EGYPT INTERCITY TRANSPORTATION MODEL

By

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1. Background of Study

The Government of Egypt, through its Ministry of Transport and Transportation Planning Authority, has been engaged in a comprehensive effort to overhaul its transportation infrastructure and to strengthen Egyptian institutional capabilities in investment planning and evaluation, and in formulation of effective maintenance, operating and pricing policies. In parallel with this thrust, we have conducted this research project through Cairo University and the Massachusetss Institute of Technology under the joint Technological Planning Program with the cooperation of the Egyptian Transport Planning Authority.

The objective of this study has been to review Egyptian transportation policy and to develop analytical methods to assess alternative transport investment, maintenance, operating and pricing policies within Egypt. The scope of this project has encompassed both passenger and freight movements on the highway, railway and inland waterway modes.

The completion of this project has entailed several interrelated areas of investigation in engineering, economics and operations research, including:

(a) A review of policies affecting intercity transportation and identification of those that could be feasibly represented within a transportation model;

(b) For those policies selected above, specification of exactly in what ways the policies affect transportation performance and costs through cause-and-effect relationships.

(c) Design and development of analytical models to capture policy-sensitive shifts in intercity travel demand, modal choice, system performance, and costs on the highway, rail and waterway networks; and

(d) Assessment of data requirements, collection of data, and calibration of models.

The presented paper thus integrate two basic aspects of our research effort. One is the design and development of a computerized model to predict transportation system performance, costs, and impacts as functions of selected transportation policies. This model is referred to as the Egypt Intercity Transportation Model. The second aspect deals with presentation of case studies in which Egypt transportation investment, maintenance, operating, and pricing policies are simulated and evaluated through the year 2000.

2. Overview of Model Structure

Analysis of transportation policy within the Intercity Model takes place within an equilibration process shown in Figure 1. On the left-hand side of Figure 1 are those factors affecting transportation demand - i.e., factors influencing the need or propensity to travel, the types and numbers (or quantities) of people and goods desiring to travel, the geographic locations at which demand for travel arises, and the characteristics of individual travelers or goods determining preferred modes of travel. On the right-hand side are those factors affecting transportation supply - i.e., factors determining the kinds of transport servicing different passengers or commodities, the levels of service provided, the costs seen by users for various levels of service and resource consumption, and associated costs seen by owners and operators of the system.

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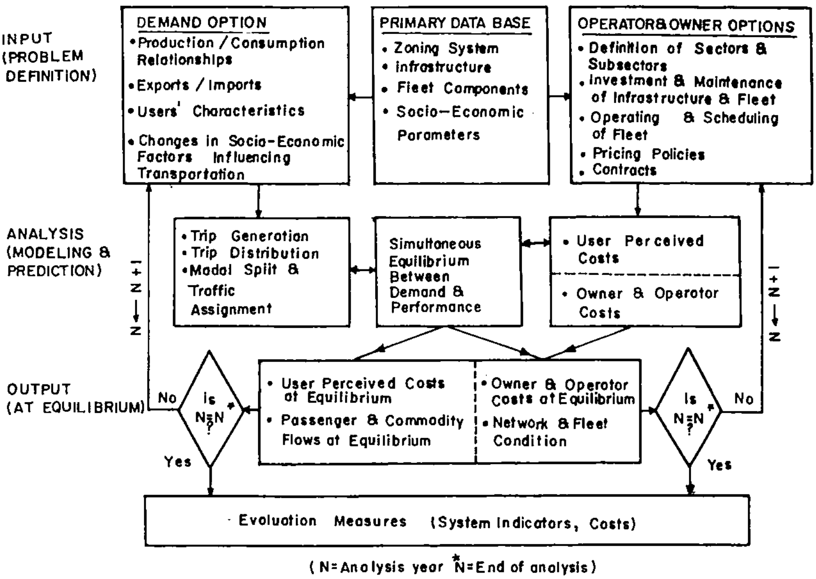

Figure 1, STRUCTURE OF THE INTERCITY TRANSPORT MODEL

2.1. Transportation Demand

It is widely recognized that the demand for transportation is not a direct demand but rather a derived one. Transportation demand arises through a combination of spatial, physical, economic and social factors. Consequently the demand for transportation services must be seen on a system-wide basis.

Transportation demands can be correctly considered only at the level of the whole transportation system as requirements for movement among a set of spatially distributed regions (whose activities are concentrated on the nodes of the network for the purposes of the analysis), and for which certain socio-economic conditions have been stated.

