	12	16.5	5.0	-	5.0
5	7.0	11.5	10^7	5.0	-

T

	1	2	3	4	5
1	-	20	60	60	30
2	20	-	40	80	50
3	60	40	-	25	10^7
4	60	80	25	-	25
5	30	50	10^7	25	-

(Cont. 2^{nd} iteration)

L

	1	2	3	4	5
1	1	1	2	1	1
2	2	2	2	1	1
3	2	2	3	3	2
4	4	1	4	4	4
5	5	1	5	5	5

3^{rd} iteration: Pivot on node 3

C

	1	2	3	4	5
1	-	4.5	12.5	12.0	7.0
2	4.5	-	8.0	13.0	11.5
3	12.5	8.0	-	5.0	10^7
4	12	13.0	5.0	-	5.0
5	7.0	11.5	10^7	5.0	-

T

	1	2	3	4	5
1	-	20	60	60	30
2	20	-	40	65	50
3	60	40	-	25	10^7
4	60	65	25	-	25
5	30	50	10^7	25	-

L

	1	2	3	4	5
1	1	1	2	1	1
2	2	2	2	3	1
3	2	2	3	3	2
4	4	3	4	4	4
5	5	1	2	5	5

4th iteration: Pivot on node 4

C

	1	2	3	4	5
1	-	4.5	12.5	12.0	7.0
2	4.5	-	8.0	13.0	11.5
3	12.5	8.0	-	5.0	10.0
4	12	13.0	5.0	-	5.0
5	7.0	11.5	10	5	-

T

	1	2	3	4	5
1	-	20	60	60	30
2	20	-	40	65	50
3	60	40	-	25	50
4	60	65	25	-	25
5	20	50	50	25	-

L

	1	2	3	4	5
1	1	1	2	1	1
2	2	2	2	3	1
3	2	2	3	3	4
4	4	3	4	4	4
5	5	1	4	5	5

5th iteration: Pivot on node 5

C

	1	2	3	4	5
1	-	4.5	12.5	12.0	7.0
2	4.5	-	8.0	13.0	11.5
3	12.5	8.0	-	5.0	10.0
4	12	13.0	5.0	-	5.0
5	7.0	11.5	10.0	5.0	-

T

	1	2	3	4	5
1	-	20	60	60	30
2	20	-	40	65	50
3	60	40	-	25	50
4	60	65	25	-	25
5	30	50	50	25	-

(cont. 5th iteration)

	L 1	2	3	4	5
1	1	1	2	1	1
2	2	2	2	3	1
3	2	2	3	3	4
4	4	3	4	4	4
5	5	1	4	5	5

Therefore the minimum cost route for each O-D pair has been found. e.g For the (2-5) pair, the vehicle operating costs are $11.5, the travel time 50 minutes, and the route is (2-1), (1-5).

APPENDIX 2: Example about Congestion

This is an example to show how the approach of computing congestion costs can be applied. The following data is assumed for the example:

CAP (road capacity): 2000 PCU/hr and DIS (Length): 100kms;

Road Design speed: 95 km/hr; rise and fall: 3.0m/100m ;

The number of vehicles per vehicle type and their speeds are:

	VEHICLE TYPES			
	1	2	3	4
Medium volume road traffice	800	400	500	400
Low volume road traffice	100	100	50	80
Speed (in km/hr)	70	60	55	50

a. Road design index (RDI) and road condition factor (ROC)

RDI= 3.67 - 0.027 *95= 1.1

ROC= 3*1.10= 3.3

b. Vehicles Equivalent factors is given by (3-2) So:

PCE (1)= 1., PCE (2)= 5.3, PCE (3)= 6.95, PCE (4)=8.6

c.1 Average daily traffic: (low volume road)

ADT= 1565 PCU/day

d. Daily link capacity: DCAP= 16 *CAP=32000 PCU/day

e.1 Volume to capacity Vatio:

$$VOLCAP=\frac{1565}{32000}=0.05$$ less than 0.10. Therefore no congestion will occur.

c.2. Average daily traffic (Medium volume road)

ADT= 9250 PCU/day

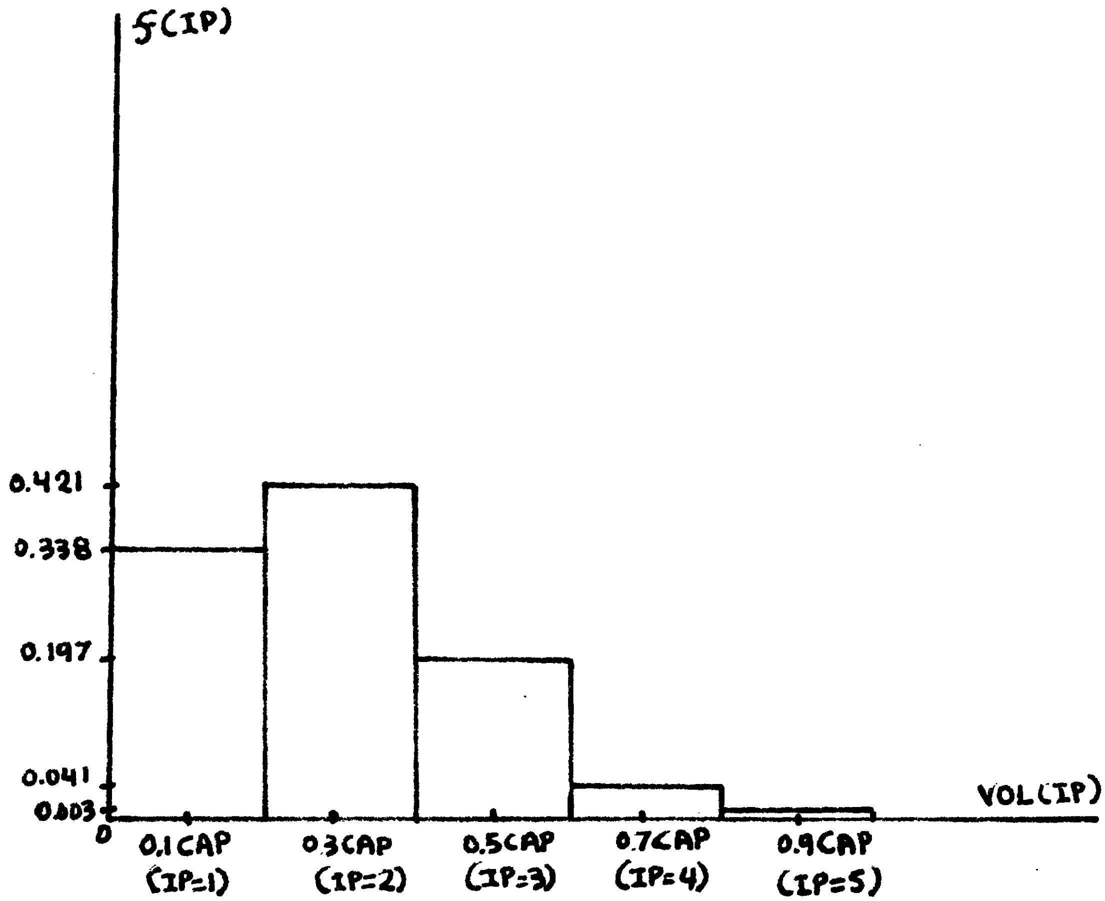


Figure 3.9: The Traffic Distribution

e.2 Volume to capacity vatio:

$$VOLCAP=\frac{9280}{32000} = 0.29$$

f. Probability mass function (represented infigure 3.9)

RVOL= 1.25 *(VOLCAP - 0.10)=0.2375

$f (1) = 1.*(1\text{-RVOL})^4 = 0.338$

$f (2) = 4* \text{RVOL} \times (1\text{-RVOL})^3 = 0.421$

$f (3) = 6* \text{RVOL}^2 \times (1\text{-RVOL})^2 = 0.197$

$f (4) = 4* \text{RVOL}^3 \times (1\text{-RVOL}) = 0.041$

$f (5) = 1*\text{RVOL}^4 = 0.003$

g. Equivalent number of vehicles

VEHNO (1) = 0.338 *3,200 = 1,081.6

VEHNO (2) = 0.421 *9,600 = 4,041.6

VEHNO (3) = 0.197 *16,000= 3,152.

VEHNO (4) = 0.041 *22,400= 918.4

VEHNO (5) = 0,003 *28,800 =86.4

h. Vehicle speeds on each volume level

Road design speed: V=95.

$VEL (1) = 95 * (1-\frac{200}{2000}) = 84.6$

VEL (2) = 95 * 0.7 = 65.8

VEL (3) = 95 * 0.5 = 47.

VEL (4) = 95 * 0.3 = 28.2

VEL (5) = 95 * 0.1 = 9.5

j. Additional travel time for the vehicles of type I

Additional travel times if it was at volume levels 1,...,5

AT (1)= 0. (VEL (L)) speed of vehicle type I)

AT (2)= $\frac{100}{65.8} - \frac{100}{70}$ = 1.52 - 1.43= 0.09 hrs.

AT (3)= 2.13 - 1.43= 0.70 hrs.

CHAPTER FOUR

THE NETWORK SIMULATION MODEL

4.1 Overview

The developed model generates, screens and evaluates network development strategies for a rural road networks. Given actual road network demand on an origin-destination basis, and potential demand, if road service were provided, and data on the cost and value of potential investments on network links, the model generates sequences of link investments, screens them for overall value and satisfaction of economic constraints, and allows cost-benefit analysis of the most interesting strategies. The model is integrated with the Highway Cost Model which carries out a simulation and evaluation of the investment strategies for a single link. It may deal with the individual link with the accuracy of the HCM or use more aggregate costs. Its final output may be a ranked list of network strategies, with their evaluation, and the timing of each of the link investments.

The model consists of four computer packages and their data files. The data files store network configuration and strategy data, link strategy data, and origin-destination demand data. The packages are an input data processor, the Highway Cost Model (HCM), a network strategy generator, and an evaluator which simulates the operation of the network over the analysis time span. The model simulates the construction and maintenance activities of each link by using government costs, segregated by local and foreign currency etc., developed by the

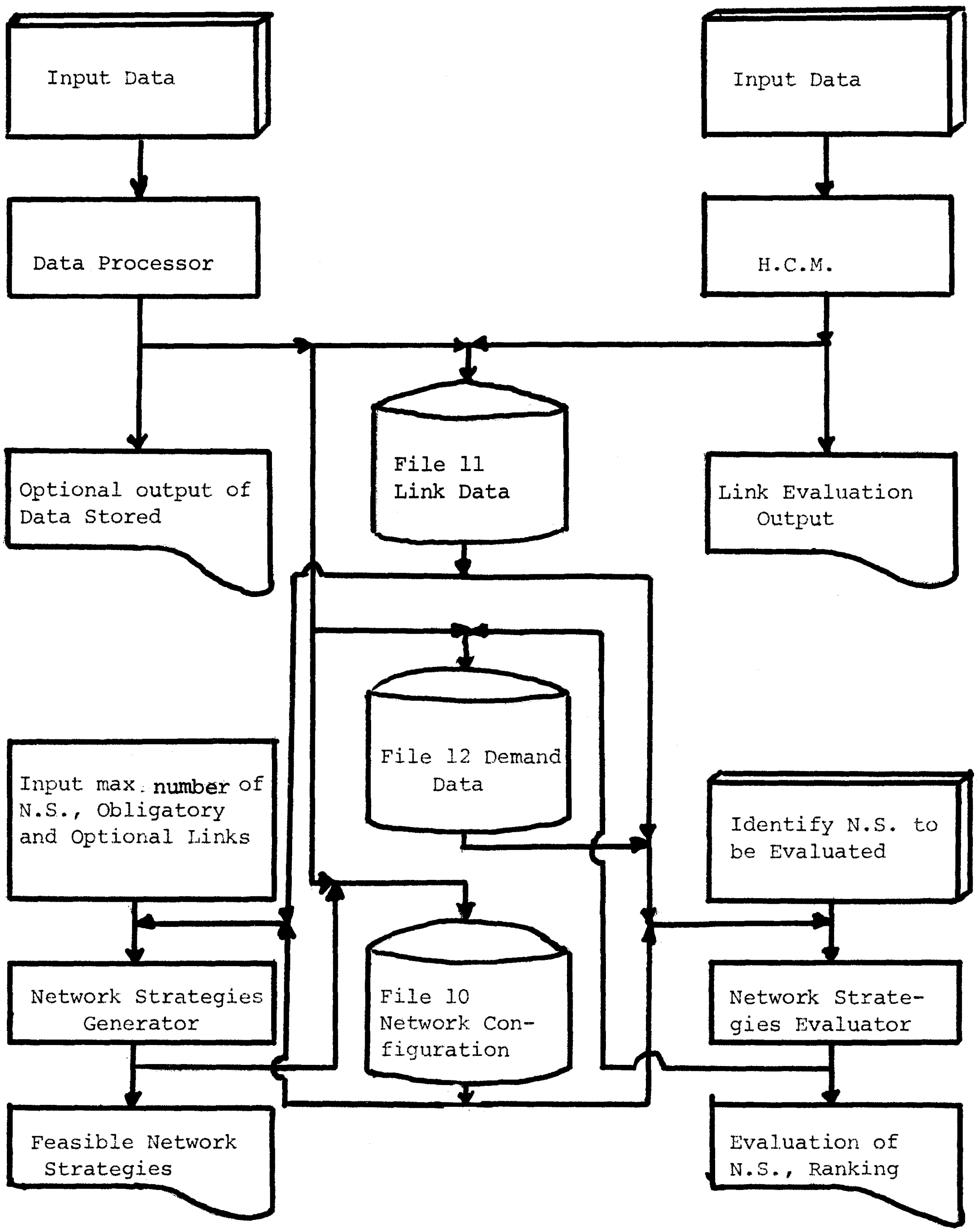


Figure 4.1.: Network simulation system flow

HCM or elsewhere. Simulation of the network operation includes the routing of traffic, based on vehicle operating costs, using a minimum cost path criterion. The flow of information in the model is shown on figure 4.1.

The generation of network strategies, to be evaluated and ranked later, is based upon two types of constraints and a single criterion. The first constraints are limits on the timing of link strategies, the amount by which such a strategy can slip in time from its initial sequencing with the HCM. The second are constraints on the capacity for constructing and maintaining the network. Initially we included financial and skilled manpower constraints by regions of the road network. To limit and choose among the large number of remaining potential combinations of link strategies, the model, allows the analyst to assign a social criticality index for each link strategy. The criteria for choice of strategies is to maximize the cumulative criticality indices for included strategies. Only a small number of strategies are kept and evaluated at the analyst's request.

The evaluation of the network strategies follows the simulation of network performance over the time horizon during which: it finds the route of the vehicles from an origin to a distination, computes the total transport costs, compares them with those of the base strategy- i.e., the network to be changed or remain the same according to a present plan-, performs the demand adjustments and computes the benefits, i.e. the savings in transport costs.

4.2 Link simulation (HCM)

The link is simulated by the HCM over the time horizon of interest. All the activities of construction and maintenance are simulated and therefore the financial and economic costs are computed, giving the total expenditures for the road link in each year over the time horizon. Also, the HCM simulates the vehicle operation of a link according to the road conditions but not considering the presence of other vehicles on the link. The network simulation model takes the information about the vehicle operation costs and simulates the vehicle operation according to the traffic calculated to be on the link. Any delays due to possible congestion are computed and the total transport costs on the link for each vehicle type are calculated as the operation costs plus the time loss costs.

It is useful to point out that a link is composed of different segments. Each one may have different surface type, alignment etc. Each project is redated to one segment and consists of upgrating or changing the surface type, applying a certain maintenance policy. The HCM simulates the different projects on the link over time, simulates the vehicles operations on the link, then computes the resulting financial and economic costs. Note that a link strategy to be used as a term later is a series of projects over time on the link.

4.3 Network strategies generation

The purpose of each network strategy is to specify a feasible program to improve the existing network over the time horizon. The existing network, or base network, consists of the links, in the condition they are in the beginning of the time horizon plus any link improvements or additions, which are fully fixed and have been decided in advance by the decision makers, and not to be changed or delayed. To be feasible, it must satisfy regional budget, foreign exchange and skilled labor constraints in each year. The network strategies are generated from the link strategies introduced by the decision maker. Two types of link strategies are considered; mandatory strategies, with no restriction of when they will be implemented and optional strategies. In using these terms, we are naming the link upgrading strategies as link strategies. For a link multiple strategies may be proposed for implementation and it is up to the model to choose the one to be part of the network strategy.

The generation is coordinated with a branch and bound technique. Because of large calculation requirements, it is not looking for the best feasible solution but for a reasonable set of feasible solutions.

A network strategy is generated as follows: All obligatory links are to have one of their strategies included in the network strategy. The sum of the critical indices of the obligatory link strategies is compared with the network minimal index. If the sum is less, links from the optional set are included until either the minimum critical index is reached or there is no link left to be included. A link strategy critical index is an arbritary number set by the decision maker. It may reflect the priorities for the link strategies set by the decision makers. The higher it is, the more likely for the link strategy to be included in a feasible network strategy. It may merely reflect the importance of a link according to decision maker's intution, it may be set high to include a specific link and its importance of connecting remote areas, or it may reflect the importance of a link to the economic activities of an area. The network strategies minimal critical index is very important, since it prunes all network strategies with lower critical indices than it.

When the preliminary network strategy has been generated, it is tested to see that it verifies the constraints (regional budget, skilled labor and foreign exchange) for each year. If it does, then the generated preliminary network strategy is feasible, and one the strategies of the optional links will be included, but the link will be different than the ones, the network strategy consists of. If one of the constraints is not verified then the model tries to slip the last included link strategy by a number of years (not exceeding the specified maximum slippage for each link strategy) to have the constraints verified. If this can be accomplished the generated network strategy is feasible and it proceeds to generate another one. If the verification of constraints is impossible, it tries to include another link strategy, if available, of the same link, and it tests if the constraints are verified. If they are not, it slips it by a number of years (less than the allowable slippage). If the constraints are verified, it proceeds to generate another one, otherwise it tries to include another link strategy of the same link. If there is one, the same procedure will be repeated, otherwise it drops the link from the network strategy and tries to fit another one, repeating the same. If none of the remaining links can be fitted in the network strategy, it generates the network strategy as it is. If a link strategy is included, it searches for one from another link to be added. It repeats the same procedure until either no more links are available or no more link strategies can be included in the network strategy. Had the number of feasible network strategies equaled the number of strategies to be generated, as specified by the decision maker, the algorithm keeps the ones with the highest critical indices. However, it keeps only a specified percentage of the generated ones. These are the ones to be evaluated by the network strategies evaluator and be ranked according to their computed NPV's.

4.4. Network strategies evaluation

4.4.1 Base network strategy

The base network strategy establishes the basis for evaluation, since it is to if that strategy against which other network strategies are compared. The base network is the existing network in the beginning of the time horizon; plus link improvements or additions, which are fully fixed, decided in advance by the decision makers, not to be changed or delayed.

The base network is simulated to the same detail as other network strategies. The demand for each O-D pair may change over the years of the time horizon, as specified by input. This input is based on 1st year transport costs; thus, the input demand for other than the 1st year is computed from the first year applying the annual growth factors, not taking into account any change in transport costs.

4.4.2 Demand adjustments

For the base network transport demand may change over the years, if the transport costs have changed. This is the result of the demand function: (equation 3.20).

$$T=A\cdot\theta^{-ELA} \qquad (4\text{-}1)$$

if θ changes, so will T; (since the demand is sensitive to transport price changes if the price elasticity is not zero). Therefore the new demand will be:

$$T' = A\cdot(\theta')^{-ELA} \qquad (4\text{-}2)$$

Since the initial demand is known, as well as the transport costs, dividing the two expressions:

$$T' = T\cdot\left(\frac{\theta'}{\theta}\right)^{ELA} \qquad (4\text{-}3)$$

Where:

ELA: elasticity of demand with respect to price
T,T': traffic demands before and after the improvement
θ,θ': unit transport costs before and after the improvement.

Demand adjustment will happen also when a network strategy is considered. However, this will be the outcome of change in transport costs those of base network as opposed to those of the network under consideration. In this case θ is the transport cost of the base network and θ' the transport costs of the new network. The transport costs may increase if congestion occurs. Thus, the model checks if congestion exists at any link and if it does the transport cost are updated properly and the demands are adjusted.

4.4.3 Network simulation

For every network strategy the network is simulated through the time horizon having the specified characteristics and road conditions by the network strategy under evaluation. The simulation is done for these years of the time horizon, during which an improvement has been terminated or the demand at least for one O-D pair has changed. At the analyst's request the simulation may be done for any year specified by him. The benefits and the costs from one year to the other will remain the same, if no improvement has been undertaken or any change in demand structure has been noticed:

The simulation is done as follows:

a. For each link the passenger car equivalents, PCE, for every vehicle type are computed according to the road conditions, applying equations 3-2 and 3-3. .

b.1 For an Origin-Destination pair the minimum transport cost route is found for every vehicle type, and the corresponding economic and financial transport costs are computed. (The process is described in § 3.6.1).

b.2 If the economic transport costs are greater than the price, the user is willing or could afford to pay for the transport, no traffic will be generated from the origin.

b.3 Otherwise, the traffic generated is assigned to the links that belong to the O-D pair minimum cost route. The traffic is computed in number of vehicles per vehicle type and in passenger car units, PCU, applying the computed PCE

c. The steps (b.1),(b.2) and (b.3) are repeated for all O-D pairs for which demand exists.

d.1 For each link the possibility of congestion is checked. If it is not congested, no change in the already computed transport cost will be made. In case it is congested, the congestion costs, due to the additional travel time are computed, and added to the already calculated transport costs. (The process is described in § 3.6.2).

d.2 The step d.1 is done for all links of the network, thus the total transport costs for all vehicle types are calculated.

e. For each O-D pair the demands are adjusted for the new transport costs applying the equation:**4-3**:

$$T' = T \cdot \left(\frac{\theta'}{\theta}\right)^{-ELA}$$

where:

T' : the new demand

T : the demand as it would be, if the base network strategy was applied

θ' : the new transport costs

θ : the transport costs, if the base network strategy was applied.

ELA: the elasticity of demand with respect to transport costs. The demand is measured in number of vehicles (in case that it is given in tons for the commodities, dividing the tons by the vehicle capacity times the load factor, we come out with the number of vehicles). If no route existed before the improvement connecting the two nodes, (O-D), θ is set to be the maximum transport costs the user is willing to pay for the transport. In the case of a commodity this maximum cost is the difference of the selling price at destination and the production costs at the origin. Having the simulation done, we may proceed to evaluate the network strategy comparing it with the base network strategy.

4.4.4 Network strategies evaluation

To do the evaluation the benefits and the cost of the network strategy must be calculated. The network strategy costs, are the economic costs associated with the activities of construction and maintenance proposed by the strategy, less those costs of the base network strategy. They are calculated for each year of simulation, remaining the same until the next simulation.

The benefits are computed for each year of the simulation, and for each O-D pair generally applying the equation 3-17 :

$$BEN = \frac{1}{2} (T+T') \cdot \Delta\theta \qquad (4-4)$$

for every vehicle type. (The variables are as specified in page. The total benefits of the year are the sum of the benefits al all O-D pairs. They remain the same until the next simulation. There are some special cases to be considered in calculating the benefits:

i. If no traffic exists between an origin-destination pair, although there is potential demand, the benefits are zero.

ii. If no route existed before the improvement connecting an origin to destination, although there is potentional demand, the benefits are computed applying equation (4-3). However, instead of θ being the transport costs of the base network strategy- which in this case would be infinity since no route exists-, θ equals to the maximum price the user could affort to pay for the transport between origin to destination.

Having computed both costs and benefits the calculation of the net benefits is done:

$$NETBEN = BEN-COSTS \tag{4-5}$$

Finally, the net present value of benefits and costs is calculated discounting the net benefits to the present and adding them for all years:

$$NPV = \sum_{I=1}^{N} NETBEN*(1+r)^{-(I-1)}$$

where:

r: the discount rate and I: the year number.

Thus, the network strategy has been evaluated. It will be compared with the others and finally a ranking of the generated network strategies will be undertaken, the first being the one with the greater net present value. This will be the strategy recommended by our approach for implementation.

The following application of the model in Ethiopia's regional network of Asela-Dodola will show its capabilities and possible limitations from the introduced assumptions.

CHAPTER FIVE

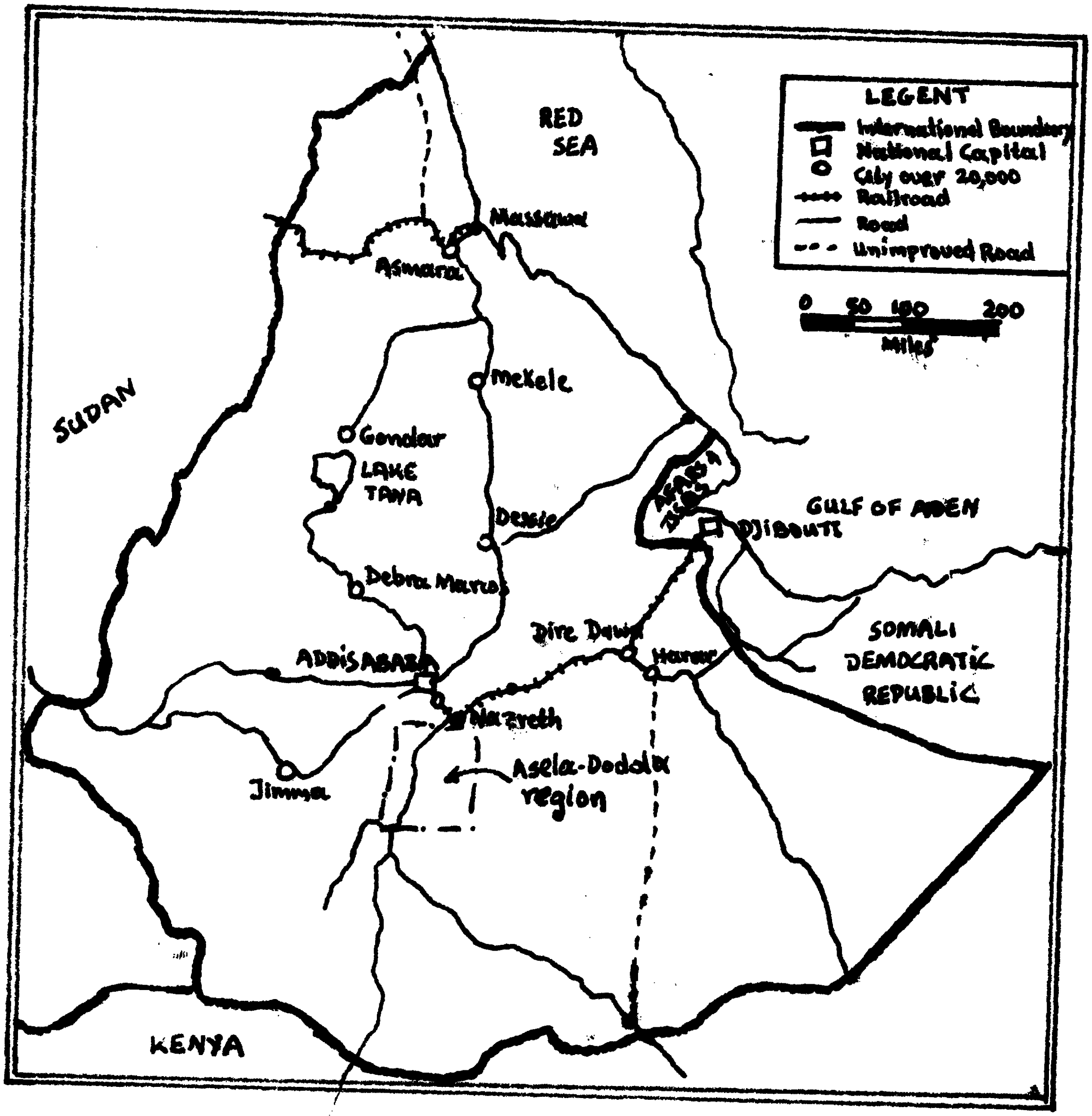
APPLICATION OF THE MODEL IN ETHIOPIA

5.1 Ethiopia

Ethiopia lies in the Horn of Africa, the north-east of the continent bordered by the Indian Ocean and the Gulf of Aden. The country is situated just north of the Equator, and is bounded to the east by Somalia and the French Territory of Afars and Issas, so that its own costline of about 1,000 kms lies on the Red Sea. Ethiopia's other neighbors are Kenya, to the south, and Sudan, to the west. (A map is provided in the next pages).

Its area is 1,220,000 square kilometres, mainly high plateaux and mountains. The official population is 26,000,000 people, and the annual growth rate ranges 2.0% to 2.6%. In terms of urban areas, there are only two cities of significant size: They are Addis Ababa, the capital with a population of 1,000,000 and Asmara with a population approaching 300,000. All other towns, including the provincial capitals, have a population of less than 50,000. With 90% of its population living in the countryside, Ethiopia is basically an agricultural country. Ethiopia's economy is to a large extent dependent on farming and cattle raising. At present, Ethiopia's main crops are teff (staple food of the Central Highlands), maize, sorghum, wheat, barley, soybeans, coffee, oil, seeds, pulses, cotton and sugar cane.

Ethiopia's major industry is construction followed by textile, food and beverage processing and marketing. Most of the industries are located in or near the three largest cities, Addis Ababa, Smora and



Map 1 - Ethiopia

Diredawa. The handful of major industries not located in these cities are widely scattered and include a refinery, a cement factory, a textile mill and two sugar factories. The country's only sea ports are at Assab and Massawa.

Ethiopia's main imports are machinery, vehicles, spare parts, crude oil, rubber, electrical supplies and building materials.

5.2. Ethiopia's transport network

Ethiopia's development has been hindered by the slow improvement and growth of its transportation network. In a country that covers 1,300,00 square kilometers, the total length of its transport network of roads and railroads is limited to 30,000 kms. The country has two lines of railroad, one from Massawa to Asmara and from Djibouti to Addis Ababa. The Ethiopian Highway Authority (EHA) is responsible for the maintenance of 7,000-8,000 kms of existing all weather roads and some 16,000-20,000 kms of dry weather roads including trails made "servicable" by the provincial authorities. The EHA is responsible for the planning, supervision and maintenance of the most additions to the road system. Domestic air transportation is minimal although about 50 towns over the country are serviced. Freight movement by air is limited to coffee shipments from a few regions that lack adequate surface transportation. The bulk of air traffic is passenger.

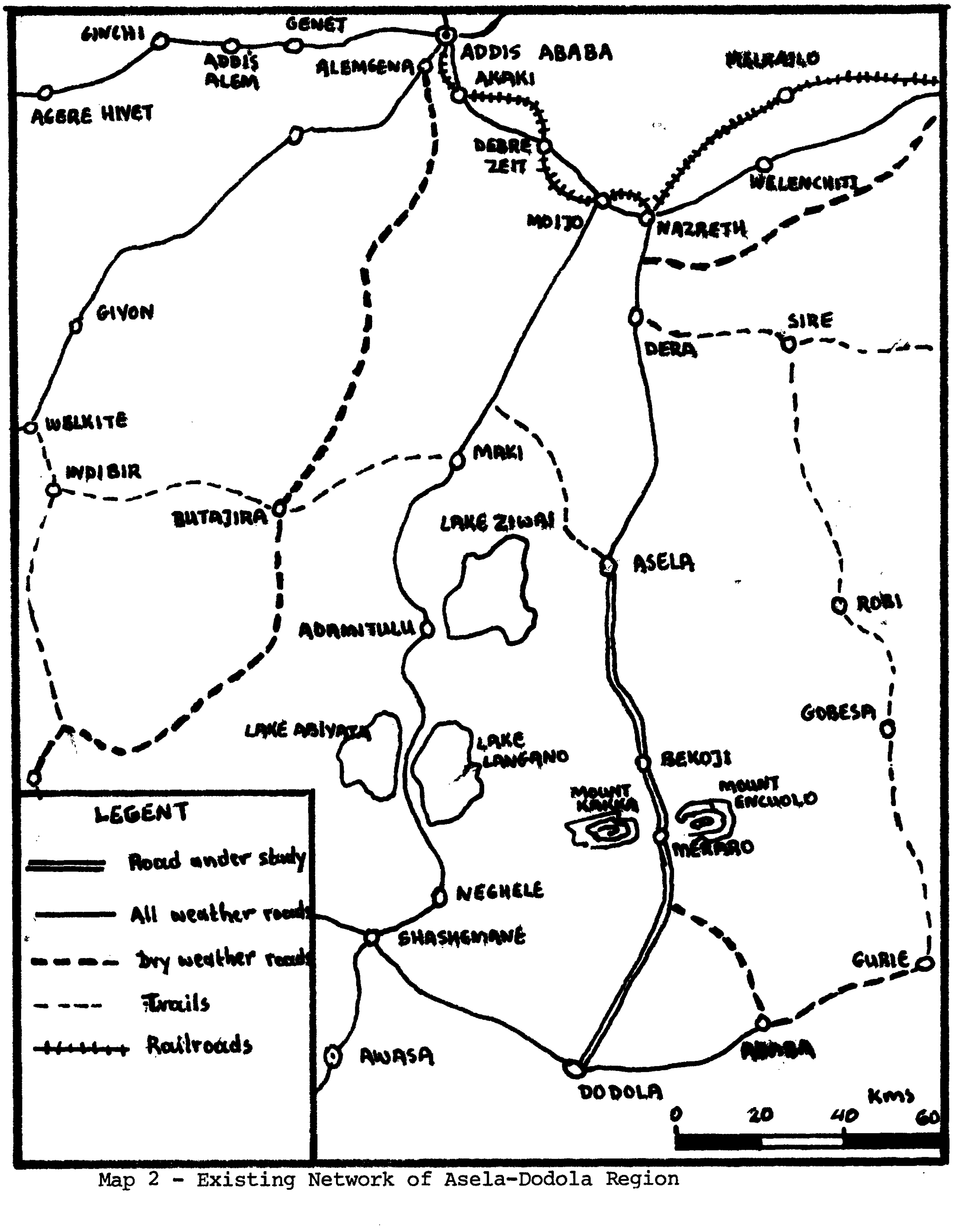
In regard to road transportation, the majority of roads have been built to connect the provincial capitals to Addis Ababa. The country has a severe lack of penetration and farm to market roads. This is the result of inadequate budget and the difficult terrain as well the weather conditions prevailing in the central, west and Southwestern regions.

The Fourth Highway Program, with a planned level of investment in road construction during the second Five Year Plan of E$140,100, 000, had actual expenditures of E$130,100, 000, or 93% of the target. This tends, however, to mask the fact that the mileage of new roads actually constructed was under implemented by 40%. The Third Five Year Plan proposes an investment in road construction amounting to E$250,000,000. According to the Plan provisions, the constructions of the Asela-Dodola road was to be undertaken. Our analysis and evaluation is concerned with this construction and its effect on the regions transport network.

5.3 Asela-Dodola road and the surrounding region

The Asela-Dodola project was envisioned primarily as a service road to be used by farmers in the area to deliver their products to large population center. The region the road is currently engaged in an agricultural development program which is expected to produce (or increase) surpluses in several crops. The region is now served by dirt tracks, which make it both difficult and expensive to deliver products to the markets. The EHA planned to make these markets accessible and thus spur development of the region.

For the purpose of describing the regions traffic characteristics, the area primarily affected by the road can be divided into two zones.



Map 2 - Existing Network of Asela-Dodola Region

The first zone is about 20 kms. wide and 70 kms long stretching from Asela to Meraro. The second zone is 20 kms wide and 51 kms long, beginning at Meraro and ending at Dodola. (see Map 2).

The region which encompasses the two zones is served by a network of five roads. They are: Mojo-Shashemane, Shashemane-Dodola, Dodola-Asela, Asela-Nazreth, and Nazreth-Mojo. The Shashemane-Dodola road (76 kms) is a gravel road in good condition. The Mojo-Nazreth road (24.7 kms) and the first 16 kms. of the Nazreth-Asela road are highly designed, bituminous in good condition. The other 62 kms. of the Nazreth-Asela road is gravel and in good condition. The Mojo-Shashemane road (182 kms) is bituminous surfaced and in fair condition. The road we are primarily concerned with, Asela-Dodola, is an earth track, most of which is washed out during the rainy season. While the section from Asela to Meraro is in fair shape, the section from Meraro to Dodola is passable only with 4-wheel drive vehicles even during the dry season. It is almost impossible to travel the length of the road during the wet season; as such there is no through traffic during that part of the year. On the network, the majority of the vehicles using the link is through traffic having neither its origin nor destination within the region served. The purpose of the planned road is to provide a shorter, faster route for through traffic and provide an access to markets for the agricultural surpluses of zones one and two. The agricultural development program now in progress is expected to increase the freight traffic originating in the two zones. Also, an increase in personal income is likely to encourage more passenger traffic. The road improvement is also seen as part of Ethiopia's continuing effort to upgrade its transportation network.

5.4 Feasibility analysis of the road by Sauti consultants

The feasibility analysis of the Asela-Dodola road's potential for upgrading was conducted by Sauti (42) in 1969 and 1970. The road had earlier been investigated by the Ethiopian Highway Authority (EHA) to determine the feasibility of upgrading the road to a gravel, secondary road (see EHA road standards, table #5.1). The information from this investigation was combined with information from the General Road Study (43) and their own investigation served as a data base for the study. The options that were to be investigated were: optimal size (feeder, secondary or primary standard), gravel vs. surface treated, optimal timing of the project and labor intensive vs. capital intensive construction. Several assumptions were made to facilitate the study. Among the assumptions were: complete information for traffic forecasts are certain, inelastic transport demand, and inclusion of only direct benefits (user savings and maintenance savings). The investigation was to cover a twenty year life of the project.

5.4.1 Construction and maintenance

As previously noted the EHA had evaluated the feasibility of upgrading the Asela-Dodola road to a gravel, secondary road. The Sauti team had this information available when their study began. After reviewing the EHA's calculation for accuracy, it was determined that these calculations could be used as a basis for estimation of earthwork. The EHA's calculations were based on a secondary road so it was necessary

Table 5.1 Road Design Standards

Topography	Flat			Rolling			Mountainous		
Secondary	Pri-mary	Secon-dary	Feeder	Pri-mary	Secon-dary	Feeder	Pri-mary	Secon-dary	Feeder
Design speed (km/h)	100	90	80	80	70	60	50	40	30
Width of pavement (m)	7	6	5	7	6	5	7	6	5
Total width (m)	8	7	6	8	7	6	8	7	6
Radius: minimum (m)	500	300	250	300	175	125	175	100	60
Radius: mirimum exceptional (m)	300	175	125	175	100	60	100	60	40
Maximum gradient (%)	4	4	5	4	5	6	5	6	7
Maximum exceptional gradient (%)	6	8	8	7	9	9	8	9	10

to determine the variance in earthwork quantities between primary, secondary and feeder standards roads. The variance in earthwork quantities could then be applied to determine quantities for feeder and primary roads. Investigations were made by the Sauti team to determine the unit cost of different construction operations (for gravel and for surface treatment), was also determined. These costs with that of the clearing effort gave the costs for the entire operation.

In terms of road maintenance, the Sauti team used a, estimation technique to determine the costs. The technique is an application of the conclusions of the Highway Research Board Bulletin 155, January 1956. The procedure takes into account the type of pavement, traffic intensity and the road width in determining the annual average maintenance costs on a per kilometer basis. The "basic maintenance costs" (minimum maintenance costs for a certain type surface encountered up to a certain traffic level) was determined through investigations with the EHA; this basic maintenance cost with adjustment factors for road width and traffic above a certain level produces an annual cost per kilometer for routine and periodic maintenance.

5.4.2 Traffic and vehicle operating costs

The Sauti team estimated traffic based on the traffic data of the General Road Study and the expected traffic due to an agricultural development program in the area. The increased level of production expected in the area was determined from yield/hectare estimates. The surplus was determined by subtracting from this figure, the local consumption and the loss due to spoilage and re-utilization. The surplus was then allocated to deficit zones in ten ton trucks to determine the increased traffic from agricultural activity. The investigating team also considered diversion of traffic from other roads in the network in their estimation of traffic. The traffic growth was presented in the form of projected average daily traffic (according to three vehicle types) for 1970, 1980, and 1990. The calculation of vehicle operating cost was through the use of "virtual lengths" of road. Information was already available for the costs of operating each vehicle type.

5.4.3 Conclusions

The Sauti team investigators concluded that the best alternative was a primary road with bituminous surface treatment for the first seventy kilometers, Asela to Meraro, and a secondary road with bituminous surface treatment for the last fifty kilometers, Meraro and Dodola. The optional opening year would be 1981 if the road was constructed with capital intensive technique and 1977 if constructed with labor intensive technique. The investigators concluded that staged construction does not improve the solution because of the slow growth of traffic and the major benefits accruing after the second stage of construction. In determining the net benefits, the benefit/cost ratio, the cost of construction and savings in user cost and maintenance were discounted to the opening year of the road. The results of the calculations using a 10% discount rate are shown below.

Table 5.2.a Base network Links characteristics

Link	Length (kms)	Capa-city (PCU/hr)	Design speed (Kms/hr)	Rise and fall (m/100m)	Costs (in E$)			
					Finan-cial	Econo-mic	Foreign Exchange	Skilled Labor
1: Moijo-Nazreth	25.0	2000	95	1.7	50,000	40,000	20,000	1,000
2: Nazreth-Asela	73	1550	75	4.8	58,000	48,000	20,000	3,000
3: Asela-Meraro	71	900	45	6.9	46,000	35,500	1,000	500
4: Meraro-Dodola	49	900	45	6.9	32,000	24,500	1,000	500
5: Dodola-Shashmene	73	1370	80	4.0	58,000	47,000	20,000	1,000
6: Shashmene-Moijo	182	1750	95	1.7	364,000	291,000	70,000	5,000

Table 5.2.b Base Network Vehicle Operation on Links

No.	Link	CAR			BUS			TRUCK		
		Travel Time (in hrs.)	Finan-cial cost (inE$)	Econo-mic costs (inE$)	Travel Time (in hrs)	Finan-cial cost (inE$)	Econo-mic cost (inE$)	Travel Time (in hrs)	Finan-cial costs (inE$)	Econo-mic costs (inE$)
1	Moijo-Nazreth	0.40	4.30	2.20	0.45	26.90	18.70	0.45	18.0	13.50
2	Nazreth-Asela	1.20	15.0	7.60	1.40	61.50	42.60	1.40	42.0	30.10
3	Asela-Meraro	1.80	23.30	14.40	2.0	104.40	79.50	2.0	68.30	56.70
4	Meraro-Dodola	1.6	16.0	9.0	1.9	69.0	56.0	1.9	47.0	40.0
5	Dodola-Shashmene	1.40	19.50	11.20	1.80	68.0	62.0	1.80	48.0	45.0
6	Shashmene-Moijo	3.10	35	22	3.50	130	113	3.50	93	84

	Capital Intensive	Labor Intensive
Net Benefit (E$)	4,817,000	5,784,000
Benefit/Cost Ratio	2.2	2.2
Cost of Construction		
(financial)	6,020,000	7,139,000
(economic)	4,174,000	5,015,000

5.5 Applications of the Model

5.5.1 Inputs

5.5.1.1 Network configuration

The network considered is the one consisting of the links Mojo-Shashemane, Shashemane-Dodola, Dodola-Meraro, Meraro-Asela, Asela-Nazreth and Nazreth-Mojo. Only links Dodola-Meraro and Meraro-Asela are to improved. The figure 5.1 represents the network with its links and nodes numbers. The network configuration inputs are handled by the Input Data Processor.

5.5.1.2 Links characteristics and strategies

Also, the link characteristics and the link strategies are handled by the Input Data Processor; however, some of the data will be provided by the HCM performing the link simulation, when its modification will be done.

Table 5.2 presents the link characteristics if the base network strategy will be applied. The characteristics, being the same for all years of the time horizon, are being presented only for year 1.

