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Conference on Transportation Planning Policy

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4. Traffic Volume/Travel Behavior Survey Documentation by El-Hawary, Brigham, Barry, Owais, and Salmawy.
5. Public Transit Survey Methodology: April 17-20, 1978 by the Urban Transportation Project Teams - Cairo University, Transport Planning Authority and Cairo Transit Authority.
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11. Road Axle Load Distributions in Egypt by El-Hawary, Moavenzadeh, Owais, Brademeyer, and Khalil.

PREFACE

The presentations and working papers of the Conference as presented in this document describe various studies undertaken under the sponsorship of the Technology Adaptation Program at the Massachusetts Institute of Technology.

In 1971, the United States Department of State, through the Agency for International Development, awarded the Massachusetts Institute of Technology a grant. The purpose of this grant was to provide support at M.I.T. for the development, in conjunction with institutions in selected developing countries, of capabilities useful in the adaptation of technologies and problem-solving techniques to the needs of those countries. At M.I.T., the Technology Adaptation Program provides the means by which the long-term objectives for which the A.I.D. grant was made, can be reached.

This study was conducted, under the auspices of the M.I.T. Technology Adaptation Program by the Cairo University/M.I.T. Technological Planning Program which is funded on an interim basis by the United States Agency for International Development, Cairo, Egypt. The views and opinions expressed in this report, however, are those of the authors and do not necessarily reflect those of the sponsor, the Massachusetts Institute of Technology, Cairo University, or the Ministry of Transport, GOE. No part of this document may be reprinted or quoted in any way without the written consent of the authors.

جامعة القـــاهرة - معهـــد ماساتشوستس للتكنولوجيـــا

برنامج التخطيط التكنولوجى

CAIRO UNIVERSITY - MASSACHUSETTS INSTITUTE OF TECHNOLOGY

TECHNOLOGICAL PLANNING PROGRAM

I. PARTICIPANTS - TRANSPORTATION PLANNING IN EGYPT
CU/MIT PROJECT

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Mr. Francisco Toureilles: Graduate Research Assistant.

جامعة القاهرة - معهد ماساتشوستس للتكنولوجيا

برنامج التخطيط التكنولوجى

CAIRO UNIVERSITY - MASSACHUSETTS INSTITUTE OF TECHNOLOGY

TECHNOLOGICAL PLANNING PROGRAM

II. SUMMARIES OF CONFERENCE PRESENTATIONS

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SESSION I - OPENING

1. OVERVIEW OF CU/MIT TECHNOLOGICAL PLANNING PROGRAM - DR. H. HAMDY

Under the auspices of TAP, the Cairo University/MIT Technoligical Planning Program, funded on an interim basis by the USAID Mission in Egypt, began a year ago with a focus on improved planning of development projects in Egypt. The overall objective of the program is to expand the capabilities of Egyptian ministries and other government agencies to formulate and implement technical programs designed to achieve national development goals. The research projects focus on a broad range of engineering, economic, and social service topics. The key element in each of these efforts is the interdisciplinary team drawn from faculty and staff from MIT, Cairo University, and government ministry personnel responsible for planning development projects in the topic area. Effective utilization of the Egyptian academic and government resources has been one of the principal reasons for the success of the program to date. In addition to the specific research projects, emphasis has been placed on the training of in-country personnel in the techniques of project identification, evaluation, and management, and the development and maintenance of the data necessary to design and monitor their projects. To provide a channel for continuous, convenient communication between government agencies and the academic expertise involved in this program, a permanent Institute for Technological Planning will be established at Cairo University. This Institute will eventually organize a centralized body of technological, economic, and social science expertise both internal and external to Egypt in the general area of development planning.

2. OVERVIEW OF CU/MIT PROGRAM IN TRANSPORTATION - DR. M. EL-HAWARY

The objective of this study is to strengthen the capabilities of Egyptian institutions and public agencies concerned with transportation in the area of the analysis, planning and programming of the transport investments, and to develop methodologies by which these agencies can monitor the performance of the transport sector.

The project contains two primary areas of concern: urban transportation and intercity transport planning.

Activities during the past eighteen months were as follows:

URBAN TRANSPORTATION PROJECT

The primary objectives of this research project are to create tools and solve problems in order to facilitate urban tripmaking, and to relieve traffic congestion. This involves traffic studies and studies of project development. The tools developed are being documented for use by interested persons in Cairo transportation.

Considerable effort was devoted to preparation for surveys. This included the preparation of questionnaires, the adaptation of measurement standards to Cairo, survey area delineation, determination of origin-destination zones and the location of survey stations. Three surveys were developed: (1) Traffic volume counts at key intersections all over the central part of the city; (2) Speed and delay measurements; and (3) Origin-destination and trip purpose surveys (both of vehicle trips and transit trips).

The procedures developed for these surveys have been standardized and described in a series of manuals. The data have been prepared for use in travel assignment models which can estimate the consequences to traffic flows in the network of any changes in the transportation facilities of the city or their use.

There is a section of the project dealing with project programming. In this element we have studied the process of project development in Cairo in order to learn the benchmarks and problems that occur in the process. There has been a review and synthesis of the literature on programming in the U.S. From these two activities we have generated a prototype project programming method to be adapted in relevance to the Egyptian situation.

The project has also begun studies of auto ownership. The object is to identify factors which most influence the level and pattern of auto ownership in Egypt.

This year, research is being especially devoted to mass transit. This includes origin-destination survey analysis, and studies of the supply of service. Mass transit suffers from severe problems of under-investment and overcrowding, while in terms of its social role and its significance to the growing economy, mass transit is the most important

mode in Cairo.

INTERCITY TRANSPORT PLANNING PROJECT

The primary objective of the cooperative effort in this project so far has been to apply and calibrate an existing evaluation framework - the Road Investment Analysis Model - for use in the highway investments decisions in Egypt and to train the Transport Planning Authority, Highway Authority and Cairo University personnel in the use of data collection and analysis techniques and to develop the necessary procedures for its modification and adaptation to the local Egyptian conditions. The main issues in this cooperative effort are:

- Economic evaluation of proposed projects (new construction and upgrading of existing links)
- Economic evaluation of design and maintenance standards
- Projections of future maintenance requirements and traffic patterns
- Recommendation of equipment required to develop and maintain the data inventory of the network condition and maintenance activities.

The research activities have been divided into four general phases. The initial phase is coordination of the research effort, identification of an area of study. The second phase is installation of the computer model at the Cairo University Scientific Computation Center. The third phase is detailed data collection and compilation. The last phase, evaluation of road transport in a zone on a link basis.

The team is currently engaged with the application of network investment model to a segment of the road network in the Delta, considering the fact that renewal or maintenance of a certain link affects the traffic flows on the other links and consequently the network total transport cost.

Effort during the coming period will be concentrated on the development of an evaluation methodology that will make possible the systematic analysis of future transportation policy proposals in the country. Independent models developed for different modes; (Highways, Railways, and Waterways) will be integrated into one multi-modal network model.

3. TRANSPORT INVESTMENT POLICY - DR. F. MOAVENZADEH.

The level and structure of demand for transportation services in a particular country greatly depend on its stage of development. The increase in the level of socio-economic activities which is generally

associated with economic development will cause changes in demand for transportation. Failure to recognize and anticipate these changes will result in important socio-economic bottlenecks, which will undoubtedly retard or even detain the development process of a country. It, therefore, becomes of primary importance to develop a clear understanding of the different demographic, socio-economic and political factors that will determine transportation demand and supply, as well as an understanding of the pattern of their evolution in the next decades in the context of each country.

Demographic factors in determining the absolute level, composition and spatial location of the population will have a fundamental effect on demand for both passenger (urban and intercity) and freight transportation services. From a demographic point of view, developing countries are expected to be characterized in the next decades by high population growth, high population density, substantial levels of rural urban migration and urbanization and maintenance of a large dependency ratio.

Economic factors will also be important determinants of demand for passenger and freight transportation services, since they will primarily influence the physical situation, size and structure of industrial and agricultural output. Most developing countries are likely to maintain relatively modest average rates of annual growth for the remainder of the century, due primarily to their present heavy foreign indebtedness, high expected future oil prices, reductions in foreign investment, and unfavorable developments in international markets for their exports. The economies of most developing countries are therefore likely to grow slowly and to become less diversified and consequently more unstable, while expanded supply and sluggishly increasing demand in international commodity markets will almost certainly cause large price drops and a marked deterioration in their terms of trade.

Economic and political factors will largely determine the supply of transportation services and the characteristics of transport policy and strategy. The expected demographic and economic developments very likely point to a rather uneasy future social environment in the less developed countries. The handling of such a situation could very probably require the establishment of centralized planning agencies which will be concerned with allocation of the limited available resources to several competing programs.

Transport institutions and regulatory bodies in almost all developing countries are among the least developed or organized components of the transport industry. Particular emphasis should be given to the establishment of regulatory bodies and legislation, which would ensure that the transport system structure and operation remain in accordance with both national development plans and public policies, and to the continued provision, through an adequate organizational structure, of proper maintenance and conservation operations.

Once the relevant demographic, economic and political factors have been identified, and an expected future scenario has been developed, it is then possible to analyze how they will affect the transport sector in general (and within it the different sub-sectors; urban versus rural and freight versus passenger transportation), and the supply and demand of transportation services for the individual modes in particular.

4. TRANSPORT PLANNING IN EGYPT - DR. M. EL-HAWARY.

In this paper, an overview of the important transport studies conducted in Egypt during the last ten years are summarized. Objectives of each study, methodology and main findings are presented. The data base for these studies, especially those collected through traffic surveys, are stated in brief. Description of the different methodologies adopted focuses on the transport modeling and the computational procedures.

The studies presented are classified into three groups:

- Urban transportation studies
- Regional transportation studies
- National transportation studies

The specific studies to be discussed within these three groups are:

-Urban transportation:

- Cairo Transportation Study, 1973
- Greater Cairo Entrance Study, 1975

- Regional transportation:

This group includes those transportation studies carried out during the period 1975-1977 within the frame-work of the master-planning of the following regions:

Ismailia, Suez, Tenth of Ramadan, Sadat cities and the western coast region.

- National transportation:
  - Egypt national transport study, 1977
  - Egyptian port policy, 1978

Comments on the adequacy and accuracy of the data base, the methodologies and findings of these studies will be presented.

SESSION II - NATIONAL TRANSPORT POLICY

1. TRANSPORT AND SOCIAL DEVELOPMENT - H.E. DR. A. ISMAIL

The historical growth of economic development can be described in terms of the growth of division of labour.

The effect of the division of labour is that every producer has a relative surplus of his own particular product and a relative deficiency in other goods which he requires for his consumption as well as his productive purposes.

It is this gap between producer and consumer which brings to the fore the function of transport.

Entering into every process of every industry and distribution, transport affects the entire population.

The location of industry is necessarily affected by the transport relations of each place to the natural resources and markets.

The proximity of natural waterways must always have played a large part in determining the location of industrial populations. Conveyance by natural waterways provided the cheapest method of conveying goods of all kinds.

Railway development enlarged the markets for the products of the various parts of the country and removed or partly removed the obstacles to the regional specialization and concentration of industry.

The twentieth century has been the rise of a flexible system of conveyance, i.e. road transport. This system has given many manufacturers a wider choice of location, coupled in many cases with a reduced cost of transport.

The development of road transport with its characteristic feature of not necessarily existing on dense traffic alone, has led to the creation of transport facilities in areas and between points that are not being served in the same manner by railway transport.

This extension of transport facilities has created new possibilities of industrial development in areas not previously served by railway transport.

It is due to the growth of road transport that residential areas beyond any reach of trains have grown up around most of the big cities.

The combined effect, however, of the development of road transport,

and the improvement of railway transport has been to enable urban aggregations to increase to a size that would not otherwise have been possible, and in this way have increased the attractions of Cairo, Alexandria and to a less extent other existing densely populated centers by offering both large markets for goods and large reservoirs of labour.

The attempt to mitigate traffic congestion in the centers of cities requires the provision of additional transport facilities of an expensive character e.g. tube railways and the demolition and reconstruction of big thoroughfares, which is of course a costly business.

The growth in the size of towns increased the time and money spent by the workers on their daily journey to and from work.

This has adverse effects on the workers which are reflected in no small measure on their efficiency and output, and in turn, on the employers' cost of production.

The unregulated industrial growth and decline of many towns and areas in same highly developed countries led their guts to adopt a policy of the diversification of industries in the different areas of the country.

The proper policy, should take account of costs - among them transport costs - in directing or suggesting sites to industries, at one place or another.

The five year plan 1978-1982, should be so discussed to see, how it will be able to face difficulties and problems which have been exposed in the above text.

2. TRANSPORT INNOVATION RESEARCH POLICY - DR. J. WARD

The encouragement of appropriate technological innovation is of key importance to any nation. Many economists believe it to be the central driving force behind long-run economic development and growth. The purpose of this discussion is to develop a perspective on how to think about the process of technological innovation, particularly as it applies to transportation, and therefore how to rationally formulate policies coward it.

If there is a single most important lesson to be learned from association with transportation R&D projects, it is that the big problem is implementation. This is true whether the output is a new piece of hardware, a new scheme or operation, or a new technique of analysis. R&D is

relatively easy, implementation of the results of R&D is not: It takes place in a much more complex, real-life environment and it typically requires both substantially more money and more dedicated effort. It thus results that while the technical work of implementing some new approach may be carried out by the technical people, the decision to implement or not to implement is made by the people who can allocate the resources required.

This basic point applies to new technologies and new techniques from all sources, whether they be newly generated from current R&D, or already developed and waiting on-the-shelf. None of these have any impact whatsoever on productivity, on our capability in any area, until the resources are allocated to bring them into actual use. Innovation embodies implementation. The central theme of this paper is that the primary determinant of the rate and nature of technological innovation is the resource allocation process at all levels of the economy. Government policies to influence technological innovation must operate through how they influence resource allocation decisions, both private and public. Innovation--change--is an option imbedded in the resource allocation decisions being made every day at all levels and in all parts of the economy and society.

Clearly, many of the major resource allocation decisions in Egypt and other nations are already public sector decisions. For these, the primary problem is how to make them wisely, a point being discussed from many aspects throughout this conference. As difficult as this is, it is vastly more complex to determine when it is appropriate and what mechanisms to use to influence private sector behavior. Some examples from U.S. experience illustrating some of the issues and pitfalls will be presented.

The principal conclusions are:

There is almost unquestionably a correlation between economic growth and technological innovation. It is therefore an important concern of any government.

The rate and nature of technological innovation is primarily determined by the character of resource allocation throughout the economy. The option to innovate, to introduce change, is imbedded in an investment decision.

Government can influence innovation by influencing or biasing the way investment decisions are made, both in the private sector and within the government itself.

The inventiveness and willingness to adapt technologies to local conditions stems largely from the perceived attitudes toward risk-taking and the consequences of success or failure, attitudes that are reflected from the policies toward resource allocation processes.

Since things rarely develop exactly as expected, and since unanticipated secondary consequences of innovation is common, there are advantages in leaving room for descretionary response to the unexpected.

Because of the quality of decisions depends in part on the understanding of the decision maker of the real issues involved, resource allocation decisions should be made where the most informed judgements can be brought to bear.

3. TRANSPORTATION SUPPLY AND DEMAND - DR. S. LERMAN

The analysis and forecasting of future travel demand and the transportation system's performance requires that the planner understand a complex set of variables and their interrelationships. In attempting to evaluate transportation investments and operating policies, this understanding must be translated into the capability to predict both performance and demand over a relatively wide range of future conditions.

In general, a transportation system consists of facilities and operating policies which provide different level of service depending on how heavily they are used. This functional relationship between level of service and the volume of users has been termed a supply relationship, though perhaps the term congestion function, performance function or service function would be more appropriate.

A wide range of methodologies have been used to model supply relationships. These include relatively simple empirical models, traffic flow theory, models of probabilistic processes, computer simulation and mathematical programming.

A second basic relationship of concern to the transportation planner is the demand for transportation service, which in turn depends on the quality of service the transportation system provides. As in the case of the supply relationship, a large number of widely varying methods have been derived from economic theory, though recently psychological and sociological methodologies have been applied.

In the most general case, the transportation planner is confronted

with the problem of modelling both supply and demand, and then developing a computationally practical procedure for solving supply and demand relationships simultaneously to obtain a consistent set of forecasts. For a given time horizon, such forecasts constitute the system's equilibrium. In any particular planning context, it may be possible to simplify this basic paradigm. For example, in analyzing infrequently used rural roads, congestion may be negligible and only demand need be forecast. Conversely, for certain analyses, demand may be for all practical purposes fixed (e.g. agricultural exports in any particular year) or at least virtually independent of the level of service provided by the transport system.

In this paper, the equilibrium paradigm will be reviewed and some of the various methodologies for both supply and demand analysis will be summarized. The paper is intended to be qualitive in nature and will provide a reader with some general background into transportation systems analysis. More detailed discussions will be referenced for interested readers.

SESSION III - TRANSPORT SYSTEMS ANALYSIS

1. TRANSPORT PROJECT EVALUATION - DR. T. FRIESZ

Developing countries have characteristically designated large sums of money (sometimes up to 40% of their national budgets) to capital investment in the transport sector. Given the relative magnitude of the investment share devoted to the transportation sector and the generalized capital scarcity prevalent in most developing countries, the question of how to optimally allocate these funds, both in space and time, among different modes, and of how to evaluate the resulting alternative configurations becomes a very important one.

Traditionally this evaluation and allocation process has been resolved through the use of benefit-cost analysis. For every possible different alternative each attribute is valued in terms of some common "numeraire" (dollars) and thus every system design can be reduced to one dimension. This permits a comparison across different alternatives and produces a rank ordering of them.

Even though benefit-cost analysis has been widely used in the past, it suffers from two main deficiencies which are particularly relevant in developing countries:

a) It fails to account for the multiplicity of regions and interest groups which brings with it the need to consider multiple development objectives which cannot be expressed in terms of a single numeraire; in particular benefit-cost analysis has tended to emphasize economic efficiency while ignoring distributional considerations.

b) It does not make explicit the trade-offs among development objectives which cannot be expressed in terms of a single numeraire.

As a result of these shortcomings a substantial body of literature has been developed recently in an effort to construct alternative "multi-criteria" approaches to the project evaluation and fund allocation processes.

Multiobjective optimization models, whether of a mathematical programming or optimal control nature may be solved in either of two general manners. The first set of solution procedures consists of the so called "generating methods" which are designed to generate the subset of "non-

inferior" or "Pareto efficient" points within the feasible region. They include the weighting method, the constraint method, the noninferior set estimation method and the multiobjective simplex method. These procedures as their name suggests, do not attempt to provide a final unique "optimal" solution through the application of a set of implicit or explicit trade-offs, but instead to generate the set of efficient points from which the decision maker will pick the final solution; they are therefore efficiency evaluation models rather than optimization models.

Preference incorporation techniques seek to identify the best compromise solution to a multiobjective planning problem. In these techniques preferences are articulated in a variety of ways but in general an approximate knowledge of the decision maker's "utility" or preference structure is required.

In general, preference incorporation methods are less computationally intensive than generating methods since they do not require specification of the entire non-inferior set; they are nevertheless more restricted in their applicability to multicriteria evaluation problems.

Several applications of these techniques have been made in the U.S. to solve problems in the areas of irrigation and water resources management, considerable potential exists nevertheless in other areas in general and in transportation in particular.

2. ROAD NETWORK ANALYSIS - ENG. B. BRADEMEYER

This paper describes and documents an analytic model - the Road Investment Analysis Model - for use in evaluating alternative design, construction, and maintenance strategies on low volume roads at either the link or network level. The focus of the model is on project-level engineering decisions and their implications for total transport costs. The types of decisions which are within the scope of the model include the choice of alignment, geometric standard, surface type, maintenance policy, and construction and maintenance methods. The costs considered include total maintenance costs; normal and generated traffic vehicle operating and travel time costs; and exogenous costs; all described in financial, economic, and foreign exchange terms. The model may be used at both the prefeasibility and feasibility stages of project evaluation, and has been structured so

that it provides information useful in both budgetary and economic planning of low-volume roads, as well as the impacts of foreign exchange requirements and network configurations.

The basic function of the Model is to estimate construction, maintenance, exogenous, and user costs for a system of roads which are to be designed, constructed and maintained to specific standards, and subject to known traffic demands and ancillary investments. This is done by simulating the life of each road from initial construction, through periodic upgrading, and through the annual cycle of use, deterioration, and maintenance.

The simulation is accomplished by determining construction and maintenance activities to be performed, and by estimating road conditions, traffic volumes, ancillary investments, and all associated costs on a year-by-year basis throughout the analysis period. The specific operations undertaken in each year are as follows:

- A construction submodel schedules projects, allocates a percentage of construction costs to the current year, and updates the status of the link and activates generated traffic and/or exogenous cost/benefits (if any) as projects are completed. The various types of construction projects which may be undertaken include new construction, overlaying, pavement reconstruction, widening, widening and reconstruction, realignment, and removal from service. Updating of the road includes the opening of sections to traffic and the abandonment of older sections. All costs are input by the User, in financial, economic, and foreign exchange terms.

A road deterioration and maintenance submodel estimates the average and final surface conditions for the year as a function of the initial design standard, last year's surface conditions, the volume and composition of the traffic during the current year, the local environment, and the specified maintenance policy. Surface deterioration may be estimated for both paved and unpaved roads. A range of typical maintenance activities may be specified for each surface type on either a scheduled or demand responsive basis; these are priced in financial, economic, and foreign exchange terms according to the amount of maintenance which is actually performed. The condition of the road is expressed in terms of roughness and rut depth (all roads), cracking and patching (paved roads), and looseness and moisture content (unpaved roads).

A User cost submodel estimates the costs of operating vehicles over each road as a function of surface type and condition, environment, design

geometrics (grade, curvature, and width), and vehicle characteristics. The components of vehicle operating costs include running costs (fuel, oil, tire, maintenance parts, and maintenance labor), annual fixed costs (depreciation, interest, crew costs, and overhead costs), and travel time costs (passenger time and cargo holding costs). Cost estimates are prepared for a fleet of vehicles representative of those which will actually be using the road, by vehicle type, in financial, economic, and foreign exchange terms.

A traffic submodel estimates the current year's traffic and the anticipated growth, by vehicle type, for both normal and generated traffic. If the network option is used, the origin-destination demands are assigned to the system using a stochastic user-equilibrium approach. Both the actual and perceived costs of travel are then recorded in financial terms, to measure the consumer surplus of the system.

The traffic assignment model assigns the origin-destination (O-D) flows to the links of the network, based on the operating and travel time costs of the relevant paths and the vehicle diversion parameters. It also grows the traffic O-D demands for the current year. The most recent vehicle operating costs and travel times over the various links will be used in conjunction with the origin-destination demands and the network data (available paths) to predict the link volumes. Each link's volume (vehicles per day) will be used by the deterioration models to calculate the maintenance costs incurred and the condition of the link at the end of the year. This information will be used to calculate the level of service (road users' costs and travel times) of the link. The financial users' costs and travel times will be part of the generalized price used by the assignment procedure to load the network flows in the successive year, while the economic costs will be stored for later use in the economic analysis of the investment alternative.

An exogenous costs benefits submodel estimates the current year's exogenous net costs based on the previous year's costs and benefits and anticipated growth, in financial, economic, and foreign exchange terms.

The results of the simulation include a record of the expenditures incurred by the Highway Authority for capital improvements and maintenance; a record of the costs incurred by road users, both normal and generated; a detailed history of the status and deterioration of each road;

and a history of the traffic volumes and ancillary investments. All estimates, other than construction and ancillary investments, are made in terms on physical quantities, from which total costs are obtained by applying the appropriate unit rates. The Model is therefore not dependent on the use of a particular monetary system, not is it affected by changes in relative prices. All costs are estimated in financial, economic, and foreign exchange terms.

The User cost relationships are based on the TRRL results from Kenya (1) and reflect free flowing conditions, driver behavior, and the types of vehicles typical of East Africa. These relationships do not include the effects of congestion or of non-motorized traffic on vehicle operations, nor do they incorporate the traffic interaction effects of single lane roads. In addition, the results are applicable for gravel and paved roads only.

The paved road deterioration and maintenance relationships are based on the AASHO road tests (2) and on the results of the TRRL studies in Kenya (3). As such, their direct applicability is limited to high standard asphalt concrete roads (modified structural number greater than 3.0) and to bituminous treated, cement stabilized base roads (modified structural numbers between 2.5 and 4.0) which are subject to a limited range of traffic conditions and maintenance policies. The gravel road relationships are based on the TRRL results, and are limited in applicability to relatively well-constructed gravel roads.

While the Model can be used outside the range of conditions described above, the results which are obtained in these situations should be critically evaluated and used with caution.

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[1]Hide, H., et al. The Kenya Road Transport Cost Model: Research on Vehicle Operating Costs. Department of the Environment, TRRL Report LR672, Crowthorne, 1975 (Transport and Road Research Laboratory).

[2]American Association of State Highway and Transportation Officials, "AASHTO Interim Guide for Design of Pavement Structures", Washington, D.C. 1972.

[3]Hodges, J.W., et al. The Kenya Road Transport Cost Study: Research on Road Deterioration. Department of the Environment, TRRL Report LR673. Crowthorne, 1975 (Transport and Road Research Laboratory).

3. CALIBRATION OF AASHO DETERIORATION MODEL FOR EGYPT CONDITIONS - DR. A. GAI

The AASHO basic equation for flexible pavement structures provides a relationship between drop in serviceability, traffic and pavement thickness. In these equations, drop in serviceability is expressed in terms of reduction in PSI, traffic is represented by equivalent 18-kips single-axle load applications and pavement thickness and physical characteristics are represented by a modified structure number.

The modified structure number is defined by an emperical relationship in which the thickness and strength of the pavement layers are combined together, in addition it takes into account the strength of subgrade, environmental impact, and drainage characteristics of the base and subbase differing from those at the AASHO road test site.

Of the design parameters considered in the AASHO equations, the regional factor is probably the least well defined. In most cases, the selection of the proper regional factor value is based upon local conditions of the highway in combination with engineering judgement. When a regional and drainage factor of one was used in the deterioration model as a part of the application of the road investment analysis model to Egypt road network, the predicted road condition did not agree with the existing field conditions. This indicated the importance of calibrating the deterioration model for Egypt condition.

The main purpose of this study was to calibrate the AASHO deterioration model for Egypt condition. This includes calibration of the modified structural number equation together with evaluating the regional and drainage factor for Egypt condition. This evaluation is based on the climatic conditions, subgrade soil type, drainage, pavement performance, and engineering judgement.

Field and laboratory tests were conducted on selected roadway links within the study area.

The study resulted in a number of significant results. However, it must be emphasized that the conclusions pertain to the inference conditions used in this study. The following is a brief summary of the findings:

1. The best suited regional and drainage factor for Egypt conditions (Delta region and cultivated areas) is 0.4.
2. Pavement structure number that is less than 3 has to be adjusted by incorporating the effective subgrade layer as a part of the

pavement structure and using subgrade strength coefficient of 0.05.

3. The inclusion of the effect of the subgrade layer in adjusting the pavement structural number, together with the fact that subgrade CBR values for the study area were about the same as the standard CBR (CBR_0 = 2.69), nullifies the effect of CBR on the modified Sn equation.

The presented findings pertain to the following conditions:

1. These concepts are valid for roadway links located within the Delta region and cultivated areas. Desert roads are not incorporated in the study.
2. Roadway links do not have an adjacent irrigation canal.
3. Embankment height range between 50 cm. and 150 cm.
4. Pavement structural number range between 1.5 and 2.5.

4. ROAD AXLE LOAD DISTRIBUTION IN EGYPT - ENG. M. KHALIL

The amount of damage done to a road by a moving vehicle depends very strongly on the axle load of the vehicle. The relationship between this damage and the axle load is extremely important for the proper design of roads. In Egypt, as in most developing countries, axle-load spectrum of the vehicle population has not been determined for use in modern pavement design. This paper presents the results of an axle-load weighing survey initiated to provide adequate information on pavement loads of commercial vehicles to be used in design and maintenance purposes of highways in Egypt. The survey was carried out during February, 1978, and covered four sites on the major highways, three of them are major approach highways to Cairo and the fourth one near Alexandria.

Basically, the survey procedure is weighing each axle. This was carried out by weighing the wheel of each axle at the same time. At the same time the drivers were interviewed to get information about empty and pay load and type of cargo.

Remarks and Conclusions:

1) Major differences have been found between the magnitude of axle load in different survey stations;
2) All loads above 8000 Kg. are about 44% and cause about 95% of the damage to the roads. This means that roads are being damaged

at very high rates compared with the rate of damage experienced by pavements in Europe;

3) Axle loads above 8000 Kg. represents 55% for Alexandria - Cairo road, 53% for Guiza - Badrashire road, 13% for Cairo - Alexandria road and 28% for Ismailia - Cairo road. These give an average equivalent standard axle for mentioned roads: 3.0. 2.55, 1.94 and 1.42 respectively;
4) Alexandria - Cairo road results show the highest axle load factor. This is due to trucks carrying heavy cargos from Alexandria harbour to all the country;
5) A significant percentage of trucks was found in the weighing survey to be overloaded by factors up to 50% and sometimes 80% more than was documented from information given about empty and payload, a case which seriously should be looked upon when fixing a legal axle load in a developing country.

The average truck factors for Egypt highways were found to rate from 2.49 for 2 axle trucks to 11.58 for five axle trucks with trailer and the average axle - load factors to rate from 1.25 for trucks with two axles to 2.32 for five axle trucks with trailers.

In general, the total number of axle loads analyzed in this survey were 1163, corresponds to 384 commercial vehicles.

The average truck factor was found to be 6.64 (standard axle/truck) and the average axle factor was found to be 2.19 (standard axle/axle).

5. ROAD VEHICLE OPERATING COSTS IN EGYPT - DR. A. LASHINE

Road vehicle operating costs represent a major item in the economic analysis of projects related to road improvement schemes. Apart from the data collected two years ago during phase I of the Egypt National Transport Study, there has previously been no major effort directed towards establishing the basic vehicle operating costs for vehicles typical of the Egyptian fleet. For the adaptation of the Highway Cost Model to examine some items of the maintenance strategies of parts of the Egyptian road network, it was considered essential to examine in detail available operating data and verify and complement these data by conducting field surveys if necessary.

The present paper first examines vehicle classification as originally

outlined in the HCM and the suitability of application of this classification under prevailing operating conditions in Egypt. Intercity passenger transport in Egypt depends heavily upon intercity taxis. In view of its unique operating characteristics, this type of vehicle was evaluated seperately from other types of the Egyptian fleet. On the other hand light-goods vehicles do not represent any appreciable percentage among the different types of vehicles on the Egyptian road network. A reclassification was introduced including five different types of vehicles.

The second part of the paper deals with the analysis of available data for the operating costs of publicly owned fleets of buses, medium and heavy lorries.

The third part deals with two field surveys conducted to establish the operating costs of privately owned cars as well as intercity taxis.

For each type, operating costs have been established in both economic and financial terms.

The last part of the paper deals with the summary of the findings as well as concluding remarks.

6. RESULTS OF APPLICATION OF HIGHWAY TRANSPORT INVESTMENT MODEL IN EGYPT - DR. M. OWAIS

The purpose of this study is to demonstrate the application of an existing framework, the Road Investment Analysis Model, to road transport investment decisions in Egypt, and to develop the necessary procedures for its modification and adaptation to the local Egyptian conditions.

The scope of the research effort during its first phase was restricted to the evaluation of road transport in a zone comprising roughly one-fourth of the paved road network of the Delta. Five reconstruction and subsequent maintenance policy alternatives included do-nothing; a premix overlay followed by either scheduled or demand-responsive maintenance; and a double (asphalt over premix) overlay followed by either scheduled or demand-responsive maintenance. For each alternative and on each link economic analysis of net present value, first year benefits, and internal rate of return were performed against the do-nothing alternative. Where data were lacking or unreliable, surveys were undertaken or engineering judgements were used.

The results of the twenty-five link-evaluation applications of the

Road Investment Analysis Model indicated that there were three classes of link performance in the study zone under the proposed structural overlays and subsequent maintenance standards. These classes were:

1) links which are in excellent present condition and for which the proposed investments may be postponed;
2) links which are in poor present condition and for which the proposed investments produce acceptable results. This means that the heavier structural overlay performs satisfactorily for the entire analysis period thus requiring no major subsequent maintenance investments;
3) links which are in poor present condition and which performed marginally under the proposed investments, in that the heavier structural overlay failed in from 5 - 14 years requiring major subsequent maintenance investments, and for which heavier initial investments should be considered.

A tentative general finding which held on all links analyzed was that, of the four post-construction maintenance policies studied, the one with the heaviest overlay dominated the economic analysis, independent of the effectiveness of the original double (asphalt over premix) overlay, which was the more extensive of the two construction options analyzed.

Thus, on all links studied, the heaviest construction and maintenance investments produced the greatest economic net present values. This and the above performance classification are being reviewed in light of assumptions made during data collection. A visual inspection was made of representative links in the study zone to verify these predictions.

The network analysis model is being used to calibrate the traffic assignment parameters (values of time and diversion intensity) through a series of preliminary network analysis. The study network will then be analyzed under the proposed alternative maintenance policies and investment schedules as renewal or maintenance of a certain link affects the traffic flows on the other links and consequently the network total transport cost.

SESSION IV - TRANSPORT MODES

1. EGYPTIAN RAILWAYS INVESTMENT PROGRAMS - ENG. A. HESHMAT.

During the last years, the Egyptian Railways has passed through the most critical stage in its life. This is mainly due to the hard economical conditions which faced the country during this period and which hindered the allocation of the necessary investments for the renewal and modernization programs and resulted in the deterioration of this important organization and consequently led to its incapability of facing the obligations laid upon it.

As the investments play an important role in the life of railways, the International Railway Congress which assembles every four years, has specialised its coming session during May 1979 in Stockholm for the study of "Investments: A Determining Factor for the Future of the Railways."

In this presentation, we will address the following subjects:

1. The reduced investments allocated to the Egyptian Railways for three Five Year Plans from 1960 to 1975 and its impact.
2. Action taken to face the situation since 1976.
3. The respective results achieved since 1976.
4. Conclusions.

2. AIR TRANSPORT - ENG. A. BOSEILA

Air transport planning corresponds to air traffic forecasting, followed by planning for required flying equipment, aerodromes, airway facilities, and manpower to operate the whole system.

The deadline involved by the design and implementation of these large scale investments makes it desirable to make a cut-off point of 10 to 15 years. This in turn, makes forecasting a difficult issue.

Forecasting for international air traffic is made easier due to many factors. The difficulties of forecasting for domestic air traffic are enormous and stem from many variables.

There is a real need to perform studies related to this subject. The main issue will be presented in an endeavour to encourage research to find the required solutions.

Main issues are:

1. Gathering relevant data.
2. Deciding on policies: industrial
   tourist
   land reclamation
   social
   foreign
3. One of the most important policies which is not clear is the intermodal-transportation policy:
   3.1 Air transport as an input to the system.
   3.2 Air transport as a relief to the system.
   3.3 Only suitable system.
   3.4 Relief to a sub-system.
4. Forecasting models to be used, and suitability of each to the Egyptian environment.
5. Validity and relevance of historical data.
6. Egyptian share in the international market.

One of the problems which faces Egypt is the difficulty in training planning personnel due to:

1. Infrequency of planning needs.
2. General educational system.
3. Scarcity of data bases.
4. Difference in environments.
5. The infrastructure.

Research on those points, and knowledge of the most efficient and least expensive sources for consultations is one of the basic requirements for successful planning.

3. HIGHWAY TRANSPORTATION - ENG. A. EL-DAGHESTANY

The topic of this paper is Highway Passenger and Goods Transport in Egypt, with emphasis on the impact of research and studies on decision-making and policy formulation. This subject is appropriate - at this time - as we have recently embarked on nation-wide studies and some preliminary results are now available.

The paper will focus on the activities of the highway transport which seems simple when viewed as a single mode. In fact it is rather complex

when viewed in the context of the total transportation system. The general trend indicates that the most important mode of both freight and passenger movements is highway transport. This results in higher-than-necessary transport costs.

Study and research are thus not only desirable but also essential if decision-making and policy formulation are to be taken with some degree of confidence.

The paper will first describe the geographical and economic environment in which the highway transport operates; then touch on services provided and traffic volumes.

In fact development is achieved if we can identify the major problems and recognize the possible alternative solutions in a systematic way. Only then we can proceed to reach rational decisions.

4. WATER TRANSPORT - DR. A. EL-MEZAWIE

The paper gives a brief description of the inland waterways system of Egypt, the fleet, its capacity and performance. Then it introduces the pattern of improvement of inland waterways in the United States and the implications of the improvements on providing low-cost water transport.

Some thoughts are reflected on the improvement of inland waterways in Egypt. Although these improvements have followed the same pattern as in the United States, they go at a much slower pace.

Development of inland waterways in Egypt has rested on a traditional policy and certain rules of thumb. No extensive research program has been developed to provide certain tools that can help improve the efficiency of decisions on the allocation of resources to navigation and barges.

Then the paper exposes, in a brief way, some of the research studies originated in the United States hoping that some of these research projects may be adopted along the same lines for Egypt.

The data base furnished by Egypt National Transport Study assures researchers that they are not going to start from scratch.

SESSION V - URBAN TRANSPORTATION

1. ISSUES IN CAIRO URBAN TRANSPORTATION - DR. R. GAKENHEIMER

This urban transportation project is the case of closest collaboration between professional counterparts from two nations in which I have ever been involved. As such, it has been an extraordinary pleasure, and a more significant learning experience for those of us on the MIT team than ever could have been hoped for at the outset. Accordingly, you will notice that the topics treated in these comments are virtually the same as in Professor El-Hawary's comments on the first day of this conference. The difference is somewhat different levels of emphasis among them, and a somewhat different perspective. In particular, I would like to use this opportunity to bring out special issues and findings in the studies.

What is technology transfer in urban transportation? First, it is adapting standard models of transportation analysis for application in a new environment. This we are doing. The Cairo University team has adapted transportation methods to the special speed and delay characteristics of Cairo's streets. They have developed special forms of survey procedure to discover the origins and destinations of trips, and so forth.

Secondly, technology transfer is finding tools which provide new ways of dealing with institutions and decision processes. The first step is to understand the institutions. The MIT team has given a great deal of attention to understanding the way transportation projects are prepared and put into implementation in Cairo--with detailed advice from the Cairo University team at each step, and from distinguished members of the public transportation agencies. In this way we have learned something about the process of planning and budgeting, the bases for participation of agencies in the field, and the particular sources of uncertainty in project development which exist. In the United States a great deal of attention has been given to the development of "programming methods. These are means for allocating budget and expediting projects into implementation. We are using our growing knowledge of the transportation planning process in Egypt to propose modified programming methods which fit the Egyptian reality.

Thirdly, technology transfer is choosing the right problem. As Professor El-Hawary has already noted, the analysis of auto ownership is a topic not engaged in the high income countries where a great deal of transportation research is done. In those countries, auto ownership is considered to be saturated, and not likely to change much in the future. In Egypt the government has great capability potentially, for controlling congestion in the streets of Cairo by changes in the import tariffs on autos and by controls on the national auto assembly industry. Another example: In some other countries, planners enact policies to restrain auto trips to the central city in the expectation that this will encourage greater use of transit. In Cairo, the transit is already used to capacity. The problems are qualitatively different. Some of the most valuable time spent by the joint Cairo/MIT team is in discussing the most productive forms of the problems to engage.

Our project development research has been based on "project biographies." That is, we have followed the lives of projects from their inception to their accomplishment. In this manner we have studied some 12 projects in Cairo. We have found, for example, that participation of the national agencies is widespread and a wide variety of projects are in simultaneous progress. This has led us to the concept of a "slate" of projects, an array of projects under simultaneous progress, moving ahead under the watchful eyes of various agencies. Although programmers would like to consider the annual budget as the basic controlling mechanism of project development, we find that in the Cairo context it is not appropriate for planners to hopefully assume a specific budget that will be available for a specific future date. We are attempting to modify programming practice to cope with circumstances such as these.

The tools of traffic analysis and travel demand analysis, mentioned earlier by Professor El-Hawary, are invaluable as general purpose tools to interested professionals of the transportation sector. They are also crucial to the operability of programming. They have been developed with a view to serving both these purposes.

2. PARA-TRANSIT SYSTEMS - DR. D. ROOS

Para-transit is a term normally used to describe tansportation services which, in a spectrum of services, lies between fixed route

bus and exclusive ride taxicab. As such, the term has been described as an "uncomfortable" one, in that it does not fit into the standard system of classification used to describe transportation infrastructure or policy.

In North America, para-transit systems have been established and operated as both independent systems and as key portions of an integrated group or "family" of transportation services. Successful peak hour services have typically consisted of forms of ridesharing, in which each day the same people are picked up at their homes and are brought to a common destination. These forms have included van pooling, bus pooling, as well as car pooling. Demand responsive systems have been established to serve both peak and off-peak markets. These services vary from the totally flexible to systems which contain both fixed and flexibly routed elements and are operated by public transit companies, taxi companies and private non-profit organizations.

In developing nations, the most common form of para-transit is the collective taxi or shared car. From 5% of all motorized trips in Dakar and Taipei to 40% in Caracas and Istanbul to 65% or higher in Manilla and other cities of Southeast Asia are made by this mode. In Egypt, a prime example exists in the form of the Intercity Taxi. Typically, these systems are disapproved of by local governments because they are seen to compete with public transit, violate traffic regulations and generally operate outside the law.

The key point that I would like to stress is that in Egypt and developing nations in general, consideration should be seriously given to accepting and integrating para-transit into the network of urban and inter-urban transportation services. The reasons for this are related to both transportation and the economics of development. Specifically, typical forms of para-transit provide a specific group of travellers with mobility which would not be provided by the larger government-run organizations. Further, para-transit tends to be labor intensive rather than capital-intensive. These systems tend to generate jobs at skill levels and in locations where labor is available.

The irony of the current state of para-transit development is that in developing nations, a number of efforts are being made to eradicate para-transit systems in favor of heirarchical transit organizations,

while in the West, efforts are being made to adapt the flexible, low capital-cost systems. Perhaps the lesson to all is that there is a role for both transit and para-transit to play in the provision of mobility and access.

3. PERSPECTIVES ON URBAN TRANSPORTATION MANAGEMENT IN CAIRO - ENG. T. BRIGHAM

The objective of this presentation is to provide a view of the contributions of the TPA/CU/MIT urban transportation project to the management of transportation and traffic, and a general perspective on future options for transportation in Cairo.

The initial element of the project, the traffic volume and private vehicular origin-destination studies, will provide data for the analysis of traffic flows in Cairo from a systems perspective. The objective of such analysis will be to aid in the reduction of congestion by improving traffic flows through the city. This approach has been effectively demonstrated by the work done last summer on the 6th of October and Galla bridge crossings of the Nile. The second phase of the current project will include study of the transit system in Cairo, with a view to providing suggestions for changing the transit network to reduce the proportion of multi-line passenger-trips and consequently increase system efficiency. Data on passenger origin-destination patterns and other characteristics were recently collected in a city-wide transit survey.

These two study efforts will provide the beginnings of a valuable urban transportation data base which must be augmented regularly in years to come with similar studies. To this end, the Cairo University team is preparing manuals to be used by governmental agencies in replicating these studies. An ongoing, regularly augmented data base will provide a flexible resource that can be used to effectively analyze, forecast and plan urban transportation in Cairo.

The next step is to examine the application of these data to transportation in Cairo. The data will help to explain where and when people want to travel, and how these characteristics vary by mode.

It might be useful, however, to step back from the detailed analysis of the urban transportation problem to gain a larger perspective. It may, for example, be useful to view travel in Cairo from the standpoint

of general mobility. Currently, as in many large cities, certain streets are congested and traffic moves slowly. When one attempts to subjectively forecast mobility in Cairo, whether by private auto, taxi, or transit, the outlook is rendered less than optimistic by present auto ownership patterns. That is, although the effects of urban congestion are currently felt in Cairo, levels of auto ownership are low, relative to either the West, or to what potential levels are likely to be, given the perceived demand for the private auto. Hence, although much can and will be done to increase traffic flows and ease congestion in Cairo, an expected increase in the number of automobiles in use in the metropolitan area is likely to negate many of the anticipated improvements

Often, in the West, the response to increased levels of traffic congestion has been to increase the capacity of the urban roadway system and to increase parking opportunities in the central city. This pattern has been particularly true in many cities in the United States. Typically, this policy has resulted in increasing the volume of vehicular traffic into and out of the central city, and in many cases has hastened the movement of middle class urban dwellers to the lower density areas in the suburbs. The end result, in many, if not all cases, has been the creation of a central city environment more favorably disposed toward the automobile than toward the human inhabitant.

Several options are available to deal with the problem of urban congestion. It is urged that the decision-makers take advantage of knowledge gained from mistakes made in accomodation of the automobile in Western cities and consider the interests of the inhabitants of Cairo in terms of not only urban mobility, but also the future viability and liveability of the central city.

4. URBAN TRANSPORTATION IN CAIRO - ENG. A. SALMAWY.

This paper deals with the transportation and traffic problem in greater Cairo, the efforts exerted to face it and the different projects that are underway or that are still under study.

The paper discusses in brief the following basic subjects: -

A. Brief Description of Greater Cairo and the Transportation Demand and Its Evolution During the Last 25 Years

Greater Cairo is the 8th largest city of the world, 1st city of Africa and capital of the Arab World. It groups in addition to Cairo governorate, parts of Giza and Calubiya. The geographical urban area of Greater Cairo is about 250 sq. km.

The present population of Greater Cairo is about eight million inhabitants served by a comprehensive public transport network which includes railway services, tram services, public bus services, trolly bus services, Nile bus services and Heliopolis Metro services.

B. Description of the Transportation Systems Network and Facilities in the City as well as the Services Offered by These Different Systems.

The total number of daily trips are as follows: -

- By the general railway system	65,000	Trips/day
- El Marg line	120,000	" "
- Helwan line	230,000	" "
- Tram system	252,000	" "
- Bus system	3,200,000	" "
- Trolley Bus system	89,000	" "
- Nile Bus system	23,000	" "
- Heliopolis Metro svcs.	120,000	" "
	4,099,000	

C. The Expected Evolution in Transport Demand up to Year 1990.

Over the past twenty-five years, the number of cars has increased four times and the demand for public transport system increased eight times (from 438 million trips in 1954 to 3480 million trips in 1975) and it will reach 13.6 million trips by the year 1990.

D. Previous Studies Carried out to Face the Problem and the Proposals Offered by These Studies.

Several transport studies for Greater Cairo have been undertaken since 1954 by local and foreign experts. Most of these studies were brief and concentrated only on the feasibility of construction of an underground network rather than a comprehensive Master Plan for the organisation.

A comprehensive study was carried out by the French company "SOFRETU" to undertake a scientific study to execute a comprehensive transport Master Plan for both public and private transport in Greater Cairo,

and this was elaborated in 1973.

The study proposed as a solution to the transport problem, short and long term plans. The first constitutes the installation of several measures for the reorganization of the surface network (both infrastructure and equipment), and the second implies the construction of an underground network to combine with the surface network in satisfying the future transport demand.

E. Present Transportation Projects Under Execution and Planned For the Future.

Since the elaboration of this study in 1973, many transport infrastrutures have been constructed or proposed to be constructed such as:

- Improvement of Imbaba bridge.
- Abu El-Ela bridge.
- Rod El-Farag bridge.
- Kornish El Nile road widening.
- Helwan/Heliopolis Autostrade.
- Amr Ebn El Ass Crossing.

F. The Shared Project of the MIT, Cairo University and TPA

A research program has been developed by Massachusetts Institute of Technology (MIT) and Cairo University; in conjunction with the Transport Planning Authority to conduct a study on "Urban Transportation relating short-term options to long-term consequences in Cairo Metropolitan area".

The main purpose of this project is to determine the parameters and indicators which affect traffic flow characteristics taking into account the present and future effect after the implementation of these new transport infrastructures.

Recommendations: -

Two groups of recommendations are given:

1. The reorganization of Public Transport Authorities in Greater Cairo.
2. Proposals for: -
   a. Accelerating execution.
   b. Stipulation of financial regulations for such projects
   c. Priorities of projects executions and programming of this execution.

5. ORIGIN - DESTINATION SURVEY DATA PROCESSING - DR. F. BARRY

The objective of the traffic survey for greater Cairo is to provide planners and researchers with the necessary transportation data base. The collected information will provide a valuable tool to be used in the design and evaluation of alternative actions in the transport sector. Traffic volumes and travel behavior were monitored on a standard procedure for the survey, data processing and documentation to allow its repetition every five years.