Although macro-economic predictions are not included within the Intercity Model, shifts in demand (which can be specified exogenously would result from actions such as the following:

(a) Structural changes or growth in various sectors of the economy: e.g., creation of new industrial or manufacturing plants, development of natural resources, shifts in food, fodder or cash crops grown, investment programs in housing or public or private facilities, opening of new areas for tourism; etc.

(b) Encouragement of, or responses to, changes in production and consumption of goods.

(c) Changes in the geographic dispersion of people and goods: opening of new areas for development, construction of satellite cities, increased urbanization of areas surrounding major cities;

(d) Changes in the social fabric: e.g. rates of population growth, and shifts in the structure composition, and demographic characteristics of families.

2.2. Transportation Supply

Supply of transportation services arises through the allocation of resources and regulation of operations and prices by owners of transport links and operators of transport fleets throughout the network. The transport industry comprises many individual owners and operators (both public and private), and the net level of service prerceived by users is the result of interactions among all actors in the network: e.g., the interaction of highway owners (the Government) and trucking operators (public or private companies) to make available truck freight services to users; interferences among many operators on an owner's link (congestion); and competition for scarce fleet capacity among potential users (crowding; foreclosure of modal choice).

To enable one to calculate the equilibrium between demand and supply in Figure 1, those aspects of system performance (supply) relevant to user choice of transportation services (demand) are represented by the selection of the least-cost available path among all modes (accounting for both link and fleet capacity) for each commodity between each origin-destination pair. Individual cost terms (e.g., fare or tariff; travel time costs; perceived costs attributable to loss or damage, reliability of travel time, and so forth) are then assembled within a Generalized Cost Function which forms the basis for calculating equilibrium.

In network models the Generalized Cost Function has traditionally been evaluated on a link-by-link basis; system-wide effects have not been included in any of the cost terms. However, questions of investment and maintenance of the vehicle fleet, and allocation of the available fleet to competing commodities, are highly significant in assessing intercity transport performance and costs. These are system-wide considerations, and the Egypt Intercity Transport Model has treated them in the Generalized Cost Function as dependent upon network, rather than individual link, characterisitcs.

Some examples of the types of policies influencing supply of transport services (in terms of transportation performance and costs) that could be considered within the Intercity Model are as follows:

(a) Restoration or expansion of highway, rail or waterway capacity.

(b) Restoration or expansion of available fleet capacity.

(c) Changes in price/service characteristics: e.g., adjustments in tariffs; revisions in operating schedules or points of the intercity network served by a carrier; conveyance of goods under fixed contract.

(d) Encouragement of, or responses to, changes in the economic situation surrounding transportation: e.g., relative inflation in fuel prices, etc.

2.3. Model Components

The logical components of the Intercity Model needed to analyze transportation policies at equilibrium are identified at three levels of the structure in Figure 1. Basically these levels can be thought of as dealing with problem definition, model simulation, and evaluation respectively.

2.3.1. Problem Definition

Problem definition by the Intercity Model user encompasses descriptions of the geographic, engineering, organizational, and economic characteristics of the transportation system, and specification of policies that will act on the system over time. This information is represented by the first level of the flow chart in Figure 1.

The description of the system is split between performance- and demand-related items. On the peformance side are found the definition of the transportation network and infrastructure set of nodes, line haul links, terminals, ports, zones of production or consumption, and so forth (Figure 2 presents an example for the Highway Network). The engineering characteristics and condition of each link; the route structure, tariff schedule, and operational characteristics of various entities providing transportation services; the size, composition, and condition of vehicle fleets in use; and data supporting various investment, maintenance, operating and pricing options that may be investigated in the analysis. On the demand side the descriptions include, for example, classifications of the commodities and passengers to be considered in the analysis; the demographic characteristics of each zone of production or consumption; breakdowns of exports and imports among ports; and data supporting various possible changes in production or consumption patterns.