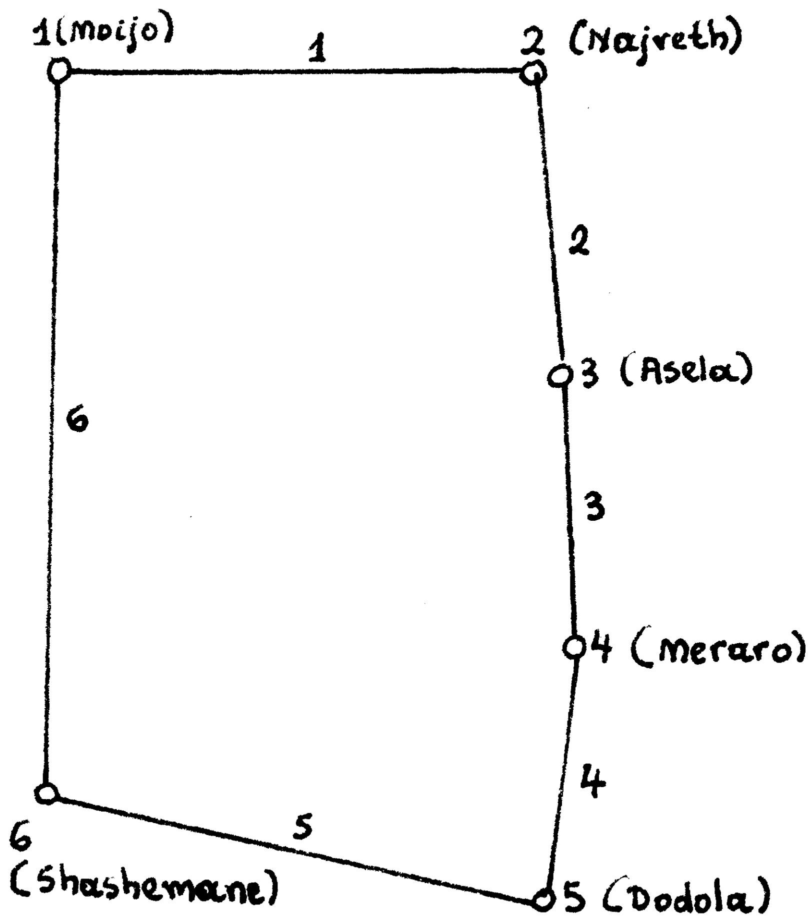


Figure 5.1: Representation of the Asela-Dodola Region's Network

Table 5.3.a. Link #3 Characteristics, according to strategy followed

Strategy Followed	Year(s)	Capa- city (PCU/hr)	Design speed (kms/hr)	Length (kms)	Rise and Fall (m/ 100m)	Cost (inE $)			
						Finan- cial	Econo- mic	Foreign Exchange	Skilled Labor
1: No change	1.20	900	45	72	6.9	46,000	35,500	1,000	500
2: Capital intensive techniques, Primary Road Standards	1	2000	85	72	4.5	9,640,000	6,560,000	6,508,000	1,000,000
	2-20	2000	85	72	4.5	142,000	113,6000	40,000	3,500
3: Capital Intensive tech., sec. road stand.	1	1750	75	71	4.5	8,000,000	5,400,000	6,110,000	900,000
	2.20	1750	75	71	4.5	122,000	103,000	35,000	3,000
4: Capital in- tensive tech., feeder road standar	1	1550	60	71	4.5	6,600,000	4,400,000	4,600,000	800,000
	2-20	1550	60	71	4.5	100,000	195,000	28,000	2,500
5: Labor in- tensive tech.,: primary road stand.	1	2000	85	71	4.5	7,630,000	5,300,000	3,800,000	500,000
	2-20	2000	85	71	4.5	130,000	105,000	30,000	1,000

Continuation of Table 5.3.a

Strategy Followed	Years(s)	Capa-city (PUC/hr)	Design Speed (kms/hr)	Length (kms)	Rise and Fall (m/100m)	Cost (inE$)			
						Finan-cial	Econo-mic	Foreign Exchange	Skilled Labor
6: Labor Intensive technique: Secondary Road Standards	1	1,750	75	71	4.5	6,400,000	4,400,000	3,170,000	400,000
	2-20	1,750	75	71	4.5	113,000	93,000	25,000	800
7: Labor Intensive technique: Feeder Road Standards	1	1,550	60	71	4.5	5,3000,000	3,600,000	2,600,000	300,000
	2-20	1,550	60	71	4.5	100,000	85,000	20,000	600

Table 5.3.b Vehicles operation on link #3 according to strategy followed

Link Strategies	CAR			BUS			TRUCK		
	Travel Time (in hrs.)	Financial cost (inE$)	Economic costs (inE$)	Travel Time (in hrs)	Financial costs (inE$)	Economic cost (inE$)	Travel Time (in hrs)	Financial costs (inE$)	Economic costs (inE$)
1	1.80	23.30	14.40	2.0	104.40	79.50	2.0	68.30	56.70
2,5	0.95	13.50	7.00	1.10	57.0	40.0	1.10	39.0	29.00
3,6	1.01	14.40	7.50	1.16	60.0	41.50	1.16	41.0	30.0
4,7	1.30	19.0	10.15	1.50	80.0	55.7	1.50	54.0	40.0

Table 5.4.a Link #4 Characteristics according to strategy followed

Strategy Followed	Years(s)	Capacity (PCU/hr)	Design Speed (kms/hr)	Length (kms)	Rise and Fall (m/100m)	Cost (inE$) Financial	Economic	Foreign Exchange	Skilled Labor
1: No change	1-20	900	45	49	6.9	32,000	24,500	1,000	500
2: Capital intensive technique: Primary Rd. Standards	1	2000	85	49	4.5	6,650,000	4,500,000	4,850,000	700,000
	2-20	2000	85	49	4.5	98,000	78,000	25,000	2,500
3: Capital Intensive Techniques: Secondary Road Standards	1	1,750	75	49	4.5	5,500,000	3,730,000	4,200,000	500,000
	2-20	1,750	75	49	4.5	90,000	72,000	20,000	2,000
4: Capital Intensive Technique: Feeder Rd. Standards	1	1,550	60	49	4.5	4,550,000	3,000,000	1,900,000	300,000
	2-20	1,550	60	49	4.5	83,000	67,000	15,000	1,500
5: Labor intensive tech., Primary Rd. Standards	1	2,000	85	49	4.5	5,260,000	3,640,000	2,650,000	200,000
	2-20	2,000	85	49	4.5	90,000	73,000	20,000	600

Continuation of Table 5.4 .a

Strategy Followed	Years(s)	Capa-city (PCU/hr)	Design Speed (kms/hr)	Length (kms)	Rise and Fall (m/100m)	Cost (inE$)			
						Finan-cial	Econo-mic	Foreign Exchange	Skilled Labor
6: Labor Inten-sive Tech., Secondary Road Standars	1	1,750	75	49	4.5	4,400,000	3,000,000	2,200,000	200,000
	2-20	1,750	75	49	4.5	82,000	67,000	17,000	500
7: Labor Intensive Technique Feeder Rd. Standards	1	1,550	60	49	4.5	3,600,000	2,500,000	1,800,000	100,000
	2-20	1,550	60	49	4.5	75,000	61,000	14,000	400

Table 5.4.b Vehicles operation on Link #4 according to strategy followed

Link Strategies	CAR			BUS			TRUCK		
	Travel Time (in hrs)	Financial costs (inE$)	Economic costs (inE$)	Travel Time (in hrs)	Financial costs (inE$)	Economic costs (inE$)	Travel Time (in hrs)	Financial costs (inE$)	Economic costs (inE$)
1	1.6	16.0	9.0	1.9	69.0	56.0	1.9	47.0	40.0
2,5	0.65	9.0	4.70	0.75	38.0	27.0	0.75	25.50	19.00
3,6	0.70	10.0	5.10	0.80	41.0	28.70	0.80	28.0	20.0
4,7	0.90	13.0	7.0	1.02	55.0	38.50	1.02	38.0	27.30

Tables 5.3 and 5.4 present the characteristics of links 3 (Asela-Meraro) and 4 (Meraro-Dodola) respectively, according to the proposed link strategies. The data used in the application of the model is the same with what the Sauti consultants used, with some differences in vehicle operating costs.

5.5.1.3 Demand

The demand is given on a O-D pair basis in number of vehicles, Three types of vehicles have been considered: a 5-passengers car, a 45-50 passengers bus and a 7.0 ton-truck. The load factors, common for all O-D pairs demands, are 50% for passenger cars and 75% for bus and trucks. Also, common are: the elasticity of demand, being 1% for all vehicles types and the value of travel time being: E$0.24/pass-hr for cars and bus and E$.001/ton-hr for the trucks.

Table 5. 5 presents the demand in vehicle numbers for each O-D pair and the maximum price the user is willing to pay for transport in E$/vehicle.

It should be noticed that the demand although shown as originating from Moijo, it is actually originating from Addis Ababa, the link Addis-Ababa-Moijo being omitted for simplicity. Furthermore, it is assumed that the traffic, having destinations at intermediate points on the links, it is not considered. The data about the data has been derived from the information provided by the Sauti report. It is given for the opening year 1977 and it is updated every 5 years. The assumptions that the demand will remain constant over the 5 year period,

Table 55. Demand Between O-D Pairs

O-D Pair	Number of cars				Number of Busses				Number of Trucks				Maximum price to be paid for transport (in E$/veh)		
	Years				Years				Years				Cars	Busses	Trucks
	1-4	5-9	10-14	15-20	1-4	5-9	10-14	15-20	1-4	5-9	10-14	15-20			
1-2	8	11	15	20	4	6	9	11	7	9	13	15	8.	35.	25.
1-3	42	60	75	90	20	30	45	60	30	45	60	80	30.	110.	70.
1-4	9	12	17	22	4	6	8	10	4	6	8	10	50.	230.	135.
1-5	7	10	15	20	15	20	30	40	28	35	50	65	60.	250.	150.
1-6	12	20	30	40	7	10	15	20	4	5	7	10	40.	160.	100.
2-3	25	30	40	50	15	20	30	40	15	20	30	40	20.	80.	50.
3-4	8	12	15	18	6	8	10	14	7	10	13	18	25.	125.	70.
3-5	11	15	20	26	5	6	8	10	20	28	32	40	24.	166.	95.
4-5	11	15	20	28	3	4	6	8	15	20	28	35	9.	70.	39.
5-6	3	4	6	8	6	8	10	12	6	7	9	11	25.	90.	55.

made by the Sauti study will prevail in our study too. All inputs are handled by the Input Data Processor, i.e., they are provided exogeneously, since the interface of the system with the HCM has not yet been accomplished.

5.5.2. Network strategies generation

From the provided 7 strategies for the two links: Asela-Meraro and Meraro-Dodola and the 5 years allowable delay in implementing a strategy, the network strategies generator, comes out with 29 feasible network strategies. Each network strategy is composed of link strategies and the corresponding opening year. They are presented in Table 5.6.

5.5.3. The network strategies evaluation

Table 5.6 presents the results of the evaluation of the 29 network strategies. They are ranked according to their net present value of their costs and benefits. The NPV is given for discount rate 10% and considering as present the opening year 1977.

5.5.4. Conclusions

Our approach proposes as the best alternative, the network strategy applying labor intensive techniques for the construction of both links. When the discount rates are 10% and 12% the optimal is the one that proposes the two roads to be constructed to a secondary road design standards. However, when the discount rate is 8% the optimal alternative turns out to be the one that proposes the Asela-Meraro road to

Table 5.6. Network Strategies

Rank	N.S.# (as Generated)	NPV (in E$) (Discount rate 10%)	Description of N.S.			
			Link 3		Link 4	
			L.S. #	Opening year	L.S. #	Opening year
1	29	14,438,980.	6	1977	6	1977
2	25	14,358,145.	6	1977	5	1977
3	24	14, 117,486	5	1977	6	1977
4	1	14,036,645	5	1977	5	1977
5	28	13,667,174	6	1977	3	1977
6	27	13,283,984	6	1977	2	1977
7	22	13,223,532	5	1977	3	1977
8	19	13,143,983	3	1977	5	1977
9	21	13,062,926	5	1977	2	1977
10	16	12,693,551	2	1977	6	1977
11	14	12,662,880	2	1977	5	1977
12	18	12,283,983	3	1977	2	1977
13	6	11,963,551	2	1977	3	1977
14	2	11,802,898	2	1977	2	1977
15	15	10,038,860	2	1977	5	1982
16	9	9,576,466	2	1982	3	1982
17	8	9,544,378	2	1982	3	1977
18	7	9,525,780	2	1977	3	1982
19	5	9,502,151	2	1982	2	1982
20	3	9,451,621	2	1977	2	1982
21	4	9,307,841	2	1982	2	1977
22	26	7,038,169	5	1977	7	1977
23	23	6,538,165	5	1977	4	1977
24	17	5,778,170	2	1977	7	1977
25	10	5,278,158	2	1977	4	1977
26	13	4,536,436	2	1982	4	1982
27	11	4,485,769	2	1977	4	1982
28	12	4,199,106	2	1982	4	1977
29	20	2,779,301	5	1977	1	-

Explanation of symbols in page .

<u>Continuation of Table 5.6:</u>

Explanations of symbols:

L.S. = Link Strategy ; N.S. = Network Strategy

L.S. #1: No improvement

L.S. #2: Construction to primary road with capital intensive techniques

L.S. #3: Construction to secondary road with capital intensive techniques

L.S. #4: Construction to feeder road with capital intensive techniques

L.S. #5: Construction to primary road with labor intensive techniques

L.S. #6: Construction to secondary road with labor intensive techniques

L.S. #7: Construction to feeder road with labor intensive techniques.

be constructed according to secondary road design standards and the Meraro-Dodola road according to primary road design standards. In all cases the opening year turns out to be 1977, i.e., no delay in initial construction.

Since the first 4 best alternative network strategies have resulted close NPV's all four are included in Tables 5.7, 5.8, and 5.9, where the NPV's are computed for 3 discount rates 8%, 10% and 12% and possible delays in initial construction are considered as new alternatives network strategies. Tables 5.7, 5.8 and 5.9 give the total discounted costs, total discounted benefits and the NPV for each network strategy.

We conclude that the optimal network strategy will propose opening year 1977 and the roads to be constructed according to secondary road design standards, since the 10% discount rate is the one more frequently applied in the evaluation of transport investment. Table 5.10 presents the traffic on the links of the network if the above network strategy is implemented.

The conclusions derived from the analysis are:

(1) The low demand for almost all O-D pairs, suggests that any change in the elasticity of demand will not increase the demand significantly. e.g. From Table 5.5., between Mojo and Asela the average daily traffic consists of 7 cars, 15 buses and 28 trucks. Considering the demand for trucks, the transport costs before the improvement were 129 E$/vehicle. If the optimal network strategy is implemented the new transport costs will be 93.60 E$/vehicle.

TABLE 5.7 The 4 Best Network Strategies = 1,24,25,29

Discount rate: 8%

N.S. # Gas Generated	Opening Year	Total Discounted costs (in E$)	Total Discount Benefits (in E$)	Net Present Value (in E$)	Rank
1	1977	10,013,272	27,892,953	17,879,681	3
24	1977	9,142,776	27,008,457	17,865,681	4
25	1977	8,825,152	26,927,463	18,102,311	1
29	1977	8,127,528	26,215,814	18,088,286	2
1	1982	7,156,000	21,525,996	14,369,996	
24	1982	7,239,296	20,976,266	13,736,970	
25	1982	6,418,996	20,912,823	14,493,827	
29	1982	5,910,844	20,363,115	14,452,271	

Table 5.8 The 4 Best Network Strategies: 1,24,25,29

Discount rate 10%

N.S. # (as Generated)	Opening year	Total Discounted costs (in E $)	Total Discounted costs (in E $)	Net Present value (E$)	Rank
1	1977	9,716,500	23,753,145	14,036,645	4
24	1977	9,026,310	23,143,796	14,117,486	3
25	1977	8,716,120	23,074,265	14,358,145	2
29	1977	8,025,930	22,464,910	14,438,980	1
1	1982	6,584,540	17,699,021	11,114,481	
24	1982	6,116,250	17,247,462	11,131,212	
25	1982	5,907,500	17,195,010	11,287,510	
29	1982	5,439,210	16,743,396	11,304,186	

Table 5.9 The 4 Best Network Strategies: 1,24,25,29

Discount rate: 12%

N.S. # (as Generated)	Opening year	Total discounted costs (in E $)	Total discounted benefits (in E $)	Net present value (in E $)	Rank
1	1977	9,616,600	20,619,080	11,002,480	4
24	1977	8,932,404	20,090,481	11,158,077	3
25	1977	8,628,208	20,029,991	11,401,783	2
29	1977	7,944,012	19,634,130	11,690,118	1
1	1982	6,080,580	14,696,591	8,616,011	
24	1982	5,647,566	14,321,924	8,674,358	
25	1982	5,456,232	14,278,199.	8,821,967	
29	1982	5,023,218	13,903,539	8,880,321	

Table 5.10 Average daily traffic on links

(Simulated by the model for the optimal network strategy 29)

Links	Vehicle Type	Years 1977	1982	1987	1992
Moijo-Nazreth	cars	66	93	122	152
	bus	43	62	92	121
	trucks	69	95	131	170
	in PCU's	431	612	849	1100
Nazreth-Asela	cars	83	112	147	182
	bus	54	76	113	150
	trucks	77	106	148	195
	in PCU's	1183	1725	2339	3079
Asela-Meraro	cars	35	49	67	86
	bus	30	40	56	74
	trucks	59	79	103	133
	in P.C.U.'s	658	1037	1180	1535
Meraro-Dodola	cars	29	40	55	74
	bus	23	30	44	58
	trucks	63	83	110	140
	in P.C.U.'	631	969	1133	1460
Dodola-Shashemane	cars	3	4	6	8
	bus	6	8	10	12
	trucks	6	7	9	11
	in P.C.U.'s	113	139	181	219
Shashemane-Moijo	cars	12	20	30	40
	bus	7	10	15	20
	trucks	4	5	7	10
	in P.C.U.'s	46	69	98	132

Applying the equation 3.19 about the new demand due to decrease in transport costs, we have:

$$T' = 28* \left(\frac{93.6}{129}\right)^{-ELA} .$$

The new demand is changing as the elasticity changes:

ELA = 0. (inelastic demand): T=28 (no change)

ELA = 0.1 (elastic demand) T = 28.9 (3.2% increase)

ELA = 0.01 (approaching inelastic demand)

T = 28.09 (.32% increase)

(2) Any postponement of the initial construction is not worth it, since the traffic is at such high level that it pays to improve the road immediately.

(3) The case of constructing the road according to feeder road design standards does not have to be considered in any further analysis, since it comes up with low NPV.

(4) Congestion did not occur at any link. (It may be seen also in Table 5.10 how low the traffic is on the links).

5.6 Comparison with the Sauti study

The Sauti investigators concluded that the best alternative was a primary road for Asela to Meraro and a secondary road from Meraro to Dodola. They set opening year 1977 if the road is constructed using labor intensive techniques and 1981, if capital intensive techniques are used. Our approach concluded that the best alternative was a secondary road for both Asela-Meraro and Meraro-Dododla. This results from: (i) not considering any maintenance costs over the years in the Sauti study for the improved road; however ours takes them into account,

(ii) Our approach considers the demand on a O-D pair basis and computes the benefits attributed to each O-D pair; they consider demand on a link-basis and they compute the benefits resulting from the travel on the each link,

(iii) As an evaluation criterion the Sauti Consultants have used the Benefit/cost ratio; our approach uses the net present value criterion.

According to our model the alternative that the Sauti study proposes as the optimal has a NPV by E$321,500 less than the one of the best alternative proposed by our approach. Therefore, we may conclude that both alternatives are acceptable for implementation, and it is up to the decision maker, to choose the one proposed by the approach he thinks best.

CHAPTER SIX

CONCLUSIONS, RECOMMENDATIONS

The development model has found to be a very useful tool for the network strategies evaluation. It is capable of generating the 29 most interesting network strategies, to simulate the network activities to evaluate them and to rank them. Work that may require in a consultant firm months of computation and analysis by engineers, it may be done in few minutes and with minimal expenses applying the developed model.

The presented case study showed the model's capabilities efficiency. The comparison with the Sauti study found it in a better position.

Although the model, as it has been developed, is appropriate for less developed countries, some additions would be useful. The issue of demand generation is an important one. A model may be developed to generate the demand not only according to transport costs flunctuations, but according to population growth, the per capital income changes, etc. The issue of other modes competing for the same O-D pair may be considered. As a result the demand for the O-D pair will be distributed to different modes according to the offered transport prices.

The issue of multi-regional distribution of the same commodity will complicate the model, but it would be very useful. The nature of this is that a truck may not follow the minimum cost route for each O-D pair having to distribute a payload of a commodity to more than one distribution points. It will follow the route that will maximize the revenues of the shipper (how much he is going to get selling the commodity minus the costs of transport).

Another issue to be addressed in the possible redistribution of traffic after the first assignment if congestion occurs to some links.

However if all these are included in a model, it will become very complicated, sophisticated and hard to be applied in a less developed country, since it would require disaggregate data, sophisticated computer facilities and a lot of planning.

APPENDIX A

DRAFT USER'S MANUAL

The Network Evaluation Model consists of four computer packages: the Highway Cost Model, the Input Data Processor, the Network Strategies Generator and the Network Strategies Evaluator. A description of each and its subroutines appear in Chapter 4 and Appendix B of this document. A listing of the computer programs is presented in Appendix C.

The Network Evaluation Model (NEM) allows a user to investigate, in a searching, probing manner, the behavior of a rural highway network to the consequences of investment criteria and constraints. It is a data base system, thus allowing the user to reuse prior information and results, to change small amounts of information for sensitivity analysis, and to direct the evaluation process himself. Each processor may be applied numerous times. Constraints on this probing an minimal, and logical. Network strategies must be generated prior to evaluation, the base network against which alternative strategies are compared must be evaluated first. Demand and user cost data must be input prior to evaluation and link strategy data provided for generation. Whenever a process is executed the most recent and existing data and intermediate results are used.

1. Language Conventions for the Model's Input

The language used for the Input to NEM is a flexible problem oriented language. It allows great freedom in the ordering and presentation of input. Each communication to the computer program is given through a statement called a command. Each of these commands either supplies some data to the program or instructs it to perform some calculations on the data already specified, or both.

There are three basic elements that are used to make up the various commands. They are:

(a) Integers: These are numbers that do not contain a decimal point. Examples: 1, 38, +999, -108. Possible errors (non-integers): 6.0 - This contains a decimal point 10,000 - This contains a comma. If a sign is omitted, it is assumed to be plus(+). The notation used for the integers is: i_1, i_2,..., or n_1,n_2,... in the language description.

(b) Real numbers: These must contain a decimal point. Only normal decimals are accepted in the commands. They consist of digits only, a decimal point, and optionally a sign.

Example: 6.0 3.14 -2. .003

If a sign is omitted, it is assumed to be plus(+). The notation used for the real numbers for the language description is x_1,x_2,... or y_1,y_2,... or z_1,z_2,... I_n some commands integers may be used where real numbers are expected.

c) words: Various words and single letters have specific meaning as input to the models. These words may be used in commands and are not chosen by the user. They are symbols that are recognized by the processors. Words are shown in the language description in capital letters. If a word in the language description is in parenthesis, this means that the word may be omitted or included. Unless its inclusion is merely cosmetic, the consequences of including or omitting a word is explained in the description of the command. A word may be consisted of letters and numbers. Since the processors read only the three first character of each word, any additional characters may be omitted. Words are also used in special ways as data labels, identifying the meaning of the data value immediately following the label. For convenience, data labels may be ommitted if the standard order (given in the command description) is used. If only selected data values are given or the data is given in a different sequences, labels are needed. The one exception is that labels are not needed, if the standard order is used, but proceeds through only part of the potential input. Note: non-inputted data in a command remains unchanged from its prior value, unless otherwise stated in the command description. Labels are identified with brackets, [ ], in the command descriptions.

The input commands for the processors must be punched onto cards and submitted as program data. In doing so, all 80 columns of the card may be utilized, in free format. A blank and/or comma must separate each field in a command. If more than 80 columns are needed for any command, the user will use the continuation symbol $ at the 80th column of the card and continue on the next. If the user desives to insert comments into the input data, he may punch in the column 1 of any card the $. This card is taken as a comment card, echo printed on the output listing, and its contents.

2. Language Description for the Model's Input. Instructions for its Application

2.1 Data Input Processor

The commands are divided into six categories: (1) System commands, (2) Network configuration, (3) Link Characteristics, (4) Demand Input, (5) Budget input and (6) Additional minor data input commands.

2.1.1 System commands

At the beginning of a run, the user must indicate whether he wants to start accumulating data, or supplement or modifying prior data. He does so using one of the following two commands:

INITIALIZE: performs initialization of the files and the zeroing of any previously stored data. The data input node is then assumed to be ADD.

UPDATE: initializes without zeroing data, in preparation for new input which will add to, change or delete prior data. The ADD mode is also assumed initially. Data may be input not only to add new information to the data base, but also to change or delete prior input. An input mode is therefore identified with one of the following commands, and all subsequent input so treated until the mode is changed.

CHANGE: part or all of some existing data is to be changed. If data to be changed does not exist, a warning message is given and the data added as new.

DELETE; used when the stored data is to delected.

PRINT: used to print all the data stored on the files.

FINISHED: used to terminate execution.

STORE: used to store the basic data on the files.

These commands are one-word commands; each must appear on a separate card.

2.1.2 Network Information

The network configuration is input with the NETWORK and LINK DATA commands:

NETWORK [LINKS] i_1 [NODES] i_2 [REGIONS] i_3

where:

i_1: the number of links in the network

i_2: the number of nodes in the network

i_3: the number of regions.

Note that the words and their corresponding numbers may change order.

LINK DATA

[LINK] i_1 [BEGINS] i_2 [CONCLUDES] i_3 [REGION] i_4 [FEASIBLE STRATEGIES]

END

where:

i_1 = link number

i_2 = node, where link begins

i_3 = node, where link concludes

i_4 = region, where link belongs

i_5 = total number of link strategies.

The data for the link characteristics must begin with the word LINK or its number. If the user wants to change the order of the other numbers or ommit one of them, he must use, in front of all numbers, the corresponding word. Otherwise, he may ommit the words, but keep the numbers in the specified order.

END denotes the end of the command, i.e. the data about links connectivity.

2.1.3 Link Characteristics

Following is the way to input the data about: the travel time, the financial and economic costs of the vehicles travelling on the links, the costs resulting from any construction and maintenance activities on the links and the link characteristics, such as capacity, design speed and rise and fall.

LINK i_1 [STRATEGY] i_2 [INDEX] i_3 [SLIPPAGE] i_4

(η_i) ATT [V1] x_1 [V2] x_2 [V3] x_3 [V4] x_4 [V5] x_5 [V6] x_6 [V7] x_7

(η_i) EOC [V1] x_1 [V2] x_2 [V3] x_3 [V4] x_4 [V5] x_5 [V6] x_6 [V7] x_7

(η_i) FOC [V1] x_1 [V2] x_2 [V3] x_3 [V4] x_4 [V5] x_5 [V6] x_6 [V7] x_7

(η_i) [ETC] y_1 [FTC] y_2 [FOR] y_3 [SKL] y_4

(η_i) [LEN] z_1 [CAP] z_2 [RAF] z_3 [DSP] z_4

END

where:

i_1 = link number

i_2 = link strategy number

i_3 = critical index of the link strategy

i_4 = maximum allowable delay indicative of the strategy

If not given, i_2 is assumed equal to 1, i_3 and i_4 equal to zero.

η_i = the year number. Data need be given in the ADD mode only for years when values change. Intermediate years up to the time horizon are automatically inserted with prior year values.

ATT = average travel time over the link in hours, for each vehicle type.

[VN] x_n = denotes the average travel time x_n in hours of vehicle type vn. Up to 7 vehicle types may be used.

EOC = economic costs of vehicle operation over the link, with x_n in \$/vehicle.

FOC = financial costs of vehicle operation over the link, with x_n in \$/vehicle.

y_1 = economic costs of construction and maintenance activities on the link in given year (in \$).

y_2 = financial costs for the same.

y_3 = foreign exchange costs for the same.

y_4 = skilled labor costs for the same.

z_1 = link's length (in kms).

z_2 = link's capacity (in PCU/hr)

z_3 = link's rise and fall (in m/100m)

z_4 = link's design speed (in kms/hr).

It should be pointed out that only the first data card for a year must contain the year. The order of the cards for a year may be altered, and not all cards given for a year. Labels must be used on the construction and maintenance cost and link characteristics cards. In the ADD mode, years must be given in accending order. Except for the header data and the years, both integer and real numbers are acceptable for the data.

2.1.4 Demand

The data about demand is given by O-D pair using the multi-statement DEMAND command.

DEMAND (O) i_1 (D) i_2

n_i VOLUME [V1] x_1 [V2] x_2 [V3] x_3 [V4] x_4 [V5] x_5 [V6] x_6 [V7] x_7

ELASTICITY [V1] x_1 [V2] x_2 [V3] x_3 [V4] x_4 [V5] x_5 [V6] x_6 [V7] x_7

COMMODITY PRICE [V1] x_1 [V2] x_2 [V3] x_3 [V4] x_4 [V5] x_5 [V6] x_6 [V7] x_7

TIME VALUE [V1] x_1 [V2] x_2 [V3] x_3 [V4] x_4 [V5] x_5 [V6] x_6 [V7] x_7

LOAD FACTOR [V1] x_1 [V2] x_2 [V3] x_3 [V4] x_4 [V5] x_5 [V6] x_6 [V7] x_7

END

where:

i_1 = origin node

i_2 = destination node

η_i = the year number for the volume data.

Volume data may be given for each vehicle type either in vehicles per day or, for truck types, in tons per day. This latter form is designated by the user by issuing a command to this effect prior to demand input. This is currently an OPTION 1 command. In the ADD node, demand volumes must be given for assending years, and after the first only for those years when values change from the previous year.

The remaining data is considered to be year independent. The elasticity is given in terms of the percentage change in demand due to a percentage change is user costs over the links. The commodity price is the maximum transportation cost that would result in any shipment between O-D pair, given in demand units. These values are used to determine whether or not a demand is likely to be fulfilled, and the consumers surplus for newly generated demands. Similarly, the time value of the transported goods, given in $/passenger-hour and for V1 and V2, and $/ton-hour for trucks is used for benefit calculation. Load factor are given as decimal fractions of load.

2.1.5 Budget constraints

The following command used input of budget constraints:

BEDGET CONSTRAINTS

REGION i_1

η_i [TB] x_1 [FE] x_2 [SL] x_3

END

where:

i_1 = region number. All budget constraints are input separately for every region, and therefore must proceed regional budget data.

η_i = year number

x_1 = Total budget available in \$, for year

x_2 = Foreign exchange available in \$; for year

x_3 = Skilled labor available is \$, for year.

In the ADD mode, years, after the first, unchanged from the prior year for a region need not be repeated in input.

2.1.6 Additional minor data

The user must input the following data:

i. The vehicle capacities, their input to be handled by the command:

VEHICLE CAPACITIES [V1] x_1 [V2] x_2 [V3] x_3 [V4] x_4 [V5] x_5 [V6] x_6 [V7] x_7

where x_i will be given in pass./vehicle for vehicle types 1 and 2 and in tons/vehicle for the rest vehicle types.

ii. The interest rate, to be given by the command:

INTEREST RATE x_1

where x_1 is a percentage number (e.g. 10, for 10%)

and

iii. The time horizon, which is stated with the command:

TIME HORIZON i_1

where i_1 the total number of years.

2.2 Network Strategies Generator

The network strategy generator takes link strategy and budget constraint data and generates interesting and feasible alternatives.

It considers three types of links, unchanged links in the base network, for which a single defined strategy is taken, obligatory links, for which one among alternate strategies must be taken (the difference might merely represent slippage), and optional links, for which one alternative strategy may be taken, or the link left unalterel. The later two links are specified with the commands

OBLIGATORY (LINKS) $n_1, n_2, \ldots$

OPTIONAL (LINKS) $n_1, n_2, \ldots$

where n_i are link numbers. For all links, the strategy 1 is assumed to be the base network.

Four data input commands are given to allow more efficient generation of alternatives. The command

SLIPPAGE (INCREMENT) i

provides an alternative to considering year by year slippage combinations. The command

MINIMUM CRITICALITY INDEX i

provides an additional pruning rule. Until the sum of the link CI's for all included links exceeds the value i, other constraints need not be checked. If, when it does exceed i, it also, exceed busget constraints, the branch in the search, may be terminated.

For efficiency, this processor generated a block of feasible network strategies at one time, rank orders these, and discards the worst. These are then replaced with more and the process repeated. The size of the block is specified with the command

NETWORK (STRATEGIES) n

taken usually to be about 100. The percentage retained after ranking is specified with

PERCENTAGE (OR) (NETWORK) (STRATEGIES) x

x being a decimal number.

Generation is performed with a command GENERATE at the n*x best strategies identified in the data use for evaluation.

2.3 Network Strategies Evaluator

With the network strategies generated, the user looks at the output, chooses those he wants to evaluate further. He does so with a series of simple, directive commands. These commands are of two types, those which cause an operation, such as the evaluation of a strategy to take place, and those which provide data for the operations.

2.3.1 Data Input Commands

The simulate command, in the form:

SIMULATE $n_1, n_2, \ldots$ (YEARS)

is used to define to the evaluation operations the year for which, at a minimum, the network must be analyzed. Results from one year will be used in subsequent years up to the next analysis year or the end of the time horizon. Intermediate analysis years will be inserted by the processor. In any year user or government costs change on any link.

The PRINT command, similarly, in the form

PRINT $n_1, n_2, \ldots$ (YEARS)

is used to state years for which detailed output is to be provided. This output consists of:

1. The routing of the traffic

2. The traffic volumes or the links.

3. The economic and financial transport costs for O-D pair.

2.3.2 Operational commands

For a particular network configuration, the user compares alternatives against a base network strategy. He may do so by selectively requesting the evaluation of specific generated strategies, and even going back to the generator and, by changing some input, generating new strategies for evaluation. Prior to such evaluations, the base network must be analyzed and, if any of its conditions changed, reanalyzed. To analyze the base network the user uses the command:

ANALYZE (BASE) (NETWORK)

He may then evaluate alternatives using the command:

EVALUATE (N.S.) n_i

or

EVALUATE ALL (n_j) (N.S.)

where n_i is a strategy number and

n_j is the number of strategies, 1 to n_j, evaluated.

Any number of EVALUATE commands may be given, and the results stred in the data base. If n_j is omitted, all saved generated strategies are evaluated. Evaluation go to the point of determining the net present value of the total costs and benefits of the alternative relative to the base network.

The RANK command, with no arguments, provides a ranked list of network strategies ordered on decreasing NPV. It considers all alter-

alternatives for which evaluation results have been stred in the data base.

3. Job Control Language Cards

The Network Evaluation Model needs the following Job Control Cards to be operational in the IPC Computer facility of MIT.

In the beginning of each one of the computer programs the JCL cards are:

```
//' name of the user',  REGION=200K
/*   MITID (problem no, programmers no, passeword)
/*   MAIN LINES=15
//   EXEC FORCGO
//   C. SYSIN DD.*, DCB=BLKSIZE=2000
```

At the end of the main program and before the data cards the JCL cards are:

```
//G.FT10F001 DD DSNAME=U.M11943. 12404. BASIC DATA
//DISP=(OLD, KEEP)
//UNIT=STORAGE, SPACE=(3600,(6))

//G.FT11F001 DD DSNAME=U.M11943. 12404. LINK. DATA,
  DISP=(OLD-KEEP),
// UNIT = STORAGE, SPACE=(2332,(300))
// G.FT12F001 DD DSNAME=U.M11943. 12404. DEMAND DATA,
  DISP=(OLD,KEEP),
// UNIT=STORAGE, SPACE=(1792,(30))
/*
// G.SYSIN DD*, DCB=BLKSIZE=2000
```

APPENDIX B

SYSTEMS DOCUMENTATIONS

1. System structure and file usage

The system consists of four computer packages: the HCM, the Input Data Processor, the Network Strategies Generator, and the Network Strategies Evaluator. It allows flow of input-output from one computer package to the other with the use of files, independent runs of each computer package, changes in the inputs. The system is presented in the figure B.1. All the computer packages are written in FORTRAN language and with the DEFINE FILE command, and the READ - WRITE statements for the access to the files.

There are three files with the identification numbers 10, 11 and 12, as they have been initialized in the IPC Computer facility of MIT.

1.1 File 10

File 10 stores data provided by the Input Data Processor and the Network Strategies Generator. It consists of 6 records each of 900 words length.

a. Record 1

The following variables are stored with the WRITE statement from the Input Data Processor (with the only exception of NRANK which is stored from the Network Strategies Evaluator):

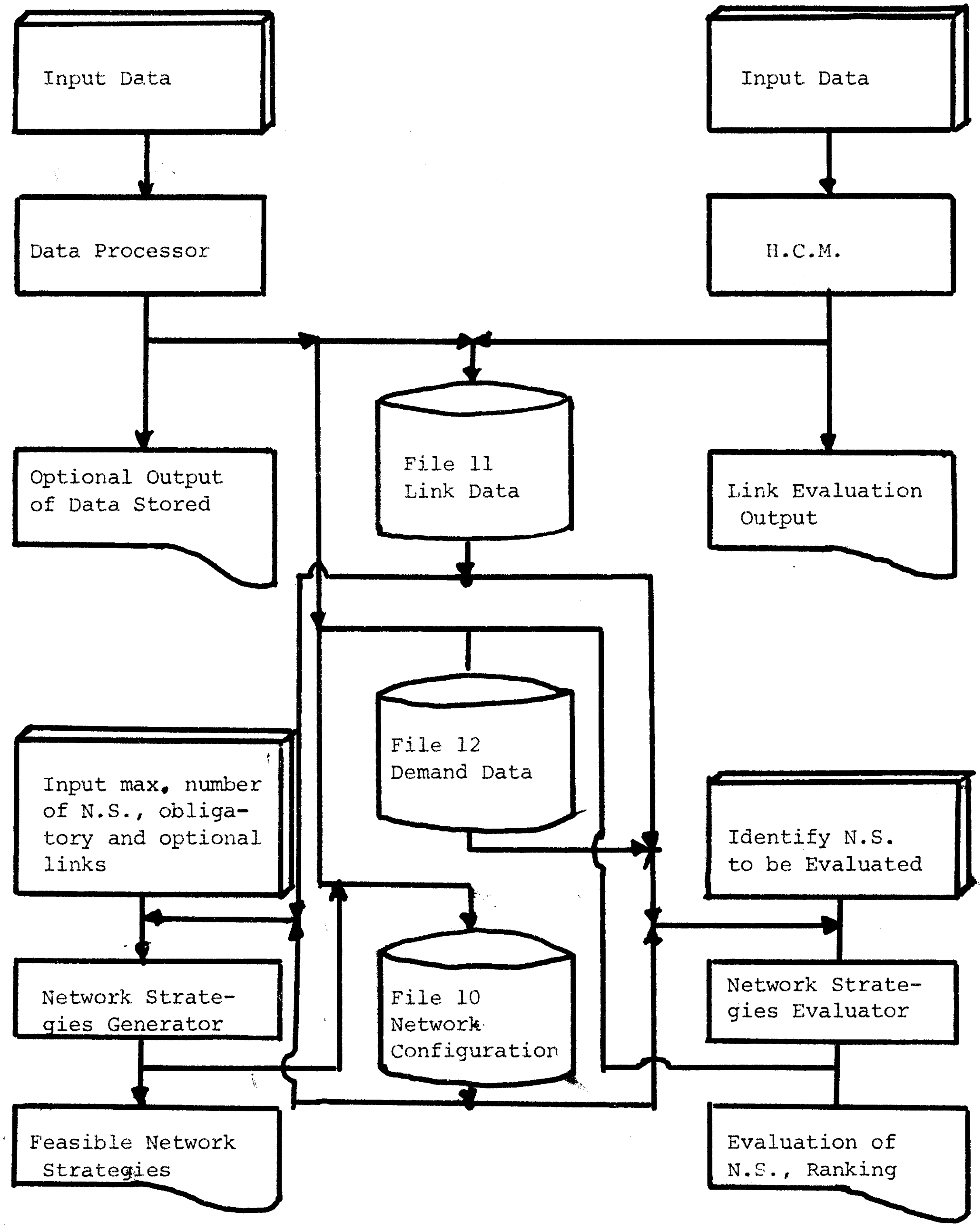


Figure B.1: Network simulation system flow

VARIABLES	WORDS	COMMENTS
NLINK	1	Number of links in the network
NODE	1	Number of nodes in the network
NREG	1	Number of regions
IHORIZ	1	Time Horizon
JIM	1	Number of O-D pairs
RATE	1	Interest rate
VCAP	7	Vehicle capacities for the 7 types (in pass. for 1,2 and tons for the rest)
LBEG	30	Node where a link (x) begins
LEND	30	Node where a link (x) ends
LST	30	Number of strategies per link
MDIS	30	Region where a link (x) belongs
IOPT	1	Index number for option of demand data units (tons or vehicles)
COSTMA	200	A (10,20) array about annual re-regional budget constraints
FOCAMA	200	A (10,20) array about annual re-regional foreign exchange constraints
SKLAMA	200	A (10,20) array about annual re-gional skilled labor constraints
NRANK	30	Rank of the N.S. according to their NPV.

Total length of the record (actual): 794 words.

b. Record 2

It stores only one array LLA(30,30) provided by the Input Data Processor. LLA is the link incidence matrix, giving for each node pair the corresponding link number, if it exists.

Total length of the record (actual): 900 words.

c. Record 3

It stores the array LOD(30,30) provided by the Input Data Processor. Since the Input Data Processor arbritrary assigns a number to each O-D pair, LOD facilitates to found the O-D pair given this number.

Total length of the record (actual): 900 words.

d. Record 4

It stores NWSTR(30,30) provided by the Network Strategies Generator. NWSTR stores the link strategy to be implemented given the specified network strategy and the link number.

Total length of the record (actual): 900 words.

e. Record 5

It stores NWSL(30,30) provided by the Network Strategies Generator. NWSL stores the link strategy slippage to be implemented given the specified network strategy and the link number.

Total length of the record (actual): 900 words.

f. Record 6

It stores TCOST(30,20), BCOST(20), IAA(30) provided by the Network Strategies Generator.

TCOST Stores the annual total costs for each network strategy.

BCOST Stores the annual total costs for the base network strategy.

IAA Stores the correspondance between the actual link number, as specified in Record 1 and the number given to each link by the Network Strategies Generator.

Total length of the record (actual): 650 words.

1.2 File 11

File 11 includes identical records of total length of 583 words. Each record stores information for each link strategy. Only ten strategies per link are permitted. The number is given to each record as follow: Assuming a link has the number: x. (Note that x should be at the most 30), and the specified link strategy is y $(1 \leq y \leq 10)$. The record number is then: $10 \cdot (x-1)+y$. Therefore no matter how the data of the links is provided, the record number is specified. The total number of records are 300 (30 links times 10 strategies). The data is provided partially by the HCM and by the Input Data Processor. The variables stored are:

VARIABLES	WORDS	COMMENTS
ATT	140	A (20,7) array about average travel time on the link (assumed uncongested) per vehicle type, per year.
EOC	140	A (20,7) array about vehicle economic costs of operation on the link per vehicle type, per year.

VARIABLES	WORDS	COMMENTS
FOC	140	A (20,7) array about vehicle financial costs of operation on the link per vehicle type, per year.
ETC	20	Array about annual economic costs of link construction and maintenance according to the specific link strategy.
FTC	20	Array about annual financial costs of link construction and maintenance according to the specified link strategy.
SKL	20	Array about annual skilled labor costs of link construction and maintenance according to the specified link strategy.
FOR	20	Array about annual foreign exchange of link construction and maintenance according to the specified link strategy for every year.
DIS	20	Array about link length according to the specified link strategy.
CP	20	Array about link capacity according to the specified link strategy for every year.