The study area for executing the survey has been carefully chosen to include the necessary traffic flow pattern and trip characteristics. The zoning system for the study as a whole contains 76 main zones distributed according to:

37 rural governorate zones,

14 urban zones in between the outer cordon of greater Cairo and the cordon of the enlarged downtown (the study area),

25 zones - which were subsequently divided into 67 subzones - within the study area

On Monday, 18 April, 1977, the main survey was conducted utilizing 267 counting stations at about 96% of which interviews were also carried out to determine the travel behavior characteristics. Following the collection of data, the computers of Cairo University and CAPMAS were used to sort and tabulate the results.

The main outputs are as follows: -

a) Traffic volumes: they were processed to produce:
   - traffic volume by vehicle type for 10 minute intervals, summation for the whole hour and percentage of traffic composition.
   - the traffic volumes were converted into equivalent passenger car units (P.C.E.'s)

b) Road side interviews: they were processed to produce:
   - occupancy rate by vehicle type,
   - trip purpose by time of the day and vehicle type,
   - expanded O/D matrices by P.C.E.'s for each hour of the day and summary matrix for the entire survey period,
   - overnight parking by zone,
   - number of vehicles registered by governorate and
   - trip type (central-central, ..., rural-central)

c) In order to calibrate a traffic assignment model accurately to be used in greater Cairo, relationships between traffic capacity, volume and speed over the network are needed to be determined, hence speed and delay measurements were made. Furthermore, travel time measurements on nine main radial streets to conduct isochronic curves have been executed. In addition to the above items, a street inventory study was conducted to get the physical characteristics of every link in the study area.

All the above results were processed and published as "Traffic volumes/Travel behavior" manual for greater Cairo and are available for regular use at any governmental agencies within the transportation sector.

III. CONFERENCE WORKING PAPERS

جامعة القاهرة - معهد ماساتشوستس للتكنولوجيا

برنامج التخطيط التكنولوجي

CAIRO UNIVERSITY - MASSACHUSETTS INSTITUTE OF TECHNOLOGY

TECHNOLOGICAL PLANNING PROGRAM

CONFERENCE ON

TRANSPORTATION PLANNING POLICY

JUNE 20-22, 1978

CAIRO, EGYPT

III.1

INTERIM REPORT

URBAN TRANSPORTATION PROJECT

BY

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INTRODUCTION AND SUMMARY

The research reported in this interim summary was accomplished from the Public Works Department of the Faculty of Civil Engineering, Cairo University, the Transport Planning Authority of the Ministry of Transportation of Egypt, and the Departments of Urban Studies and Planning and Civil Engineering of MIT.

The purpose of the research is to improve the process of project development and implementation in urban transportation for the Cairo metropolitan area. This takes the form of preparing a project programming method and also along the way providing elemental tools and analyses to government agencies for the solution of special problems and as general analytical resources.

The work has been done by closely collaborating subgroups from the Egyptian government, Cairo University and M.I.T. The effectiveness of the cooperation between these groups is suggested by the fact that parts of this report have been drafted by eight individual members of the two national groups--four from each of them.

The sponsoring program has been the Technology Adaptation Program of US A.I.D. at MIT. In addition to the general support of the project, AID/Cairo has separately supported the traffic survey which was an important part of this year's activity.

Briefly summarized, the contract activities have included three major elements: Programming and project development, traffic survey and analysis, and auto ownership analysis.

In transportation project development we have conducted interviews, reviewed documentation, and completed project questionnaires to better understand the de facto process by which projects come into acceptance and move toward implementation in Cairo. These studies have resulted in a working paper, "The Project Development and Implementation process in Cairo" (Nov. 1977). Also during the contract period the literature on project programming has been reviewed, and memoranda prepared on the adaptation of these methods to the Cairo setting. These memoranda (cited

further on) culminate for this period in the tentative proposal of a prototype method to be the focus of our further study and refinement (see "Prototype Procedure", October 1977).

The traffic survey and analysis element began with the preparation of a traffic volume and travel behavior survey in April 1977. There was a brief pilot survey which focussed on the 6th October Bridge-Tahrir Bridge axes. It served to refine survey methods and also resulted in recommendations to the Ministry of Transport for the solution of a difficult traffic problem. These recommendations were implenented almost immediately (see the working paper "A Study of Traffic Flows on the 6th October and Tahrir Bridge Axes"). The full-scale survey which followed then produced information adequate to construct a complete set of origin-destination matrices and street capacity standards. It was fully documented for replication in the future by the Transportation Planning Authority. Preparations have been made for the use of computer programs to analyze this data. These programs have been installed at MIT and are being operationalized at Cairo University to assess and analyze the consequences of changes in the transportation system, such as those represented by the completion of new facilities. Certain auxiliary studies were performed to adapt the trip analysis programs to use in the Cairo setting. The resulting trip assignment capability will serve as a basis for the development of further travel analysis method, and as a component of the programming method mentioned above.

Initial data collection was undertaken on auto ownership in order to gain perspective on the possibilities for an analysis of this phenomenon in the future. Information was collected on the production of the industry, on imports, and on auto ownership. Plans were made for the study of auto ownership in Cairo at the level of O-D zones by relating it to economic and social characteristics. These studies will be continued in the future.

SECTION I

PROJECT REVIEW AND IMPLEMENTATION PROGRAMMING

1. TRANSPORTATION PROJECT DEVELOPMENT

The work of adapting project programming processes to Egyptian needs has been divided into three elements. First an analysis of current Egyptian transportation project development and implementation activities was undertaken as a means of understanding the environment in which any adapted programming process must function. Second, a review of existing and proposed United States based programming methodologies was initiated to identify a range of alternative procedures which might be adaptable in whole or in part for use in Egypt. And finally, building upon the first two elements, the development of programming process for Egypt--either through the selection and modification of an existing U.S. methodology, or through the construction of a new process, drawing on the U.S. programming experience.

Our analysis of current Egyptian project development and implementation activities is based on a review of the history and current status of a number of transportation projects in the Cairo area, the location of a large majority of Egypt's urban transport projects. This project review was carried out jointly by MIT team members who traveled to Egypt during June, and the Cairo counterpart team. The team first developed a project status questionnaire, designed to assist in the systematic collection of information concerning each transportation project to be reviewed. The questionnaire included questions in five areas:

1. physical characteristics (the nature of the project, its components, and elements of construction);

2. functional characteristics (anticipated utilization, expected impact on the city-wide transportation network, relationship to other proposed projects, and non-transport impacts);

3. project organization characteristics (agencies responsible for planning, designing and executing the project);

4. funding characteristics (sources of funds, delays due to funding); and

5. sources of obstruction and delay

The survey of projects was partially accomplished during the visit of the MIT team to Cairo in June. The MIT team returned to Cambridge to begin the analysis of the information then available, and the survey was completed by the Cairo counterpart team in July and August, when the results were brought to Cambridge.

While in Cairo during June, the MIT team also conducted a number of discussions and interviews with persons associated with the overall project development and implementation process, as well as persons involved with particular transportation projects. Discussions were held with faculty at Cairo University; officials of the Ministry of Transportation, the Ministry of Planning, the Ministry of Housing and Reconstruction, and the Ministry of the Economy; Cairo and Giza Governorate officials; and members of domestic and foreign public and private firms involved in the design and construction of projects.

In addition to the assembling of information pertaining to the overall project development, implementation, and budgeting procedures, this data collection effort has permitted the compiling of detailed descriptions of eleven transportation projects in the Cairo area. These projects are currently in various stages of development and implementation.

The analysis of this data by the MIT team in Cambridge began in July, and continued to the end of the contract year. During their September/October visit to Cambridge, members of the Cairo counterpart team actively

participated in the analytical work. The entirety of the analysis is detailed in a paper titled "Transportation Project Development and Implementation in Cairo, Egypt"; portions of the results of the analysis are outlined below.

The history of a Cairo transportation project - from its conceptualization to the completion of construction - may typically be divided into two segments: The development phase and the implementation phase. The boundary between these two is identified as the point at which the decision is made to implement the project. The development phase is characterized by efforts to reach a favorable implementation decision concerning the project. During this time, the project concept moves from generality to specificity.

A decision to implement the project is signified by its addition to what we describe as a "slate." The slate does not have an official existence in Egypt, but rather we identify the slate as an abstraction of what we see as a very important characteristic of project development and implementation in Egypt. The 'slate' is the total set of projects which have been accepted as those which will be implemented. While the current 'slate' consists of approximately ten projects, there are no indications that the set is restricted to this scale. In fact, the dimensions of the slate may be determined at any moment in time by the particular present and anticipated transportation capital expenditure budgets, the domestic capacities to supervise, design and construct the set of projects, and the inter-institutional relationships. Not all project concepts are 'slated', and the length of the development phase appears to vary from project to project.

One prominent characteristic of the project development phase is the present situation where no single authority exists as a controlling force over transportation sector project development and implementation activities. Rather, the activities result from the complex interaction of a large number of national and local government agencies and public/private design and construction organizations. A certain number of individuals--often associated with the previously indicated organizations--are influential in the process. The process of attempting to 'slate' a particular project is primarily one of building a consensus among a sufficient number of these organizations and individuals that the project should be constructed. When this occurs, a project is 'slated'.

The 'slating' of a project initiates its implementation phase. Even though its eventual completion is assumed, the time table of such completion is uncertain.

This uncertainty is a feature of the entire project development and implementation process in Egypt. The lengthy period of consensus building during project development arises in part from the uncertainty associated with the future behavior of the involved organizations and individuals. This is linked to the ambiguous and changing nature of the roles which these individuals and organizations assume with each new project. A major source of uncertainty is the capital investment budgeting process at the national level. In part due to established procedures for determining the budget each year (a task of the 33 member cabinet), and in part linked to the uncertainty associated with very important foreign loan funds which finance some of the projects, predictions of annual and long range transportation sector and individual project budgets is subject to considerable uncertainty.

Other certain factors of the environment include the rate of inflation in general, and specifically as it influences labor, construction material and foreign loan costs. The prediction of the cost of a project, then, is also uncertain (tending to be understated). This in turn is dependent on predictions of construction timetables (also tending to be understated). And construction timetable predictions are directly tied to often unanticipatable problems encountered during construction, delays due to unavailability of materials and the annual flow of funds to the projects. The extent of the uncertainty in the environment is a significant characteristic, and will be an important factor in the adaptation of a programming process.

Several other characteristics of the current project development and implementation process will likely influence the form of programming which will be adapted. Currently, it seems that there is little opportunity for the systematic comparison of the impacts of potential projects, and annual budget allocations for the continuance of projects appear to be linked to a number of political, social, and economic factors -- with comparative systematic impact analysis not playing a significant role. One of the first and more fundamental impacts of any adopted programming process may in fact be to provide a framework and impetus for such analysis.

One potential obstacle facing a programming process is what appears to be a tendency to disperse transportation investment funds over the entire slate of projects, rather than concentrating these funds in an effort to more quickly complete a few projects. The political and institutional factors which influence the size and composition of the slate make their impact here also.

The pattern of responsibility for the various activities which are elements of developing and implementing projects will also be a factor in a programming process. The flow of allocated funds to specific projects may be channeled through several government ministries and subordinate organizations -- largely due to the fact that the responsibilities for a project may be in any one of several government organizations. While the Gorernorates are responsible for the implementation of a majority of the projects, Transportation Planning Authority, the Egyptian Railway Authority and agencies within the Ministry of Housing and Reconstruction are also currently directly involved in urban transportation project implementation. The large design and construction firms also are active forces in the implementation of major projects, at times to the point of assisting in the supervision of the implementation effort.

Three additional characteristics of the current process will be briefly mentioned here. Several projects have been delayed by the uncovering of unanticipated underground utilities. This event occurred primarily in projects under construction in the older, central section of Cairo. This technical problem may result in project redesign or utility relocation, both of which cause delay.

There are indications that on occasion there is some lack of complete coordination between agencies which propose to undertake public service projects (e.g., transportation and utilities). They may also lead to a situation requiring design changes and/or delay when such projects interfere with one another.

Finally, the shortage of housing in Cairo appears to make its affects known in transportation project development (an implicit desire to design projects so as to minimize the amount of resident relocation) and implementation (delays caused by the often lengthy process of expropriation).

The work of the Cairo and MIT teams in describing and analyzing the urban transportation project environment concludes with a series of observations -- briefly summarized above -- which provide a framework into which an adapted programming process must be fit. While the project development and implementation analysis was proceeding, work had also been initiated in Cambridge to review existing and proposed U.S. based programming methodologies. This work; the second of three elements of the urban transportation project programming endeavor; and its links to the observations made during the project review, is discussed below.

CONCEPTS OF PROGRAMMING

Project programming is said to be the activity of staging projects over time. The need for staging usually arises from the limited budgets available. Therefore, project programming has been viewed as a problem of budget allocation. Budget allocation is a problem of search for that combination and sequence of projects which achieve maximal benefits with a given budget. Typically, optimization techniques are called upon, such as mathematical optimization procedures (linear programming, integer programming, dynamic programming, etc.) or heuristics (marginal analysis, for instance). These optimization techniques differ with respect to their capabilities of handling some of the properties of transportation projects; benefit interdependencies, mutual exclusivity, contingency,

and indivisibility. Not surprisingly, as the level of sophistication increases the feasible problem size decreases in terms of the number of projects and the number of constraints. In North American practice the large number of both projects and constraints usually excludes techniques other than linear programming and heuristics.

The fact that transportation projects always are part of a network is of basic importance. Contemporary thinking in network equilibrium theory suggests that any network change causes changes of traffic flows in large parts of the network. Since methods capable of analytically determinant network equilibrium are not operational, assignment algorithms are usually applied which provide a solution through iterative approximation. Yet the linkage of programming with trip assignment creates a dilemma arising from simultaneity;assignment needs as input a network configuration while a major criterion for setting up the network configuration must be imputed by the assignment. Opening up the perspective onto the level of transportation systems analysis, and considering contemporary thinking as expressed by the general equilibrium theory(of which the transportation systems paradigm is a version) enforces recognizing further complexity. Incorporating the time factor into consideration, for instance, reveals that notions like mutual exclusivity, contingency, and independency are ambiguous, unclear, maybe even misleading. Of course, a formal integration of programming into a land-use/transportation model poses formidable problems.

It has come to wide recognition that the attributes attached to projects in terms of benefits and costs are not known with certainty,

nor is the determination of some of the items an undisputed matter. The value of travel time, for instance, has always been a subject for debate. It can be stated that benefits and costs are estimates, based on experience and assumptions. The projects in Cairo are not an exception in that respect. The fact that transportation projects are long lived constitutes a major source of uncertainty because estimating future benefits and costs requires assumptions to be made as to the future social and economic characteristics of the city. Furthermore, since the budget is a constraining factor to project implementation, assumptions are needed regarding future budgets. Recognizing the variety of uncertainties gives rise to methodological questions which are apt to reach the level of the metaprocedure perspective: what efforts should be undertaken to reduce uncertainty?

A project program specifies the sequence of projects to be implemented during a long period of time. Since the departure from the master plan philosophy, grounds have been missing for solely assuming that projects scheduled for the far future will actually be implemented. A variety of reasons may cause abandonment. The uncertainty involved in future decision puts emphasis on the decisions on the first stage investment, and at the same time, necessitates examining the first stage investment in the light of various future courses of action. In other words, programming must balance short-range considerations with long-range concerns.

While there exists general agreement that the intent of programming is to make the best use of the monies available, assessing a project's desirability has become a very difficult undertaking. Programming has essentially been viewed as a search problem. But recognizing the limitations

of economic analysis, and rejecting the notion of a single desirability measure adds a second dimension: evaluation.

In summary, then, transportation project programming is a richly faceted problem. As an area it is only beginning to be recognized in the USA. Consequently a theory of programming is missing which would cover all the aspects, and a comprehensive operational procedure is, of course, missing as well. Operationality for practical use can only be achieved through simplifying assumptions. Because the simplifications always imply omitting some aspects there is the danger to lose responsiveness to matters of concern. In many cases, operationality and responsiveness are in a trade-off situation. We have decided to explore this trade-off by means of a prototype procedure which seeks to explore both the impacts of simplification and the issues to be addressed by programming.

During the study of programming strategies and methods, leading forward the proposal of a prototype method, a series of memoranda were prepared. These papers consider the applicability of various approaches to the Cairo setting, increasingly linking programming features to the results of our reasearch in project development and implementation.

Papers:

-- Programming/Implementation: Brief Statement August, 1977

-- Programming: A Proposal September 6, 1977

-- Programming: Possibilities and Problems, Sept. 6, 1977

-- Uncertainty: An Attempt to Structure the Issue, Sept. 6, 1977

-- Discussion Paper: Programming Options, Oct. 5, 1977

-- The Budget Estimation Problem, Oct. 6, 1977

-- Prototype Procedure, Oct. 29, 1977

-- Urban Transportation Project Development and Implementation in Cairo, December 1977

SECTION II

TRAFFIC SURVEYS

The primary objective of the traffi summary element of the urban transportation project is to enable Ministry planners to assemble and use a transportation data base, and to feed our programming method. Traffic volumes and travel behavior in the greater Cairo area were monitored on a prototypical basis so that standard survey procedures, analytical methods and documentation could be developed for Ministry use. Replication of the surveys in the future will provide a valuable data base from which analyses and projections can be made. It is anticipated that the project will provide a number of guidelines and tools necessary to effectively apply the data in designing and evaluating alternative actions in the transport sector.

1. CRITERIA SELECTION

As originally proposed, an objective of the first year of the project was to conduct reasonably comprehensive traffic volume and travel behavior surveys for both private vehicular and transient trips. In April 1977, members of the project team from Cairo University, the Transport Planning Authority and MIT agreed upon a change in the work statement to include comprehensive speed and delay studies for arterial and collector streets forming key segments of the street network under study. In addition, it is now assumed that a final product of the project will be an on-site (Cairo) operational assignment model which can predict traffic flows and speeds given alternative forms of the Cairo street network.

Primary survey criteria agreed upon by the participants, in addition to the criterion of transferability, were as follows:

a) The O-D Survey was to be concentrated on private and private for hire vehicular traffic. In addition to the limitations imposed by our resources, this constraint on the breadth of the study was imposed to allow focusing on the segment of greater Cairo vehicular flows which would provide the greatest component of future traffic congestion. Although it is estimated that at present less than 10 percent of Cairo person-trips are taken by private automobile, ownership of such vehicles is increasing rapidly and with this increase comes the prospect for greater future congestion.

b) In order to provide the greatest probability that the results of the survey and subsequent analyses will be truly beneficial in solution of current transportation problems in Cairo, the comprehensiveness of any data collected was considered essential. Hence, given the size and cost of the data collection effort proposed, the wiser course appeared to be the completion of a comprehensive private vehicular survey as opposed to a less than comprehensive public transit or mixed-mode survey.

c) It was also desired that the O-D and other data collected as adequately refined, sufficiently detailed and of a reliable enough sample size to allow the use of a sophisticated assignment model package. This criterion required for a city the size of Cario, that enough volume and O-D stations be established to allow use of a large number of zones, nodes and links, which in turn would allow the model to more accurately describe reality.

Based on these criteria, the survey effort was established with two principal parts. First, a preliminary traffic volume and O-D survey was performed in order to train supervisory personnel for the larger survey,

and also to obtain data with which to analyze the 6th October/Tahrir/Galaa bridge problem. The analysis of the resulting data allowed the staff to gain familiarity with the tasks which will largely be computer-performed during the comprehensive survey. (See also Section 5 below). Second, the main survey was conducted utilizing 267 counting stations, roughly 96 percent of which were also O-D survey stations.

3. SELECTION OF THE STUDY AREA

The area to be covered by the origin-destination survey and traffic counting program was selected in order to satisfy several criteria. Participants in the selection included members of the project team from the Transport Planning Authority, Cairo University and MIT. Also included were representatives of the Ministry of the Interior interested in application of the resulting data to solution of intergovernate transportation problems.

The criteria used in selection were a) inclusion of all congested portions of the greater Cairo metropolitan area, b) inclusion of all major streets handling circumferential traffic, c) inclusion of all major trip generators, d) inclusion of all crossings of the Nile likely to be used for intra-urban trips, and e) formation of the study area boundaries so as to coincide with natural or man-made boundaries.

The criteria listed above were used in the selection of the "Enlarged Central Area". In the presence of preparing the O-D Survey, it was found that a number of external trips were made to and from villages within 10-20 Km of the Enlarged Central Area Boundary, which were not of the same nature as intercity passenger or goods movement. In addition, anticipated

growth in the Cairo area is likely to transform many of these villages surrounding the study area into suburbs, with attendant growth in travel. For purposes of projecting future growth and translating impacts of growth in a way that contributes to a national planning process, a study area and zonal system which contains potential growth areas was seen to be desirable. Hence, a large area peripheral to the central area was delineated, called the "Greater Cairo Metro Area".

3. DATA COLLECTION

3.1 Selection of Origin - Destination Zones

Zone boundaries were selected so as to provide homogeneity of socio-economic status within each zone, to coincide to the greatest extent possible with local administrative boundaries and to provide consistency of land use within each zone.

3.2 Station Location

Stations for the origin-destination interviews and traffic volume were located so that all major traffic flows within the inner or Enlarged Central area and to and from this area would be sampled. All O-D interview stations were established in conjunction with a traffic counting station so that each individual sample size could be established and expansion factors determined. Traffic counting stations were established on all "major arterial" and arterial streets. Many collector streets were also counted, and those that were ignored were located such that accurate volume estimates could be obtained by comparing volumes on connecting streets.

The O-D interview stations were positioned to make maximum use of the traffic light stop cycles, resulting in minimal delay of traffic. In cases in which traffic lights were not used, traffic controllers directed

a sample of passing traffic into a clearly delineated survey lane. A total of 267 stations were established and used, the majority of which included both interview and counting functions.

3.3 Development of Survey Forms

Two different forms were developed for survey use:

a) Traffic Volume - designed to allow counting of all the major types of vehicles, and in addition to provide destinction between private and public transit buses, among the three principal types of public transit vehicles, (streetcars, buses and trolley buses) and between private autos and taxis. For a complete listing of vehicle types counted, refer to the working paper on documentation of traffic volume and travel behavior.

b) On-Route Interview - origin/destination and trip purpose are the key data elements desired. In addition, vehicle type, occupancy, governate of registration and over-night parking location were also asked. Once again, for a complete listing of information obtained, refer to the working paper.

4. SURVEY EXECUTION

Following selection of survey station locations based on the network to be studied, manpower requirements were determined by providing a) sufficient traffic counting personnel to allow counting of 100 percent of the traffic and b) sufficient O-D survey personnel at the survey locations to allow a reasonably consistent sample size to be taken.

A total of approximately 780 personnel were assigned to 267 stations, an average of 2.6 per station. In addition, a reserve or backup group of 50 was used to relieve other surveyors, who became tired, and to provide additional manpower where and when needed.

Due to the large manpower requirement, it was deemed desirable to first train a group of supervisors who could in turn handle a portion of the training for a group under their control. 36 supervisors and 34 other students were given lectures and a demonstration of the survey and interview technique, and participated in a preliminary survey centered on approaches to the 6th October and Tahrir bridges. Three hours of surveying were conducted on April 14th between 7 and 10 AM and guidance and supervision were provided by Dr. El Hawary and other members of the Cairo University team and the local Traffic Research Unit. The results of the initial survey were used to make minor adjustments in the survey procedures, and to suggest further refinements in the logistics for the larger survey.

The main body of surveyors and supervisors were divided into 10 groups. Surveyors were assigned to stations based on traffic volume estimates. Each surveyor was given a copy of a diagram of his station (see Exhibit B), copies of the survey forms and an instruction sheet explaining proper methods for traffic counting, or O-D surveying. A total of approximately 16,000 traffic counting, and 50,000 O-D survey forms were used.

On April 16th all supervisors and surveyors were given a series of lectures explaining the process and giving them administrative instructions. On the 17th of April, the day prior to the survey day, all the supervisors and surveyors were assembled and given a pep talk. Each of the 10 groups were then assembled and supervisors for each survey station explained procedures, answered questions, etc. Each of the 10 groups was assigned a bus which would distribute each of the members of the group to his respective station. Each bus driver was given a map which detailed the route to be taken.

Following the general meeting of April 17th, the surveyors were taken to the stations in the same fashion that would be used the next morning

on the day of the actual survey. In the field each supervisor pointed out each surveyor's location, indicated which traffic flows to count or interview, answered further questions, etc.

On the day of the survey, a survey control room was also established to facilitate dispatching of additional surveyors (from the 50 held in reserve) via vehicles to stations in the field. Each vehicle was responsible for checking regularly with specified stations in order to minimize data lost due to lack of personnel, supplies or from any other source. At the end of the survey day at 10 PM the groups were returned to the starting point, forms and materials were collected, forms were checked to make sure that results from each station had been turned in, and then the groups were released.

5. DATA PROCESSING DESIGN

Coding for the origin destination and overnight parking was accomplished by subdividing the large-scale map of the Cairo area into major zones or neighborhoods. Each of these major zones was divided into two to seven sub-zones (see Section 3.1 above "Selection of Zones"), total 108. A map of each major zone was prepared, detailing its sub-zones and the local street system. The coders, working in pairs to minimize errors and to combine knowledge of the city, obtained the correct large-zone map and determined the correct sub-zone by pin-pointing the street address. The use of a number of smaller large-scale maps obviates the need to have a number of people simultaneously pouring over a single very large map.

At the completion of key-punching of the data at the scientific computational center at Cairo University, data processing began. The key outputs are tables of traffic volumes that can easily be associated with geographic locations,

and origin-destination matrices. It is planned that results will be assembled and presented in several formats. The formats are described below in Sections 5.1 and 5.2.

5.1 Traffic Counts

a) Volume of each vehicle type collected by 10-minute time interval, summed over each hour and over the survey period. Also hourly volume of each vehicle type expressed as a percentage of total volume counted during the hour. A table has been created for each traffic counting station, along with a summary table for all stations.

b) Similar to a), traffic volumes are expressed in passengar car equivalents (PCE). PCE's used are as follows:

Vehicle Type	PCE
Private car	1.00
Taxi	1.00
Microbus (Van)	1.25
Non-Transit bus	2.00
Transit bus	2.50
Tram	5.00
Trolley bus	3.50
Pickup truck	1.50
Truck	2.50
Tractor-trailer	4.50
2-wheeled Vehicle	0.50
Animal Cart	8.00
Human-powered cart	2.00

5.2 Street Interview Survey

a) A summary table of occupancy rate by selected vehicle types (private auto, taxi, van, private bus) taken over most of the stations and all hours of the survey.

b) A summary table of trip purpose by time of day for all origins and destinations. A summation of private auto, taxi, van, private bus and bicycle/motorcycle is used. Table will display volume of trips (number of vehicles x occupancy rate), and the percentage of total trips for each hour represented by each trip purpose. Totals for each hour (over all purposes) and for all hours of the survey are given.

c) A summary table of trip purposes for private cars and taxis for all origins and destinations and for all hours of the survey. Totals for each of the two vehicle types (over all purposes) are given.

d) Number of vehicles stopped for interview(s) by vehicle type and hour of day over all O-D for each station. The summary table provides the same format, but includes all stations.

e) The sample size of vehicles stopped for interview(s) by vehicle type and hour of day for each O-D station. There is also a summary table of all stations.

f) Expanded (using results from 5.2-e) O-D matrices for each vehicle type and each hour of the survey period (i.e. each matrix represents expanded O-D information for one vehicle type for one hour). There is a summary matrix for each vehicle type for the entire survey period.

g) Expanded O-D matrices by PEC's for each hour of the day. Summary matrix for the entire survey period.

h) Number of vehicles parked overnight by zone for all private vehicle types for each hour of the day. (Each table will represent one hour). Summary table to show data for entire survey period. Expanded data used.

i) Number of vehicles registered by governate for private car, taxi, van and private bus, pickup truck, truck, tractor-trailer trucks and bicycle/motorcycle for each hour of the survey period. Summary table for entire day. Expanded data used.

width (number of usable lanes), the presence or absence of parking, consistency of adjacent land use, traffic volume, traffic speed and general vehicular mix. A thorough investigation of the Cairo street network under study was conducted in order to identify candidates for link samples. In addition, the street inventory (see Section 8) was conducted prior to execution of the speed and delay survey.

Execution

The survey employed the "Floating Car"technique. That is, a survey car was used to drive the selected routes in order to obtain representative travel times for various levels of traffic volume. In the "Floating Car" technique the driver attempts to approximate the median speed of traffic by passing as many vehicles as pass him. Two observers were assigned to each car, one to measure times and one to register data. In all but one case, one car was sufficient to obtain the minimum of six runs per hour. A total of 11 test cars and 22 observers (excluding drivers) were employed.

In order to provide traffic volume data coincident with the speed data collected by the test car, simultaneous traffic volume counts were made for five minute time segments in the same manner that volume counts were collected for the larger survey (see section 4 , above). A total of 54 personnel were used, including 6 counters who acted as substitutes and relief counters. The speed runs and volume counts were conducted during the morning and afternoon peak periods, as well as during off-peak hours.

7. TRAVEL TIME SURVEY

The travel time survey was conducted in order to measure all forms of accessibility to the down-town area of Cairo along the most important radial

axes. The CBD was represented by Ataba Square and as the most important radial axes, the following routes were chosen:

From Ataba Square to
- Heliopolis
- Kolapha El-Rashidieu Mosque
- Embaba Bridge
- Boulah El Bakrour railway crossing
- El-Ahreu Street (Giza)
- Maadi
- Shoubora El Masallat Square
- Heliopolis-Roxy
- Shoubra

The survey was performed by engineering students travelling by car on these routes. Travel times were recorded on prepared forms. Prior to the survey test-runs were conducted. Monday, 18 July 1977 was chosen as the data of the survey since Mondays appeared to represent average transportation conditions. The measurements covered the period from 7 AM til 4 PM.

Since travel time was recorded on various points on each route, it was possible to process the data into travel time isochrones. Each isochrone displays the points that can be reached from Alaba Square within the time specified by the isochrone. Three minutes interval separates one isochrone from the other. Thus, the isochrones documented in form of maps give a very detailed picture of the true accessibility from and to the CBD via the main axes.

3. STREET INVENTORY

In order to conduct accurate analysis of the Cairo street systems, it was necessary to inventory the street characteristics. This inventory assisted the studies of the speed and delay relationships on different types

of streets, and the two efforts resulted in a reasonably complete description of the road network.

As mentioned earlier, the study area was divided into 11 zones; for each of them a detailed map was prepared. A team consisting of 3 engineering students and one person for traffic control was sent to the zonal areas in order to collect the data on previously prepared forms.

Specifically, the following prime data was collected for each link:

- number of usable lanes
- number of parking lanes
- type of parking allowed
- total width of the link
- width of link usable for traffic
- number of access roads

These data were documented in tables and some 11 major streets were processed in the speed and delay study so that it was possible to categorize facility types and capacities under various conditions of operation.

9. MICRO ANALYSIS OF CAR OWNERSHIP

Car ownership is one of the most important parameters which affect trip-making, both in urban and intercity travel. Unlike cities of the U.S. and Western Europe, Cairo cannot be regarded as having levels of car ownership which are stable over time and represent the saturation of current demand. The matter requires special analysis. The aim of this introductory analysis is to find a mathematical model which relates car ownership with parameters representing social and economic characteristics of zonal populations in the Greater Cairo Area. Input data for construction such models are collected and are as follows:

Social and Economic Data

The necessary socio-economic data for this analysis is being made available from a census carried out by CAPMAS (Central Agency for Public Mobilization and Statistics) in November 1976. The economic data are based on a survey conducted in 1975 in the 26 districts of the metropolitan area. The social and economic factors which affect the level of car ownership can be classified into four groups:

1. Income levels of the residents
2. Demographic data, including sex, age, family, size, etc.
3. Economic activities in each zone
4. Provision of auto-associated facilities, such as roads and parking

The following data have been selected and collected from the census mentioned above for each administrative district in the Greater Cairo Area.

- Area of the administrative district (shiaka)
- Employed/unemployed population (6 years of age and over)
- Inhabitants by age (less than 12, 12 to 64, 65 years and over)
- Number of males and females
- Level of education (both male and female separately) by categories: illiterate, literate but less than grammar school graduate, grammar school graduate, high school graduate.
- Number of dwelling units by number of rooms
- Housing density (persons per room)
- Average income and average personal expenditure on transportation and communication in 1975

Method of Analysis

Multiple regression analysis will be used to analyze these data. The factors affecting car ownership must be expressed as variables available to

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the analysis for present and future dates. Zonal variables selected are as follows:

X_1 Population density (zonal population/zonal area)

X_2 Percentage of educated population (zonal literate population/total zonal population

X_3 Average per capita income (stratified income figures are being sought)

X_4 Percentage of income spent on transportation

X_5 Employed Population

X_6 Distance between the zonal centroid and the central business district

These are the basic variables to be used to begin regression analysis in the near future. More refined data will be obtained later on.

SECTION III

TRAVEL ANALYSIS

1. A STUDY OF TRAFFIC FLOWS ON THE 6TH OCTOBER AND TAHRIR BRIDGE AXES

Introduction and Objective of the Study

The traffic problems in Cairo are similar to those of many of the large cities of the world. Auto ownership in Cairo, however, is lower than the rates in cities of developed countries. Whereas in Cairo it does not exceed 13 per thousand inhabitants, it reaches 300 to 450 per thousand in Europe and the United States respectively. At the same time, 27% of the total Cairo land area is road area -- a figure which is typical among major developed country cities. This is an indication that the road network of Cairo is capable of accomodating present traffic volumes. Furthermore, increased traffic volumes can possibly be accomodated by the existing network provided traffic control is planned carefully. This refers in particular to traffic corridors which currently suffer from considerable congestion at peak hours.

Due to the fact that traffic across the Nile is subject to long delays, a committee of officials in charge of traffic studies, planning and implementation was formed by order of the Deputy Minister of Interior. The purpose of this committee was to study the traffic problem at the western entrance to the Galaa Bridge, at some axes within Cairo and primarily on the Ramses Street axis and to suggest solutions. The study was a contribution of the CU/MIT Research Group, making use of the data collected in the small-scale pilot study survey which was conducted on Thursday, April 14, 1977.

The intent of this study was to analyze traffic in the area of the 6th of October (Ramses) Bridge and the Tahrir Bridge. The objective was to determine the traffic characteristics on these bridges and on the important intersections of the main traffic axes, so as to achieve improved flow and safety conditions:

Data Collection, Processing and Analysis:

As previously mentioned, use was made of the data collected in traffic counts and interviews gathered in the test survey. Twenty stations were selected for counts and interviews in the area and 4 more stations were chosen on the bridge for traffic counts only.

The survey was conducted during the 'peak hour' between 8:30 AM and 9:30 AM. After completion of the counting and questionnaire procedures, tabulation, classification and analysis of the collected data was ready begin.

For purposes of analysis, origins and destinations in the city were zoned into six districts:

- Downtown
- Dokki, Agouza, Zamalek
- South Cairo, east of the Nile
- Giza, Pyramids
- North Cairo, east of the Nile
- Kit Kat, Embaba

Total traffic flow matrices were then produced. A trip assignment of the origin-destination matrix indicated reasonable representativeness of the samples selected.

Outline of Alternative Proposals and Analysis Elements

Six alternatives were tested to identify problems and propose solutions. The analysis of each alternative included the following element:

- Assignment of flows from zones West and East of the Nile to the various links of an alternative in accordance with the corresponding travel paths.
- Comparison of link capacity to assigned volume of traffic

- Analysis of new situations which may arise at important intersections resulting from the new assignment, describing the advantages, disadvantages, and feasibility.

Conclusions drawn from the analysis were as follows:

- The 6th October Bridge on and off ramps are now completed on the West side of the Nile, thus permitting their use according to their original design. This is particularly important because the Western end of the bridge lies in an area with considerable trip operation.
- Delay at the Galaa Square intersection during peak hours is unacceptable.
- Tahrir St. between the Galaa Bridge and Saad Zaghlool Square offers spare capacity in the form of unused lanes.
- Traffic using Zamalek Bridge from Guiza to Zamalek encounters some bottlenecks
- Operating Galaa Bridge in both directions would not create a reduction in delay time at western Galaa Bridge Square.
- Changes in the operation of A. Riad Square would create bottlenecks additional to those already encountered.
- The operation of the temporary Eastern ramp Abd-el-Moneim Riad Square for traffic from Giza to Cairo would generate traffic volume which would far exceed its capacity, and additionally create the risk of traffic queuing on the ramp.

As the optimal solution for improved traffic flow at present, on the 6th October, Galaa, and Tahrir Bridges axes, it was proposed that:

- Traffic be permitted to travel on the 6th October Bridge in both directions from the Agricultural Museum to the ramp from Sarai Guezireh St.; the ramp to be used as an off ramp for traffic from Guiza to Zamalek; the remaining part of the Bridge to the two temporary ramps on the Eastern end to be used for one-way traffic coming from Cairo to Guiza or to Zamalek.
- Traffic be permitted to move one-way on Galaa Bridge axis and Tahrir St. up to Saad Zaghlool Square, for trips from Guiza or from the 6th October Bridge via the Sarai Guezireh ramp and one-way to Gabalaya St. Cairo.
- Traffic be permitted to move in both directions on Tahrir Bridge.
- One-way operation of Gabalaya St. between Exhibition St. and Tahrir St. for traffic moving to the Tahrir Bridge.

In accordance with this proposal:

1. a section of the planted area surrounding the Saad Zaghlool statue should be removed to allow the smoother flow of traffic going to Tahrir Bridge.
2. 150 meters of the median island of Tahrir St. between Galaa and Tahrir Bridges should be removed and this part should be channelized to facilitate the merging of traffic prior to its arrival in Saad Zaghlool Square.
3. the Tahrir Bridge should be rechannelized to provide 3 lanes for traffic moving from Guiza to Cairo and 2 lanes for traffic moving in the opposite direction.

Conclusion:

The intent of this study was to analyze traffic moving east and west over the Nile River across the 6th October and Tahrir Bridges. The research team conducted pilot traffic counts and origin-destination surveys so as to determine the volume and direction of the traffic crossing the Nile in this area and also to train the survey team in a first test survey. The team tabulated and analyzed the data collected. Their findings were a set of solutions to the traffic flow problems which existed at the approaches to these two crossings of the Nile. These solutions were successfully implemented.

2. EGYPTIAN CAPACITY STANDARDS

Development of capacity standards for roadways in Cairo was performed subsequent to the speed and delay surveys documented in Section II-6, above.

The data were plotted displaying speed versus traffic volume for the streets surveyed. Standard regression analyses were made to obtain the relationships of best fit to the data.

The most important application of these relationships in the context of the urban transportation project is to derive speed/volume measures used in the traffic assignment modeling process. The most common form of input, as in the case of the UTPS package, is to specify practical capacity and free-flow speed for links of various width, with various adjacent land areas and of various configurations (one or two way arterials with or without parking).

Figures 1 and 2, which indicate typical speed vs. volume and delay vs. volume relationships are provided to indicate the manner in which free flow speed and practical capacity are derived. Practical capacity is defined as

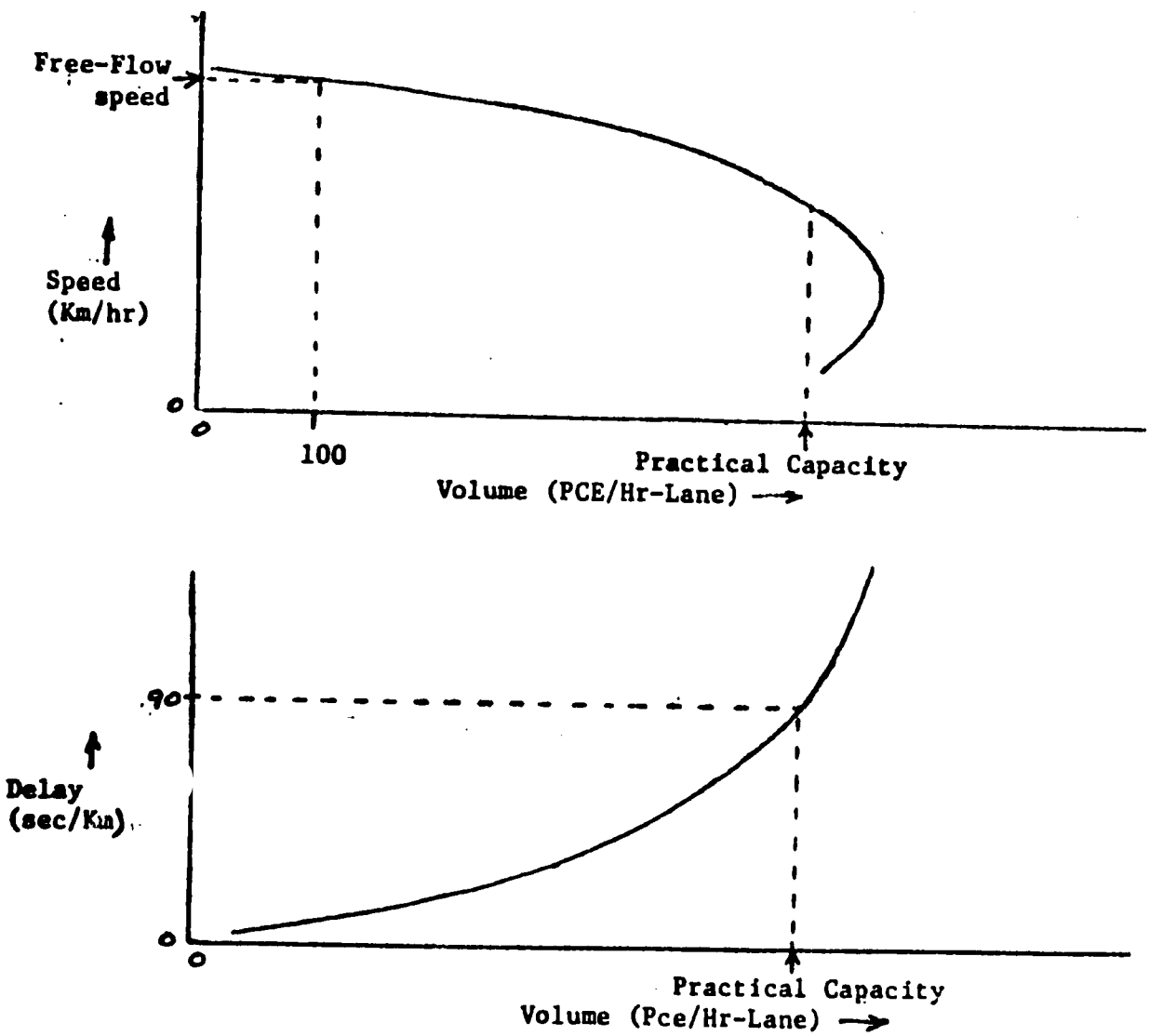
link capacity at which average delay of 90 seconds per km is incurred in the case of main arterials with no parking.

For other arterials with parking, practical capacity in the volume at which average delays reach 140 sec/km. Free flow speed is defined as average speed at volumes of 100 P.C.E.'s per hour per traffic lane.

For practical capacities and free-flow speeds derived for both the test links and for the general Cairo context, refer to the working paper by Dr. M. Owais,"Speed/Flow and Delay Time Measurements in Cairo.

Figure 1

Main Arterial



3. TRAFFIC ASSIGNMENT MODEL SELECTION

Introduction

A principal tool used in travel analysis is the traffic assignment model. This model allows the analyst to simulate a city street network, impose a group of trips upon the network and calculate either trip-specific or aggregate travel time or distance data. The input data, or record of daily or hourly tripmaking is prepared in the form of an origin-destination matrix. Each cell of a matrix of this type indicates the number of trips during the designated time period that occur from an origin to a destination, e.g. from a zone "A" to a zone "B". A separate cell indicates trips from "B" to "A", and thus trips in both directions between every pair of zones in the city are portrayed.

The first stage in the use of the model is to calibrate it so that when present-day origin-destination records are provided as input, the output is an accurate representation of present-day traffic volumes on the major streets. The second stage of model use basically consists of predicting changes in traffic congestion and travel times given input from forecasted future origin-destination travel demand based on a number of factors and/or changing elements of the network, such as adding capacity to streets or making certain streets one way.

The Urban Transportation Project will use both forms of the model application, the first as a component of programming methodology applied to major transportation projects and the second applied to short term solutions of present-day traffic congestion.

Model Selection

Selection and implementation of an appropriate model for project use has required a multi-faceted approach. The initial objective of implementing identical programs at Cairo University and MIT was modified due to the fact that there presently exists no program which will operate on both the ICL computer at Cairo University and the IBM machine at MIT.

At C.U., a program designed by ICL and David Abraham and Associates is being implemented. At MIT, The Urban Transportation Planning System (UTPS) developed by the U.S. Department of Transportation has been installed and will be used to do analyses parallel to those performed in Cairo. In support of the efforts at C.U., the project has been investigating the possibility of operating the UTPS program on one of the two IBM machines located in Cairo outside the University. Such an application would also require that changes be made to the program. This possibility is currently being pursued with the Department of Transportation and IBM.

Since these packages each contain various forms of the assignment model, it will be possible to apply several of them. Our preparation permits the use of alternative trip paths and capacity restraints.

4. NETWORK CODING

Application of a traffic assignment model required that the physical road network of the study area be formalized by defining the links and nodes which represented the street network. The sub-zones into which the study area was divided were connected to the network by imaginary links

between the zone-controls and the adjacent nodes. The zones which surround the study area, as well as all the governerates of Egypt were also connected to the coded network by imaginary links.

Each computer package considered (see Section III iii, above) specifies the technical requirements for coding. In order to provide flexibility regarding the computer package to be used the nodes were coded serially. In particular the main intersection of Ataba Square was given number 1. Beginning with this node all nodes were assigned sequential numbers. Should more than one traffic assignment model package be used, serial coding allows for comparison of the results in an efficient manner.

Application of the assignment model at the Urban Transportation Planning System (UTPS) requires that two restrictions be observed. First, the controls must be coded serially beginning with number 1, and second a node may not consist of more than four links. In order to meet the first restriction, the serial coding numbers of the nodes previously prepared were changed into four digit numbers i.e. the node number one became node number 1001, etc. In order to meet the second restriction, intersections having more than four links were divided into two nodes connected by a "zero" link. The coded network consists of 393 nodes and 696 links. In addition to that there are 338 imaginary and "zero" links. The coded network is the one essential input to the assignment model, the other being the origin-destination matrices. Having prepared both these inputs, the assignment model can be operated so as to examine and analyze alternative network configurations.

A LOOK AHEAD

This has been a productive year. We have completed a traffic and travel behavior survey, supported its analysis with specialized studies adapted to Cairo conditions, and documented the activity for replication by the government. Advice emerging from these studies on the 6th October-Tahrir Bridge axes has been implemented by the government with conspicious positive results. We have completed a project development survey and have produced an introductory analysis of project development and implementation in Cairo. Our review and adaptation of transportation programming method is moving steadily into place as a focus for the contribution of our other work.

At the same time, these months have been important as preparation for the steps ahead. Perhaps most importantly, they have served to cement agreeable personal ties among the members of the two national teams, instilling understanding and respect for each others' capabilities.

We have learned a great deal about the use of available computer system components in both countries. We have solved some of the problems of obtaining the most usable software and developing viable relationships with computer staffs. The year has also been a useful experience in mobilization for large scale survey. The Cairo team has performed this task very well, demonstrating that the project resources are up to high levels of performance in this respect. We have also learned a good deal about the constraints and benchmarks of the project development process that will be very useful for the creation of programming method.

Relating these experiences to the next phase of research makes the value of this inertia which we have gained very clear.

The transit surveys for accomplishment in the coming year are supported by the demonstrated capability of the Cairo team in survey mobilization. The software packages being installed for the analysis of this year's survey also contain programs for the analysis of next year's. Project participants have become experienced through the last year in the tasks of data processing and analysis. Associations with appropriate officers of the related agencies (especially the Cairo Transportation Authority) have been made along the way. We already have volume counts of transit vehicles through this year's survey.

Our proposed projections of vehicle trip-making into the future are aided by the fact that we will have prepared the static trip generation levels and origin-destination matrix. The computer program packages being installed in Cairo (already installed at MIT) include the features required for this analysis. We have made useful contacts in the national statistical organization for acquiring the necessary data on population and employment distributions.

To move more directly into the programming task, we have a draft prototype programming method paper presently in hand and being refined toward a role as the focus of this activity. The completed project development analysis paper is a source of input to this task.

Our tentative interest in auto ownership during the last year has produced a basis for continuation. The data is in hand to begin micro-analysis of auto ownership as a function of social and economic characteristics. As to the larger scale industry and important determinants of auto ownership, survey has indicated the general dimensions of the problem and produced some associations and some data for further pursuit.