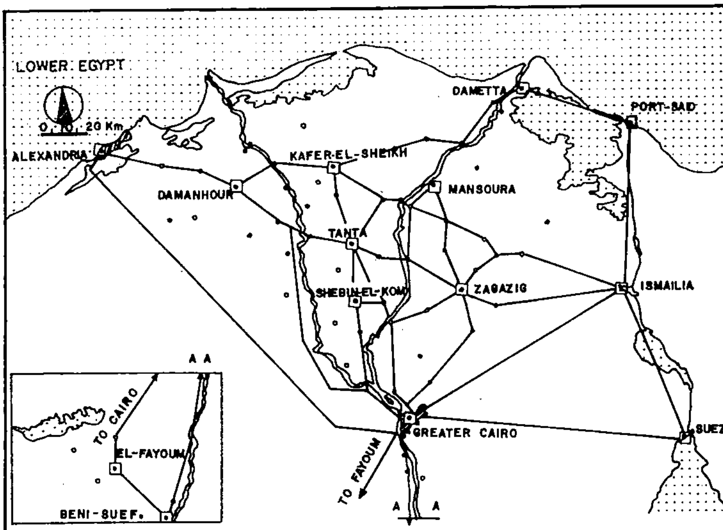

Figure 2, PRIMARY HIGHWAY NETWORK USED IN THE STUDY FOR LOWER EGYPT

Virtually any aspect of these system descriptions may be modified over time by policies exercised in the transportation sphere, as indicated in Figure 1. Examples of policies whose effects could be simulated by the Intercity Model fall into the following categories:

Transportation Demand:

* Changes in zonal production or consumption of goods, in generation or attraction of passenger travel or in destributions of imports and exports among ports;
* Changes in the social, economic or demographic characteristics of zones.

Transportation Performance:

* Link investment and maintenance programs; changes in the operating characteristics of links;
* Fleet investment and maintenance;
* Adjustments in tariffs by commodity or passenger class;
* Changes in route structure, scheduling or fleet allocations by operators.
* Contract agreements to haul specific commodities between two points.

Policy specifications by the user define what types of changes are proposed in the transport system, where the changes are to take place, and when. The impacts of different policies are then assessed for each time period in the Intercity Model by a set of simulation models, described below.

2.3.2. Simulation Models

The second level in Figure 1 represents the analytical core of the Intercity Model. It comprises three sets of procedures dealing respectively with transportation demand, system performance and the equilibrium between the two.

The left-hand block includes the models representing the demand for transportation in the system. The main objective of the procedures in this block is to simulate the actual behaviour of users of the system as a function of national and zonal socio-economic policies, their own socio-economic characteristics, and the system's performance. This has involved the development of the basic behavioral assumptions, the functional forms, and the calibration of a set of trip generation, trip distribution, modal split and assignment models.

The right-hand block includes the models representing system performance and costs, from the user's point of view (link cost models leading to the Generalized Cost Function) and from the owners' and operators' points of view (owner and operator cost models). The main objective of the activities in this block is to simulate the actual performance of each component of the transport system as a function of transport policies by owners, operators or the national Government. This has involved the development of relationships both for technical system performance under different levels of demand, and subject to different investment, maintenance, operating and pricing policies; and for costs perceived by the different actors in the system.

The middle block represents the interface between the demand and the supply sides. This work has involved the formulation of a model to compute equilibrium between demand and performance, and the development of computational algorithms supporting this theoretical approach. The main objective of the procedures in this block is to balance simultaneously the predictions of trip generation, distribution, modal split and assignment against corresponding predictions of system performance and costs, such that the results converge to equilibrium in a mathematically efficient way.

2.3.3. Evaluation

The third level in Figure 1 represents the production of results by the Intercity Model and their evaluation by users. The types of results produced include financial and economic costs, system performance measures, and activity or production indices. Results are stratified by owner, operator and user according to the relevance of information to each actor.

2.4. Innovative Aspects

From an analytical perspective the Intercity Model contains several innovative features. These special characteristics are highlighted below:

(a) In computing equilibrium between demand and supply, the Model employs a simultaneous (in lieu of a sequential) procedure to solve the generation, distribution, modal split, and assignment problems. This approach guarantees a unique, convergent solution for a general network situation (including congestion and capacity constraints).

(b) Link costs (composing the Generalized Cost Functions) are estimated by simulation models in lieu of closed-form relationships. These models permit a detailed investigation not only of costs, but also of transport system performance, ecompassing both the condition of the system and the level of service provided to users.

(c) The simulation models permit an explicit treatment of fleet capacity constraints - i.e., the inability to satisfy latent demand because of shortages of operable vehicles. This issue is distinct from that of link congestion (arising from volume/capacity effects on speed and flow). Mathematical treatment of fleet capacity, and options to remove capacity constraints through fleet investment and maintenance, were designed for the Model because of the severity of this problem among many surface modes in Egypt.