VARIABLES	WORDS	COMMENTS
RAF	20	Array about rise and fall of the road surface according to the specified link strategy for every year.
DSP	20	Array about the design speed of the road surface according to the specified link strategy for every year.
ISTR	1	Link strategy number
NCRIT	1	Critical Index for the link strategy.
NSLIM	1	Max slippage for the link strategy.

The variables CP, ISTR, NCRIT and NSLIM are provided only by the Input Data Processor. The others may be provided by the HCM.

1.3 File 12

It includes identical records of total length of 448. The data is provided by the Input Data Processor, except of the BVEC, BVFC variables provided by the Network Strategies Evaluator. The record number is assigned arbitrary to each O-D pair, however once it is set, it remains the same. The variables are:

VARIABLES	WORDS	COMMENTS
DEMAND	140	A (20,7) array about the daily demand per commodity type for the O-D pair. For types 1, and 2 it gives in vehicles, for the rest it depends on the options (either tons or vehicles).

VARIABLES	WORDS	COMMENTS
ELA	7	Elasticity of demand with respect to transport costs for each commodity type.
PRICE	7	maximum transport cost per unit of commodity, per commodity type, to be worthing the production. ($/unit of comm.).
VALT	7	Value of loss of time for each commodity type ($/hr.unit).
FLOAD	7	Load factor of each vehicle type.
BVEC	140	A (20,7) array about the transport economic costs of each commodity type.
BVFC	140	A (20,7) array about the transport financial costs of each commodity type, if the base network strategy was to be implemented.

2. HCM modification and interface with the system

The HCM is designed to simulate the costs of various investments strategies on a road link. It simulates: (i) the construction and maintenance activities over the time horizon of each alternative link strategy and (ii) the vehicles operation on the link.

The HCM simulates one link at a time. However, it may simulate alternative link strategies in each run. The role of the HCM in the system is the following: For each link, that either no data about costs (for construction or maintenance activities or vehicle operation) exists; or the link will be improved; or the link was not existed before and it will be constructed, the HCM will simulate the activities and provide (1) the financial and economic costs of the construction and maintenance activities over the time horizon, as well the skilled labor costs and the foreign exchange; (2) the vehicle operation costs (financial and economic) and the average travel time for the whole link over the time horizon according to the link strategy followed. Note that it always simulates the link for the'base strategy', i.e., no activity different than the existing one up to date would take place. This data is stored on disk according to the number the link has in the network and the strategy followed. This data complemented by the data provided by the Data Processor will be input data to the Network Strategies Generator and Evaluator.

3. The Input Data Processor

The purpose of this computer package is to read the data required for the function of the system and to store it into disks for further use.

It has the capability to read from the same card words and numbers. This simplified the input of the data, minimize possible errors and allows the change of any part of the data stored. This is accomplished with the use of the SUBROUTINE MATCH, developed originally by R.D. Logcher et.al.

3.1 MATCH subroutine

MATCH is designed to be usable with FORTRAN for operations on logical input fields. The translation of a field identifies its form and meaning. MATCH reads a card into a alphanumeric array, converts each column to an integer code in a numeric array and decodes each logical field on the card. Each code number represents a character and is formed into list words by combining the code times some power of 100. Therefore each words need to be read has to be included in an integer array (to be called dictionnary) with its corresponding integer numbers. Although MATCH provides a general input capability, versatile translation requires extensive logical programming. Branching on translated words is accomplished with the "computed GO TO" statement, with the control variable determined from the position of the translated word in the dictionary. The subroutine MATCH is used by the Data Processor program, the card to be read and the dictionnary to be utilized have been specified. The MATCH gives back the word read, for the branching, or the number read.

Virtually any type of input can be performed. Even if a word is read from the card but not found in the dictionnary, and it is not neccesary to be translated, it is possible with the appropriate logic in programming for this case to makeMATCH to skip it.

3.2 Input data

Input to the Data Processor can be separated into the following types:

(i) Systems commands: The processor may handle the cases of updating

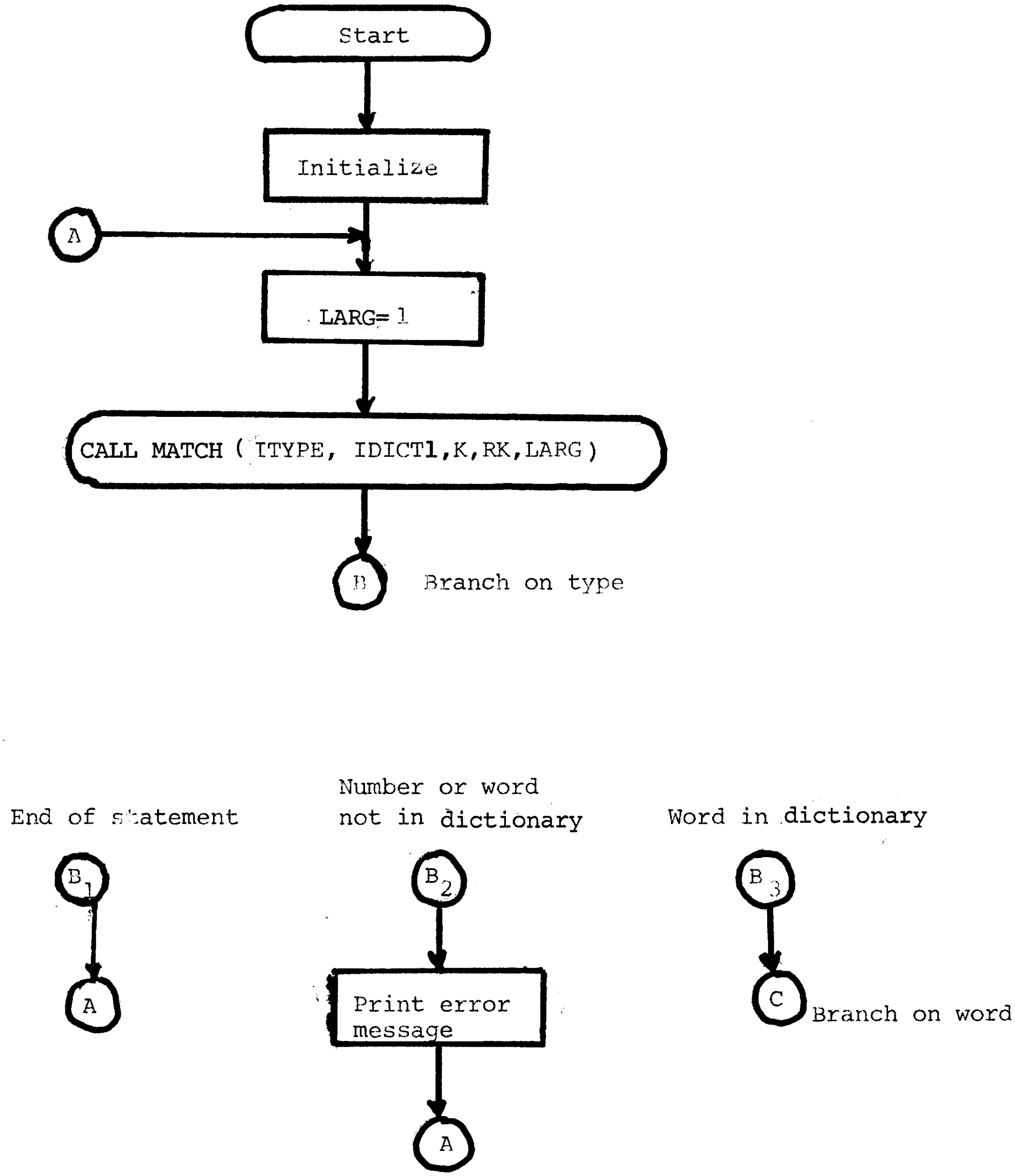


Figure B.2: Input Data Processor - Flow Chart (Partial)

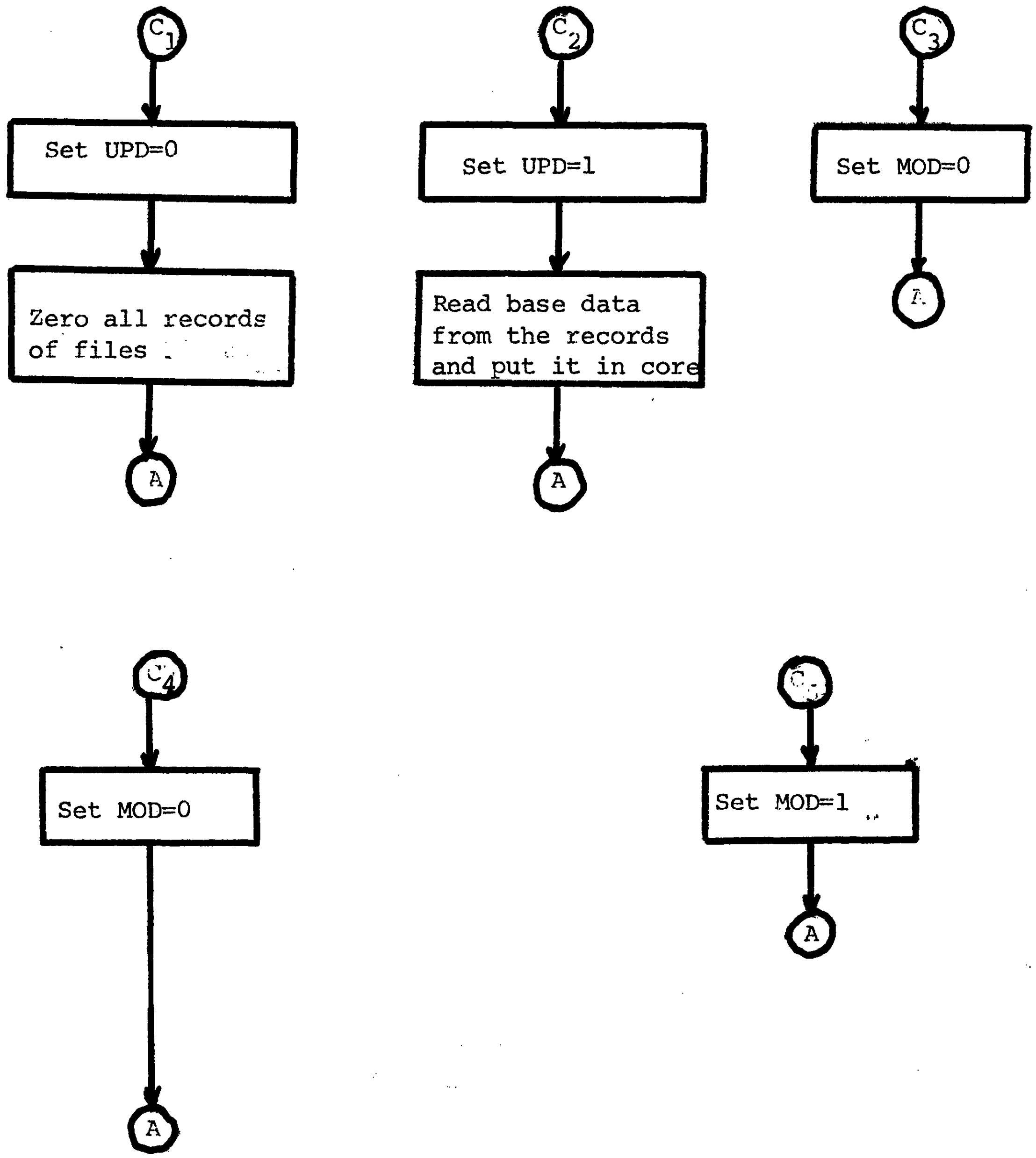


Figure B.2: (Continued) Input Data Processor - Flow Chart

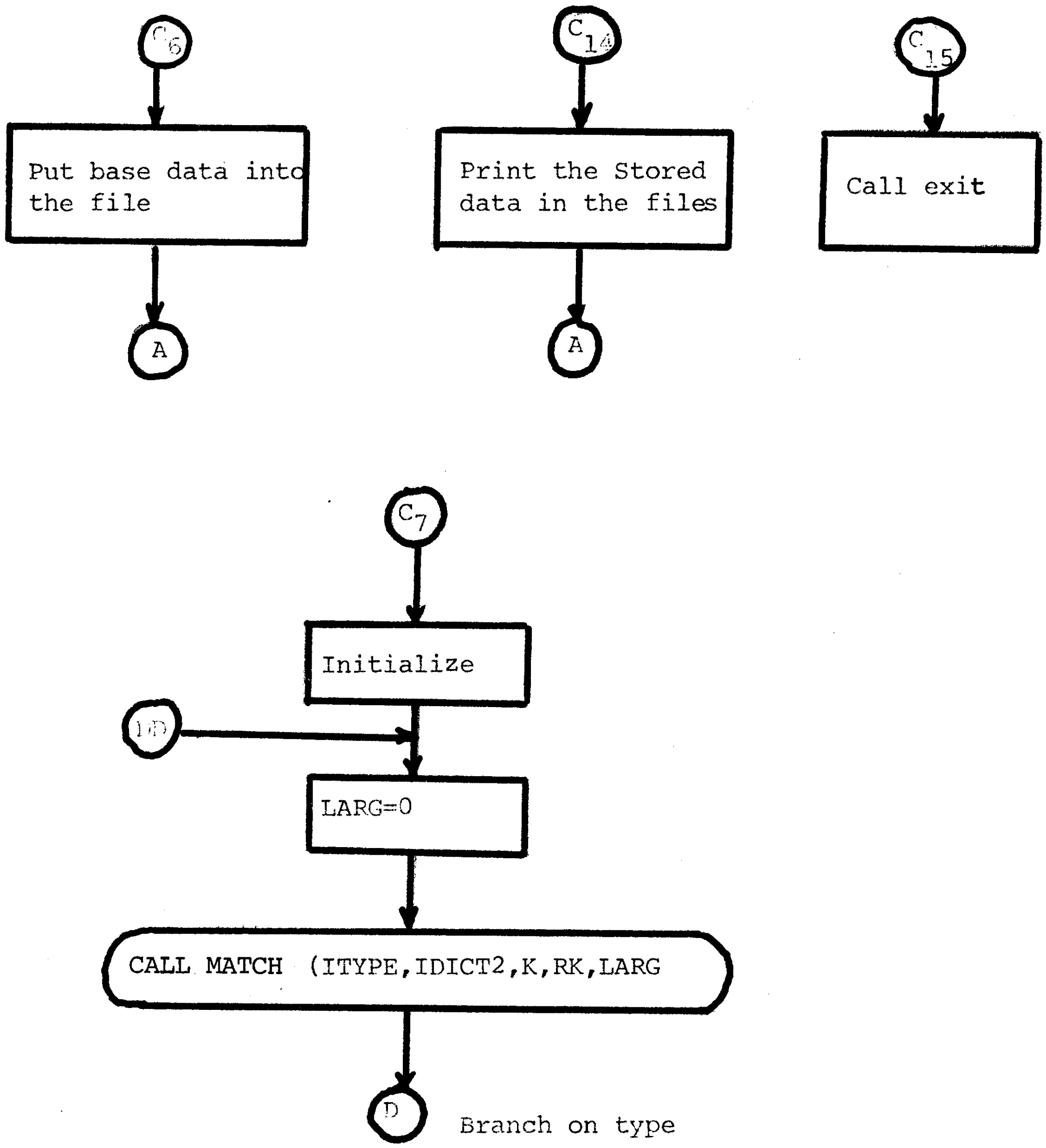


Figure B.2: ((Continued) Input Data Processor - Flow Chart

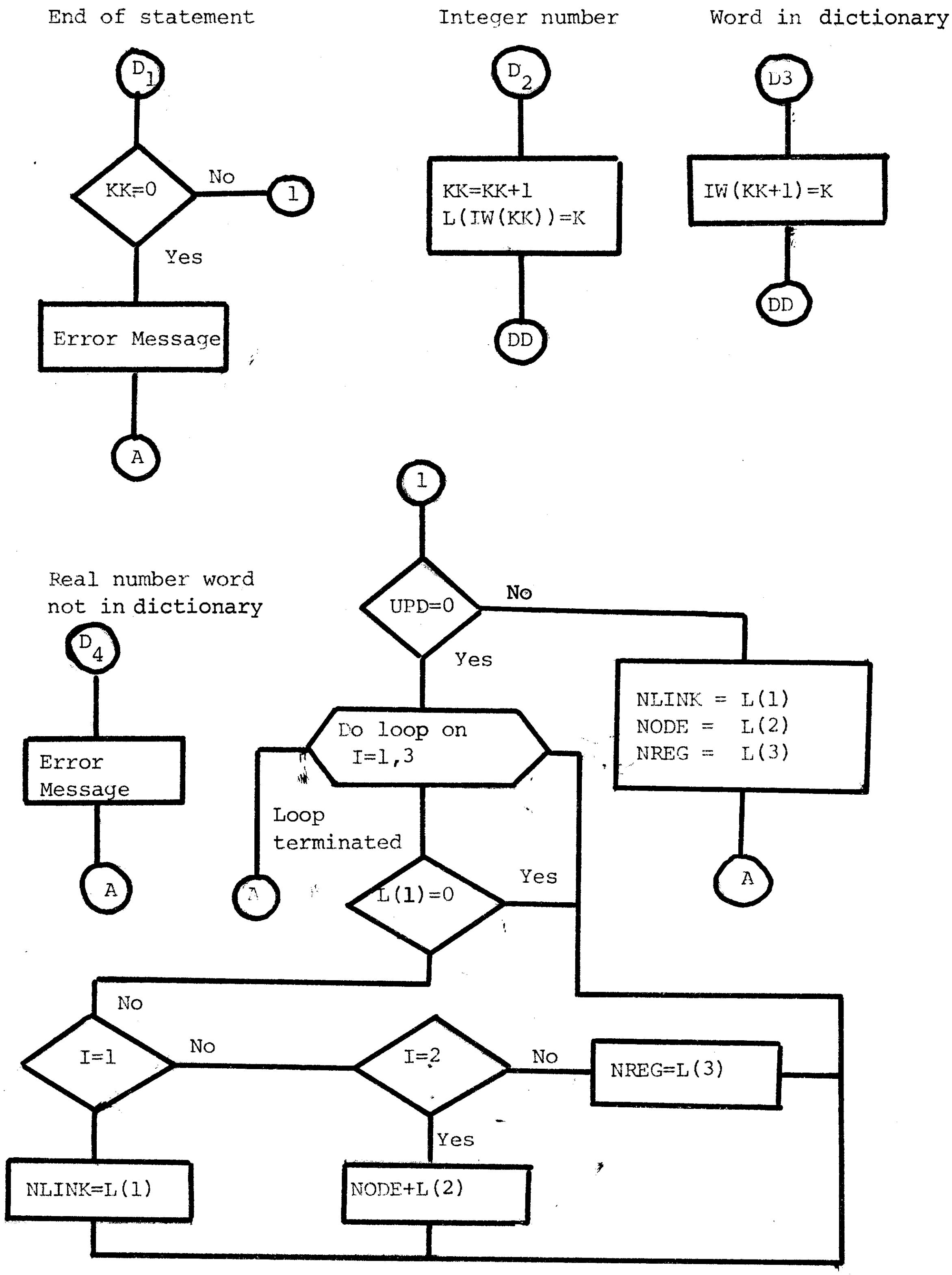


Figure B.2: (Continued) Input Data Processor - Flow Chart already existed data; changing parts of it; delete portions or add others. The format is simple. One-word commands, i.e., INITIATE, UPDATE, DELETE, CHANGE, ADD.

(ii) Network Information: This data type describes the network, assigning numbers on the nodes and links; specifies the regions to be examined and the links they belong to each of them .

(iii) Budget Information: For each year the available budget, the skilled labor and the foreign exchange for each region is provided.

(iv) Demand Information: Two options of demands are provided. Option 1 gives the demand in vehicle numbers. Seven types of vehicles are possible. Option 2 gives the demand in vehicle numbers for the passenger cars and buses but in tons for the rest 5 types, assuming a commodity will be transported by its corresponding vehicle (i.e. commodity, its demand given by type 3, will be transported by vehicle type 3). Demand for both options is given on an average daily basis, for each year, for each supply-demand nodes pair. (to be called origin destination pair). Also for each O-D pair the following data is provided: the elasticity of demand with respect to transport costs; the maximum transport price the operator is willing to pay (where costs equal to revenues for the vehicle's operator); the value of travel time (in $/hr/passenger for the passenger cars and buses and in $/hr./ton for the trucks); the load factor of the vehicles. Also the capacities of the vehicles used are specified: In passengers for cars and buses and in tons for trucks.

(v) Link Information: Portion of this data may be provided from the HCM. This portion includes: the average travel time on the link, the link length, the design speed of the link, the rise and fall, the vehicle operating costs (financial and economic), costs of construction and/or maintenance (financial and economic). If a link have not been stimulated by the HCM this data should be provided here. The portion that has to be inputed here includes the link capacity in PCU/hour, the critical index for each link strategy (to be specified in the Network Strategies Generator) and the maximum allowable slippage in years of a link strategy.

This is the data required as input to the Network Strategies Generator and Network Strategies Evaluator. The presented flow chart of the part of the Data Processor handling the instructions about the System gives a feeling of how the computer package works: It is a branching mechanism. (Branch on each key-word). The Data Processor has the option of printing the data stored on files.

4. Network Strategies Generator. (Developed originally by Y. Lasage)

The objective of this computer package is the generation of feasible network strategies for the improvement of a given network of roads over the time horizon. A network strategy will be feasible if it verifies the following regional constraints per year:

(i) budget (ii) skilled labor (iii) foreign exchange.

It is assumed that four kinds of links exist:

(i) link with maintenance activities (maybe no maintenance at all)

(ii) link with activities of either initial construction or improvement; however according to a fixed strategy. (they belong to the so-called "base network").

(iii) link with mandatory activities of either initial construction or improvement; however the timing of the strategy may change (obligatory link).

(iv) link with optional activities of initial construction or improvement (optional link).

The Generator deals with (iii) and (iv) kinds of links. Base network is the original network as it is up to date to which the links of kinds (i) and (ii) are added.

The inputs to the Generator are (1) the data stored on files by the HCM and the Data Processor and (2) the desired feasible network strategies to be generated; the optional and obligatory links; a minimal network strategy critical index. The inputs (2) are read with the use of SUBROUTINE MATCH, the input formats being words and numbers.

The output is stored on files for further use by the Network Strategies Evaluator. The output consists of two matrices: matrix NWSTR will give the links and their corresponding link strategies included in each generated feasible network strategy. Matrix NWSL will give the links, and the corresponding slippage in years of their defined link strategy in matrix NWSTR, for each generated feasible network strategy.

4.1 The approach

In order to clarify the approach we describe the treatment of link (iv). (Note that the treatment of link type (iii) is quite similar)

Definitions:

i: number of the link I considered

$\bar{i}$: maximum number of links

ℓ: number of strategy L considered

$\bar{\ell}$: maximum number of strategies

j: number of N.S.

The algorithm is the following:

STEP 1: Initialization: i=1, j=1, ℓ=1, k'=1

STEP 2: Consider the N.S. j

STEP 3: Add the L.S. (link strategy) (i,ℓ) to NS_j

-If NS_j verifies the constraints set k=i Go To 4

-If NS_j does not verify the constraints Go To 6

STEP 4: Set: i=i+2

If i is greater than $\bar{i}$ Go To 5

If i is not greater than $\bar{i}$, make ℓ=1 and Go To 2

STEP 5: Set j=j+i and i=k

Include in NS_j all LS of NS(j-1) [LS(i,ℓ)] Go To 6

STEP 6: Substract LS (i,ℓ) from NS_j.

Slippage of LS (i,ℓ) possible?

Yes: slip it and Go To 3

No: Go To 7

STEP 7: Is there another strategy available for link i?

Yes: $\ell=\ell+1$ Go To 3

No: Go To 8

STEP 8: Is k'=k?

No: Set k'=k Go To 4

Yes: Go To 9

STEP 9: Is k'=1?

No: k=k-1, k'=k and i=k Go To 4

Yes: END

4.2 Description of SUBROUTINES

4.2.1 SUBROUTINE ADDCOM (N,VBAR,V1,V2,V)

Objectives: This subroutine computes the sum of two vectors V2 and V, taking in account a slippage of N components between the two vectors. Then it compares the sum to a vector VBAR.

If V1 > VBAR INDEX=1

V1 $\leq$ VBAR INDEX=0

N.B. V1 > VBAR if one of the components of V1 at least is greater than its corresponding component of VBAR.

4.2.2 SUBROUTINE ADDCO1 (N,ABAR,A1,A2,V)

Objectives: This subroutine is similar to ADDCOM for the arrays.

4.2.3 SUBROUTINE CALCUL

Objectives: This subroutine uses ADDCOM and ADDCO1 to verify that a N.S. verifies all the constraints.

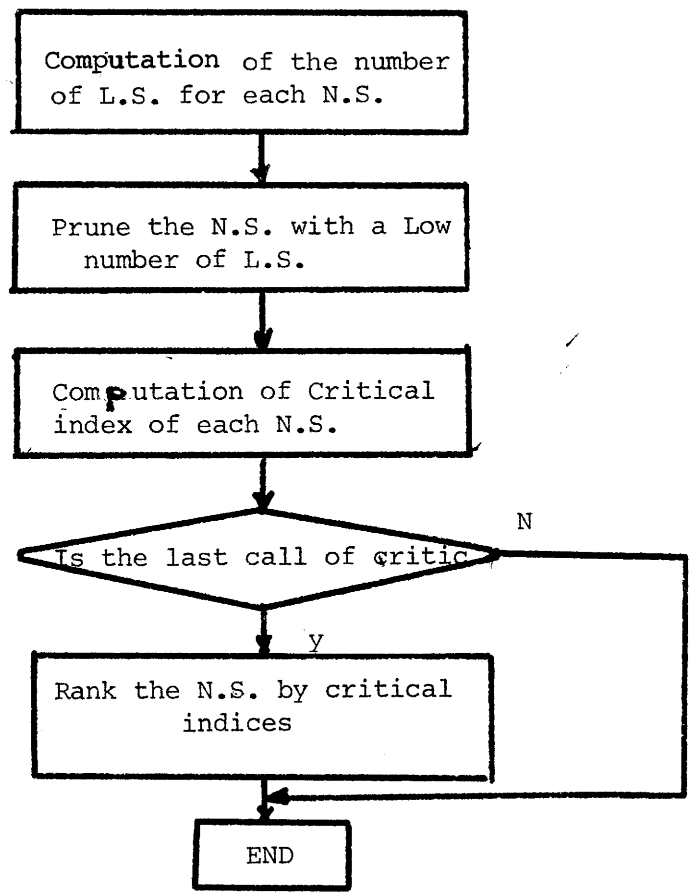


Figure B.3: Network Strategies Generator
Flow Chart of Subroutine CRITIC

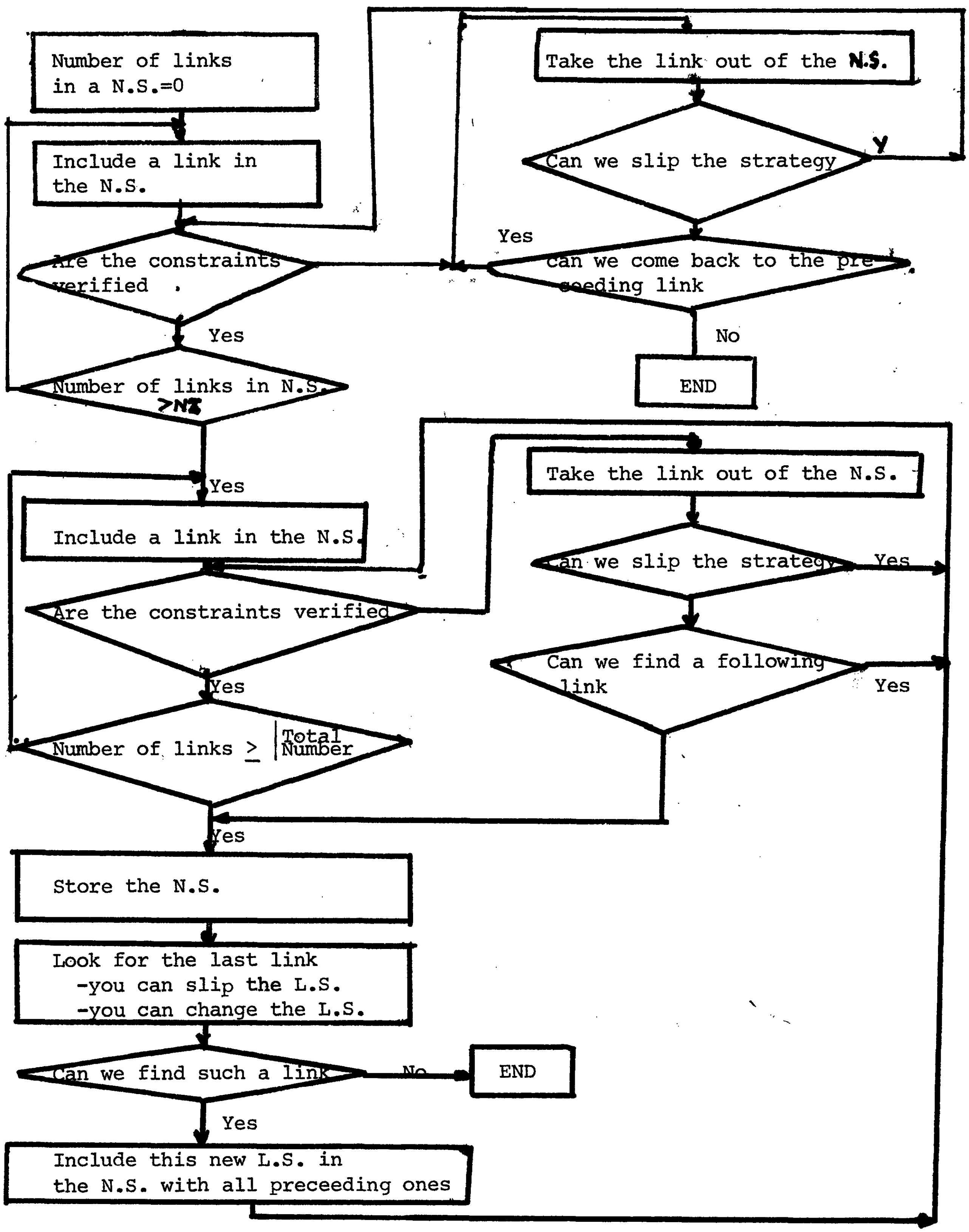


Figure B.4. Network Strategies Generator. Flow chart of subroutine VERCAL

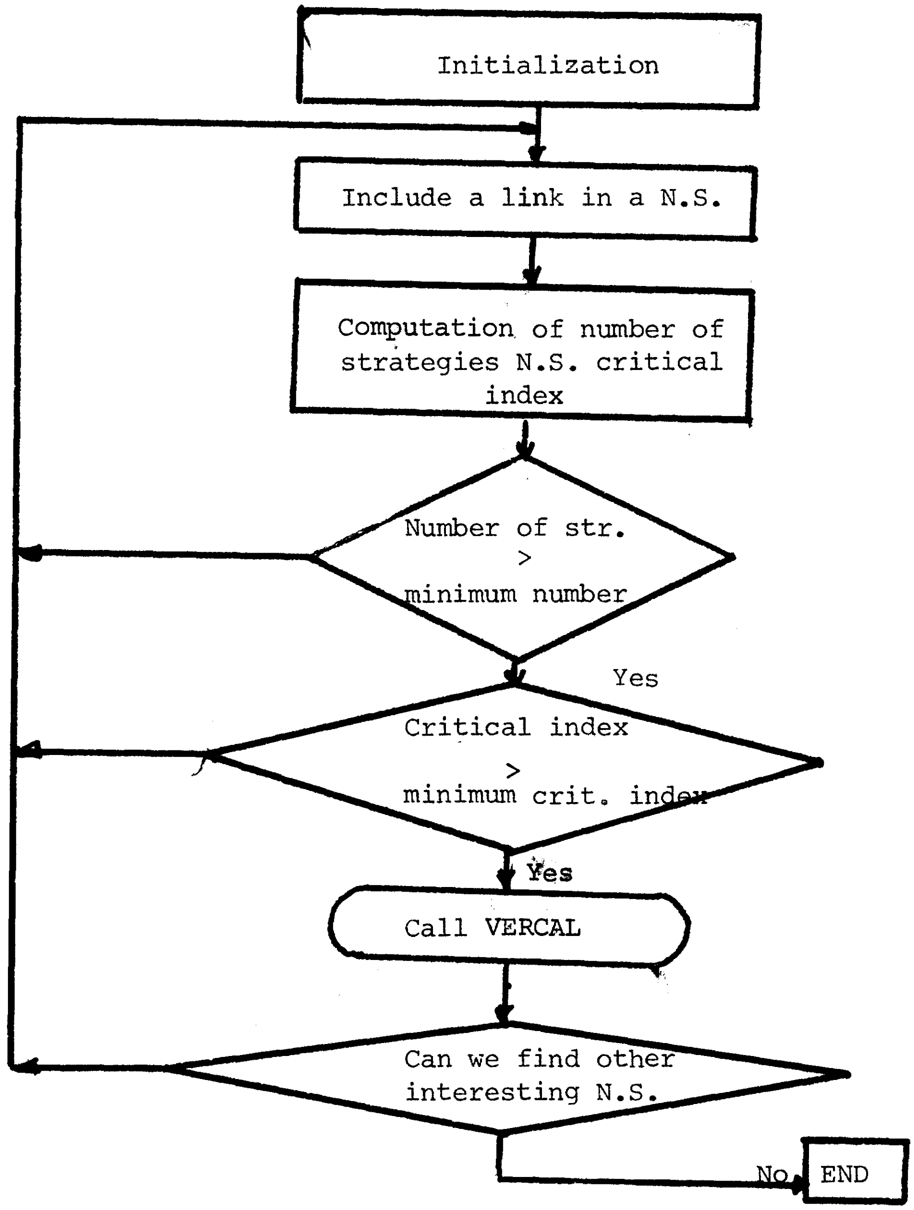


Figure B.5: Network strategies generator
Flow chart of MAIN

4.2.4 SUBROUTINE REMEMB

Objective: This subroutine reinitializes matrices when a N.S. does not verify the constraints.

4.2.5 SUBROUTINE REINIT

Objective: This subroutine reinitializes matrices when a N.S. verifies the constraints.

4.2.6 SUBROUTINE RECAL

Objective: This subroutine, as REMEMB, reinitializes matrices but when the reinitalization does not concern the same number of L.S. in a N.S.

4.2.7 SUBROUTINE CRITIC

Objective: This subroutine computes

a. the number of L.S. in each N.S.

b. the N.S. critical index from L.S. critical indices

Then it prunes the feasible N.S. with a low number of L.S. and with a low critical index.

4.2.8 SUBROUTINE VERCAL

Objective: This subroutine generates N.S. from the L.S. It operates on links.

A link may be either a link the inclusion of which is obligatory: L1, or a link the inclusion of which is facultative: L2.

L1 have only one strategy which may be slipped by a variable number of years, L2 have as many strategies as the Decision Maker asks.

4.2.9 MAIN

Objective: The main program defines the set of obligatory and links for VERCAL. In order to do this selection, it uses a minimal critical index, and a minimal number of strategies.

4.2.10 SUBROUTINE BUDGET

Objective: This subroutine computes the economic costs of base network strategy construction and maintenance activities. It substracts the financial costs from the available budget and if the resulting budget turns out to be less or equal to zero the task of generation is abadonned. It updates also the available foreign exchange and the skilled labor.

4.2.11 SUBROUTINE INITIA

Objective: Reads the data from the files and from the input cards.

4.2.12 SUBROUTINE ECRIRE

Objective: Writes the NWSTR and NWSL arrays to the records 5 and 6 of file 10 and prints out the results.

5. Network strategies evaluator

This computer package evaluate each network strategy applying the NPV criterion for the economic costs of the construction and maintenance activities proposed by the strategy and the resulting benefits.

It needs only as Input data the desired network strategies to be evaluated, chosen from the generated ones the years to be simullated and the years for which the detail results will be printed. The rest of the data is read from the files. In the event the base network has been analysed previously, it is not necessary to be analysed again, if no change has been occurred to it. The results of the analysis may be read from the file and used directly for the evaluation. Also, there is the option of keeping the ranking of previously evaluated N.S.

The provided output for each network strategy consists of:

(1) The net present value, (2) the annual benefits and costs, (3) the average daily traffic on links every year of the time horizon, (4) for each origin-destination pair the minimum cost route. Finally, a ranking of all network strategies according to their NPV is provided.

5.1 Description of SUBROUTINES

5.1.1. SUBROUTINE BASENE

Objective: It simulates each year of the base network. If no change occurs the same data of the previous year is saved for this year.

If changes occur, then it computes the new transport costs between the O-D pairs and updates the demand according to the elasticity of demand with respect to price, as follows:

$$DEMAND' = DEMAND* \left(\frac{BVFV(I)}{BVFV(I-1)}\right)^{-ELA}, \text{ where:}$$

DEMAND: old demand

DEMAND': new demand

BVFV(I): transport costs of year I

BVFV(I-1): transport costs of previous year (I-1).

Finally it saves the results into file 12 according to the O-D pair number.

5.1.2. SUBROUTINE ROUTE

Objective: It finds the minimum cost route of each vehicle type, computes the transport costs (both economic and financial) as a sum of the vehicle operation costs and the loss of time costs. Then it assigns the traffic on the links. The algorithm that computes the minimum cost route is described in Chapter 3.