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III.2

URBAN TRANSPORTATION PROGRAMMING: PREPARING THE PROGRAMMING PROTOTYPE PROCEDURE FOR CAIRO

BY

THE M.I.T. URBAN TRANSPORTATION PROJECT TEAM

INTRODUCTION

This paper describes the nature and intent of transportation facility programming. It also explains the adaptations we are attempting to make in programming technique to enhance its relevance to the Cairo situation. The overall form and special characteristics of the proposed prototype procedure is described.

The prototype procedure is described in much more detail in an 80-page report entitled "Programming: Prototype Procedure" (March 18, 1978) by Donald Keller.

1. THE IDEA OF PROGRAMMING TRANSPORTATION PROJECTS

"Programming" deals with the budget allocation problem; that is with the problem arising from the situation in which there is a set of candidate projects, a limited amount of public monies available, and a need to implement projects so as to maximize the resulting benefits. In its pure form programming the allocation of budget is solved by an optimization algorithm. In that form programming has attracted considerable attention in the theoretical literature. At the practical level, however, programming exposes many problems of decision and achievement; issues of delay and obstruction in the building of transportation systems. As a result, the scope of ultimate concern here is the entire project development process.

Programming has a potentially very significant role in transportation. As applied in the United States it has been applied to a serious problem: Active planning over the last two decades has generated an enormous number of projects which is far from being matched by monies available in the near future for building them. Each U.S. State's Department of Transportation;

then, faces the problem of how to sequence projects. In Cairo, similarly, there is a set of transportation projects the implementation of which is generally viewed as important, yet implementing all of them at once would necessitate that national priorities be shifted mightily toward transportation.

Even in its most limited form, the application of programming to transportation projects, regardless of the country, is not as straightforward as one might wish. The following are the principal reasons:

1. On a purely technical level there is a trade-off situation between the programming problem size (expressed by the number of projects and the number of constraints) and the capability of dealing analytically with issues such as the special forms of interdependency between projects (for example, the way completion of one project affects the need for another one by changing the travel demand pattern).

2. The long lifetime of transportation projects necessitates estimating costs and benefits that will accumulate over a long period. As a result, project desirability bears some uncertainty.

3. There is usually considerable instability of the programming environment in terms of available budgets and the factors affecting the costs and benefits of projects in future years (such as land use changes and inflation).

4. There are apt to be changes in the opinion of decision-makers about the priorities of projects, resulting in changes in the full group of projects to be programmed.

5. Finally, in U.S. practice, the boundary between planning and programming has become increasingly fluid. Since the programmed disposition of the project is of great importance, it is planned from the start with a view toward that process.

Programming is nonetheless a fundamental requirement. One may say it is always done. The only question is whether it is done systematically or by default.

2. TRANSPORTATION PROJECT PROGRAMMING IN THE UNITED STATES

The Departments of Transportation of the United States are in charge of programming. Much more than applying an optimization procedure is involved. There is first of all the task of keeping information and control over the large transportation network, the numerous projects, and the large amount of ongoing implementation. This is a task of a magnitude calling for management information systems capable of storing information in an orderly fashion and providing easy access to the data compiled. To offer assistance in this, the government has sponsored a substantial amount of research on programming technique.

For a state Department of Transportation, pursuing the objective of allocating its monies so as to achieve maximum benefits implies examining new projects as well as the upgrading of existing sections of the transportation network.

For the latter kind of investment options, the assessment deficiency has been given considerable attention. The quantification of the extent to which an existing facility deviates from a certain standard involves measuring the surface conditions, its impacts on travel costs, its impact on safety, the conditions at the intersection with other facilities must be evaluated. All these items must be given weight in order to arrive at a single measure of deficiency.

As regards the new projects, their desirability must be given some form of expression. There is increasing recognition of the fact that the quantification of the benefits and costs of transportation projects can be a controversial issue, especially if social aspects are considered. Moreover, recent experience has demonstrated that the weights to be attached to the various aspects of desirability tend to be subject to change over time and are not at all the same for the diverse groups of society.

Prioritizing, based on assessment of the deficiencies of existing facilities and assessing the desirability of new projects, is a procedure which requires coping with substantial uncertainties. These uncertainties are getting increasing attention in the literature. It is also necessary to analyze interdependencies between projects. Consider, as a simple example, the case of two bridge projects crossing a river within a few kilometers of each other. The desirability of each bridge, as measured in economic terms, is very much determined by the extent to which it will be used. This, in turn, depends on whether and when the other bridge will be built.

For a U.S. State Department of Transportation the budget is essentially external to the procedure determined by the tax revenues from gasoline sold and other considerations. However, it is the task of the agency to estimate the budget that will be available for expenditures. In recent years it has become increasingly difficult to establish reliable budget estimates, for the factors influencing gasoline consumption show considerable fluctuation and the long-term trends are difficult to estimate. Yet an even more serious source for concern has been inflation which

distorts the purchasing capability of the estimated budget. As a result it has become necessary to recognize the budget as being considerably uncertain. This is unfortunate because programming in the form of optimization is quite sensitive to the budget. The budget acts both as a constraint and as a target.

In spite of all this, programming is a robust activity in the U.S. and, as we might expect, large scale, computer-based equipment is employed by the states for management information systems and as tools for generating project implementation schedules. Such equipment is capable of providing optimal programs including hundreds of projects and dozens of minimal and maximal constraints.

In recent years a new perspective on programming in the U.S. has been emerging. It is based on the union of two observations:

- First, the accumulated costs of the projects ready for construction by far exceed the budget available in the near future. Programming essentially selects a relatively few projects for immediate implementation and postpones the majority of the projects for later implementation. For a variety of reasons, the implementation of postponed projects must be considered quite uncertain. Hence, it is programming that has become the vehicle of decision-making rather than the long-range master plan which was formerly regarded as the main source of guidance.

- Second, U.S. transportation planning has experienced a radical departure from the former long-range perspective and has moved toward emphasizing the short-range. This creates considerable danger in view of the long lifetime of transportation projects.

Based on these (and other) insights, the emerging approach advocates programming as a form of decision-making adjusted to an era of prevailing interests in the short-run but with very important consequences for the long run. Programming has potential to link project-level to system-level concerns and the short-run to the long-run.

Thus far it is the efforts to interpret this viewpoint that have resulted in a framework for conventional programming approaches within which consideration is given to the issues of uncertainty, interdependency and the assessment of desirability.

3. THE CAIRO SETTING

The important fact is that programming in Cairo has to operate in an urban area, implying that the transportation network is very complex per se, and the interrelationships between the supply system and the demand profile are intricate. (Most U.S. programming is for state-wide, intercity use). The issue of interdependency is very apparent It clearly goes beyond the simple example mentioned before, and it involves relationships between the various modes which change over time.

Furthermore, Cairo experiences development in which various processes interact. Population growth from various, shifting sources, urbanization of rural land, growth and structural change of the economic activities, and so forth are all interrelated. The result is that adjustments in social and economic conditions incur dynamic changes. Because of the dynamics involved, the prediction of future socio-economic characteristics is very difficult. Consequently the future desirability of transportation projects bears some uncertainty.

Turning to the decision-making process, there exists at least three central features of relevance to programming:

- There is a fairly definite set of projects awaiting implementation. These projects belong to a "state" by virtue of having received widespread consensus as to their desirability in the decision-making community. The question at stake is: When should each project be implemented?
- The decision to be taken is on the direct allocation of the national budget to projects. There is no fully reliable budget over time for the projects under consideration.
- The decision-making body is ultimately the Cabinet, constituted by all the Ministers. The Ministries of Transportation, Planning and Local Affairs together with other agencies fill advisory roles to the Cabinet regarding transportation matters.

Comparing just these very few characteristics of the Cairo setting with the conditions usually prevailing in the USA immediately makes evident the problems of a methodology transfer: The situation calls for method adaptation.

Much more is involved in adaptation than just tailoring a methodology to the physical givens and the official decision-making. As an extreme, adaptation could be interpreted as redesigning a methodology such that all conditions remain untouched in which it is to operate. That is, the formal and informal functions of all participating agencies remain exactly as they are, the method serving only to expedite and document their actions.

Whether this kind of method adaptation is feasible and desirable are, however, open questions. Under most of the conceivable circumstances a process of mutual adaptation will have to take place; that is, the methodology will be adapted to organizational particularities, individual proclivities, etc. and in turn, engineers, administrators, organizational units, etc. will somewhat adapt to the methodology. In this manner, the institutions are respected, their basic procedures reflecting national realities are preserved, but the budget allocations process is somewhat further rationalized.

Envisioning this kind of process of mutual adaptation, the idea emerges to initiate it with a prototype procedure, rather than with a prematurely polished package, because a prototype procedure can provide the structure necessary to accomodate the physical and decision-making requirements while remaining flexible with regard to the numerous design details.

A programming prototype procedure for Cairo has been developed. It is documented in the form of a working paper. Though subject to modifications, the procedure has reached specificity enough to demonstrate operationality. It will shortly produce transportation project programs.

4. PROGRAMMING PROTOTYPE PROCEDURE

Programming is to prepare for and assist in, reaching a decision. The decisions at stake are investment decisions. In contrast to conventional U.S. programming, in which the objectives of decision are single projects, the prototype procedure specifies projects sets as investment alternatives. Each project set consists of several projects from the state, all sets together amount to the slate. The reason for

specifying project sets is simply that transportation decisions in Cairo will in likelihood, and for good reasons, continue to include more than one project at a time. Therefore, operating with project sets conforms with reality. Further it is the only way to escape an unresolvable complex interdependency problem. Once sets are formed, interdependencies of projects between sets need to be considered but not within each set.

For determining how projects of the slate are assembled into sets, three guidelines are provided:

The first guideline is based on funding considerations: Although a formal budget for the slated projects does not exist, we must assume thresholds in the Cabinet's willingness to spend its resources on transportation projects. Therefore, one estimates an amount of funds which each project set must not exceed.

The second guideline concerns efficiency of implementation. The idea is that the project combinations which cannot be implemented efficiently in the time period should be discarded from further consideration. (Note that no projects are discarded, only particular proposed sets of them.)

The third guideline takes agency and client group interests into account. It is inappropriate that a series of projects all favoring a particular user group, or all stressing the resources of a single implementing agency, be selected. By this means another inacceptable group of project sets are removed from consideration.

Having formulated budgetary feasible, efficiently implementable and politically acceptable project sets, it is then possible to lay out all the possible investment sequences and to evaluate them.

At issue here is not the absolute desirability of each project - this can be a priori assumed because of the reasons mentioned earlier- but rather the focus is on the relative desirability of the conceivable investment sequences. It should be noted that unlike conventional programming, the prototype procedure is in the position to differentiate between sequences, for instance between the sequence A,B,C and B,C,A.

Two forms of evaluation are distinguished: Economic evaluation and functional evaluation. In economic evaluation, the concern is for the system-wide aggregate benefits expressed in travel time savings and travel cost savings. Both the benefits and the costs associated with the investments substantially depend upon future social and economic conditions. As mentioned earlier, these are dynamically changing and therefore difficult to predict;they represent a source of uncertainty. Furthermore, it must be recognized that the implementation of project sets scheduled for the medium or long range cannot confidently be assumed. Therefore, the desirability of a project set scheduled for immediate implementation is not independent from the implementation of the other sets. Further decisions represent a second source of uncertainty. Due to operating with project sets and thanks to a special formalization of the socio-economic factors it was possible to superimpose two - in themselves superimposed - constructs of decision analysis on the investment sequences. As a result, uncertainty can be dealt with in a rational fashion. It should be noted that the prototype procedure is the first real world programming procedure that explicitly and comprehensively deals with uncertainty.

Functional evaluation involves the examination of a variety of impacts and includes the concern for the smaller scale consequences. For the latter the idea is to explore the effects of the project sets on the urban, transport-related activities in the neighborhood of the new facilities, and on the operation of the various modes on adjacent roads and intersections. However, the content must be adjusted to include functional interrelationships between project sets. Examining the traffic flows it is possible to identify important relationships. A project set may shift the flows in a way so as to strongly suggest the subsequent implementation of the one project set rather than another. Thus, aside from assessing small scale and detailed impacts, functional evaluation provides operational meaning to the notions of foreclosed options and favored options which are getting a great deal of attention currently in the literature.

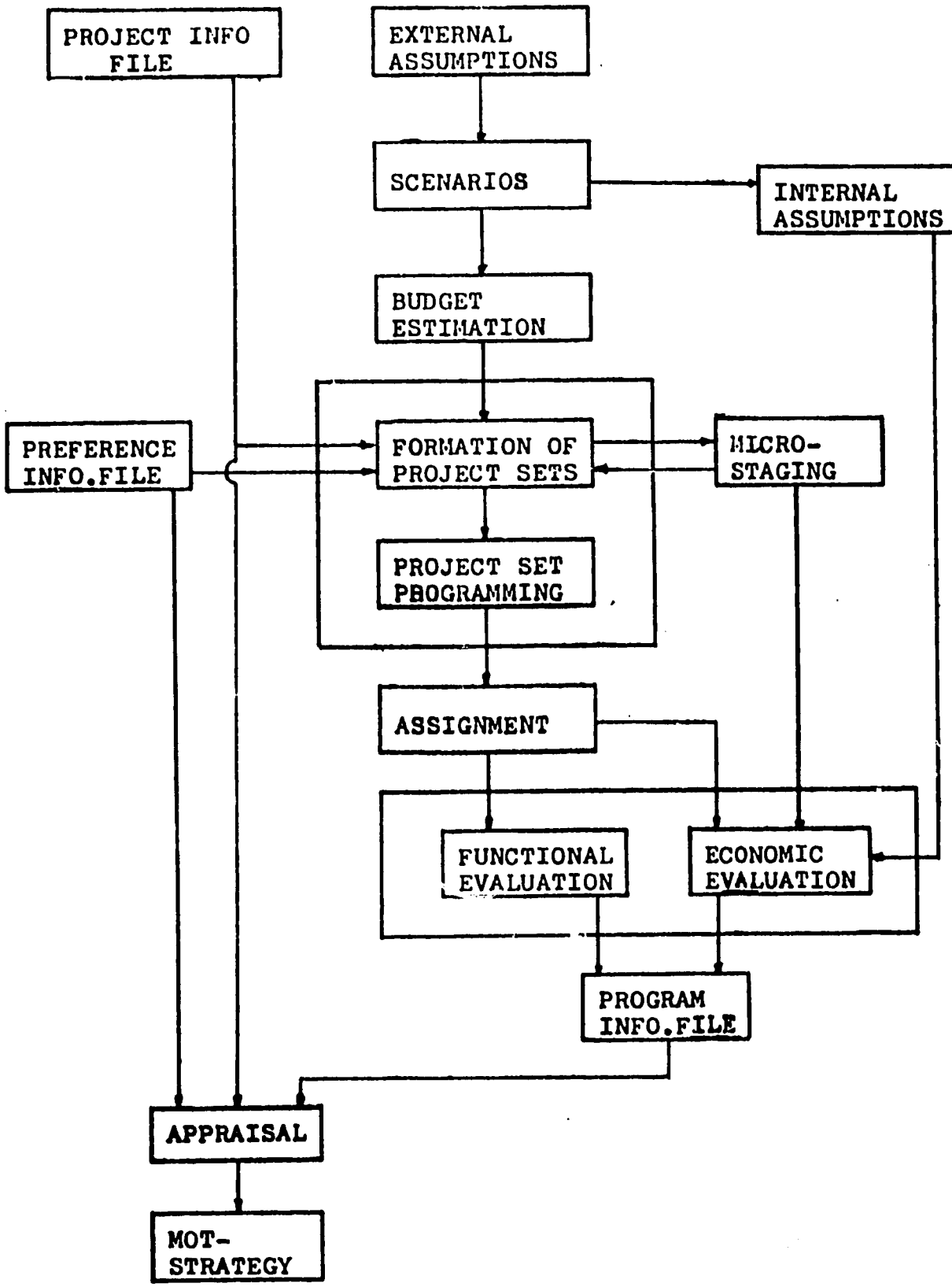
Perhaps most importantly, the prototype procedure does not assume the existence of a single best solution. Most conventional programming methods aim to produce a narrowly defined best program as a result of the use of optimization algorithms. In contrast to this the prototype procedure is fundamentally based upon the premise that transportation projects are characterized by subtle, complex, and richly faceted desirability profiles. The premise is revealed in many features.To mention some: Both economic and functional evaluation examines all conceivable programs and thus set the stage for trade-off analysis. To facilitate this the results of both forms

of evaluation are to be clearly portrayed in a program information file. Additional information which does not fit into these evaluation schemes is also stored in the project information file for this purpose. To complete the picture, preference characteristics, portraying concerns of agencies and interest groups are also included. In combination these features serve decision with information relative to the choice of project sets without pretending to determine the best program analytically.

From assuming a broad perspective on programming there arises the need to carefully structure the information; on the input side for the sake of efficiency and consistency, on the side of the output in order to make the results comprehensible. Therefore the prototype procedure contains several information files for which the content is specified while the format must be designed based upon the needs yet to be articulated.

The overall structure of the prototype method is portrayed in the following chart. The three basic beginning points are the Project Information File, the Preference Information File, and the External Assumptions. The External Assumptions, positing conditions of society and economy in present and future time periods, are the basis for identifying scenarios of conditions relevant to future project implementation and system performance. These lead to identifying reasonable transportation Budget Estimates. This information, together with the content of the Project Information File and the Preference Information file, leads to the formation of Project Sets (by rules mentioned in the text above). Traffic Assignments are performed on the sets and the two

STRUCTURE


PROJECT INFO FILE
EXTERNAL ASSUMPTIONS
SCENARIOS
INTERNAL ASSUMPTIONS
BUDGET ESTIMATION
PREFERENCE INFO.FILE
FORMATION OF PROJECT SETS
MICRO-STAGING
PROJECT SET PROGRAMMING
ASSIGNMENT
FUNCTIONAL EVALUATION
ECONOMIC EVALUATION
PROGRAM INFO.FILE
APPRAISAL
MOT-STRATEGY

forms of Evaluation are then applied as the final analytic contribution to decision-making information. The various sources of project and program information togethen, then, are the basis for appraisal and the preparation of a strategy.

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III.3

TRANSPORTATION PROJECT DEVELOPMENT AND IMPLEMENTATION IN CAIRO, EGYPT

BY

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APPENDIX I: DESCRIPTIONS OF PROJECTS STUDIED

I. INTRODUCTION

A. PURPOSES OF THE PAPER

This paper is about the conceptualization, planning, design and execution of projects to facilitate urban transportation in the Cairo metropolitan area. It is written as a prelude to the preparation of problem-solving methods for transportation planning.

As a means of doing this, it is convenient to ask: What are the benchmarks of the present project development process in Cairo? We seek to discover whether there are forseeable constraints on budget for various purposes in transportation project development. We try to identify the roles of participating institutions --customary roles and amplitudes of permissible roles. The procedures used for selecting and controlling the agents responsible for the various phases of project development and implementation are important. Government attitudes toward the use of foreign credit and investments are important. The government agencies' overall capacity of manpower for public sector work is important. All such matters as these are ways of anchoring our approach to planning and programming in the institutional reality of the Cairo metropolitan area, so that programming requirements can be feasible and can be met by responsive agencies.

Our interest also requires that we give careful attention to the pitfalls in the project development and implementation process. The problems encountered in this process in Cairo are largely

similar to those in many other countries, but each national environment gives a slightly different cast to these problems. In fact, Cairo presents in many ways a healthy context for project development, despite certain irregularities and confusions in the institutional framework. In Cairo, agreement among relevant actors to slate projects for implementation appears to be consensual and stable. The projects slated are all defensible ones; there appear to be no instances of the exercise of special interests by individual agencies or powerful private actors. Even under the severe financial strains of recent Egyptian history, slated projects are apparently never abandoned, though their construction time may be longer than initially anticipated due to low annual allocations of funds and the interruptions of national urgencies.

At the same time, many of the classical project development and implementation problems are found. It is extremely difficult to reliably predict the annual budget for transport investment in Cairo more than one year into the future. Offers of credit by foreign nations may have some influence on project development. The institutional context includes some instabilities as to agency roles. There is considerable leverage on the transportation problem outside the transportation sector itself--especially as regards control of auto ownership by regulations of the import tariffs.

Transportation project development and implementation is a robust activity in Cairo, but one which is subject to many of the problems characteristic of industrializing countries. Specifically addressing the circumstances of Egypt, the question is: What can programming do?

B. BASIC FRAMEWORK OF ANALYSIS

This study of transportation project generation and implementation has developed out of an examination of a number of projects which are planned or currently in progress in Egypt. This approach--the examination of a series of projects--was selected because the initial discussions with individuals in the transportation sector in Egypt revealed that the set of projects is a unifying element which links together the large number of organizations and individuals which are involved in the generation and implementation of transportation projects. Other interrelationships exist, as they do everywhere; formal hierarchies, historical patterns, contacts between individuals working in the sector; but the common concern which motivates their activities in the urban transportation arena is the project. Each of these individuals and organizations exercises different types and different degrees of influence over project implementation, and their roles are dynamically linked so that there exists a continually changing pattern of relationships.

In the absence of an agreed methodological framework for planning in transportation, and given the shifting and multiple institutional roles which make the planning process difficult to study from that point of view, project histories were found the best way of organizing the Cairo experience. Additionally, several external processes interact with project implementation--the budget cycle, the national political process, the political processes concerning the Middle Easte as a whole, and the links to foreign economic processes are prominent examples.

The procedure which we utilized to increase our understanding of project generation and implementation in Egypt is based on the notion that each project has a developmental history. By tracing the history of each of a number of projects, and examining each in terms of a common set of questions concerning its origination, its funding, its difficulties, its progression from idea to constructed facility, and the institutions which played a part in that progression, we found that some sense of a project development and implementation process could be outlined.

More specifically, it will be seen that each project begins, logically, as an idea, generated by some individual or organization. The project then moves through a series of stages and finally reaches completion. The examination of the projects was aimed at identifying these stages, as well as the companion processes which influence project development and implementation, and the source and nature of the forces which move the project along the trajectory from idea to completion. This project development process is displayed graphically in Diagram I-1, both in order to clarify the framework upon which the study rests, and to introduce and begin to define terminology.

It should be noted here that:

1. "Planning" means the definition of project functional role and determining the relationship of this role to the surrounding environment;

2. "Design" means the detailed specification of a physical system to perform that role;

3. "Implementation" is the term used to describe activities occurring after a project is 'slated' (the latter is explained in following sections) and continues until the project is completed;

4. the trajectory of the project may not be a continuum (i.e., project development may be interrupted);

5. the trajectory may loop back through previous revisions which occur after the initiation of construction;

6. at any point along the trajectory, a large number of public and private organizations and individuals are influencing the "movement" of the project toward completion;

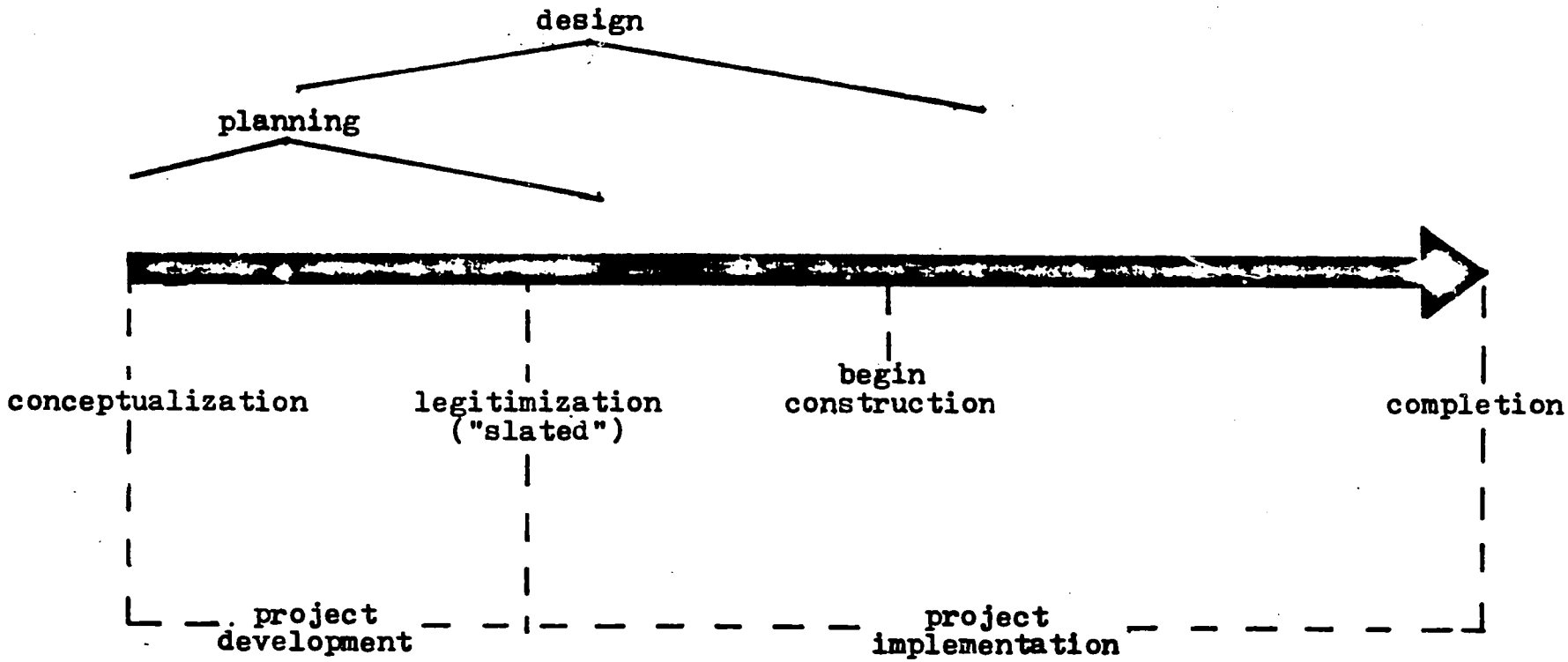
7. there are several projects--each one on a separate trajectory --in various stages of development at any moment in time. Additionally, the trajectories are not entirely independent of one another--the projects influence each other since they are developing simultaneously. They are calling on the same resources, fulfilling related commitments, and so forth.

8. Diagram I-1 is not intended to be interpreted as illustrating a rigid, well-defined process. The activities may not always occur in the specific sequence indicated in the diagram. Planning and design activities, for example, may occur in alternating, incremental phases. The relative duration of activities can change (e.g., planning may take place during many years and then design may take place in a few months). The periods of overlap between planning, design and construction may also vary from project to project.

The analytical work of this paper is an attempt to identify consistencies in the project development and implementation process, as well as to pinpoint irregularities--and patterns of irregularities.

Diagram I-1

HISTORICAL PHASES OF PROJECT DEVELOPMENT AND IMPLEMENTATION



II. ORGANIZATIONS INVOLVED IN TRANSPORTATION PROJECT CONCEPTUALIZATION, SELECTION AND IMPLEMENTATION

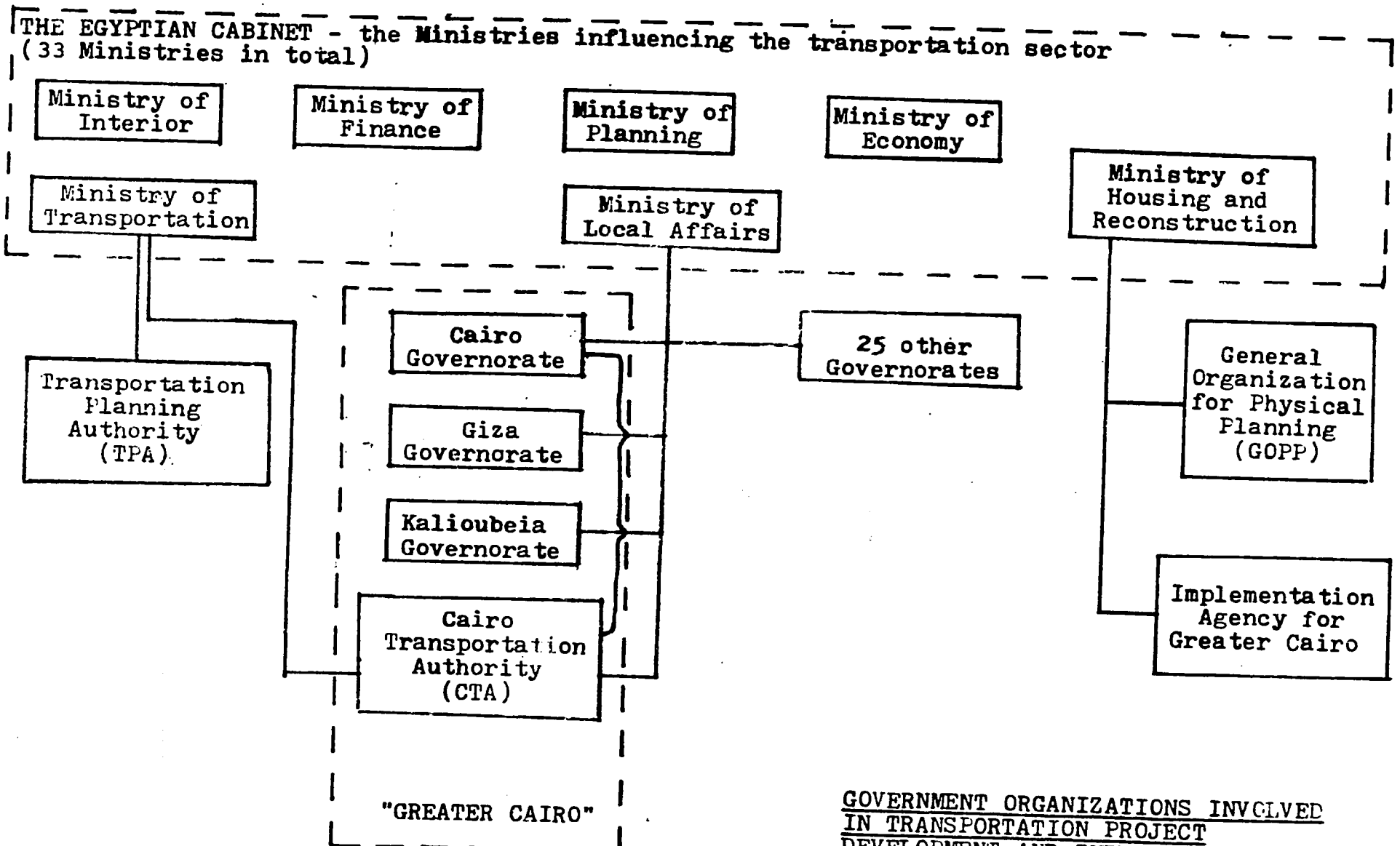
There are many agents involved in transportation project development and implementation. Their roles are to some extent defined by government mandate, but they are also established by momentary custom and needs. It should be emphasized that these roles are fluid and susceptible to change over time. The formal organizational relationships of the agencies described below are depicted in Diagram II-1. The descriptions that follow are intended to define responsibilities, and describe some of the more subtle, informal patterns of interrelationships.

1. The People's Assembly is the national legislative body, consisting of 350 members elected by secret ballot from 175 geographically-defined districts. As an institution it can trace its history back to 1923, when a representative, popularly-elected body was established. Members serve 5 year terms, and the law requires that at least 1/2 of the members be workers and farmers. The Assembly divides itself into 18 committees, one of which is the Committee on Transport and Communications, which generally oversees the transportation sector.

The Assembly's involvement in the implementation or transportation projects concerns the national budget, which, after preparation by the cabinet, is approved by the Assembly. As a result, the Assembly has a potential role in the urban transport sector.

2. The Cabinet consists of 33 Ministers and serves under the President, as the national policy-setting and budget-making body. It is understandable that the interaction of the ministries, each actively working in its area of responsibility and yet cognizant of national goals, results in a situation where a large number of governmental decisions are discussed and finalized at the cabinet level.

3. The Ministry of Transportation is the official representative of the transportation sector within the government. The Ministry is involved, through its subdivisions, in all phases of project development. It is responsible for transportation planning (urban, regional and national); this activity occurs primarily in the Ministry's Transportation Planning Authority. It is involved in operations; the Egyptian Railway Authority, for example, is a subdivision of the Ministry. It is involved in budgeting; the Cairo Transportation Authority's capital funding is allocated through the Ministry. It occasionally becomes closely associated with project implementation, as in the case of its current involvement as technical advisor to the Cairo Governorate supervising the execution of the signal synchronization project for central Cairo. In addition, the Ministry has the role of advisory review for all proposed projects. There is a general sense that the Ministry's advisory role is becoming its most significant contribution to the project development and implementation process. It is important to note



GOVERNMENT ORGANIZATIONS INVOLVED IN TRANSPORTATION PROJECT DEVELOPMENT AND IMPLEMENTATION IN THE CAIRO METROPOLITAN AREA

Diagram II.1

that the Ministry is often the originator of new project ideas in urban transportation, particularly via the activities of its Transportation Planning Authority.

4. The Transportation Planning Authority (TPA) is one of several subdivisions of the Ministry of Transportation, and the agency within the Ministry most active in project initiation, planning, and implementation. It has coordinated technical advice and supervised implementation for the signal synchronization system, and it has presided over the planning of the rapid transit system. Its attention to Cairo, however, is primarily via projects and less so through comprehensive system planning. The TPA did supervise the preparation of a comprehensive transportation plan of the metropolitan area in 1971-73, which was done by a foreign firm. That plan unified the perspective on urban transport projects to some degree, but shows little indication of having become in any sense a framework for the subsequent consideration of projects.

5. The Ministry of Finance is the cabinet-level organization responsible for preparation of the national budgets for operations and wages/salaries. It also has a role to play in currency controls. In this way, the Ministry ultimately exercises certain control over the allocation of funds for transport facilities. Its primary role is to set outside expenditure limits within which the budgetary process takes place.

6. The Ministry of Local Affairs is the cabinet agency representing the interests of the 28 governorates of Egypt, as well as political subdivisions within the governorates (municipalities, towns, shiakets). The Ministry serves as the channel of funds and projects to the governorate level. The Ministry of Local Affairs appears to be the sole source of influence on the project development process whose concerns are strictly geographically based--the People's Assembly, with its regional representatives, should ideally serve a similar function, but as noted earlier, it currently has a more peripheral impact on project development, through the budgeting cycle.

It is difficult to connect the condition of geographical representation with the current geographical distribution of projects. It is true that virtually all the major urban transportation projects likely to be implemented in the near future are in the Cairo area. On the other hand, most objective measures of need in urban transportation would lead to focusing resources there. Nonetheless, strong regional influence in project development would most likely make a marked difference in the geographical distribution of projects.

7. The Cairo Transportation Authority is the government agency responsible for the operation of public mass transportation facilities in the Greater Cairo area. The modes include buses, a street car system, a trolley bus system, and river ferries. The CTA provides all the public transportation for the metropolitan area (Cairo, and parts of Giza and Kalioubeia governorates), with the exception of a small part of the tram network

(the 'Heliopolis Metro') which is in the hands of a separate public corporation, and the commuter railway service.

The CTA also normally initiates, plans and executes new projects and extensions of the existing mass transportation systems. As such, it is the principal agency concerned with the current streetcar network extensions, the acquisition of the new fleet of buses for the service in Cairo, and the negotiations necessary whenever a new project alters or disturbs transit services--such as the Embaba Bridge. It is not responsible for supervising the development of the proposed metropolitan subway (this project is being guided by the Transportation Planning Authority), and it remains unclear how the operation of the Metro would be handled. The CTA receives its capital budget allocations through the Ministry of Transportation.

8. The Heliopolis Housing Company is responsible for public services in the Heliopolis district. This includes the planning for and operation of the 'Heliopolis Metro', a tram network which operates within Heliopolis itself, and also links the district to Cairo.

9. The Ministry of Planning has the responsibility of preparing the annual national capital-investment budget for submission to the People's Assembly for approval. This authority allows the Ministry of Planning to play a major role in the determination of which projects will be constructed at what time. It has a transportation section of about 50 professionals within

which transportation proposals are considered. (The obligations of this group include all the nation's transportation systems, including the Suez Canal.) Consideration is on a project by project basis, rather than involving any broader view of the problems in Cairo. In the course of project evaluation, trade-offs considered are first intra-sectoral, and subsequently between sectors.

The Ministry's stated criteria are to favor (1) projects which maintain service standards to current levels, (2) the completion of projects already in progress (except in extreme cases), and (3) projects for which special foreign credit is assured. Its requirements of agencies which submit projects for evaluation and scheduling are that plans include cost estimates, project appraisals (including the concise statement of project objectives), and an implementation schedule (including separate identification of elements financed by domestic currency and foreign currency). The Ministry sometimes changes the cost estimates to conform with the standards it uses.

10. The Ministry of Economy usually plays only a minor role in transportation project development. Projects involving high cost or extraordinary impact will often bring the Ministry of Economy to a more active position, especially if they involve issues of foreign exchange. For example, it was a decision of the Minister of Economy in June 1977 which will postpone the undertaking of rapid transit construction for two years. Projects dependent on foreign assistance are normally channeled through

the Ministry of Economy. A major U.S.A.I.D. commodities import loan, for instance, which is being utilized in part for the purchases of buses, was initially granted to the Ministry of Economy.

11. The Ministry of Housing and Reconstruction (MOHR) was established initially as the Ministry of Housing. At the end of the 1973 war, the Ministry was made responsible for the redevelopment activities along the Suez Canal. The Ministry's background at developing and supervising the construction of these projects and decisions of national leadership led to an expansion of its role, primarily into the Greater Cairo area, where it has assumed responsibility for the development of several sewage, water supply, and transportation projects.

In Egypt the majority of construction firms are owned by the government. Until recently (May 1978), their formal attachment was to this Ministry. There was a period during which the Ministry of Transportation was settling into a policy-advisory role, while the Ministry of Housing and Reconstruction was assuming a project-implementor role. Lately, however, four major road construction companies were changed to report to the Ministry of Transportation, so these roles are in a state of flux.

12. General Organization for Physical Planning (GOPP) is an agency within the Ministry of Housing and Reconstruction, responsible for the overall planning for Cairo--as well as the

whole of Egypt. The GOPP was originally an agency of the Governate of Cairo, and responsible for planning in the metropolitan area. It was later incorporated into the Ministry and given broader responsibilities. It completed preparation of a master plan for the metropolitan area in 1970, and is reportedly in the process of updating that plan at the present time. The 1970 document is primarily a land development plan, but it includes a brief focus on urban transportation facilities.

The history of the GOPP is similar to many of the public organizations involved in planning--there appear to be periodic expansions and contractions in its areas of responsibility and functions. There are indications that the GOPP has in the past occupied a more influential position concerning transportation projects (specifically in the implementation of projects) than it currently does, in part due to the increasingly active roles of several of the other organizations described here.

13. The Implementation Agency for Greater Cairo is an agency originally created, with a different title, within the Ministry of Housing and Reconstruction. This agency was specifically responsible for the implementation of the Suez Canal reconstruction projects. As mentioned earlier, the success of these efforts has enhanced the position of the Ministry of Housing and Reconstruction and, in particular, the Implementation Agency. In fact, the Implementation Agency now appears to be to a large extent autonomous, with direct links to other ministries and and organizations. The Implementation Agency currently is

supervising the implementation of the Helwan-Heliopolis Autostrade project.

14. The Governorates of Cairo, Giza, and Kalioubeia are significant factors in project development. There are indications that many of the projects originate with the governorates, no doubt because these territorially oriented units of government are most accessible to people who complain about unsatisfactory transportation conditions; and also because of the governorates' access to the cabinet through the Ministry of Local Affairs. The governorates prepare local plans and have on hand a number of unslated project proposals, in general produced by brief sketch planning exercises.

The governorates are also formally responsible for the supervision of transport project execution. It is not possible to evaluate the extent to which this role is successfully managed at the present time. Since the process involves relatively small units of government supervising the work of powerful firms, the function may well present problems.

Thus, the governorates are primarily involved in idea-generation and project execution; the intermediary stages of planning, evaluation and programming are the primary concern of the national organizations described here.

Two other institutions occasionally are involved in project implementation. The Ministry of the Interior, through its

Police Traffic Bureau, is responsible for the enforcement of traffic regulations. This includes such activities as the installation of temporary roadblocks to manage traffic flow during project construction (e.g., the 6th of October Bridge). And, finally, steering committees (consisting of representatives from government agencies involved in a project) may be created on an ad hoc project-by-project basis as a coordinating mechanism.

In sum, the agencies of the Egyptian government involved in urban transportation project development and implementation are numerous. Note that our listing does not include those organizations significant to the sector from other perspectives--such as in the manufacturing and import of vehicles. The agencies' roles in urban transportation may be described in general terms, but the form of their performance from project to project can be very different, and the levels of involvement of an agency can vary greatly from one project to another.

This view of organizations in the sector has been distilled from our cases and from interviews. Our eventual purpose is to relate the essential capabilities of these agencies to a process that might productively regularize project development and implementation. Meanwhile we turn to the de facto process.

III. THE DE FACTO PROJECT DEVELOPMENT PROCESS

A. PROJECT CONCEPTUALIZATION

The sources of "ideas for potential projects" are numerous, and it is often difficult to verify a source. A review of the projects indicates that credit for urban transportation project ideas for metropolitan Cairo is usually given to one of three organizations: the General Organization for Physical Planning (GOPP), the Transportation Planning Authority (TPA), or the Cairo Governorate. This breakdown, however, ignores the complex relationships and interactions among the many government agencies at the ministerial, governorate and local level, the elected national representative organization (the People's Assembly), private design firms and public/private construction contractors, foreign governments and consultants, and domestic university faculty.

It should be made clear that by "project conceptualization" we mean the act of project explication which puts the idea into currency, not necessarily the mental act of inventing it. Of the three agencies mentioned, the GOPP would at first glance appear to be the most likely candidate for the role of project conceptualizer. The description of its formal responsibilties includes that of overall planning for the Cairo metropolitan area. In 1970, the GOPP did prepare the first general plan for the Greater Cairo Area (the entirety of the Cairo, and portions of the Giza and Kalioubeia, governorates). The transportation element of the 1970 plan, however, served primarily to collect

and unify existing transportation project proposals, rather than to generate new projects. Project ideas seem to arise sporadically, and apparently may be considered for implementation as they arise. Further, the GOPP plan describes projects only in very general terms, their refinement occurring gradually as they receive continued scrutiny for possible implementation.

The TPA--another agency cited as a project conceptualizer--is currently deeply involved in the implementation of two projects. It serves as technical advisor on the Cairo synchronized signal system, and has supervised the planning of the proposed underground. (The original idea for the underground seems to have developed a number of years ago from within Egyptian Ministerial circles.)

The Cairo Governorate is also cited as a project idea source. While it is true that the governorate is responsible for the implementation of a majority of the urban transportation projects, and it does have in hand a number of unslated project proposals, the extent to which it actually conceptualizes projects is unclear.

Overall, the 'project conceptualizer' role which might be attributed to these organizations may itself be overstated. The GOPP, the TPA, and even more so, the Cairo Governorate, may serve less as concept generators than as concept-legitimizers.

The labeling of a project-idea as "belonging" to one of these agencies may be one of several steps involved in moving a project from the conceptualization stage to construction; the labeling being the transformation of an idea which was previously discussed and analyzed in an informal, private manner into an idea open to more widespread scrutiny and discussion among governmental organizations and their consultants.

The relationship between these "legitimizing" agencies and the various other organizations and individuals described in Section I becomes more apparent with a closer examination of the history of several projects. (The projects are described in greater detail in Appendix I). As mentioned earlier, the United States Agency for International Development (USAID) has extended a commodity import loan to the Egyptian government. These loaned funds were initially awarded to the Ministry of the Economy, which in turn distributed them among the various ministries in response to proposals for use of the funds. The Ministry of Transportation proposed to use a part of the loan to purchase buses for inter- and intra-city travel. The buses to be utilized within Cairo are purchased via the capital budget of the Cairo Transportation Authority. Operating under a constraint of scarce capital resources, a purchase of buses may theoretically not have been optimal, and the decision to purchase buses may not have arisen independently within the Ministry of Transportation. Rather, this decision may have been influenced to some extent by USAID regulations concerning the possible uses of the commodity import loan (e.g., purchase from a U.S. manufacturer). It may have been influenced by

USAID organizational prefeerences for customary uses of such loans (e.g., tractors, engines, pieces of industrial machinery --where suppliers are known and the process of supply known to be workable). The timing of the availability of the loan is also significant. It may have influenced the rapidity with which organizations were required to develop proposals, and so set limits on the comprehensiveness on evaluations of need as a basis for the allocation of the funds. We should make this clear: There is every reason to believe that the use of these funds for buses was a very good choice, and no doubt agreement with this judgement by key actors significantly facilitated the transaction. Still, the origin and path of the proposal suggest that external factors may have influenced the judgements of the legitimizing agencies.

The Cairo Synchronized Signal System and the subway are both examples of close collaboration between an Egyptian government agency (the TPA) and foreign consultants (TRT and SOFRETU, respectively, both French-based) in the development of project ideas. Here, the form which a legitimized concept takes is influenced by customary solution preferences of the consultants. The green wave system is a technology directly represented by the TRT, and the design of a rail rapid transit is a field in which the SOFRETU is especially well experienced.

The Gold Island Bridge is an interesting example of project conceptualization involving domestic and foreign organizational relationships. The concept of a bridge across the Nile to the south of Cairo to carry traffic around the periphery of the city

apparently has been discussed informally and sporadically over a number of years. The Ministry of Tourism and the GOPP incorporated this concept into a possible scheme for a tourist development on Gold Island in the Nile outh of Cairo. The island is presently undeveloped and unconnected to the mainland, and the price of riverside residential land has been rising explosivel in recent years. The GOPP employed a foreign consultant to develop an overall plan for traffic movement into, out of, and around Cairo (this plan is entitled "Entrances to Cairo") and the bridge concept was incorporated into the plan as an element of a proposed ring road. Since publication of this plan, the Gold Island Bridge concept has been examined further (on an informal basis). Discussion now favors the retention of the bridge as a possible future project, disassociated from the Gold Island tourist development proposal (primarily for traffic-flow reasons). Whatever the nature of these informal discussions, the concept can not yet be labeled as a project idea "belonging" to a particular Egyptian government agency--it is not yet legitimized.

In spite of the relative uniqueness of each project in terms of its conceptualization, its process of becoming legitimized, and the organization to which it "belongs", a broad outline of institutional interests may be drawn from the set of projects which we have examined. The TPA appears to be involved in those projects characterized by higher-level, innovative technologies (and thus more likely to be linked to foreign sources of funding and technical advice) such as the synchronized signal system and the underground, while the Cairo Governorate

and the GOPP focus their activities on more labor intensive, domestically-based projects such as bridges and roadworks.

This is a distinction with far-reaching consequences for the institutional and analytical aspects of project programming, because the two kinds of projects comport very differently in the project development process. The innovative/foreign-related projects inevitably involve some participation in the decision-making by agents outside the country. This in no way suggests that the government is pressured or coerced. As implied by the examples of buses, synchronized traffic signals and the subway above, it is an inescapable consequence of the fact that potential foreign partidipants have their own limitations of action, and have initial problem perspectives formed independently from Egypt's national priorities. Since the funding for innovative/foreign-related projects is likely to be available on terms made possible by the foreign participant, it is difficult to compare the costs and benefits of these projects with the other slated projects. Finally, these projects tend to be of a larger scale than those which are entirely domestic in nature, and this may be a source of difficulty in a comparative evaluation. As a result, the evaluation and programming of the innovative/foreign-related projects are difficult tasks, and may have to be done on the basis of the contributions and liabilities of the project under consideration alone, rather than by relating it in detail to the other slated projects.

The domestic/traditional projects have different characteristics. They tend to have more manageable trade-offs with one another; they have comparable impacts on traffic flow, for example. As a result it is easier to compare these projects with one another. Finally, the negotiators involved in project development of this type are all acting within the national political and economic context. As a result the programming process can be somewhat more structured for these projects. By virtue of the same reasoning, it is not surprising that the two different kinds of projects tend to have different institutional bases in the national government.

A very significant factor in project conceptualization, but one difficult to fully appraise, is the involvement of engineering consulting firms. Having worked for many years in Cairo with responsibilities for major projects, the staffs of these firms are involved and able to present project ideas in convincing detail. There is evidence that they do so. They may well be the most important actors in generating projects. This presents some problems. While there is every reason to respect their capabilities, the very strength of their ability to engage the task of planning risks truncating the proper public decision-making process. Further, they may have a tendency to overdesign through a desire to exercise their skills and generate activity. There is evidence also that this is the case.