(d) The effects of transportation policies are simulated as changes in one or more variables within sets of performance and cost equations, or as changes in sets of constraints upon these equations (e.g., the route structure of different operators). In this way the Model is able to treat not only different kinds of transport policies (investment, maintenance, operating, pricing), but also the interactions among them.

(e) Multiple copies of the transport network are maintained simultaneously to address different aspects of the problem. For example, the "actual" network simulates the impacts of link investment, maintenance, upgrading, and rehabilitation; the set of "subsector" networks represents the route structures (i.e., available paths in the actual network) served by different transport operators over time; and the set of "composed" networks represents the paths available to each commodity or passenger class during equilibration.

(f) The information needed to support this analytical approach is extensive and detailed. Data have therefore been organized within a hierarchical structure, in which components of the transport problem may be assembled in logical fashion. Aside from the planning capabilities of the Intercity Model itself, the creation of an organized body of information on the transport network is viewed as a very beneficial by-product of this research.

2.5. Data Structure of the Intercity Model

The structuring of information for the Intercity Model is within a hierarchical format as shown in Figure 3. The four levels differentiate among the detail of information stored and its applicability from one run to another. Information that remains valid for a large set of runs is termed "permanent", while information that is specific to one run is "variable".

At the fourth level lies the transportation inventory - i.e. comprehensive information describing the system network and fleet. At this level is found descriptions of, for example, network infrastructure for the three intercity surface modes, and respective vehicle fleets. This inventory is intended as a permanent feature, to be updated only as changes in the actual system occur. It is the primary database for the Intercity Model.

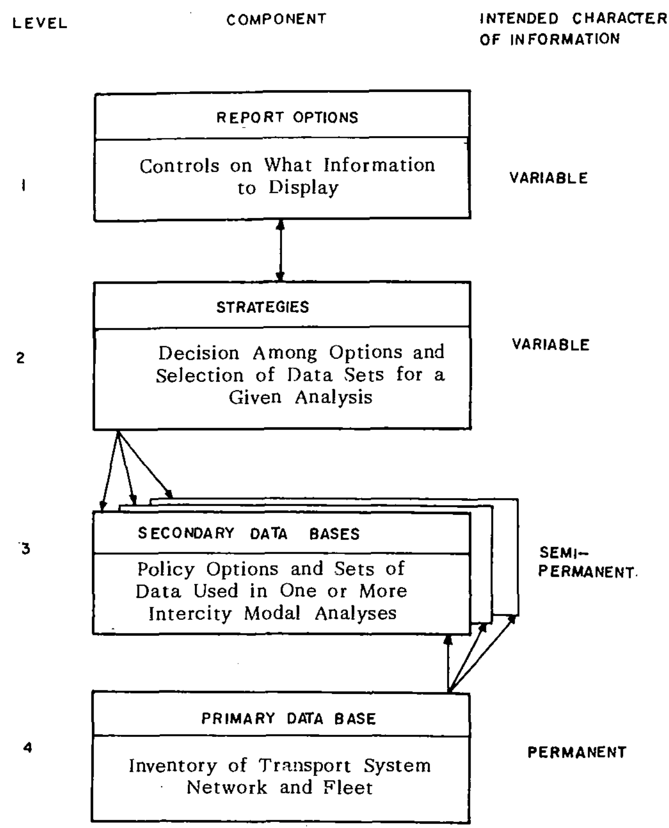

Figure 3, STRUCTURE OF INTERCITY TRANSPORT MODEL DATA BASE

At the third level lie a series of smaller databases, all drawn from the primary. These secondary datasets comprise subsets of information contained in the primary, plus additional information provided by the analyst to describe alternative policies and scenarios. These secondary files of information allow one to reduce the size of the information block used during the calculation of equilibrium without sacrificing the precision of information embodied in the primary database.
In contrast to the primary database, the secondary databases might be considered semi-permanent created to look at a specific set of issues (and therefore to serve several Model runs) at a particular time, but not of lasting value.

At the second level are commands and specifications that control the scheduling and points of application of simulated transport policies i.e., the transportation strategy to be tested. At this level analysts identify what investmetn, operating, pricing, and demand-related policies (described at level3) are to be tested, and when and where each policy is to be invoked. Information at this level is variable, intended to be modified with each run.