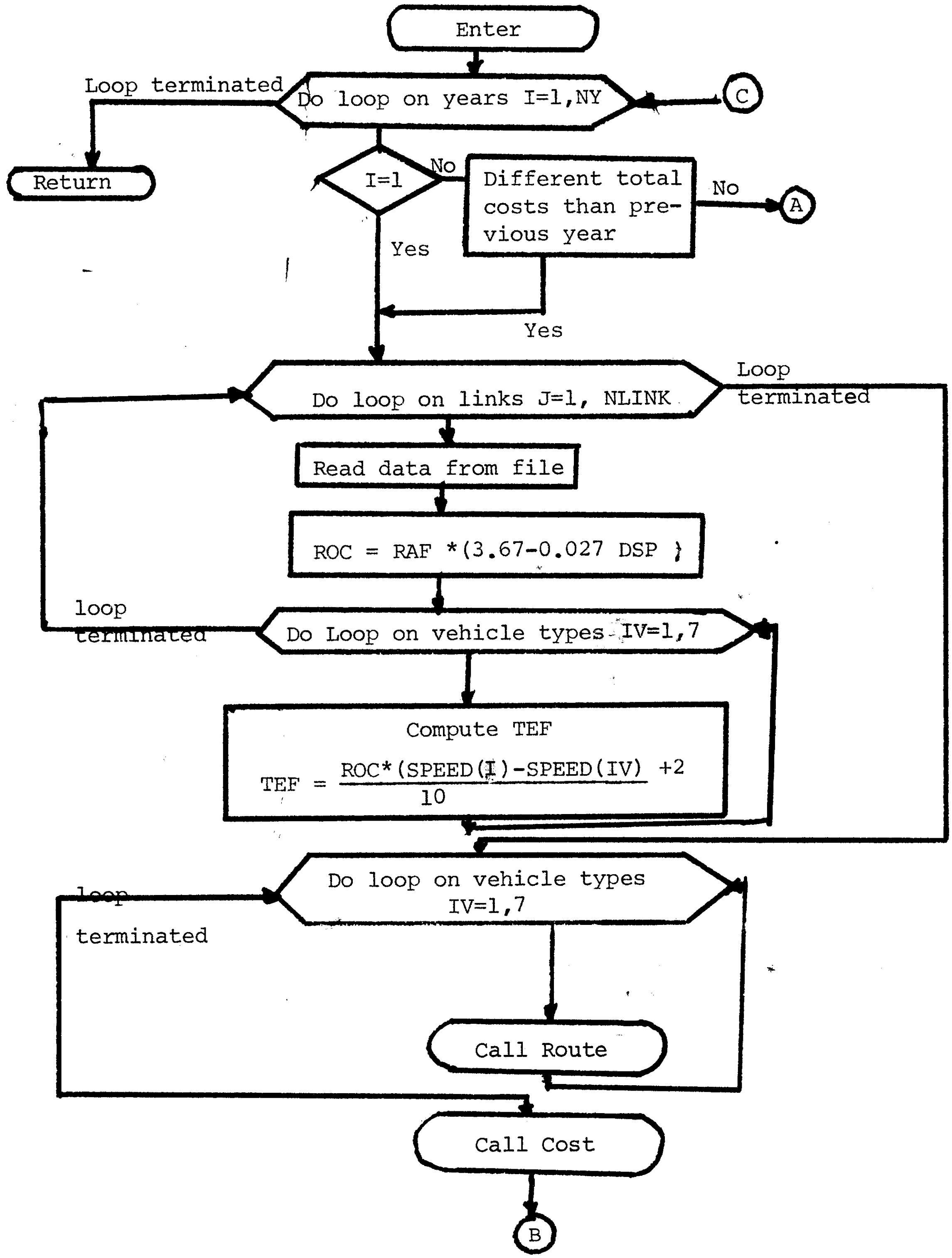


Figure B.6: Network strategies evaluator - Flow Chart of Subroutine BASENE

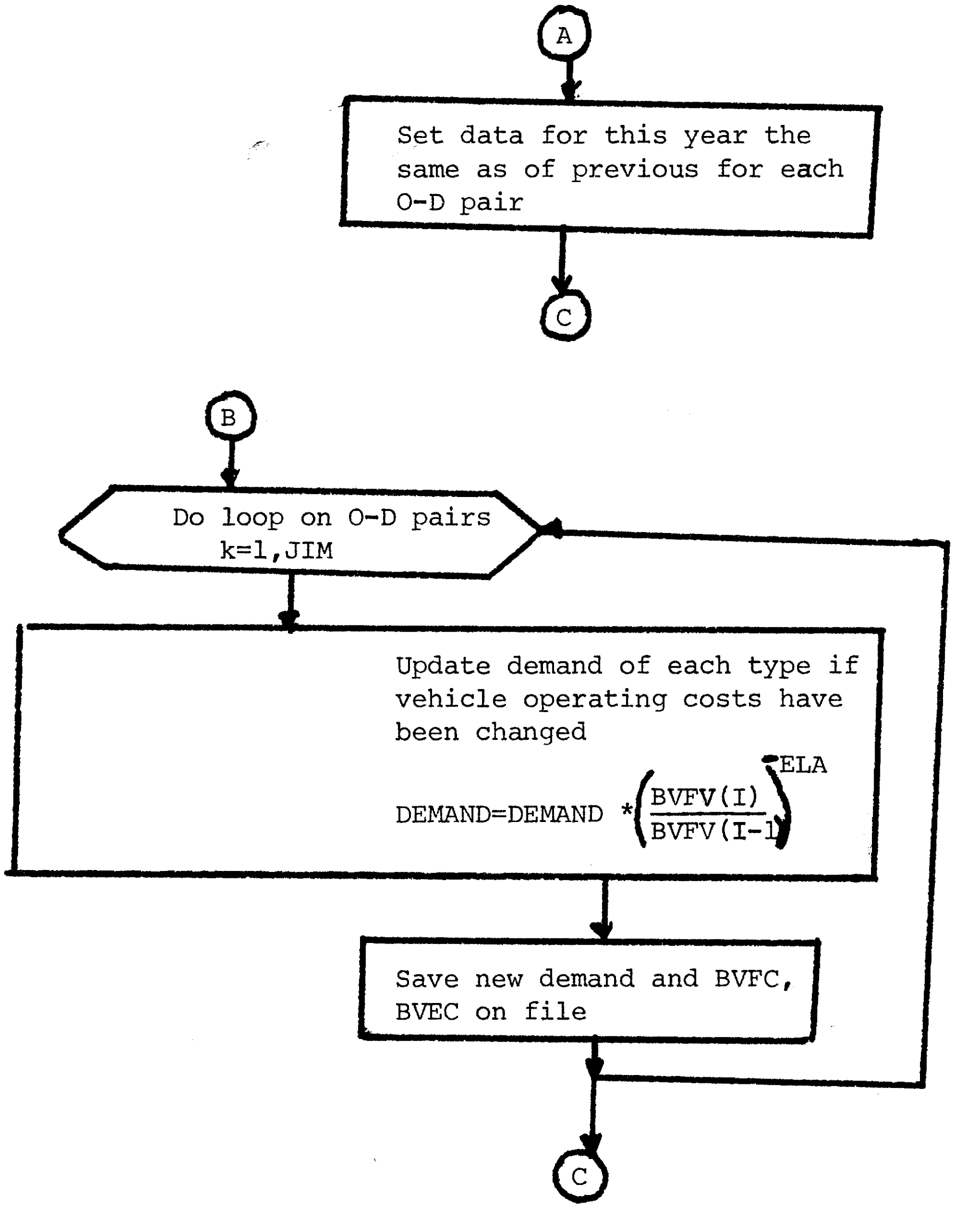


Figure B.6:(Continued) Network strategies evaluator
Flow Chart of Subroutine BASENE

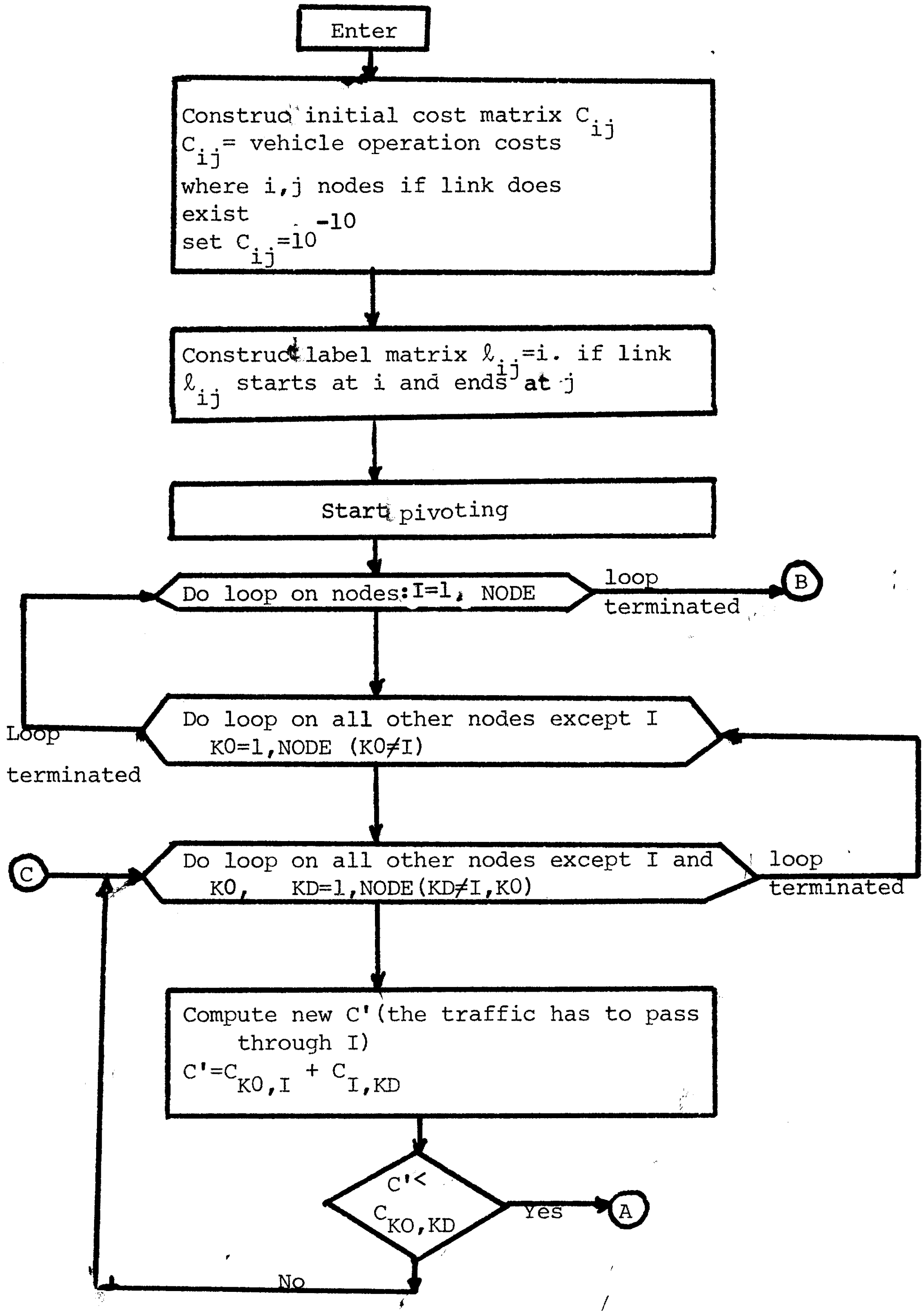


Figure B.7: Network strategies evaluator. Flow Chart of Subroutine ROUTE

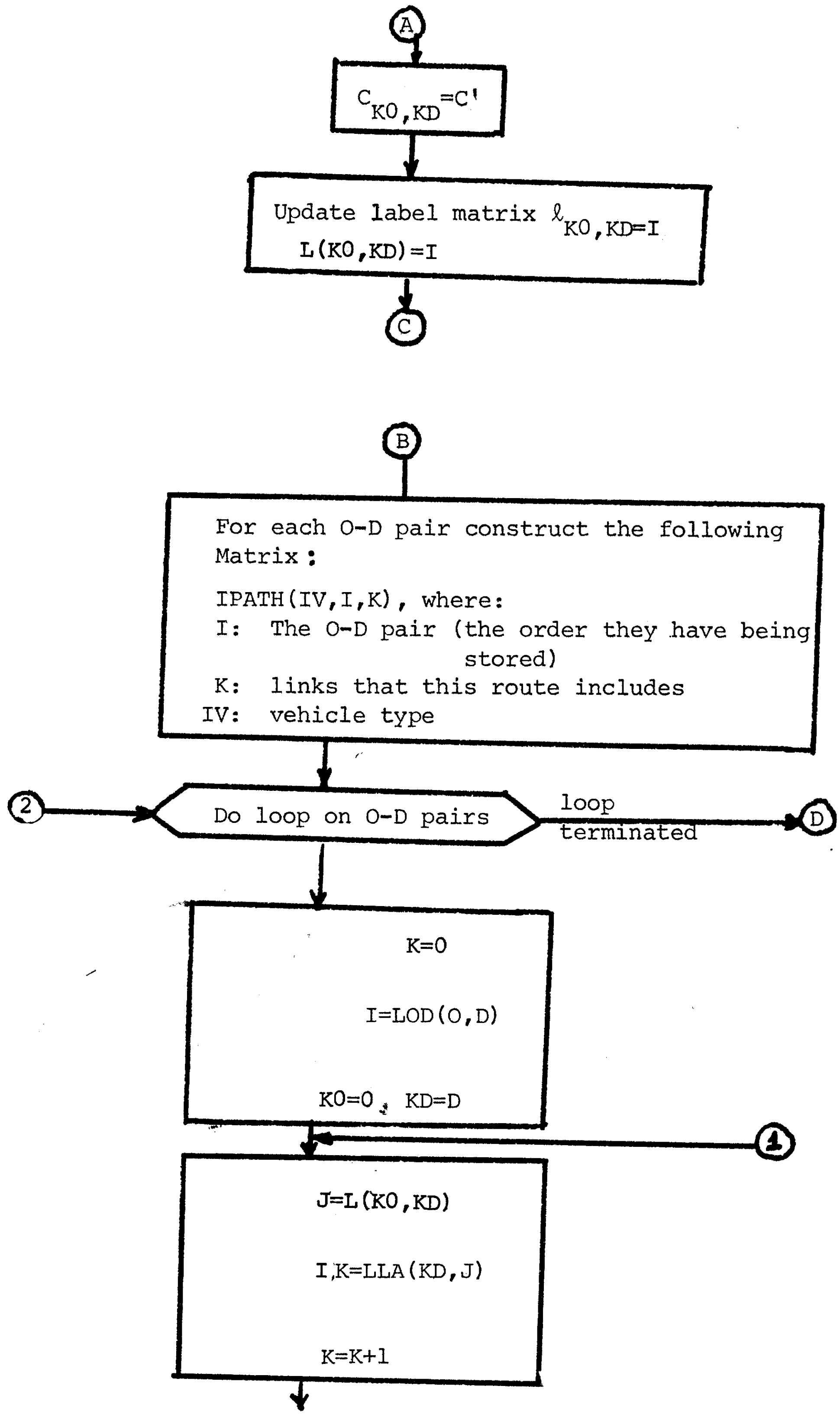


Figure B.7: Network strategies evaluator. Flow Chart of Subroutine ROUTE

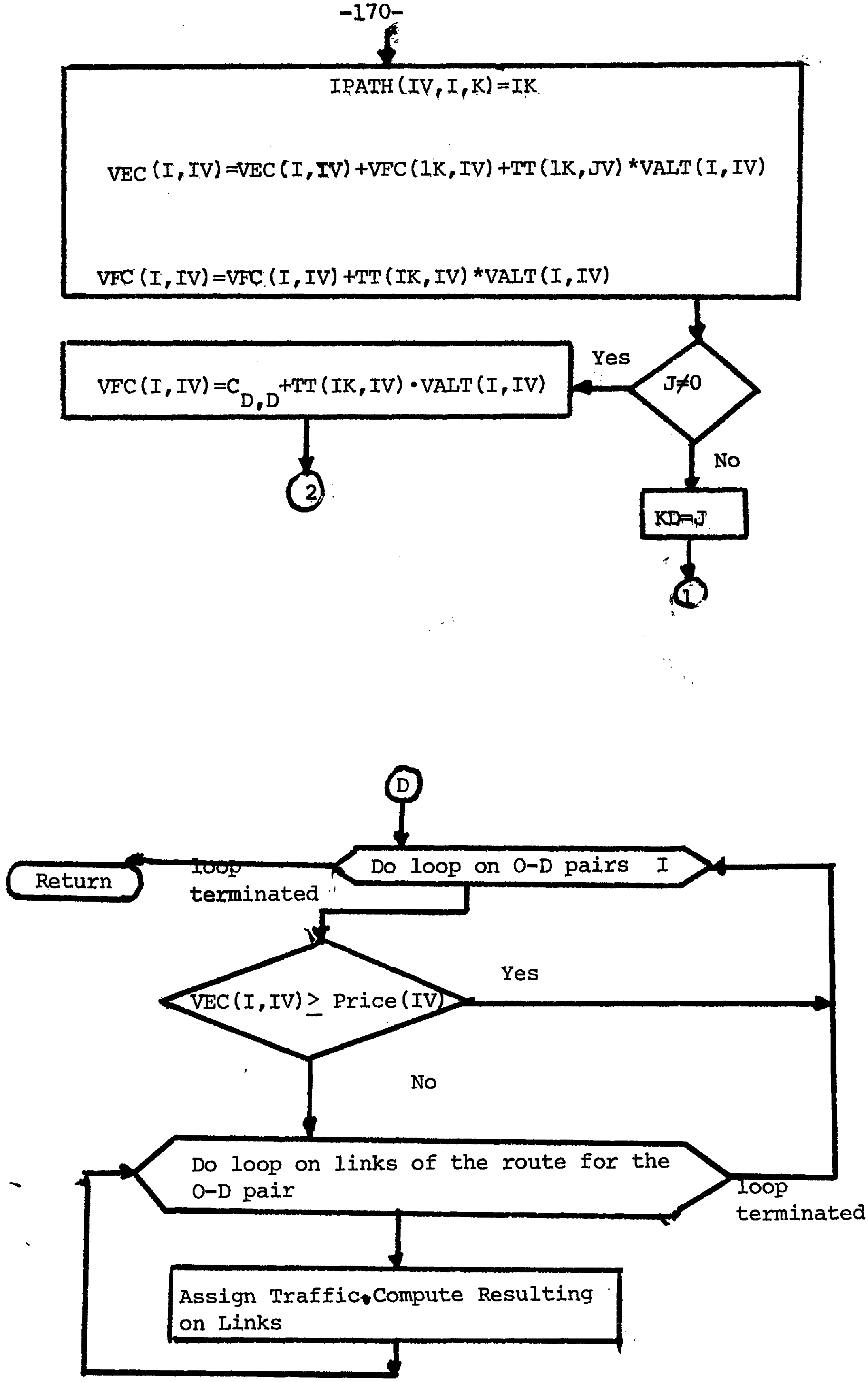


Figure B.7: Network strategies evaluator. Flow Chart of Subroutine ROUTE

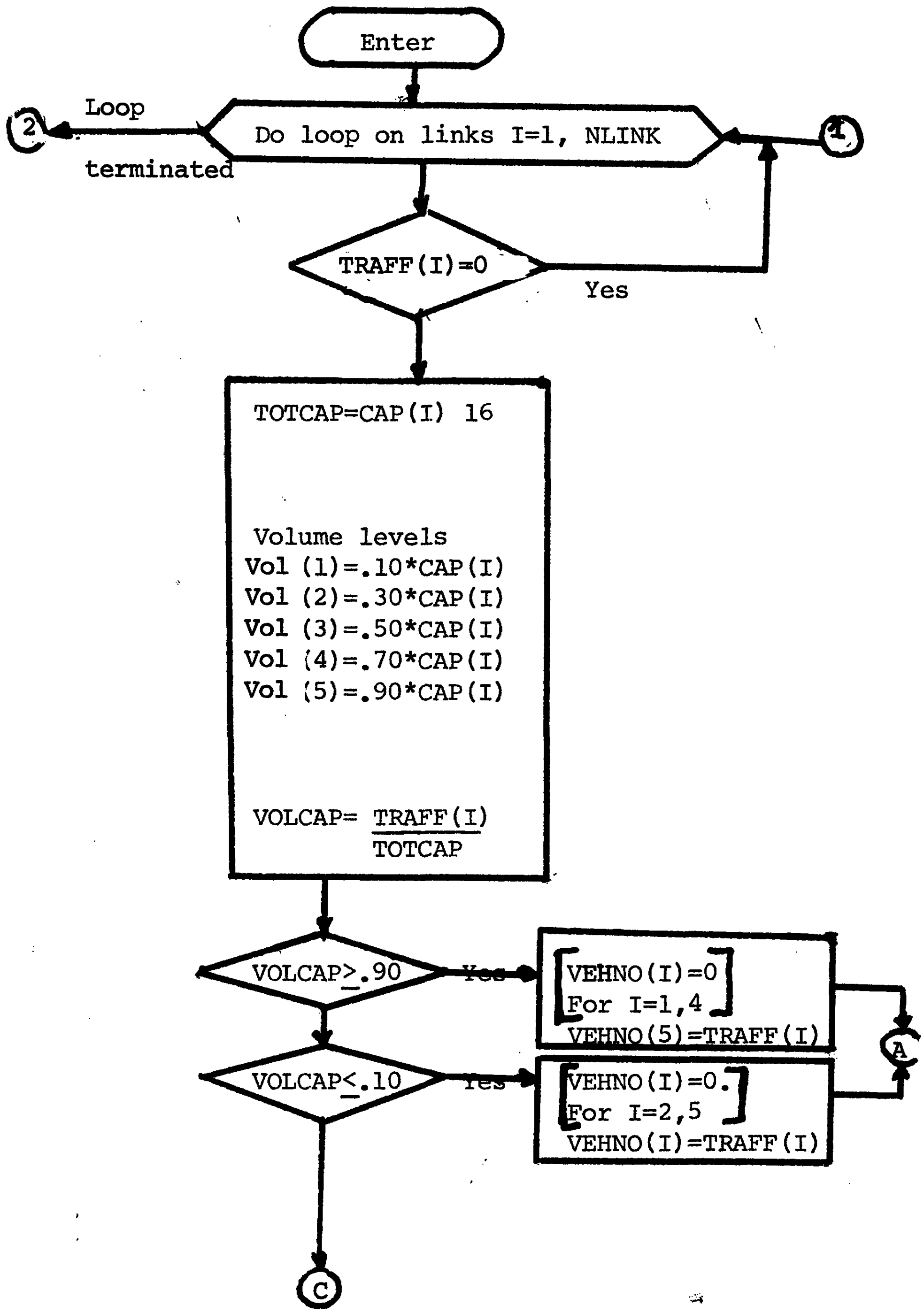


Figure B.8 Network Strategies Evaluator. Flow chart of subroutine COST.

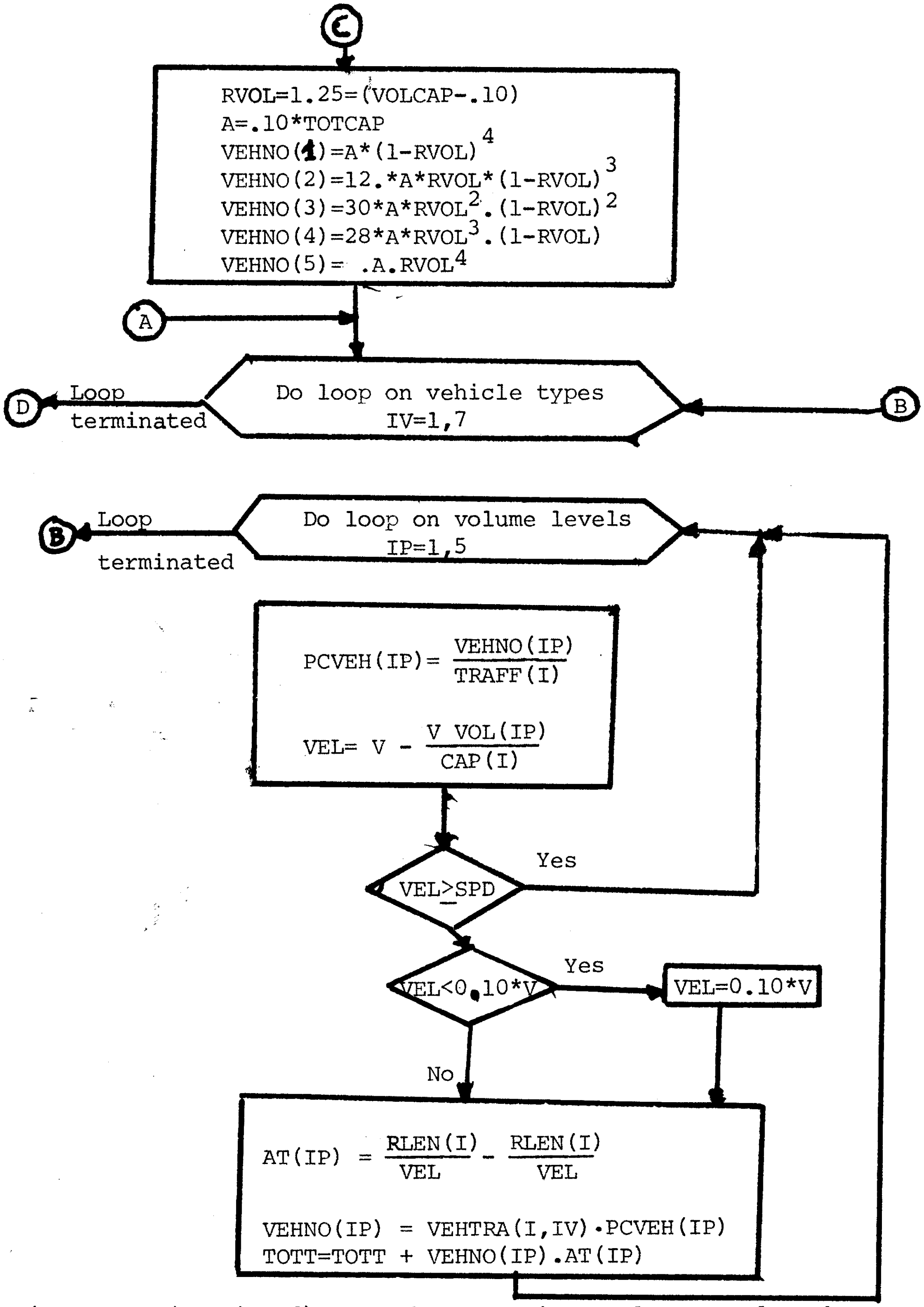


Figure B.8 (Continued) Network Strategies Evaluator. Flow chart of subroutine COST.

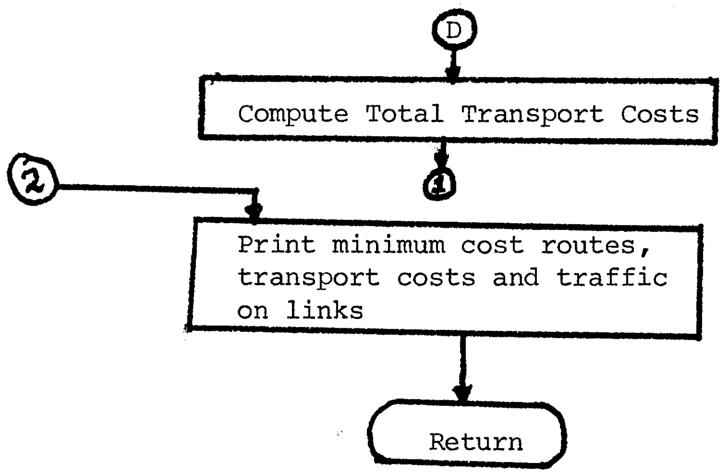


Figure B.8 (Continued) Network Strategies Evaluator. Flow chart of subroutine COST

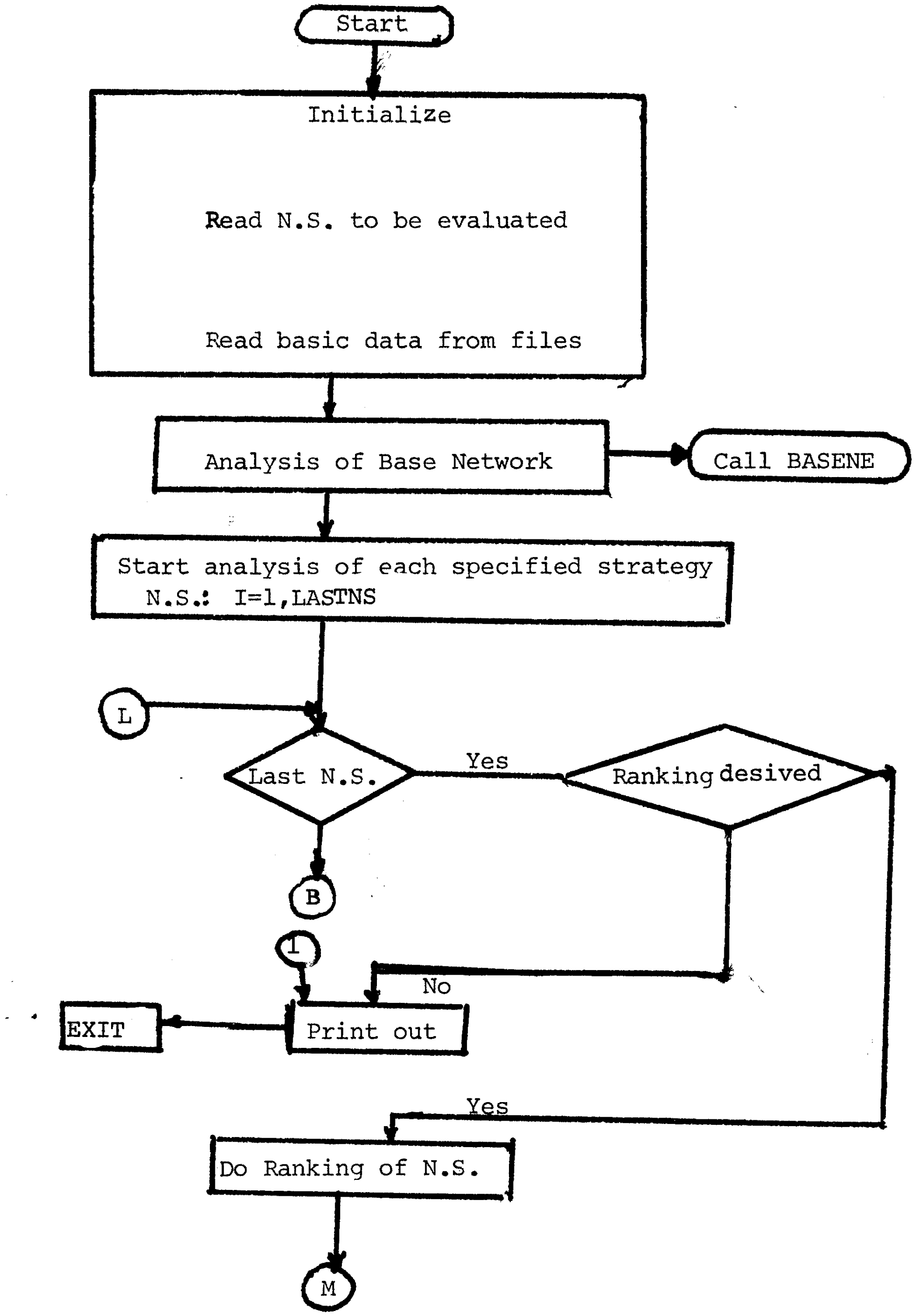


Figure B.9: Network strategies evaluator.
Flow chart of MAIN

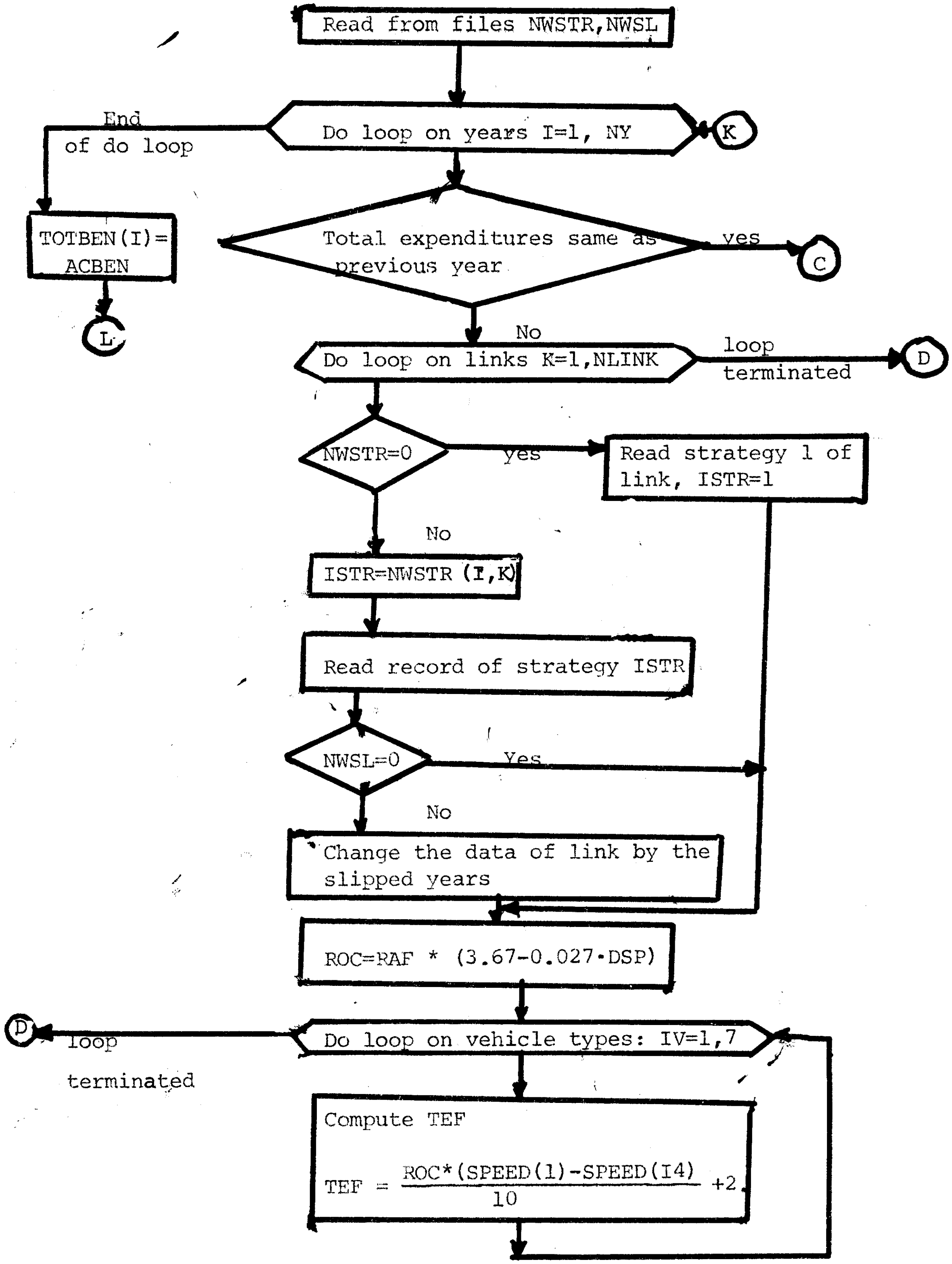


Figure B.9. Network strategies evaluator. Flow chart of MAIN

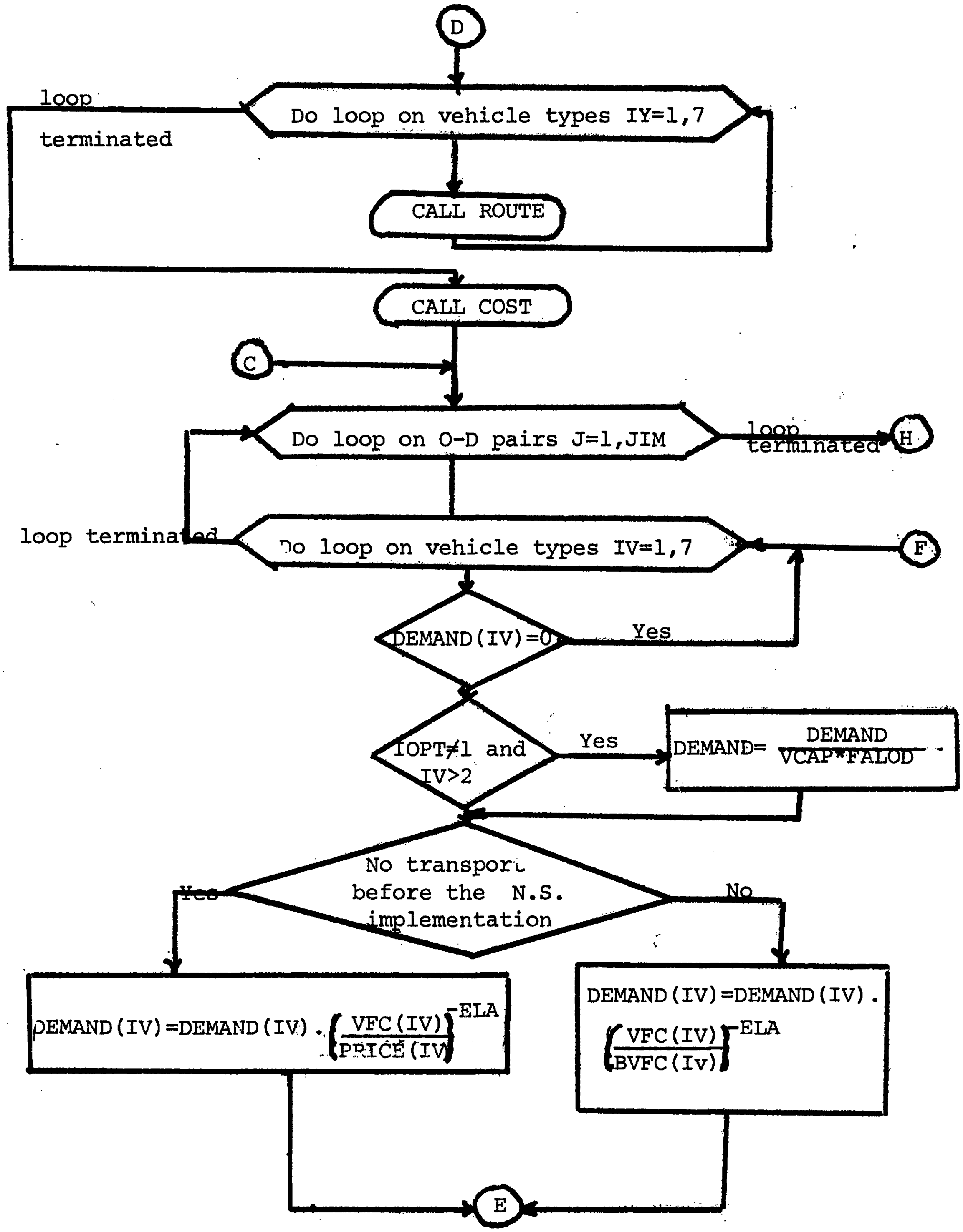


Figure B.9. Network strategies evaluator. Flow chart of MAIN

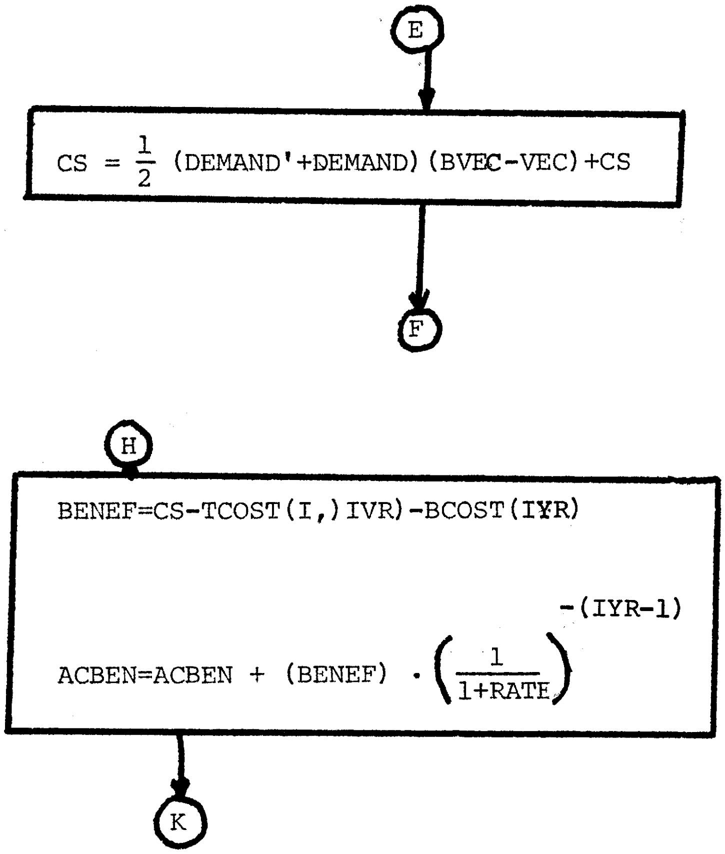


Figure B.9. Network strategies evaluator. Flow chart of MAIN

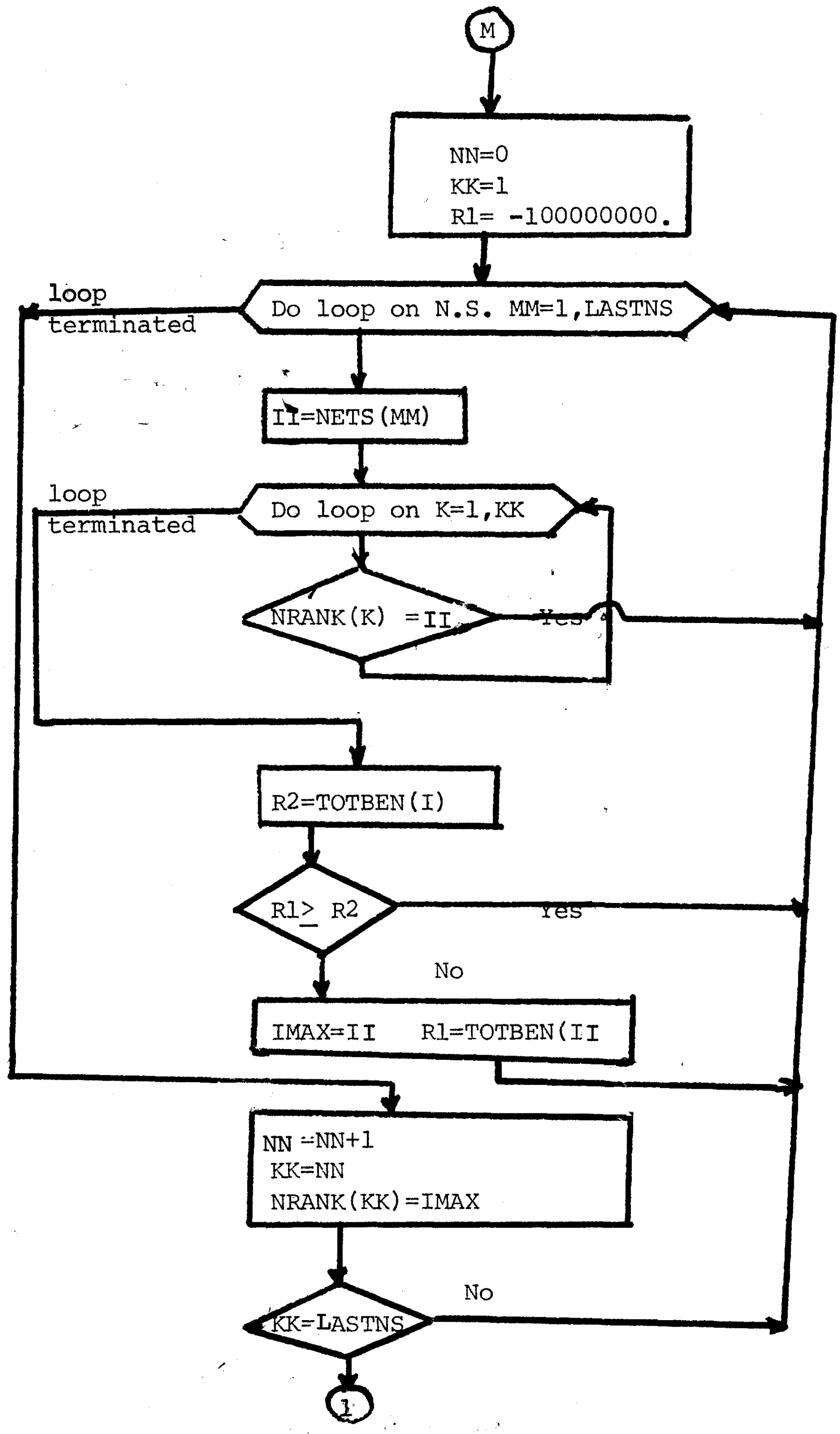


Figure B.9. Network strategies evaluator. Flow chart of MAIN

5.1.3. SUBROUTINE COST

Objective: It checks if congestion occurs. If it does, it computes the congestion costs. (The method is described in Chapter 3). Finally, it computes the total transport costs for each O-D pair.

5.1.4 MAIN

Objective: It reads the data from the cards and the files. For each network strategy it does the evaluation. It computes for each O-D pair the minimum cost routes calling ROUTE, it computes the vehicle equivalent factors and it calls COST to do the congestion computations. It computes the benefits, applying the formula (in general form):

$$CS = \frac{1}{2}(T+T')(C-C'), \text{ where:}$$

T,C: the demand and the costs of the base network

$T' = T \cdot \left(\frac{C'}{C}\right)^{-ELA}$ the new demand and, C' = the new costs.

Next it computes the net benefits of the year

NETBENEFITS = (TOTAL BENEFITS-TOTAL COSTS).

It discounds them to the present and it computes the NPV for all years of the time horizon.

If desired, it ranks the alternative network strategies according to their computed NPV.