B. PROJECT SELECTION

Setting the Slate

While no written form of an official program of transportation construction projects exists, and projects are only broadly and not all-inclusively outlined in the Greater Cairo Area Plan prepared by the GOPP, there seems to be a general consensus as to the "slate" of transportation projects which should be implemented in the near (though undefined) future. The discussions with Cairo University faculty, Ministry of Transportation officials, government officials in the GOPP and Ministry of Housing and Reconstruction, and the important engineering design firm, Moharum and Bakhoum, centered consistently on a set of approximately 14 transportation projects proposed (or currently in progress) for the Greater Cairo Area.

The nature of the consensus on the "slate" of projects is fairly well defined. While there are differing opinions as to the details of projects, such as precise siting or design characteristics, these disagreements never appear to take the form of questioning the conceptual validity of a project in its broad outlines. Similarly, the relative importance of the projects (that is, "prioritization") is not strictly formalized and is open to disagreement, though the disagreement is almost always focused on the order of project construction, not on whether any individual project should be undertaken at all.

The latter characteristic--the notion of a consensual "slate" without consensual priortization or detailed specification-- is of particular interest in the context of the development of a programming methodology. First, as indicated earlier, there are numerous organizations and individuals, both public and private, which contribute to transportation project idea generation. No doubt each of these has its own "favorite projects", and perhaps some sense of prioritization of these within the universe of all possible project ideas at any one time. Given this situation of a multitude of projects and a large number of involved parties with differing (and thus conflicting) priorities, the "slate" may have evolved as a mechanism for narrowing the range of possible projects to a set which would be manageable for future debate concerning detail and prioritization, while retaining the involvement and support of the appropriate range of organizations and individuals. The latter point may be viewed as a necessity when the transportation sector as a whole must compete with other sectors for scarce capital resources, and also to ensure that intra-sectoral disputes are not permitted to block the progress of all projects as they move from idea-generation to construction.

In other words, the size of the "slate" may be large enough to involve sufficient institutional and individual elements in order to ensure that the overall project conceptualization, planning, designing, construction, and supervision process is viable, yet

small enough to in effect limit debate to a relatively small number of projects. In this way the stage is set for project implementation. Having arrived at the point where a consensus exists on the set of projects to be constructed, attention of decision participants then shifts to the interactions required to move one of these projects to the construction stage.
An alternative explanation concerning the nature of the slate may be rooted in the notion that there exists no deliberate control over the dimensions of the "slate" as proposed above, but that they are determined only by the limits on the available manpower and technology to generate projects for the slate. That is, given the complex (and occasionally unstable) organizational relationships among the large number of organizations which potentially play a role in project development, and the large number of project possibilities, the investment of 'energy' required to conceive and develop a transportation project may itself serve as a constraining mechanism on the size of the slate. Each of the involved organizations has a limited number of personnel who are in a bureaucratic position that enables them to actively participate in project conceptualization and development, and each of these individuals may have a limited amount of time to devote to this activity. (This is not to imply that the agencies are undermanned, or that individuals employed there lack technical expertise. The latter point is, from our experience, untrue, while the former point was a matter of debate among those we interviewed in Egypt). But working

within these limits (which exist for whatever reasons), the overall capacity of the Egyptian transportation sector as a whole to develop projects might be measured by the size of the "slate."

These two hypotheses about the appearance of the project slate are interrelated. The first may be interpreted in part as a set of constraints on actions portrayed by the second. That is, if the Egyptian transportation sector were capable of generating and developing more projects, some means would have to be devised to limit the number of such project ideas which would be open for serious consideration. The "slate" accomplishes this.

Less clear than the notions of project conceptualization and the "slate" is the manner in which the two are linked. What determines whether a project concept is legitimized and slated, rather than abandoned? A number of factors may be hypothesized as contributing to the legitimization process. The appearance of these factors cannot be empirically identified in Cairo, but are likely to be part of the system which begins to reveal itself in the foregoing pages:

(1) The availability of foreign means. Transportation project development at any time is partially constrained by available planning and design skills and means of financing. Innovative technologies in particular require specialized skills

built on experiences with early trials in other countries, as well as special sources of funding. The possibilities of considering projects, based on such technologies, then, is necessarily limited by factors such as the marketing practices of firms, decisions made in the international agencies, the nuances of international relationships. This is not to say that the legitimization is in any sense forced, especially if the government agencies keep their eyes open to maximize the range of possibilities and have a firm concept of their own priorities. Nevertheless, the range of options is necessarily confined.

There may be several stages of intervention of these factors in project development. The initial interest of a foreign agent may bring a project into view as a possibility, the undertaking of competent detailed planning and design may be an important contribution to slating the project, and the perception what means of financing might be available may advance the project further.

(2) The degree of institutional and individual support for a project idea from the numerous domestic organizations involved in planning, designing, funding and constructing a project may well be an important differentiator between legitimized and abandoned project concepts. Though the various organizations are capable of exerting differing degrees of influence

over the project selection process, none may be capable of pushing a project through to completion using only its own resources. The necessity of consensus (or at the least, non-opposition) building is a powerful force in idea-legitimization. The ability to "rally" institutional support around a particular project will depend on its potential significance in the eyes of the public sector generally, the anticipated negative and positive impacts of the project (such as dislocation, better traffic flow) and the reciprocal patterns of organizational support which can be arranged.

(3) Some sense of the public "need" for a particular project-concept may also influence the likelihood of project legitimization. Outside the concerns for financing and consensus building, there exists the element of institutional responsiveness to what is perceived to be a "public need." The definitions of "public need," and the degree to which this influences the activities of a public organization, will vary from agency to agency, in part due to differing degrees of public access (e.g., the Governorates--as a more localized administrative agency--may be more cognizant of and responsive to its public than a more hierarchically isolated agency).

Two additional factors which may affect project slating or abandonment might be:

(4) The "status" of the specific individuals and organizations which support a project concept. Returning to the necessity

of building institutional support to move a project from concept to "slate," the different organizations involved will have different degrees of influence on other organizations, based on such things as formal and informal relationships, parallel actors, influence in the budget cycle and funding allocations, and the perceived importance of an organization within the bureaucracy.

(5) And finally, the anticipated opposition which a potential project will encounter may be important. This might take the form of anticipated opposition from influential agency leadership, vested interest, or from elements of the public. These factors will influence the decisions of an organization to support a particular project.

The Current Slate in Metropolitan Cairo

Appendix I describes the projects individually, but several characteristics of the current slate as a whole are summarized here:

(1) The projects involve, for the most part, large expenditures of capital and a considerable investment of organizational resources for the supervision of project development. None of the projects involve the repair or maintenance of existing facilities, and all were large scale.

(2) Each of the projects appears to promise a considerable impact on the transport system in Cairo. The set excludes project proposals offering small-scale, incremental benefits.

(3) The projects all appear to be feasible in terms of the existing design and construction technologies available to Cairo. While several of the projects involved new technologies in Egypt--the tunneling for the underground and the computer technology of the synchronized signal system being prime examples--these projects are closely linked to foreign sources of design and construction technologies. Even in these instances, although the projects involve new types of technologies for the Cairo transportation sector, the national professionals involved in the design and construction appear to be at ease with them. In no instances did the successful implementation of a concept or project appear to be dependent on a process or technology not yet developed or tenuously available.

(4) The set consists primarily of road and road structure transportation projects. The exceptions to this are the proposed underground, the USAID loan for buses (in reality not a 'project' as implicitly defined herein, and the tramway extensions.

The process of selection which occurs as projects move from concepts to the slate seems to work in such a way so as to favor projects (i.e. the slate overwhelmingly consists of projects) with the four characteristics listed above.

Two final points should be made in reference to the project conceptualization and "slating" process. First, the reconciliation of differing opinions of priority within the slate of projects occurs largely outside the limits of the transportation sector. It occurs during the complex national budget-setting activities of the cabinet (described later in the paper). Currently, no single individual, organization, or methodology serves this purpose.

Secondly, decisions to place a project on the slate, and also decisions to initiate construction (whether they are reached through consensus, negotiation, or the actions of independent agencies), appear to be made with little explicit comparative analysis of the "value" (however defined) of the projects. While the organizations involved may be utilizing some intuitive, relatively simplistic comparisons, there is little formalization of this. In our discussions only the Ministry of Planning mentioned current efforts to systematically analyze and compare the merits of the slate projects.

Project slating is a form of national planning. It substitutes for complex exercises in transport systems planning where these skills are not widely available, where data are lacking, or where instabilities encourage short-range thinking about major improvements. It constitutes a useful departure from which to move into a more elaborate planning process.

C. PROJECT IMPLEMENTATION

The Roles of Planning and Design

The movement of a particular project from the slate through construction to its completion is to a large extent controlled by forces very similar to those which move a project from conceptualization to legitimization--forces such as domestic and foreign financial and institutional support, concurrent political and budgetary processes, and inter and intra-sectoral competition for funds. Prior to a discussion of the overall process of project implementation, two activities which overlap and tie together the project development and implementation phases will be described. These are "planning" and "design." (Recall Diagram I-1)

(1) The use of the word planning here is in the context of a single project. It is used to describe a transportation project idea-refinement process, consisting of the imposition of "real world" considerations onto that idea so as to lead to greater specificity as a necessary prerequisite to project design. For example, planning occurs when the concept of a bridge linking the two banks of the Nile south of Cairo (a "project idea") is, first, fit into the context of the overall transportation network (e.g., "this bridge will divert through traffic which currently must move through downtown Cairo"), and second, when it is considered in terms of specific needs and projected uses (e.g., "we need a bridge that will carry approximately 30,000 vehicles per day and allow traffic to move at a minimum speed of 30 m.p.h.").

Employing this definition, planning as an activity is intimately involved in the project development phase as illustrated in Diagram I-1. The building of institutional support, and the attracting of domestic and foreign financing, for example, are both partially dependent on the specificity of a project concept. Some degree of planning; at least at a rudimentary level, must be accomplished if legitimization--"slating"--is to occur. Beyond an initial modest threshold effort, however, the degree of planning required for slating is variable. A number of other forces (e.g., foreign loans, political realities) may propel a project idea to the slate in spite of a minimal degree of planning. The refinement of the planning may continue into design and construction phases; this may be evidenced in the changing of design details during construction due to unforeseen technical obstructions. The readiness to initiate the latter activities--design and construction--may in fact serve as a device to force the completion of planning, as both are dependent on it.

(2) We use the word design here in a relatively narrow sense--the process of developing a set of specifications for project construction. In design, the outputs of planning ("a bridge to carry 30,000 vehicles per day at 30 m.p.h.) are translated into detailed requirements (e.g., "6 lanes, two way with widths of ten feet...") and matched to site-specific considerations (e.g., "concrete piles resting on bedrock 15 feet below the bottom of the river") to produce a set of directions for construction activities.

Design, as indicated earlier, must be preceded by a threshold level of planning, and it seems that in a majority of the case examples from Egypt (as in other nations), the planning and designing activities overlap and blend. When this overlapping occurs, it seems that as a project enters the design stage, final resolution of planning issues often takes place simultaneously with decision points in the design process (e.g., the need to determine access ramp configurations might lead to a decision concerning some of the functional characteristics of a bridge). The making of these planning decisions--either through an independent activity or conjunctive with the design activity--enables further designing to occur, based on the increased specificity of the concept. This iterative-like process of increasing project 'realism' appears to be a characteristic of project implementation in Egypt.

One of the significant transitions which takes place in moving from planning to design is the change of actors. Planning is done by governmental agencies (or short term contractors to them), while design is typically done by large firms tied to the construction industry. Since there is no substantial amount of institutionalization of the planning process in Egypt, planning tends not to gather special strength. The designers, to whom the projects are subsequently passed, are likely to be highly capable, aggressive professionals with a concern for promoting the project in question toward early implementation. As a result

they are likely to seek constructive management of the project--and many projects are modified; in effect, "replaced", at the design stage. This is a characteristic of sufficient significance that one can say a great deal of the transportation planning in Cairo is done by engineering designers.

At some point during this planning-designing process, construction work begins. This may be induced by the simple reason that the project has reached the stage where construction work is feasible, or it may be initiated by outside pressures, such as the readiness of a construction contracting firm to begin work on the project.

In terms of time efficiency, some measure of planning-designing-constructing overlap may be desirable. The point to emphasize here is that there exists in Egypt past experiences of project implementation where this overlap is of a nature which might have required that decisions concerning project specifics be made out of logical sequence, hurriedly, without adequate consideration, or as a by-product.

The Budgeting Process

One significant aspect of implementation is the funding process --the source of funds, the formal allocation of budget, and finally the ultimate flow of funds into project construction.

The collection and allocation of public funds in Egypt is centralized--only the national government has the authority to collect revenues, which are then allocated, in part, down to the regional and local administrative levels of government. The total national budget is prepared annually, and consists of three separate budgets: the "operating budget," the "wages and salaries" budget, and the "capital expenditures" budget.

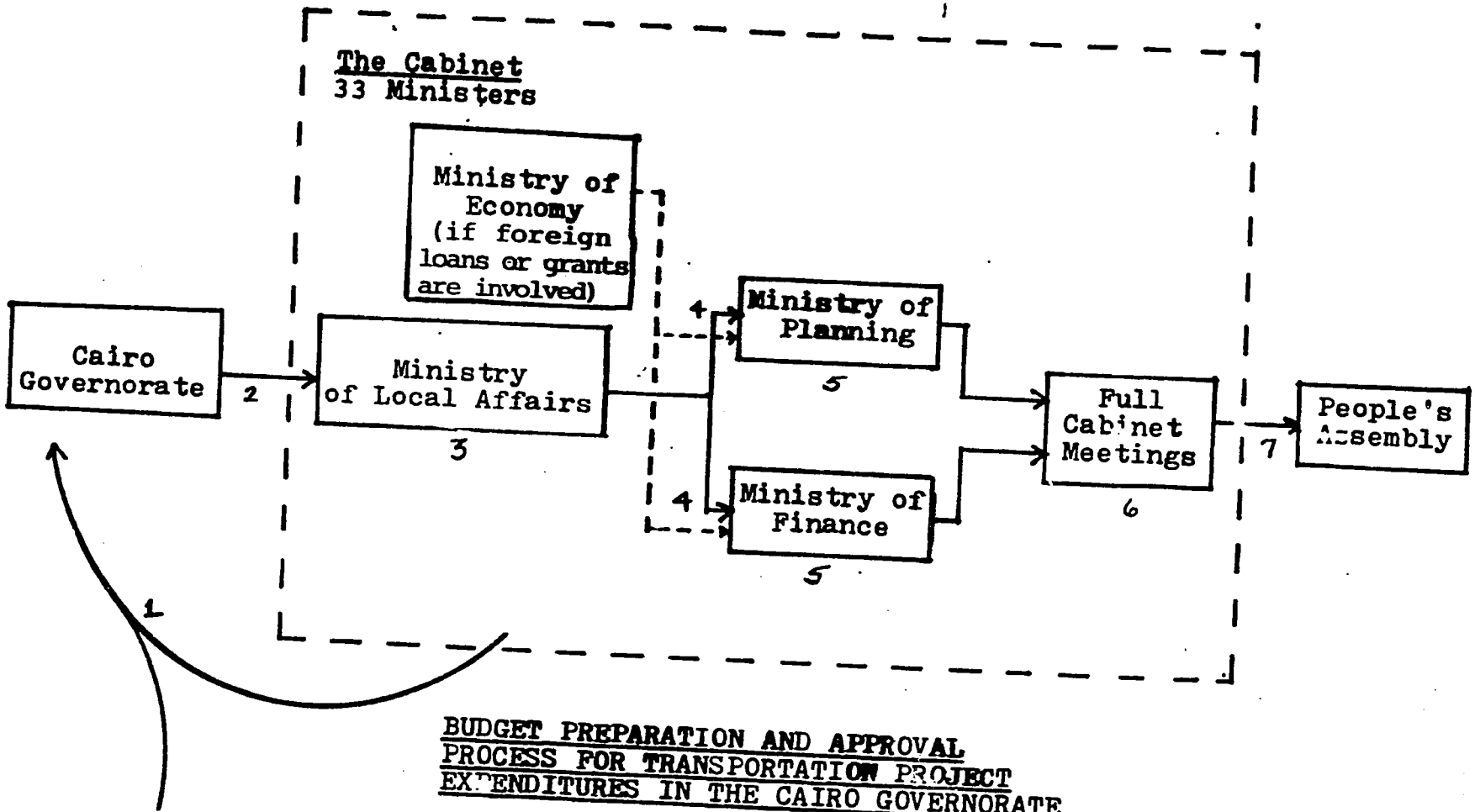
The administrative elements of the government are responsible for the preparation of the proposed annual budget, which is then submitted (in accordance with the Constitution) to the People's Assembly for review, adjustment, and adoption. Within the administrative element of the government, the Ministry of Finance is the responsible agency for development of the "operating" and "wages/salaries" budget, while the Ministry of Planning develops the "capital expenditures" budget. These proposed budgets are subject to extensive debate and revision in the full cabinet, where all 37 ministries are represented and negotiate for their interests.

While a cursory examination of the budget process might lead one to conclude that the budget review by the People's Assembly may be without significant impact, the review does occur annually, and even its marginal impact may have been understated by those we spoke to.

This tri-budget distinction is carried over into the allocation of budgeted funds. For example, the total annual budget of the Ministry of Transportation consists of three elements: an "operating", a "wages and salaries" and a "capital expenditures" budget. It is possible for an agency (such as the Ministry of Transportation) to adjust the allocation of funds from project to project within its annual "capital expenditures" budget, but this is apparently an infrequent occurence because of complications (it requires the approval of the Ministry of Planning). Even less frequent are instances of an agency shifting funds from one of its three budgets to another. On occasion, however, an agency has successfully sought a mid-budget-cycle increase in one of its budgets from either the Ministry of Planning or Finance, which also control the flow of allocated funds.

While the locus of authority concerning the size and characteristics of the national budgets lies primarily in the Cabinet (appointed by the President), the Ministries of Finance and Planning, and the People's Assembly, the budget development process also relies heavily on a more "localized" government level. An example of the involvement of the local government and the overall process is described in Diagram III-1. The example in this case is the preparation of the budget requests for transportation projects by the Cairo Governorate.

Diagram III-1
(The link numbers are keys to the discussion in the text)



BUDGET PREPARATION AND APPROVAL PROCESS FOR TRANSPORTATION PROJECT EXPENDITURES IN THE CAIRO GOVERNORATE

(The numbers here are keyed to the links in Diagram III-1).

1. Though never clearly indicated, some broadly outlined sense of an "acceptable" budget level proposal must be communicated in order to place limits on the possible budget proposals to be prepared by the Cairo Governorate. The assumption here is that the Cairo Governorate does not develop a proposal totally "in the dark", that it must have some prior sense of a range of rational (from the viewpoint of superior agencies) proposed budget expenditures. The means of identifying this expected range may be fairly formalized (e.g., based on previous annual budgets) or more ad hoc (e.g., informal assessments of political receptivity and institutional competitors for funds).

2. The Cairo Governorate (as well as the other Governorates) submit a proposed 3-element budget to the Ministry of Local Government. This budget proposal includes along with other items, all of the transportation projects and expenditures for the upcoming year which are to be controlled by the Governorate.

3. The budget proposals of the 25 governorates are reviewed, adjusted, negotiated, and consolidated into the 3-part budget request of the Ministry of Local Government.

4. The "capital expenditures" budget request is submitted to the Ministry of Planning; the "wages and salaries" and "operating" budget to the Ministry of Finance.

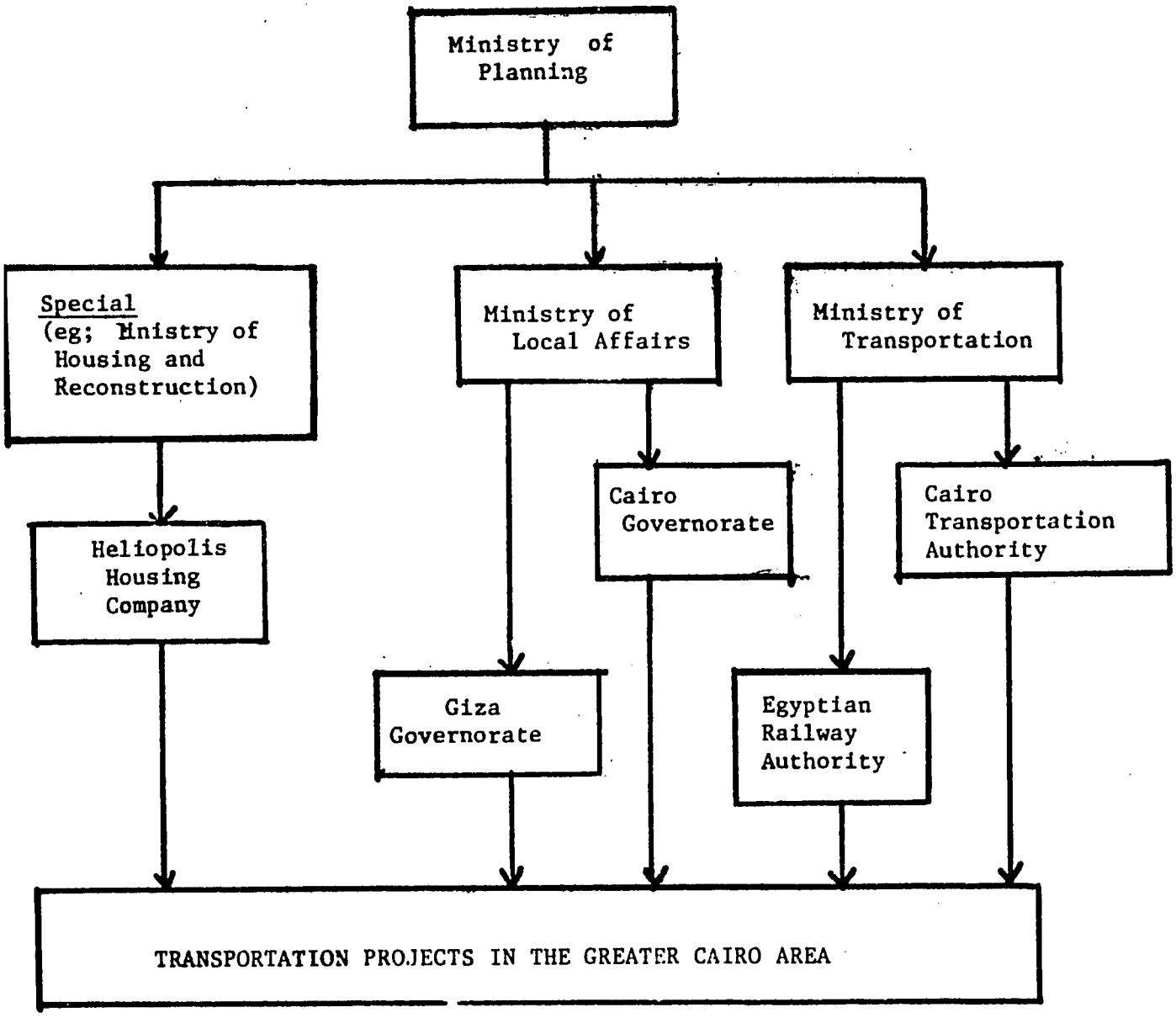
5. The Ministries of Planning and Finance review, adjust, and consolidate the budget requests of the various Ministries into a proposed national budget. In the instances where foreign loans or grants are involved, the approval of the Ministry of Economy will be secured.

6. The proposed budgets are discussed and adjusted in the full cabinet.

7. After finalization of the proposed budgets by the Cabinet, they are submitted to the People's Assembly for review, adjustment, and approval.

Not only the source, but also the flow, of allocated funds has an important influence on the construction of transportation projects in terms of the control, the timing, and the selection of projects. Funds may be handled by several intermediaries, each with its own sense of priorities and bureaucratic preferences, and the cumulative effects of this flow of funds through a variety of hands at least marginally affects project implementation. ~~As an~~ example, Diagram III-2 depicts the flow of "capital expenditures" funds for transportation projects in the Greater ~~Cairo~~ Area, based on our short project case studies. (The Cairo area is the focus of this study due to the overwhelming concentration of transportation projects there. It may be atypically complex with respect to the flow of project funds, due to the concentration of government agencies of all levels and the substantial sums of money associated with the large projects there.)

DIAGRAM III-2



FLOWS OF CAPITAL FUNDS FOR TRANSPORTATION PROJECTS IN THE GREATER CAIRO AREA

We reviewed projects which were representative of each of the capital funding patterns illustrated in Diagram III-2. The Cairo Synchronized Signal System project is funded through the Ministry of Local Affairs and the Cairo Governorate--as are a majority of the projects. In these instances, the Governorate not only handles the funds, but is also assigned responsibility for the implementation of the project. Railway line improvements and extensions would be funded through the Ministry of Transportation's Egyptian Railway Authority, and streetcar line construction would be funded by this Ministry through the Cairo Transportation Authority.

There is also at least one instance--the Helwan-Heliopolis Autostrade--of special funding patterns which appear to have been established for a specific project only. The Autostrade project was originally under the control of the GOPP (of the Ministry of Housing and Reconstruction). At this time, the supervision of the construction of the Autostrade has been shifted to the Implementation Agency for the General Rehabilitation of Cairo.

Perhaps the most general statement to be made here concerning project capital funding flows is that there is some measure of uncertainty in terms of predicting who will handle the capital funds for any one project. The governorate handles the majority,

the Ministry of Transportation is involved in certain fairly well defined areas, but the option of "special case" funding arrangements always exists. An example of the latter--in the form of a "blending of funds"--is the project to construct additions to the Embaba Bridge. This project is being funded primarily by the Cairo Transportation Authority, with the assistance of the Cairo Governorate. The former receives its capital budget from the Ministry of Transportation (which is the parent organization of the Egyptian Railway Authority, the agency that owns the bridge and is actually constructing a major portion of the addition); while the Governorate receives its capital budget from the Ministry of Local Affairs.

Funding and Project Implementation

The impacts of the entire funding process upon project implementation are several:

(1) The large number of organizations which are involved in budget determination complicates the implementing phase. Not only must sufficient instutitional support be gathered to "legitimize" a project, but continual effort must be made throughout implementation to conserve this support. As most of the large projects extend over a number of years, the annual budget making procedures may place the status of funding for each project in jeopardy.

(2) The fact that the pattern of funding flows through a variety of intermediaries also necessitates the continuing effort to

maintain support for a project. Here, instead of the possibility of project budget cuts on an annual basis, the possibility of interrupted, discontinued, or reduced flow of funds throughout the year exists.

(3) In partial contradiction to the implications of these factors, the complicated channels for funding projects may in fact be an asset to project implementation. This situation may allow the creation of alternative funding channels (e.g., Helwan-Heliopolis Austrade) to minimize possible obstruction by any one intermediary organization on project implementation.

In addition to the role which domestic budgeting and funding play in determining which projects are implemented and how quickly they are completed, the special situation of Egypt as a developing nation introduces an additional factor. Domestically-generated capital expenditure funds are scarce, and the nation has turned to foreign loan sources to finance portions of several major projects (the underground, the autostrade, the synchronized signal system, and the buses). Table III-1 presents a general picture of the relationship between domestic and foreign capital investment in the transportation sector since 1973. It is evident that a significant portion of the funds invested in the transportation sector over the past four years have been non-domestic.

Beyond this partial involvement of non-domestic capital funds, the implementation of several of the larger projects (the underground

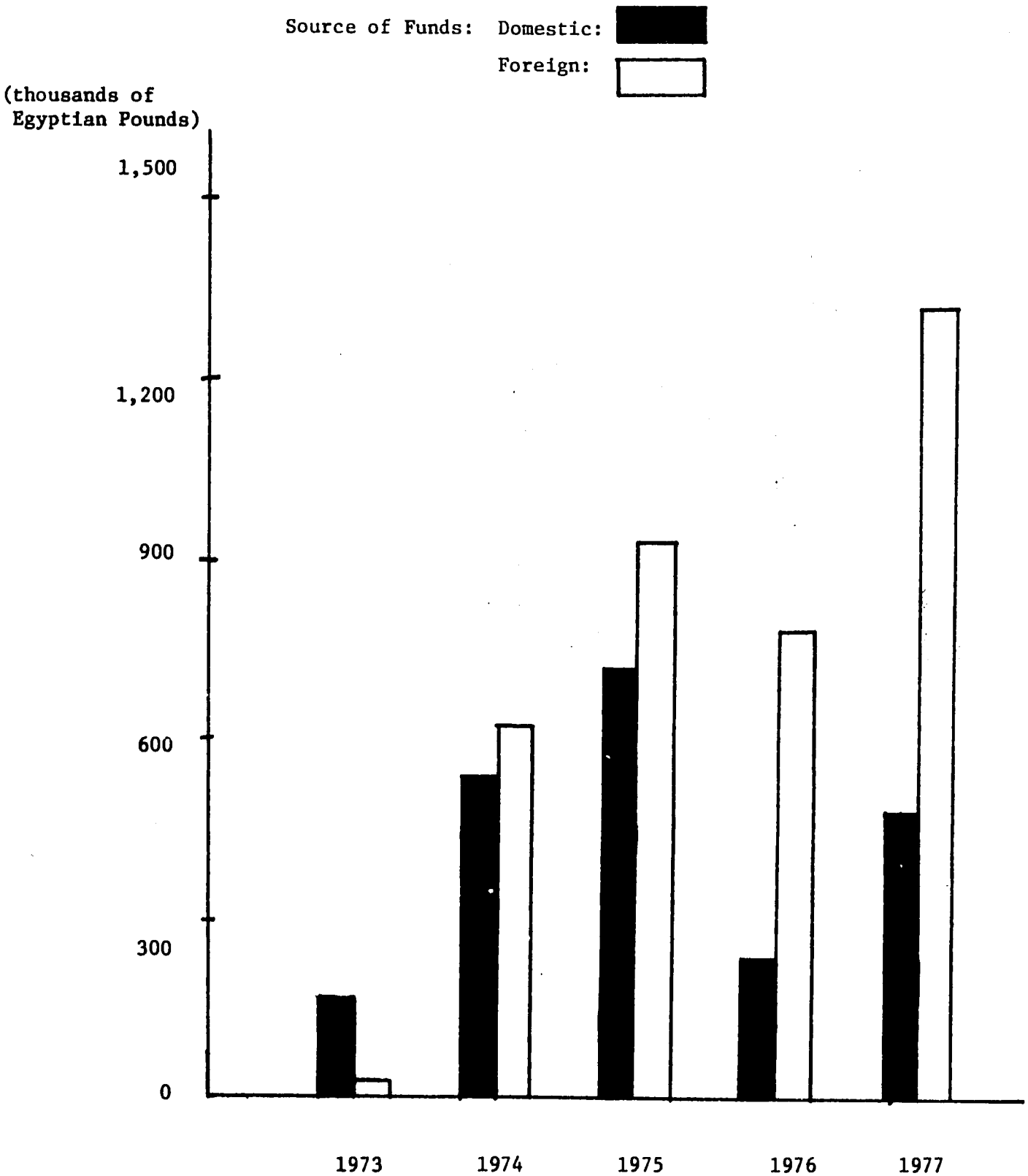
DIAGRAM III-3

INVESTMENTS IN THE TRANSPORTATION SECTOR FROM 1973 TO 1977 (in thousands of £.E.)

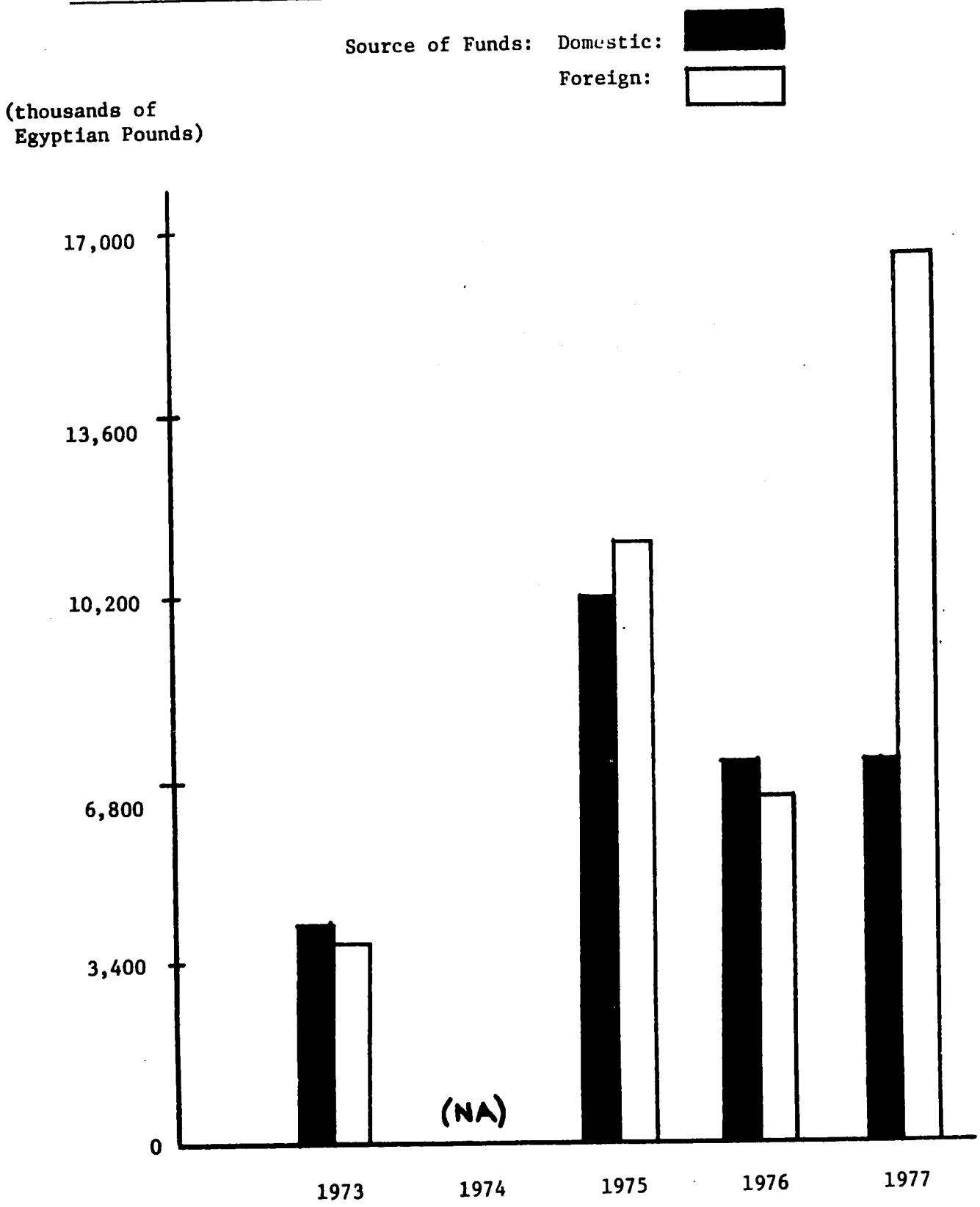
year / organization	1973		1974		1975		1976		1977		Total (1973 through 1977)	
	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign
Transport Planning Authority (Cairo only)	172	24	535	618	737	964	240	760	471.2	1342.5	2155.2	3708.5
Railway Authority (All Egypt)	6890	10310	10059	9078	11396	14104	12302	6698	13754.3	29927	54401.3	70[illegible]
Cairo Transport Authority (Cairo only)	4223	3977	-	-	10829	11391	7270	6500	7417.7	16915.7	29739.7	38783.7
Passenger Transport Between Governorates (All Egypt)	825	500	2428	1579	5081	5763	2150	1850	7972	27745	18456	37437
Highway Freight Transport Organization (All Egypt)	395	247	340	70	2208	1700	-	-	1883	3407	4826	5424
Inland Waterways Organization (All Egypt)	707	1358	1275	425	2108	943	2140	860	1285	1365	8208	4951
Roads & Bridges Organization (Cities not included)	3600	700	2200	300	3110	750	4000	500	6174.4	723.2	19084.4	2973.2
TOTAL	16182	17116	16837	12070	36162	35615	28102	17168	38957.6	81425.4	136879.6	163394.4

Source: Transport Planning Authority, Ministry of Transportation.

CAIRO URBAN TRANSPORTATION INVESTMENTS BY THE TRANSPORTATION PLANNING AUTHORITY, MINISTRY OF TRANSPORTATION: 1973 - 1977



CAIRO URBAN TRANSPORTATION INVESTMENTS BY THE CAIRO TRANSPORTATION AUTHORITY: 1973 - 1977



and the synchronized signal system) are based on previous experiences in more developed nations adjusted to local conditions. Additionally, materials import requirements serve as links to foreign sources; part of the reinforcing steel and steel "joints" for bridges and tunnels must be imported, as do many of the replacement parts for previously-imported equipment. The Helwan Steelworks produce the steel utilized for a majority of such components.

These components import requirements are inevitably significant in the legitimization and implementation phases. In the legitimization phase a commitment of non-domestic funds may permit a project to move onto the slate with less competitive scrutiny than domestically funded projects. Similarly, a commitment of foreign funds can remove impedances which might arise for domestically funded projects during the implementation stage. If the availability of foreign funds would be jeopardized by failure to match them with promised domestic funding for a given project, then the involved project may be more likely to get national funding than another which is completely within the national budget. Recall from our discussion of the Ministry of Planning that one of its specific policies is to give priority to projects whose foreign funding component is already arranged.

The implementation of transportation projects in Egypt (particularly in terms of the relative scheduling of the initiation of construction and the "speed" of project completion) is thus linked to the activities of foreign public and private organizations.

The focus on the budgeting and financing procedures here in this section should not be interpreted as meaning that other factors are unimportant or non-existent. The organizations which, as a network, serve as the backdrop for project conceptualization, and which serve as the elements of support which assemble themselves in continually shifting patterns which lead to legitimization, do not abandon their interrelationships once a project is slated. During the project implementation stage, the attention of these organizations shifts to a focus on budgeting and financing. Once legitimized, the existence of a project is slated. During the project implementation stage, the attention of these organizations shifts to a focus on budgeting and financing. Once legitimized, the existence of a project is secured--the issue shifts from "if" to "when." And the critical determinant becomes the availability of funds. Behind the domestic budgeting and domestic/foreign financing processes is that same dynamic network of organizational relationships.

The implementation process is also unquestionably affected by the fact that the construction firms are often large, highly capitalized organizations capable of exerting some impact on the process. In certain cases firms have made loans to the government in order to get projects started. Certainly the disposition of their equipment and their commitement to prior projects affects the program of implementation.

We have considered many streams of effect in the project development and implementation process. The detailed consequences of each cannot be easily appraised in any case--their strength across many projects is even more difficult to evaluate. They are nonetheless effects which must be considered in the programming process.

IV. ISSUES IN PROJECT DEVELOPMENT AND IMPLEMENTATION

Having outlined the project development and implementation process, described patterns of project funding, and indicated the roles of the various agencies involved in projects, the intent here is to pinpoint specific characteristics of the current process which are of particular interest to our research. Bearing in mind the underlying goal of adapting transportation project programming methodologies to the Cairo situation, we identified characteristics as significant because they fell under one or more of the following categories:

1. They are characteristics which heavily dominate the shape of project conceptualization, legitimization and implementation;

2. Defining, for the moment, "delay" as a manifestation of a "problem", these characteristics consistently frustrate efforts to develop and implement urban transportation projects by causing delay; and

3. In addition, characteristics are discussed which one might have assumed (based on experiences in other nations) would have appeared as problems, but are absent in the Egyptian context. These are guards against poor intuitive method adaptation.

The labeling of any characteristic as a "problem" is of course a matter of perspective, and it should be noted here that our

purpose is not to pose as critics or reformers of existing institutions and processes so much as to outline the framework into which any proposed programming methodology must fit. In reference to delay, it is difficult to pinpoint the exact causes in any single project. There are, however, a series of circumstances which seem to recur from project to project which may lead to project delay and/or difficulty of implementation.

1. As described earlier in the paper, the roles and responsibilities for each of the numerous agencies involved in transportation project conceptualization, legitimization, planning, design, construction and overall implementation are at times ambiguous. This, coupled with the large number of such agencies, results in a complex network of interaction. On a formalized level, this is evidenced in the multiple reviews and approval-granting steps to which a project is subjected. (Essentially, the project must be reviewed by virtually all of the organizations previously described). On a more informal level, the ambiguity of roles results in overlapping institutional "domains" (spheres of influence), and concern among the organizations as to their relative status. Organizational energies which might theoretically be more profitably invested in the completion of projects are expended in concern for--and protection of--the institutional domain. (In this context, the boundaries of an organization's "domain" -- and the measure of its expansion

or contraction-seemingly are linked to the particular role which an organization has in the development and implementation of specific projects, and the number and scale of projects in which an organization is involved. The Ministry of Transportation currently appears to be attempting to define its domain as one of overseer and advisor, while the Implementation Agency for Greater Cairo is developing an institutional domain characterized as "large project implementation").

Contributing to the complexity of this process is the state of flux of inter-institutional relationships. Virtually each new major project which is slated and implemented is accompanied by some relative changes in institutional roles and degree of involvement.

It should also be considered, however, that the uncertainty arising from this situation may also be viewed as a positive factor. With a lack of rigid institutional role definitions may be associated a higher degree of flexibility and adaptability.

2. Even though the legitimization process leads to the development of "slate"of projects, there is apparently no time during the development and implementation of projects when the projects are comparatively evaluated except in an ad hoc manner. Projects tend to be viewed (in terms of impact) almost entirely as individual entities, with little opportunity allowed for evaluation in terms of their interactive or cumulative effects.

This may in part be due to a lack of the methodologies and project information necessary for such an undertaking. On the other hand, the current process of legitimizing projects has evolved in response to the particular needs of Egypt, and, up to the present, the more systematic comparison of projects may have been viewed as unnecessary, difficult to impose, or threatening.

This is a very important consequence of project slating as a form of planning. In this scheme the unit for initiating discussion of system development is "the project." This is in strict contrast to schemes in which projects emerge from efforts to attain overall objectives derived in a planning process. In the Egyptian scheme, projects arise independently as contributions sponsored by individual government agencies. As a result, comparative evaluation is a potentially envidious and divisive activity.

3. The project development process always needs to be monitored in order to balance the participation of the many actors involved. In many countries there is a tendency for the transportation facility building industry, including consulting civil engineers, to have a heavy participation in this process. Egypt is no exception. The firms have the advantage of including most of the nation's active facility design engineers. They are often expected to take the

initiative in facility development at the design stage. They are naturally anxious to make use of their competences on behalf of national development, and obviously have some interest in increasing the volume of activity in the sector. The nature of their professional roots leads to adherence to relatively high design standards, and the preference for capital intensive solutions (for example, facilities rather than traffic management).

The influence of these firms in the project development process is valuable and should be welcomed. On the other hand it needs to be guided. It is likely to be the most intensive at two points in the process, that of project conceptualization and during the design and implementation stages. At the initial conceptualization stage, it is necessary to consider newly presented projects within a context of overall concern for the transportation system. A well-presented functional design by a consulting firm may have inappropriate advantages in comparison with sketchier projects generated within the public sector (e.g. by a governorate). The act of moving projects onto the slate must be sensitive to their relative merits as projects without reference to their level of current conceptual development. The second point of intervention is more difficult to guide. During the process of design and execution, it is often necessary to vary initial project concepts in order to accommodate constraints encountered only during the design

process or changes of circumstances in the project environment since the initial planning. It is important, however, that these adjustments take place under the surveillance of public agencies. Judgements as to whether particular design adjustments are within the intent of the original plan, and are merited by the pattern of demands and constraints, are often very subtle judgements. In particular, there should be careful investigation of whether elevated expressway facilities are really required in Cairo, whether they convey more benefits than at-grade facilities. Similarly, traffic management solutions should be compared with proposals such as the widening of the Corneish.

4. In project implementation the reliability of two estimates --the total project cost and project implementation timetables--were identified as major sources of delay for almost all of the projects we examined.

Among cost projections, two elements were often cited as being unreliable: costs of superstructure and costs of foundation work. Linked to this is the circumstance that in almost all of the projects, one indicated source of delay was the insufficiency of the <u>total</u> appropriation of funds for the project. (The latter might also be credited to intentional under-allocation by the budget-makers, but it is at least partially linked to the usual occurrence of initial underestimation of project costs.)

The origins of project cost underestimation are difficult to trace, but our discussions in Cairo brought to light these two key sources:

(a) Initial minimum estimation. Whatever conflicts might arise concerning prioritization, all of the organizations involved in the implementation of projects have a generalized interest in seeing the construction of as many projects as possible. With severe budget constraints as exist in Egypt, a primary consideration of the budget-makers (the cabinet) is the cost of a proposed project. These circumstances create a powerful incentive to keep project cost estimations as a minimum, even at the risk of error and the need to raise the estimates at later dates. The critical point here seems to be the approval of the initiation of a project--in the form of an initial budget allocation. As indicated earlier, project abandonment is almost non-existent, and while there is strong evidence that project implementation timetables are frequently extended due to slow appropriation of funds from year to year, once a project is begun, there is a high certainty of its eventual completion. Thus, the intense desire to get a project started may contribute to cost underestimation.

(b) Inflation. Until the last few years, Egypt has experienced a high inflation rate, and apparently a fairly erratic one. This, in turn, creates an inability to forecast costs with any degree of accuracy. As indicated just above, there is considerable pressure to underestimate such costs, and in an atmosphere of doubt concerning the ability to forecast accurately, underestimation of inflation (whether intentional or not) would be expected.

The estimation of project implementation timetables is also a problem--and as in project costs, the tendency is to underestimate. The two are closely linked. Initial examinations of project costs and timetables must occur early in the development-implementation process in order to secure legitimization and budget allocations. Low budget estimates may rebound in requiring longer time to fulfill the stages of project development, a very typical situation. This, in turn, may exacerbate the insufficiency of budget estimates, and so forth. In any case, the process involves the potential intervention of so many outside influences and the estimate to time and accomplish tasks is inherently so uncertain that the calculation is at best unreliable.

Timetable underestimation, again, may be a consequence of pressures to minimize or not--though with a history of project

implementation experiences on which to draw, it may be reasonable to hypothesize that at least some of this sort of underestimation occurs. The reasons are exactly the same as in the underestimation of project costs--a desire to present the best possible case for implementing a particular project. (One possible solution to this problem might be to abandon a "under the best circumstances" estimate and adjust the estimated timetables to include more anticipated delay time).

5. The uncertainty of government commitment to the completion of a project on schedule may cause implementors to arrange the schedule of work so as to always maximize the priority of the next phase of construction. In an extreme case, this may take the form of building project components in such a sequence, for example, that the project is essentially inoperable until the last component is in place, rather than sequencing them to maximize the usefulness of the project at all phases of implementation. Highway projects may be undertaken by beginning the independently less useful links, and moving from them to those expected to be more heavily travelled. It may be useful to seek means of checking such inclinations. It is possible at our present level of observation to say that this inclination is not nearly as much a problem in Egypt as in many other countries.

6. Closely associated with the circumstances of the insufficiency of <u>total</u> project appropriations discussed above is the situation of low <u>annual</u> allocations for each project. Given the

options of substantial funding of a few projects in order to complete them quickly, or funding a larger number of projects at a lower level, there appears to be a strong preference for the latter. Behind this situation are at least two factors:

(a) The problems associated with narrowing the list of projects down to just a few of very high priority would be difficult. With the numerous organizations involved, it is probable that the funding of a number of projects --even at a lower level--maintains greater stability in the project development and implementation process.

(b) From the agencies' point of view there is likely to be more impact gained from initiating a new project than from accelerating the movement toward completion of current projects. While it is true that there is dissatisfaction with the slow completion of projects, there seems to be greater pressure to begin new ones. Thus, informal political priorities may be continuously shifting away from partially completed projects toward new projects at the initiation stage.

In addition to the generally low level of annual funding, there appears to be a high degree of unpredicability concerning the year-to-year funding of a project. Fluctuations in funding levels for each project from year-to-year indicate that priorities shift at least that frequently, and it is possible that a continuous process of priority adjustment exists.

7. In several cases, changes in project design resulted in delay of project implementation (e.g., 6th October Bridge, Rod el Farag Bridge, synchronized signal system, and the Abu Ela Bridge). In addition to the extensive initial review of a project proposal by a large number of organizations (leading to design changes), the longer the time period of implementation, the greater the probability that shifting priorities will force design changes. Additionally, unanticipated technical problems which arise during the course of implementation may require design changes (this is a significant factor discussed in the following section). And whatever the reason, a design change may necessitate a renewal of consensus building activities, as even marginal changes in design may alter an organization's decision as to whether or not it should be constructed.

8. Technical difficulties are also a major source of delay. The most persistent of these is the interference of unknown underground utilities during construction. (This was cited as a source of delay for each project we examined). Particularly a problem in the older sections of the city (where the mapping of utilities locations is poorer), the uncovering of unanticipated utilities often forces revision of implementation timetables, delay due to design changes, and increase of cost.