The breadth and detail of results predicted by the Intercity Model are captured within a series of reports that may be displayed at the option of the analyst. Controlling these options requires that the analyst provide a separate block of information, shown at the first level in Figure 3. Since these controls of reports do not interact with the primary, secondary, or strategy databases, they do not affect the performance of the Intercity Model simulations or their outcomes in any way. Their sole function is to permit efficient access to Intercity Model results.

The hierarchical structure in Figure 3 presents two advantages for use in the Intercity Model. First, the creation of two related but distinct levels of data (the primary and the secondary) provides an effective compromise between the long-term need for an extensive, detailed system inventory, and the shorter-term requirements of a particular analysis. Thus, detailed information can be selectively transferred from the primary to the secondary files if required to simulate a particular set of policies; yet the analysis need not be encumbered by the weight of the entire primary database. Second, through use of the strategy-level commands (which invoke blocks of information from the secondary level), one can analyze policy alternatives quickly and efficiently; variations in the timing of policies, or in the parts of the system affected by each policy can also be investigated rapidly and accurately.

3. Case Studies

Previous sections in this paper described in brief the formulation of the Intercity Model, an analytical procedure to assess the costs and impacts of applying alternative transportation policies. To demonstrate the application of the Intercity Model, and the analysis and interpretation of results in light of the goals and objectives proposed in Egypt's plans for the intercity transportation sector, selected case studies were conducted. The purpose of these case studies was not to develop a master plan but rather to demonstrate the application of the Intercity Model in realistic planning situations. The following is a brief summary of these activities.

3.1. Outline of Case Studies

For purposes of this exercise, a series of case studies was designed. These case studies fall, in general, into two major groups:

(a) A Base Case; establishing a benchmark for comparison. The base case was drawn generally from the policy recommendations by the National Transport Study, Phase II, (9), and of all case studies performed, the base case was analyzed in greatest depth to diagnose the major trends and interactions which govern Egyptian intercity transportation through the year 2000.

(b) Based upon the results of the base case, a second set of runs was made to test specific policies and focusing on a single unifying theme: to investigate whether the Egyptian railways can increase its market, among what users, and by providing what services? Four different policies were then investigated to achieve these desired objectives:

- Changes in the market structure of the railroad;
- Improvements in the standards of rehabilitation of railroad links and other improvements in link efficiency systemwide;
- Improvement in service and scheduling;
- Revisions in pricing;

3.2. Base Case Study

The base case analysis was established on the following premises:

* An analysis period of 1979 - 2000, consistent with the period adopted by Phase II of the National Transport Study completed in 1981.
* An assumption of constant financial and economic prices throughout the analysis period, with the exception of fuel, for which it was assumed that the financial cost would gradually approach its economic cost during the analysis period; and
* No changes in tariff levels after 1983, to assess transportation behavior under the current pricing scheme and to identify existing patterns in revenues vs. operating costs.

The case study was organized for the purpose of demonstration, and not for the investigation or the proposal of actual planning alternatives. Nevertheless, the case study was structured to provide the most realistic examples possible of the data produced by the Intercity Model, the analyses that could be conducted, and tbe interpretations that could be made.

The results of the base case analysis in terms of aggregate passenger and freight movements, are shown in Figures 4 and 5. These results were analyzed in considerable detail in several project reports (1, 2 and 5), including detailed discussions of the basic forces underlying modal share, users' preferences for specific services within each mode, distributions of operating revenues and costs, and costs and impacts of investment programs. Within the assumptions and limitations of the case study, the findings that emerged are summarized as follows:

* Given the policies simulated in the case study, Egyptian intercity transportation represented a constrained system, especially at the lower income levels.
* Highway transport absorbs most of the growth in passenger and freight movements, because autos, taxis, and trucks are the only services with sufficient capacity and flexibility to accommodate increased demand throughout the system;
* The potential for market growth and retention exists in railroad among both passengers and freight, but its attainment will require additional investment to increase both fleet capacity and reliability of service;
* Several different services in highway and railway can cover operating costs at current price levels; other highway and railway services are being subsidized or are losing money.
* Recommended investment programs do represent a shift from wide-ranging new projects and purchases to more limited new commitments, and greater emphasis on maintenance, rehabilitation, and upgrading of the existing networks and fleets; and
* Despite increased investments in the railroad, the total economic investment by both public and private sources in highways remains dominant.