APPENDIX C:

COMPUTER LISTINGS

INPUT DATA PROCESSOR

```
C MAIN PROGRAM TO READ INPUT DATA FOR NETWORK EVALUATION
      DEFINE  FILE 10 (6,900,U,INF)
      DEFINE  FILE  11(300,583,U,LAU)
      DEFINE FILE 12(30,448,U,JIMC)
      DIMENSION F10(900),F11(583),F12(168),VCAP(7),LBEG(30),LEND(30),
     1LST(30),LREG(30),RAF(20),  TB(10,20),FF(10,20),SL(10,20),LLA(30,30
     2),LOD(30,30),ATT(20,7),EOC(20,7),FOC(20,7),ETC(20),FTC(20),SKL(20)
     3,FOR(20),CAP(20),DEMAND(20,7),ELA(7),PRICE(7),VALT(7),FLOAD(7),
     5IDICT1(19),IDICT2(5),IDICT3(9),IDICT4(7),IDICT5(14),IDICT6(8),
     6IDICT7(11),IW(10),L(10),RL(11),IDICT8(8),DSP(20)
      INTEGER UED,RG
      REAL LEN(20)
C WORDS IN IDICT1: INITIALIZE,UPDATE,ADD,DELETE,CHANGE,STOP,NETWORK,TIME,LINK,
C                  BUDGET,DEMAND,INTEREST,VEHICLE,END,PRINT,FINISHED,OPTION
C WORDS IN IDICT2:  LINKS,NODES,REGIONS
C WORDS IN IDICT3: STRATEGY,DATA,O,D,END,INDEX,SLIPPAGE
C WORDS IN IDICT4: TB,FE,SL,END,REGION
C WORDS IN IDICT5: ATT,EOC,FOC,ETC,FTC,SKL,FOR,LEN,CAP,RAF,DSP,END
C WORDS IN IDICT6: VOLUME,ELASTICITY,COMMODITY,TIME,LOAD,END
C WORDS IN IDICT7: V1,V2,V3,V4,V5,V6,V7,VOLUME,CAPACITIES
C  WORDS  IN  IDICT8:  LINK,BEGINS,CONCLUDES,REGION,FEASIBLE,STRATEGIES
      DATA IDICT1/3,17,283328,403523,202323,232431,222720,
     1383934,332439,392832,312833,214023,232432,283339,412427,243323,353
     2728,252833,343539/
      DATA  IDICT2/3,3,312833,333423,372426/
      DATA IDICT3/3,7,383937,232039,341414,231414,243323,283323,383128/
      DATA IDICT4/3,5,392114,252414,383114,243323,372426/
      DATA IDICT5/3,12,203939,243422,253422,243922,253922,383031,253437,
     1312433,222035,372025,233835,243323/
      DATA IDICT6/3,6,413431,243120,223432,392832,313420,243323/
      DATA  IDICT7/3,9,410114,410214,410314,410414,410514,410614,410714,
     1413431,222035/
      DATA  IDICT8/3,6,312833,212426,223433,372426,252420,383937/
      JIM=0
      IOPT=0
      DATA F10/900*0./
                                                                 PAGE    1
```

```
      DATA  F11/583*0./
      DATA  F12/168*0./
      DATA  VCAP/7*0./
      DATA  LBEG/30*0/
      DATA   LEND/30*0/
      DATA   LST/30*0/
      DATA  LREG/ 30*0/
      DATA  LIA/900*0/
      DATA  LOD/900*0/
      DATA  TB/200*0./
      DATA  FE/200*0./
      DATA  SL/200*0./
C EXECUTION BEGINS.
C FIND THE FIRST WORD OF THE CARD
   10 LARG=1
      CALL MATCH(ITYPE,IDICT1,K,RK,LARG)
      GO TO (10,11,11,11,12,45),ITYPE
   11 GO TO 2001
   12 IK1=K
      GO TO (15,50,100,105,110,3000,150,200,250,400,500,800,850,10,40,45
     1,900),IK1
C INITIATE COMMAND. ZERO ALL RECORDS.
   15 UPD=0
      DO 20 INF=1,3
      WRITE(10'INF)F10
   20 CONTINUE
      DO  30  JIMC=1,30
      WRITE(12'JIMC)F12
   30 CONTINUE
      GO TO 10
   40 CALL  GRAPHE
      GO  TO  10
  900 LARG=0
      CALL  MATCH(ITYPE,IDICT2,K,RK,LARG)
      GO  TO  (10,911,910,900,900),ITYPE
  910 K=RK
```

```
  911 IOPT=K
      GO  TO  10
C IF UPDATE OCCURS: PUT IN CORE ALL BASE DATA
   50 UPD=1
      INF=1
      READ(10'1)NLINK,NODE,NREG,IHORIZ,JIM,RATE,VCAP,LBEG,LEND,LST,LREG,
     1TB,FE,SL,IOPT
      READ(10'2)LLA
      READ(10'3)LOD
      GO TO 10
CCC CHECK FOR TYPE OF UPDATE
  100 MOD=0
      GO TO 10
  105 MOD=2
                GO  TO  10
  101 DO  25  IAU=1,300
      WRITE(11'LAU)F11
   25 CONTINUE
      GO TO 10
  110 MOD=1
      GO TO 10
C  EXECUTION  TERMINATED
 3000 WRITE(10'1)NLINK,NODE,NREG,IHORIZ,JIM,RATE,VCAP,LBEG,LEND,LST,LREG
     1,TB,FE,SL,IOPT
      WRITE(10'2)LLA
      WRITE(10'3)LOD
      GO  TO  10
   45 CONTINUE
      CALL  EXIT
C INFORMATION ABOUT THE NETWORK
  150 KK=0
      L(1)=0
      L(2)=0
      L(3)=0
      IW(1)=1
      IW(2)=2
```

PAGE 3

```
      IW(3)=3                                                           PGM10109
  160 CALL MATCH(ITYPE,IDICT2,K,RK,0)                                   PGM10110
      GO TO (165,185,2005,2005,190),ITYPE                               PGM10111
  165 IF(KK.EQ.0) GO TO 2005                                            PGM10112
      IF(UPD.EQ.0)  GO  TO  180                                         PGM10113
      DO  175  I=1,3                                                    PGM10114
      IF(L(1).EQ.0)  GO  TO  171                                        PGM10115
      NLINK=L(1)                                                        PGM10116
  171 IF(L(2).EQ.0)  GO  TO  172                                        PGM10117
      NODE=L(2)                                                         PGM10118
  172 IF(L(3).EQ.0)  GO  TO  175                                        PGM10119
      NREG=L(3)                                                         PGM10120
  175 CONTINUE                                                          PGM10121
      GO  TO  10                                                        PGM10122
  180 NLINK=L(1)                                                        PGM10123
      NODE=L(2)                                                         PGM10124
      NREG=L(3)                                                         PGM10125
      GO  TO  10                                                        PGM10126
  185 KK=KK+1                                                           PGM10127
      L(IW(KK))=K                                                       PGM10128
      GO TO 160                                                         PGM10129
  190 IW(KK+1)=K                                                        PGM10130
      GO TO 160                                                         PGM10131
C INFORMATION ABOUT THE TIME                                            PGM10132
  200 CALL MATCH(ITYPE,IDICT2,K,RK,0)                                   PGM10133
      GO TO (10,205,2010,200,200),ITYPE                                 PGM10134
  205 IHORIZ=K                                                          PGM10135
      GO TO 10                                                          PGM10136
C INFORMATION ABOUT THE LINKS. CONSTRUCTION OF MATRICES INDICATING OF   PGM10137
C WHICH NODES A LINK IS BOUNDED.                                        PGM10138
  250 CALL MATCH(ITYPE,IDICT3,K,RK,0)                                   PGM10139
      GO TO (260,1000,2015,2015,255),ITYPE                              PGM10140
  255 IF(K.NE.2) GO TO 2015                                             PGM10141
  260 LARG=1                                                            PGM10142
      KK=0                                                              PGM10143
      L(1)=0                                                            PGM10144
```

```
      L(2)=0
      L(3)=0
      L(4)=0
      L(5)=1
  265 CALL MATCH(ITYPE,IDICT3,K,RK,LARG)
      GO TO (300,270,2020,275,280),ITYPE
  270 KK=KK+1
      L(KK)=K
  275 LARG=0
      GO TO 265
  280 IF(K.NE.5) GO TO 275
      GO TO 10
  300 IF(KK.EQ.0) GO TO 2020
      IF(UPD.NE.0) GO TO 340
  301 IF(L(1).EQ.0 .OR. L(2).EQ.0 .OR. L(3).EQ.0) GO TO 2020
  305 LINK=L(1)
      KO=L(2)
      KD=L(3)
      LLA(KO,KD)=LINK
      LLA(KD,KO)=LINK
      LBEG(LINK)=KO
      LEND(LINK)=KD
      LREG(LINK)=L(4)
      LST(LINK)=L(5)
      GO TO 260
  340 IF(MOD.EQ.0) GO TO 301
      IF(L(1).EQ.0 .OR. L(2).EQ.0 .OR. L(3).EQ.0) GO TO 2020
      LINK=L(1)
      KO=L(2)
      KD=L(3)
      KLINK=LLA(KO,KD)
      MLINK=LLA(KD,KO)
      IF(KLINK.EQ.LINK.OR.MLINK.EQ.LINK)  GO  TO  350
C LINK IS A DIFFERENT THAN WHICH OUGHT TO BE. ERASE RECORDS OF KLINK
      I=10*(KLINK-1)+1
      DO 342 J=1,583
```

```
      F11(J)=0.
  342 CONTINUE
      II=I+9
      DO  345  IAU=I,II
      WRITE(11'IAU)F11
  345 CONTINUE
  350 IF(L(4).NE.0)  GO  TO  355
      L(4)=LREG(LINK)
  355 IF(L(5).NE.0)  GO  TO  305
      L(5)=LST(LINK)
      GO TO 305
C INFORMATION ABOUT BUDGET CONSTRAINTS (TOTAL BUDGET, FOREIGN
C EXCHANGE, SKILLED LABOR)
  400 KK=0
      RL(1)=0.
      RL(2)=0.
      RL(3)=0.
      IW(1)=1
      IW(2)=2
      IW(3)=3
      CALL MATCH(ITYPE,IDICT4,K,RK,1)
      GO TO (2025,410,2025,2025,405),ITYPE
  405 IF(K.EQ.4)  GO  TO  10
      IF(K.NE.5)  GO  TO  2027
      CALL  MATCH(ITYPE,IDICT4,K,RK,0)
      GO  TO  (2027,406,2027,2027,2027),ITYPE
  406 RG=K
      GO  TO  400
  410 IYR=K
  415 CALL MATCH(ITYPE,IDICT4,K,RK,0)
      GO TO (420,450,452,2025,460),ITYPE
  420 IF(KK.EQ.0) GO TO 2025
      DO  440  KKK=1,KK
      I=IW(KKK)
      GO TO (425,430,435),I
  425 TB(RG,IYR)=RL(1)
```

```
      GO TO 440
  430 FE(RG,IYR)=RL(2)
      GO TO 440
  435 SL(RG,IYR)=RL(3)
  440 CONTINUE
      IF(UPD.EQ.0) GO TO 470
      IF(MOD.NE.0) GO TO 400
  470 CONTINUE
      II=IYR+1
      DO  480  I=II,20
      TB(RG,I)=TB(RG,IYR)
      FE(RG,I)=FE(RG,IYR)
      SL(RG,I)=SL(RG,IYR)
  480 CONTINUE
      GO TO 400
  450 RK=K
  452 KK=KK+1
      RL(IW(KK))=RK
      GO TO 415
  460 IW(KK+1)=K
      GO TO 415
C INFORMATION ABOUT THE DEMAND
  500 KK=0
C ZERO THE ARRAYS IN CORE
      DO  700  I=1,20
      DO  690  J=1,7
      DEMAND(I,J)=0.
  690 CONTINUE
  700 CONTINUE
      DO 710 I=1,7
      ELA(I)=0.
      PRICE(I)=0.
      VALT(I)=0.
      FLOAD(I)=0.
  710 CONTINUE
  505 CALL MATCH(ITYPE,IDICT3,K,RK,0)
```

```
      GO TO (510,530,2030,2030,505),ITYPE                                PGM10253
  510 IF(KK.EQ.0) GO TO 2030                                             PGM10254
      IF(UPD.EQ.0) GO TO 600                                             PGM10255
      JIMC=LOD(KO,KD)                                                    PGM10256
      IF(JIMC.NE.0) GO TO 515                                            PGM10257
      JIM=JIM+1                                                          PGM10258
      JIMC=JIM                                                           PGM10259
      LOD(KO,KD)=JIMC                                                    PGM10260
  515 IF(MOD.EQ.2) GO TO 540                                             PGM10261
      JIMC1=JIMC                                                         PGM10262
      READ(12'JIMC)DEMAND,ELA,PRICE,VALT,FLOAD                           PGM10263
      GO TO 600                                                          PGM10264
  530 KK=KK+1                                                            PGM10265
      IF(KK.EQ.1) GO TO 535                                              PGM10266
      KD=K                                                               PGM10267
      GO TO 505                                                          PGM10268
  535 KO=K                                                               PGM10269
      GO TO 505                                                          PGM10270
  540 CONTINUE                                                           PGM10271
      DO 545 I=1,168                                                     PGM10272
      F12(I)=0.                                                          PGM10273
  545 CONTINUE                                                           PGM10274
      WRITE(12'JIMC)F12                                                  PGM10275
      GO TO 10                                                           PGM10276
C START READING THE CARDS WITH THE DATA                                  PGM10277
  600 KK=0                                                               PGM10278
      DO 608 I=1,7                                                       PGM10279
      RL(I)=0.                                                           PGM10280
      IW(I)=0                                                            PGM10281
  608 CONTINUE                                                           PGM10282
      CALL MATCH(ITYPE,IDICT6,K,RK,1)                                    PGM10283
      GO TO (2035,605,2035,2035,670),ITYPE                               PGM10284
C READ DATA SET OF VOLUME BETWEEN C-D PAIR.                               PGM10285
  605 IYR=K                                                              PGM10286
  610 CALL MATCH(ITYPE,IDICT7,K,RK,0)                                    PGM10287
      GO TO (620,650,652,2040,660),ITYPE                                 PGM10288
```

```
  620 IF(KK.EQ.0) GO TO 2040
      DO  625  KKK=1,KK
      IK=IW(KKK)
      DEMAND(IYR,IK)=RL(IK)
  625 CONTINUE
  628 IF(UPD.EQ.0) GO TO 630
      IF(MOD.EQ.1) GO TO 600
  630 II=IYR+1
      DO  640  I=II,20
      DO 635 KK=1,7
      IF(RL(KK).EQ.0.)  GO  TO  635
      DEMAND(I,KK)=DEMAND(IYR,KK)
  635 CONTINUE
  640 CONTINUE
      GO TO 600
  650 RK=K
  652 KK=KK+1
      IF(IW(KK).NE.0) GO TO 655
      IW(KK)=KK
  655 RL(IW(KK))=RK
      GO TO 610
  660 IF(K.EQ.8) GO TO 610
      IW(KK+1)=K
      GO TO 610
C BRANCH ON WORD TYPE IN DATA SET.
C END OF DATA FOR O-D PAIR.
  670 IK1=K
      GO TO (2040,720,750,780,760,675),IK1
C UPDATE THE RECORD NUMBER. STORE IN THE RECORD THE DATA
  675 IF(UPD.NE.0) GO TO 680
      JIM=JIM+1
      JIMC=JIM
      LOD(KO,KD)=JIMC
      GO  TO  685
  680 JIMC=JIMC1
  685 WRITE(12'JIMC)DEMAND,FLA,PRICE,VALT,FLOAD
```

```
      GO TO 10
C DATA ABOUT ELASTICITY OF DEMAND
  720 CALL MATCH(ITYPE,IDICT7,K,RK,0)
      GO TO (725,740,742,2045,748),ITYPE
  725 IF(KK.EQ.0) GO TO 2045
      DO  730  KKK=1,KK
      IK=IW(KKK)
      ELA(IK)=RL(IK)
  730 CONTINUE
      GO TO 600
  740 RK=K
  742 KK=KK+1
      IF(IW(KK).NE.0) GO TO 745
      IW(KK)=KK
  745 RL(IW(KK))=RK
      GO TO 720
  748 IW(KK+1)=K
      GO TO 720
C DATA ABOUT COMMODITY PRICE
  750 CALL MATCH(ITYPE,IDICT7,K,RK,0)
      GO TO (755,770,772,750,778),ITYPE
  755 IF(KK.EQ.0) GO TO 2050
      DO  758   KKK=1,KK
      IK=IW(KKK)
      PRICE(IK)=RL(IK)
  758 CONTINUE
      GO TO 600
  770 RK=K
  772 KK=KK+1
      IF(IW(KK).NE.0) GO TO 775
      IW(KK)=KK
  775 RL(IW(KK))=RK
      GO TO 750
  778 IW(KK+1)=K
      GO TO 750
C DATA ABOUT VALUE OF TIME
```

```
  780 CALL MATCH(ITYPE,IDICT7,K,RK,0)                                PGM10361
      GO TO (781,790,792,780,798),ITYPE                              PGM10362
  781 IF(KK.EQ.0) GO TO 2055                                         PGM10363
      DO 785 KKK=1,KK                                                PGM10364
      IK=IW(KKK)                                                     PGM10365
      VALT(IK)=RL(IK)                                                PGM10366
  785 CONTINUE                                                       PGM10367
      GO TO 600                                                      PGM10368
  790 RK=K                                                           PGM10369
  792 KK=KK+1                                                        PGM10370
      IF(IW(KK).NE.0) GO TO 795                                      PGM10371
      IW(KK)=KK                                                      PGM10372
  795 RL(IW(KK))=RK                                                  PGM10373
      GO TO 780                                                      PGM10374
  798 IW(KK+1)=K                                                     PGM10375
      GO TO 780                                                      PGM10376
C  DATA  ABOUT  LOAD  FACTORS                                        PGM10377
  760 CALL  MATCH(ITYPE,IDICT7,K,RK,0)                               PGM10378
      GO  TO  (761,765,766,760,768),ITYPE                            PGM10379
  761 IF(KK.EQ.0)  GO  TO  2057                                      PGM10380
      DO  764  KKK=1,KK                                              PGM10381
      IK=IW(KKK)                                                     PGM10382
      FLOAD(IK)=RL(IK)                                               PGM10383
  764 CONTINUE                                                       PGM10384
      GO  TO  600                                                    PGM10385
  765 RK=K                                                           PGM10386
  766 KK=KK+1                                                        PGM10387
      IF(IW(KK).NE.0)  GO  TO  767                                   PGM10388
      IW(KK)=KK                                                      PGM10389
  767 RL(IW(KK))=RK                                                  PGM10390
      GO  TO  760                                                    PGM10391
  768 IW(KK+1)=K                                                     PGM10392
      GO  TO  760                                                    PGM10393
C INTEREST RATE                                                      PGM10394
  800 CALL MATCH(ITYPE,IDICT2,K,RK,0)                                PGM10395
      GO TO (10,810,815,800,800),ITYPE                               PGM10396
                                                                PAGE  11
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  810 RK=K
  815 RATE=RK
      GO TO 10
C VEHICLE CAPACITIES
  850 KK=0
      DO 860 I=1,7
      RL(I)=0.
      IW(I)=0
  860 CONTINUE
  865 CALL MATCH(ITYPE,IDICT7,K,RK,0)
      GO TO (870,880,885,2060,890),ITYPE
  870 IF(KK.EQ.0) GO TO 2060
      DO  875  KKK=1,KK
      IK=IW(KKK)
      VCAP(IK)=RL(IK)
  875 CONTINUE
      GO TO 10
  880 RK=K
  885 KK=KK+1
      IF(IW(KK).NE.0) GO TO 888
      IW(KK)=KK
  888 RL(IW(KK))=RK
      GO TO 865
  890 IF(K.EQ.9)  GO  TO  865
      IW(KK+1)=K
      GO TO 865
C DATA ABOUT LINK CHARACTERISTICS.
C FIND LINK NUMBER AND STRATEGY NUMBER.
 1000 LINK=K
      DO 1088 I=1,20
      DO 1085 J=1,7
      ATT(I,J)=0.
      ECC(I,J)=0.
      FOC(I,J)=0.
 1085 CONTINUE
 1088 CONTINUE
```

```
      DO 1090 I=1,20                                              PGM10433
      ETC(I)=0.                                                   PGM10434
      FTC(I)=0.                                                   PGM10435
      SKL(I)=0.                                                   PGM10436
      FOR(I)=0.                                                   PGM10437
      LEN(I)=0.                                                   PGM10438
      CAP(I)=0.                                                   PGM10439
      RAF(I)=0.                                                   PGM10440
      DSP(I)=0.                                                   PGM10441
 1090 CONTINUE                                                    PGM10442
      NCRIT=0                                                     PGM10443
      NSLIM=0                                                     PGM10444
      ISTR=0                                                      PGM10445
      KK=0                                                        PGM10446
      DO  1001  I=1,7                                             PGM10447
      L(I)=0                                                      PGM10448
      IW(I)=0                                                     PGM10449
 1001 CONTINUE                                                    PGM10450
 1005 CALL MATCH(ITYPE,IDICT3,K,RK,0)                             PGM10451
      GO TO (1020,1010,2065,2065,1015),ITYPE                      PGM10452
 1010 KK=KK+1                                                     PGM10453
      L(IW(KK))=K                                                 PGM10454
      GO  TO  1005                                                PGM10455
 1015 IW(KK+1)=K                                                  PGM10456
      GO  TO  1005                                                PGM10457
 1020 IF(L(1).EQ.0)  GO  TO  1021                                 PGM10458
      ISTR=L(1)                                                   PGM10459
      GO  TO  1025                                                PGM10460
 1021 ISTR=1                                                      PGM10461
      L(1)=1                                                      PGM10462
C FIND THE RECORD NUMBER. READ DATA FROM FILE IF UPDATE           PGM10463
 1025 LAU=10*(LINK-1)+ISTR                                        PGM10464
      LAU2=LAU                                                    PGM10465
      IF(UPD.EQ.0) GO TO 1041                                     PGM10466
      IF(MOD.NE.2) GO TO 1040                                     PGM10467
      DO 1030 I=1,583                                             PGM10468
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```
      F11(I)=0.
 1030 CONTINUE
      WRITE(11'LAU)F11
      GO TO 10
 1040 READ(11'LAU)ATT,EOC,FOC,ETC,FTC,SKL,FOR,LEN,CAP,RAF,DSP,ISTR,NCRIT
     1,NSLIM
      IF(L(6).NE.0)  GO  TO  1042
      L(6)=NCRIT
 1042 IF(L(7).NE.0)  GO  TO  1043
      L(7)=NSLIM
 1041 CONTINUE
 1043 NCRIT=L(6)
      NSLIM=L(7)
      ISTR=L(1)
C READ DATA ABOUT THE LINK
 1045 LARG=1
 1050 CALL MATCH(ITYPE,IDICT5,K,RK,LARG)
      GO TO (1045,1060,2070,2070,1080),ITYPE
 1060 IYR=K
      KK=0
      DO 1065 I=1,7
      RL(I)=0.
      IW(I)=0
 1065 CONTINUE
 1070 CALL MATCH(ITYPE,IDICT5,K,RK,0)
      GO TO (2070,2070,2070,2070,1100),ITYPE
 1080 IF(K.NE.12) GO TO 1095
      LAU=LAU2
      WRITE(11'LAU)ATT,EOC,FOC,ETC,FTC,SKL,FOR,LEN,CAP,RAF,DSP,ISTR,NCRI
     1T,NSLIM
      GO TO 10
 1095 KK=0
      DO 1098 I=1,7
      RL(I)=0.
      IW(I)=0
 1098 CONTINUE
```

```
 1100 IK1=K                                                             PGM10505
      GO  TO  (1105,1200,1300,1400,1400,1400,1400,1500,1500,1500,1500),I PGM10506
     1K1                                                                PGM10507
C DATA ABOUT AVERAGE TRAVEL TIME.                                       PGM10508
 1105 CALL MATCH(ITYPE,IDICT7,K,RK,0)                                   PGM10509
      GO TO (1150,1110,1112,2075, 1120),ITYPE                           PGM10510
 1110 RK=K                                                              PGM10511
 1112 KK=KK+1                                                           PGM10512
      IF(IW(KK).NE.0) GO TO 1115                                        PGM10513
      IW(KK)=KK                                                         PGM10514
 1115 RL(IW(KK))=RK                                                     PGM10515
      GO TO 1105                                                        PGM10516
 1120 IW(KK+1)=K                                                        PGM10517
      GO TO 1105                                                        PGM10518
 1150 IF(KK.EQ.0) GO TO 2075                                            PGM10519
      DO  1155  KKK=1,KK                                                PGM10520
      IK=IW(KKK)                                                        PGM10521
      ATT(IYR,IK)=RL(IK)                                                PGM10522
 1155 CONTINUE                                                          PGM10523
 1160 IF(UPD.EQ.0) GO TO 1165                                           PGM10524
      IF(MOD.EQ.1) GO TO 1045                                           PGM10525
 1165 II=IYR+1                                                          PGM10526
      DO  1170  I=II,20                                                 PGM10527
      DO 1168 KK=1,7                                                    PGM10528
      IF(RL(KK).EQ.0.)  GO  TO  1168                                    PGM10529
      ATT(I,KK)=ATT(IYR,KK)                                             PGM10530
 1168 CONTINUE                                                          PGM10531
 1170 CONTINUE                                                          PGM10532
      GO  TO  1045                                                      PGM10533
C DATA ABOUT ECONOMIC COSTS OF VEHICLE OPERATION                        PGM10534
 1200 CALL MATCH(ITYPE,IDICT7,K,RK,0)                                   PGM10535
      GO TO (1250,1210,1212,2080,1220),ITYPE                            PGM10536
 1210 RK=K                                                              PGM10537
 1212 KK=KK+1                                                           PGM10538
      IF(IW(KK).NE.0) GO TO 1215                                        PGM10539
      IW(KK)=KK                                                         PGM10540
```

```
 1215 RL(IW(KK))=RK
      GO TO 1200
 1220 IW(KK+1)=K
      GO TO 1200
 1250 IF(KK.EQ.0) GO TO 2080
      DO  1255  KKK=1,KK
      IK=IW(KKK)
      EOC(IYR,IK)=RL(IK)
 1255 CONTINUE
 1260 IF(UPD.EQ.0) GO TO 1265
      IF(MOD.EQ.1) GO TO 1045
 1265 II=IYR+1
      DO  1270  I=II,20
      DO 1268 KK=1,7
      IF(RL(KK).EQ.0.)  GO  TO  1268
      EOC(I,KK)=EOC(IYR,KK)
 1268 CONTINUE
 1270 CONTINUE
      GO  TO  1045
C DATA ABOUT FINANCIAL COSTS OF VEHICLE OPERATION
 1300 CALL MATCH(ITYPE,IDICT7,K,RK,0)
      GO TO (1350,1310,1312,2085,1320),ITYPE
 1310 RK=K
 1312 KK=KK+1
      IF(IW(KK).NE.0) GO TO 1315
      IW(KK)=KK
 1315 RL(IW(KK))=RK
      GO TO 1300
 1320 IW(KK+1)=K
      GO TO 1300
 1350 IF(KK.EQ.0) GO TO 2085
      DO  1355   KKK=1,KK
      IK=IW(KKK)
      FOC(IYR,IK)=RL(IK)
 1355 CONTINUE
 1360 IF(UPD.EQ.0) GO TO 1365
```

```
      IF(MOD.EQ.1) GO TO 1045
 1365 II=IYR+1
      DO  1370  I=II,20
      DO 1368 KK=1,7
      IF(RL(KK).EQ.0.)  GO  TO  1368
      FOC(I,KK)=FOC(IYR,KK)
 1368 CONTINUE
 1370 CONTINUE
      GO  TO  1045
C DATA ABOUT COSTS ASSOCIATED WITH LINK IMPROVEMENT, IF ANY.
 1400 IW(KK+1)=IK1
 1405 CALL MATCH(ITYPE,IDICT5,K,RK,0)
      GO TO (1430,1410,1412,2090,1420),ITYPE
 1410 RK=K
 1412 KK=KK+1
      RL(IW(KK))=RK
      GO TO 1405
 1420 IW(KK+1)=K
      GO TO 1405
 1430 CONTINUE
      DO  1445  KKK=1,KK
      IK=IW(KKK)
      IKK=IK-3
      GO TO (1431,1435,1440,1444),IKK
 1431 ETC(IYR)=RL(4)
      GO TO 1445
 1435 FTC(IYR)=RL(5)
      GO TO 1445
 1440 SKL(IYR)=RL(6)
      GO TO 1445
 1444 FOR(IYR)=RL(7)
 1445 CONTINUE
 1450 IF(UPD.EQ.0) GO TO 1455
      IF(MOD.EQ.1) GO TO 1045
 1455 CONTINUE
      II=IYR+1
```

```
      DO   1490   I=IT,20                                                PGM10613
      IF(RL(4).EQ.0.)   GO   TO   1460                                   PGM10614
      ETC(I)=ETC(IYR)                                                    PGM10615
 1460 IF(RL(5).EQ.0.)   GO   TO   1465                                   PGM10616
      FTC(I)=FTC(IYR)                                                    PGM10617
 1465 IF(RL(6).EQ.0.)   GO   TO   1470                                   PGM10618
      SKL(I)=SKL(IYR)                                                    PGM10619
 1470 IF(RL(7).EQ.0.)   GO   TO   1490                                   PGM10620
      FOR(I)=FOR(IYR)                                                    PGM10621
 1490 CONTINUE                                                           PGM10622
      LARG=0                                                             PGM10623
      GO TO 1050                                                         PGM10624
C  DATA  ABOUT LINK LENGTH, CAPACITY, RISE AND FALL, DESIGN SPEED        PGM10625
 1500 IW(KK+1)=IK1                                                       PGM10626
 1505 CALL MATCH(ITYPE,IDICT5,K,RK,0)                                    PGM10627
      GO TO (1530,1510,1512,2095,1520),ITYPE                             PGM10628
 1510 RK=K                                                               PGM10629
 1512 KK=KK+1                                                            PGM10630
      RL(IW(KK))=RK                                                      PGM10631
      GO TO 1505                                                         PGM10632
 1520 IW(KK+1)=K                                                         PGM10633
      GO TO 1505                                                         PGM10634
 1530 CONTINUE                                                           PGM10635
      DO   1545   KKK=1,KK                                               PGM10636
      IK=IW(KKK)                                                         PGM10637
      IKK=IK-7                                                           PGM10638
      GO TO (1535,1540,1570,1580),IKK                                    PGM10639
 1535 LEN(IYR)=RL(8)                                                     PGM10640
      GO TO 1545                                                         PGM10641
 1540 CAP(IYR)=RL(9)                                                     PGM10642
      GO   TO   1545                                                     PGM10643
 1570 RAF(IYR)=RL(10)                                                    PGM10644
      GO   TO   1545                                                     PGM10645
 1580 DSP(IYR)=RL(11)                                                    PGM10646
 1545 CONTINUE                                                           PGM10647
 1550 IF(UPD.EQ.0) GO TO 1555                                            PGM10648
```

```
      IF(MOD.EQ.1) GO TO 1045
 1555 CONTINUE
      II=IYR+1
      DO  1590  I=II,20
      IF(RL(8).EQ.0.)  GO  TO  1560
      LEN(I)=LEN(IYR)
 1560 IF(RL(9).EQ.0.)  GO  TO  1575
      CAP(I)=CAP(IYR)
 1575 IF(RL(10).EQ.0.)  GO  TO  1585
      RAF(I)=RAF(IYR)
 1585 IF(RL(11).EQ.0.)  GO  TO  1590
      DSP(I)=DSP(IYR)
 1590 CONTINUE
      LARG=0
      GO TO 1050
C ERRORS FORMATS
 2001 WRITE(6,2002)
 2002 FORMAT(/,'FORMAT ERROR IN FIRST COMMAND CARD')
      GO TO 10
 2005 WRITE(6,2006)
 2006 FORMAT(/,'FORMAT ERROR IN NETWORK COMMAND OR DATA CARDS')
      GO TO 10
 2010 WRITE(6,2011)
 2011 FORMAT(/,'FORMAT ERROR IN TIME HORIZON COMMAND CARD')
      GO TO 10
 2015 WRITE(6,2016)
 2016 FORMAT(/,'FORMAT ERROR IN LINK DATA OR STRATEGY COMMAND CARD')
      GO TO 10
 2020 WRITE(6,2021)
 2021 FORMAT(/,'FORMAT ERROR IN LINK DATA CARDS')
      GO TO 10
 2025 WRITE(6,2026)
 2026 FORMAT(/,'FORMAT ERROR IN BUDGET DATA CARDS')
      GO  TO  400
 2027 WRITE(6,2028)
 2028 FORMAT(/,'   FORMAT  ERROR  IN  BUDGET  CARDS')
```

```
      GO  TO  10                                                        PGM10685
 2030 WRITE(6,2031)                                                     PGM10686
 2031 FORMAT(/,'FORMAT ERROR IN DEMAND O-D CARD')                       PGM10687
      GO TO 10                                                          PGM10688
 2035 WRITE(6,2036)                                                     PGM10689
 2036 FORMAT(/,'FORMAT ERROR IN DATA CARDS OF O-D DEMAND')              PGM10690
      GO TO 10                                                          PGM10691
 2040 WRITE(6,2041)                                                     PGM10692
 2041 FORMAT(/,'FORMAT ERROR IN DATA CARD OF VOLUME')                   PGM10693
      GO  TO  600                                                       PGM10694
 2045 WRITE(6,2046)                                                     PGM10695
 2046 FORMAT(/,'FORMAT ERROR IN DATA CARD OF ELASTICITY')               PGM10696
      GO  TO  600                                                       PGM10697
 2050 WRITE(6,2051)                                                     PGM10698
 2051 FORMAT(/,'FORMAT ERROR IN DATA CARD OF COMMODITY PRICE')          PGM10699
      GO  TO  600                                                       PGM10700
 2055 WRITE(6,2056)                                                     PGM10701
 2056 FORMAT(/,'FORMAT ERROR IN DATA CARD OF VALUE OF TIME')            PGM10702
      GO  TO  600                                                       PGM10703
 2057 WRITE(6,2058)                                                     PGM10704
 2058 FORMAT(/'  FORMAT  ERROR  IN  DATA  CARD  OF  LOAD  FACTOR')      PGM10705
      GO  TO  600                                                       PGM10706
 2060 WRITE(6,2061)                                                     PGM10707
 2061 FORMAT(/,'FORMAT ERROR IN DATA OF VEHICLE CAPACITIES')            PGM10708
      GO TO 10                                                          PGM10709
 2065 WRITE(6,2066)                                                     PGM10710
 2066 FORMAT(/,'FORMAT ERROR IN LINK-STRATEGY CARD')                    PGM10711
      GO TO 10                                                          PGM10712
 2070 WRITE(6,2071)                                                     PGM10713
 2071 FORMAT(/,'FORMAT ERROR IN LINK CHARACTERISTICS DATA CARD')        PGM10714
      GO  TO  1045                                                      PGM10715
 2075 WRITE(6,2076)                                                     PGM10716
 2076 FORMAT(/,'FORMAT ERROR IN AVERAGE TRAVEL TIME DATA CARD')         PGM10717
      GO  TO  1045                                                      PGM10718
 2080 WRITE(6,2081)                                                     PGM10719
 2081 FORMAT(/,'FORMAT ERROR IN ECONOMIC COSTS OF VEHICLE OPERATION DATA PGM10720
```

```
     1 CARD')
      GO  TO  1045
 2085 WRITE(6,2086)
 2086 FORMAT(/,'FORMAT ERROR IN FINANCIAL COSTS OF VEHICLE OPERATION DAT
     1A CARD')
      GO  TO  1045
 2090 WRITE(6,2091)
 2091 FORMAT(/,'FORMAT ERROR IN COST DATA ABOUT THE LINK')
      GO  TO  1045
 2095 WRITE(6,2096)
 2096 FORMAT(/,'FORMAT ERROR IN LINK LENGTH AND CAPACITY DATA')
      GO  TO  1045
 9999 STOP
      END
```

```
      SUBROUTINE GRAPHE
C PROGRAM TO TEST IF DATA IS WRITTEN ACCURATELY IN THE DISK
      DIMENSION VCAP(7),LBEG(30),LEND(30),LST(30),LREG(30),TB(10,20),FE(
     110,20),SL(10,20),LLA(30,30),LOD(30,30),ATT(20,7),EOC(20,7),
     2FOC(20,7),ETC(20),FTC(20),SKL(20),FOR(20),CAP(20),
     3DEMAND(20,7),ELA(7),PRICE(7),VALT(7),FLOAD(7),RAF(20),DSP(20)
      REAL LFN(20)
C READ THE BASIC DATA
      READ(10'1)NLINK,NODE,NREG,IHORIZ,JIM,RATE,VCAP,LBEG,LEND,LST,LREG,
     1TB,FE,SL,IOPT
      READ(10'2)LLA
      READ(10'3)LOD
C PRINT THE BASIC DATA
      WRITE(6,10)NLINK,NODE,IHORIZ,RATE,NREG
   10 FORMAT(/,'   THE NUMBER OF LINKS IN THE NETWORK ARE:',
     1I5,/,'   THE NUMBER OF NODES IN THE NETWORK ARE:',I5,/,
     2'   THE TIME HORIZON FOR THE EVALUATION IS:',I5,/,
     3'   THE DISCOUNT RATE IS:',F10.5,/,'    THE  NUMBER  OF  REGIONS
     4 ARE:  ',I3)
      DO  80  I=1,NREG
      WRITE(6,85) I
   85 FORMAT(/,25X,'FOR REGION',I3)
      WRITE(6,70)
   70 FORMAT                      (/,3X,'YEAR',5X,'TOTAL   BUDGET',10X,
     1' FOREIGN  EXCHANGE',7X,'  SKILLED  LABOR')
      DO  75  J=1,IHORIZ
      WRITE(6,60)J,TB(I,J),FE(I,J),SL(I,J)
   60 FORMAT(3X,I3,7X,F15.5,9X,F15.5,9X,F15.5)
   75 CONTINUE
   80 CONTINUE
      WRITE(6,12) (I,I=1,7)
   12 FORMAT(/,25X,'VEHICLE CAPACITIES',/,5X,'TYPES',13X,7(I2,12X))
      WRITE(6,14) (VCAP(I),I=1,7)
   14 FORMAT(20X,F5.0,'PASS.',5X,F5.0,'PASS.',4X,5(2X,F8.2,'TONS'))
   15 CONTINUE
      LAU=0
```

```
      DO 300 I=1,NLINK
      LAUC=10*(I-1)
      KK=LST(I)
      DO 290 J=1,KK
      LAU=LAUC+J
      READ(11'LAU) ATT,EOC,FOC,ETC,FTC,SKL,FOR,LEN,CAP,RAF,DSP,ISTR,NCRIT
     1,NSLIM
      WRITE(6,195) I
  195 FORMAT(///'  LINK',I5,/,13X,'STARTS',2X,'ENDS',2X,'REGION',2X,'STR
     1ATEGY #',2X,'CRITICAL INDEX',2X,'MAX SLIPPAGE')
      WRITE(6,20) LBEG(I),LEND(I),LREG(I),ISTR,NCRIT,NSLIM
   20 FORMAT(15X,I2,5X,I2,5X,I2,11X,I2,11X,I2,12X,I2)
      WRITE(6,215)
  215 FORMAT(//40X,'VEHICLE  INFORMATION')
      WRITE(6,217)
  217 FORMAT(/15X,'TRAVEL TIME ON THE LINK IN HOURS')
      WRITE(6,218)
  218 FORMAT(/20X,'VEHICLE TYPE:',8X,'V1',10X,'V2',10X,'V3',10X,'V4',10X
     1,'V5',10X,'V6',10X,'V7',/,10X,'YEAR')
      DO 220     IK=1,IHORIZ
      WRITE(6,225) IK,(ATT(IK,IV),IV=1,7)
  225 FORMAT(11X,I2,22X,7(2X,F8.3,2X))
  220 CONTINUE
      WRITE(6,227)
  227 FORMAT(/15X,'VEHICLE ECONOMIC COSTS IN $ FOR THE WHOLE LINK')
      WRITE(6,228)
  228 FORMAT(/20X,'VEHICLE TYPE:',8X,'V1',10X,'V2',10X,'V3',10X,'V4',10X
     1,'V5',10X,'V6',10X,'V7',/,10X,'YEAR')
      DO  230  IK=1,IHORIZ
      WRITE(6,235)IK,(EOC(IK,IV),IV=1,7)
  235 FORMAT(11X,I2,22X,7(2X,F8.3,2X))
  230 CONTINUE
      WRITE(6,237)
  237 FORMAT(/15X,'VEHICLE FINANCIAL COSTS IN $ FOR THE WHOLE LINK')
      WRITE(6,238)
  238 FORMAT(/20X,'VEHICLE TYPE:',8X,'V1',10X,'V2',10X,'V3',10X,'V4',10X
```

```
    1,'V5',10X,'V6',10X,'V7',/,10X,'YEAR')
     DO  240  IK=1,IHORIZ
     WRITE(6,245) IK,(FOC(IK,IV),IV=1,7)
245  FORMAT(11X,I2,22X,7(2X,F8.3,2X))
240  CONTINUE
     WRITE(6,250)
250  FORMAT(//40X,'LINK  INFORMATION')
     WRITE(6,301)
301  FORMAT(/1X,'YEAR',2X,'FINANCIAL COST',2X,'ECONOMIC COST',2X,'FOREI
    1GN EXCHANGE',2X,'SKILLED LABOR',2X,'LINK LENGTH',2X,'LINK CAPACITY
    2',2X,'RISE-FALL',2X,'DESIGN SPEED',/,12X,'($)',13X,'($)',15X,'($)'
    3,14X,'($)',10X,'(KMS)',8X,'(PCU/HR)',4X,'(M/100M)',5X,'(KMS/HR)')
     DO  310  IK=1,IHORIZ
     WRITE(6,315) IK,FTC(IK),ETC(IK),FOR(IK),SKL(IK),LEN(IK),CAP(IK),RA
    1F(IK),DSP(IK)
315  FORMAT (/,I3,1X,F15.3,1X,F14.3,3X,F15.3,1X,F14.3,1X,F13.3,1X,F15.3
    1,1X,F9.4,2X,F12.4)
310  CONTINUE
     DO  260  IK=1,IHORIZ
     ETC(IK)=0.
     FTC(IK)=0.
     SKL(IK)=0.
     FOR(IK)=0.
     LEN(IK)=0.
     CAP(IK)=0.
     RAF(IK)=0.
     DSP(IK)=0.
     DO  255  IV=1,7
     ATT(IK,IV)=0.
     ECC(IK,IV)=0.
     FOC(IK,IV)=0.
255  CONTINUE
260  CONTINUE
290  CONTINUE
300  CONTINUE
     DO 200 K0=1,NODE
```

```
      DO 190 KD=1,NODE
      IF(LOD(KO,KD).EQ.0) GO TO 190
      WRITE(6,100)KO,KD,LOD(KO,KD)
  100 FORMAT(///,'      DATA  FOR  O-D  PAIR:',I2,'-',I2,'   (STORED  IN
     1  RECORD',I2,')')
      JIMC=LOD(KO,KD)
      READ(12'JIMC)DEMAND,ELA,PRICE,VALT,FLOAD
      WRITE(6,102)
  102 FORMAT(/30X,'DEMAND')
      WRITE(6,105)
  105 FORMAT(/5X,'YEAR',5X,'TYPE:',5X,'V1',10X,'V2',10X,'V3',10X,'V4',10
     1X,'V5',10X,'V6',10X,'V7')
      IF (IOPT.EQ.1)  GO  TO  500
      WRITE(6,106)
  106 FORMAT(21X,'VEHICLES',4X,'VEHICLES',2X,5(4X,'TONS',4X))
      GO  TO  550
  500 WRITE(6,510)
  510 FORMAT(19X,7(2X,'VEHICLES',2X))
  550 DO 140 I=1,IHORIZ
      WRITE(6,115)I,(DEMAND(I,J),J=1,7)
  115 FORMAT(5X,I2,10X,7(2X,F8.2,2X))
  140 CONTINUE
      DO  143  I=1,IHORIZ
      DO  142  J=1,7
      DEMAND(I,J)=0.
  142 CONTINUE
  143 CONTINUE
      WRITE(6,145)
  145 FORMAT(/10X,'TYPE:',33X,'V1',10X,'V2',10X,'V3',10X,'V4',10X,'V5',1
     10X,'V6',10X,'V7')
      WRITE(6,150) (ELA(I),I=1,7)
  150  FORMAT(/'  ELASTICITY WITH RESPECT TO TRANSPORT COSTS',7(2X,F8.4,
     12X))
      WRITE(6,152) (PRICE(I),I=1,7)
  152   FORMAT('  COST  OF TRANSPORT  ($/VEH.)',14X,7(2X,F8.3,2X))
      WRITE(6,153) (VALT(I),I=1,7)
```

```
153   FORMAT('  VALUE OF TIME-PASSENGERS ($/PASS-HR)',5X,2(2X,F8.3,2X)
     1,/,16X,'COMMODITIES ($/TON-HR)',31X,5(2X,F8.5,2X))
      WRITE(6,154) (FLOAD(I),I=1,7)
154   FORMAT('  LOAD FACTOR',31X,7(2X,F8.4,2X))
      DO  151  IV=1,7
      ELA(IV)=0.
      FLOAD(IV)=0.
      PRICE(IV)=0.
      VALT(IV)=0.
151   CONTINUE
190   CONTINUE
200   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MATCH (NATCH,LIST,K,RK,IARG)
C
C     MATCH READS A CARD IN 80A1 FORMAT INTO JBUF, CONVERTS EACH
C     COLUMN TO AN INTEGER CODE IN IBUF, AND DECODES EACH LOGICAL
C     FIELD ON THE CARD. THE LAST USEABLE COLUMN IS INDICATED BY THE
C     DATA SPECIFICATION FOR 'LASTCC'.
C     EACH CODE NUMBER REPRESENTS A CHARACTER AND IS FORMED
C     INTO LIST WORDS BY COMBINING THE CODE TIMES SOME
C     POWER OF 100.  THUS IF A WORD MAY CONTAIN 4 CHARACTERS,
C     (LIST(1)=4), AND THE WORD 'THE' IS TO BE REPRESENTED, THE CODED
C     WORD IS  39272414,  BLANK PADDED (14) ON THE RIGHT
C     LIST=DICTIONARY ADDRESS(INTEGER ARRAY)
C           LIST(1)=NUMBER OF CHARACTERS/WORD
C           LIST(2)=NUMBER OF LIST WORDS IN DICTIONARY
C           LIST(3)....TO LIST(N) ARE CODED WORDS
C           TOTAL LENGTH=LIST(2)+2 INTEGER WORDS
C
C     NATCH=
C           1,END OF STATEMENT
C           2,INTEGER NUMBER
C           3,REAL NUMBER
C           4,WORD NOT IN DICTIONARY
C           5,WORD IN DICTIONARY
C     CODE IS INTEGER DECIMAL, 00 TO 45, AS INDICATED BELOW.
C     THE CODES ARE AS FOLLOWS...
C           CODE        CHARACTER REPRESENTED
C              0        0
C              1        1
C              2        2
C              3        3
C              4        4
C              5        5
C              6        6
C              7        7
C              8        8
C              9        9
```

```
C              10     +                                      00000410 PGM30037
C              11     -                                      00000420 PGM30038
C              12     .                                      00000430 PGM30039
C              13     ,                                      00000440 PGM30040
C              14     BLANK                                  00000450 PGM30041
C              15     *                                      00000460 PGM30042
C              16     /                                      00000470 PGM30043
C              17     $                                      00000480 PGM30044
C              18     =                                      00000490 PGM30045
C              19     "                                      00000500 PGM30046
C              20     A                                      00000510 PGM30047
C              21     B                                      00000520 PGM30048
C              22     C                                      00000530 PGM30049
C              23     D                                      00000540 PGM30050
C              24     E                                      00000550 PGM30051
C              25     F                                      00000560 PGM30052
C              26     G                                      00000570 PGM30053
C              27     H                                      00000580 PGM30054
C              28     I                                      00000590 PGM30055
C              29     J                                      00000600 PGM30056
C              30     K                                      00000610 PGM30057
C              31     L                                      00000620 PGM30058
C              32     M                                      00000630 PGM30059
C              33     N                                      00000640 PGM30060
C              34     O                                      00000650 PGM30061
C              35     P                                      00000660 PGM30062
C              36     Q                                      00000670 PGM30063
C              37     R                                      00000680 PGM30064
C              38     S                                      00000690 PGM30065
C              39     T                                      00000700 PGM30066
C              40     U                                      00000710 PGM30067
C              41     V                                      00000720 PGM30068
C              42     W                                      00000730 PGM30069
C              43     X                                      00000740 PGM30070
C              44     Y                                      00000750 PGM30071
C              45     Z                                      00000760 PGM30072
                                                                PAGE  28
```

```
C
C     K=POSITION OF WORD IN DICTIONARY(EXCLUSIVE OF FIRST 2 CONTROL
C       WORDS) IF MATCH=5
C      =NUMBER IF MATCH=2
C      =SUBSCRIPT IN JBUF OF FIRST CHARACTER OF UNRECOGNIZED WORD
C       IF MATCH=4
C     RK=REAL NUMBER IF MATCH=3
C
C     LARG=0,READ NEXT FIELD ON CARD
C         =1,READ NEW CARD-FIRST FIELD
C
C     ' $' IS CONTINUATION CARD MARK
C     $ IN CC1 IS A COMMENT CARD
C
C     THE MAXIMUM NUMBER OF CHARACTERS PER WORD DEPENDS ON THE
C     ALLOWABLE NUMBER OF DECIMAL DIGITS PER INTEGER WORD.
C     IN SUBROUTINE CODES
C     THE ABOVE CODES ARE SET BY A DATA SPECIFICATION FOR LET(1-46)
C     LET(I) HAS THE CHARACTER REPRESENTATION (1H) OF THE CHARACTER
C     WITH CODE I-1.  THUS LET(21)=1HA.
C
      INTEGER BLANK,COMMA,PLUS,MINUS,DP
      INTEGER LIST(2)
      DIMENSION LET(46),IBUF(80)
      DATA LET/'0','1','2','3','4','5','6','7','8','9','+','-','.',',',
     1' ','*','/','$','=','"','A','B','C','D','E','F','G','H','I','J',
     2'K','L','M','N','O','P','Q','R','S','T','U','V','W','X','Y','Z'/
C
      DATA LASTC,IREAD,IPRNT, BLANK,COMMA,PLUS,MINUS,DP/80,5,6,14,13,10,
     $11,12/
C
C     ENTRY POINT-CHECK OP CODE
      ANUMB=0.0
      L=LARG
      IF(L.EQ.0) GO TO 110
C     L=1,READ NEW CARD,CONVERT TO DECIMAL CODE,SET BUFFER POINTER IC
```

```
C      TO FIRST NON-BLANK CHAR.
       DO 800 ISS=1,80
       IBUF(ISS)=LET(15)
  800  CONTINUE
       READ(IREAD,1000,ERR=801,END=802) IBUF
 1000  FORMAT(80A1)
       GO  TO  801
  802  NATCH=6
       GO  TO  280
  801  DO 101 I=1,80
       DO 102 J=1,46
       IF(IBUF(I)-LET(J)) 102,103,102
  102  CONTINUE
C      NO MATCH-ILLEGAL CHARACTER,SET=50 IN IBUF
       IBUF(I)=50
       GO TO 101
C      MATCHED
103    IBUF(I)=J-1
  101  CONTINUE
C      SET IC AS FIRST NON-BLANK COLUMN
       DO 104 I=1,LASTC
       IF(IBUF(I)-BLANK)105,104,105
  104  CONTINUE
  105  IC=I
C
C      POINTER IS ALWAYS SET TO FIRST CHARACTER OF NEW FIELD ON LEAVING
C      MATCH OR BY READING A NEW CARD-IT MAY BE LEFT PAST THE LAST
C      RECOGNIZABLE COLUMN,LASTCC
110    ICAR=IBUF(IC)
       IF(IC-LASTC )115,115,120
C      END OF STATEMENT
  120  NATCH=1
280    RETURN
C
C      OK-CHECK IF NEW FIELD IS A NUMMER,0-9,+,-,OR.
  115  IF(ICAR-12)125,125,300
```

```
C
C     NUMBER FOUND-SET INITIAL PARAMETERS
C     DECIMAL POINT=NO
  125 IDP=0
C     NEGATIVE=NO
      ISGN=0
C     NO GIGNIFICANT DIGIT YET
      ISIG=0
C     NUMERICAL VALUE OF NUMBER(REAL OR INTEGER)
      NUMB=0
C     SAVE START OF NUMBER
      ICSTR =IC
C     IS FIRST CHAR A PLUS SIGN-IGNORE IF YES
      IF(ICAR-PLUS) 126,130,126
C     CHECK IF MINUS SIGN-SET ISIGN=1 IF YES
  126 IF(ICAR-MINUS) 135,127,135
127   ISGN=1
C     LEADING PLUS OR MINUS SIGN-BUMP CARD COLUMN POINTER-CHECK
C     IF END OF FIELD
C     THIS IS GENERAL CC BUMPER SECTION OF CODE
  130 IC=IC+1
      ICAR=IBUF(IC)
      IF(IC-LASTC ) 135,135,140
C     CHECK IF CC IS BLANK OR COMMA
  135 IF(ICAR-BLANK) 145,140,145
  145 IF(ICAR-COMMA) 150,140,150
C     NOT END OF FIELD-IS IT A DIGIT...
  150 IF(ICAR-9) 155,155,160
C     DIGIT 0-9,DECIAML POINT YET...
  155 IF(IDP-1) 165,170,165
C     ALREADY HAVE DP,N IS THUS NEGATIVE,NUMBER IN ANUMB
  170 ANUMB=ANUMB+FLOAT(ICAR)*(10.**N)
      N=N-1
      GO TO 130
C     NO DP YET,IS DIGIT A ZERO...
  165 IF(ICAR) 175,180,175
```

```
C       NOT ZERO,THUS IT IS SIGNIFICANT
  175 ISIG=1
      GO TO 185
C       ZERO-CHECK IF SIGNIFICANT,IF NOT SKIP
  180 IF(ISIG-1)130,185,130
185     NUMB=10*NUMB+ICAR
      GO TO 130
C
C       CHARACTER NOT DIGIT IS IT DP...
  160 IF(ICAR-DP)195,190,195
C       YES,WAS ONE GIVEN PREVIOUSLY...
  190 IF(IDP-1)200,99,200
200     N=-1
      IDP=1
      ANUMB=NUMB
      GO TO 130
C
C       NOT DIGIT OR DP,IS IT E...,IF NOT,ERROR(99)
195     IF(ICAR-24)99,205,99
C       E FORM-E(PLUS OR MINUS)N1,(N2)
  205 IF(IDP-1)210,214,210
C       NO DP YET,FLOAT NUMBER
  210 ANUMB=NUMB
      IDP=1
  214 I=1
C       SIGN OF EXPONENT=PLUS
      IEP=+1
C       VALUE OF EXPONENT=0
      IEX=0
C       NEXT COLUMN
  215 IC=IC+1
      ICAR=IBUF(IC)
      IF(IC-LASTC )216,216,99
  216 IF(ICAR-BLANK)217,99,217
  217 IF(ICAR-COMMA)218,99,218
  218 GO TO (220,225),I
```

```
C     CHARACTER AFTER E,IS IT PLUS,MIMUS,OR DIGIT...
220   IF(ICAR-PLUS)226,230,235
235   IF(ICAR-MINUS)99,240,99
C     MINUS SIGN
  240 IEP=-1
C     HERE FOR PLUS SIGN ALSO
C     RESET SWITCH AND GET NEXT COLUMN
  230 I=2
      GO TO 215
C     FIRST OF ONE OR TWO EXPONENT DIGITS
225   IF(ICAR-9)226,226,99
  226 IEX=ICAR
      I=1
  223 IC=IC+1
      ICAR=IBUF(IC)
      IF(IC-LASTC )231,231,250
231   IF(ICAR-BLANK)227,250,227
227   IF(ICAR-COMMA)228,250,228
  228 GO TO (224,99),I
224   IF(ICAR-9)229,229,99
  229 I=2
      IEX=10*IEX+ICAR
      GO TO 223
C     END OF E FORM-MULTIPLY NUMBER BY EXPONENT
  250 ANUMB=ANUMB*(10.**(IEP*IEX))
C
C     END OF NUMBER,POINTER AT BLANK,COMMA,OR EOC
C     IDP=0,INTEGER IN NUMB-IDP=1,READ IN ANUMB
140   IF(ISGN-1)144,141,144
C     NEGATE-CHECK IF INTEGER OR REAL
  141 IF(IDP) 142,143,142
C     REAL
142   ANUMB=-ANUMB
      GO TO 144
C     INTEGER
  143 NUMB=-NUMB
```

```
  144 NATCH=IDE+2                                                         00002510 PGM30253
      K=NUMB                                                              00002520 PGM30254
      RK=ANUMB                                                            00002530 PGM30255
C                                                                         00002540 PGM30256
C     POINTER AT BLANK,COMMA,OR EOC-BUMP TO A NON-BLANK,NON-COMMA         00002550 PGM30257
C     CHARACTER OR LEAVE AT ECC-THIS SECTION OF CODE IS USED              00002560 PGM30258
C     BEFORE RETURNING                                                    00002570 PGM30259
  270 IF(IC-LASTC )271,271,280                                            00002580 PGM30260
  271 IC=IC+1                                                             00002590 PGM30261
      IF(IC-LASTC )272,272,280                                            00002600 PGM30262
  272 IF(IBUF(IC)-BLANK)273,271,273                                       00002610 PGM30263
  273 IF(IBUF(IC)-COMMA)280,271,280                                       00002620 PGM30264
C                                                                         00002630 PGM30265
C                                                                         00002640 PGM30266
C     FIRST CHAR IS NOT EOC,NUMBER-IS IT $...                             00002650 PGM30267
300   IF(ICAR-17)330,120,330                                              00002660 PGM30268
C                                                                         00002670 PGM30269
C                                                                         00002680 PGM30270
C     BY ELIMINATION,THE FIELD IS A WORD-SAVE IC AND GET END OF WORD.     00002690 PGM30271
C     FORM PACKED WORD IN DECIMAL CODE TO COMPARE AGAINST LIST-NEED       00002700 PGM30272
C     FIRST WORD IN LIST AS NUMBER OF CHARS IN WORD.                      00002710 PGM30273
C     BLANK PAD ON RIGHT.                                                 00002720 PGM30274
  330 ICSTR =IC                                                           00002730 PGM30275
  410 IC=IC+1                                                             00002740 PGM30276
      ICAR=IBUF(IC)                                                       00002750 PGM30277
      IF(IC-LASTC )415,415,420                                            00002760 PGM30278
  415 IF(ICAR-COMMA)405,420,405                                           00002770 PGM30279
  405 IF(ICAR-BLANK)410,420,410                                           00002780 PGM30280
C     END OF FIELD                                                        00002790 PGM30281
  420 IEND=IC-1                                                           00002800 PGM30282
C     USE LIST FIRST                                                      00002810 PGM30283
      NC=LIST(1)                                                          00002820 PGM30284
C     GET CHARACTERS IN WORD                                              00002830 PGM30285
      NCW=IEND+1-ICSTR                                                    00002840 PGM30286
      NCW1=NCW+1                                                          00002850 PGM30287
      IWD=0                                                               00002860 PGM30288
                                                                             PAGE  34
```

```
C     CHECK IF FIELDS IS SHORTER THAN DICT. WORDS
      IF(NCW-NC)440,455,455
C     SHORTER-BLANK PAD
  440 DO 445 I=1,NCW
      IJK=ICSTR +I-1
445   IWD=100*IWD+IBUF(IJK)
      DO 450 I=NCW1,NC
450   IWD=100*IWD+BLANK
      GO TO 465
C     NCW,GE,NC
  455 DO 460 I=1,NC
      IJK=ICSTR +I-1
460   IWD=100*IWD+IBUF(IJK)
C
C     NOW IWD CONTAINS NC CHARACTERS TO COMPARE
C     TO DICTIONARY WORDS
465   NWDS=LIST(2)
      DO 475 I=1,NWDS
      IF(IWD-LIST(I+2))475,480,475
  475 CONTINUE
C     WORD NOT FOUND IN DICTIONARY
      NATCH=4
      K=ICSTR
      GO TO 270
C     WORD FOUND IN DICTIONARY
  480 K=I
      NATCH=5
      GO TO 270
C
C
C     ERROR IN NUMBER FIELD
99    WRITE(IPRNT, 999)
      K=ICSTR
      NATCH =4
      GO TO 270
999   FORMAT(25H  ERROR IN NUMERIC FIELD.)
```

```
C                                                         00003230 PGM30325
C                                                         00003240 PGM30326
      RETURN                                                       PGM30327
      END                                                 00003250 PGM30328
```