Unfortunately, little can be done to moderate this problem. Maps of utility locations in the older sections of Cairo are sometimes incomplete.

As a result, the location of underground utilities may be unknown until the excavation associated with a new transportation project reveals them--necessitating project redesign or utility relocation. (Utilities are the primary problem, but on occasion the "unknown" factor takes other forms. The construction of some of the ramps for the Abu el Ela Bridge has been delayed due to the uncovering during excavations of a large granite base of a no longer existing monument. Similarly, pile driving work on the 6th October Bridge access ramps was delayed due to the interference of large boulders from former fortification works--underground and unrecorded).

9. In addition, a lack of coordination of the project development activities among agencies may impact on transportation project implementation. While this was not as frequently mentioned a problem as other situations described here, it did appear specifically in connection with a construction project in Giza, where completion of the King Faisal Road (a divided, 6 lane highway with median) is stalled while the governorate's utility-installation organization replaces two utility pipelines under a yet-to-be completed 3 lanes of the project. Delay in the pipeline replacement has forced a delay in the highway construction project. There is another case in the Helwan-Heliopolis Autostrade, where a utilities agency's plan for the installation of structures is incompatible with the highway alignment. The design of the

synchronized signal system has required on-going negotiation among agencies concerned about various aspects of the city's street system. There is no antipathy among agencies implied by these problems. It is just that overlapping uses of land by different agencies requires sometimes time-consuming negotiation in order to attain successful solution. As far as we know there are no cases of special acrimony or stalemate.

10. In reference to the Governorates, the fact that the implementation of a majority of the urban transportation projects is their responsibility poses several problems. From all appearances and as indicated by our discussions in Cairo, the Governorates tend to have relatively small technical staffs to guide implementation. (In part due to higher wages opportunities available to such personnel in other Arab countries). Additionally, the design and construction firms which the governorates are to supervise are very large (at least on major projects in the Cairo area) and seem to wield considerable influence over project development and implementation. The notion that the governorate staffs somehow supervise the project activities of these large organizations may be somewhat illusory. This situation is formally recognized in the situation where a governorate contracts with a large design firm not only to design a project, but also to supervise its construction.

11. The most pervasive source of delay involves the expropriation of privately owned land and dwellings. In all instances --whether the project is being implemented through the Cairo Governorate, the Ministry of Transport, or other means--the governorate itself is responsible for the expropriation of required land.

While not explicitly stated, the level of expropriation which a potential transportation project requires appears to play a role in the general acceptability of project (i.e., the likelihood that it will be "slated"). In discussions concerning the Rod el Farag Bridge, considerable emphasis was placed on the fact that there were few delays primarily because all land-based construction is located entirely on Egyptian Railway Authority-owned land--and thus no expropriation was required. The completion of the access ramps for the 6th October Bridge, on the other hand, relies on the completion of a new Cathedral (financed by the Governorate and delayed due to construction difficulties at the new site) to replace the existing cathedral at the eastern end of the bridge. In the discussions of the various projects, a recurring consideration when questions arose concerning the likelihood of successful completion on schedule was the required amount of expropriated land.

The delays due to expropriation appear to arise out of the public disfavor for the dislocation of residence, a litigation process which allows owners to appeal to the courts concerning

compensatory offers for land expropriated by the governorates, and the scheduling of the expropriation event in the overall implementation process. In many instances, construction work was initiated on project components prior to the finalization of expropriation required for adjacent components. The 6th of October Bridge has previously been mentioned with regard to this; the construction work has also already been completed on sections of the Abu el Ela bridge, with plans and funds for required expropriation of homes yet to be finalized.

12. Delay in the approval of projects is often caused by lengthy consideration of the projects on the part of the local governorate assemblies. This is a problem confronted by the governments of many nations. It is a tribute to the Egyptian system that local approval is required before implementation, since local perspective is apt to be different than that of the sponsoring national agencies, and in some ways more significant. On the other hand, the interests in play when considering project development at the local level are also likely to be more varied, less focussed on a single sense of project objectives, and therefore less easily organized for purposes of decision. As a result, the government would do well to provide advice for the guidance of local decisionmaking on transportation projects. Such advice, perhaps supplemented by decision deadlines, might facilitate this complex local process.

13. The fact that a relatively high percentage (about 10%) of Egypt's work force is currently employed in other Arab nations appears to impact the technical needs of the government staffs. It is not clear to what extent this problem is exacerbated by simply the inability of the government (especially the governorates) to pay salaries competitive with the domestic private sector. In any case the deficit of experienced professional manpower in government agencies may have considerable impact on the development and implementation activities of the agencies.

    The private design and construction firms do not seem to suffer a problem of deficit in professional manpower. They appear to have little problem with construction labor either--other than the fact that they have sustained a faster rise in the cost of labor as a construction component than in other components.

The 'non-problems' which might have been anticipated but did not appear include:

14. While land expropriation and displacement present major obstacles to project completion, other external impact considerations receive minimal attention. In particular, various forms of "pollution"--noise,air, or water--are not a contentious point in project development and implementation. And the issue of land expropriation arises primarily with regard to residential displacement, to a lesser extent

with regard to farm land, and apparently not at all for non-cultivated land. Aesthetic concerns appear not to be of major significance, though the design for the intersection of the proposed widening of the Cornish-el-Nil and Salah Salem Street is currently in dispute due to consideration of an underpass or overpass configuration and the consequent visual obstruction. The raised pedestrian circles to move foot traffic around El Tahrir Square and Ramses Square were also subject to some debate in the press on the grounds of their visual effect prior to their construction.

15. And finally, despite some reliance on foreign sources for reinforcing steel and joints for bridges, there are few instances where this factor resulted in project delays. In fact, this was specifically identified as a "non-problem." It appears that once the foreign currency is available to purchase foreign goods, the importation of construction elements is routine.

V. IMPLICATIONS FOR PROGRAMMING

In concluding this review of transportation project development and implementation in Egypt, our intent is to lay the groundwork for the proposed adaptation of a programming process to Egyptian needs. The following is an effort to structure the insights gained from the project review into a broad outline of the form which a programming process might assume.

As discussed earlier in the paper, project development and implementation in Egypt involves a large number of domestic organizations and individuals. The nature of their involvement ranges from close and direct contact with project development to incidental and indirect. The roles of each of these organizations and individuals may generally be described as non-static through time --the role of each has attached to it a measure of ambiguity and changeability. This, in turn, creates uncertainty as to their future behavior. This uncertainty manifests itself in the lengthy, rather complicated consensus-building phase of project development, and also in the nature of the budget determination procedures. In such an environment, organizations and individuals attempt to increase the predictability of the behavior of others, for example, through consensus-building.

Among the large number of those involved, it is clear that no single organization or individual exercises controlling influence over the project development and implementation process. The Ministry

of Transportation serves as a sectoral representative and advisor, yet it is not in an overall decision-making position with respect to the programming of projects. The Ministry of Planning functions in a role consistent with its title, but it acts primarily in evaluating projects submitted by interested agencies. Although it may appear to be the best single candidate in the organizational network to direct the project programming effort, it is probably not in a position to take firm leadership of the process. It seems clear that, barring dramatic changes in the resources and span of control of these two organizations, whatever programming process is adapted for use in Egypt, its products will serve primarily as additional inputs into the overall project-programming decision-making process.

An important initial step in the effort to adapt a programming process to meet Egyptian needs is to consider the type of interface which each proposed process might require with the existing procedures of project development and implementation. In this regard, we believe that the process must operate in the context of the particular project selection activity--slating--described previously.

Project development in Egypt focuses on the 'slate'--the set of projects generally accepted as those which will be implemented. While it is relatively easy to determine if a project is considered to be slated or if it is not, it is difficult to isolate

a discrete indicator of the point in time when slating occurs. There is not yet a simple scale to measure the combination of institutional support, domestic budget expectations and impacts of foreign loan funds which is sufficient to slate a project. But, once a project is slated (even if the timing of the event is difficult to pinpoint), that project may be almost certainly considered as a project to be implemented. Relative priorities of slated projects may shift, but projects are not "de-slated."

The significance of this process to programming is illustrated by comparison with U.S. practice. Traditionally, project selection and project programming are overlapping (if not concurrent) activities in the United States. In a given programming activity, almost all potentially implementable projects are "programmed"--with the implicit understanding that some programmed projects (e.g., those of low priority) will not be funded. The programming activity thus serves also as a form of project selection.

We have seen that in Egypt the situation is much different. Project selection is a distinct activity, which is followed by programming the project into implementation.

In adopting a programming process for use in this environment, consideration must be given to its expected use. Narrowly defined, it may be utilized as a means of allocating capital investment funds among the set of slated projects; more broadly, it may be intended for use partially as a project selection tool, evaluating

the entire set of slated and non-slated projects and thus possibly impacting the contents of the slate itself.

There appear to be few conventions for generating data on individual projects. This situation complicates the task of systematically analyzing any proposed set of projects.

The use of a programming process may initially have its greatest impact in this regard. Such a process, constructed so as to require specific types of information on each project to be programmed, will undoubtedly encourage more rigorous comparative evaluation of the costs and benefits of each project than takes place now. If the initial impacts of the introduction of a programming process center on the generation of more refined, consistent project information--and this subsequently results in a greater awareness of and interest in the system-wide, cumulative effects of projects--much will have been gained.

Due to the fact that not all projects are constructed immediately after slating, we can infer that certain constraints must exist on development and implementation. The availability of personnel, construction equipment, and construction materials, the unforeseen technical problems and the overlapping organization responsibilities and concerns, have all been cited as sources of project delay--that is, as constraints on project implementation. But in reviewing the shape of present project development and implementation, and the problems encountered enroute to project com-

pletion, we come to the conclusion that the most significant constraint is the size and distribution of the capital investment budgets each year. The most important factor in determining when and with what intensity a project is undertaken is the funds allocated to it.

This suggests that a programming process adopted for use in Egypt must incorporate budget data as a major factor. Current practice in the United States is increasingly reliant on optimization methodologies as a means of programming projects in a budget constraint situation. Such an approach would be difficult to adopt for Egyptian use, due to the unpredictability of future budgets, the lack of knowledge concerning the budget-setting procedures within the cabinet, and the nature of the often substantial foreign loans, which are both unpredictable and often linked to specific projects. Additionally, many important considerations, organizational strategies, aesthetic impacts, etc., are currently outside the realm of optimization methodologies. These problems create pressure to develop a programming process not heavily reliant on optimization methodologies.

As noted earlier, predicting project costs (both annual and total) and project construction timetables is problematic. Both tend to be underestimated. To some extent, the uncertainty associated with these predictions may be reduced by increased emphasis on accuracy, by further research into the elements creating this uncertainty, and by standardizing data inputs on these topics. However, to the extent that these uncertainties

are linked to factors which are themselves largely unpredictable (e.g., technical problems arising from the discovery during construction of unanticipated underground utilities, or to factors whose complexity is considerable (e.g. inflation), these cost and timetable estimates will not be fully responsive to efforts at increasing their accuracy.

A programming process might conceivably react to this uncertainty by essentially ignoring it--that is, to assume certainty where it may not exist. Depending on the level of distortion resulting from this strategy, it may be acceptable in some instances. However, the ignorance of uncertainties may seriously undermine the usefulness, and acceptability of the output. In fact, perhaps the most significant single difference between the Egyptian project development environment and that of a developed country is the greater uncertainties in Egypt. Therefore, ignoring uncertainties is probably the greatest danger in method transfer. The matter is worthy of close attention.

A more difficult, but potentially more satisfactory, approach would be to structure the programming process in such a way as to deal explicitly with the uncertainties associated with its data inputs.

Due to the pervasiveness of the issue of uncertainty, Table VI-1 has been constructed to lay out the sources and forms of uncertainty.

Table V-1

ELEMENTS OF UNCERTAINTY IN THE DEVELOPMENT AND IMPLEMENTATION OF TRANSPORTATION PROJECTS IN EGYPT

Elements	Factors Contributing to the Uncertainty of Elements
1. Likelihood that any project will be 'slated'	- Success in building institutional support within Egypt - Foreign financial support - Current slate of projects
2. Prediction of project costs	- Inflation - Duration of project - Unanticipated problems in construction (e.g. unknown utility locations)
3. Prediction of project construction	- Materials procurement problems - Unanticipated problems in construction - Appearance of 'competing' projects - Relocation problems - Availability of supervisory and construction personnel - Unknown utilities locations
4. Urban Transportation Capital Investment Budget	- Size of the national budget - Interagency politics - Configuration of the slated projects - Strategy on extent to which funds are focussed on few projects or spread over many - Availability of foreign loan funds
5. Level of Funding for a project on year-to-year basis	- Unpredictability of national and transportation sector budgets - Development of new projects which compete for scarce investment resources
6. Agency responsible for implementation of a particular proposed project	- Several alternatives available, with some ambiguity of roles (This uncertainty is less significant than others listed here.)

Elements	Factors Contributing to the Uncertainty of Elements
7. "Path" of funding flow for a project	- Involvement of foreign funding sources - Strengths and strategies of domestic organizations involved - Roles of organizations
8. Foreign loan funds availability	- International relationships - Competences of foreign lenders - Strategies of foreign lenders

A particularly difficult issue in the adaptation of a programming process will be the manner in which it copes with the impacts of foreign loan funds. These funds, being characteristically linked directly to specific projects, are as such not truly "allocatable" in the programming process. They account for a significant proportion of capital used in the major projects and, as noted, may have considerable influence in project selection.

In addition, the foreign funds are a source of considerable uncertainty. The total amount of such funds available in any given time period, and their availability for particular proposed projects, is unpredictable. And the fact that these funds are primarily loans, will necessitate that any programming process consider them as the current encumbrance of future domestic capital.

There is evidence of a tendency to disperse transportation investment funds among many of the slated projects in any single year, rather than concentrating these funds on a few projects. If this, as we have hypothesized, arises in part from political and institutional necessities, then the output of a programming process may not be useful if it suggests concentrated investment of funds. A programming process must be capable of recognizing these necessities which lie outside the bounds of traditional analysis.

The locus of responsibility for the inputs to the programming process is a matter for consideration. By some means, information

must be generated for each project to be programmed. This task might be assumed centrally by the Ministry of Transportation; this would encourage greater accuracy, consistency, and specificity. However, in such a scheme, the Ministry might also open itself to charges of bias or incompleteness. Reliance on other organizations in the transportation sector for information concerning projects with which they are closely associated may be beneficial in terms of inter-organizational relationships--a factor of major importance if the programming process is to have any significant impact. Yet this approach to information generation may increase variability in the quality of data.

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TECHNOLOGICAL PLANNING PROGRAM

CONFERENCE ON

TRANSPORTATION PLANNING POLICY

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III.4

TRAFFIC VOLUME/TRAVEL BEHAVIOR SURVEY DOCUMENTATION

BY

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1. CRITERIA SELECTION: PROGRAM FORMULATION

The primary objective of the traffic survey element of the urban transportation project is to enable Ministry planners to assemble and use a transportation data base, and to provide input data for our programming method. Traffic volumes and travel behavior in the greater Cairo area were monitored on a prototypical basis so that standard survey procedures, analytical methods and documentation could be developed for Ministry use. Replication of the surveys in the future will provide a valuable data base from which analyses and projections can be made. It is anticipated that the project will provide a number of guidelines and tools necessary to effectively apply the data in designing and evaluating alternative actions in the transport sector.

As originally stated, the objective of Element I of the project was to conduct reasonably comprehensive traffic volume and travel behavior surveys for both private vehicular and transit movements, and to document the process of survey design, implementation and analysis. The documentation was expected to be thorough enough to allow the Transport Planning Authority of the Ministry of Transport, or the Ministry of the Interior to replecate the survey with a minimum of confusion, and a maximum of data validity and comparability.

In April, members of the project team from Cairo University, the Transport Planning Authority and MIT agreed upon a change in the work statement included in the original proposal. The scope of the work was modified to include comprehensive speed and delay

studies for arterial streets forming key segments of the street network under study. In addition, it is now assumed that a final product of the project will be an on-site (Cairo) operational assignment model which can predict traffic flows and speeds given alternative forms of the Cairo street network. It was further decided that the transit O-D survey will be excluded from this year's program, due to the fact that the number of stations which could have been included given the resources available would not have provided sufficiently comprehensive data. This exclusion allowed expansion of the private vehicular O-D survey and a corresponding increase in its eventual usefulness.

Primary survey criteria agreed upon by the participants, in addition to the criterion of transferability stated above, are as follows:

(a) O-D Survey is to be concentrated on vehicular traffic. In addition to the limitations imposed by finite resources, this constraint on the breadth of the study was imposed to allow focusing on the segment of greater Cairo vehicular flows which will provide the greatest component of future traffic congestion. Although it is estimated that at present less than 10 percent of Cairo person-trips are taken by private automobile, ownership of such vehicles is increasing rapidly and with this increase comes the prospect for greater future congestion.

(b) In order to provide the greatest probability that the results of the survey and subsequent analyses will be truly beneficial in solution of current transportation problems in Cairo,

the comprehensiveness of any data collected was considered essential. Hence, given the size and cost of the data collection effort proposed, the wiser course appeared to be the completion of a comprehensive vehicular survey as opposed to a less than comprehensive public transit or mixed-mode survey.

(c) It was also desired that the O-D and other data collected be adequately refined, sufficiently detailed and of a reliable enough sample size to allow the use of a sophisticated assignment model package. This criterion requires, for a city the size of Cairo, that enough volume and O-D stations be established to allow use of a large number of zones, nodes and links, which in turn allow the model to more accurately describe reality.

Based on these criteria, the survey effort was established with five principal parts. First, a preliminary traffic volume and O-D survey was performed in order to train supervisory personnel for the larger survey, and also to obtain data with which to analyze the 6th of October/Tahrir/Galaa bridge problem. The analysis of the resulting data allowed the staff to gain familiarity with the tasks which will largely be computer-performed during the comprehensive survey. (See also section 5 below). Second, the main survey was conducted utilizing 267 counting stations, roughly 96 percent of which were also O-D survey stations. Third, in order to calibrate a traffic assignment model accurately enough to allow it to be used in Egypt, relationships between traffic capacity, volume and speed over the network needed to be determined. Hence, speed and delay surveys were conducted on sufficient numbers of

streets and intersections to develop Cairo-specific parameters for relationships between link speed and traffic volume for streets of various widths, and for various types of adjacent land use. Fourth, all arterial and selected collector streets in the study area were inventoried to provide basic information to be used in future analysis. Number of usable lanes, parking regulations, adjacent land use and type of roadway were among the categories of data collected. Fifth, travel time measurements were made on nine key arterial streets which radiate from the Cairo CBD. These primary corridors to the CBD were profiled with respect to travel time, a process which highlighted areas of relatively severe congestion.

2. SELECTION OF THE STUDY AREA

The area to be covered by the origin-destination survey and traffic counting program was selected in order to satisfy several criteria. Participants in the selection included members of the project team from the Transport Planning Authority, Cairo University and MIT. Also included were representatives of the Ministry of the Interior interested in application of the resulting data to solution of intergovernate transportation problems.

Criteria for selection included the following:

(a) Inclusion of all congested protions of the greater Cairo metropolitan area. In order to avoid suboptimal solutions to regional problems, an area considerably larger than that covered during the SOFRETU short-run study of 1973 was considered essential.

(b) Inclusion within the study area of all major arterial, arterial and collector streets which handle cross-town, or circumferential traffic. It was assumed that all radially oriented streets would automatically be included.

(c) Inclusion of all major trip generators in the Cairo area. Major residential sectors, places of employment, educational institutions and shopping sectors were to be included.

(d) Inclusion of all crossings of the Nile likely to be used for intra-urban trips.

(e) Formation of the boundary of the study area so as to coincide with natural or man-made boundarys as much as possible.

The criteria listed above were used in the selection of the "Enlarged Central Area". In the process preparing the O-D Survey, it was found that a number of external trips were made to and from villages within 10-20 Km of the Enlarged Central Area Boundary, which were not of the same nature as intercity passenger or goods movement. In addition, anticipated growth in the Cairo area is likely to transform many of these villages surrounding the study area into suburbs, with attendent growth in travel. For purposes of projecting future growth and translating impacts of growth in a way that contributes to a rational planning process, a study area and zonal system which contains potential growth areas was seen to be desirable. Hence a large area peripheral to the central area was delineated, called the "Greater Cairo Metro Area".

3.1 DATA COLLECTION: Selection of Origin - Destination Zones

Zone boundary selection was made on the basis of the following criteria:

(a) Homogeneity of socio-economic status within each zone; to the extent to which each zone represents a single ethnic background, economic level, etc., the assumptions of relatively uniform trip frequency, and similar trip destinations and purposes will be accurate.

(b) Coincidence, to as great an extent as possible, with local administrative boundarys. If future trends are to be projected using data which has been collected and tabulated on the basis of the administrative zones, then this coincidence of boundarys can save considerable time and tabulation effort.

(c) Consistency of land use within each zone. Similar rationale to that for (a), above.

(d) Location of zone boundarys such that the boundarys run, as much as possible, at right angles to principal streets, rather than along or within the street.

3.2 DATA COLLECTION: Development of Survey Forms

Three different forms were developed for use in the first element of the project. These were as follows:

(a) Traffic Volume - designed to allow counting of all the major types of vehicles; and in addition to provide distinction between private and public transit buses, among the three principal types of public transit vehicles (trams, buses, and trolley buses),

and between private autos and taxis. For a complete listing of vehicle types counted, refer to section 6, "Survey Results, Formats and Codes." Also, a copy of the form used is attached as exhibit A.

(b) On-Route Interview - origin/destination and trip purpose are the key data elements desired. In addition, vehicle type, occupancy, governate of registration and over-night parking location were also asked. Once again, for a complete listing of information obtained, refer to the "Formats and Codes", section. A copy of the form used is attached as Exhibit B.

(c) Speed and Delay - designed to provide data for derivation of traffic speed and delay relationships along arterial streets and intersections and traffic circles. The surveys were conducted using the floating car technique. The survey form was designed to allow all major blocks of time spent moving or standing to be measured. A copy of this form is attached as Exhibit C. Traffic volume counts performed coincidentally were recorded on the form designed for this purpose. (Exhibit A).

(d) Travel time measurement - designed to record time lapsed between two points while travelling by car. A copy of this form is attached as Exhibit D.

(e) Street Inventory - designed to collect all necessary information concerning the physical characteristics of the street network. A copy of this form is attached as Exhibit E.

4. SURVEY EXECUTION

Following selection of survey station locations based on the network to be studied, manpower requirements were determined by

providing (a) sufficient traffic counting personnel to allow counting of 100 percent of the traffic at selected stations and (b) sufficient O-D survey personnel at the survey locations to allow a reasonably consistent sample size to be taken.

A total of approximately 780 personnel were assigned to 267 stations, an average of 2.6 per station. In addition, a reserve or backup group of 50 was used to relieve other surveyors who became tired, and to provide additional manpower where and when needed.

Due to the large manpower requirement, it was deemed desirable to first train a group of supervisors who would in turn handle a portion of the training for a group under their control. 36 supervisors and 34 other students were given lectures and a demonstration of the survey and interview technique, and participated in a preliminary survey centered on approaches to the 6th of October and Tahrir bridges. Three hours of surveying were conducted on April 14, between 7 and 10 am, during which guidance and supervision were provided by Dr. El Hawary and other members of the Cairo University team and the local Traffic Research Unit. The results of the initial survey were used to make minor adjustments in the survey procedures, and to suggest further refinements in the logistics for the larger survey.

The main body of surveyors and supervisors were divided into 10 groups. Surveyors were assigned to stations based on traffic volume estimates. Each surveyor was given a copy of a diagram of his station (see Exhibit F), copies of the survey forms and an instruction sheet explaining proper methods for traffic counting, or

O-D surveying. A total of approximately 16,000 traffic counting, and 50,000 O-D survey forms were used.

On April 16th all supervisors and surveyors were given a series of lectures explaining the process and giving them administrative instructions. On the 17th of April, the day prior to the survey day, all the supervisors and surveyors were assembled and given a pep talk. Each of the 10 groups were then assembled and supervisors for each survey station explained procedures, answered questions, etc. Each of the 10 groups was assigned a bus which would distribute each of the members of the group to his respective station. Each bus driver was given a map (see Exhibit G) which detailed the route to be taken.

Following the general meeting of April 17th, the surveyors were taken to the stations in the same fashion that would be used the next morning on the day of the actual survey. In the field each supervisor pointed out each surveyor's location, indicated which traffic flows to count or interview, answered further questions, etc.

On the day of the survey, ten radio-equipped cars were borrowed to assist with field emergencies and logistical control. A survey control room was also established to facilitate dispatching of additional surveyors (from the 50 held in reserve) via the vehicles to stations in the field. Each vehicle was responsible for checking regularly with specified stations in order to minimise data lost due to lack of personnel, supplies or from any other source. At the end of the survey day at 10 pm the groups were returned to the

starting point, forms and materials were collected, forms were checked to make sure that results from each station had been turned in, and then the groups were released.

5. DATA PROCESSING DESIGN

The data contained on the forms was coded and key-punched according to the keys in the "Formats and Codes" section.

Coding for the origin destination and overnight parking data was accomplished by subdividing the large-scale map of the Cairo area into major zones or neighborhoods. Each of these major zones was divided into two to seven sub-zones (see section 3.1, above "Selection of Zones"), totaling 66 within and 42 outside the study area. A map of each major zone was prepared which overlaid sub-zones on the local street system. The coders, working in pairs to minimize errors and to combine knowledge of the city, obtained the correct large-zone map and determined the correct sub-zone by pin-pointing the street address. The use of a number of smaller large-scale maps obviates the need to have a number of people simultaneously pouring over a single very large map.

At the completion of key-punching of the data at the scientific computational center at Cairo University, data processing began. The key outputs are tables of traffic volumes that can easily be associated with grographic locations, and origin-destination matrices. The results have been assembled and presented as follows:

5.1 Traffic Counts

(a) Volume of each vehicle type collected by 10-minute time interval, summed over each hour and over the survey period. Also

hourly volume of each vehicle type is expressed as a percentage of total volume counted during the hour. A table has been created for each traffic counting station, along with a summary table for all stations. Format is as follows:

TRAFFIC VOLUME IN VEHICLES
Station No. XY

Vehicle Type

Time Interval	Private Auto	Taxi	. . . . .	Animal Cart	Human Cart	Total
7:00-7:10	xxx	xxx	...	xxx	xxx	xxxx
7:10-7:20	xxx	...				
7:20-7:30						
.	.					.
.	.					.
.						
7:50-8:00	xxx					xxxx
7:00-8:00 am	Σ xxxx	Σ xxxx	....			Σ xxxx
%[1]	yy%	yy%	....			100%
8:00-8:10	xxx	xxx				
8:10-8:20	.					
8:20-8:30	.					

[1]Percent of Total Vehicles Counted During the Hour

b) Similar to a), except that volumes are expressed in passenger car equivalents (PCE).

The conversion factors used are as follows:

Vehicle Type	PCE
Private car	1.00
Taxi	1.00
Microbus (Van)	1.25
Non-transit bus	2.00
Transit bus	2.50
Tram	5.00
Trolley bus	3.50
Pickup truck	1.50
Truck	2.50
Tractor-trailer	4.50
2-wheeled Vehicle	0.50
Animal cart	8.00
Human-powered cart	2.00

5.2 Roadside Interview Survey

a) Occupancy Rate by Vehicle Type:

Occupancy rate is defined as the average number of people per vehicle. Occupancy rates for specific vehicle types are calculated as averages for all stations and hours of the survey. Format of the output is as follows:

OCCUPANCY RATE FOR SELECTED VEHICLE TYPES; PASSENGERS PER VEHICLE

Private Car	Taxi	Micro-Bus	Private & Government Buses	Bicycle or Motorcycle
X.X	X.X	XX.X	XX.X	X.X

b) Purpose by Time of Day:

A summary table of trip purpose by time of day for all trips is prepared. A summation of data for private cars, taxis, vans, private buses, bicycles and motorcycles. Table displays volume of trips for each purpose and hour, and the percentage of total trips for each hour represented by each trip purpose. Total for each hour (overall purposes) and for all hours of the survey are given.

Format is as follows:

TRIP PURPOSE BY TIME OF DAY

EXPRESSED IN PASSENGER TRIPS

TIME INTER.	TRIP PURPOSE				
	1 HOME/WORK WORK/HOME	2 HOME/ED ED/HOME	3 HOME/OTHER OTHER/HOME	4 OTHER/ NOT HOME	5 TOTAL
7.00 8.00 Percentage	XXXX YY%	XXXX YY %	XXXX YY %	XXXX YY %	XXXXX 100
8.00 9.00 Percentage					XXXXX 100
9.00 10.00 Percentage					XXXXX 100
10.00 11.00 Percentage					
13.00 14.00 Percentage					
4					
21.00 22.00 Percentage					
Total Percentage	XXXX ZZ%	XXXX			XXXXX 100

1) Trip Purposes 01, 02, 20, 15, 60 (Refer to page of codes) for explanation

2) Trip Purposes 03, 04, 16, 40

3) Trip Purposes 05, 06, 30

4) Trip Purposes 07 through 14 + 99.

c) A summary table of trip purposes for vehicles types 02, 03, (private cars and taxis) for all trips and for all hours of the survey. Totals for each vehicle type (over all purposes) are given.

Format is as follows:

TRIP PURPOSE FOR PRIVATE AUTOS AND TAXIS

EXPRESSED IN PASSENGER-TRIPS [1]

VEHICLE TYPE	HOME/WORK WORK/HOME	HOME/ED ED/HOME	HOME/OTHER OTHER/HOME	OTHER	TOTAL
PRIVATE AUTOS(02)	XXXX	XXXX	XXXX	XXXX	XXXXX
PERCENTAGE	YY %	YY %			100%
TAXI(03)	XXXX	XXXX			XXXXX
PERCENTAGE	YY %	YY %			100%

1 - Number of Passengers is Obtained from the Corresponding Column in the O.D. Form.

d) Number of vehicles interviewed by vehicle type and hour of day for each station. Summary table provides same format, but includes all stations.

Format:

NUMBER OF VEHICLES INTERVIEWED

STATION NO ...

TIME INTERVAL	PRIVATE CARS	TAXIS	MICRO-BUSES	...	TOTAL
7.00 8.00	XXX	XXX	XXX		XXX
8.00 9.00					
↯					
20.00 21.00					
TOTAL	XXX	XXX	XXX		

e) Sample size (Ratio) of vehicles interviewed by vehicle type and hour of day for each O-D station. Summary table of all stations. [1]

Format:

SAMPLE SIZE BY VEHICLE TYPE

STATION NO. .....

TIME INTERV.	PRIVATE AUTOS	TAXI	.....
7.00 8.00	XXX	XXX	
8.00 9.00	XXX	XXX	
↯			
20.00 21.00	XXX	XXX	
TOTAL [2]	XXX	XXX	

1 - The sample size is defined as the ratio between the no. of vehicles interviewed (4) divided by the volume of vehicles passing the station during the same period (see output by hour and vehicle types of traffic count processing).

2 - Total ratio is obtained by dividing the no. of vehicles interviewed over the 10 hour period by the total volume of traffic over the 10 hours (see output of traffic counts).

f) Expanded (using results from e) O-D matrices for each vehicle type and each hour of the survey period, (i.e., each matrix represents expanded O-D information for one vehicle type for one hour). Summary matrix for each vehicle type for the entire survey period.

Format:

ORIGIN/DESTINATION MATRIX (EXPANDED DATA)
VEHICLE TYPE ..... TIME OF DAY .. 00 .. 00

DEST. / ORIGIN	XXXXX	XXXXX					TOTAL
XXXXX	XXX	XXX					XXX
XXXXX	XXX	XXX					
XXXXX	XXX						
TOTAL	XXXXX	XXXXX					

g) Expanded O/D matrices by PCEs for each hour of the day.

Summary matrix for the entire survey period.

Format:

ORIGIN/DESTINATION MATRIX: EXPANDED DATA
VOLUMES EXPRESSED IN PASSENGER CAR EQUIVALENTS
TIME OF DAY ..., 00 -- ..., 00

DEST. ORIGIN	XXXXX	XXXXX			TOTAL
XXXXX	XXX	XXX			XXX
XXXXX	XXX	XXX			XXX
TOTAL	XXX	XXX			XXX

h) Number of vehicles parked overnight by zone by vehicle type 02, 03, 04, 05, 09, 10, 11, 12, 13 and 14 for eadh hour of the day. Each table will represent one hour. Summary table to show data for entire survey. Expanded data will be used in both hourly and summary tables.

Format:

OVERNIGHT PARKING BY ZONE: EXPANDED DATA

TIME OF DAY: ---, 00 ---, 00

ZONE NUMBER	PRIVATE AUTOS	TAXI	MICRO-BUS	...	TOTAL
XXXXX	XXX	XXX	XXX		
XXXXX	XXX	XXX	XXX		
↳					
XXXXX					
TOTAL	XXX				

i) Number of vehicles registered by governorate for vehicle types 02, 03, 04, 05, 09, 10, 11 and 12 for each hour of the survey period. Summary table for entire period. Expanded data to be used.

Format:

VEHICLE REGISTRATION BY GOVERNORATES
EXPANDED DATA
TIME OF DAY ..., 00 ..., 00

GOVERNORATE	PRIVATE AUTOS	TAXI	MICRO-BUS	...	TOTAL
Cairo	XXX	XXX	XXX		
Giza	XXX	XXX	XXX		
↯					
Aswan	XXX	XXX			
Total					

j. Tables indicating whether vehicle trips are internal, external, or some combination of the two. The enlarged central area, the Greater Cairo Metro Area and the remainder of Egypt (external trips) are areas used. Three tables are generated:

--- Number of vehicle trips by area combination and vehicle type for all hours surveyed. Data are summed both over all vehicle types for each area combination, and over all area combinations for each vehicle type.

--- Percentage of vehicle trips of each vehicle type for each area combination.

--- Percentage of vehicle trips of each area combination for each vehicle type.

Format:

TRIP TYPE BY TYPE OF VEHICLE
NUMBER OF VEHICLE TRIPS; EXPANDED DATA
TRIP TYPE

VEHICLE TYPE	CENTRAL-CENTRAL	CENTRAL-METRO	CENTRAL-EXTERNAL	METRO-METRO	METRO-EXTERNAL	EXTERNAL-EXTERNAL	TOTAL
PRIVATE AUTOS	XXX	XXX	XXX				XXX
TAXI	XXX	XXX	XXX				XXX
↯							
TOTAL	XXX	XXX	XXX				XXX

6. SURVEY RESULTS: FORMATS AND CODES

Each data card will represent two ten-minute time segments of counting at a specific station.

6.1 Data card is as follows:

Col. No.	Total Cols. No.	Value
1 - 3	3	Station No.
4 - 7	4	Time of beginning count
8 - 10	3	Private car
11 - 13	3	Taxi
14 - 15	2	Micro-bus (Van)
16 - 17	2	Private Bus
18 - 19	2	Transit Bus
21 - 21	2	Tram
22 - 23	2	Trolley Bus
24 - 25	2	Pickup Truck
26 - 27	2	Truck
28 - 29	2	Truck with Trailer-Tractor
30 - 31	2	Bicycle/Motorcycle
32 - 33	2	Animal Cart
34 - 35	2	Human Powered cart
36 - 39	4	Time of Count beginning
40 - 42	3	Private Car
43 - 45	3	Taxi
46 - 47	2	Microbus
48 - 49	2	Private Bus
50 - 51	2	Transit Bus
52 - 53	2	Tram
54 - 55	2	Trolley Bus
56 - 57	2	Pickup Truck
58 - 59	2	Truck
60 - 61	2	Truck with Trailer/Tractor
62 - 63	2	Bicycle Motorcycle
64 - 65	2	Animal Cart
66 - 67	2	Human Powered Cart.

6.2 O-D Survey

Each data card will represent three interviews at a specific station. Data card format is as follows:

Col. No.	Total Col.	Data Element
1 - 3	3	Station identifying No.
4 - 5	3	Data form serial No.
6 - 9	4	Time of day[1]
10 - 11	2	Vehicle Type
12 - 13	2	No. of passengers
14 - 18	5	Origin
19 - 23	5	Destination
24 - 25	2	Purpose
26 - 30	5	Location of Parking overnight
31 - 32	2	Vehicle registration Governorate
33 - 34[2]		Vehicle type.

1: Time at beginning of 10-minute period during which the three interviews were conducted.

2: Vehicle type for second of three interviews.

Codes for the above data elements are as follows:

Data Element	Code Value	Interpretation
Station Category	1	Station located on outer cordon
	2	Station located on inner cordon
	3	Station located between cordons
Vehicle type	02	Private car
	03	Taxi
	04	Microbus (van)
	05	Private bus
	06	Transit bus
	07	Tram
	08	Trolley bus
	09	Pickup truck
	10	Truck
	11	Tractor-Trailer
	12	Bicycle/Motorcycle
	13	Animal cart
	14	Human-powered cart
	99	Vehicle type not entered

Data Element	Code Value	Interpretation
Origin or destination	0 (1st digit)	Trip began/ended outside Cairo metro area
	1 "	Began/ended between Cairo metro boundary and Cairo city boundary.
	2 "	Within Cairo city boundary
	digits 2;3[1)]	Zone number
	digits 4;5[1)]	Sub-zone number
Trip purpose	01	Home - work
	02	Work - home
	03	Home - education
	04	Education - home
	05	Home - other
	06	Other - home
	07	Work - work
	08	Other - other
	09	Work - other
	10	Other - work
	11	Other - education
	12	Education - other
	13	Education - work
	14	Work - education
	15	Home - home
	16	Education - education
	20	Work
	30	Other
	40	Education
	50	Trucks
	60	Home
	99	No entry

1) location of overnight parking

1) governate of registration

DATA ELEMENT

Zones and Subzones

Note:

The Codes for origins and destinations within the study area have a "2" in their first digit. The second and third are the number of the zone, and the fourth and fifth digits are the number of the subzone.

Zone	Subzone Code No.	Serial Subzone Code No. For O.D. Matrices	Subzone Name
1	20101	1	El-Mounib
	20102	2	Rabei El-Guizi
2	20201	3	El-Gamaa Wasat
	20202	4	Boulak El-Dakrour
3	20301	5	El-Mesaha-Orman
	20302	6	El-Dokki Wasat
	20303	7	Makar Garage
4	20401	8	Agouza Wasat
	20402	9	Nady El-Said
5	20501	10	El Mohandessen
	20502	11	Sphinx Square
	20503	12	El-Sahafyeen City
6	20600	13	Embaba-Kit Kat-Mounira
7	20702	14	El-Roda
	20701	15	El-Manial
8	20801	16	El-Zamalik Bahri
	20602	17	El-Zamalek Kebli
9	20901	18	Masr El-Kadima
	20902	19	Fom El-Khaleeg-Dair El Nahas
10	21001	20	Saida Zeinab Square
	21002	21	El-Khalifa
	21003	22	Zainhom - Abou El reesh

Zone	Subzone Code No.	Serial Subzone Code No. For O.D. Matrices	Subzone Name
11	21101	23	Garden City
	21102	24	Area of Ministries
12	21201	25	El-Tahrir
	21202	26	Talat Harb Square
	21203	27	Ataba
	21204	28	Abdeen
	21205	29	Klott Bek
	21206	30	Tawfikia
	21207	31	Ramses, Galaa
13	21301	32	Bulak, Abu El Ela
	21302	33	Kolali, Sabtia
14	21401	34	Bab El-Khalk
	21402	35	El-Kalaa
15	21501	36	Azhar - Ghoria
	21502	37	El-Darrasaa
	21503	38	Bab El-Sharia
	21504	39	El-Guiesh Square
16	21601	40	Ghamra
	21602	41	El-Fagala, El-Zaher
17	21701	42	Road El-Farag
	21702	43	Nafak Shoubra
	21703	44	El-Teraa El-Boulakia
18	21801	45	El-Sahel

Zone	Subzone Code No.	Serial Subzone Code No. For O.D. Matrices	Subzone Name
18	21802	46	Hadaik Shoubra
	21803	47	El-Mazalat
19	21901	48	Sharabia
	21902	49	El Kablat, Mostorod
20	22001	50	El-Demerdash
	22002	51	Abdou Basha
21	22101	52	Seket El-Waili
	22102	53	Cargo Station
	22103	54	Dair El-Malak
	22104	55	Manshiet El-Sadr
	22105	56	Saray El-Koba
22	22201	57	El-Sawah
	22202	58	El-Ameria
23	22301	59	El-Zeitoon
	22302	60	Kobri El-Kobah
24	22401	61	Nasser Mosque
	22402	62	Manshiet El-Bakri
25	22501	63	Roxi
	22502	64	Ismailia Square
	22503	65	El Gamee Square
	22504	66	El-Hegaz

Zones which lie between the study area and the "greater Cairo" area boundary are delineated and coded as follows:

Subzone Code No.	Serial Subzone Code No. For O.D. Matrices	Subzone Name
10100	67	South of Mounib
10200	68	West of Guiza and Ahram
10300	69	West of Boulak El-Dakrour
10400	70	North of Embaba
10500	71	North of Shubra
10600	72	Mostorod
10700	73	Abou Zaabal and Khanka
10800	74	El-Nozha
10900	75	North of El-Nozha
11000	76	East of Oronba street
11100	77	Nasr city
11200	78	El-Gabal El-Ahmer
11300	79	El-Basateen
11400	80	South of Masr El-Kadima

Zones outside the cordon of Greater Cairo (Governorates) are as foolows:

Subzone Code No.	Serial Subzone Code No. For O.D. Matrices	Subzone Name
00400	81	Kalioubia
00700	82	Sharkia-Dakahlia
01000	83	Sharkia
01300	84	Suez
01600	85	Ismailia
01900	86	Port Said
02200	87	Dakahlia
03100	88	Gharbia
03400	89	Gharbia
02500	90	Demiat
02800	91	Menoufia
03700	92	Dakahlia - Kafr El-Sheikh
04000	93	Kafr El-Sheikh
04300	94	Kafr El-Sheikh-Behaira
04600	95	Behaira
04900	96	Behaira
05200	97	Behaira
05500	98	Behaira
05800	99	10th of Ramadan
07000	100	Guiza - Bani Sonaif
07300	101	El-Menia
07600	102	Assute
07900	103	Souhag
08200	104	Kena
08500	105	Aswan
06700	106	El-Gayoum
08800	107	El-Wadi El-Gadeed
09100	108	Red Sea

EXHIBIT A

TRAFFIC VOLUME DATA COLLECTION FORM

SHEET 2

VOLUME COUNTS SHEET

Area Type:

Facility Type:

PAGE NO. ____ STATION NO. ____ DATE ____

1	2	3	4	5	6	7	8	9	10	11	12	13	14
TIMING	PRIVATE CAR	TAXI	MICRO-BUS	PRIVATE BUS	P.T. BUS	TRAM	TROLLEY BUS	SEMI LORRY	LORRY	LORRY WITH TRAILER	BICY-CLE	CAR	TRI-CYCLE

211

Ministry of Interior - Ministry of Transportation

Street Survey by [illegible]

STREET [illegible] FORM

Start Time

End Time

Station on the outer cordon

Station on the inner cordon

Station between the inner and outer cordon

1	2	3	4	5	6	7	8	9	10
[illegible]	[illegible]	[illegible]	[illegible]	Origin	Destination	Trip Purpose	Parking by night (place)	Governorate of Registration	Remarks

Best Available Document

EXHIBIT C

SHEET 1

Trip No. | | |

Page No. | | |

Date | | |

Travel Time and Delay Study Form

Area Type:-

Facility Type:-

Name of Observers:-

Enterance Node:- Intersection: Street:

Exit Node:- Intersection:

No. of Workable Lanes:- No. of design Lanes:

Next Link: Next Street:

	HR.		MIN.		SEC.	
Time at Intefance Node						
Time at Exit Node						

Steps:-

1	2		Reasons For Stops
Serial No. of Stops	Step Time		
	Minutes	Seconds	
1st			
2nd			
3rd			
4th			
5th			
6th			
7th			
8th			
Total Delay Time			

REASONS KEY:- Traffic Signal TS Traffic Congestion: C Stop sign: SS

Zebra Crossing: Z Parking: P. Turn Left: Lt Bus: BT Taxi: TP

Traffic Weaving: T

Miscellaneous: M

Travel Time On Link No.:- m

Total Time of Stops On Link: m

Actual Travel Time: m

Length between Entrance and Exit Nodes :

Operation Speed

Operation Condition: Free Flow ☐ Peak Flow ☐

EXHIBIT D

Travel Time Study

Trip No.

Page No.

Date

Name of Observer:

Route No:

Starting Point at Going:

Time of Starting at Going: hr. min. sec.

Time of Ending at Return: hr. min. sec.

No. of Station	TRIP: Name of Station	GOING: Time at Passing on Station (sec min hr)	GOING: Time on The Link (sec min hr)	GOING: Notes	RETURN: Time at Passing on Station (sec min hr)	RETURN: Time on The Link (sec min hr)	RETURN: Notes
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

Place of end at Station

Time of End of Trips sec. min. hr.

Place of Start for Return

Time of starting for return sec. min. hr.