3.3. Policy Analysis

To demonstrate the application of the Intercity Model, it was felt to be more helpful to focus on a single unifying theme or objective, against which different transportation policies could be tested. The base case had identified Egyptian Railway's problems as those of constrained capacity, combined with unattractive or unreliable service. Consequently, the selected policies focused on a single unifying theme: to investigate whether the Egyptian railroad can increase its market, among what users, and by providing what services.

The four policies selected encompass improvements in (1) market structure of the railroad, (2) link rehabilitation standards, (3) level of service and scheduling, and (4) relative pricing.

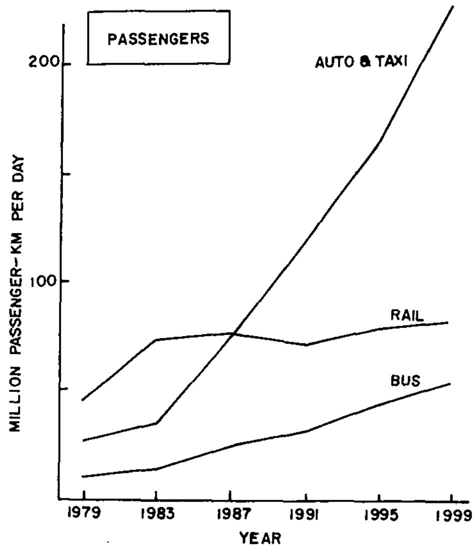

Figure 4, MODAL SPLIT OF PASSENGERS SIMULATED IN CASE STUDY

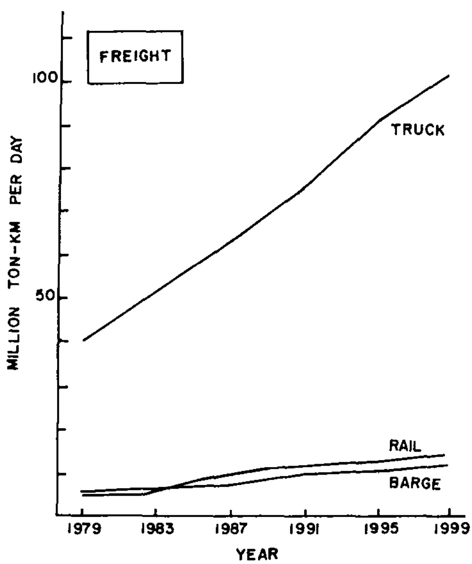

Figure 5, MODAL SPLIT OF FREIGHT SIMULATED IN CASE STUDY

The following is a brief summary of the significant findings as compared with the base case condition:

* The volume of freight transported by rail increased significantly under all these policies as shown in Figure 6. However, passenger travel responded most directly to better service (Figure 7). In addition, Figure 8, presents an example for the gains in rail freight market resulting from diversions from truck and barge. In the presented example, the railway created virtually a new market in metal products (formerly transported by truck), based upon the transport policies simulated.
* For passengers, only the policy simulating improvements in service and scheduling had significant impact on transport production as compared to the base case (Figure 7). This increase in passenger travel was a direct result of, and consistent with, the increased frequency of scheduled service on the railroad.
* The gains in market share (and increased revenues for the railroad) were achieved with greater efficiency in fleet utilization, and without major costly new investments above and beyond those contemplated in the base case.