NETWORK STRATEGIES GENERATOR

```
      DEFINE  FILE 10(6,900,U,INF)
      DEFINE  FILE  11(300,583,U,LAU)
C
C THIS PROGRAM GENERATES NETWORK SRTATEGIES FROM LINK-STRATEGIES
C
      COMMON /AME/ IDICA(32),NGENE(32),IDILIM
      COMMON /CRI/ PERCE,NCRITI(100)
      COMMON /MIN/ MINCRI,MINSTR
      COMMON /NUM/ NUMCUM(32),NUMMM
      COMMON /PER/ IMP,LEC
      COMMON /SLI/ NSLIP,MC,NUMSTR,IDIC,NSTR
      COMMON/LYS/NSLIMA(100),NUMBER(30),MDIS(30)
      COMMON/FILE/ NLINK,NREG,LST(30),IAA(30)
      COMMON /STR/ ILIM,JMAX,NUMLIM,NADD
C
      INTEGER*2  IAA
      DIMENSION NGECRI(32)
C
      CALL INITIA
      IDICA(JMAX+1)=JMAX+1
      NUMSTR=1
      ILIMFO=ILIM
      MINSTR=ILIMFO
      NUMMM=1
      DO 1 I=1,JMAX
      IDICA(I)=I
      NGENE(I)=0
    1 CONTINUE
      IDIR=1
      IDIL=1
      NGENE(1)=1
      NCRIGE=NCRITI(1)
      NGECRI(1)=0
      NGECRI(2)=NCRIGE
    4 IDIL=IDIL+1
      IF(IDIL.GT.JMAX) GO TO 2
```

```
 11 IF(NGENE(IDIL).LT.NUMBER(IDIL)) GO TO 3
    NGENE(IDIL)=0
    IF(IDIL.LE.ILIMFO) GO TO 8
    GO TO 4
  8 IF(IDIL.EQ.1) GO TO 9
    IDIL=IDIL-2
    IDIR=IDIR-1
    GO TO 7
  9 IF(NUMSTR.NE.1) GO TO 16
    WRITE(IMP,502)
502 FORMAT('1',' IT IS IMPOSSIBLE TO FIND A NETWORK-STRATEGY WHICH INC
   1LUDES ALL OBLIGATORY LINK-STRATEGIES'/'1')
    STOP
 16 NUMMM=0
    CALL CRITIC
    CALL ECRIRE
    STOP
  3 IDIR=IDIR+1
    IDICA(IDIR)=IDIL
    NGENE(IDIL)=NGENE(IDIL)+1
    MC=NUMCUM(IDIL)+NGENE(IDIL)-1
    NCRIGE=NCRIGE+NCRITI(MC)
    NGECRI(IDIL+1)=NCRIGE
    IF(NCRIGE.LT.MINCRI) GO TO 4
    IF(IDIR.LT.MINSTR) GO TO 4
    IDILIM=IDIR
    ILIM=IDIL
    CALL VERCAL
    IDIR=IDILIM-1
    IDIL=ILIM
    I1=IDIL+1
    IF(I1.GT.JMAX) GO TO 19
    DO 12 I=I1,JMAX
    NGENE(I)=0
 12 CONTINUE
 19 CONTINUE
```

```
      MC=NUMCUM(IDIL)+NGENE(IDIL)-1
      NCRIGE=NGECRI(IDIL+1)-NCRITI(MC)
      GO TO 11
    7 ILIM=IDIL+1
      MC=NUMCUM(ILIM)+NGENE(ILIM)-1
      NCRIGE=NGECRI(ILIM+1)-NCRITI(MC)
      I1=ILIM+1
      DO 10 I=I1,JMAX
      NGENE(I)=0
   10 CONTINUE
      GO TO 4
    2 DO 5 I=1,JMAX
      I1=JMAX-I+1
      IF(NGENE(I1).EQ.0) GO TO 5
      IDIL=I1-1
      IDIR=0
      DO 6 J=1,IDIL
      IF(NGENE(J).NE.0) IDIR=IDIR+1
    6 CONTINUE
      GO TO 7
    5 CONTINUE
      NUMMM=0
      CALL CRITIC
      CALL ECRIRE
      STOP
      END
```

```
      SUBROUTINE VERCAL
C
      COMMON /AME/ IDICA(32),NGENE(32),IDILIM
      COMMON /CCM/ KOMPTE,KCMLIM
      COMMON /IND/ INDEX
      COMMON /IDR/ IDIR
      COMMON/LYS/NSLIMA(100),NUMBER(30),MDIS(30)
      COMMON /NUM/ NUMCUM(32),NUMMM
      COMMON /RES/ NWSTRA(102,20),NWSLIP(102,20)
      COMMON /PER/ IMP,LEC
      COMMON /SLI/ NSLIP,MC,NUMSTR,IDIC,NSTR
      COMMON /STR/ ILIM,JMAX,NUMLIM,NADD
      COMMON /YEA/ NY,NUMDIS
      COMMON/FILE/ NLINK,NREG,LST(30),IAA(30)
      COMMON/VB/LL
C
      INTEGER*2  IAA
      DIMENSION IONVER(31)
C
C FIRST PART OF THE PROGRAM   SEARCH OF A NETWORK STRATEGY WHICH INCLUDE
C OBLIGATORY LINK-STRATEGIES
C
      LL=1
      CALL ZERO
      DO 27 I=1,JMAX
      IONVER(I)=0
   27 CONTINUE
      NUMST2=NUMSTR
      IDIR=1
      NSTR=0
      INDEX=0
      IDIC=IDICA(1)
      IF(ILIM.EQ.0)  GO  TO  1
    2 NSLIP=-NADD
      NUMDIS=MDIS(IDIC)
    3 NSTR=NGENE(IDIC)
```

```
      MC=NUMCUM(IDIC)+NSTR-1
    4 NSLIP=NSLIP+NADD
      CALL CALCUL
      IF(INDEX.EQ.1) GO TO 5
      IONVER(IDIR)=1
      CALL REINIT
      IF(IDIC.LE.ILIM)  GO  TO  2
      IF(JMAX.GT.ILIM) GO TO 1
      GO TO 19
    5 CALL REMEMB
    6 IF(LL.EQ.0)  GO  TO  26
      IF(NSLIP.LT.NSLIMA(MC)) GO TO 4
      IF(IDIR.EQ.1) GO TO 7
      NWSTRA(NUMSTR,IDIC)=0
      IDIR=IDIR-1
      IDIC=IDICA(IDIR)
      CALL  RECAL
      GO TO 6
C
C SECOND PART OF THE PROGRAM  SEARCH OF LINK-STRATEGIES WHICH MIGHT FIT
C THE NETWORK-STRATEGY ALREADY FOUND
C
    1 CONTINUE
    8 NSLIP=-NADD
      NUMDIS=MDIS(IDIC)
    9 NSTR=NSTR+1
      MC=NUMCUM(IDIC)+NSTR-1
   10 NSLIP=NSLIP+NADD
      CALL CALCUL
      IF(INDEX.EQ.1) GO TO 11
      CALL REINIT
   15 IF(IDIC.LE.JMAX) GO TO 8
   19 NUMSTR=NUMSTR+1
      DO 13 I=1,JMAX
      NWSTRA(NUMSTR,I)=NWSTRA(NUMSTR-1,I)
      NWSLIP(NUMSTR,I)=NWSLIP(NUMSTR-1,I)
```

```
 13 CONTINUE                                                PGM20073
    CALL CRITIC                                             PGM20074
    IF(NUMSTR.LT.NUMLIM) GO TO 12                           PGM20075
    NUMST2=0                                                PGM20076
 12 CONTINUE                                                PGM20077
    DO 20 I=1,JMAX                                          PGM20078
    I1=JMAX+1-I                                             PGM20079
    IF(NWSTRA(NUMSTR,I1).EQ.0) GO TO 20                     PGM20080
    MC=NUMCUM(I1)+NWSTRA(NUMSTR,I1)-1                       PGM20081
    IF(NWSLIP(NUMSTR,I1).LT.NSLIMA(MC)) GO TO 21            PGM20082
    IF(I1.LE.ILIM) GO TO 28                                 PGM20083
    IF(NWSTRA(NUMSTR,I1).LT.NUMBER(I1)) GO TO 21            PGM20084
 28 NWSTRA(NUMSTR,I1)=0                                     PGM20085
 20 CONTINUE                                                PGM20086
    GO TO 26                                                PGM20087
 21 IDIC=I1                                                 PGM20088
    CALL RECAL                                              PGM20089
    IF(IDIC.GT.ILIM) GO TO 14                               PGM20090
    IDIR=0                                                  PGM20091
    DO 25 I=1,IDIC                                          PGM20092
    IF(NWSTRA(NUMSTR,I).NE.0) IDIR=IDIR+1                   PGM20093
 25 CONTINUE                                                PGM20094
    IDIR=IDIR+1                                             PGM20095
    GO TO 6                                                 PGM20096
 11 CALL REMEMB                                             PGM20097
 14 IF(NSLIP.LT.NSLIMA(MC)) GO TO 10                        PGM20098
    NSLIP=-NADD                                             PGM20099
    IF(NSTR.LT.NUMBER(IDIC)) GO TO 9                        PGM20100
    IDIC=IDIC+1                                             PGM20101
    NSTR=0                                                  PGM20102
    GO TO 15                                                PGM20103
7   IF(NUMSTR.LE.NUMST2) GO TO 16                           PGM20104
    GO TO 26                                                PGM20105
 16 DO 23 J=1,IDILIM                                        PGM20106
    I=IDILIM+1-J                                            PGM20107
    IF(ICONVER(I).EQ.0) GO TO 23                            PGM20108
```

```
      ILIM=IDICA(I)                                                     PGM20109
      IDILIM=I                                                          PGM20110
      GO TO 26                                                          PGM20111
   23 CONTINUE                                                          PGM20112
      RETURN                                                            PGM20113
   26 CONTINUE                                                          PGM20114
      DO 24 I=1,JMAX                                                    PGM20115
      NWSTRA(NUMSTR,I)=0                                                PGM20116
   24 CONTINUE                                                          PGM20117
      RETURN                                                            PGM20118
      END                                                               PGM20119
```

```
      SUBROUTINE  ADDCOM(CBAR,C1,C2,C)
C  THIS  SUBROUTINE  MAKES  C1=C2+C  TAKING  INTO  ACCOUNT A SLIPPAGE OF N YEARS
C ,  AND  COMPARES  THE  C1  TO  CBAR.  INDEX=1  IF  ONE  OF  THE  ELEMENTS
C  OF C1  IS  GREATER  THAN  THE  CORRESPONDING  ELEMENT  IN  CBAR.  INDEX=2
C OTHERWISE
      DIMENSION CBAR(10,20),C1(10,20),C2(10,20),C(20)
      COMMON /IND/ INDEX
      COMMON /SLI/ NSLIP,MC,NUMSTR,IDIC,NSTR
      COMMON /YEA/ NY,NUMDIS
      COMMON/FILE/ NLINK,NREG,LST(30),IAA(30)
      INTEGER*2  IAA
C
      N1=NSLIP+1
      IF(N1.LE.NY) GO TO 3
      WRITE(6,501)
  501 FORMAT('1 ','SOMETHING STRANGE   ONE SLIPPAGE EQUALS NY OR MORE'/'
     11')
      STOP
    3 DO 4 I=N1,NY
      C1(NUMDIS,I)=C2(NUMDIS,I)+C(I-NSLIP)
      IF(C1(NUMDIS,I).LE.CBAR(NUMDIS,I))  GO  TO  4
      INDEX=1
      RETURN
    4 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE CALCUL
C
      COMMON/AVE/ GECO1(10,20),GECO2(10,20),GEFO1(10,20),GEFO2(10,20),
     1GESK1(10,20),GESK2(10,20)
      COMMON /COM/ KOMPTE,KOMLIM
      COMMON /IND/ INDEX
      COMMON/LIM/ COSTMA(10,20),FOCAMA(10,20),SKLAMA(10,20)
      COMMON/PAR/ COST(20,100),FOREIG(20,100),SKILLE(20,100)
      COMMON /SLI/ NSLIP,MC,NUMSTR,IDIC,NSTR
C
C  FOR  REGIONAL  BUDGET  CONSTRAINTS
      CALL  ADDCOM(COSTMA,GECO2, GECO1,COST(1,MC))
      IF(INDEX.EQ.1) RETURN
C  FOR  REGIONAL  FOREIGN  EXCHANGE
      CALL  ADDCOM(FOCAMA,GEFO2,GEFO1,FOREIG(1,MC))
      IF(INDEX.EQ.1)  RETURN
C  FOR  REGIONAL  SKILLED  LABOR
      CALL  ADDCOM(SKLAMA,GESK2,GESK1,SKILLE(1,MC))
      RETURN
      END
```

```
      SUBROUTINE REMEMB
C
C THIS SUBROUTINE GIVES BACK THE OLD VALUES TO THE VECTORS USED IN PRUNI
C
      COMMON/AVE/ GECO1(10,20),GECO2(10,20),GEFO1(10,20),GEFO2(10,20),
     1GESK1(10,20),GESK2(10,20)
      COMMON /IND/ INDEX
      COMMON /SLI/ NSLIP,MC,NUMSTR,IDIC,NSTR
      COMMON /YEA/ NY,NUMDIS
C
      N1=NSLIP+1
      IF(N1.GT.NY) RETURN
      DO 1 I=N1,NY
      GECO2(NUMDIS,I)=GECO1(NUMDIS,I)
      GEFO2(NUMDIS,I)=GEFO1(NUMDIS,I)
      GESK2(NUMDIS,I)=GESK1(NUMDIS,I)
    1 CONTINUE
      INDEX=0
      RETURN
      END
```

```
      SUBROUTINE RECAL
C
C THIS SUBROUTINE INITIALIZES SOME MATRICES AFTER GOING BACK TO A LINK
C STRATEGY WITH A LOWER NUMBER OF REFERENCE
C
      COMMON /AME/ IDICA(32),NGENE(32),IDILIM
      COMMON/AVE/ GECO1(10,20),GECO2(10,20),GEFO1(10,20),GEFO2(10,20),
     1GESK1(10,20),GESK2(10,20)
      COMMON /IDR/ IDIR
      COMMON/LYS/NSLIMA(100),NUMBER(30),MDIS(30)
      COMMON /NUM/ NUMCUM(32),NUMMM
      COMMON/RAP/  RECOST(30,10,20),REFORE(30,10,20),RESKIL(30,10,20)
      COMMON /RES/ NWSTRA(102,20),NWSLIP(102,20)
      COMMON /SLI/ NSLIP,MC,NUMSTR,IDIC,NSTR
      COMMON /STR/ ILIM,JMAX,NUMLIM,NADD
      COMMON /YEA/ NY,NUMDIS
      COMMON/FILE/ NLINK,NREG,LST(30),IAA(30)
      INTEGER*2  IAA
C
      NSTR=NWSTRA(NUMSTR,IDIC)
      NSLIP=NWSLIP(NUMSTR,IDIC)
       NUMDIS=MDIS(IDIC)
      MC=NUMCUM(IDIC)+NSTR-1
      IF(IDIC.EQ.1) GO TO 8
      I1=IDIC-1
      DO  3  I=1,NREG
      DO  4  J=1,I1
      J1=IDIC-J
      IF(NWSTRA(NUMSTR,J1).EQ.0)  GO  TO  4
      IF(I.NE.MDIS(J1))  GO  TO  4
      DO  5  K=1,NY
      GECO2(I,K)=RECOST(J1,I,K)
      GECO1(I,K)=GECO2(I,K)
      GEFO2(I,K)=REFORE(J1,I,K)
      GEFO1(I,K)=GEFO2(I,K)
      GESK2(I,K)=RESKIL(J1,I,K)
```

```
      SUBROUTINE REINIT
C
C THIS SUBROUTINE INITIALIZES SOME MATRICES AFTER A LINK STRATEGY IS FOU
C TO FIT INTO A NETWORK STRATEGY
C
      COMMON /AME/ IDICA(32),NGFNE(32),IDILIM
      COMMON/AVE/ GECO1(10,20),GECO2(10,20),GEFO1(10,20),GEFO2(10,20),
     1GESK1(10,20),GESK2(10,20)
      COMMON /IDR/ IDIR
      COMMON/RAF/  RECOST(30,10,20),REFORE(30,10,20),RESKIL(30,10,20)
      COMMON /RES/ NWSTRA(102,20),NWSLIP(102,20)
      COMMON /SLI/ NSLIP,MC,NUMSTR,IDIC,NSTR
      COMMON /YEA/ NY,NUMDIS
C
      NWSTRA(NUMSTR,IDIC)=NSTR
      NWSLIP(NUMSTR,IDIC)=NSLIP
      DO  1 I=1,NY
      RECOST(IDIC,NUMDIS,I)=GECO2(NUMDIS,I)
      REFORE(IDIC,NUMDIS,I)=GEFO2(NUMDIS,I)
      RESKIL(IDIC,NUMDIS,I)=GESK2(NUMDIS,I)
      GECO1(NUMDIS,I)=GECO2(NUMDIS,I)
      GEFO1(NUMDIS,I)=GEFO2(NUMDIS,I)
      GESK1(NUMDIS,I)=GESK2(NUMDIS,I)
    1 CONTINUE
      NSTR=0
      IF(IDIR.GE.IDILIM) GO TO 2
      IDIR=IDIR+1
      IDIC=IDICA(IDIR)
      GO TO 3
    2 IDIC=IDIC+1
    3 CONTINUE
      RETURN
      END
```

```
      GESK1(I,K)=GESK2(I,K)                                            PGM70037
    5 CONTINUE                                                         PGM70038
      GO  TO  3                                                        PGM70039
    4 CONTINUE                                                         PGM70040
    3 CONTINUE                                                         PGM70041
      GO TO 11                                                         PGM70042
    8 CONTINUE                                                         PGM70043
      CALL ZERO                                                        PGM70044
   11 CONTINUE                                                         PGM70045
      DO 2 I=IDIC,JMAX                                                 PGM70046
      NWSTRA(NUMSTR,I)=0                                               PGM70047
    2 CONTINUE                                                         PGM70048
      RETURN                                                           PGM70049
      END                                                              PGM70050
```

```
      SUBROUTINE CRITIC
C
C THIS SUBROUTINE COMPUTES CRITICAL INDICES FOR NETWORK-STRATEGIES AND
C PRUNE STRATEGIES WITH LOW INDEX
C
      COMMON /CRI/ PERCE,NCRITI(100)
      COMMON /RES/ NWSTRA(102,20),NWSLIP(102,20)
      COMMON /MIN/ MINCRI,MINSTR
      COMMON /NUM/ NUMCUM(32),NUMMM
      COMMON /SII/ NSLIP,MC,NUMSTR,IDIC,NSTR
      COMMON /STR/ ILIM,JMAX,NUMLIM,NADD
      COMMON /TRA/ NUMAX
      COMMON/FILE/ NLINK,NBEG,LST(30),IAA(30)
      COMMON /YEA/ NY,NUMDIS
      COMMON/LYS/NSLIMA(100),NUMBER(30),MDIS(30)
      COMMON/PAR/ COST(20,100),FOREIG(20,100),SKILLE(20,100)
      COMMON/VB/LL
      INTEGER*2  IAA
      DIMENSION NWCRIT(102)
      DIMENSION NBSTRA(102)
      NUMST1=NUMSTR-1
      IF(NUMST1.GE.NUMAX) GO TO 28
      IF(NUMMM.NE.0) RETURN
      NUMST1=NUMSTR
      NUMAX=NUMST1
   28 CONTINUE
      DO 21 I=1,NUMST1
      J=0
      DO 22 K=1,JMAX
      IF(NWSTRA(I,K).EQ.0) GO TO 22
      J=J+1
   22 CONTINUE
      NBSTRA(I)=J
   21 CONTINUE
      DO 23 I=1,NUMAX
      J=0
```

```
      DO 24 K=1,NUMST1                                                  PGM80037
      JJ=NBSTRA(K)                                                      PGM80038
      IF(JJ.LE.J) GO TO 24                                              PGM80039
      J=JJ                                                              PGM80040
      K1=K                                                              PGM80041
   24 CONTINUE                                                          PGM80042
      NBSTRA(K1)=-J                                                     PGM80043
   23 CONTINUE                                                          PGM80044
      JJ=-NBSTRA(K1)                                                    PGM80045
      J=0                                                               PGM80046
      DO 25 I=1,NUMST1                                                  PGM80047
      IF(NBSTRA(I).LT.0) GO TO 26                                       PGM80048
      IF(NBSTRA(I).LT.JJ) GO TO 25                                      PGM80049
   26 J=J+1                                                             PGM80050
      IF(I.EQ.J) GO TO 25                                               PGM80051
      DO 27 K=1,JMAX                                                    PGM80052
      NWSTRA(J,K)=NWSTRA(I,K)                                           PGM80053
   27 CONTINUE                                                          PGM80054
   25 CONTINUE                                                          PGM80055
      NUMST1=J                                                          PGM80056
      IF(NUMST1.LT.NUMAX) NUMST1=NUMAX                                  PGM80057
      MINSTR=JJ                                                         PGM80058
      DO 1 I=1,NUMST1                                                   PGM80059
      J=0                                                               PGM80060
      DO 2 K=1,JMAX                                                     PGM80061
      IF(NWSTRA(I,K).EQ.0) GO TO 2                                      PGM80062
      MC=NUMCUM(K)+NWSTRA(I,K)-1                                        PGM80063
      J=J+NCRITI(MC)                                                    PGM80064
    2 CONTINUE                                                          PGM80065
      NWCRIT(I)=J                                                       PGM80066
    1 CONTINUE                                                          PGM80067
      LI=0                                                              PGM80068
       DO 5 I=1,NUMAX                                                   PGM80069
      J=0                                                               PGM80070
      DO 6 K=1,NUMST1                                                   PGM80071
      JJ=NWCRIT(K)                                                      PGM80072
```

```
      IF(JJ.LE.J) GO TO 6                                               PGM80073
      J=JJ                                                              PGM80074
      K1=K                                                              PGM80075
    6 CONTINUE                                                          PGM80076
      NWCRIT(K1)=-J                                                     PGM80077
    5 CONTINUE                                                          PGM80078
      K=1                                                               PGM80079
      JJ=-100000                                                        PGM80080
      DO 7 I=1,NUMST1                                                   PGM80081
      IF(NWCRIT(I).GE.0) GO TC 7                                        PGM80082
      IF(NWCRIT(I).GT.JJ) JJ=NWCRIT(I)                                  PGM80083
      DC 8 J=1,JMAX                                                     PGM80084
      IF(K.NE.I)  LL=1                                                  PGM80085
      NWSTRA(K,J)=NWSTRA(I,J)                                           PGM80086
      NWSLIP(K,J)=NWSLIP(I,J)                                           PGM80087
    8 CONTINUE                                                          PGM80088
      K=K+1                                                             PGM80089
      IF(K.GT.NUMAX) GO TC 9                                            PGM80090
    7 CCNTINUE                                                          PGM80091
    9 NUMSTR=NUMAX+1                                                    PGM80092
      MINCRI=-JJ                                                        PGM80093
      IF (NUMMM.NE.1)  GO  TO  11                                       PGM80094
      DO 10 I=1,JMAX                                                    PGM80095
      NWSTRA(NUMSTR,I)=NWSTRA(NUMLIM,I)                                 PGM80096
      NWSLIP(NUMSTR,I)=NWSLIP(NUMLIM,I)                                 PGM80097
   10 CCNTINUE                                                          PGM80098
      RETURN                                                            PGM80099
   11 K=NUMAX-1                                                         PGM80100
      DO 12 I=1,K                                                       PGM80101
      I1=I                                                              PGM80102
      JJ=I+1                                                            PGM80103
      K1=NWCRIT(I)                                                      PGM80104
      DC 13 J=JJ,NUMAX                                                  PGM80105
      IF(K1.LT.NWCRIT(J)) GC TO 13                                      PGM80106
      K1=NWCRIT(J)                                                      PGM80107
      I1=J                                                              PGM80108
```

```
13 CONTINUE
   IF(I1.EQ.I) GO TO 12
   DO 14 J=1,JMAX
   N1=NWSTRA(I1,J)
   N2=NWSLIP(I1,J)
   NWSTRA(I1,J)=NWSTRA(I,J)
   NWSLIP(I1,J)=NWSLIP(I,J)
   NWSTRA(I,J)=N1
   NWSLIP(I,J)=N2
14 CONTINUE
12 CONTINUE
   RETURN
   END
```

```
      SUBROUTINE ECRIRE
C
      COMMON/PAR/ COST(20,100),FOREIG(20,100),SKILLE(20,100)
      COMMON /PER/ IMP,LEC
      COMMON /RES/ NWSTRA(102,20),NWSLIP(102,20)
      COMMON /STR/ ILIM,JMAX,NUMLIM,NADD
      COMMON /TRA/ NUMAX
      COMMON/LYS/NSLIMA(100),NUMBER(30),MDIS(30)
      COMMON /NUM/ NUMCUM(32),NUMMM
      COMMON /CRI/ PERCE,NCRITI(100)
      COMMON/EXP/TCOST(30,20),BCOST(20)
      COMMON /YEA/ NY,NUMDIS
      COMMON/FILE/ NLINK,NREG,LST(30),IAA(30)
C
      INTEGER*2  IAA
      INTEGER*2 LET(52),MWSTRA(30,30),MWSLIP(30,30),IN(30,30)
      DIMENSION  NWSTR(30,30),NWSL(30,30),DUM(420),ETC(20),ETCB(20)
C
      DATA  LET/2H 0,2H 1,2H 2,2H 3,2H 4,2H 5,2H 6,2H 7,2H 8,2H 9,2H10,2
     1H11,2H12,2H13,2H14,2H15,2H16,2H17,2H18,2H19,2H20,2H21,2H22,2H23,2H
     224,2H25,2H26,2H27,2H28,2H29,2H30,2H31,2H32,2H33,2H34,2H35,2H36,2H3
     37,2H38,2H39,2H40,2H41,2H42,2H43,2H44,2H45,2H46,2H47,2H48,2H49,2H50
     4,2H  /
      DATA NWSTR/900*0/
      DATA  NWSL/900*0/
      DO  1 I=1,NUMAX
      DO  50  JJ=1,16
      MWSTRA(I,JJ)=LET(52)
      MWSLIP(I,JJ)=LET(52)
      IN(I,JJ)=LET(52)
   50 CONTINUE
      KKK=JMAX+1
      IF(KKK.GT.16)  GO  TO  53
      DO  52  KJ=KKK,16
      IAA(KJ)=LET(52)
   52 CONTINUE
```

```
53   DO 2 K=1,JMAX
     IF(NWSTRA(I,K).EQ.0) GO TO 2
     DO 4 L=1,16
     IF(NWSTRA(I,K).EQ.L) GO TO 5
   4 CONTINUE
   5 MWSTRA(I,K)=LET(L+1)
     DO 6 L=1,17
     L1=L-1
     IF(NWSLIP(I,K).EQ.L1) GO TO 7
   6 CONTINUE
   7 MWSLIP(I,K)=LET(L)
   2 CONTINUE
   1 CONTINUE
     DO   30   I=1,NUMAX
     DO   25    K=1,NLINK
     DO   26   IE=1,20
     ETC(IE)=0.
  26 CONTINUE
     DO   41   KK=1,JMAX
     IF(K.NE.IAA(KK))   GO   TO   41
     IK=NWSTRA(I,KK)
     IF(IK.EQ.0)   GO   TO   51
     GO   TO   62
  41 CONTINUE
     IY=0
  51 LAU=10*(K-1)+1
     GO   TO   71
  62 LAU=10*(K-1)+IK
     IY=NWSLIP(I,KK)
  71 READ(11'LAU)DUM,ETC
     DO   81   N=1,NY
     IF(N.EQ.1)   GO   TO   325
     IF(N.GT.IY)   GO   TO   330
 325 IF(IY.EQ.0)   GO   TO   326
     IF(ETC(1).GT.ETC(2))   GO   TO   310
 326 TCOST(I,N)=TCOST(I,N)+ETC(1)
```

```
      GO  TO  81
  310 LAU=10*(K-1)+1
      DO  315  IE=1,20
      ETCB(IE)=0.
  315 CONTINUE
      READ(11'LAU)DUM,ETCB
      TCOST(I,N)=TCOST(I,N)+ETCB(1)
      GO  TO  81
  330 NN=N-IY
      TCOST(I,N)=TCOST(I,N)+ETC(NN)
   81 CONTINUE
   25 CONTINUE
   30 CONTINUE
      WRITE(IMP,500)
  500 FORMAT('1')
      WRITE(6,501)  (IAA(K),K=1,16)
  501 FORMAT(1X,127('*')/' *',13X,'*',16(6X,'*')/' * LINK NUMBER *',16(2
     1X,I2,2X,'*')/' *',13X,'*',16(6X,'*')/1X,127('*'))
      DO 8 I=1,NUMAX
      DO  10  K=1,JMAX
      IF(NWSTRA(I,K).EQ.0)  GO  TO  10
      II=NUMCUM(K)-1+NWSTRA(I,K)
      DO  20  L=1,52
      L1=L-1
      IF(NCRITI(II).EQ.L1)  GO  TO  27
   20 CONTINUE
   27 IN(I,K)=IFT(L)
   10 CONTINUE
      KK=JMAX+1
      IF(KK.GE.15)  GO  TO  40
   40 WRITE(6,502)I,(MWSTRA(I,K),K=1,16),(MWSLIP(I,K),K=1,16),(IN(I,K),K
     1=1,16)
  502 FORMAT(' *',13X,'*',16(6X,'*')/' * N.S.  ',I3,'   *',16(2X,A2,2X,'
     1*')/' *',13X,'*',16(6X,'*')/' * SLACK',7X,'*',16(2X,A2,2X,'*')/' *
     2 CR.I.',7X,'*',16(2X,A2,2X,'*')/' *',13X,'*',16(6X,'*')/1X,127('*'
     3))
```

```
  8 CONTINUE                                                              PGM90109
    DO  150  I=1,NUMAX                                                    PGM90110
    DO  140  K=1,JMAX                                                     PGM90111
    LJ=IAA(K)                                                             PGM90112
    NWSTR(I,LJ)=NWSTRA(I,K)                                               PGM90113
    NWSL(I,LJ)=NWSLIP(I,K)                                                PGM90114
140 CONTINUE                                                              PGM90115
150 CONTINUE                                                              PGM90116
    WRITE(10'4) NWSTR                                                     PGM90117
    WRITE(10'5) NWSL                                                      PGM90118
    WRITE(10'6) TCOST,BCOST,IAA                                           PGM90119
    DO  190  I=1,NUMAX,5                                                  PGM90120
    KK=I                                                                  PGM90121
    II=I+4                                                                PGM90122
    WRITE(6,85)  (K,K=KK,II)                                              PGM90123
 85 FORMAT('1',20X,'TOTAL EXPENDITURES  ($)',/,20X,23('*'),/,2X,'YEAR'    PGM90124
   1,5X,5(6X,'N.S.',I3,9X))                                               PGM90125
    DO  200  J=1,NY                                                       PGM90126
    WRITE(6,87)  J,(TCOST(K,J),K=KK,II)                                   PGM90127
 87 FORMAT(3X,I2,6X,5(F20.0,2X))                                          PGM90128
200 CONTINUE                                                              PGM90129
190 CONTINUE                                                              PGM90130
    WRITE(6,100)                                                          PGM90131
100 FORMAT(//,20X,'BASE NETWORK',/,20X,12('*'),/,5X,'YEAR',5X,'TOTAL      PGM90132
   1EXPENDITURES  ($)')                                                   PGM90133
    DO  210  J=1,NY                                                       PGM90134
    WRITE(6,102) J,BCOST(J)                                               PGM90135
102 FORMAT(6X,I2,8X,F20.3)                                                PGM90136
210 CONTINUE                                                              PGM90137
    RETURN                                                                PGM90138
    END                                                                   PGM90139
```

```
      SUBROUTINE MATCH (NATCH,LIST,K,RK,LARG)
      INTEGER BLANK,COMMA,PLUS,MINUS,DP
      INTEGER  LIST(8)
      DIMENSION LET(46),IBUF(80)
      DATA LET/'0','1','2','3','4','5','6','7','8','9','+','-','.',',',
     1' ','*','/','$','=','"','A','B','C','D','E','F','G','H','I','J',
     2'K','L','M','N','O','P','Q','R','S','T','U','V','W','X','Y','Z'/
C
      DATA LASTC,IREAD,IPRNT, BLANK,COMMA,PLUS,MINUS,DP/80,5,6,14,13,10,
     $11,12/
C
C      ENTRY POINT-CHECK OP CODE
      ANUMB=0.0
      L=LARG
      IF(L.EQ.0) GO TO 110
C     L=1,READ NEW CARD,CONVERT TO DECIMAL CODE,SET BUFFER POINTER IC
C     TO FIRST NON-BLANK CHAR.
      DO 800 ISS=1,80
      IBUF(ISS)=LET(15)
  800 CONTINUE
      READ(IREAD,1000,ERR=801,END=802)IBUF
 1000 FORMAT(80A1)
      GO  TO  801
  802 NATCH=6
      GO  TO  280
  801 DO 101 I=1,80
      DO 102 J=1,46
      IF(IBUF(I)-LET(J))102,103,102
  102 CONTINUE
C     NO MATCH-ILLEGAL CHARACTER,SET=50 IN IBUF
      IBUF(I)=50
      GO TO 101
C     MATCHED
103   IBUF(I)=J-1
  101 CONTINUE
C     SET IC AS FIRST NON-BLANK COLUMN
```

```
      DO 104 I=1,LASTC
      IF(IBUF(I)-BLANK)105,104,105
  104 CONTINUE
  105 IC=I
C
C     POINTER IS ALWAYS SET TO FIRST CHARACTER OF NEW FIELD ON LEAVING
C     MATCH OR BY READING A NEW CARD-IT MAY BE LEFT PAST THE LAST
C     RECOGNIZABLE COLUMN,LASTCC
110   ICAR=IBUF(IC)
      IF(IC-LASTC )115,115,120
C     END OF STATEMENT
  120 MATCH=1
280   RETURN
C
C     OK-CHECK IF NEW FIELD IS A NUMBER,0-9,+,-,OR.
  115 IF(ICAR-12)125,125,300
C
C     NUMBER FOUND-SET INITIAL PARAMETERS
C     DECIMAL POINT=NO
  125 IDP=0
C     NEGATIVE=NO
      ISGN=0
C     NO SIGNIFICANT DIGIT YET
      ISIG=0
C     NUMERICAL VALUE OF NUMBER(REAL OR INTEGER)
      NUMB=0
C     SAVE START OF NUMBER
      ICSTR =IC
C     IS FIRST CHAR A PLUS SIGN-IGNORE IF YES
      IF(ICAR-PLUS)126,130,126
C     CHECK IF MINUS SIGN-SET ISIGN=1 IF YES
  126 IF(ICAR-MINUS)135,127,135
127   ISGN=1
C     LEADING PLUS OR MINUS SIGN-BUMP CARD COLUMN POINTER-CHECK
C     IF END OF FIELD
C     THIS IS GENERAL CC BUMPER SECTION OF CODE
```

```
  130 IC=IC+1
      ICAR=IBUF(IC)
      IF(IC-LASTC )135,135,140
C     CHECK IF CC IS BLANK OR COMMA
  135 IF(ICAR-BLANK)145,140,145
  145 IF(ICAR-COMMA)150,140,150
C     NOT END OF FIELD-IS IT A DIGIT...
  150 IF(ICAR-9)155,155,160
C     DIGIT 0-9,DECIAML POINT YET...
  155 IF(IDP-1)165,170,165
C     ALREADY HAVE DP,N IS THUS NEGATIVE,NUMBER IN ANUMB
 170  ANUMB=ANUMB+FLOAT(ICAR)*(10.**N)
      N=N-1
      GO TO 130
C     NO DP YET,IS DIGIT A ZERO...
  165 IF(ICAR)175,180,175
C     NOT ZERO,THUS IT IS SIGNIFICANT
  175 ISIG=1
      GO TO 185
C     ZERO-CHECK IF SIGNIFICANT,IF NOT SKIP
  180 IF(ISIG-1)130,185,130
 185  NUMB=10*NUMB+ICAR
      GO TO 130
C
C     CHARACTER NOT DIGIT IS IT DP...
  160 IF(ICAR-DP)195,190,195
C     YES,WAS ONE GIVEN PREVIOUSLY...
  190 IF(IDP-1)200,99,200
 200  N=-1
      IDP=1
      ANUMB=NUMB
      GO TO 130
C
C     NOT DIGIT OR DP,IS IT E...,IF NOT,ERROR(99)
 195  IF(ICAR-24)99,205,99
C     E FORM-E(PLUS OR MINUS)N1,(N2)
```

```
  205 IF(IDP-1)210,214,210
C     NO DP YET,FLOAT NUMBER
  210 ANUMB=NUMB
      IDP=1
  214 I=1
C     SIGN OF EXPONENT=PLUS
      IEP=+1
C     VALUE OF EXPONENT=0
      IEX=0
C     NEXT COLUMN
  215 IC=IC+1
      ICAR=IBUF(IC)
      IF(IC-LASTC )216,216,99
  216 IF(ICAR-BLANK)217,99,217
  217 IF(ICAR-COMMA)218,99,218
  218 GO TO (220,225),I
C     CHARACTER AFTER E,IS IT PLUS,MIMUS,OR DIGIT...
220   IF(ICAR-PLUS)226,230,235
235   IF(ICAR-MINUS)99,240,99
C     MINUS SIGN
  240 IEP=-1
C     HERE FOR PLUS SIGN ALSO
C     RESET SWITCH AND GET NEXT COLUMN
  230 I=2
      GO TO 215
C     FIRST OF ONE OR TWO EXPONENT DIGITS
225   IF(ICAR-9)226,226,99
  226 IEX=ICAR
      I=1
  223 IC=IC+1
      ICAR=IBUF(IC)
      IF(IC-LASTC )231,231,250
231   IF(ICAR-BLANK)227,250,227
227   IF(ICAR-COMMA)228,250,228
  228 GO TO (224,99),I
224   IF(ICAR-9)229,229,99
```

```
  229 I=2                                                               00002350 PGM10145
      IEX=10*IEX+ICAR                                                   00002360 PGM10146
      GO TO 223                                                         00002370 PGM10147
C     END OF E FORM-MULTIPLY NUMBER BY EXPONENT                         00002380 PGM10148
  250 ANUMB=ANUMB*(10.**(IEP*IEX))                                      00002390 PGM10149
C                                                                       00002400 PGM10150
C     END OF NUMBER,POINTER AT BLANK,COMMA,OR EOC                       00002410 PGM10151
140   IF(ISGN-1)144,141,144                                             00002430 PGM10152
C     IDP=0,INTEGER IN NUMB-IDP=1,READ IN ANUMB                         00002420 PGM10153
C     NEGATE-CHECK IF INTEGER OR REAL                                   00002440 PGM10154
  141 IF(IDP) 142,143,142                                               00002450 PGM10155
C     REAL                                                              00002460 PGM10156
142   ANUMB=-ANUMB                                                      00002470 PGM10157
      GO TO 144                                                         00002480 PGM10158
C     INTEGER                                                           00002490 PGM10159
  143 NUMB=-NUMB                                                        00002500 PGM10160
  144 NATCH=IDP+2                                                       00002510 PGM10161
      K=NUMB                                                            00002520 PGM10162
      RK=ANUMB                                                          00002530 PGM10163
C                                                                       00002540 PGM10164
C     POINTER AT BLANK,COMMA,OR EOC-BUMP TO A NON-BLANK,NON-COMMA       00002550 PGM10165
C     CHARACTER OR LEAVE AT EOC-THIS SECTION OF CODE IS USED            00002560 PGM10166
C     BEFORE RETURNING                                                  00002570 PGM10167
  270 IF(IC-LASTC )271,271,280                                          00002580 PGM10168
  271 IC=IC+1                                                           00002590 PGM10169
      IF(IC-LASTC )272,272,280                                          00002600 PGM10170
  272 IF(IBUF(IC)-BLANK)273,271,273                                     00002610 PGM10171
  273 IF(IBUF(IC)-COMMA)280,271,280                                     00002620 PGM10172
C                                                                       00002630 PGM10173
C                                                                       00002640 PGM10174
C     FIRST CHAR IS NOT EOC,NUMBER-IS IT $...                           00002650 PGM10175
300   IF(ICAR-17)330,120,330                                            00002660 PGM10176
C                                                                       00002670 PGM10177
C                                                                       00002680 PGM10178
C     BY ELIMINATION,THE FIELD IS A WORD-SAVE IC AND GET END OF WORD.   00002690 PGM10179
C     FORM PACKED WORD IN DECIMAL CODE TO COMPARE AGAINST LIST-NEED     00002700 PGM10180
```

```
C     FIRST WORD IN LIST AS NUMBER OF CHARS IN WORD.                    00002710 PGM10181
C     BLANK PAD ON RIGHT.                                               00002720 PGM10182
  330 ICSTR =IC                                                         00002730 PGM10183
  410 IC=IC+1                                                           00002740 PGM10184
      ICAR=IBUF(IC)                                                     00002750 PGM10185
      IF(IC-LASTC )415,415,420                                          00002760 PGM10186
  415 IF(ICAR-COMMA)405,420,405                                         00002770 PGM10187
  405 IF(ICAR-BLANK)410,420,410                                         00002780 PGM10188
C     END OF FIELD                                                      00002790 PGM10189
  420 IEND=IC-1                                                         00002800 PGM10190
C     USE LIST FIRST                                                    00002810 PGM10191
      NC=LIST(1)                                                        00002820 PGM10192
C     GET CHARACTERS IN WORD                                            00002830 PGM10193
      NCW=IEND+1-ICSTR                                                  00002840 PGM10194
      NCW1=NCW+1                                                        00002850 PGM10195
      IWD=0                                                             00002860 PGM10196
C     CHECK IF FIELDS IS SHORTER THAN DICT. WORDS                       00002870 PGM10197
      IF(NCW-NC)440,455,455                                             00002880 PGM10198
C     SHORTER-BLANK PAD                                                 00002890 PGM10199
  440 DO 445 I=1,NCW                                                    00002900 PGM10200
      IJK=ICSTR +I-1                                                    00002910 PGM10201
445   IWD=100*IWD+IBUF(IJK)                                             00002920 PGM10202
      DO 450 I=NCW1,NC                                                  00002930 PGM10203
      GO TO 465                                                         00002950 PGM10204
450   IWD=100*IWD+BLANK                                                 00002940 PGM10205
C     NCW,GE,NC                                                         00002960 PGM10206
  455 DO 460 I=1,NC                                                     00002970 PGM10207
      IJK=ICSTR +I-1                                                    00002980 PGM10208
460   IWD=100*IWD+IBUF(IJK)                                             00002990 PGM10209
C                                                                       00003000 PGM10210
C     NOW IWD CONTAINS NC CHARACTERS TO COMPARE                         00003010 PGM10211
C     TO DICTIONARY WORDS                                               00003020 PGM10212
465   NWDS=LIST(2)                                                      00003030 PGM10213
      DO 475 I=1,NWDS                                                   00003040 PGM10214
      IF(IWD-LIST(I+2))475,480,475                                      00003050 PGM10215
  475 CONTINUE                                                          00003060 PGM10216
```

```
C      WORD NOT FOUND IN DICTIONARY                                     00003070 PGM10217
       NATCH=4                                                          00003080 PGM10218
       K=ICSTR                                                          00003090 PGM10219
       GO TO 270                                                        00003100 PGM10220
C      WORD FOUND IN DICTIONARY                                         00003110 PGM10221
  480  K=I                                                              00003120 PGM10222
       NATCH=5                                                          00003130 PGM10223
       GO TO 270                                                        00003140 PGM10224
C                                                                       00003150 PGM10225
C                                                                       00003160 PGM10226
C      ERROR IN NUMBER FIELD                                            00003170 PGM10227
99     WRITE(IERNT, 999)                                                00003180 PGM10228
       K=ICSTR                                                          00003190 PGM10229
       NATCH =4                                                         00003200 PGM10230
       GO TO 270                                                        00003210 PGM10231
999    FORMAT(25H  ERROR IN NUMERIC FIELD.)                             00003220 PGM10232
C                                                                       00003230 PGM10233
C                                                                       00003240 PGM10234
       RETURN                                                                    PGM10235
       END                                                              00003250 PGM10236
```

```
      SUBROUTINE INITIA
      COMMON/AVE/ GECO1(10,20),GECO2(10,20),GEFO1(10,20),GEFO2(10,20),
     1GESK1(10,20),GESK2(10,20)
      COMMON /CCM/ KOMPTE,KOMLIM
      COMMON /CRI/ PERCE,NCRITI(100)
      COMMON/LIM/ COSTMA(10,20),FOCAMA(10,20),SKLAMA(10,20)
      COMMON/LYS/NSLIMA(100),NUMBER(30),MDIS(30)
      COMMON /MIN/ MINCRI,MINSTR
      COMMON /NUM/ NUMCUM(32),NUMMM
      COMMON/PAR/ COST(20,100),FOREIG(20,100),SKILLE(20,100)
      COMMON /PER/ IMP,LEC
      COMMON/EXP/TCOST(30,20),BCOST(20)
      COMMON/FAP/  RECOST(30,10,20),REFORE(30,10,20),RESKIL(30,10,20)
      COMMON /RES/ NWSTRA(102,20),NWSLIP(102,20)
      COMMON /STR/ ILIM,JMAX,NUMLIM,NADD
      COMMON /TRA/ NUMAX
      COMMON /YEA/ NY,NUMDIS
      COMMON/FILE/ NLINK,NREG,IST(30),IAA(30)
      INTEGER*2  IAA
      DIMENSION VCAP(7),LDUM(60), DUMMY(420),ETC(20),FTC(20),SKL(20),FOR
     1(20),IDICT(9),F10(900),IUM(80)
C
C WORDS IN IDICT: NETWORK,OBLIGATORY,OPTIONAL,PERCENTAGE,MINIMUM,SLIPPAGE,GENERA
C  TE
      DATA  IDICT/3,7,332439,342131,343539,352437,322833,383128,262433/
      IMP=6
      LEC=5
      NUMMM=0
      KOMPTE=0
      KOMLIM=1
      DATA  F10/900*0./
      WRITE(10'4)F10
      WRITE(10'5) F10
      WRITE(10'6) F10
      ILIM=0
      JMAX=0
```

```
      DO   51   I=1,30
      IAA(I)=0
   51 CONTINUE
      DO   61   I1=1,30
      DO   62    N=1,20
      TCOST(I1,N)=0.
   62 CONTINUE
   61 CONTINUE
C  ASSIGN  DATA  TO  THE  VARIABLES
C  READ  THE  BASIC  FILE
      READ(10'1)NLINK,NODE,NREG,NY,JIM,RATE,VCAP,LDUM,LST,MDIS,COSTMA,FO
     1CAMA,SKLAMA
   10 CALL  MATCH(ITYPE,IDICT,K,RK,1)
      GO   TO   (100,100,100,100,18,95),ITYPE
   18 IK1=K
      GO   TO   (20,30,50,70,80,40,90),IK1
C  NETWORK  STRATEGIES
   20 CALL  MATCH(ITYPE,IDICT,K,RK,0)
      GO   TO   (10,25,110,20,20),ITYPE
   25 NUMLIM=K
      GO   TO   10
C  OBLIGATORY  LINKS
   30 KK=0
   35 CALL  MATCH(ITYPE,IDICT,K,RK,0)
      GO   TO   (39,38,120,35,35),ITYPE
   38 KK=KK+1
      IAA(KK)=K
      GO   TO   35
   39 ILIM=KK
      JMAX=ILIM
      GO   TO   10
C  INCREMENTAL  SLIPPAGE
   40 CALL  MATCH(ITYPE,IDICT,K,RK,0)
      GO   TO   (10,48,45,40,40),ITYPE
   45 K=RK
   48 NADD=K
```

```
      GO TO 10
C   OPTIONAL LINKS
   50 KK=0
   55 CALL MATCH(ITYPE,IDICT,K,RK,0)
      GO TO (60,58,130,55,55),ITYPE
   58 KK=KK+1
      J=ILIM+KK
      IAA(J)=K
      GO TO 55
   60 JMAX=ILIM+KK
      GO TO 10
C   PERCENTAGE OF N.S.
   70 CALL MATCH(ITYPE,IDICT,K,RK,0)
      GO TO (10,140,75,70,70),ITYPE
   75 PERCE=RK
      GO TO 10
   80 CALL MATCH(ITYPE,IDICT,K,RK,0)
      GO TO (10,85,150,80,80),ITYPE
   85 MINCRI=K
      GO TO 10
  100 WRITE(6,105)
  105 FORMAT(/,'   ERROR IN COMMAND CARD')
      GO TO 10
  110 WRITE(6,115)
  115 FORMAT(/,'   ERROR IN NETWORK CARD')
      GO TO 10
  120 WRITE(6,125)
  125 FORMAT(/,'   ERROR IN OBLIGATORY LINKS CARD')
      GO TO 10
  130 WRITE(6,135)
  135 FORMAT(/,'   ERROR IN OPTIONAL LINKS CARD')
      GO TO 10
  140 WRITE(6,145)
  145 FORMAT(/,'   ERROR IN PERCENTAGE CARD')
      GO TO 10
  150 WRITE(6,155)
```

```
155 FORMAT(/,'    ERROR   IN   CRITICAL   INDEX   CARD')              PGM10109
    GO  TO  10                                                          PGM10110
 95 CALL  EXIT                                                          PGM10111
 90  CONTINUE                                                           PGM10112
    CALL  BUDGET(JMAX)                                                  PGM10113
    NUMCUM(1)=1                                                         PGM10114
    DO  250  I=1,JMAX                                                   PGM10115
    LINK=IAA(I)                                                         PGM10116
    NUMBER(I)=LST(LINK)                                                 PGM10117
    NN=NUMBER(I)                                                        PGM10118
    NUMCUM(I+1)=NUMCUM(I)+NN                                            PGM10119
    LAUC=10*(LINK-1)                                                    PGM10120
    DO  240  II=1,NN                                                    PGM10121
    LAU=LAUC+II                                                         PGM10122
    READ(11'LAU) DUMMY,ETC,FTC,SKL,FOR,DUM,ISTR,NCRIT,NSLIM             PGM10123
    J=NUMCUM(I)-1+II                                                    PGM10124
    DO  230  K=1,NY                                                     PGM10125
    COST(K,J)=FTC(K)                                                    PGM10126
    FOREIG(K,J)=FOR(K)                                                  PGM10127
    SKILLE(K,J)=SKL(K)                                                  PGM10128
230 CONTINUE                                                            PGM10129
    NSLIMA(J)=NSLIM                                                     PGM10130
    NCRITI(J)=NCRIT                                                     PGM10131
    NSLIM=0                                                             PGM10132
    NCRIT=0                                                             PGM10133
    DO  225  K=1,NY                                                     PGM10134
    FTC(K)=0.                                                           PGM10135
    FOR(K)=0.                                                           PGM10136
    SKL(K)=0.                                                           PGM10137
225 CONTINUE                                                            PGM10138
240 CONTINUE                                                            PGM10139
250 CONTINUE                                                            PGM10140
    N1=NUMCUM(JMAX+1)-1                                                 PGM10141
    DO  2  J=1,NREG                                                     PGM10142
    DO 3 I=1,NY                                                         PGM10143
    GECO1(J,I)=0.                                                       PGM10144
```

```
      GEFO1(J,I)=0.
      GESK1(J,I)=0.
      RECOST(1,J,I)=0.
      REFORE(1,J,I)=0.
      RESKIL(1,J,I)=0.
    3 CONTINUE
    2 CONTINUE
      DO 6 I=1,JMAX
      DO 5 J=1,NUMLIM
      NWSTRA(J,I)=0
    5 CONTINUE
    6 CONTINUE
      NUMAX=NUMLIM*PERCE
      RETURN
      END
```

```
      SUBROUTINE ZERO
      COMMON/AVE/ GECC1(10,20),GECO2(10,20),GEFO1(10,20),GEFO2(10,20),
     1GESK1(10,20),GESK2(10,20)
      COMMON /REG/ NREG
      CCMMON /YEA/ NY,NUMDIS
      DC  20  K=1,NREG
      DC 19 I=1,NY
      GECO1(K,I)=0.
      GECO2(K,I)=0.
      GEFO1(K,I)=0.
      GEFO2(K,I)=0.
      GESK1(K,I)=0.
      GFSK2(K,I)=0.
   19 CCNTINUE
   20 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE  BUDGET(JMAX)
      COMMON/LIM/ COSTMA(10,20),FOCAMA(10,20),SKLAMA(10,20)
      COMMON/LYS/NSLIMA(100),NUMBER(30),MDIS(30)
      COMMON/FILE/ NLINK,NREG,LST(30),IAA(30)
      COMMON /YEA/ NY,NUMDIS
      COMMON/EXP/TCOST(30,20),BCOST(20)
      INTEGER*2  IAA
      DIMENSION DUMMY(420),ETC(20),FTC(20),SKL(20),FCR(20),DUM(80)
      DO  10  I=1,NY
      BCOST(I)=0.
   10 CONTINUE
      DO  100  I=1,NLINK
      LAUC=10*(I-1)
      LAU=LAUC+1
      DO  30  K=1,20
      SKL(K)=0.
      FCR(K)=0.
      FTC(K)=0.
      ETC(I)=0.
   30 CONTINUE
      READ(11'LAU) DUMMY,ETC,FTC,SKL,FOR,DUM,ISTR,NCRIT,NSLTM
      L=MDIS(I)
      DO  50  KK=1,NY
      BCOST(KK)=BCOST(KK)+ETC(KK)
      A=COSTMA(I,KK)
      A1=A-FTC(KK)
      IF(A1.LE.0.)  GO  TO  200
      COSTMA(L,KK)=A1
      B=FOCAMA(L,KK)
      B1=B-FOR(KK)
      IF(B1.LE.0.)  GO  TO  210
      FOCAMA(L,KK)=B1
      D=SKLAMA(L,KK)
      D1=D-SKL(KK)
      IF(D1.LE.0.)  GO  TO  220
      SKLAMA(L,KK)=D1
```

```
 50 CONTINUE                                                          PGM10037
100 CONTINUE                                                          PGM10038
    GO  TO  250                                                       PGM10039
200 WRITE(6,205) L,KK                                                 PGM10040
205 FORMAT(/,'   THE AVAILAELE BUDGET FOR REGION ',I2,' AND  THE YEAR PGM10041
   1',I2,'  HAS  BEEN EXHAUSTED')                                     PGM10042
    GO  TO  240                                                       PGM10043
220 WRITE(6,225) L,KK                                                 PGM10044
225 FORMAT(/,'  THE AVAILABLE  SKILLED LABOR FOR REGION ',I2,'  AND YE PGM10045
   1AR ',I2,'  HAS  BEEN EXHAUSTED')                                  PGM10046
    GO  TO  240                                                       PGM10047
210 WRITE(6,215) L,KK                                                 PGM10048
215 FORMAT(/,'   THE  AVAILABLE FOREIGN EXCHANGE FOR REGION ',I2,'  AN PGM10049
   1D YEAR ',I2,'  HAS  BEEN  EXHAUSTED')                             PGM10050
240 CONTINUE                                                          PGM10051
    CALL EXIT                                                         PGM10052
250 CONTINUF                                                          PGM10053
    RETURN                                                            PGM10054
    END                                                               PGM10055
```