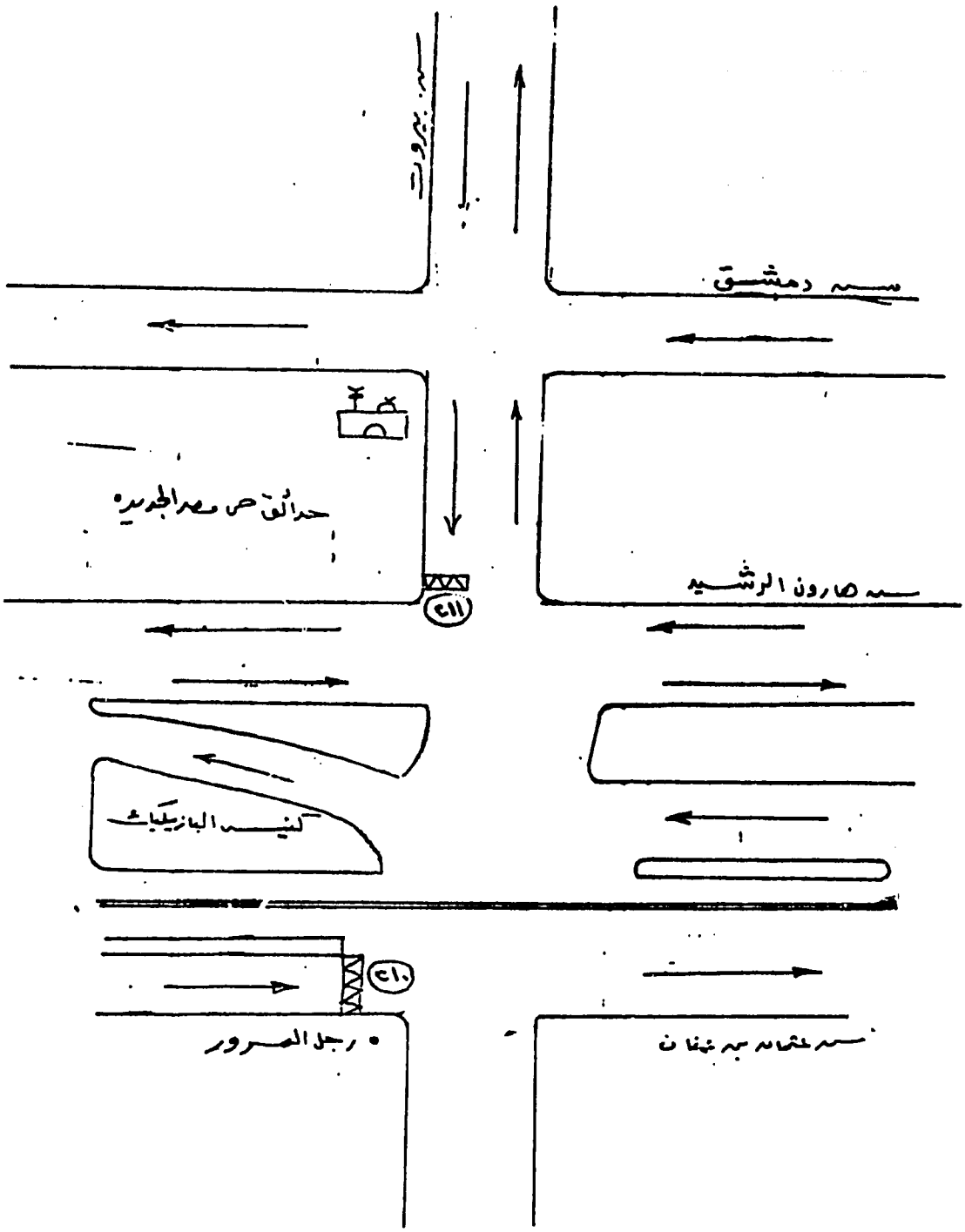
EXHIBIT E

PHYSICAL CHARACTERISTICS OF
LINKS IN CAIRO ENLARGED DOWNTOWN

from node	to node	Street Name	No.of Work-able lanes	No.of Park-ing lanes	Kind of Parking	total width of street (m)	width of work-ing carriage way	No.of Excess Roads	Capa-city cata-gor-ies

محطة رقم ٢١١ ، ٢١٠
تقاطع بيروت وهارون الرشيد

EXHIBIT F
SAMPLE SURVEY STATION
LAYOUT DIAGRAM

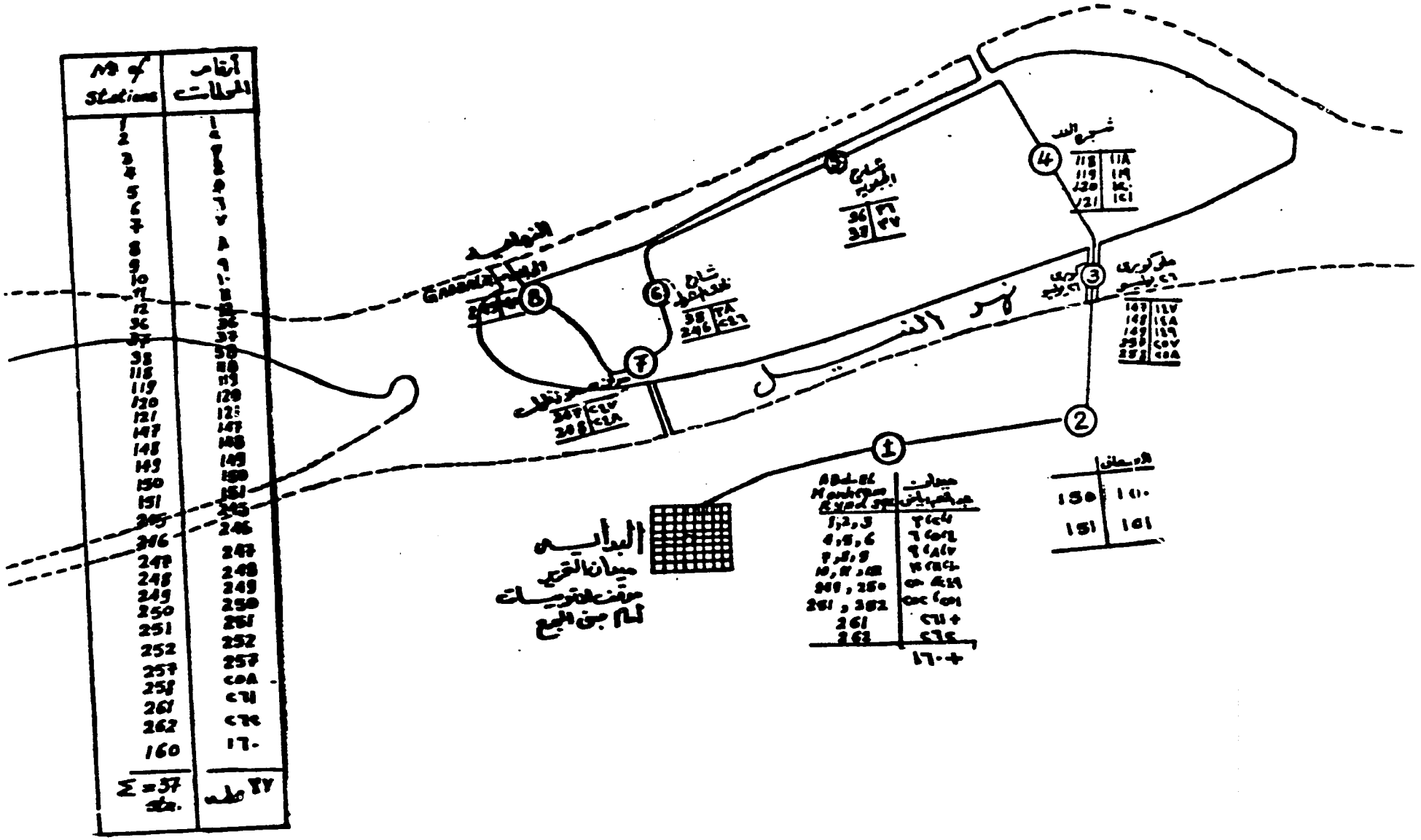


محطة رقم	عدد الافراد		رجل المرور
	عدد	استقرار	عدد
٢١٠	١	١	١
٢١١	١	١	١

EXHIBIT G
SAMPLE BUS ROUTE

المجموعة الخامسة

خط سير أتوبيس رقم (5)



No of Stations	أرقام المحطات
1	١
2	٢
3	٣
4	٤
5	٥
6	٦
7	٧
8	٨
9	٩
10	١٠
11	١١
12	١٢
36	٣٦
37	٣٧
38	٣٨
118	١١٨
119	١١٩
120	١٢٠
121	١٢١
147	١٤٧
148	١٤٨
149	١٤٩
150	١٥٠
151	١٥١
245	٢٤٥
246	٢٤٦
247	٢٤٧
248	٢٤٨
249	٢٤٩
250	٢٥٠
251	٢٥١
252	٢٥٢
257	٢٥٧
258	٢٥٨
261	٢٦١
262	٢٦٢
160	١٦٠
Σ = 37 Sta.	٣٧ محطة

ABLOK Numbers Block Sections	ميادين
1, 2, 3	١، ٢، ٣
4, 5, 6	٤، ٥، ٦
7, 8, 9	٧، ٨، ٩
10, 11, 12	١٠، ١١، ١٢
249, 250	٢٤٩، ٢٥٠
251, 252	٢٥١، ٢٥٢
261	٢٦١
262	٢٦٢
	١٦٠ +

150	١٥٠
151	١٥١

جامعة القاهرة - معهد ماساتشوستس للتكنولوجيا

برنامج التخطيط التكنولوجى

CAIRO UNIVERSITY - MASSACHUSETTS INSTITUTE OF TECHNOLOGY

TECHNOLOGICAL PLANNING PROGRAM

CONFERENCE ON

TRANSPORTATION PLANNING POLICY

JUNE 20-22, 1978

CAIRO, EGYPT

III.5

PUBLIC TRANSIT SURVEY METHODOLOGY:

APRIL 17-20 and 22, 1978

BY

THE URBAN TRANSPORTATION PROJECT TEAM - CAIRO UNIVERSITY,

TRANSPORT PLANNING AUTHORITY AND CAIRO TRANSIT AUTHORITY

1. INTRODUCTION

Mobility is a major problem facing Cairo's motorists and passengers alike. Cairo's public transport system, serving the major city of a developing country with very low levels of automobile ownership in comparison to developed countries, will play an important role in any proposal intended to 'solve' this mobility problem.

A study of Cairo's public transport system has been undertaken, its principal objectives being:

(a) To develop an analytical tool which can be relied upon to give realistic simulations of public transport travel demand and supply.

(b) To identify deficiencies which may exist in the public transport services of Cairo.

(c) To analyze proposed modifications and extensions of the public transport network.

(d) To extend the capabilities of the transportation project programming methodology, which is concurrently under development, to include public transport projects as candidates for future funding.

In order to achieve these objectives, Origin-Destination matrices for public transport passenger movements by trip purpose and by time of day on different modes will be developed. This report describes the methodology selected to achieve this aim, together with a detailed description of the preparation and execution of the fieldwork.

The public transport sources of Cairo are operated by three different organizations:

(a) the Cairo Transportation Authority, which is an element of the Cairo Governorate and under the technical supervision of the Ministry of Transport and communications. The Authority operates buses, trams,

trolley-buses and ferries in the Greater Cairo Area.

(b) the Heliopolis Reconstruction Company, which is an element of the Ministry of Housing and Reconstruction. The Company operates the Heliopolis Metro transit line.

(c) the General Organization of Egyptian Railways, an independent organization which operates the urban railway lines between Kobry El Laman and El Marg, and between Bab el Luk and Helwan.

The survey described in the report was carried out in the period of April 17-20 and 22, 1978. The first four days of the survey focused on the primary public transport mode -- the bus network, with all other modes surveyed on the fifth day.

2. SELECTION OF THE APPROPRIATE SURVEY TECHNIQUE

In order to permit the integration of the results of the public transport survey with the results of the private vehicular survey which was conducted in 1977, it was determined that the same 60-zone configuration would be utilized for the public transport survey. This will facilitate comprehensive studies and analysis in the future.

2.1 Survey Techniques for All Modes Other Than the Urban Railway Line.

The ticketing and boarding procedures of the urban railway lines necessitated a special survey technique, described in Section 2.2 below. The procedures outlined here were utilized for buses, trams, trolleys and ferries.

2.1.1 Survey Technique: Location of Interviews

There were basically two possible interview locations. These two alternatives were:

(a) Interviewing passengers at boarding/disembarkment stops. This technique offers two primary advantages:

(1) avoidance of the problems associated with interviewing passengers on board the frequently overcrowded vehicles.

(2) all interviews could be grouped on an hourly basis for computational purposes.

It had the following disadvantages:

(1) interviewing at stops would tend to exclude arriving passengers and include primarily those waiting to board.

(2) in cases where more than one line serves a single stop, enlargement of the interview sample to population size would be impossible within reasonable levels of accuracy.

(b) Interviewing passengers on board. The procedure would have one interviewer surveying passengers on board throughout each run. To achieve a safe minimum sample size, one interviewer would be assigned to each vehicle along each route. The interviewers would be assigned a seat, varying in position, on successive vehicles in the following pattern: next to the front door in the first vehicle, at an intermediate position in the second vehicle, and near the back door in the third vehicle. The advantage ot this procedure would be avoidance of biasing the sample toward those passengers who boarded at one end or the other of the route.

In order to assess the difficulties associated with each of the alternative techniques, and to measure the rate at which interviews could be completed, a test of both methods was conducted on January 17, 1978, from 6:30 a.m. to 2:30 p.m. Two ten-man teams of trained interviewers from the Cairo Transport Authority were assembled. Ten interviewers were assigned to bus routes number 44, 44', and 26 (one per bus), and

ten interviewers were assigned to bus stops.

The analysis of the results of these interviews indicated that passengers were very cooperative and responded to the questions asked by the interviewers. The on-board surveyors averaged twelve interviews per hour; the rate for the surveyors at the bus stops was twenty-give interviews per hour. Aside from the crowded conditions on the buses, a key reason for the difference in the interview rates was that the passengers surveyes on-board asked a number of questions about the survey and also used the opportunity to lodge service complaints. Passenger interviewers at bus stops did not experience this delay-causing factor.

As a result of this experiment, it was decided to adopt the on-board survey technique in order to avoid bias in the results.

2.1.2 Survey Technique: Sampling Procedure

A review of the plans for the public transport survey was conducted by the Cairo University and MIT teams near the end of March. It was decided to include two additional items in the survey form: sex of interviewee and shopping as a possible trip purpose. (See Form 2, Appendix 1.)

It was also determined that further investigation of possible biases in the sampling technique should be investigated; particularly with regard to a potential bias toward long-distance passengers who would have a higher probability of being interviewed during the survey. An experiment was conducted to test for any such bias.

Two bus routes were selected for this experiment. The first, Bus Route Number 50, extends from Guesr El Suez to Tahrir Square. This route (17.95 km) is representative of long-distance routes. The second, Bus Route Number 5, extends from Mit Okba to Ataba Square. This route

(5.1 km) is representative of short-distance routes. These routes were selected so as to fulfill the following criteria:

(a) Each route should pass through several zones.

(b) No route should be circular.

(c) The overall trip-lengths between terminals should be representative of both long and short distance routes.

Two alternative data collection procedures were tested:

Alternative A. In this procedure, three vehicles on each bus route were surveyed, with one interviewer per bus. The position of the interviewer varied for each vehicle; next to the front door in the first vehicle, near the back door in the second vehicle, and in an intermediate position in the third vehicle. The intermediate position was included so as to avoid collecting data solely from the short distance passengers who usually stand by the doorways.

Alternative B. In this procedure, three interviewers were allocated to one vehicle along each bus route. They were seated one near the front entrance, one near the rear, and one in an intermediate position. The hypothesis here is that this procedure will, by increasing the sample size of passengers interviewed on a single bus, result in an unbiased sample of the total population. The primary drawback of this procedure is that only one-third as many buses can be surveyed as in Alternative A due to manpower limitations.

The interview procedures also had several characteristics in common:

(a) A common questionnaire was utilized.

(b) On the day of the experiment, two conductors were allocated to each vehicle surveyed in order to effect a decrease in the number of passengers traveling free illegally.

(c) Similarly, two inspectors were allocated to each vehicle. Each was provided with a counting sheet (see Form 3, Appendix 1), on which they recorded information on every passenger (if possible) with respect to the bus stop of the origin and of their destination.

(d) The inspectors were also asked to make a visible mark on the ticket or pass of each passenger he interviewed in order to avoid duplication.

(e) The survey was implemented during the morning peak period, and included three round trips on each vehicle.

For each bus route, the following calculations were made:

(a) Origin/Destination matrices were constructed from the count sheets with respect to the bus stops along the route -- these represent the total passenger population. Similar matrices were constructed from the survey sheets -- these represent the sample.

(b) With data concerning the distance between successive stops, it was possible to construct an Origin/Destination matrix of distances between any pair of stops along the route.

(c) From (a) and (b) above, it was possible to calculate a frequency distribution of the passengers with respect to their trip length along the route for both the sample and total passenger populations for each alternative.

The statistical analysis of the experiment data consisted of testing the goodness of fit of the frequency distribution of the sample to the frequency distribution of the population. The results of this test are shown in Table 1 through 5.

TABLE 1

The Average Sample Size and Population Size Per Round Trip of Each Route for Each Alternative

Bus Route	ALTERNATIVE A		ALTERNATIVE B	
	Sample (1 interviewer per bus)	Population (2 inspectors)	Sample (3 interviewers per bus)	Population (2 inspectors)
50'	80	366	180	294
5	46	173	60	213

TABLE 2

BUS ROUTE 50'. ALTERNATIVE A

CLASS INTERVAL (KM)	FREQUENCY Population		Sample	X^2 TEST Observed (O)	Expected (E)	O^2/E
0 - 1.0	4	(0.87)*	0			
1.01 - 2.0	20	(4.37)	8	8	5.24	12.21
2.01 - 3.0	38	(8.31)	8	8	8.31	7.70
3.01 - 4.0	56	(12.24)	10	10	12.24	8.17
4.01 - 5.0	80	(17.49)	18	18	17.49	18.52
5.01 - 6.0	80	(17.49)	12	12	17.49	8.23
6.01 - 7.0	76	(16.61)	14	14	16.61	11.80
7.01 - 8.0	84	(18.36)	10	10	18.36	5.45
8.01 - 9.0	50	(10.93)	12	12	10.93	13.17
9.01 -10.0	62	(13.55)	26	26	13.55	44.89
10.01 -11.0	40	(8.74)	12	12	8.74	16.47
11.01 -12.0	28	(6.12)	2			
12.01 -13.0	26	(5.68)	6	8	11.80	5.42
13.01 -14.0	20	(4.37)	4			
14.01 -15.0	16	(3.50)	2	6	7.87	4.57
15.01 -16.0	14	(3.06)	4			
16.01 -17.0	14	(3.06)	10			
17.01 -18.0	24	(5.25)	2	16	11.37	22.52
TOTAL	732	(160.0)	160	160	160	184.13

$$X^2 = \sum \frac{O^2}{E} - N = 184.13 - 160 = 24.13$$

Number of degrees of Freedom = 13 - 1 = 12

Tabulated $X^2_{(\alpha = 0.05)} = 21.03$

*Figures in brackets represent the frequency of the population at the respective class interval after reducing it by the ratio of sample size to population size in order to apply the X^2 test.

TABLE 3

BUS ROUTE 50'. ALTERNATIVE B

CLASS INTERVAL (KM)	FREQUENCY			X^2 TEST		
	Population		Sample	Observed (O)	Expected (E)	O^2/E
0 - 1.0	2	(0.82)*	1.33**			
1.01 - 2.0	9	(3.69)	3.33			
2.01 - 3.0	17	(6.98)	4.67	9.33	11.49	7.58
3.01 - 4.0	17	(6.98)	10.67	10.67	6.98	16.31
4.01 - 5.0	17	(6.98)	13.33	13.33	6.98	25.46
5.01 - 6.0	16	(6.57)	12.67	12.67	6.57	24.43
6.01 - 7.0	37	(15.19)	11.33	11.33	15.19	8.45
7.01 - 8.0	32	(13.14)	6.67	6.67	13.14	3.39
8.01 - 9.0	24	(9.85)	10.00	10.00	9.85	10.15
9.01 -10.0	27	(11.08)	11.33	11.33	11.08	11.59
10.01 -11.0	19	(2.80)	8.67	8.67	7.80	9.64
11.01 -12.0	16	(6.57)	8.00	8.00	6.57	9.74
12.01 -13.0	15	(6.16)	2.67			
13.01 -14.0	13	(5.34)	4.67	7.44	11.50	4.81
14.01 -15.0	4	(1.64)	0.67			
15.01 -16.0	6	(2.46)	4.67			
16.01 -17.0	10	(4.10)	2.00			
17.01 -18.0	13	(5.34)	4.00	11.34	13.54	9.50
TOTAL	294	(120.69)	(120.68)	120.68	120.69	141.05

$$X^2 = \sum \frac{O^2}{E} - N = 141.05 - 120.69 = 20.36$$

Number of degrees of freedom = 12 - 1 = 11

Tabulated $X^2_{(\alpha = 0.05)} = 19.06$

*Figures in brackets represent the frequency of the population at the respective class interval after reducing it by the ratio of sample size to population size in order to apply the X^2 test.

**On the day of the experiment, one of the buses carrying one interviewer on board broke down. In order to obtain a fair comparison between the two alternatives, the frequency distribution of the passengers interviewed on the bus carrying 3 interviewers was multiplied by 2/3.

TABLE 4

BUS ROUTE 5. ALTERNATIVE A

CLASS INTERVAL (M)	FREQUENCY			X^2 TEST		
	Population		Sample	Observed (O)	Expected (E)	O^2/E
0 - 500	0	(0.0)*	0			
501 - 1000	8	(2.12)	2			
1001 - 1500	24	(6.38)	12	14	8.50	23.00
1501 - 2000	50	(13.30)	12	12	13.30	10.83
2001 - 2500	62	(16.48)	12	12	16.48	8.14
2501 - 3000	842	(22.34)	16	16	22.34	11.46
3001 - 3500	40	(10.64)	8	8	10.64	6.02
3501 - 4000	20	(5.32)	4			
4001 - 4500	42	(11.16)	14			
4501 - 5000	0		0			
5001 - 5500	16	(4.26)	12	30	20.74	43.39
TOTAL	346	(92.0)	92	92	92.00	103.5

$$X^2 = \sum \frac{O^2}{E} - N = 103.5 - 92 = 11.5$$

Number of degrees of freedom = 6 - 1 = 5

Tabulated $X^2_{(\alpha = 0.05)} = 11.07$

*Figures in brackets represent the frequency of the population at the respective class interval after reducing it by the ratio of sample size to population size in order to apply the X^2 test.

TABLE 5

BUS ROUTE 5. ALTERNATIVE B

CLASS INTERVAL (M)	FREQUENCY			X^2 TEST		
	Population		Sample	Observed (O)	Expected (E)	O^2/E
0 - 500	1	(0.19)*	0.00**			
501 - 1000	2	(0.38)	1.33			
1001 - 1500	16	(3.00)	3.33			
1501 - 2000	27	(5.07)	2.67	7.33	8.64	6.22
2001 - 2500	39	(7.32)	4.67			
2501 - 3000	42	(7.89)	5.33	10.00	15.21	6.57
3001 - 3500	27	(5.07)	2.67			
3501 - 4000	9	(1.69)	3.33	6.00	6.76	5.33
4001 - 4500	22	(4.13)	2.67			
4501 - 5000	0	(0.00)	0.00			
5001 - 5500	28	(5.26)	14.00	16.67	9.39	29.59
TOTAL	213	(40.0)	40	40.00	40.00	47.71

$$X^2 = \sum \frac{O^2}{E} - N \quad = 47.71 - 40 = 7.71$$

Number of degrees of freedom = 4 - 1 = 3

Tabulated $X^2_{(\alpha = 0.05)} = 7.81$

*Figures in brackets represent the frequency of the population at the respective class interval after reducing it by the ratio of sample size to population size in order to apply the X^2 test.

2.1.3 Conclusions Drawn from the Experiments

From the results of the experiment of alternative sampling techniques, it can be seen that the data collected by three interviewers on a single bus more closely fit the frequency distribution of the total population than the data collected by three interviewers on three consecutive busses. Both bus routes produced the same results, though it is significant at the 5% level only for bus route 5. However, in the case of bus route 50, the degree of confidence associated with Alternative A (one interviewer per bus and three buses) was 1.95%, while that associated with Alternative B (three interviewers per bus and one bus) was 4.06%.

The conclusion was to assign as many interviewers as possible per vehicle (within the manpower limitations), and also to assign two inspectors per vehicle to collect the on and off counts that will serve as the basis for enlarging the sample to represent the total population. The on and off counts were tallied on the forms previously prepared by the Cairo Transport Authority (see Form 4, Appendix 1).

2.1.4 The Sample-to-Population Enlargement Factor

The procedure for deriving the enlargement factor for each line is outlined below:

(a) Let: N = total number of passengers traveling on surveyed vehicles on a specific line. Taken from count sheets of the inspectors for the entire survey time period.

T = total number of tickets sold by the conductor for the same surveyed vehicles during the same time period. Taken from conductor's manifesto.

Then CF = N/T

where: CF = a correction factor (greater than one) arising from the

fact that some passengers are using season tickets or are traveling free illegally.

(b) Multiply the number of tickets sold on all vehicles of this line by the correction factor (CF).

(c) Let: R_i = number of runs for surveyed vehicles on a specific line during hour i.

M_i = number of runs for all vehicles on that line during hour i.

S_i = number of tickets sold during hour i for surveyed vehicles on that line taken from conductor's manifesto.

Then: $P_i = S_i \times CF \times \frac{M_i}{R_i}$

where P_i = total number of passengers using that line during hour i.

(d) Let: I_i = total number of passengers interviewed on that line by the surveyors in a given hour. From Form 2.

Then: $E_i = \frac{P_i}{I_i}$

where E_i = enlargement factor for each line during hour i.

2.2 Survey Technique for the Urban Railway Lines

The on-board survey technique described above cannot be utilized for the urban railway lines for the following reasons:

(a) Urban railway tickets sold by the ticket office are valid for a one-hour period -- the passenger may board any train that passes through during the next hour. Therefore, the number of tickets sold does not represent the number of passengers on any specific train.

(b) The number of passengers carried on each line is approximately

250,000 per day, the result being very overcrowded conditions in the railway cars. This would seriously hinder an interviewer attempting to conduct the survey.

For these reasons, it was decided that an adapted platform survey technique would be utilized for the urban railway lines. Two factors facilitate data processing for the survey: every stop is served by only one line, and collected data can be classified as a predetermined time interval. The survey form used was Form 5 (see Appendix 1).

Tickets for use on the urban railway lines may be purchased from the ticket office at the platform or from an on-board conductor. Seasonal tickets are also available.

A full record of origin and destination for the tickets sold from the ticket office can be assembled by assigning an observer at each ticket-selling position at every station. The observor recorded -- on a special form (see Form 6, Appendix 1) -- the destination of every passenger buying a ticket at the ticket office.

Special procedures were developed to deal with on-board ticket-purchases, and also seasonal tickets.

2.2.1 Treatment of On-Board Ticket Purchases

On both lines, tickets can be purchased on board from the conductor (at a higher price). These tickets do not show station origin and destination, but rather show zonal origin and destination (each zone has a flat fare). Because zones contain more than one station, a difficulty arises when station-to-station data is desired. The following procedure was utilized to distribute on-board ticket purchases to the different stations.

Let:

n = number of Stations along the route

K_{ij} = number of trips originating from Station i with destination Station j . (Data obtained from count sheets -- Form 6 -- of observation at each ticket.

N_1 = total number of tickets sold by the conductor while traveling from Station 1 to Station n .

N_2 = total number of tickets sold by the conductor while traveling from Station n to Station 1 .

k_{ij} = number of tickets sold by the conductor while traveling from Station 1 to Station n which are allocated to each call (where $j \geq i$).

x_{ij} = number of tickets sold by the conductor while traveling from station to Station which are allocated to each cell (where $i \geq j$).

Then:

$$k_{ij} = \frac{N_1 \times \sum_{j=i}^{n} K_{ij} \times K_{ij}}{\sum_{i=1}^{n} \sum_{j=i}^{n} K_{ij} \times \sum_{j=i}^{n} K_{ij}}$$

AND

$$k_{ij} = \frac{N_1 \times K_{ij}}{\sum_{i=1}^{n} \sum_{j=i}^{n} K_{ij}}$$

And similarly:

$$x_{ij} = \frac{N_2 \times K_{ij}}{\sum_{i=1}^{n} \sum_{j=1}^{i} K_{ij}}$$

In an effort to reduce the number of tickets purchased from the on-board conductor (increasing the usage of ticket offices and thus reducing the overall impact of the above approximation procedure), extensive ticket inspections were carried out for three days on both routes prior to the survey day. This has the effect of discouraging passengers from boarding the train without a pass.

2.2.2 Treatment of Season Ticket Purchases

Season tickets, each valid for a particular inter-zonal travel pattern, may be purchased for one month, three months or one year periods. These tickets were included in our calculations utilizing the following procedure.

Let: N = total number of season tickets purchased for travel to a certain zone.

m = number of stations within that zone.

$\sum_{i=1}^{m} K_{ij}$ = total number of non-seasonal tickets (purchases from ticket offices and conductors) from Station i to any other station in a certain zone (in either direction).

K_{ij} = number of tickets from Station i to Station j.

k_{ij} = number of trips made with a season ticket from Station i to Station j.

Then:

$$k_{ij} = \frac{N \times K_{ij}}{\sum_{i=1}^{m} K_{ij}}$$

3. THE IMPLEMENTATION OF THE SURVEY

3.1 Vehicles Surveyed

As noted earlier, the large size of the bus fleet (1439 buses) necessitated that the survey be carried out on four successive days. Table 6 shows the number of buses included in the survey, the total number of buses operating from each of the garages, and the date of the survey for each garage.

The number of buses surveyed on a particular route was a proportion of the total number of buses operating on that route. The ratios used are shown in Table 7.

The determination of which garage's buses to survey on which days was made with the intent of maximizing the area of the city covered in the survey every day.

The survey of all other modes was carried out on April 22. Table 8 shows the number of units surveyed (based on the ratios shown in Table 7) and the distribution of the different fleets and their garages. Details of each route are included in Appendix 2.

TABLE 6

DISTRIBUTION OF BUSES AND NUMBER OF BUSES SURVEYED

Serial Number	Garage	Survey Date	Number of Lines	Total Number of Buses	Number of buses Included in the Survey
1	El Mezallat	17/4/78	22	173	63
2	Guesr El Suez		17	117	29
3	Asar El Naby		19	109	25
4	El Teraa	18/4/78	22	158	60
5	El Amireya		18	119	31
6	El Guiza		11	60	14
7	Port Said	19/4/78	4	57	10
8	Nasr		18	123	32
9	El Bassateen		33	160	38
10	Fateh	20/4/78	19	117	26
11	Embaba		20	117	29
12	El Moneeb		17	129	28
TOTAL			220	1439	345

TABLE 7

PROPORTIONS OF OPERATING BUSES SURVEYED ON EACH ROUTE

Number of Buses Running on a Route	Number of Buses Included in the Survey
6	1
7-10	2
10	3

TABLE 8

DISTRIBUTION OF VEHICLES OF OTHER MODES AND NUMBER SURVEYED

Mode	Garage	Survey Date	Number of Lines	Total Number of Units	Number of Units Surveyed
Tram	Abassieh	22/4/78	13	91	17
	Mezallat		7	53	10
	Port Said		1	12	3
	TOTAL		21	156	30
Trolley	El Moneeb	22/4/78	6	74	16
Ferries		22/4/78	6	18	6
Heliopolis Metro	Nozha	22/4/78	1	7	2
	Merghany		1	6	1
	Abdel Aziz		1	7	2
	Aif Maskan		1	4	1
	Roxy		1	7	2
	Mataveya		2	9	3
	Almaza		1	5	1
	TOTAL		8	45	12
Urban Railways	Bab el Luk	22/4/78	1	72	(conducted at Stations)
	El Marg		1	30	

3.2 Manpower

Tables 9 and 10 show the pattern of manpower utilization (interviewers, inspectors and observers) for the survey. With regard to all but the urban railway mode, the plan was to assign four interviewers and two inspectors for each unit. Some modification of this plan was required for the following reasons:

(a) Some of the buses (operating from the Port Said garage) are articulated vehicles with two doors per unit.

(b) The minibuses (Routes 30, 70, 80 and 90), and the Nile River ferries were assigned two interviewers and one inspector per unit.

(c) When the surveyor substitutes (see Section 3.3) available exceeded the number of absentee surveyors, 5 surveyors were assigned to each unit.

For the urban railway line survey, the number of interviewers assigned to each station was based on prior counts of the number of passengers utilizing a station, and the number of ticket office observers at a station was equal to the number of ticket selling positions at a station (see Appendix for further details).

TABLE 9

DISTRIBUTION OF SURVEY MANPOWER: BUSES, TRAMS, TROLLEY BUSES AND METROS

Mode	Garage	Manpower	
		Interviewers	Inspectors
Buses	El Mezallat	165	79
	Guesr El Suez	112	57
	Asar El Naby	102	50
	El Teraa	162	80
	El Amireya	131	62
	El Guiza	67	28
	Port Said	38	37
	Nasr	132	59
	El Basateen	151	76
	Fatah	104	50
	Embaba	131	56
	El Moneeb	119	56
Trams	Abbassieh	71	48
	Mezallat	41	30
	Port Said	30	17
Trolley Buses	El Moneeb	68	32
River Ferries		27	6
Heliopolis Metro	Nozha	39	24
	Merghany	18	12
	Abdel Aziz Fahmy	30	24
	AIP Maskan	8	6
	Roxy	16	12
	Matareya	29	22
	Almaza	6	6
TOTAL		1797	929

TABLE 10

DISTRIBUTION OF SURVEY MANPOWER: URBAN RAILWAY LINES

Route	MANPOWER	
	Interviewers	Ticket Office Observers
Kobry El Lammson-El Marg	39	14
Bab el Luk-Helwan	45	23
TOTAL	84	37

3.3 Survey Logistics

The manpower utilized for the survey consisted of 660 students from the Faculty of Engineering, Cairo University, who volunteered to work one or more days of the survey (130 students were assigned to the urban railway survey on the fifth day). The Cairo Transit Authority provided 200 men to record the on and off counts on buses, trams, trolley buses and the Heliopolis Metro.

A survey file, with appropriate forms enclosed, was constructed for each interviewer, inspector and observer. These were distributed to personnel each morning of the survey. Table 11 shows the number of each of the forms printed, and the number placed in each file.

TABLE 11

NUMBER OF FORMS

Form Number	Total Number Printed	Number Forms Per File
2	60,000	25
4	7,000	4
5	35,000	35
6	35,000	35

The following information was included on each file's cover:

- Mode
- Garage
- Student Name
- Student Serial Number
- Route Number (station name for urban railway survey)
- Vehicle number (omitted)
- Type of work to be carried out
- Survey starting time
- Survey ending time

Each student was provided with a card which listed his name and serial number, and has his photograph attached. On the reverse side, the card contained all the information listed above for each day the student was to participate in the survey.

Training lectures for the student surveyors were held at the

Faculty of Engineering, Cairo University, on April 15, 16 and 21, 1978. Instruction sheets for survey methodology (see Appendix 3) were distributed at these lectures.

A notice requesting the public's cooperation with the survey personnel was posted in the urban railway stations and in the vehicles of the other modes.

Transportation was provided for students to travel to the garages on appropriate days. Nine Greater Cairo Area bus routes gathered the students at their homes and transported them to Cairo University where special buses were scheduled to take them to the garages.

Two buses from every garage operating vehicles to be surveyed sent two buses to the assembly point at the University. Students identified the appropriate garages and transport bus from the schedule cards they were given (see above). Buses left the Cairo University assembly point at 4:30 A.M.

For the urban railway survey, the interviewers and ticket office observers assigned to the stations along the route rode the first trains out to El Marg and Helwan so as to be prepared to start the survey at 5:30 A.M. The work at the stations was supervised by sixteen men from the General Organization of Egyptian Railways.

For all other modes, a team of six men (three men on the minibus and ferry routes) was assigned to each vehicle -- four student interviewers and two on-and-off counting inspectors provided by the Cairo Transit Authority. One of the latter was designated as the team leader and had the following responsibilities:

(a) facilitating the interviewers' jobs.

(b) distributing the files to the team at the beginning of the shift and collecting at the end of the shift.

(c) collecting information about the number of tickets sold every trip from the terminal stations' headmasters.

Every garage was assigned a group leader responsible for the operation as a whole. He was equipped with a radio car to facilitate his communications with other garages and the supervisors at the main terminal stations.

As a vehicle to be surveyed left the garage, it was boarded by one team.

Every garage was allocated an extra 10% of its manpower as substitutes who were to take over in the case of any absence. Where the number of substitutes exceeded the number of absentees, they were assigned as a fifth interviewer on the overloaded routes. A similar arrangement was undertaken for the urban railways. As discussed earlier, the manpower limitation led to the restriction of the survey to a morning shift only. Consequently, in order to cover the two morning peaks (to and from work), it was decided to end the survey with a trip ending at one terminal at or later than 3:30 p.m.

Certain additional items of information were collected at the end of the survey:

- Information related to the urban railway lines:

  (a) Total number of tickets sold by the conductors during one trip.

  (a) The actual departure and arrival times of each train for each trip.

  (c) Total number of season tickets valid on the day of the survey.

- Information rel ed to all other modes:

  The manifestos for all routes under study -ere collected at the end of the day and photocopied because the Cairo Transit Authority utilizes this information for financial matters and cannot risk their loss.

APPENDIX 1: FORMS USED IN THE SURVEY

1. Form 2:
   Public Transport Passenger Interview Form (Revised).

2. Form 3:
   On/Off Count Sheet for Bus Passengers

3. Form 4:
   On/Off Count Sheet

4. Form 5:
   Railway Passenger Interview Form

5. Form 6:
   Railway Passenger Count Sheet

FORM 2

PUBLIC TRANSPORT PASSENGERS INTERVIEW FORM

MINISTRY OF TRANSPORT - CTA
CAIRO UNIVERSITY - MIT

MODE: BUS ☐ TRAM ☐ TROLLEY ☐ METRO ☐ FERRY ☐

INTERVIEWER NO. :
INTERVIEWER NAME:
DATE :

TRIP NO. ☐☐☐ STARTING TIME: Hr. Min. ☐☐☐☐ LINE NO. ☐☐☐☐

SHEET NO. ☐☐☐ ENDING TIME : ☐☐☐☐ UNIT SERIAL NO. ☐☐

NO. OF THE INTERVIEWERS IN THE UNIT ☐ NO. OF TICKETS SOLD IN ONE TRIP ☐

NAME OF THE STARTING TERMINAL:
NAME OF THE ENDING TERMINAL :

NAME OF TERMINAL INSPECTOR:
SIGNATURE OF TERMINAL INSPECTOR:

Were you asked before?	Serial Number	Sex		Where are you coming from?									Where are you going?									Did you change the mode during your trip?				Will you change the mode during your trip?			
										Address									Address			No	Yes			No	Yes		
		Male	Female	Home	Work	Education	Shopping	Other Purposes	At which stop did you board?	No.	Street	District	Home	Work	Education	Shopping	Other Purposes	At which stop are you getting off?	No.	Street	District		Mode	Intermediate Station	Service Number		Mode	Intermediate Station	Service Number
	1																												
	2																												
	3																												
	4																												
	5																												
	6																												

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FORM 3

MINISTRY OF TRANSPORT - CTA
CAIRO UNIVERSITY - MIT

ON-OFF COUNT FOR THE BUS PASSENGERS

TRIP NO.: STARTING TIME: LINE NUMBER : STARTING TERMINAL:

SHEET NO.: ENDING TIME: SERIAL NO. OF THE BUS: ENDING TERMINAL :

NO. OF TICKETS SOLD IN EVERY RUN _______

DID THE BUS BREAK DOWN? YES ☐ NO ☐

Passenger No.																																																		Name of the Station	Serial No. of the Station
50					45					40					35					30					25					20					15					10					5	4	3	2	1		
																																																			1
																																																			2
																																																			3
																																																			4
																																																			5

(continued)

FORM 4

MINISTRY OF TRANSPORT - CTA

ON/OFF COUNT FOR THE PASSENGERS OF VEHICLE NUMBER _____ LINE NUMBER _____

Date: _____ From: _____ To: _____

Station No.	Name of Station	Vehicle No.:			Vehicle No.:			Vehicle No.:			Vehicle No.:		
		Departure Time	No. of Passengers		Departure Time	No. of Passengers		Departure Time	No. of Passengers		Departure Time	No. of Passengers	
			ON	OFF		ON	OFF		ON	OFF		ON	OFF

248

FORM 5

MINISTRY OF TRANSPORT - GENERAL ORGANIZATION OF THE EGYPTIAN RAILWAYS
CAIRO UNIVERSITY - M.I.T.

RAILWAY PASSENGERS INTERVIEW FORM

Helwan Line ☐ El Marg Line ☐

Station _____

Station Number ☐☐

Sheet Number ☐☐☐

Starting Time ☐☐☐☐

Ending Time ☐☐☐☐

Number of interviewers on the platform ☐

Interviewer's Name _____

Interviewer's Number ☐☐☐

Were you asked before?	Serial Number	Sex		Where are you going?								Which station are you getting off at?	Did you change modes during your trip?				Where are you going?								Will you change modes during your trip?				Fare		
									Address				No	Yes								Address			No	Yes					
		Male	Female	Home	Work	Education	Shopping	Other Purposes	Number	Street	District			Mode	Intermediate Station	Service Number	Home	Work	Education	Shopping	Other Purposes	Number	Street	District		Mode	Intermediate Station	Service Number	Ticket	Season Ticket	Free Pass
	1																														
	2																														
	3																														
	4																														

949

FORM 6

MINISTRY OF TRANSPORT - THE GENERAL ORGANIZATION OF EGYPTIAN RAILWAYS
CAIRO UNIVERSITY - M.I.T.

RAILWAY PASSENGERS COUNTING FORM

Helwan Line ☐ El Marg Line ☐

Ticket Selling Position ☐

Observer's Name : _____

Observer's Number: ☐☐☐

Date : _____

Name of the Station / Timing			Bab El-Luk	El-Sayeda	El-Malek El-Salah	Marry Girgis	El-Zabra	Dar El-Salam	El-Maadi	El-Maadi	Tara El-Bialad	Kotseka	Tora El-Asmart	El-Maasara	Hadayak Helwan	Zahrak Helwan	Ein Helwan	Helwan Hamami
		El Marg	Kobri El-Loismoon	El-Demendash	El-Sadr	Kobri El-Koba	El-Hamama	Saray El-Koba	El-Zeeton	El-Helwan	El-Matarayya	Ein Shams	Exbet El-Makbet	El-Marg				
Hrs.	Min.																	

APPENDIX 2: DISTRIBUTION OF SRUVEY MANPOWER

Date: 17-4-78

El Mazzallat				
Bus Line	No. of Buses	No. of Buses Included in the Survey	No. of Inter-viewers	No. of Inspec-tors
G8	11	3	12	6
10′	5	1	4	2
22	6	1	4	2
24	10	3	13	6
24′	10	2	8	4
26′	4	1	4	2
32	7	2	8	2
100	15	4	16	8
152	8	2	8	4
152′	4	3	12	6
152″	7	2	8	4
153′	7	2	8	4
154	8	2	8	4
173	7	2	9	4
190	12	3	12	6
200	14	3	13	6
210	3	1	4	2
210′	3	1	4	2
[illegible]	5	1	2	1
70	5	1	2	1
80*	7	2	4	2
90*	5	1	1	
TOTAL	173	43	165	79

Gesr El Suez				
Bus Line	No. of Buses	No. of Buses Included in the Survey	No. of Inter-viewers	No. of Inspec-tors
G1	4	1	4	2
G2	6	1	4	1
G3	8	2	8	2
G12	6	1	4	2
48	8	2	8	4
50	8	2	8	4
50′	11	3	12	6
50*	5	1	4	2
52′	8	2	8	4
53	3	1	4	2
57	4	1	4	2
130	7	2	8	4
334	7	2	7	4
335	4	1	4	2
400	11	3	11	6
500	7	2	7	4
500′	8	2	7	4
TOTAL	117	29	112	57

Asar El Naby				
Bus Line	No. of Buses	No. of Buses Included in the Survey	No. of Inter-viewers	No. of Inspec-tors
G13	3	1	4	2
G14	8	2	8	4
2	5	1	4	2
66	5	1	4	2
95	9	2	8	4
95′	9	2	8	4
95″	3	1	4	2
96	6	1	5	2
99′	4	1	4	2
99″	4	1	4	2
150	6	1	4	2
431	9	2	8	4
432	9	2	8	4
440	3	1	4	2
441	3	1	4	2
441′	3	1	5	2
442	4	1	4	2
444	7	1	4	2
445	9	2	8	4
TOTAL	109	25	102	50

Total Number of Interviewers = 379

Total Number of Inspectors = 186

*Lines 30, 80, 90 are minibuses.

Date: 18-4-78

El Teraa				
Bus Line	No. of Buses	No. of Buses Included in the Survey	No. of Inter-viewers	No. of Inspec-tors
G11	11	3	12	6
13	3	1	4	2
13′	4	1	4	2
13″	3	1	4	2
21	4	1	4	2
24″	9	2	8	4
25	16	3	13	6
26	10	3	12	6
26″	6	1	4	2
28	8	2	8	4
33′	2	1	4	2
78	9	3	12	6
78′	10	2	8	4
81	9	2	8	4
82	9	2	6	4
93		2	8	4
134	11	4	15	8
134′	5	1	5	2
153	4	1	4	2
170	5	1	4	2
176	8	2	9	4
176′	5	1	5	2
TOTAL	158	40	162	80

El Amireya				
Bus Line	No. of Buses	No. of Buses Included In the Survey	No. of Inter-Viewers	No. of Inspec-tors
G10	6	1	4	2
35	4	1	5	2
35′	3	1	4	2
36	11	3	12	6
36′	11	3	12	6
37′	9	2	8	4
38	3	1	4	2
41	8	2	9	4
41′	8	2	8	2
42	5	1	5	2
43	7	2	9	4
43′	8	2	8	4
45	6	1	4	2
48′	8	2	8	4
49	4	1	5	2
172	4	1	4	2
300	7	3	14	6
300′	7	2	8	4
TOTAL	119	31	131	62

El Giza				
Bus Line	No. of Buses	No. of Buses Included in the Survey	No. of Inter-viewers	No. of Inspec-tors
3	7	2	9	4
3′	7	2	10	4
5	4	1	5	2
6	5	1	5	2
7	8	2	10	4
9	5	1	4	2
10	6	1	5	2
11′	4	1	5	2
15′	6	1	4	2
124	4	1	5	2
167	4	1	5	2
TOTAL	60	14	67	28

Total Number of Interviewers = 360

Total Number of Inspectors = 170

Date: 19-4-78

Port Said				
Bus Line	No. of Buses	No. of Buses Included in the Survey	No. of Inter-viewers	No. of Inspec-tors
33	6	1	4	3*
37	18	3	11	10
132	18	3	12	12
132′	15	3	11	12
*4-door buses				
TOTAL	57	10	38	37

Nasr				
Bus Line	No. of Buses	No. of Buses Included in the Survey	No. of Inter-viewers	No. of Inspec-tors
39	5	1	4	2
47′	5	1	4	2
51	5	1	4	2
52	6	1	4	2
54	6	1	4	2
54′	8	2	8	4
55	5	1	4	2
59	4	1	4	2
60′	8	2	1[illegible]	4
61	3	1	4	2
62′	2	1	4	2
64	8	2	9	4
69	4	1	4	2
69	4	1	4	2
93′	4	1	4	2
600	15	4	18	8
700	16	4	19	7
800	15	4	20	8
TOTAL	123	32	132	59

El Bassateen				
Bus Line	No. of Buses	No. of Buses Included in the Survey	No. of Inter-viewers	No. of Inspec-tors
09	3	1	4	2
4	5	1	4	2
12	4	1	4	2
12′	4	1	4	2
20	6	1	4	2
20′	3	1	4	2
68	4	1	4	2
72	10	2	8	4
72′	3	1	4	2
81′	8	2	8	4
82′	4	1	4	2
82″	7	2	8	4
84	4	1	4	2
85	4	1	4	2
87	4	1	4	2
88	7	2	9	4
88″	4	1	4	2
89	4	1	4	2
92	4	1	5	2
93″	5	1	4	2
98	6	1	4	2
134′	5	1	4	2
160	4	1	5	2
173′	4	1	4	2
174′	4	1	4	2
174″	4	1	4	2
182	5	1	4	2
401	5	1	4	2
401′	3	1	4	2
405	6	1	4	2
411	7	2	8	4
412	6	1	4	2
4[illegible]4	4	1	5	2
TOTAL	168	38	151	76

Total Number of Interviewers = 321

Total Number of Counters = 172

Date: 20-4-78

Fateh					Embaba					El Monech				
Bus Line	No. of Buses	No. of Buses Included in the Survey	No. of Inter-viewers	No. of Inspec-tors	Bus Line	No. of Buses	No. of Buses Included in the Survey	No. of Inter-viewers	No. of Inspec-tors	Bus Line	No. of Buses	No. of Buses Included in the Survey	No. of Inter-viewers	No. of Inspec-tors
G4	11	3	13	6	G6	3	1	4	2	G5	5	1	5	2
40	7	2	8	4	G7	3	1	5	2	1	5	1	4	2
40′	9	2	8	4	11	10	3	13	6	1′	5	1	5	2
44	9	2	8	4	14	3	1	4	2	1″	3	1	5	2
44′	9	2	9	4	14′	3	1	5	2	8	9	2	9	4
46	6	1	4	2	16′	6	1	4	2	8′	12	3	14	6
46′	6	1	4	2	17′	9	2	10	4	9′	16	3	13	6
47	6	1	4	2	18	7	2	8	2	15	6	1	4	2
48′	3	1	4	2	19	4	1	5	2	96′	3	1	4	2
60	6	1	4	2	99	5	1	4	2	106	12	3	12	6
60′	4	1	5	2	104	13	4	17	8	107	10	2	8	4
62	6	1	4	2	104′	5	1	5	2	107′	4	1	4	2
63	4	1	4	2	111	5	1	4	2	124′	6	1	4	2
63′	3	1	4	2	166	6	1	5	2	555	5	1	4	2
65	4	1	4	2	166′	5	1	5	2	666	7	2	8	4
68′	5	1	4	2	167′	4	1	4	2	888	10	2	8	4
120	4	1	4	2	167′	5	1	5	2	900	10	2	8	4
128	5	1	5	2	173″	5	1	5	2					
310	10	2	8	2	174	5	1	5	2					
					175	11	3	14	6					
TOTAL	117	26	104	50	TOTAL	117	29	131	56	TOTAL	129	28	119	56

Total Number of Interviewers = 354
Total Number of Counters = 162

Date: 22-4-78

Mode	Garage	Line No.	No. of Units	No. of Units Interviewed	No. of Interviewers	No. of Inspectors
Tram	Abbassieh	1	8	2	8	4
		2	6	1	4	4
		4	6	1	4	4
		6	6	1	4	4
		11	6	1	4	4
		13	6	1	4	4
		13′	5	1	4	4
		15	4	1	4	4
		21	16	2	8	4
		22	8	2	9	4
		22′	6	1	5	7
		23	4	1	4	2
		24	10	2	9	4
	Total		91	17	71	48
	Mezallat	5	5	1	4	3
		16	7	2	8	6
		8′	5	1	4	3
		10′	6	1	4	3
		20	6	1	4	3
		21	16	2	9	6
		30	8	2	8	6
	Total		53	10	41	30
	Port Said	14	12	3	30	17
	Total		12	3	30	17
Trolley	El Moneeb	15	14	3	12	6
		17	15	3	13	6
		18	8	2	9	4
		30	15	3	12	6
		44	12	3	13	6
		45	10	2	9	4
	Total		74	16	68	32
Nile Ferry		1	3	1	4	1
		2	3	1	5	1
		3	3	1	5	1
		4	3	1	5	1
		5	3	1	4	1
		6	3	1	4	1
	Total		18	6	27	6
Metro	Nozha		7	2	39	24
	Merghamy		6	1	18	12
	Abdel Aziz		7	2	30	24
	Aip Maskan		4	1	8	6
	Roxy		7	2	16	12
	Matareya		9	3	29	22
	Almaza		5	1	6	6
	Total		45	12	146	106
	Grand Total				385	239

Total Interviewers for Survey = 1881

Total Inspectors for Survey = 966

Date: 24-4-78

RAILWAYS

Line Name	Station	No. of Inter-viewers	No. of Counters
Helwan	Bab El Louk	6	5
	Sayeda	5	1
	Malek Saleh	2	1
	Marry Girgis	2	1
	Zahraa	2	1
	Dar El Salam	2	2
	Maadi	5	1
	Sakanat Maadi	2	1
	Tora El Balad	2	2
	Kotseka	2	1
	Tora Asmant	2	1
	Maasara	2	1
	Hadayek Helwan	2	1
	Zahraa Helwan	2	1
	Ein Helwan	2	1
	Hamainat Helwan	5	2
	TOTAL	45	23
El Marg	Kobri El Laimon	8	3
	Deimerdash	2	1
	Manshiat El Sadr	2	1
	Kobri El Kaba	2	1
	Hamamat El Koba	2	1
	Saray El Koba	2	1
	Zeiton	3	1
	Helmia	2	1
	Matareya	8	1
	Ein Shams	2	1
	Eizbet El Nakhl	2	1
	El Marg	6	1
	TOTAL	39	14
GRAND TOTAL		84	37

جامعة القاهرة - معهد ماساتشوستس للتكنولوجيا

برنامج التخطيط التكنولوجى

CAIRO UNIVERSITY - MASSACHUSETTS INSTITUTE OF TECHNOLOGY

TECHNOLOGICAL PLANNING PROGRAM

CONFERENCE ON

TRANSPORTATION PLANNING POLICY

JUNE 20-22, 1978

CAIRO, EGYPT

III.6

TRAFFIC SPEED/DELAY CHARACTERISTICS IN CAIRO

BY

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TRAFFIC SPEED/DELAY CHARACTERISTICS IN CAIRO

SUMMARY

This paper presents data collected during a study of traffic speed, capacity and delay in Cairo. An analysis of the data is performed and some preliminary estimates of free flow speed and practical capacity are presented. These estimates are compared to estimates made in the United States for streets occupying similar positions, in the heirarchy of urban street networks.