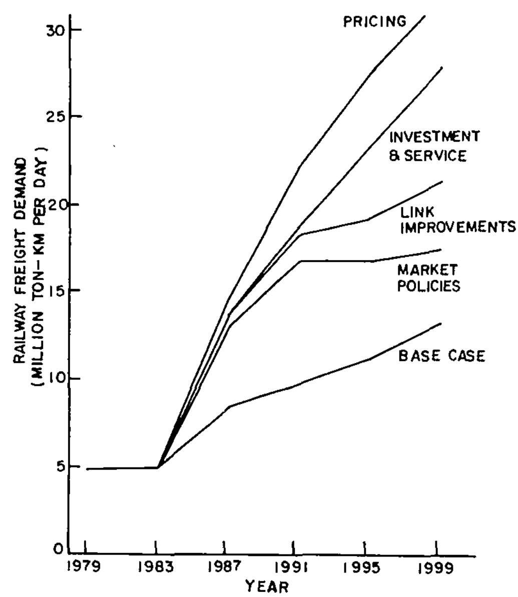

Figure 6, RAIL FREIGHT DEMAND UNDER VARIOUS TRANSPORT POLICIES

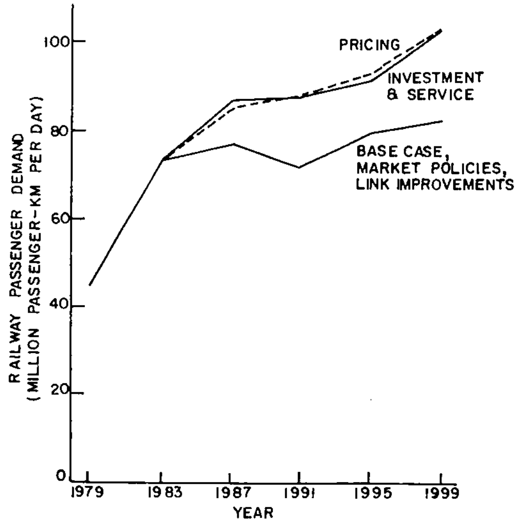

Figure 7, RAIL PASSENGER DEMAND UNDER VARIOUS TRANSPORT POLICIES

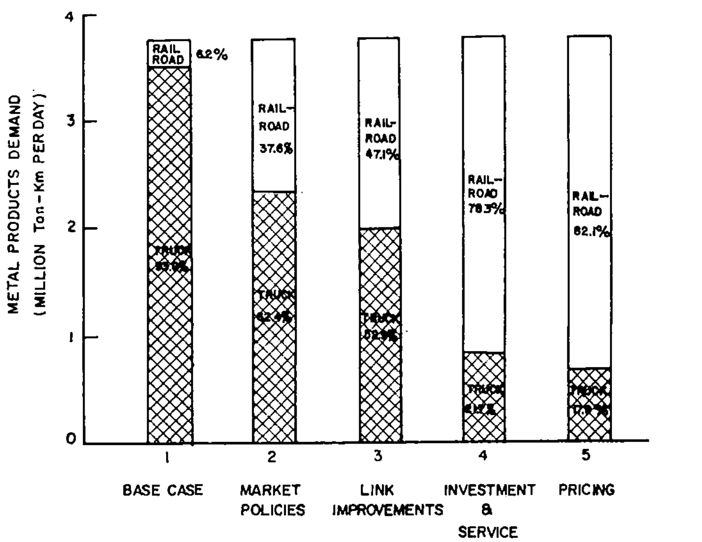

Figure 8, MODAL SHARES OF METAL PRODUCTS(Ton-Kilometers) IN 1999 UNDER VARIOUS TRANSPORT POLICIES

4. Conclusions

This paper has summarized a project addressing intercity transportation planning in Egypt. A primary product of this research has been the design and development of the Egyptian Intercity Transportation Model, which simulates transportation performance and costs in highway, railway, and waterway systems subject to specified investment, maintenance, operating, and pricing policies. The technical concepts and relationships incorporated within the Intercity Model have been described in several reports (1, 2, 3, 4, 5 and 6).

Although the policies analyzed in this series of runs were focused on the railroad, and limited to the specific objective of increasing rail's market share and viability, the diversity of policies analyzed should indicate the power and flexibility of the Model to treat a wide range of investment, maintenance, operating and pricing alternatives in the highway, railway, and waterway modes.

Some important lessons learned in this exercise should prove useful in the implementation of the Model for transportation planning. Data must be current and complete. Transportation policy options should be realistic. Used properly, the Model can assist in understanding current behavior of the transport system, diagnosing weaknesses in system performance (thus, targets of potential change), and analyzing costs and impacts of specific transport policies across all modes.

5. Acknowledgements

This paper provides an overview of a 5 year research program that was sponsored by the CU/MIT Technology Adaptation programe, DRTPC, Cairo University. The views and opinions expressed in this paper, however, are those of the authors and do not necessarily reflect those of the sponsors, Cairo University, the Massachusetts Institute of Technology, or the Egyptian Transport Planning Authority.

Acknowledgement is due to the project research team; Prof. F. Moavenzadeh, M. Markow, B. Brademeyer, M. Salehi, and K.N. Safwat of the MIT, and Drs.; F. Abdel-Barry, M. Owais, M. Noueldin, and K. Abdel-Nasser of Cairo University, who have contributed actively in this study.

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