NETWROK STRATEGIES EVALUATOR

```
C  THIS  PROGRAM EVALUATES NETWORK STRATEGIES
      DEFINE FILE 10(6,900,U,INF)
      DEFINE FILE 11(300,583,U,LAU)
      DEFINE FILE 12(30,448,U,JIMC)
      COMMON/GEN/NLINK,NODE,JIM,NS,VTIME(30,7),FALOD(30,7),BCOST(20),LBE
     1G(30),LEND(30),LOD(30,30),LLA(30,30),VCAP(7),IOPT,IVF,ISIM(20),IG
     2RAF(20)
      COMMON/CD/IPATH(7,30,15),VEC(30,7),VFC(30,7)
      COMMON/INK/TT(30,7),CFC(30,7),EOPC(30,7),CAP(30),SPD(30,7),RLEN(30
     1),TRAFF(30),TEF(30,7),RAFF(30), VEHTRA(30,7),DSPR(30)
      COMMON/ZEL/ATT(20,7),EOC(20,7),FOC(20,7),FTC(20),DIS(20),CP(20),ET
     1C(20),RAF(20),DSP(20)
      COMMON/ZED/DEMAND(20,7),ELA(7),PRICE(7),VALT(7),BVEC(20,7),BVFC(20
     1,7)
      DIMENSION IDICT(9),LST(30),MDIS(30),COSTMA(10,20),FOCAMA(10,20),SK
     1LAMA(10,20),NETS(30)
      DIMENSION   NRANK(30),NWSTR(30,30),NWSL(30,30),TCOST(30,20),IAA(30
     2),SPEED(7),TCTBEN(30),FLOAD(7),FOR(20),SKL(20),DUM(420),ETCB(20)
      INTEGER*2  IAA
C  WORDS  IN  IDICT: ANALYSIS,EVALUATE,ALL,SIMULATION,DELETE,RANK,PRINT
      DATA IDICT/3,7,203320,244120,203131,382832,232431,372033,353728/
      DATA NETS/30*0/
      DO  10  I=1,30
      DO  8  K=1,7
      VTIME(I,K)=0.
      FALOD(I,K)=0.
    8 CONTINUE
   10 CONTINUE
      DO  11  I=1,20
      ISIM(I)=0
      IGRAF(I)=0
   11 CONTINUE
      READ(10'1)NLINK,NODE,NREG,NY,JIM,RATE,VCAP,LBEG,LEND,LST,MDIS,COST
     1MA,FOCAMA,SKLAMA,IOPT,NRANK
      READ(10'2)LLA
      READ(10'3)LOD
```

```
      READ(10'4)NWSTR
      READ(10'5)NWSL
      READ(10'6)TCOST,BCOST,IAA
      RATE=RATE/100.
      MI=0
      IBANK=0
      IBASE=0
      LASTNS=0
      DO  17  I=1,7
      IF(VCAP(I).EQ.0)  GO  TO  16
   17 CONTINUE
      GO  TO  20
   16 IVP=I-1
   20 CALL MATCH(ITYPE,IDICT,K,RK,1)
      GO  TO  (100,100,100,100,22,150),ITYPE
   22 IK1=K
      GO  TO  (25,30,30,70,50,60,150),IK1
C  ANALYSIS OF BASE  NETWORK
   25 IBASE=1
      GO  TO  20
   30 CALL MATCH(ITYPE,IDICT,K,RK,0)
      GO  TO  (38,37,35,30,40),ITYPE
C  N.S.  TO  BE  EVALUATED
   35 K=RK
   37 MI=MI+1
      NETS(MI)=K
      LASTNS=MI
      GO  TO  20
   38 IF(I.EQ.0)  GO  TO  110
      GO  TO  20
C  EVALUATE  ALL  STRATEGIES  GENERATED
   40 CALL  MATCH(ITYPE,IDICT,K,RK,0)
      GO  TO  (20,47,45,40,40),ITYPE
   45 K=RK
   47 LASTNS=K
      DO  48  IK=1,LASTNS
```

```
      NETS(IK)=IK
   48 CONTINUE
      GO  TO  20
C  YEARS  OF  SIMULATION
   70 KK=0
   71 CALL  MATCH(ITYPE,IDICT,K,RK,0)
      GO  TO  (20,77,75,71,71),ITYPE
   75 K=RK
   77 KK=KK+1
      ISIM(KK)=K
      GO  TO  71
C  DELETE  THE  STORED  RANKING  OF  N.S.
   50 DO  55  II=1,30
      NRANK(II)=0
   55 CONTINUE
      GO  TO  20
   60 IRANK=1
      GO  TO  50
C  ERROR  FORMATS
  100 WRITE(6,105)
  105 FORMAT(/'  ERROR IN FORMATS')
      GO  TO  20
  110 WRITE(6,115)
  115 FORMAT(/'  NONE  N.S.  NUMBER')
      GO  TO  20
C  YEARS  TO  BE  PRINTED
  150 KK=0
  152 CALL  MATCH(ITYPE,IDICT,K,RK,0)
      GO  TO  (151,157,155,152,152),ITYPE
  155 K=RK
  157 KK=KK+1
      IGRAF(KK)=K
      GO  TO  152
  151 CONTINUE
      DO  180  I=1,JIM
      DO   165  IV=1,7
```

```
      VALT(IV)=0.
      FLOAD(IV)=0.
  165 CONTINUE
      JIMC=I
      READ(12'JIMC) DEMAND,ELA,PRICE,VALT,FLOAD
      DO  170  IV=1,7
      FALOD(I,IV) =FLOAD(IV)
      VTIME(I,IV)=VALT(IV)
  170 CONTINUE
  180 CONTINUE
C  START  ANALYSIS  OF  THE  BASE  NETWORK
      IF(IBASE.EQ.0)  GO  TO  200
      CALL  BASENE(NY)
C  START  ANALYSIS  OF  EACH  N.S.
  200 CONTINUE
      DO  1000  LJ=1,LASTNS
      I=NETS(LJ)
      WRITE(6,600)I
  600 FORMAT(///,30X,'NETWORK STRATEGY',I2,/,30X,18('*'))
      ISTR=0
      ACBEN=0.
      DO  800  IYR=1,NY
      EXP=0.
      BENEF=0.
      WRITE(6,666) IYR
  666 FORMAT(/,3X,'YEAR',I5,/,3X,9('-'))
      DO  995  LL=1,30
      DO  994  LK=1,7
      VEHTRA(LL,LK)=0.
  994 CONTINUE
  995  CONTINUE
      IF(IYR.EQ.1)  GO  TO  205
      II=IYR-1
      DIF=TCOST(I,IYR)-TCOST(I,II)
      IF(DIF.GE.1000.)  GO  TO  205
      IF(DIF.LE.-1000.)        GO  TO  205
```
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      DO   166   JJ=1,20                                         PGM10145
      IF(ISIM(JJ).EQ.IYR)   GC   TO   205                        PGM10146
      IF(IGRAF(JJ).EQ.IYR)   GC   TO   205                       PGM10147
  166 CCNTINUE                                                   PGM10148
      GC   TO   400                                              PGM10149
  205 CONTINUE                                                   PGM10150
C  ZERO  ARRAYS  OF  VEHICLE  COSIS                              PGM10151
      DO   215   J=1,30                                          PGM10152
      DO   210   IV=1,7                                          PGM10153
      VEC(J,IV)=0.                                               PGM10154
      VFC(J,IV)=0.                                               PGM10155
  210 CONTINUE                                                   PGM10156
  215 CONTINUE                                                   PGM10157
      DO   216   IV=1,7                                          PGM10158
      DO   217   J=1,30                                          PGM10159
      DC   218   JJ=1,15                                         PGM10160
      IPATH(IV,J,JJ)=0                                           PGM10161
  218 CCNTINUE                                                   PGM10162
  217 CONTINUE                                                   PGM10163
  216 CCNTINUE                                                   PGM10164
C  ZERO  ARRAYS                                                  PGM10165
      DC   230   J=1,30                                          PGM10166
      RLEN(J)=C.                                                 PGM10167
      RAFF(J)=0.                                                 PGM10168
      DSPR(J)=0.                                                 PGM10169
      TRAFF(J)=0.                                                PGM10170
      CAP(J)=C.                                                  PGM10171
      DO   235   IV=1,7                                          PGM10172
      TEF(J,IV)=0.                                               PGM10173
      TT(J,IV)=0.                                                PGM10174
      ECPC(J,IV)=0.                                              PGM10175
      OPC(J,IV)=0.                                               PGM10176
      SPD(J,IV)=0.                                               PGM10177
  235 CCNTINUE                                                   PGM10178
  230 CONTINUE                                                   PGM10179
      DO   300   KK=1,NLINK                                      PGM10180
```

```
      CALL  ZEIINK
      DO  240  JJ=1,30
      IB=IAA(JJ)
      IF(IB.EQ.KK)  GO  TO  245
  240 CONTINUE
      IK=IYR
  242 LAUC=10*(KK-1)
      LAU=LAUC+1
      READ(11'LAU) ATT,EOC,FOC,ETC,FTC,SKL,FOR,DIS,CP,RAF,DSP
      GO  TO  260
  245 ISTR=NWSTR(I,KK)
      LAUC=10*(KK-1)
      LAU=LAUC+ISTR
      READ(11'LAU) ATT,EOC,FOC,ETC,FTC,SKL,FOR,DIS,CP,RAF,DSP
      IF(NWSL(I,KK).NE.0)  GO  TO  250
      IK=IYR
      GO  TO  260
  250 ISL=NWSL(I,KK)
      IF(IYR.GT.ISL)  GO  TO  255
      K1=FTC(1)
      K2=FTC(2)
      IF(K1.GT.K2)  GO  TO  248
      IK=1
      GO  TO  260
  248 IK=1
      GO  TO  242
  255 IK=IYR-ISL
  260 CONTINUE
      DO  265 IJ=1,7
      SPEED(IJ)=0.
  265 CONTINUE
      DO  270  IV=1,IVF
      TT(KK,IV)=ATT(IK,IV)
      OPC(KK,IV)=FOC(IK,IV)
      EOPC(KK,IV)=EOC(IK,IV)
      IF(ATT(IK,IV).EQ.0.)  GO  TO  270
```

```
      SPEED(IV)=DIS(IK)/ATT(IK,IV)
      SPD(KK,IV)=SPEED(IV)
  270 CONTINUE
      CAP(KK)=CP(IK)
      RAFF(KK)=RAF(IK)
      DSPR(KK)=DSP(IK)
      RLEN(KK)=DIS(IK)
  290 CONTINUE
      RDI=3.67-0.027*DSP(IK)
      ROC=RDI*RAF(IK)
      RK1=SPEED(1)
      DO  425  IV=2,IVF
      IF(SPEED(IV).EQ.0.)  GO  TO  425
      RK2=SPEED(IV)
      TEF(KK,IV)=(ROC*(RK1-RK2)/10.)+2.
  425 CONTINUE
      TEF(KK,1)=1.
  300 CONTINUE
C  COMPUTE  TRANSPORT  COSTS
      NS=I
      DO  320  IV=1,IVF
      CALL  ROUTE(IYR,IV)
  320 CONTINUE
  325 CALL  COST(IYR)
  400 CS=0.
      IF(IOPT.EQ.1)  GO  TO  2000
      DO  500  J=1,JIM
      JIMC=J
      CALL  ZEDEM
      READ(12'JIMC)DEMAND,ELA,PRICE,VALT,FLOAD,BVEC,BVFC
      IF(BVFC(IYR,1).GE.PRICE(1))    GO  TO  480
      DO  450  IV=1,IVF
      DIF=BVFC(IYR,IV)-VEC(J,IV)
      IF(DIF.GT.0.0 .OR. DIF.LE.-.90)  GO  TO  451
      CS=CS+0.
      GO  TO  450
```

```
 451 DEM=0.
     IF(DEMAND(IYR,IV).EQ.0.)  GO  TO  450
     DEM=DEMAND(IYR,IV)*((VEC(J,IV)/BVEC(IYR,IV))**(-ELA(IV)))
     IF(IV.GT.2)  GO  TO  455
     A=365.*0.5*(DEM+DEMAND(IYR,IV))*(BVEC(IYR,IV)-VEC(J,IV))
     CS=CS+A
     GO  TO  450
 455 A=365.*(0.5*(DEM+DEMAND(IYR,IV))*(BVEC(IYR,IV)-VEC(J,IV)))/(VCAP(I
    1V)*FALOD(J,IV))
     CS=CS+A
 450 CONTINUE
     GO  TO  500
 480 DO  485  IV=1,IVF
     IF(VEC(J,IV).GE.PRICE(IV))  GO  TO  500
 481 DEM=0.
     IF(DEMAND(IYR,IV).EQ.0.)  GO  TO  485
     DEM=DEMAND(IYR,IV)*((VEC(J,IV)/PRICE(IV))**(-ELA(IV)))
     IF(IV.GT.2)  GO  TO  482
     A=365.*0.5*(DEMAND(IYR,IV)+DEM)*(PRICE(IV)-VEC(J,IV))
     CS=CS+A
     GO  TO  485
 482 A=365.*(0.5*((DEMAND(IYR,IV)+DEM)/(VCAP(IV)*FALOD(J,IV)))*(PRICE(I
    1V)-VEC(J,IV)))
     CS=CS+A
 485 CONTINUE
 500 CONTINUE
     GO  TO  599
2000 CONTINUE
     DO  2500  J=1,JIM
     JIMC=J
     CALL  ZEDEM
     READ(12'JIMC)DEMAND,ELA,PRICE,VALT,FLOAD,BVEC,BVFC
     IF(BVEC(IYR,1).GE.PRICE(1))  GO  TO  2480
     DO  2450  IV=1,IVF
     DIF=BVEC(IYR,IV)-VEC(J,IV)
     IF(DIF.GT.0.0 .OR.DIF.LE.-0.9)  GO  TO  2451
```

```
      CS=CS+0.
      GO  TO  2450
 2451 DEM=0.
      IF(DEMAND(IYR,IV).EQ.0.)  GO  TO     2450
      DEM=DEMAND(IYR,IV)*((VEC(J,IV)/BVEC(IYR,IV))**(-ELA(IV)))
      A=365.*0.5*(DEM+DEMAND(IYR,IV))*(BVEC(IYR,IV)-VEC(J,IV))
      CS=CS+A
 2450 CONTINUE
      GO  TO  2500
 2480 DO  2485  IV=1,IVF
      IF(VEC(J,IV).GE.PRICE(IV))  GO  TO  2500
 2481 DEM=0.
      IF(DEMAND(IYR,IV).EQ.0.)  GO  TO   2485
      DEM=DEMAND(IYR,IV)*((VEC(J,IV)/PRICE(IV))**(-ELA(IV)))
      A=365.*0.5*(DEMAND(IYR,IV)+DEM)*(PRICE(IV)-VEC(J,IV))
      CS=CS+A
 2485 CONTINUE
 2500 CONTINUE
  599 IT=IYR-1
      EXP=TCOST(I,IYR)-BCOST(IYR)
      BENEF=CS-EXP
      ACBEN=ACBEN+BENEF*((1.+RATE)**(-IT))
  603 WRITE(6,601)
  601 FORMAT(8X,'BENEFITS',15X,'EXPENDITURES',13X,'NET BENEFITS',9X,'ACC
     1UMULATED NET BENEFITS(NEV)')
      WRITE(6,602)  CS,EXP,BENEF,ACBEN
  602 FORMAT(2X,3(F20.5,5X),9X,F20.5)
  800 CONTINUE
      TOTBEN(I)=ACBEN
      WRITE(6,622) TOTBEN(I)
  622 FORMAT(/2X,'THE TOTAL NET BENEFITS(NPV) ARE:',F20.5)
 1000 CONTINUE
C   RANK
      IF(IRANK.EQ.0)  GO  TO  1300
      NN=0
      KK=1
```

```
      R1=-1000000000.                                                   PGM10325
 1150 DO   1200   MM=1,LASTNS                                           PGM10326
      II=NETS(MM)                                                       PGM10327
      DO   1450   K=1,KK                                                PGM10328
      IF(NRANK(K).EQ.II)   GO   TO   1200                               PGM10329
 1450 CONTINUE                                                          PGM10330
      R2=TOTBEN(II)                                                     PGM10331
      IF(R1.GE.R2)   GO   TO   1200                                     PGM10332
      IMAX=II                                                           PGM10333
      R1=TOTBEN(II)                                                     PGM10334
      GO   TO   1200                                                    PGM10335
 1200 CONTINUE                                                          PGM10336
 1100 CONTINUE                                                          PGM10337
      NN=NN+1                                                           PGM10338
      KK=NN                                                             PGM10339
      NRANK(KK)=IMAX                                                    PGM10340
      IF(KK.EQ.LASTNS)   GO   TO   1250                                 PGM10341
      R1=-1000000000.                                                   PGM10342
      GO   TO   1150                                                    PGM10343
 1250 WRITE(6,605)                                                      PGM10344
  605 FORMAT(///40X,'RANK OF THE NETWORK STRATEGIES',/,10X,'RANK',5X,'N.PGM10345
     1S.',5X,'TOTAL NET BENEFITS(NPV)')                                 PGM10346
      DO   1230   LJ=1,LASTNS                                           PGM10347
      IN=NRANK(LJ)                                                      PGM10348
      WRITE(6,610)   LJ,IN,TOTBEN(IN)                                   PGM10349
  610 FORMAT(11X,I2,7X,I2,6X,F15.5)                                     PGM10350
 1230 CONTINUE                                                          PGM10351
 1300 CONTINUE                                                          PGM10352
      WRITE(10'1)NLINK,NODE,NBEG,NY,JIM,RATE,VCAP,LBEG,LEND,LST,MDIS,COSPGM10353
     1TMA,FOCAMA,SKLAMA,IOPT,NRANK                                      PGM10354
      CALL   EXIT                                                       PGM10355
 9999 STOP                                                              PGM10356
      END                                                               PGM10357
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```
      SUBROUTINE  BASENE(NY)
C   ANALYZE  BASE  NETWORK
      COMMON/GEN/NLINK,NODE,JIM,NS,VTIME(30,7),FALCD(30,7),BCOST(20),LBE
     1G(30),IEND(30),LOD(30,30),LLA(30,30),VCAP(7),IOPT,IVF,ISIM(20),IG
     2RAF(20)
      COMMON/LNK/TT(30,7),CPC(30,7),EOPC(30,7),CAP(30),SPD(30,7),RLEN(30
     1),TRAFF(30),TEF(30,7),RAFF(30), VEHTRA(30,7),DSPR(30)
      COMMON/CD/IPATH(7,30,15),VEC(30,7),VFC(30,7)
      COMMON/ZEL/ATT(20,7),EOC(20,7),FOC(20,7),FTC(20),DIS(20),CP(20),ET
     1C(20),RAF(20),DSP(20)
      COMMON/ZED/DEMAND(20,7),ELA(7),PRICE(7),VALT(7),BVEC(20,7),BVFC(20
     1,7)
      DIMENSION  SPEED(7),SKL(20),FOR(20),FLOAD(7)
      WRITE(6,400)
  400 FORMAT(///30X,'BASE NETWORK ANALYSIS',/,30X,21('*'))
      NS=0
      DO  300  IYR=1,NY
      DO  992     LL=1,30
      DO  991  LK=1,7
      VEHTRA(LL,LK)=0.
  991 CONTINUE
  992 CONTINUE
      IF(IYR.EQ.1)  GO  TO  40
      II=IYR-1
      DIF=BCOST(IYR)-BCOST(II)
      IF(DIF.GE.1000.)  GO  TO  40
      IF(DIF.LE.-1000.)  GO  TO  40
      DO  166  JJ=1,20
      IF(ISIM(JJ).EQ.IYR)  GO  TO  40
  166 CONTINUE
      GO  TO  150
   40 CONTINUE
      DO  167      JJ=1,20
      IF(IGRAF(JJ).EQ.IYR)  GO  TO  41
  167 CONTINUE
      GO  TO  42
```