I. INTRODUCTION

1.1 Speed and Volume

One method of assessing the utilization of an urban street network is to examine the impact on the network of alternative proposals to modify the network and the system of operation by using a traffic assignment program. Current plans are to utilize the Urban Transportation Planning System computer package (UTPS) developed by the Federal Highway Administration, U.S. Department of Transportation to undertake such an analysis of the Cairo sheet network. The UROAD Traffic Assignment Program which is an element of the UTPS package subdivides a geographic study area into five 'area types' and the street network into six 'facility types'.

The five area types which UROAD defines are:

- Central Business District (C.B.D.).
- Fringe.
- Residential.
- Outer C.B.D. (small C.B.D., on periphery of large metro area)
- Rural.

The six facility types are:

- freeway
- expressway

- one-way arterial (parking both sides)
- two-way arterial (no parking)
- two-way arterial (parking both sides)
- other/centroid connector.

The UROAD traffic assignment program utilizes an empirically based built-in formula to derive the travel speeds corresponding to given traffic volumes on the links:

$$T = T_0[1 + \alpha\ (Q/C)^B] \qquad (1)$$

where: T = travel time (sec/km) corresponding to a given traffic volume (Q).

T_0 = travel time (sec/km) corresponding to free flow conditions.

C = practical capacity (P.C.E.'s/hr)

Q = traffic volume (P.C.E.'s/hr).

a,B = calibration parameters.

The UROAD traffic assignment package also includes American based data and free flow speed and practical capacity tables[3]. It was determined that the use of such data in the Cairo setting would be inappropriate, as traffic composition, road facility types and control methods, driver behavior and overall environment are observed to be very different than in the United States.

In addition to the UROAD traffic assignment package, British efforts to determine speed/flow relationships were examined. The works reviewed were published by the Road Research Laboratory[1] and J. Wardrop[2] The following speed/flow relationship was derived for a two-way road (width= 42 feet) in a study conducted in central London:

$$Q/W - 68 - 0.13V^2 \qquad (2)$$

where: Q = total flow in both directions (P.C.E.'s/hr)

W = road width (ft)

V = travel speed (mph)

Here again, it was determined that the direct adoption of this speed/flow relationship for use in Cairo would be inappropriate, the reasons

being the same as in the decision not to adopt directly the UROAD relationship.

It was decided that the correct approach would be to derive a speed/flow relationship specifically for Cairo, to be based on a survey of traffic characteristics in the city. The following information would be required to properly calibrate the UROAD package formula (see Equation 1) to the particularities of each Cairo area type - facility type combination:

- free flow speed /1
- practical capacity /2

In addition, although the use of a heirarchy of facility types, as in UTPS, would be retained, two of the facility types in UTPS are not appropriate fot the Cairo application. Two substitutes were used, such that the six facility types used for the Cairo exercise were as follows:

- one-way arterial (no parking)
- one-way arterial (parking one side)
- one-way arterial (parking both sides)
- two-way arterial (parking both sides)
- two-way arterial (no parking)
- other/centroid connector

/1 Free flow speed is an average speed under conditions of little or no traffic; no competing traffic present to stow vehicular speeds.

/2 Practical capacity is the capacity of a roadway at a predetermined level of congestion. This level of congestion (measured in terms of delay per unit length of roadway) is normally integrated at the maximum level tolerated by the community of travelers.

1.2 Analysis of Delay

Most of the work done to date on analysis of traffic has focused on delays incurred at intersections. Both uncontrolled [4] and signal-controlled[5][6] intersections have been studied. Delay is, of course, significant in examination of street networks because it provides a means by which to gauge levels of congestion and practical capacity limits. Delay is also a significant factor in the analysis of networks

with signalized intersections. At least one other delay study [7] has focused on the delay caused by certain vehicle types significantly different than the private automobile.

Delay is defined as the time lost by vehicles in traffic due to interference from other vehicles, traffic control devices and so forth. Delay can be illustrated with the aid of Figure (1), in which distance travelled is plotted against travel time.

In Figure (1), the straight line AB represents the movement of an undelayed car. The line CD E F represents the movement of a car that has stopped for some cause. The straight portions CD and EF are parallel to AB. The length XY on the time scale is the delay to the car which includes deceleration, stop-time and acceleration delays. Point X is regarded as the anticipated arrival time and Y the anticipated departure time of this car, so that the total delay is the difference between the anticipated arrival and departure times. The anticipated arrival and departure times of the next car are represented by $\bar{X}$ and $\bar{Y}$.

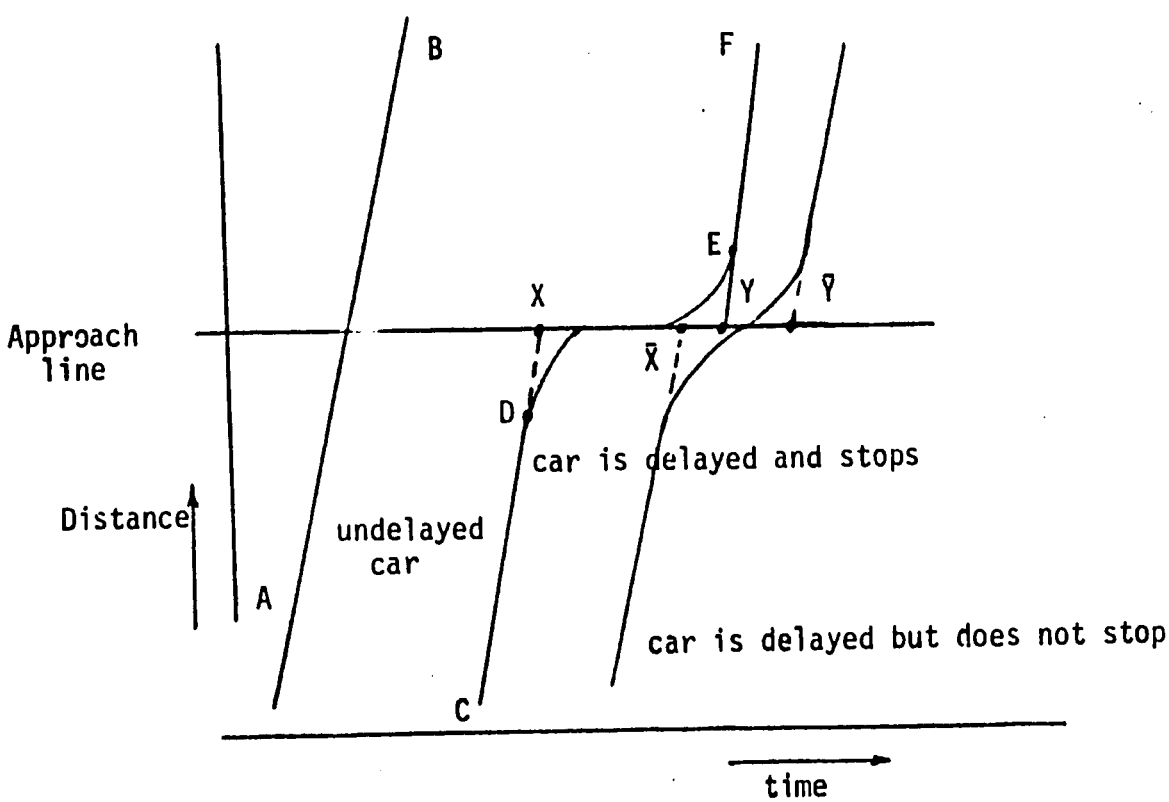

Figure (1) Diagram to illustrate the definition of delay

Delay at a fixed time traffic signat at a single road intersection is a function of: the cycle time, the proportion of the cycle that is green, the saturation flow and the arrival rate of traffic. Delay at an uncontrolled intersection is a function of the arrival rates per unit time of vehicles on the major and minor roads and the time gaps between blocks of vehicles. Additional sources of delay include the following:

- Parking of vehicles.
- Pedestrians crossing the roadway.
- Turning vehicles.
- Buses stopping to handle passengers.
- Accidents.

The difference, then, between the actual time required to cover a section of street at a certain traffic volume and the time corresponding to free flow conditions on the section is called Travel-Time delay.

II. DATA COLLECTION

Three types of data were collected: travel time on a specific route length and corresponding traffic volume; delay times; and reasons for delay.

The travel time and delay data was collected by means of a "floating car" survey technique. A test car travels a specified route in a series of runs as a means of obtaining representative travel times. This procedure requires that the test vehicle maintain a speed equal to the average speed of all traffic on the route; this is accomplished by having the test vehicle pass as many vehicles as are passing it. Actual travel time on each link, as well as traffic volume counts at five minute intervals, were recorded. American literature [8] recommends that at least six runs per hour be made by a test vehicle in each direction over each link.

The routes selected for the survey were chosen on the basis of their representativeness of the road and traffic conditions prevailing in Cairo. In particular, the routes were selected and survey test runs conducted (subject to time and budget constraints) so as to represent a

closely as possible the existing conditions in Cairo with respect to:

- physical conditions of the road network: road widths, numbers of lanes, and parking facilities
- traffic conditions on the road network: traffic volumes, uniform speeds, and composition

An inventory of the routes selected for the survey is included as Table 1.

III. PRESENTATION AND ANALYSIS OF DATA

One- way streets were analyzed by determining the travel speeds (km/hr) and corresponding traffic volumes (P.C.E.'s/hr) according to the time of day. (Traffic volume to P.C.E./hr conversion factors are listed in Table 2).

Two-way streets were analyzed by determining the mean value of the journey speeds in km/hr for each round trip of the route and the corresponding sum of the two flows in P.C.E.'s/hr according to the time of day.

Using the mean value is clearly not wholly accurate. However, assignment model application generally does not provide for the use of a function that relates flows on a link in direction AB to simultaneous flows in direction BA.

One of the difficulties encountered in the analysis is the assessment of the effect of parked cars. The number of parked cars varies considerably in relationship to the time of day. Additionally, the enforcement of parking regulations in Cairo is not as strong as might be desired, he result being occasional reductions in effective roadway width, which creates an analytical problem. For these reasons, practical capacity is determined on the basis of the designed number of lanes.

Our determination of the practical capacities for each of the facility types in specific area types rests on level of service measures[8] which are defined as follows:

Serial No.	Name of Route	Length (m)	No. of designed Lanes	Area Type	Facility Type	Signalised junction No./km	Junction No./km	Description
1	Korneish El-Nile (from the public company stores to El Malk El-Saleh Bridg)	1680	3	Rural	Two-way Devided Arterial (Parking one side)	1	-	Mixed frontage development No control cover access
2	Giza Street (from Nahdet Misr Squ. to Giza Squ.)	1550	4	Fringe	Two-way devided Arterial (Parking one side)	2	-	Residential Frontage with access
3	El-Tahrier Bridge (from Saad Zagloul Squ to Korneish)	385	2	Fringe	Two-way Devided Arterial (No Parking)	-	-	No Frontage development No access
4	Ramsis Street (from Ramsis Squ. to Abdel Monhem Ryaid Squ.	1570	3	CBD	Two-way Devided Arterial (Parking one-side)	3	9	Mixed frontage No control over access
5	Emad El-Din St. (from 26 July st., to Ramsis St.)	670	3	CBD	One-Way collector (Parking both sides)	5	7	Shopping with access
6	Gomhria St. (from Kanterct el Deka to Foam el Bagr St.)	490	4	CBD	Two-way collector (Parking both sdies	4	4	Mixed frontage
7	Subra St., (from Gaziert Badran to Massarah)	940	4	Residential	Two-way Arterial (Parking both sides)	2	10	Mixed frontage with access
8	Misr & Sudan St.	660	4	Residential	Two-way Arterial (No parking)	-	10	Residential with access
9	Salah-Salem St. (from Islamic mission squ. to Eroba Squ.)	1910	4	Fringe	Two-way Devided Arterial No parking)	1	-	Limited frontage development No access

TABLE 2

Conversion Factors: traffic volume to P.C.E./hr.

(note: conversion factors used to convert the traffic volume counts to P.C.E.'s/hr are the same as those used in the processing of the Origin/Destination survey conducted by MIT/Cairo University in 1977).

Vehicle Type	conversion factor
private car	1
taxi	1
micro-bus	1 1/4
private bus	2
public transit bus	2 1/8
tram	8
trolley bus	4
lorry	2 1/2
lorry with trailer	5
bicycle	1/2
animal carriage	6
tricycle (motorized)	1 1/2

1. For main arterials with no parking permitted (for example, Tahrir Bridge and Salah Salem Street), a maximum delay of 90 seconds/km.
2. On all other links, a maximum delay of 140 seconds/km. In addition, free flow speed was defined as the speed attainable when the traffic volume on a street was less than or equal to 100 P.C.E.'s/hr/lane. See Figures 2A and 2B below.

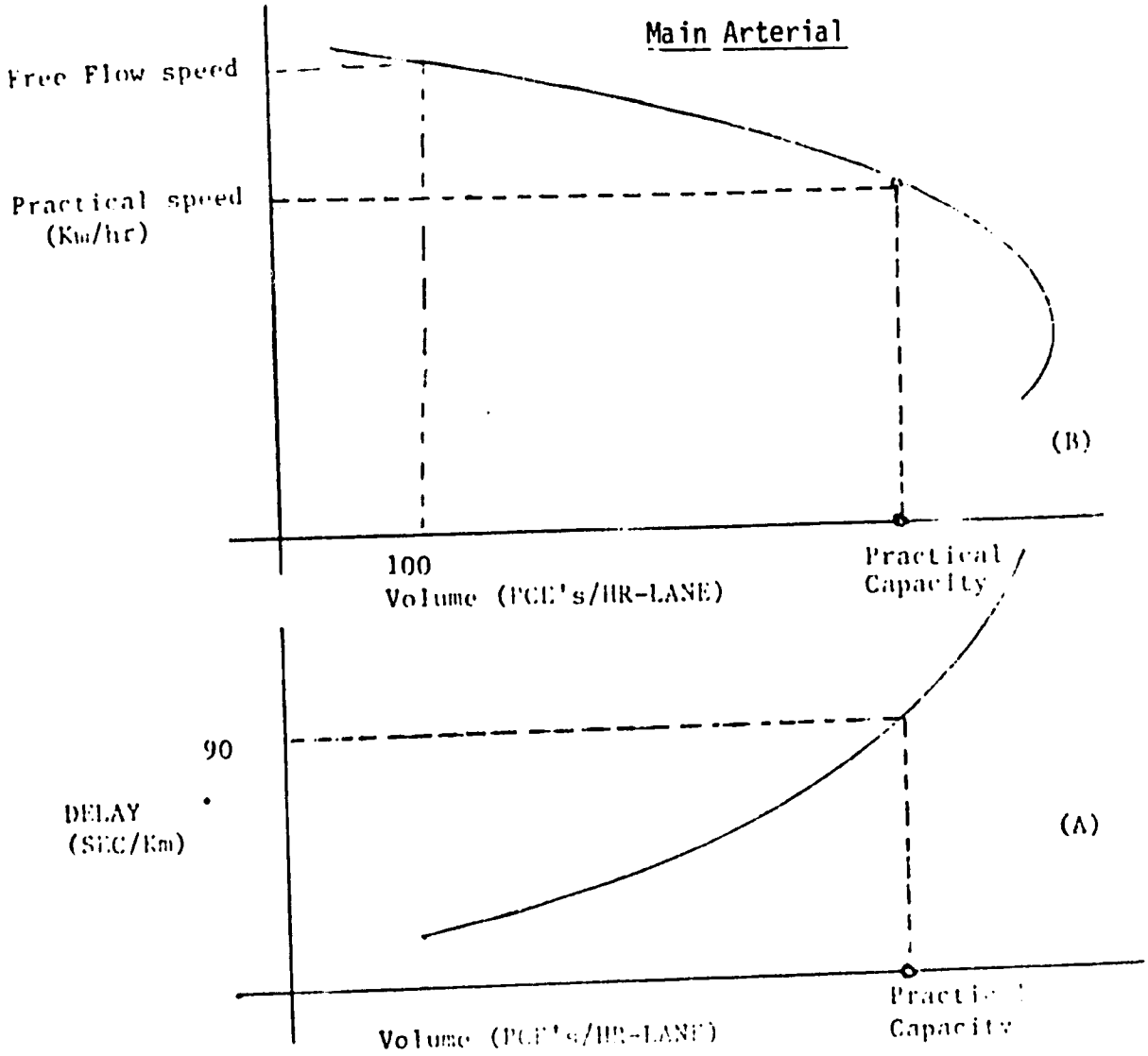

Figure (2). Free Flow Speed and Practical Capacity Concept

Table 3 (p 11) lists the estimates of practical capacities in P.C.E.'s and free flow speeds for the routes surveyed. In addition, Table 4 (p14) lists the estimates of practical capacity in P.C.E.'s/hr/land and free flow speed in km/hr for selected facility type and area type combinations, and compares these estimates derived for use with the UTPS "UROAD" program. The average amount of time elapsed while the test vehicle was completely stopped, expressed in seconds per km., by time of day is shown graphically in Figure (3). The same statistic computed for the peak periods only is shown graphically in Figure (4), and in tabular form on Table (5).

An examination of the data results in the observation that routes in the CBD are more prone to congestion and delay than routes in any other area. Ramsis, El-Gomhoria and Abdel-Khalik streets (all in the CBD) are the sites of delays in excess of 150 rec./pm. (Generally considered an unacceptable level of delay). Also, signalized intersections are the major contributors to total travel-time delays for nearly all the routes. A comparison of Tables (1) and (3) reveals that the number of signalized intersections per kilometer of roadway has a major impact on the practical capacity of the different facility types.

IV. FUTURE RESEARCH

In order to provide estimates of free-flow speed and practical capacity with a reasonable degree of statistical confidence, a number of samples of each area type-facility type combination must be taken. The precise number in each sample would depend on the variability of the data. In addition, Figure 3 indicates that continuation of the sampling process through the midday period would have been likely to produce additional interesting data.

Further examination of the effect of the number of controlled and uncontrolled intersections per kilometer on traffic speed and delay in the Egyptian context is of primary importance. It is conceivable that the length of the individual links tested would have a bearing on the results. The potential effect of this factor also deserves additional

Table 3: Link Physical Characteristics and Practical Capacity in Cairo

ne of Link	Length M	No. of Designed Lanes	Area Type	Facility Type	Practical Capacity P. C. E's/hr	Free fl Speed km/hr.
rneish El-Nile (from the Public npany stores to El Malk El Saleh ldge)	1680	3	Rural	Tow-way DD* Parking on one side Arterial	2000	40
rneish El Nile pposite direction)	1680	4	Rural		2600	50
ra St. (from Nahdet Masr squ. Giza Squ.	1550	4	Fringe	two-way DD Parking on one side Arterial	>2000	45
a St. posite directon)	1550	4	Fringe		>2000	45
Tahrier Bridge om Saad Zagloul squ. Korniesh El Nile)	385	3		Two-way DD no parking Arterial	4000	45
Tarier Bridge posite Direction)	385	2			2750	45
sis Street om Ramsis Squ. to el Monnem Squ.)	1570	4	C.B.D.	Two-way DD Parking one-side Arter.	1800	25
sis Street hosite direction)	1570	3	C.B.D		1800	25
El-Din St. m 26 July st. nmsis St.)	670	3	C.B.D	One-Way Parking both sides Collector	1500	2
ria St. m Kanteret eka to Foam ahr st.	490	4	C.B.D	Two way Parking both sides collector	2250	27
l Khalik wat St. (from Soliman st. hereif st.	577	4	C.B.D	One-way Parking on one side Collector	700	2
ra St. Gaafert Badran assarah)	840	4	Resi-dental	Two-way Parking on both sides Arterial	2700	20
Sudan St.	660	4	Resi-dental	Two-way No Parking	2700	20
h-Salem st: m Islamic Mission squ. to a squ.	1910	4	Fringe	Two-way No Parking Arterial	6000	50
h Salem st. osite direction)	1910	3	Fringe		4500	50

wo way devided highway
as not yet reached practical capacity

should be mentioned that different facility types within a specific area type have been
ected to represent the existing conditons in Cairo, and not necessarily to match those
the UROAD which reflects the American cities conditions.

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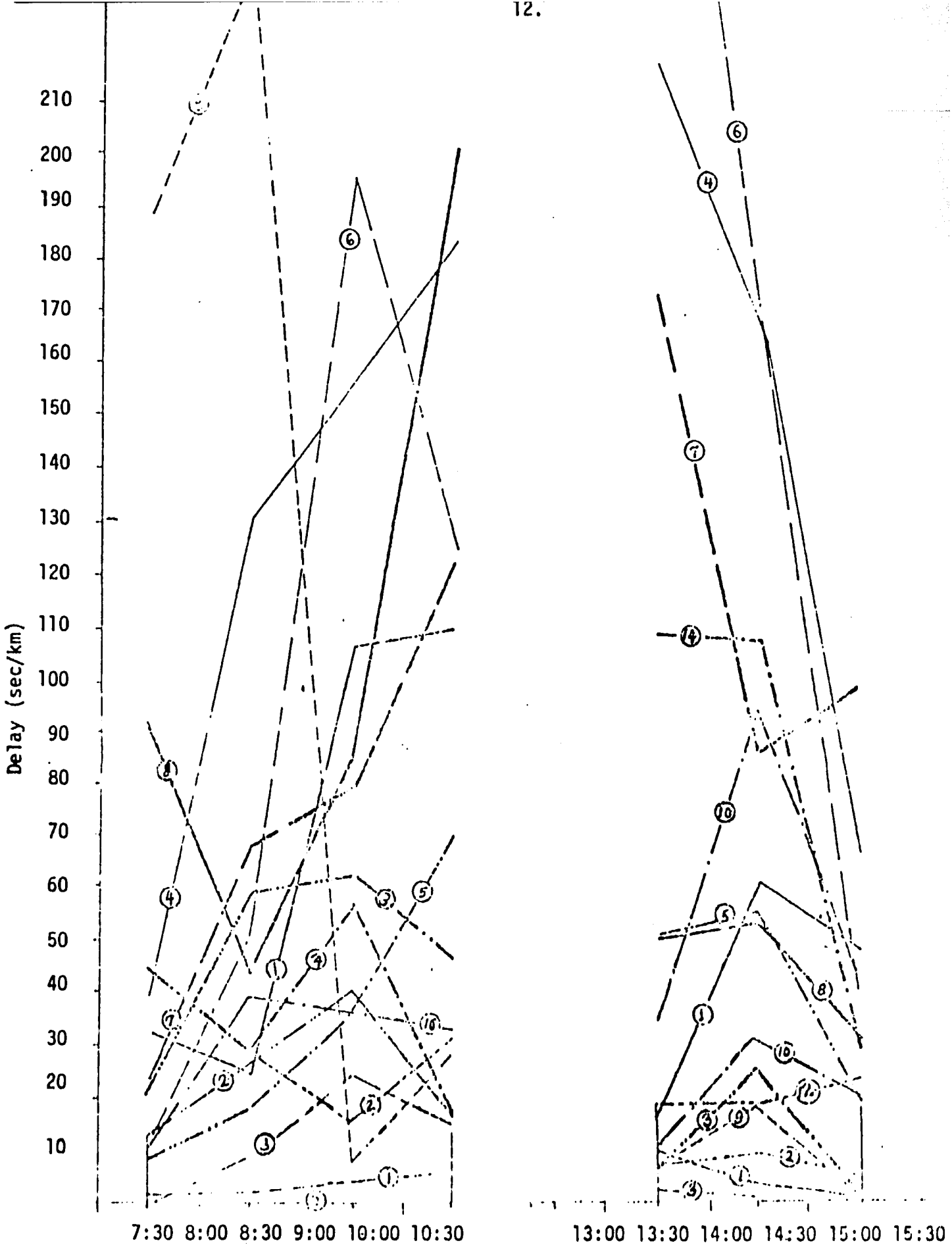

Figure 3: Time Spent Stopped (sec./km) For Different Test Routes by Time of Day

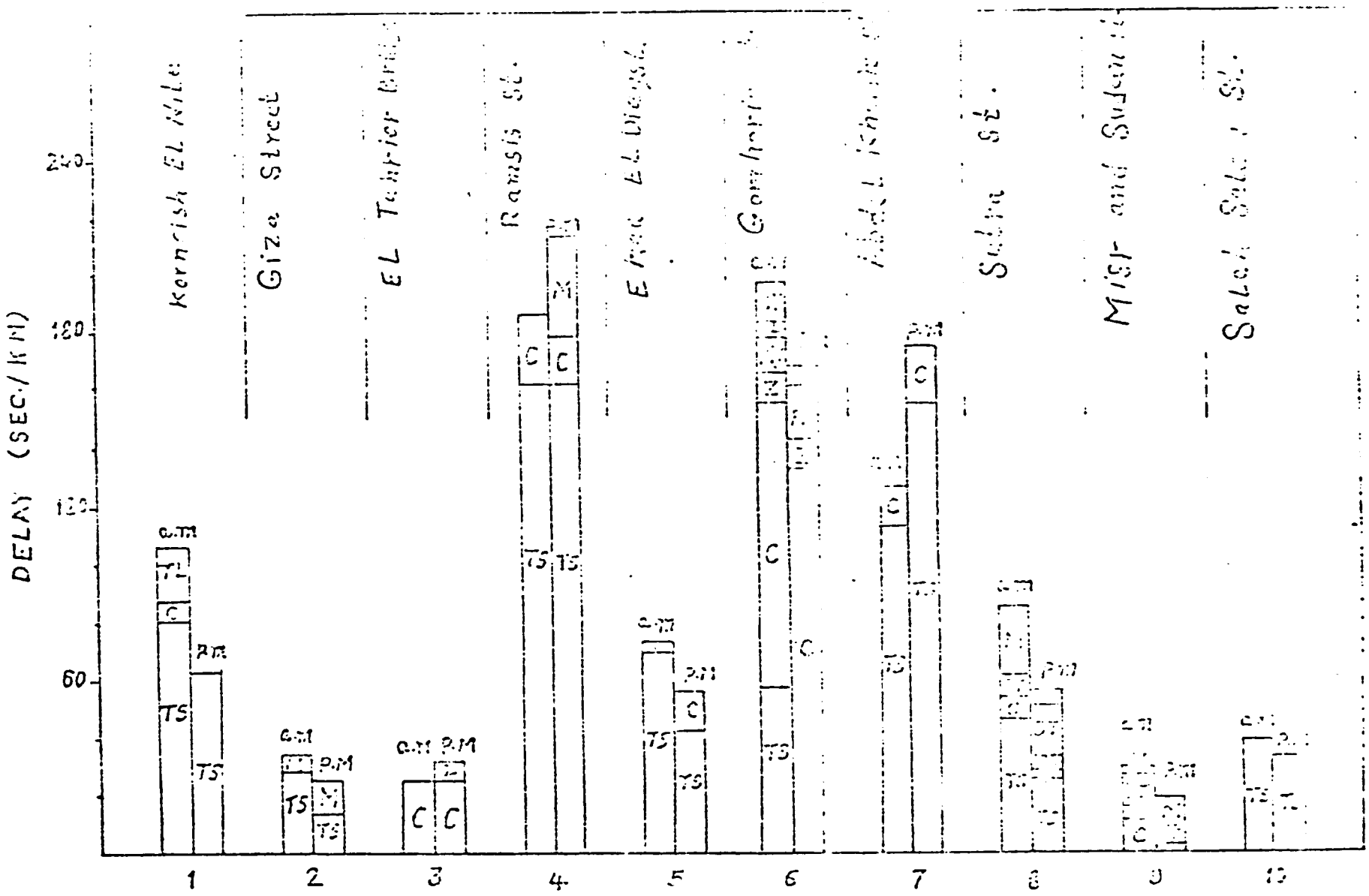

Figure 4: Time Spent Stopped (sec./km) By Cause Type for Different Test Routes (Morning and Afternoon Peaks)

KEY:
TS = Traffic Signal
C = Congestion
Z = Pedestrian

PK = Parking
TL = Turning Left

M = Miscellaneous

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Table 4: Free-Flow Speeds & Practical Capacities - Estimates Derived from Cairo Data and UTPS "URDAD" Estimates for United States Usage.

P.C.E./Hr./Lane and Km/Hr.

Facility Type / Area Type	One-Way Arterial (Parking on One Side)	One-Way Arterial (Parking on Both Sides)	Two-Way Arterial (Parking on Both Sides	One-Way Arterial (No Parking)	Other/ Centroid Connector	Two-Way Arterial (No Parking)
Cairo C.B.D.	600 28	500 28	500 27	700 30	---	600 30
UTPS	---	700/1/2 35	400 35	---	10000 16	600 35
Cairo Fringe	800	---	675	1300	---	---
UTPS	---	550 /2 46	550 40	---	10000 24	800 40
Cairo Residential	---	---	---	---	---	675 30
UTPS	---	900 /2	550 45	---	10000 24	800 45
Cairo Outer C.B.D.	---	---	---	---	---	---
UTPS	---	650 /2 38	550 35	---	10000 24	800 35
Cairo Rural	700 50	---	---	1400 50	---	---
UTPS	---	1900 /2 51	550 45	---	10000 24	800 45

/1 No parking
/2 Assumes progressive signal system in use

Table 5: Time Spent Stopped (sec./km) By Cause Type For Different Test Routes (Morning and Afternoon Peaks)

Route No.	1		2		3		4		5		6		7		8		9		10	
Name of Route	Korniesh El-Nile		Giza st.		Tahrir Br.		Ramsis st.		Emad el Din St.		Gomhoria st.		Abdel Khalik Tharwat st.		Shubra		Misr & Su. st.		[illegible] st.	
Cause of Delay	a.m	p.m	a.m	p.m	a.m	p.m	a.m	p.m	a.m	p.m	a.m	p.m	a.m	p.m	a.m	p.m	a.m	p.m	a.m	p.m
Traffic Signal	80	61	29	13	-	-	160	161	69	41	55	-	112	153	45	25	-	-	[illegible]	[illegible]
Congestion	7	-	-	-	25	25	21	17	2	15	103	131	12	19	7	3	11	2	[illegible]	[illegible]
Pedestrian crossing	-	-	-	-	-	6	-	-	-	-	10	10	-	-	1	-	-	-	-	
Parking	-	-	-	-	-	-	-	-	-	-	13	20	-	-	-	-	3	3	[illegible]	
Turning vehicles	20	-	-	-	-	-	-	-	-	-	4	6	-	-	1	3	3	3	-	
Bus stop	-	-	1	-	-	-	-	-	-	-	10	-	-	-	6	19	13	[illegible]	[illegible]	
Miscellaneous	-	-	3	11	-	-	-	33	-	-	-	-	-	-	25	4	-	-	-	
Total Stopped-Delay	107	61	33	24	25	31	184	211	71	56	195	167	124	172	85	54	29	21	[illegible]	

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study.

V. CONCLUSIONS

The research work which underlies this paper was undertaken for the purpose of determining practical capacities for the streets of the Cairo road network. This paper reports on the result of our analysis. There is a lack of published data in Egypt on this topic, and our intent is to spur discussion and the publication of the results of other similar studies.

VI. REFERENCES

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CAIRO UNIVERSITY - MASSACHUSETTS INSTITUTE OF TECHNOLOGY

TECHNOLOGICAL PLANNING PROGRAM

CONFERENCE ON

TRANSPORTATION PLANNING POLICY

JUNE 20-22, 1978

CAIRO, EGYPT

III.7

A STUDY OF TRAFFIC FLOWS ON THE 6TH OF OCTOBER AND TAHRIR BRIDGE AXES

BY

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A STUDY OF TRAFFIC FLOWS ON THE 6th OF OCTOBER AND TAHRIR BRIDGE AXES

SUMMARY

The intent of this study is to analyse traffic moving east and west over the Nile River across the 6th of October and Tahrir Bridges. The research team has conducted traffic counts and origin-destination surveys so as to determine the volume and direction of the traffic crossing the Nile in this area. The team has tabulated and analysed the data collected, and based on their findings, proposes a set of solutions to the traffic flow problems which exist at the approaches to these two crossings of the Nile.

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5. Conclusions.

6. Appendices

   Appendix 1. Area of Study, indicating traffic count and survey questionnaire stations.

   Appendix 2. Partial matrices showing flows of traffic between the different Zones.

Introduction

The traffic problem in Greater Cairo is a most pressing one, not only because it constitutes an everyday problem for the citizens of the city, but also due to its serious repercusssions on the national economy in terms of wasted time and human energy. The primary reasons for the traffic problem are:

1) The continuing of large annual increases in the number and variety of motor vehicles in Greater Cairo, together with the interference of other modes of transportation.

2) The road network has not been changed in proportion to the increase in the number of vehicles.

3) The large increase in the Cairo population due to the constant in-migration from rural areas to the city, as well as, the high rate of natural population growth within the City itself. (2.1 % and 1.9% annually respectively).

4) The great expansion of economic activity within Cairo which has occurred during the last quarter century.

The traffic problems in Cairo are similar to these of many of the large cities of the world. Data, however, indicates that auto ownership rates in Cairo are lower than the rates of cities in developed countries. Whereas, private auto ownership in Cairo does not exceed 13 per thousand inhabitants, it reaches 300 to 450 per thousand in Europe and the United States, respectively. It is known that 27% of the total Cairo land area is road area - - a figure not unreasonable in terms of city planning. This in itself is an indication that the road network of Cairo is capable of accomodating present traffic volume, as well as increased volume in the future, with greater flexibility than presently exists, provided that traffic control is planned scientifically, particularly along traffic corridors which are currently under pressure at peak hours.

Partially, in response to the problems previously outlined, an agreement has been made between Cairo University - Faculty of Engineering and the Ministry of Transportation (Transportation Planning Authority) on the one hand and the Massachussetts Institute of Technology on the other hand, to undertake studies of traffic and transportation in the Cairo metropolitan area, with the following objectives:

- The preparation and completion of a comprehensive survey of traffic and traffic flows between areas of the city, the times of trips on the different links, and delays at the important nodes. This survey is to be updated every five years so as the basis for future transportation and traffic planning in the Greater Cairo Area.

- A study of transportation projects already approved and under construction or completed, with the intent of developing a framework to facilitate the implementation of such projects, to encourage better coordination of short-term projects, and to assist in the development of an improved ability to assess the effects of a short-term project on the long-term state of the transportation infrastructure in Cairo.

- The outlining of long-term policies for transpotation and traffic in the Greater Cairo Areas, with particular emphasis on auto ownership.

Within the framework of this study, and in collaboration with the Ministry of Interior, an overall survey of traffic in the extended Cairo area was carried out on April 18, 1977. The outer boundary of the extended area includes:

- to the west of the Nile: Embaba, Agouza, Dokki and the urban area of Giza, Giza bridge, Salah Salem Road.

- and to the east of the Nile: parts of Heliopolis, Matatia,

Amira, and Embaba Bridge.

Prior to this large survey, a small-scale survey was carried out as an experiment on Thursday, April 14, 1977, at the eastern entrance to the 6th of October Bridge and the western entrance to the Galaa Bridge.

Due to the fact that traffic movement across the Nile, particularly at the western entrance to the Galaa Bridge and at some axes within Cairo, primarily the Ramses Street axis is subjected to long delays, a committee of officials in charge of traffic study, planning and implementation was formed by order of the Deputy Minister of Interior. The purpose of this committee is to study the problem and suggest solutions within existing possibilities.

The research group includes specialists in transportation and traffic from the following institutions:

- Ministry of Interior (General Administration for traffic).
- Ministry of Transport (General Authority for Transport Project Planning).
- Cairo University (Faculty of Engineering).

The study was carried out by the Research Group, making use of the data collected in the small-scale survey which was conducted on Thursday, April 14, 1977, and the larger survey which occured on April 18,. In order that suggestions as to the most suitable solutions for greater flow of traffic, and to relieve some bottlenecks at the approaches of bridge crossing, from traffic congestions. Personnel from the M.I.T. counterpart team assisted in the design of the survey forms, and participated in discussions which established overall guidances for project analysis.

May 4, 1977.

The Research Group of the Greater Cairo Urban Transportation Project.

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1. Objective of Study

The intent of this study is to analyse traffic along the areas of the 6th of October Bridge (Ramses) and the Tahrir Bridge, with the objective of determining the traffic configuration on these bridges and the important intersections on the main traffic axes, so as to achieve greater flow, safety and economy.

2. Data Collection

The selection of a method for data collection is dependent on the goals of the study. The data collection method used for this study consisted of counts within and at the boundary of the study area, and individual origin-destination interviews.

Random samples of vehicles to be questioned are obtained from all traffic either at a traffic light or with the assistance of the traffic police. The interviews questioned the vehicle occupants quickly concerning trip origin, destination, and other information relevant to the study.

Copies of the questionnaire and traffic volume collection forms are attached.

Cairo University - MIT

TRAFFIC COUNT FORM

Page No. ☐☐☐☐ Station No. ☐☐☐ Date ☐☐

Statio
Static
Stati

1		2	3	4	5	6	7	8	9	10	
Timing of starting the counting		PRIVATE CARS	TAXI	Micro-buses	Private Bus	Public Transit Buses	Trams	Trolley Buses	Semi-trucks	Normal Trucks	Tr w tr
hr	min										

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TRAFFIC COUNT FORM

b. ☐☐☐☐

Station No. ☐☐☐

Date ☐☐

Station on the outer cordon ☐

Station on the inner cordon ☐

Station between outer/inner ☐

	3	4	5	6	7	8	9	10	11	12	13	14
	TAXI	Micro-buses	Private Bus	Public Transit Buses	Trams	Trolley Buses	Semi-trucks	Normal Trucks	Trucks with trailers	Bicycles/ Motor-cycles	Animal carts	Man-pushed carts

Station on the inner cordon

End Time

Station between the inner and outer cordon

Station No.

Date

4	5	6	7	8	9	10
No. of assengers	Origin	Destination	Trip Purpose	Parking by night (place)	Governorate of Registration	Remarks

SIDE INTERVIEW FORM

Page No. ☐☐☐☐ Station No. ☐☐☐ Date ☐☐

Start Time ☐☐☐☐ Statio

End Time ☐☐☐☐ Statio and

1	2	3	4	5	6	7	8
Previous Inter-view Station	Serial Number	Vehicle Type	No. of Passengers	Origin	Destination	Trip Purpose	Parking by ni (place)

Enclosed as Appendix (1) is an aggregate map of the study area indicating the locations of the 24 traffic count stations. These stations are listed below:

STATION NO.	STREET	DIRECTION	TYPE OF STATION
3	Galaa St.	Coming from Ramses	
4	" "	" " "	
5	Ramses St.	Going to Abdel-Moneim Riad Square.	
6	" "	Going to Ramses Square.	
7	Mahmoud Basiony St.	Going Down Town.	
8	" " "	Going to A. Riad Square.	
22	Giza St.	" to Galaa Square	
23	" "	" " Giza Square.	Counting and Questionnaire.
24	Messaha St.	" " Messaha Square.	
25	Tahrir St.	" " Galaa Square.	
26	" "	" " Dokki Square.	
27	Tini St.	" " Ministry of Agriculture.	
28	Simonds Bakery St.	" " Galaa Square.	
29	Nile St.	" " Galaa Square.	
30	" "	" " Zamalek Bridge Square.	
36	Hassan Qadry St.	" " To entrance of 6th October Bridge.	
37	" " "	Going to " " " " Bridge.	
246	Giza St.	Going to " " " " Bridge.	
251	Mariat St.	Going to Tahrir Square.	
300	" "	" " A. Riad Square.	
-	October 6th Bridge Station	Going to Giza.	
-	Tahrir Bridge Station	" Cairo.	Counting only.
-	" " "	" Giza	
-	Galaa Bridge Station	" " Cairo.	

It has been agreed that the best timing for the 'peak hour' is between 8:30 a. m. and 9:30 a. m. on Thursday, this giving an accurate index of vehicle movement on roads and bridges. It was therefore, decided that the traffic count and survey be conducted on Thursday, April 14, 1977.

After completion of the counting and questionnaire procedures, tabulation, classification and analysis of the collected data began.

3. Data Tabulation

3-1. Count at Survey Stations and Conversion of Raw Counts into Equivalent Passenger Car Units.

Members of the study team aggregated at each station to attain the total number of vehicles which had passed each station during the morning peak hour, 8:30 a.m. - 9:30 a.m.

3-1-1. Conversion into Equivalent Passenger Car Units.

After calculating the total number of vehicles which had passed each station, this data was converted into equivalent passenger car units according to the following rates[x].

Vehicle	Equivalent Passenger Car Unit
Micro Bus	1 1/4
General Bus (private & Government)	2
Public Transport Authority Bus	2 1/2
Tram	8
Trolley Bus	4
Ordinary Lorry	2 1/2
Lorry with Trailer	5
Bicycle or Motorcycle	1/2
Animal-drawn Cart	6
Man-drawn Cart	1 1/2

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x Rates similar to these were utilized in two previous traffic studies in Cairo:
1. Planning of the Entrance to the Cairo Area: Arab Republic of Egypt, Ministry of Housing and Reconstruction, Parsons, Brinckerhoff, Quade, Douglas, Inc, USA, 1976
2. Greater Cairo Transportation Planning Study: Arab Republic of Egypt Ministry of Transport, Rapt SOFRETU, Paris, May 1973.

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3-2. Tabulation of Questionnaire Data

3-2-1. Zone Division

In order that the specific origin-destination replies may be analysed, trip ends in close proximity need to be aggregated and considered to have been generated by the same origin or group to the same destination. For thus, reason the total study area is subdivided into 6 zones as follows:

Zone	Area
1	Down town
2	Dokki - Agouza - Zamalek
3	South Cairo, east of the Nile
4	Giza - Pyramids
5	North Cairo - east of the Nile
6	Kit Kat - Embaba.

3-2-2. Coding

The titles of Origin-destination trips, as received from vehicle drivers, were converted into numbers in accordance with the descriptions listed above.

3-2-3. Traffic Flow Matrices (Samples)

Traffic flow matrices display the coded origin-destination data in tabular format, with origins listed vertically in the left hand column and destinations listed horizontally in the top row. Traffic flows generated by a specific origin zone and destined for a specific zone are then displayed in the cells of the matrix. A traffic flow matrix is developed for each questionnaire station.

3-2-5. Calculation of Total Matrix

After expansion of the matrices for each survey station, the research team aggregated this traffic data into a single origin-destination matrix, which displayed total traffic flows between each pair of zones:

Table I: The Total Matrix

		Destination Zone						Total
		1	2	3	4	5	6	
ORIGIN ZONE	1	530	650	220	175	420	50	2045
	2	1460	1030	410	540	865	5	4310
	3	270	600	82	83	405	130	1570
	4	765	130	2	120	375	283	1675
	5	1390	695	640	440	255	90	3510
	6	215	4	150	57	-	-	426
	Total	4630	3103	1504	1415	2320	550	13536

3-2-6. Matrix of Traffic Passing on the 6th of October and Tahrir Bridges Axes.

As the intent of this study is to analyse traffic on the axes of the 6th of October and Tahrir Bridges, it was essential to study the matrices of traffic flows into the zones west of the Nile (2,4,6) and into the zones east of the Nile (1,3,5) across the two bridges. The following two matrices (Tables 2A and 2B) display the traffic volume between these zones across both bridges during peak hour:

Table 2A: Matrix of Traffic crossing Axes of Tahrir and 6th of October Bridges (east to west across the Nile)*.

O \ D	2	4	6	Total
1	650	175	50	875
3	600	83	130	813
5	695	440	90	1225
Total	1945	698	270	2913

Table 2B: Matrix of Traffic crossing Axes of Tahrir and 6th of October Bridges (west to east across the Nile)*.

O \ D	1	3	6	Total
2	1460	410	865	2735
4	765	2	275	1142
6	215	150	-	365
Total	2440	562	1240	4242

The enclosed map (Figure 1) shows desired traffic flow between the six zones across the 6th of October and Tahrir Bridges

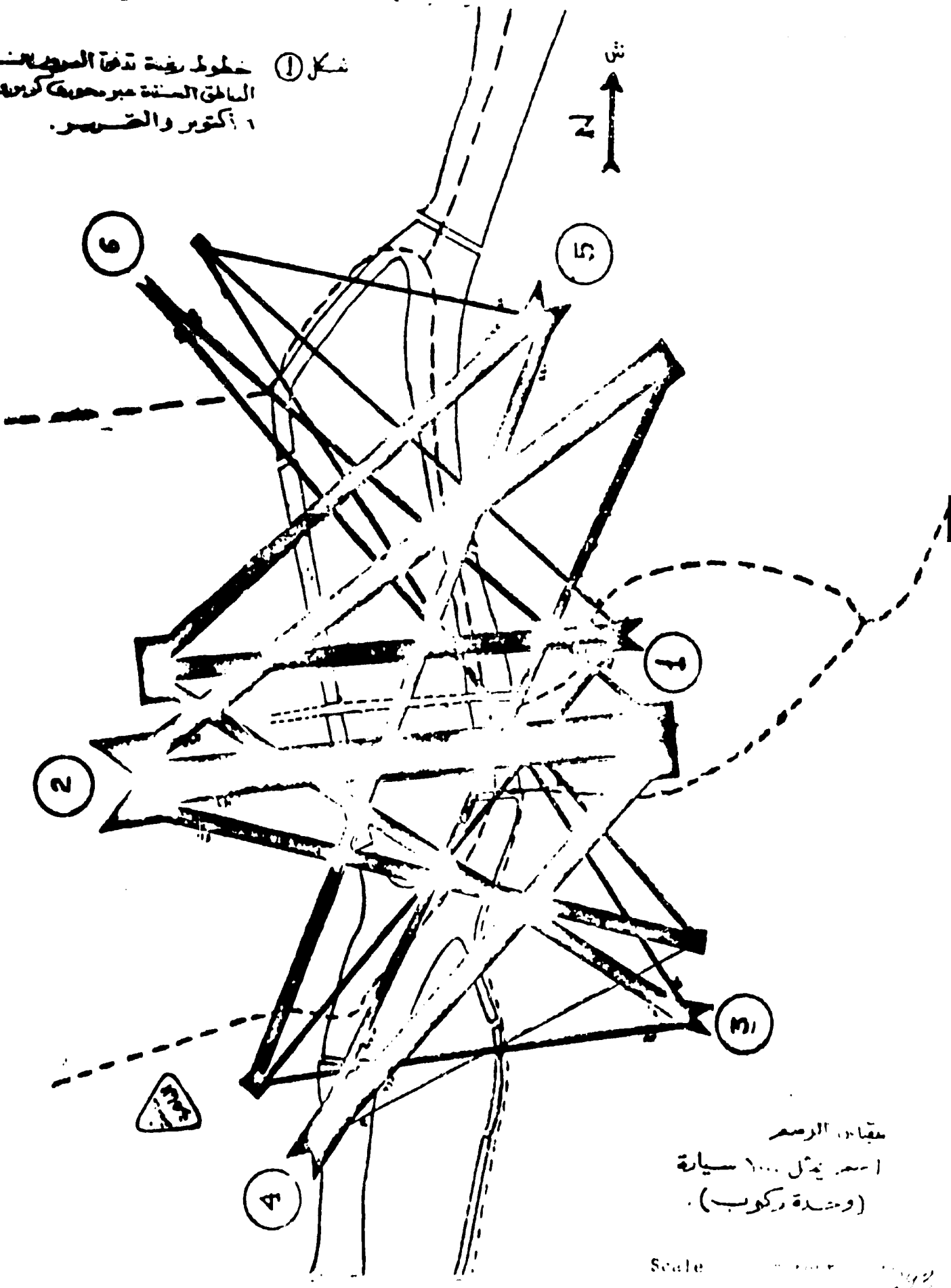
---

* Traffic volumes is represented graphically by a scale of 1cm, represents 1000 P.C.U's. For example, 1460 in the Matrix is represented by 1.46cm;

Fig (.1)

Figure 1 - Desire lines diagram

شكل (1) خطوط رغبة تدفق السيارات
الداخلة المتقاطعة عبر محور كورنيش
٦ أكتوبر والتحرير.