```
   41 WRITE(6,666)       IYR
  666 FORMAT(/,3X,'YEAR',I5,/,3X,9('-'))
C  ZERO  ARRAYS
  42  DO  45  J=1,30
      DO  48  IV=1,7
      VEC(J,IV)=0.
      VFC(J,IV)=0.
  48  CONTINUE
  45  CONTINUE
      DO  50  IV=1,7
      DO  55  J=1,30
      DO  60  JJ=1,15
      IPATH(IV,J,JJ)=0
   60 CONTINUE
   55 CONTINUE
   50 CONTINUE
      DO  70  J=1,30
      RLEN(J)=0.
      RAFF(J)=0.
      DSPR(J)=0.
      TRAFF(J)=0.
      CAP(J)=0.
      DO  65  IV=1,7
      SPD(J,IV)=0.
      TEF(J,IV)=0.
      TT(J,IV)=0.
      EOPC(J,IV)=0.
      OPC(J,IV)=0.
   65 CONTINUE
   70 CONTINUE
      DO  100  KK=1,NLINK
      CALL  ZELINK
      DO  105  IV=1,7
      SPEED(IV)=0.
  105 CONTINUE
      LAU=10*(KK-1)+1
```

```
      READ(11'LAU)ATT,EOC,FOC,ETC,FTC,SKL,FOR,DIS,CP,RAF,DSP             PGM20073
      DO  110  IV=1,IVF                                                  PGM20074
      TT(KK,IV)=ATT(IYR,IV)                                              PGM20075
      OPC(KK,IV)=FOC(IYR,IV)                                             PGM20076
      EOPC(KK,IV)=EOC(IYR,IV)                                            PGM20077
      IF(ATT(IYR,IV).EQ.0.)  GO  TO  110                                 PGM20078
      AT=ATT(IYR,IV)                                                     PGM20079
      SPEED(IV)=DIS(IYR)/AT                                              PGM20080
      SPD(KK,IV)=SPEED(IV)                                               PGM20081
  110 CONTINUE                                                           PGM20082
      RAFF(KK)=RAF(IYR)                                                  PGM20083
      DSPR(KK)=DSP(IYR)                                                  PGM20084
      CAP(KK)=CP(IYR)                                                    PGM20085
      RLEN(KK)=DIS(IYR)                                                  PGM20086
      RDI=3.67-0.027*DSP(IYR)                                            PGM20087
      ROC=RDI*RAF(IYR)                                                   PGM20088
      RK1=SPEED(1)                                                       PGM20089
      DO  425  IV=2,IVF                                                  PGM20090
      IF(SPEED(IV).EQ.0.)  GO  TO  425                                   PGM20091
      RK2=SPEED(IV)                                                      PGM20092
      TEF(KK,IV)=(ROC*(RK1-RK2)/10.)+2.                                  PGM20093
  425 CONTINUE                                                           PGM20094
      TEF(KK,1)=1.                                                       PGM20095
  100 CONTINUE                                                           PGM20096
      DO  120  IV=1,IVF                                                  PGM20097
      CALL  ROUTE(IYR,IV)                                                PGM20098
  120 CONTINUE                                                           PGM20099
  125 CALL  COST(IYR)                                                    PGM20100
      GO  TO  200                                                        PGM20101
  150 CONTINUE                                                           PGM20102
      DO  190  I=1,JIM                                                   PGM20103
      JIMC=I                                                             PGM20104
      CALL  ZEDEM                                                        PGM20105
      READ(12'JIMC)DEMAND,ELA,PRICE,WAIT,FLOAD,BVEC,BVFC                 PGM20106
      II=IYR-1                                                           PGM20107
      DO  170  IV=1,IVF                                                  PGM20108
```

```
      R1=0.
      R2=0.
      R1=BVEC(II,IV)
      R2=BVFC(II,IV)
      BVEC(IYR,IV)=R1
      BVFC(IYR,IV)=R2
  170 CONTINUE
      JIMC=I
      WRITE(12'JIMC) DEMAND,ELA,PRICE,VALT,FLOAD,BVEC,BVFC
  190 CONTINUE
      GO  TO  300
  200 CONTINUE
      DO  290  I=1,JIM
      JIMC=I
      CALL  ZEDEM
      READ(12'JIMC) DEMAND,ELA,PRICE,VALT,FLOAD,BVEC,BVFC
      II=IYR-1
      DO  280  IV=1,IVF
      BVEC(IYR,IV)=VEC(I,IV)
      BVFC(IYR,IV)=VFC(I,IV)
      IF(IYR.EQ.1)  GO  TO  280
      DEMAND(IYR,IV)=DEMAND(IYR,IV)*((BVFC(IYR,IV)/BVFC(II,IV))**(-ELA(I
     1V)))
  280 CONTINUE
  281 JIMC=I
      WRITE(12'JIMC)DEMAND,ELA,PRICE,VALT,FLOAD,BVEC,BVFC
      IF(IYR.EQ.1)  GO  TO  290
      DO  320  KO=1,NODE
      DO  310  KD=1,NODE
      IF(LOD(KO,KD).EQ.I)  GO  TO  330
  310 CONTINUE
  320 CONTINUE
      GO  TO  290
  330 WRITE(6,335)  KO,KD,(IV,IV=1,IVF)
  335 FORMAT(/,10X,'THE DEMAND OF O-D',I2,'-',I2,'  HAS CHANGED',//,30X,
     1'VEHICLE TYPES',/,10X,7(5X,I2,8X))
```

```
      WRITE(6,340)   (DEMAND(IYR,IV),IV=1,IVF)                         PGM20145
  340 FORMAT(/,10X,7(F12.5,3X))                                        PGM20146
  290 CONTINUE                                                         PGM20147
  300 CONTINUE                                                         PGM20148
      RETURN                                                           PGM20149
      END                                                              PGM20150
```

```
      SUBROUTINE  ROUTE(IYR,IV)
C  THIS  SUBROUTINE  SEARCHES  FOR  THE  MINIMUM  COST  ROUTE
      COMMON/GEN/NLINK,NODE,JIM,NS,VTIME(30,7),FALOD(30,7),BCOST(20),LBE
     1G(30),LEND(30),LOD(30,30),LLA(30,30),VCAP(7),IOPT,IVF,ISIM(20),IG
     2RAF(20)
      COMMON/OD/IPATH(7,30,15),VEC(30,7),VFC(30,7)
      COMMON/LNK/TT(30,7),OPC(30,7),EOPC(30,7),CAP(30),SPD(30,7),RLEN(30
     1),TRAFF(30),TEF(30,7),RAFF(30), VEHTRA(30,7),DSPR(30)
      COMMON/ZED/DEMAND(20,7),ELA(7),PRICE(7),VALT(7),BVEC(20,7),BVFC(20
     1,7)
      DIMENSION  CROUTE(30,30),TROUTE(30,30),LROUTE(30,30)
C CONSTRUCT  THE  COST  AND  LABEL  MATRICES
      DO  10  KO=1,30
      DO  8  KD=1,30
      CROUTE(KO,KD)=10000000.
      TROUTE(KO,KD)=10000000.
    8 CONTINUE
   10 CONTINUE
      DO  20  I=1,NLINK
      KO=LBEG(I)
      KD=LEND(I)
      IF(OPC(I,IV).EQ.0.)  GO  TO  20
      CROUTE(KO,KD)=OPC(I,IV)
      CROUTE(KD,KO)=OPC(I,IV)
      TROUTE(KO,KD)=TT(I,IV)
      TROUTE(KD,KO)=TT(I,IV)
   20 CONTINUE
      DO  40  KO=1,NODE
      DO  30  KD=1,NODE
      LROUTE(KO,KD)=KO
   30 CONTINUE
   40 CONTINUE
C  START  SEARCH  OF  MINIMUM  PATH
      DO  100  IP=1,NODE
      DO  90  KO=1,NODE
      IF(KO.EQ.IP)  GO  TO  90
```

```
      DO  80  KD=1,NODE
      IF(KD.EQ.IP)  GO  TO  80
      IF(KD.EQ.KO)  GO  TO  80
      C1=CROUTE(KO,IP)+CROUTE(IP,KD)
      C2=CROUTE(KO,KD)
      IF(C1.GE.C2)  GO  TO  80
      CROUTE(KO,KD)=C1
      LROUTE(KO,KD)=IP
      TROUTE(KO,KD)=TROUTE(KO,IP)+TROUTE(IP,KD)
   80 CONTINUE
   90 CONTINUE
  100 CONTINUE
      DO  200  KO=1,NODE
      DO  190  KD=1,NODE
      I=LOD(KO,KD)
      IF(I.EQ.0)  GO  TO  190
      K=16
      IO=KO
      ID=KD
  180 J=LROUTE(IO,ID)
  186 CONTINUE
      IK=LLA(ID,J)
      IF(IK.NE.0)  GO  TO  185
      J1=J
      J2=ID
      J=LROUTE(J1,J2)
      GO  TO  186
  185 K=K-1
      IPATH(IV,I,K)=IK
      VEC(I,IV)=VEC(I,IV)+ECPC(IK,IV)
      VFC(I,IV)=VFC(I,IV)+OPC(IK,IV)
      IF(J.EQ.KO)  GO  TO  170
      ID=J
      GO  TO  180
  170 A=TROUTE(KO,KD)*VTIME(I,IV)*VCAP(IV)*FALOD(I,IV)
      VEC(I,IV)=VEC(I,IV)+A
```

```
      VEC(I,IV)=VEC(I,IV)+A                                             PGM30073
  190 CONTINUE                                                          PGM30074
  200 CONTINUE                                                          PGM30075
C  ASSIGN  TRAFFIC  ON  LINKS                                           PGM30076
      DO  300  I=1,JIM                                                  PGM30077
      DO  310  II=1,20                                                  PGM30078
      DO  305   JJ=1,7                                                  PGM30079
      DEMAND(II,JJ)=0.                                                  PGM30080
  305 CONTINUE                                                          PGM30081
  310 CONTINUE                                                          PGM30082
      JIMC=I                                                            PGM30083
      READ(12'JIMC)DEMAND,ELA,PRICE                                     PGM30084
      IF(VEC(I,IV).GT.PRICE(IV))  GO  TO  300                           PGM30085
      IF(IOPT.EQ.1)  GO  TO  275                                        PGM30086
      IF(IV.GT.2)  GO  TO  270                                          PGM30087
  275 TRAF=DEMAND(IYR,IV)                                               PGM30088
  285 DO  280  KK=1,15                                                  PGM30089
      K=16-KK                                                           PGM30090
      IF(IPATH(IV,I,K).EQ.0)  GO  TO  300                               PGM30091
      LINK=IPATH(IV,I,K)                                                PGM30092
      TRAFF(LINK)=TRAFF(LINK)+TRAF*TEF(LINK,IV)                         PGM30093
      VEHTRA(LINK,IV)=VEHTRA(LINK,IV)+TRAF                              PGM30094
  280 CONTINUE                                                          PGM30095
      GO  TO  300                                                       PGM30096
  270 ITRAF=(DEMAND(IYR,IV)/(VCAP(IV)*FALOD(I,IV)))+1                   PGM30097
      TRAF=ITRAF                                                        PGM30098
      GO  TO  285                                                       PGM30099
  300 CONTINUE                                                          PGM30100
      RETURN                                                            PGM30101
      END                                                               PGM30102
```

```
      SUBROUTINE  COST(IYR)
C   COMPUTES  THE  NEW  COST  IF  CONGESTION  OCCURS  IN  A  LINK
      COMMON/GEN/NLINK,NODE,JIM,NS,VTIME(30,7),FALOD(30,7),BCOST(20),LBE
     1G(30),LEND(30),LOD(30,30),LLA(30,30),VCAP(7),IOPT,IVF,ISIM(20),IG
     2RAF(20)
      COMMON/CD/IPATH(7,30,15),VEC(30,7),VFC(30,7)
      COMMON/LNK/TT(30,7),OPC(30,7),EOPC(30,7),CAP(30),SPD(30,7),RLEN(30
     1),TRAFF(30),TEF(30,7),RAFF(30), VEHTRA(30,7),DSPR(30)
      DIMENSION  VOL(5),VEHNO(5),PCVEH(5),AAT(30,7),IROUTE(30),AT(5)
      DATA  AAT/210*0./
      DO  200  I=1,NLINK
      IF(TRAFF(I).EQ.0.)  GO  TO  200
      TOTCAP=CAP(I)*16.
      VOL(1)=.10*CAP(I)
      VOL(2)=.30*CAP(I)
      VOL(3)=.50*CAP(I)
      VOL(4)=.70*CAP(I)
      VOL(5)=.90*CAP(I)
      VOLCAP=TRAFF(I)/TOTCAP
      IF(VOLCAP.GE..90)  GO  TO  90
      IF(VOLCAP.LE..10)  GO  TO  80
      A=.10*TOTCAP
      RVOL=1.25*(VOLCAP-.10)
      VEHNO(1)=A*((1-RVOL)**4)
      VEHNO(2)=12.*A*RVOL*((1-RVOL)**3)
      VEHNO(3)=30.*A*(RVOL**2)*((1-RVOL)**2)
      VEHNO(4)=28.*A*(RVOL**3)*(1-RVOL)
      VEHNO(5)=9.*A*(RVOL**4)
      GO  TO  95
   90 DO  91  IP=1,4
      VEHNO(IP)=0.
   91 CONTINUE
      VEHNO(5)=TRAFF(I)
      VOL(5)=TRAFF(I)/16.
      GO  TO  95
   80 DO  81  IP=2,5
```

```
      VEHNO(IP)=0.
   81 CONTINUE
      VEHNO(1)=TRAFF(I)
      VCL(1)=TRAFF(I)/16.
   95 CONTINUE
      DO  150  IV=1,IVF
      DO  100  IP=1,5
      PCVEH(IP)=VEHNO(IP)/TRAFF(I)
      V=DSPR(I)
      VEL=V-V*VCL(IP)/CAP(I)
      IF(VEL.LT.0.10*V)  VEL=0.10*V
      IF(VEL.GT.SPD(I,IV))  GO  TO  150
      AT(IP)=(RLEN(I)/VEL)-(RLEN(I)/SPD(I,IV))
      VEHNO(IP)=VEHTRA(I,IV)*PCVEH(IP)
  100 CONTINUE
      TOTT=0.
      DO  120        IP=1,5
      TOTT=TOTT+VEHNO(IP)*AT(IP)
  120 CONTINUE
      AAT(I,IV)=TOTT/VEHTRA(I,IV)
  150 CONTINUE
  200 CONTINUE
      DO  300  IV=1,IVF
      DO  166   JJ=1,20
      IF(IGRAF(JJ).EQ.IYR)  GO  TO  604
  166 CONTINUE
      GO  TO  650
  604 WRITE(6,600)  IV
  600 FORMAT(/20X,'MINIMUM COST ROUTES OF VEHICLE TYPE:',I5,/,17X,'O-D P
     1AIR #',10X,'ROUTE(LINKS NUMBERS)')
  650 DO  290  I=1,JIM
      DO  220  LO=1,NODE
      DO  210  LD=1,NODE
      IF(I.EQ.LCD(LO,LD))  GO  TO  215
  210 CONTINUE
  220 CONTINUE
```

```
215 DO  270  L=1,30
    IROUTE(I)=0
270 CONTINUE
    KK=0
    DO  280  K=1,15
    IF(IPATH(IV,I,K).EQ.0)  GO  TO  280
    KK=KK+1
    IROUTE(KK)=IPATH(IV,I,K)
    LINK=IPATH(IV,I,K)
    IF(AAT(LINK,IV).EQ.0.)  GO  TO  280
    A=AAT(LINK,IV)*VTIME(I,IV)*VCAP(IV)*FALOD(I,IV)
    VEC(I,IV)=VEC(I,IV)+A
    VFC(I,IV)=VFC(I,IV)+A
280 CONTINUE
    DO  167   JJ=1,20
    IF(IGRAF(JJ).EQ.IYR)  GO  TO  605
167 CONTINUE
    GO  TO  290
605 WRITE(6,610) IV,LO,LD,(IROUTE(K),K=1,KK)
610 FORMAT(8X,I2,9X,I2,'-',I2,13X,15I2)
290 CONTINUE
300 CONTINUE
    DO  168  JJ=1,20
    IF(IGRAF(JJ).EQ.IYR)  GO  TO  301
168 CONTINUE
    GO  TO  500
301 WRITE(6,615)  (IV,IV=1,IVF)
615 FORMAT(/20X,'ECONOMIC VEHICLE OPERATING COSTS',/,20X,'VEHICLE TYPE
   1S',/,4X,'O-D #',6X,7(4X,I2,4X))
    DO  410  LO=1,NODE
    DO  420  LD=1,NODE
    I=LOD(LO,LD)
    IF(I.EQ.0)  GO  TO  420
    WRITE(6,620)  LO,LD,(VEC(I,IV),IV=1,IVF)
620 FORMAT(4X,I2,'-',I2,6X,7(F10.4))
420 CONTINUE
```

```
410 CONTINUE                                                           PGM40109
    WRITE(6,625)  (IV,IV=1,IVF)                                        PGM40110
625 FORMAT(/20X,'FINANCIAL VEHICLE OPERATING COSTS',/,20X,'VEHICLE TYP PGM40111
   1ES',/,4X,'O-D #',6X,7(4X,I2,4X))                                   PGM40112
    DO  450  LO=1,NODE                                                 PGM40113
    DO  460  LD=1,NODE                                                 PGM40114
    I=LOD(LO,LD)                                                       PGM40115
    IF(I.EQ.0)  GO  TO  460                                            PGM40116
    WRITE(6,630)  LO,LD,(VFC(I,IV),IV=1,IVF)                           PGM40117
630 FORMAT(4X,I2,'-',I2,6X,7(F10.4))                                   PGM40118
460 CONTINUE                                                           PGM40119
450 CONTINUE                                                           PGM40120
    WRITE(6,640)  (L,L=1,IVF)                                          PGM40121
640 FORMAT(/30X,'TOTAL TRAFFIC ON LINKS',/,2X,'LINK',5X,'IN PCU',5X,7( PGM40122
   1'OF TYPE:',I2,3X))                                                 PGM40123
    DO  500  I=1,NLINK                                                 PGM40124
    WRITE(6,645) I,TRAFF(I),(VEHTRA(I,IV),IV=1,IVF)                    PGM40125
645 FORMAT(3X,I2,3X,F10.3,4X,7(F8.0,5X))                               PGM40126
500 CONTINUE                                                           PGM40127
    RETURN                                                             PGM40128
    END                                                                PGM40129
```

```
      SUBROUTINE  ZELINK                                                PGM50001
      COMMON/ZEL/ATT(20,7),EOC(20,7),FOC(20,7),FTC(20),DIS(20),CP(20),ET PGM50002
     1C(20),RAF(20),DSP(20)                                             PGM50003
      DO  50      I=1,20                                                PGM50004
      FTC(I)=0.                                                         PGM50005
      ETC(I)=0.                                                         PGM50006
      DIS(I)=0.                                                         PGM50007
      RAF(I)=0.                                                         PGM50008
      DSP(I)=0.                                                         PGM50009
      CP(I)=0.                                                          PGM50010
      DO  20  J=1,7                                                     PGM50011
      ATT(I,J)=0.                                                       PGM50012
      EOC(I,J)=0.                                                       PGM50013
      FOC(I,J)=0.                                                       PGM50014
   20 CONTINUE                                                          PGM50015
   50 CONTINUE                                                          PGM50016
      RETURN                                                            PGM50017
      END                                                               PGM50018
```

```
      SUBROUTINE  ZEDEM
      COMMON/ZED/DEMAND(20,7),ELA(7),PRICE(7),VALT(7),BVEC(20,7),BVFC(20
     1,7)
      DO  50  I=1,20
      DO  30  J=1,7
      DEMAND(I,J)=0.
      BVEC(I,J)=0.
      BVFC(I,J)=0.
   30 CONTINUE
   50 CONTINUE
      DO  20  I=1,7
      ELA(I)=0.
      VALT(I)=0.
      PRICE(I)=0.
   20 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MATCH (NATCH,LIST,K,RK,LARG)                           00000010 PGM70001
C                                                                       00000060 PGM70002
C     MATCH READS A CARD IN 80A1 FORMAT INTO JBUF, CONVERTS EACH        00000070 PGM70003
C     COLUMN TO AN INTEGER CODE IN IBUF, AND DECODES EACH LOGICAL       00000080 PGM70004
C     FIELD ON THE CARD. THE LAST USEABLE COLUMN IS INDICATED BY THE    00000090 PGM70005
C     DATA SPECIFICATION FOR 'LASTCC'.                                  00000100 PGM70006
C     EACH CODE NUMBER REPRESENTS A CHARACTER AND IS FORMED             00000110 PGM70007
C     INTO LIST WORDS BY COMBINING THE CODE TIMES SOME                  00000120 PGM70008
C     POWER OF 100.  THUS IF A WORD MAY CONTAIN 4 CHARACTERS,           00000130 PGM70009
C     (LIST(1)=4), AND THE WORD 'THE' IS TO BE REPRESENTED, THE CODED   00000140 PGM70010
C     WORD IS  39272414,  BLANK PADDED (14) ON THE RIGHT                00000150 PGM70011
C     LIST=DICTIONARY ADDRESS(INTEGER ARRAY)                            00000160 PGM70012
C           LIST(1)=NUMBER OF CHARACTERS/WORD                           00000170 PGM70013
C           LIST(2)=NUMBER OF LIST WORDS IN DICTIONARY                  00000180 PGM70014
C           LIST(3)....TO LIST(N) ARE CODED WORDS                       00000190 PGM70015
C           TOTAL LENGTH=LIST(2)+2 INTEGER WORDS                        00000200 PGM70016
C                                                                       00000210 PGM70017
C     NATCH=                                                            00000220 PGM70018
C           1,END OF STATEMENT                                          00000230 PGM70019
C           2,INTEGER NUMBER                                            00000240 PGM70020
C           3,REAL NUMBER                                               00000250 PGM70021
C           4,WORD NOT IN DICTIONARY                                    00000260 PGM70022
C           5,WORD IN DICTIONARY                                        00000270 PGM70023
C     CODE IS INTEGER DECIMAL, 00 TO 45, AS INDICATED BELOW.            00000280 PGM70024
C     THE CODES ARE AS FOLLOWS...                                       00000290 PGM70025
C           CODE        CHARACTER REPRESENTED                           00000300 PGM70026
C              0        0                                               00000310 PGM70027
C              1        1                                               00000320 PGM70028
C              2        2                                               00000330 PGM70029
C              3        3                                               00000340 PGM70030
C              4        4                                               00000350 PGM70031
C              5        5                                               00000360 PGM70032
C              6        6                                               00000370 PGM70033
C              7        7                                               00000380 PGM70034
C              8        8                                               00000390 PGM70035
C              9        9                                               00000400 PGM70036
```

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C                   10       +                                                         00000410 PGM70037
C                   11       -                                                         00000420 PGM70038
C                   12       .                                                         00000430 PGM70039
C                   13       ,                                                         00000440 PGM70040
C                   14       BLANK                                                     00000450 PGM70041
C                   15       *                                                         00000460 PGM70042
C                   16       /                                                         00000470 PGM70043
C                   17       $                                                         00000480 PGM70044
C                   18       =                                                         00000490 PGM70045
C                   19       "                                                         00000500 PGM70046
C                   20       A                                                         00000510 PGM70047
C                   21       B                                                         00000520 PGM70048
C                   22       C                                                         00000530 PGM70049
C                   23       D                                                         00000540 PGM70050
C                   24       E                                                         00000550 PGM70051
C                   25       F                                                         00000560 PGM70052
C                   26       G                                                         00000570 PGM70053
C                   27       H                                                         00000580 PGM70054
C                   28       I                                                         00000590 PGM70055
C                   29       J                                                         00000600 PGM70056
C                   30       K                                                         00000610 PGM70057
C                   31       L                                                         00000620 PGM70058
C                   32       M                                                         00000630 PGM70059
C                   33       N                                                         00000640 PGM70060
C                   34       O                                                         00000650 PGM70061
C                   35       P                                                         00000660 PGM70062
C                   36       Q                                                         00000670 PGM70063
C                   37       R                                                         00000680 PGM70064
C                   38       S                                                         00000690 PGM70065
C                   39       T                                                         00000700 PGM70066
C                   40       U                                                         00000710 PGM70067
C                   41       V                                                         00000720 PGM70068
C                   42       W                                                         00000730 PGM70069
C                   43       X                                                         00000740 PGM70070
C                   44       Y                                                         00000750 PGM70071
C                   45       Z                                                         00000760 PGM70072
```

```
C                                                                       
C     K=POSITION OF WORD IN DICTIONARY(EXCLUSIVE OF FIRST 2 CONTROL     
C       WORDS) IF MATCH=5                                               
C      =NUMBER IF MATCH=2                                               
C      =SUBSCRIPT IN JBUF OF FIRST CHARACTER OF UNRECOGNIZED WORD       
C       IF MATCH=4                                                      
C     RK=REAL NUMBER IF MATCH=3                                         
C                                                                       
C     LARG=0,READ NEXT FIELD ON CARD                                    
C         =1,READ NEW CARD-FIRST FIELD                                  
C                                                                       
C     ' $' IS CONTINUATION CARD MARK                                    
C     $ IN CC1 IS A COMMENT CARD                                        
C                                                                       
C     THE MAXIMUM NUMBER OF CHARACTERS PER WORD DEPENDS ON THE          
C     ALLOWABLE NUMBER OF DECIMAL DIGITS PER INTEGER WORD.              
C     IN SUBROUTINE CODES                                               
C     THE ABOVE CODES ARE SET BY A DATA SPECIFICATION FOR LET(1-46)     
C     LET(I) HAS THE CHARACTER REPRESENTATION (1H) OF THE CHARACTER     
C     WITH CODE I-1.  THUS LET(21)=1HA.                                 
C                                                                       
      INTEGER  LIST(7)
      INTEGER BLANK,COMMA,PLUS,MINUS,DP
      DIMENSION LET(46),IBUF(80)
      DATA LET/'0','1','2','3','4','5','6','7','8','9','+','-','.',',',
     1' ','*','/','$','=','"','A','B','C','D','E','F','G','H','I','J',
     2'K','L','M','N','O','P','Q','R','S','T','U','V','W','X','Y','Z'/
C
      DATA LASTC,IREAD,IPRNT, BLANK,COMMA,PLUS,MINUS,DP/80,5,6,14,13,10,
     $11,12/
C
C     ENTRY POINT-CHECK OP CODE
      ANUMB=0.0
      L=LARG
      IF(L.EQ.0) GO TO 110
C     L=1,READ NEW CARD,CONVERT TO DECIMAL CODE,SET BUFFER POINTER IC
```

```
C      TO FIRST NON-BLANK CHAR.                                          00001100 PGM70109
       DO 800 ISS=1,80                                                   00001110 PGM70110
       IBUF(ISS)=LET(15)                                                 00001120 PGM70111
  800 CONTINUE                                                           00001130 PGM70112
       READ(IREAD,1000,ERR=801,END=802)IBUF                                       PGM70113
 1000 FORMAT(80A1)                                                       00001150 PGM70114
      GO  TO  801                                                                 PGM70115
  802 MATCH=6                                                                     PGM70116
      GO  TO  280                                                                 PGM70117
  801 DO 101 I=1,80                                                      00001160 PGM70118
       DO 102 J=1,46                                                     00001170 PGM70119
       IF(IBUF(I)-LET(J)) 102,103,102                                    00001180 PGM70120
  102 CONTINUE                                                           00001190 PGM70121
C      NO MATCH-ILLEGAL CHARACTER,SET=50 IN IBUF                         00001200 PGM70122
       IBUF(I)=50                                                        00001210 PGM70123
      GO TO 101                                                          00001220 PGM70124
C      MATCHED                                                           00001230 PGM70125
103    IBUF(I)=J-1                                                       00001240 PGM70126
  101 CONTINUE                                                           00001250 PGM70127
C      SET IC AS FIRST NON-BLANK COLUMN                                  00001260 PGM70128
       DO 104 I=1,LASTC                                                  00001270 PGM70129
       IF(IBUF(I)-BLANK)105,104,105                                      00001280 PGM70130
  104 CONTINUE                                                           00001290 PGM70131
  105 IC=I                                                               00001300 PGM70132
C                                                                        00001310 PGM70133
C      POINTER IS ALWAYS SET TO FIRST CHARACTER OF NEW FIELD ON LEAVING  00001320 PGM70134
C      MATCH OR BY READING A NEW CARD-IT MAY BE LEFT PAST THE LAST       00001330 PGM70135
C      RECOGNIZABLE COLUMN,LASTCC                                        00001340 PGM70136
110    ICAR=IBUF(IC)                                                     00001350 PGM70137
      IF(IC-LASTC )115,115,120                                           00001360 PGM70138
C      END OF STATEMENT                                                  00001370 PGM70139
  120 MATCH=1                                                            00001380 PGM70140
280    RETURN                                                            00001390 PGM70141
C                                                                        00001400 PGM70142
C     OK-CHECK IF NEW FIELD IS A NUMBER,0-9,+,-,OR.                      00001410 PGM70143
  115 IF(ICAR-12)125,125,300                                             00001420 PGM70144
```

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```
C
C     NUMBER FOUND-SET INITIAL PARAMETERS
C     DECIMAL POINT=NO
  125 IDP=0
C     NEGATIVE=NO
      ISGN=0
C     NO SIGNIFICANT DIGIT YET
      ISIG=0
C     NUMERICAL VALUE OF NUMBER(REAL OR INTEGER)
      NUMB=0
C     SAVE START OF NUMBER
      ICSTR =IC
C     IS FIRST CHAR A PLUS SIGN-IGNORE IF YES
      IF(ICAR-PLUS)126,130,126
C     CHECK IF MINUS SIGN-SET ISIGN=1 IF YES
  126 IF(ICAR-MINUS)135,127,135
127   ISGN=1
C     LEADING PLUS OR MINUS SIGN-BUMP CARD COLUMN POINTER-CHECK
C     IF END OF FIELD
C     THIS IS GENERAL CC BUMPER SECTION OF CODE
  130 IC=IC+1
      ICAR=IBUF(IC)
      IF(IC-LASTC )135,135,140
C     CHECK IF CC IS BLANK OR COMMA
  135 IF(ICAR-BLANK)145,140,145
  145 IF(ICAR-COMMA)150,140,150
C     NOT END OF FIELD-IS IT A DIGIT...
  150 IF(ICAR-9)155,155,160
C     DIGIT 0-9,DECIAML POINT YET...
  155 IF(IDP-1)165,170,165
C     ALREADY HAVE DP,N IS THUS NEGATIVE,NUMBER IN ANUMB
 170  ANUMB=ANUMB+FLOAT(ICAR)*(10.**N)
      N=N-1
      GO TO 130
C     NO DP YET,IS DIGIT A ZERO...
  165 IF(ICAR)175,180,175
```

```
C       NOT ZERO,THUS IT IS SIGNIFICANT
  175 ISIG=1
      GO TO 185
C       ZERO-CHECK IF SIGNIFICANT,IF NOT SKIP
  180 IF(ISIG-1)130,185,130
185   NUMB=10*NUMB+ICAR
      GO TO 130
C
C       CHARACTER NOT DIGIT IS IT DP...
  160 IF(ICAR-DP)195,190,195
C       YES,WAS ONE GIVEN PREVIOUSLY...
  190 IF(IDP-1)200,99,200
200   N=-1
      IDP=1
      ANUMB=NUMB
      GO TO 130
C
C       NOT DIGIT OR DP,IS IT E...,IF NOT,ERROR(99)
195   IF(ICAR-24)99,205,99
C       E FORM-E(PLUS OR MINUS)N1,(N2)
  205 IF(IDP-1)210,214,210
C       NO DP YET,FLOAT NUMBER
  210 ANUMB=NUMB
      IDP=1
  214 I=1
C       SIGN OF EXPONENT=PLUS
      IEP=+1
C       VALUE OF EXPONENT=0
      IEX=0
C       NEXT COLUMN
  215 IC=IC+1
      ICAR=IBUF(IC)
      IF(IC-LASTC )216,216,99
  216 IF(ICAR-BLANK)217,99,217
  217 IF(ICAR-COMMA)218,99,218
  218 GO TO (220,225),I
```

```
C      CHARACTER AFTER E,IS IT PLUS,MINUS,OR DIGIT...
220    IF(ICAR-PLUS)226,230,235
235    IF(ICAR-MINUS)99,240,99
C      MINUS SIGN
  240  IEP=-1
C      HERE FOR PLUS SIGN ALSO
C      RESET SWITCH AND GET NEXT COLUMN
  230  I=2
       GO TO 215
C      FIRST OF ONE OR TWO EXPONENT DIGITS
225    IF(ICAR-9)226,226,99
  226  IEX=ICAR
       I=1
  223  IC=IC+1
       ICAR=IBUF(IC)
       IF(IC-LASTC )231,231,250
231    IF(ICAR-BLANK)227,250,227
227    IF(ICAR-COMMA)228,250,228
  228  GO TO (224,99),I
224    IF(ICAR-9)229,229,99
  229  I=2
       IEX=10*IEX+ICAR
       GO TO 223
C      END OF E FORM-MULTIPLY NUMBER BY EXPONENT
  250  ANUMB=ANUMB*(10.**(IEP*IEX))
C
C      END OF NUMBER,POINTER AT BLANK,COMMA,OR EOC
C      IDP=0,INTEGER IN NUMB-IDP=1,READ IN ANUMB
140    IF(ISGN-1)144,141,144
C      NEGATE-CHECK IF INTEGER OR REAL
  141  IF(IDP)142,143,142
C      REAL
142    ANUMB=-ANUMB
       GO TO 144
C      INTEGER
  143  NUMB=-NUMB
```

```
  144 NATCH=IDF+2
      K=NUMB
      RK=ANUMB
C
C     POINTER AT BLANK,COMMA,OR EOC-BUMP TO A NON-BLANK,NON-COMMA
C     CHARACTER OR LEAVE AT EOC-THIS SECTION OF CODE IS USED
C     BEFORE RETURNING
  270 IF(IC-LASTC )271,271,280
  271 IC=IC+1
      IF(IC-LASTC )272,272,280
  272 IF(IBUF(IC)-BLANK)273,271,273
  273 IF(IBUF(IC)-COMMA)280,271,280
C
C
C     FIRST CHAR IS NOT EOC,NUMBER-IS IT $...
300   IF(ICAR-17)330,120,330
C
C
C     BY ELIMINATION,THE FIELD IS A WORD-SAVE IC AND GET END OF WORD.
C     FORM PACKED WORD IN DECIMAL CODE TO COMPARE AGAINST LIST-NEED
C     FIRST WORD IN LIST AS NUMBER OF CHARS IN WORD.
C     BLANK PAD ON RIGHT.
  330 ICSTR =IC
  410 IC=IC+1
      ICAR=IBUF(IC)
      IF(IC-LASTC )415,415,420
  415 IF(ICAR-COMMA)405,420,405
  405 IF(ICAR-BLANK)410,420,410
C     END OF FIELD
  420 IEND=IC-1
C     USE LIST FIRST
      NC=LIST(1)
C     GET CHARACTERS IN WORD
      NCW=IEND+1-ICSTR
      NCW1=NCW+1
      IFD=0
```

```
C       CHECK IF FIELDS IS SHORTER THAN DICT. WORDS
        IF(NCW-NC)440,455,455
C       SHORTER-BLANK PAD
  440   DO 445 I=1,NCW
        IJK=ICSTR +I-1
445     IWD=100*IWD+IBUF(IJK)
        DO 450 I=NCW1,NC
450     IWD=100*IWD+BLANK
        GO TO 465
C       NCW,GE,NC
  455   DO 460 I=1,NC
        IJK=ICSTR +I-1
460     IWD=100*IWD+IBUF(IJK)
C
C       NOW IWD CONTAINS NC CHARACTERS TO COMPARE
C       TO DICTIONARY WORDS
465     NWDS=LIST(2)
        DO 475 I=1,NWDS
        IF(IWD-LIST(I+2))475,480,475
  475   CONTINUE
C       WORD NOT FOUND IN DICTIONARY
        NATCH=4
        K=ICSTR
        GO TO 270
C       WORD FOUND IN DICTIONARY
  480   K=I
        NATCH=5
        GO TO 270
C
C
C       ERROR IN NUMBER FIELD
99      WRITE(IPRNT, 999)
        K=ICSTR
        NATCH =4
        GO TO 270
999     FORMAT(25H  ERROR IN NUMERIC FIELD.)
```

```
C
C
      RETURN
      END
```

REFERENCES

1. Roberts, Paul O., Davit T. Kresge, John R. Meyer: "An Analysis of Investment Alternatives in the Colombian Transport System", Final Report, Transport Reasearch Program, Harvard University, Cambridge, Mass.-(September 1968), p.34

2. Sadove, A. Robert and Gary Fromm, "Financing Transport Investment", in Gary From (ed.), "Transport Investment and Economic Development", The Brookings Institution, Washington, D.C. (1965), p.25

3. Lansing, John B. "Transportation and Economic Policy", The Free Press, New York, (1966) p.3

4. Roberts, Paul O.,and David T. Kresge, "Techniques of Transport Planning Volume II: Systems Analysis and Simulation Models", John R. Meyer (ed.), The Brookings Institution, Washington, D.C. (1971).

5. Taboroga, P.N., "A Model to Study Optional Transportation Policy in Chile", Research Report, R66-8 Department of Civil Engineering, M.I.T. Cambridge, Mass. (1966)

6. Richard de Neufville and David Marks (ed.), "System Planning and Design: Case Studies in Modeing, Optimization and Evaluation", Prentice Hall, Inc., Englewood Cliffs, N.J. (1974)

7. Pecknold, W.M., "The Evolution of Transport Systems: An Analysis of Time-Staged Investment Strategies under Uncertainty", Cambridge, Ma. Unpublished Ph. D. Thesis, Department of Civil Engineering, (1970)

8. Wohl, Martin, and Brian V. Martin, "Traffic System Analysis for Engineers and Planners", McGraw-Hill, New York (1967)

9. Tarplay, Fred A., and J.L. Drake, "The Timing Dimension of Urban Transport Decisions", Papers Ninth Annual Meeting, Transportation Reasearch Forum 1968.

10. Thygeson, Inge, "Long Term Planning and Timing the Implementation of Transport Investments", in J.R. Lawrence (ed.), Operational Research and Social Sciences, London (1966)

11. Marglin, Stephen A., "Public Investment Criteria", The MIT Press, Cambridge, Mass. (1967)

12. Winfrey, R., "Cost Comparison of Four Lane vs. Stage Construction on Interstate Highways", Highway Research Board Bulletin No. 306, Highway Research Board- Washington, D.C. (1961)

13. Cole, Leon M., "Optional Capacity Planning and Staging Decisions under Uncertainty", Discussion Papare No. 43, Harvard Transport Research Program, Cambridge, Mass. (June 1966)

14. Howard, G.T. and G.L. Nemhauser, "Optional Timing of Investments in Transportation Links", Department of Operations Research and Industrial Engineering, The John Hopkins University, Baltimore, Maryland (November 1966)

15. Moavenzadeh, F. "Investment Strategies for Developing Areas: Analytic Model for Choice of Strategies in Highway Transportation", Research Report R72-67, Department of Civil Engineering, M.I.T. Cambridge, Mass. (1972)

16. Roberts P.O. and Dewess R.N., "Economic Analysis for Transport Choice" A Charles River Associates Research Study, Heath-Lexington Books, Lex., Mass. (1971)

17. Putman, Stephen H. "Models of Determining Indirect Impacts of High Speed Ground Transportation Systems: Northeast Corridor", Papers Eighth Annual Meeting, Transportation Research Forum (1967)

18. Weingartner, H. Martin, "Mathematical Programming and the Analysis of Capital Budgeting Problems", Markham Dub. Co., Chicago, Illinois (1967)

19. CONSAD Research Corporation, Third Quarterly Progress Report, May 18, 1966 to August 18, 1966, "Design for Impact Studies: Northeast Corridor Transportation Project", (Prepared for the U.S. Department of Commerce, Office of Transportation Research), Pittsburgh, Penn. (August 23, 1966)

20. Mori, Yasuo, "A Highway Investment Planning Model: An Application of Dynamic Programming", Unpublished S.M. Thesis, Department of Civil Engineering, M.I.T., Cambridge, Mass. (1968)

21. Meyer, J.R., and M.R. Straszheim, "Techniques of Transport Planning Volume I: Princing and Project Evaluation, J.R. Meyer (ed.), Transport Research Program, The Brookings Institution, Washington, D.C. (1971)

22. Hershdorfer, A.M., "Optional Routing of Urban Traffic", Unpublished Ph. D. Thesis, Department of City and Regional Planning, M.I.T. Cambridge, Mass. (1965)

23. Roberts, P.O. "Transport Planning: Models for Developing Countries" Unpublished Ph. D. Thesis, Department of Civil Engineering, Northwestern University, Evanston, Illinois (1966)

24. Bergendahl, G., "Models for Investments in a Road Network", National Road Administration Stockholm, Sweden, (1968)

25. Morlok, Edward K., "A Goal-Directed Transportation Planning Model" Discussion Paper, Nortwestern University, Evanston, Illinois (1969)

26. Ochoa-Rosso, F. and A. Silva, "Optimum Project Addition in Urban Transportation Networks Via Descriptive Traffic Assignment Models", Research Report R68-44, Department of Civil Engineering, M.I.T. Cambridge, Mass. (1968) Volume V of a series.

27. Barbier, M., "Le Futur Reseau de transports en region de Paris", Cahiers de L'Institut D'Amenagement et d'Urbanizme de la region Parisienne, Volume IV-V, No. 4 (1966)

28. Stairs, S., "Selecting an Optional Traffic Network", Journal of Transport Economics and Policy (May 1968)

29. Spencer, J.W., "An Approach to Planning and Programming Local Road Improvements Based on a Network-wide Assessment of Economic Consequences", Highway Research Record, No. 224, Highway Research Board, Washington, D.C. (1968)

30. Bhatt,K.U., "Fundamental Explorations in the Comparative Analysis of Transportation Technology", Ph. D. Thesis, Department of Civil Engineering, M.I.T., Cambridge, Mass. (1971)

31. Allman, W.P., "A Network-Simulation Approach to the Railroad Freight Train Scheduling and Car Sorting Problem", Ph.. D. Dissertation, Northwestern University, Evanston, Illinois (1966)

32. Folk, J.F., "A Brief Review of Various Network Models", Research Report R72-42, Department of Civil Engineering, M.I.T., Cambridge Mass., (1972)

33. Carter, E.C., and Stowers, J.R., "Model for Funds Allocation for Urban Highway System Capacity Improvements", Highway Research Record, No. 20 (1963)

34. Quandt, R.E., "Models of Transportation and Optimal Network Construction", Journal of Regional Science- Vol. 2, (1960)

35. Beckman, M.J., "On the Theory of Traffic Flow in Networks ", Traffic Quarterly, (Jan. 1967)

36. Manheim, M.L., "Notes on Transport Systems Analysis: The Equilibrium Problem", Discussion paper T-14, Department of Civil Engineering, M.I.T., Cambridge, Mass.

37. Isard, W., "Interregional Linear Programming: An Elementary Presentation and a General Model", Journal of Regional Science, Vol. I (1958)

38. Towlin, J.A., "Minimum-Cost Multi-Commodity Network Flow", Operations Research, Vol 14, No. 1 (1966)

39. Dantzig, and Worfe, P., "The Decomposition Algorithm for Linear Programs", Econometrica, Vol. 29 (1961)

40. Floyd, Robert, W., "Shortest Path", Algorithm 97, Communications of the Association for Computing Machinery, (1962)

41. Highway Capacity Manual, Highway Research Board, Special Report 87, (1965)

42. SAUTI Consulting Engineers, "Asela-Dodola Road, Feasibility Study", Imperial Ethiopian Government, Imperial Highway Authority (1971)

43. U.N. Development Program,"Ethiopia General Road Study. Final Report, Volume 2: The Ethiopian Economy of the Transport Sector" (United Nations (1972)