مقياس الرسم
١ سم يمثل ١٠٠٠ سيارة
(وحدة ركوب).

Scale

4. Analysis

4-1. Outline of Alternative Proposals and Analysis Elements

Proposed alternatives to the existing situation are:

First: - 6th of October Bridge - traffic flows in both directions,
- Galaa Bridge - one way toward Cairo,
- Tahrir Bridge - both directions,

Second: - 6th of October Bridge - both directions,
- Tahrir and Galaa Bridges - One way, toward Cairo,

Third: - 6th of October Bridge, Tahrir Bridge, and Galaa Bridge - all both directions,

Fourth: - 6th of October Bridge - both directions between Giza (Agricultural Museum Square) and the off ramp to Sarai [illegible] St. (the second direct off ramp to be used for vehicles [illegible] across Tahrir Bridge to Giza).
- Galaa Bridge and Tahrir St. up to Saad Zaghlool Square - [illegible] for vehicles from Giza to Cairo,
- Tahrir Bridge - both directions.

A summary of the elements of the analysis follows:

(1) Assign flows from zones west and east of the Nile to the [illegible] links of an alternative in accordance with the proposed traffic directions.

(2) Comparison of link capacity to assigned volume of traffic.

(3) Analysis of new situations which may arise at important intersections resulting from the new allocation, describing the advantages, disadvantages, and feasibility.

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4-2. Present Situation

The traffic matrix which describs travel across the Nile was allocate to the links of the 6th of October, Galaa, and Tahrir Bridges as the present situation is and in accordance with the assumptions indicated in Table 3 below. In this way, the volume of vehicles in both directions was computed.

Comparison of the volume assigned in accordance with the assumptions applied in Table 3, with volume represented by equivalent passenger car units, as shown in Figures 2 A, 2 B and as concluded from the actual surveys procedures on the 6th of October and Galaa Bridges Axes, shows that the difference between assumption and fact does not exceed 27, thus, substantiating the smaple volumes as correct and also the allocation procedure assumptions as correct.

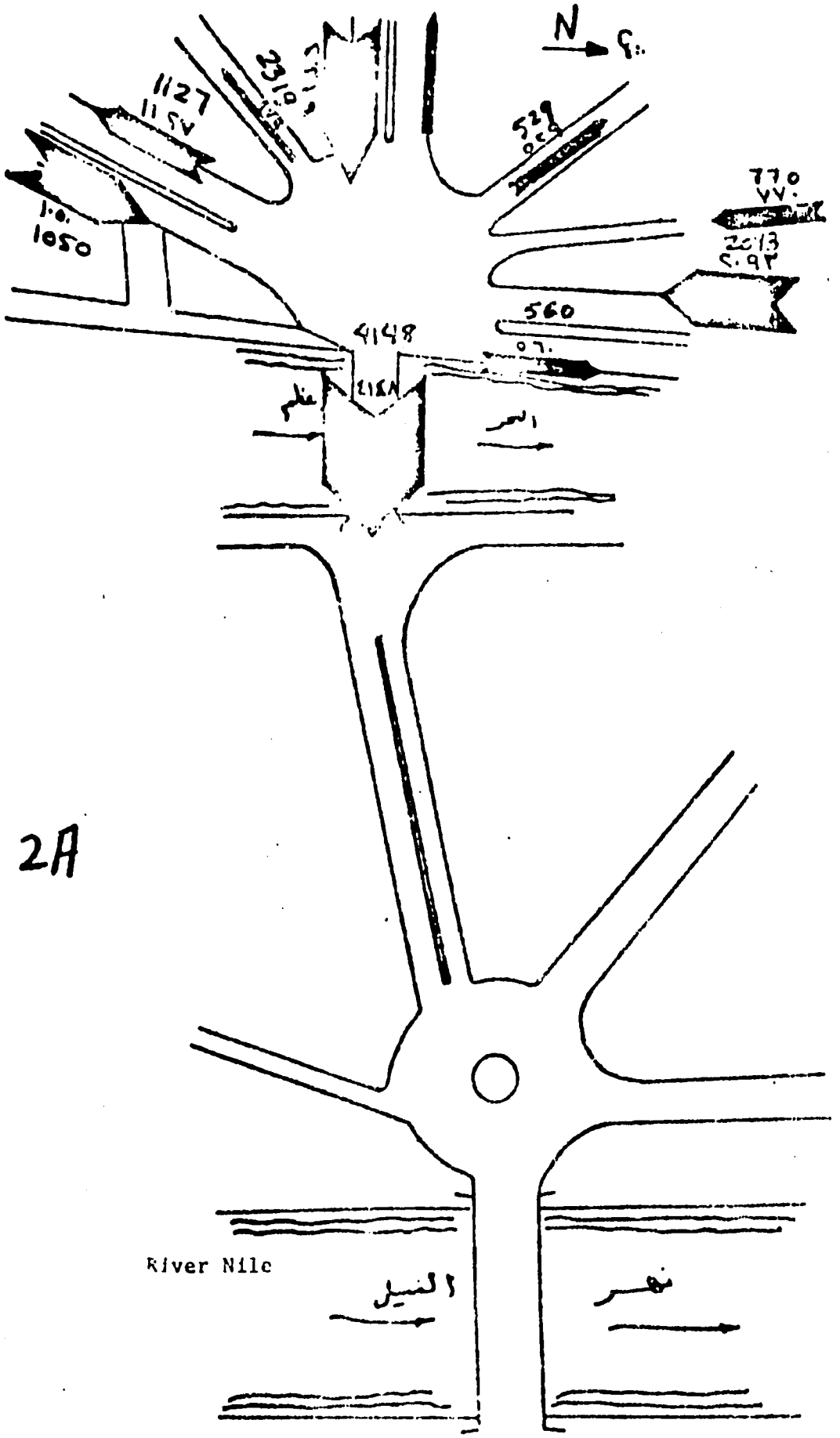


Fig 2A

شكل (٢) - (ب) حجم المرور عند نقطة التحول المؤدية الى كوبري الجلاء (الوضع الحالي).

Best Available Document

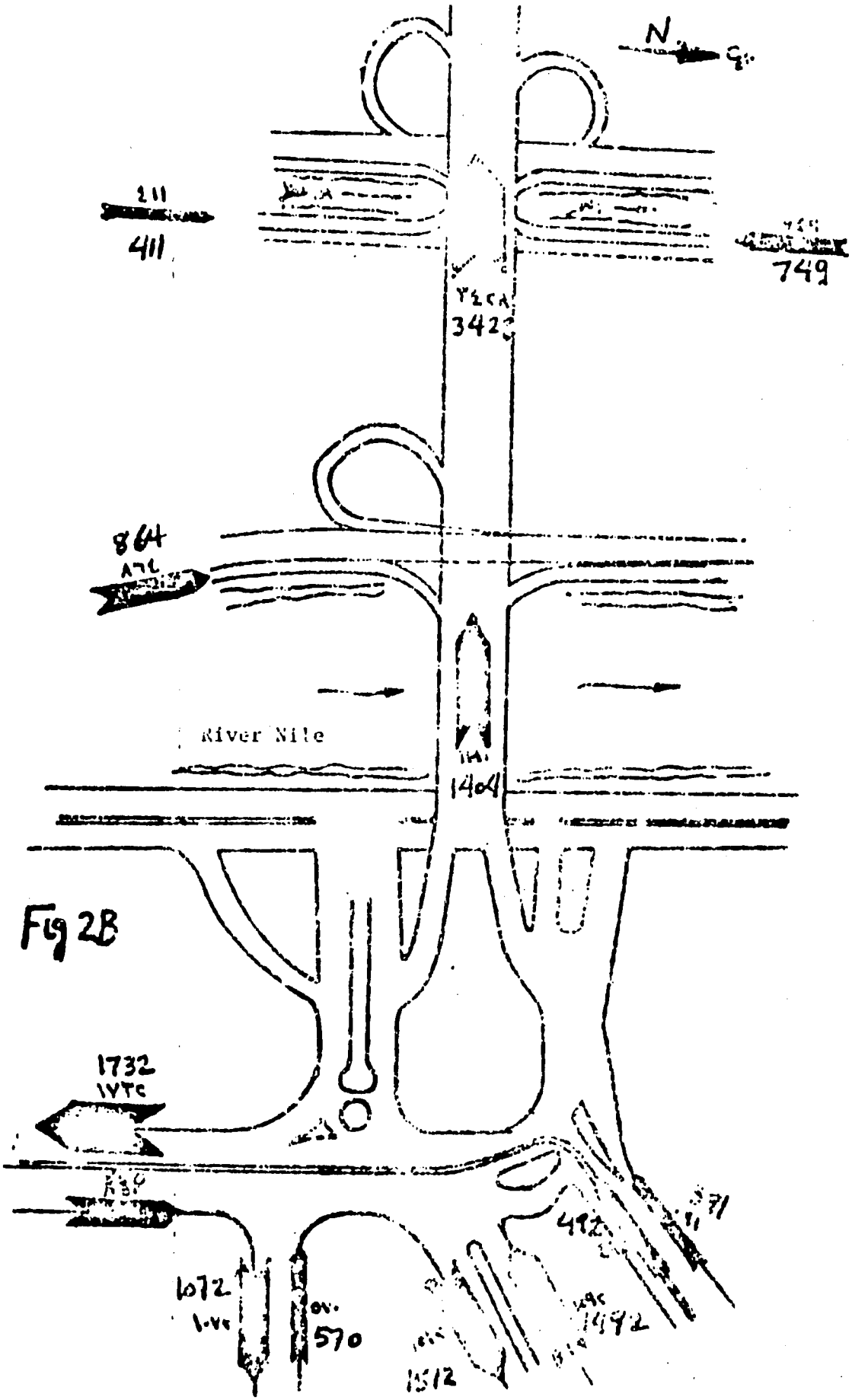


Figure 2B - Traffic Volumes on a Bridge [illegible] (Existing Situation)

شكل (٢ب) حجم المرور [illegible] الموجودة حاليا

Best Available Document

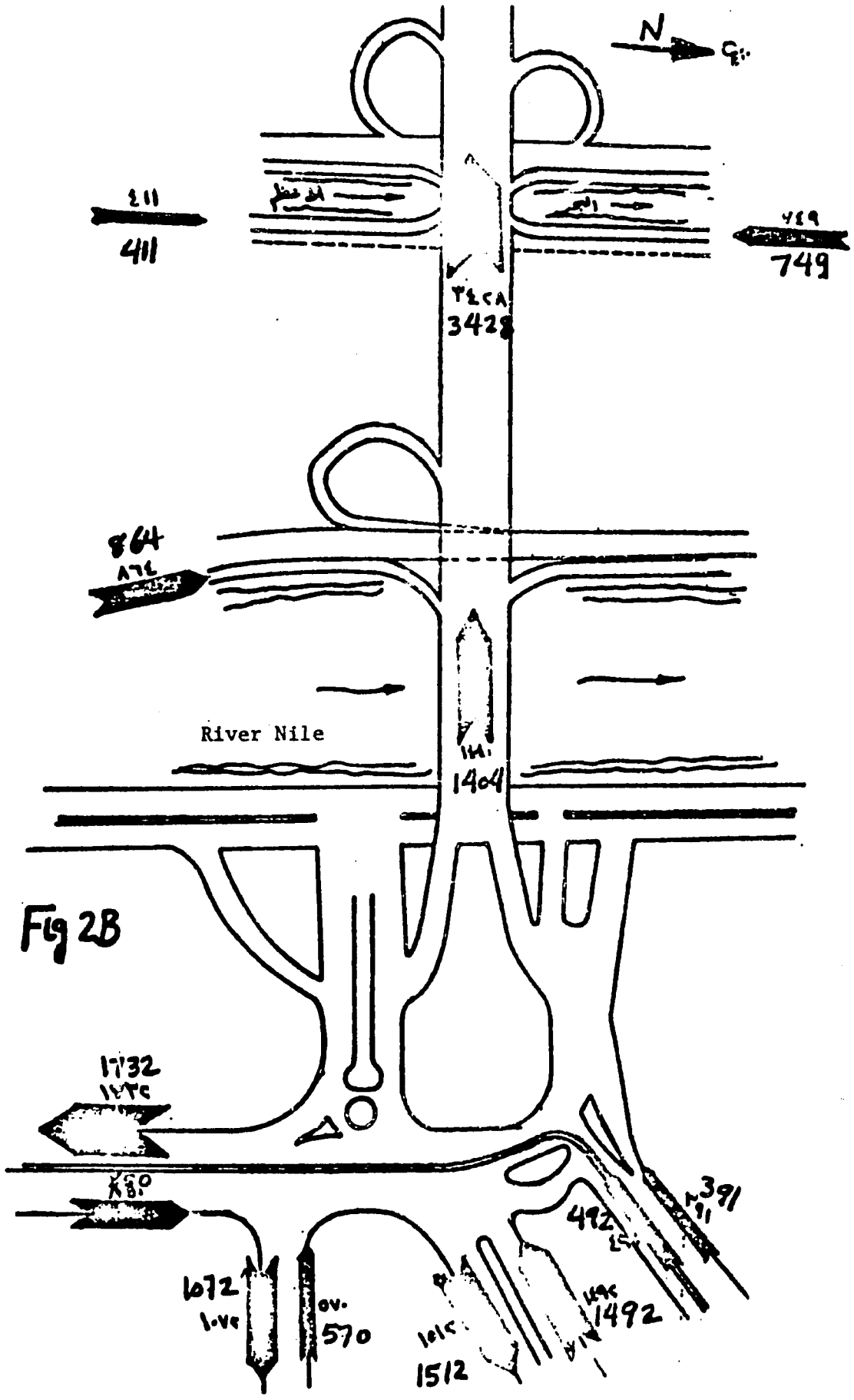


Figure 2B - Traffic Volumes on 6 October Bridge (existing situation)

شكل (٢ب): حجم المرور عند نقط الحصر المؤدية إلى كوبري ٦ أكتوبر (الوضع الحالي)

Table 3: Assignment of Traffic Flows to Present Situation

First: Traffic travelling east to west across the Nile

From Zone	To Zone	6th of October Bridge Axis	Galaa Bridge Axis	Tahrir Bridge Axis
1	2	325	-	325
1	4	-	-	175
1	6	50	-	-
3	2	-	-	600
3	4	-	-	83
3	6	65	-	65
5	2	695	-	-
5	4	220	-	220
5	6	90	-	-
		1445	-	1468

Second: Traffic travelling to east across the Nile

From Zone	To Zone	6th of October Bridge Axis	Gálaa Bridge Axis	Tahrir Bridge Axis
2	1	-	1460	1460
2	3	-	410	410
2	5	-	865	865
4	1	-	765	765
4	3	-	2	2
4	5	-	375	375
6	1	-	215	215
6	3	-	150	150
6	5	-	-	-
			4242	4242

4-3. First Proposal

Traffic volumes and directions are as follows:

- 6th of October Bridge - both directions
- Galaa Bridge - one way from Giza to Cairo.
- Tahrir Bridge - both directions.

In Table 4, (below) traffic in each directions is allocated in accordance with this proposal:

Table 4: Assignment of Traffic flows in Accordance with the First Proposal

First: Traffic travelling east to west across the Nile.

From Zone	To Zone	6th of October Bridge Axis	Galaa Bridge Axis	Tahrir Bridge Axis
1	2	325	-	325
1	4	-	-	175
1	6	50	-	-
3	2	-	-	600
3	4	-	-	83
3	6	65	-	65
5	2	695	-	-
5	4	220	-	220
5	6	90	-	-
		1445	-	1468

Second: Traffic travelling west to east across the Nile

From Zone	To Zone	6th of October Bridge Axis	Galaa Bridge Axis	Tahrir Bridge Axis
2	1	730	730	730
2	3	-	410	410
2	5	865	-	-
4	1	-	765	765
4	3	-	2	2
4	5	200	175	175
6	1	215	-	-
6	3	75	75	75
6	5	-	-	-
		2085	2157	2157

In figures 3A and 3B, traffic volume on various links of both-axis was displayed.

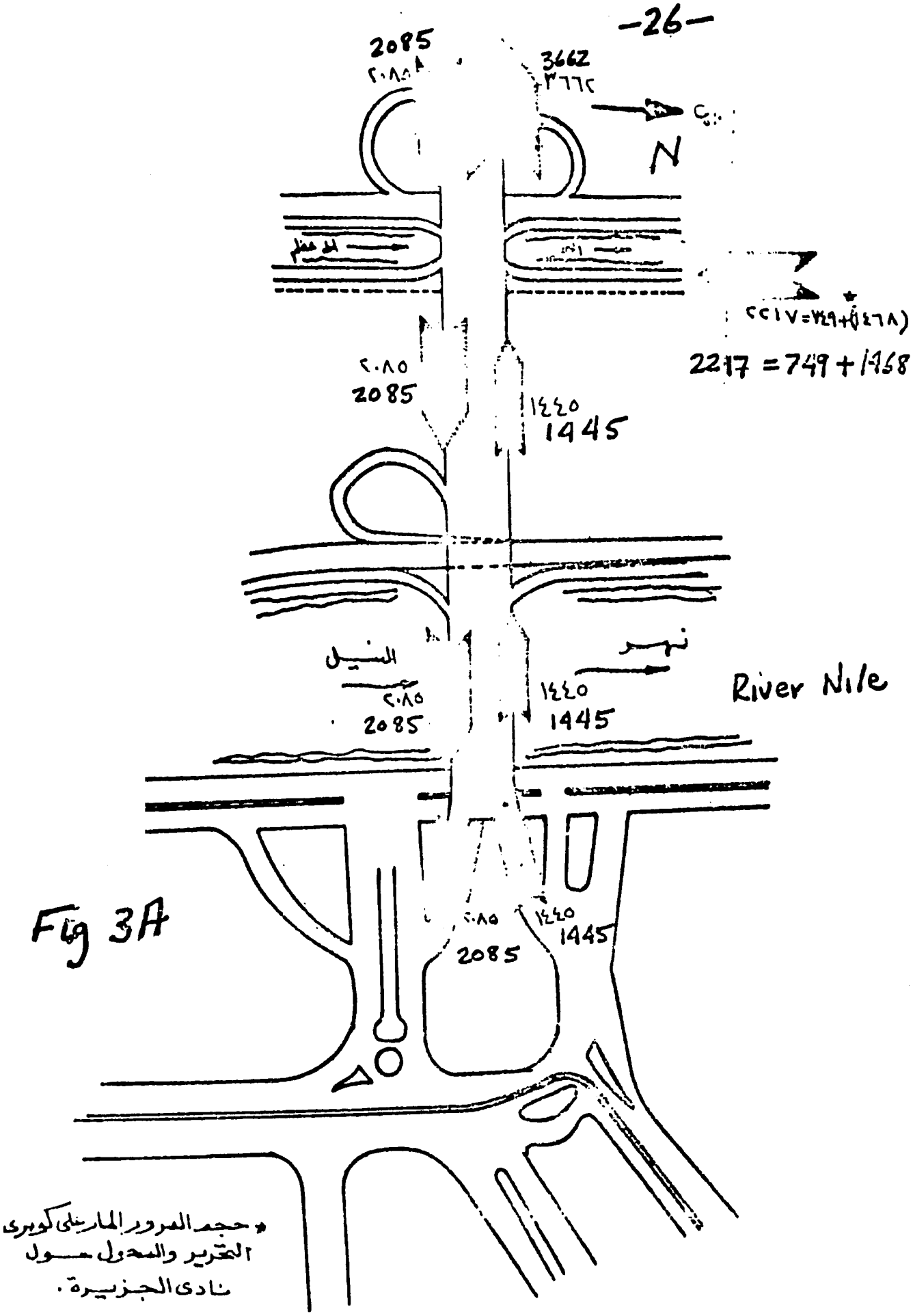


Figure 3A - Traffic Volumes on 6 October Axis in both directions
(1st proposal)

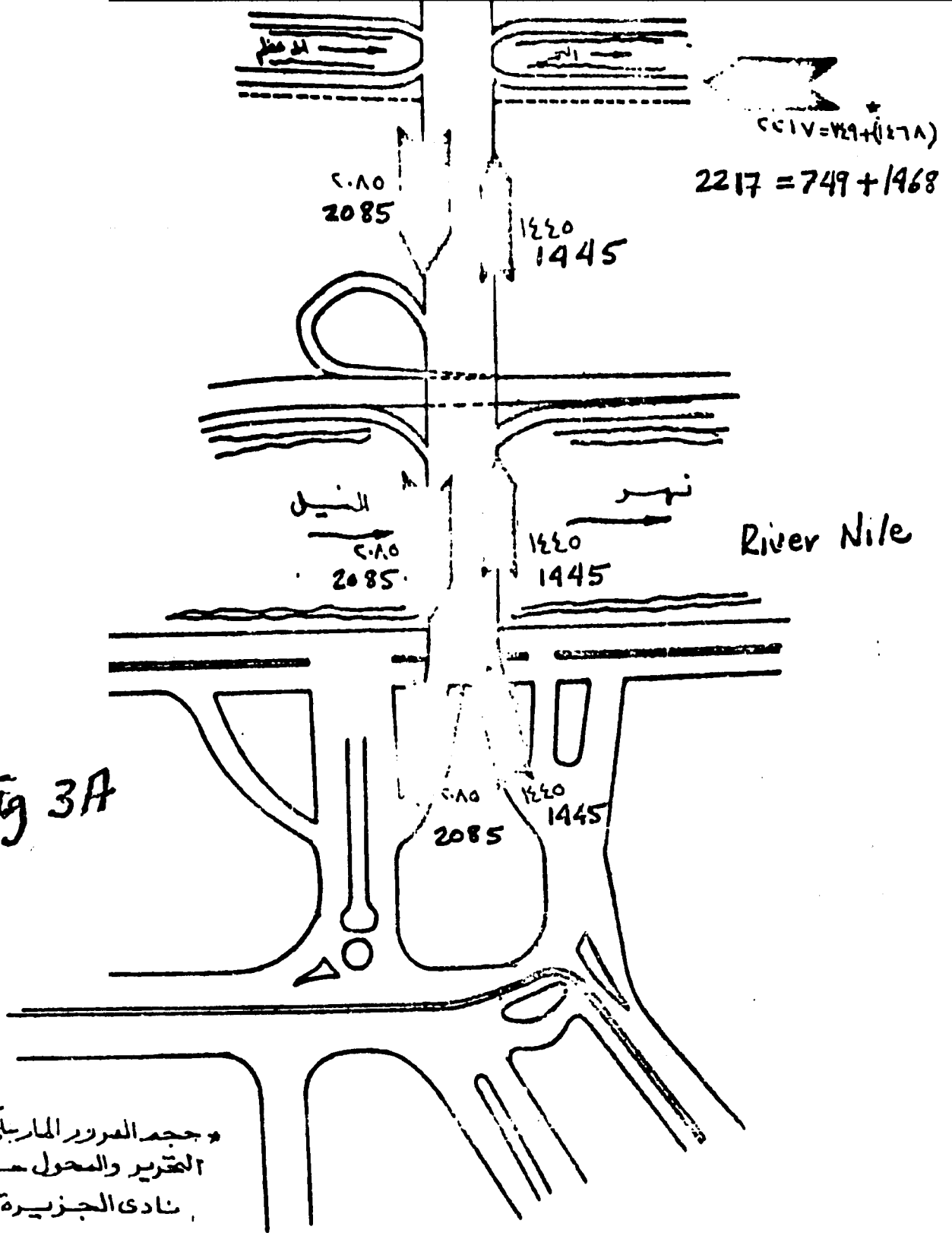
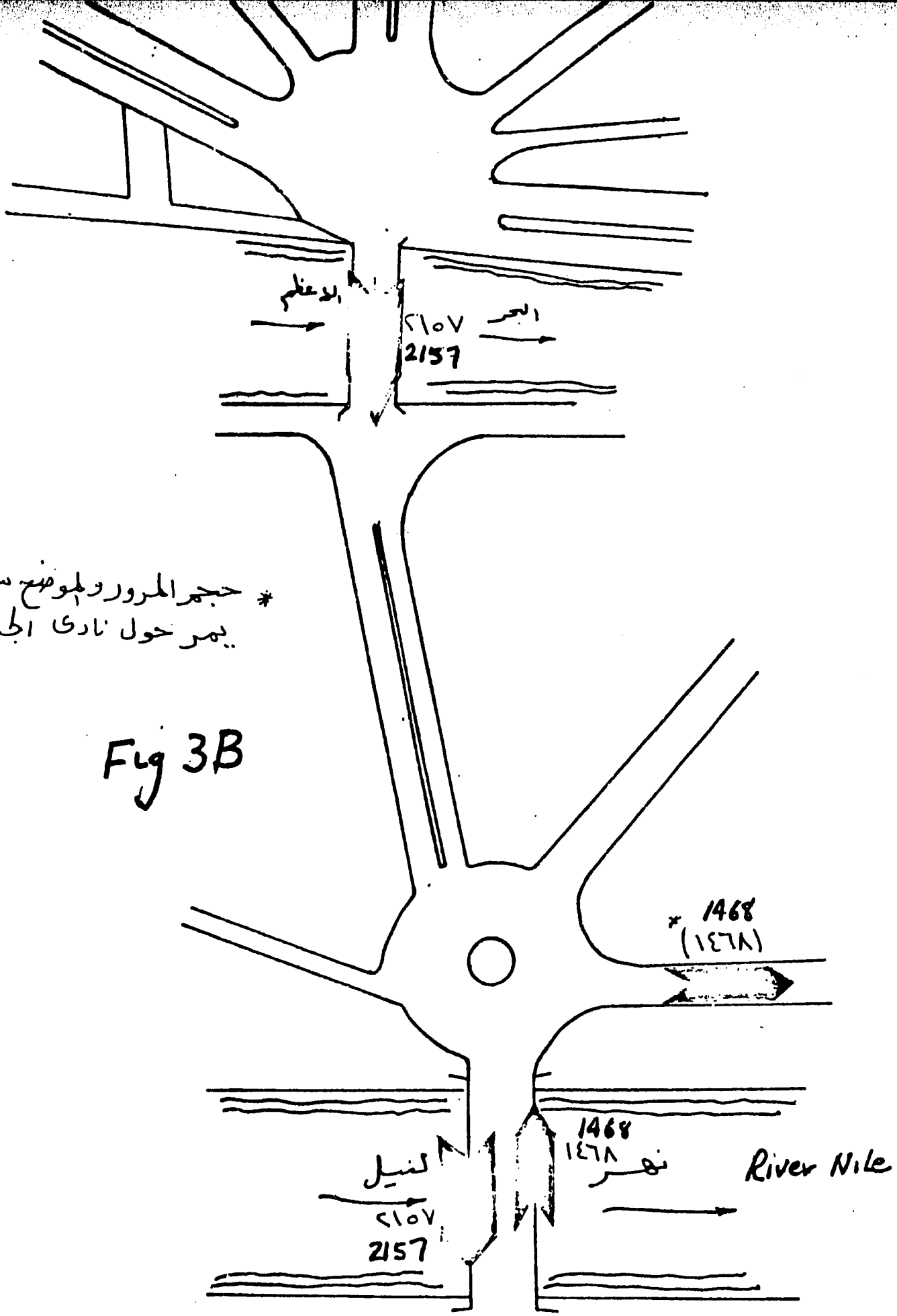


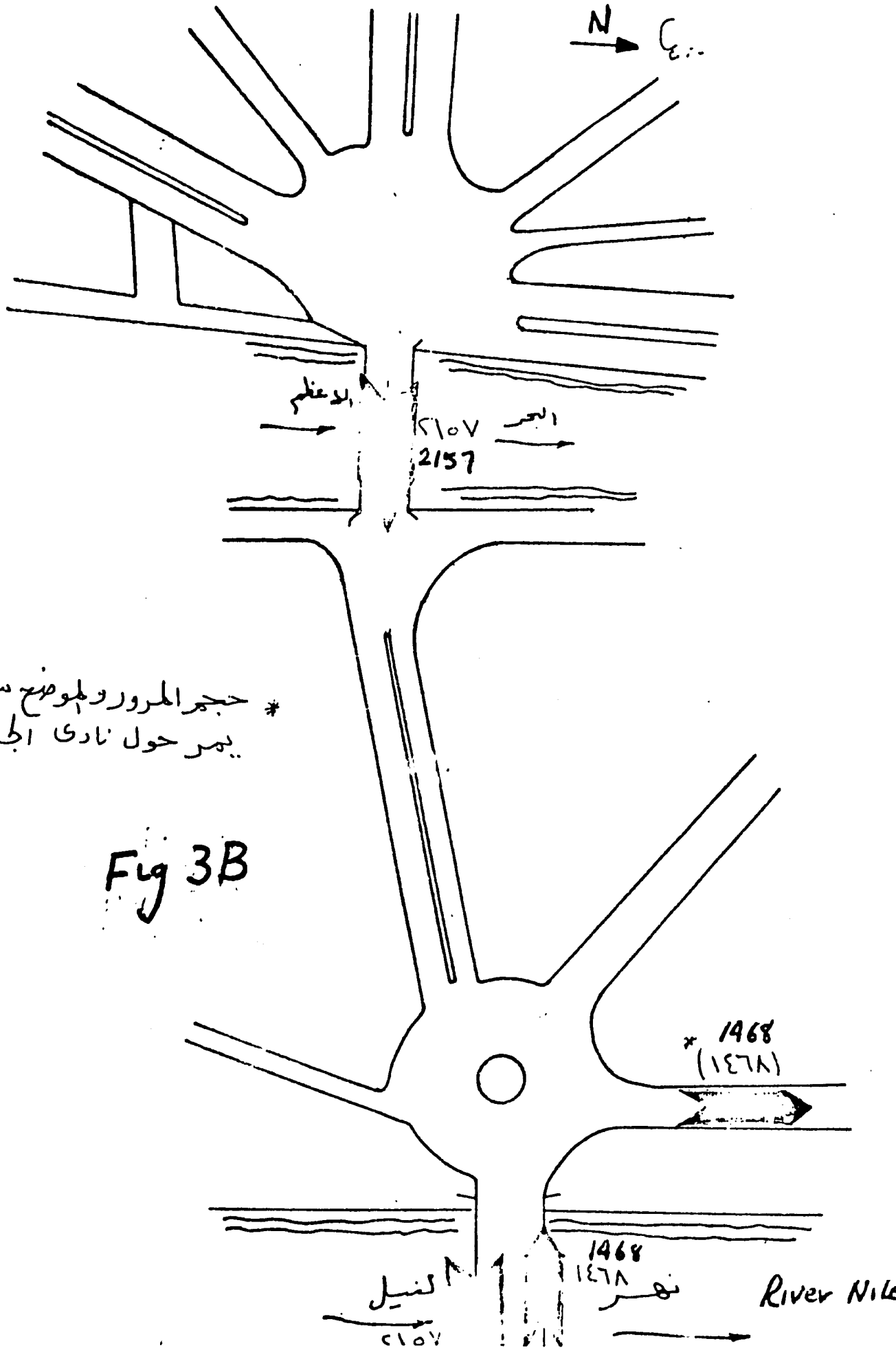
Figure 3A - Traffic Volumes on 6 October Axis in both directions
(1st proposal)

شكل (٣-١) حجم المرور على محور ٦ أكتوبر حالة تشغيلة على الاتجاهين (الإقتراح الأول)



شكل (٣-ب) حجم المرور على كوبرى الجلاء .. (الإقتراح الأول)

Figure 3B - Traffic Volume on Galaa Bridge (1st Proposal)



* حجم المرور والموضح سوف يمر حول نادى الجزيرة

Fig 3B

From the above data, it can be seen that:

1) Traffic volume on Galaa Bridge has been halved from its present volume, thus, greatly lessening delays at the entrance to Galaa Bridge.

2) Traffic from Giza to Cairo across the Tahrir Bridge has also been halved. This would have no repercussions for traffic on Tahrir Bridge, which falls within the Bridges capacity.

3) The off-ramp from the 6th of October Bridge would be over burdened, with 2085 vehicles. This exceeds the capacity of the ramps, which are 5.5 meters wide, and have a sharp, sleeply sloping curve.

4) This proposal would require the replanning of Abdel-Moneim Square so that it could handle the circular movement from the 6th of October Bridge forward Rameses St. in the direction of the 26 July and Rameses Square. The feasibility of replanning A. Riad Square will be studied later.

4-4. Second Proposal

The traffic directions in this proposal are:

- 6th of October Bridge - both directions.
- Tahrir and Galaa Bridges - one direction toward Cairo.

Table 5 shows the assignment of traffic in each direction in accordance with this proposal:

Table 5: Allocation of Traffic Flows in Accordance with the Second Proposal:

First: Traffic travelling east to west across the Nile

From Zone	To Zone	6th Ocotber Bridge Axis	Galaa Bridge Axis	Tahrir Bridge Axis
1	2	650	-	-
1	4	175	-	-
1	6	50	-	-
3	2	600	-	-
3	4	83	-	-
3	6	130	-	-
5	2	695	-	-
5	4	440	-	-
5	6	90	-	-
		2913		

Second: Traffic travelling west to east across the Nile

From Zone	To Zone	6th Ocotber Bridge Axis	Galaa Bridge Axis	Tahrir Bridge Axis
2	1	730	730	730
2	3	-	410	410
2	5	865	-	-
4	1	-	765	765
4	3	-	2	2
4	5	175	200	200
6	1	215	-	-
6	3	75	75	75
6	5	-	-	-
		2060	2182	2182

In figures 4A, 4B traffic volumes on the various links are represented.

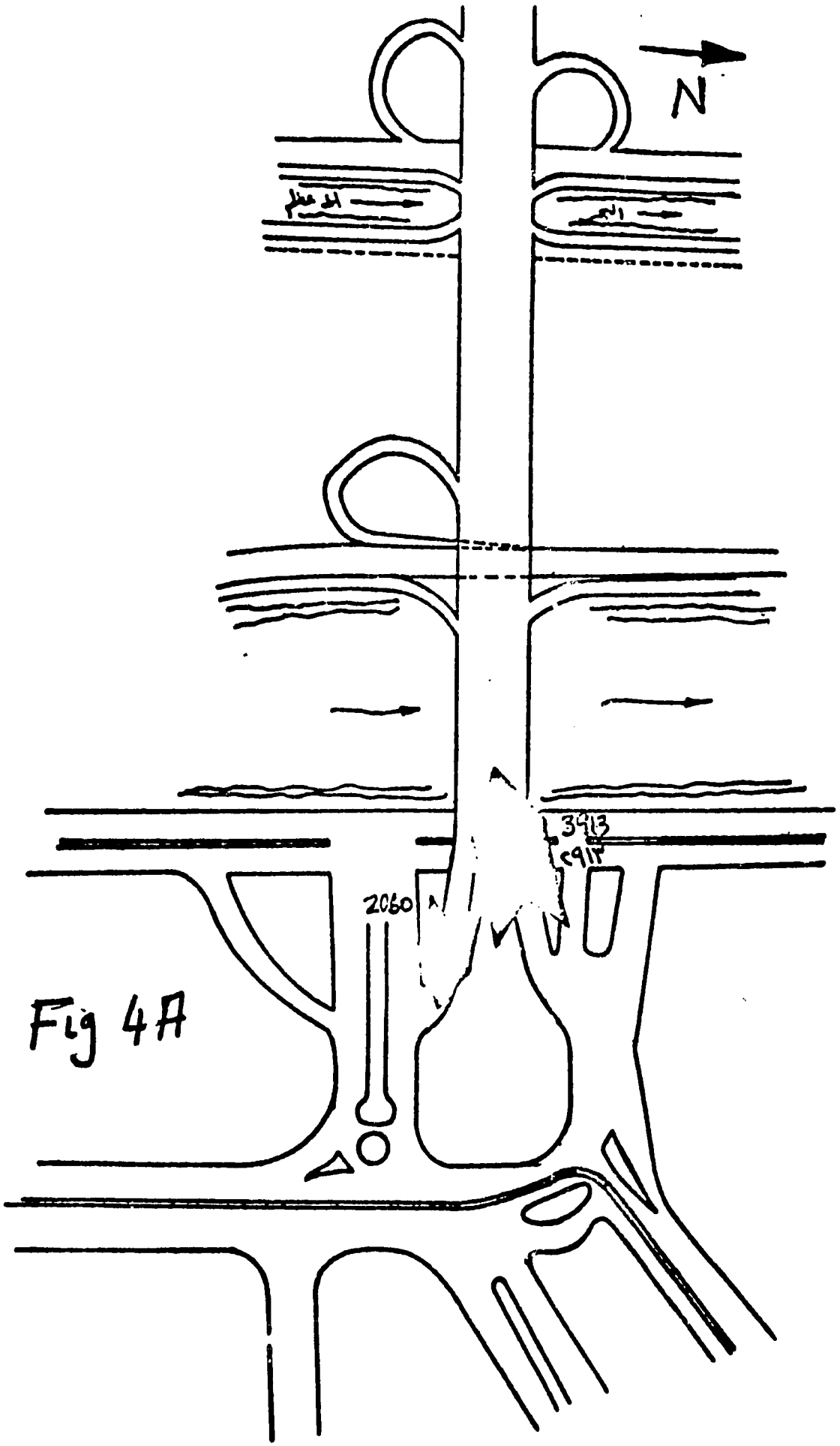
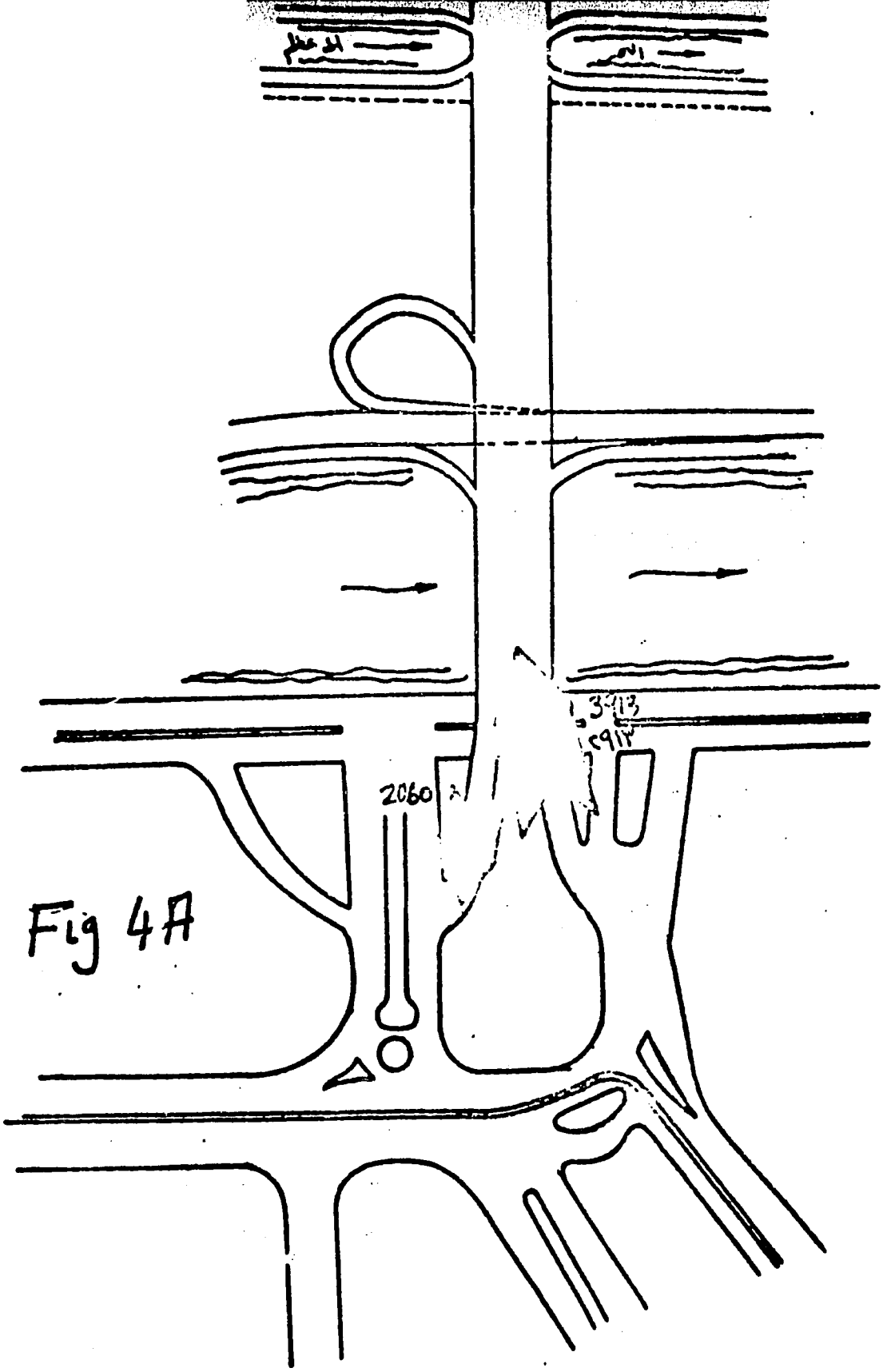


Fig 4A



شكل (٤-أ)، حجم المرور على محور ٦ أكتوبر في حالة تشغيله على اتجاهين (الإقتراح الثاني)

Figure 38 - Traffic Volume on 6 October in 2 directions - (2nd

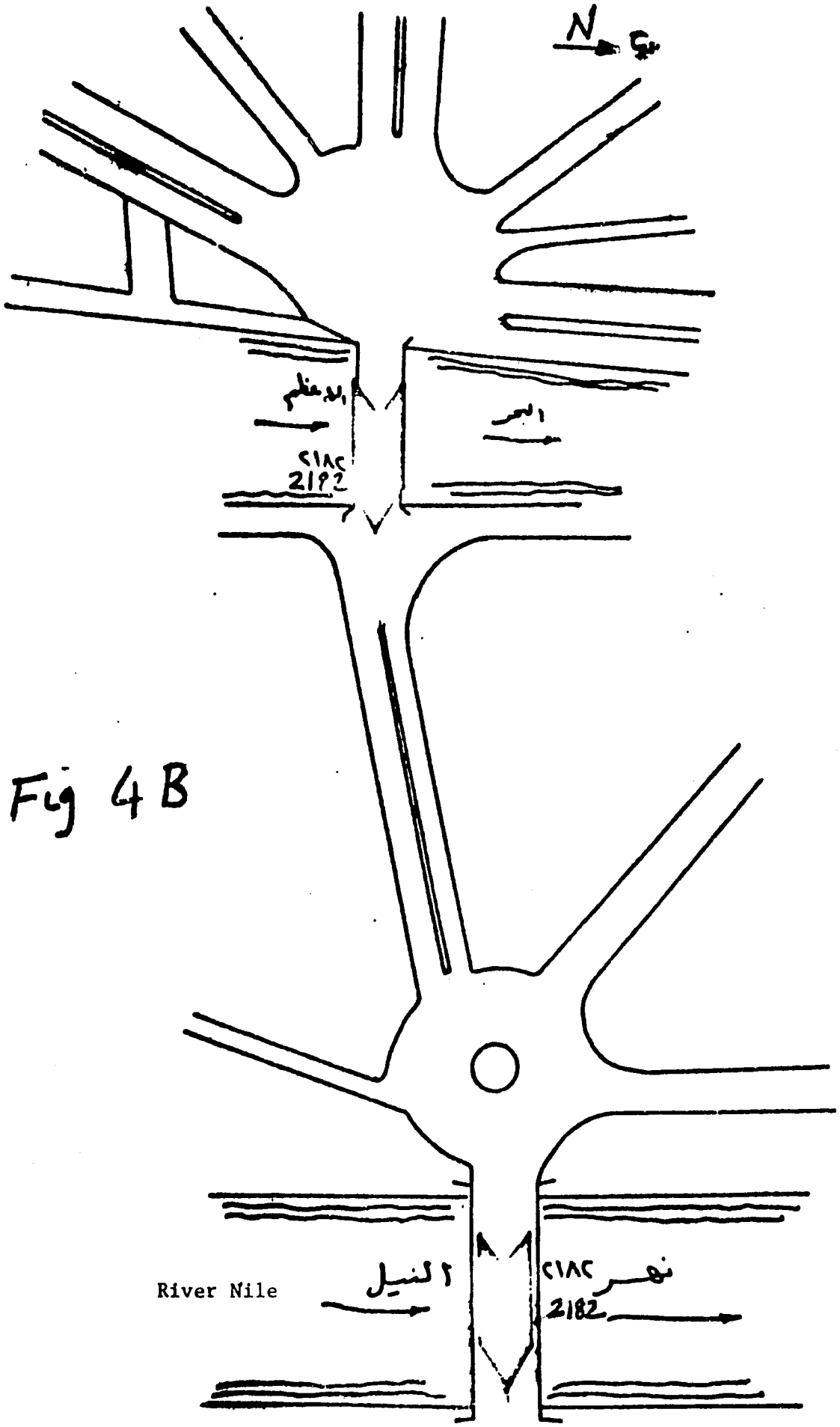


Fig 4B

شكل (٤-ب) حجم المرور على كوبرى الجلاء والتحرير فى حالة تشغيلها فى اتجاه واحد (الإقتراح الثانى)

Figure 4B - Traffic Volume on Galaa Bridge & Tahrir Bridge (2nd proposal)

Based on the above data, the following conclusions can be made:

1) It would be possible for traffic coming from east to west across the Nile from running around Guezereh.
2) There would be no delays at the entrance to the Galaa Bridge.
3) Traffic volume on the temporary ramps on the east end of the 6th of October Bridge would exceed the capacity of the ramps, resulting in excessive delays.
4) This proposal would require the replanning of A.Riad Square due to the different traffic directions. This will be discussed later in the analysis.

4-5. Third Proposal

This proposal recommends that the 6th of Ocotber, Tahrir, and Galaa Bridges all carry traffic in both directions. Table 6 shows the assignment of traffic:

Table 6: Assignment of Traffic Flows in Accordance with the Third Proposal.

First: Traffic traveling East to West across the Nile

From Zone	To Zone	6th Ocotber Bridge Axis	Galaa Bridge Axis	Tahrir Bridge Axis
1	2	325	325	325
1	4	-	175	175
1	6	50	-	-
3	2	-	600	600
3	4	-	83	83
3	6	65	65	65
5	2	695	-	-
5	4	220	220	220
5	6	90	-	-
		1445	1468	1468

Second: Traffic traveling West to East across the Nile

From Zone	To Zone	6th Ocotober Bridge Axis	Galaa Bridge Axis	Tahrir Bridge Axis
2	1	730	730	730
2	3	-	410	410
2	5	895	-	-
4	1	-	765	765
4	3	-	2	2
4	5	200	175	175
6	1	215	-	-
6	3	75	75	75
6	5	-	-	-
		2085	2157	2157

Figure 5A and 5B represent the traffic volumes on the different links:

The conclusions which may be drown from the above data are:

1) All links would have suitable traffic volumes except for the temporary off-ramps to A,Riad Square, where volume exceeds capacity.

2) The volume of traffic crossing the Nile from Galaa Square would drop from 4242 to 3619 (+), but the proposal adds an additional directional flow to Galaa Square, which would lower its capacity by far more than the reduction in volume. Hence, delays would not be lessened in Galaa Square.

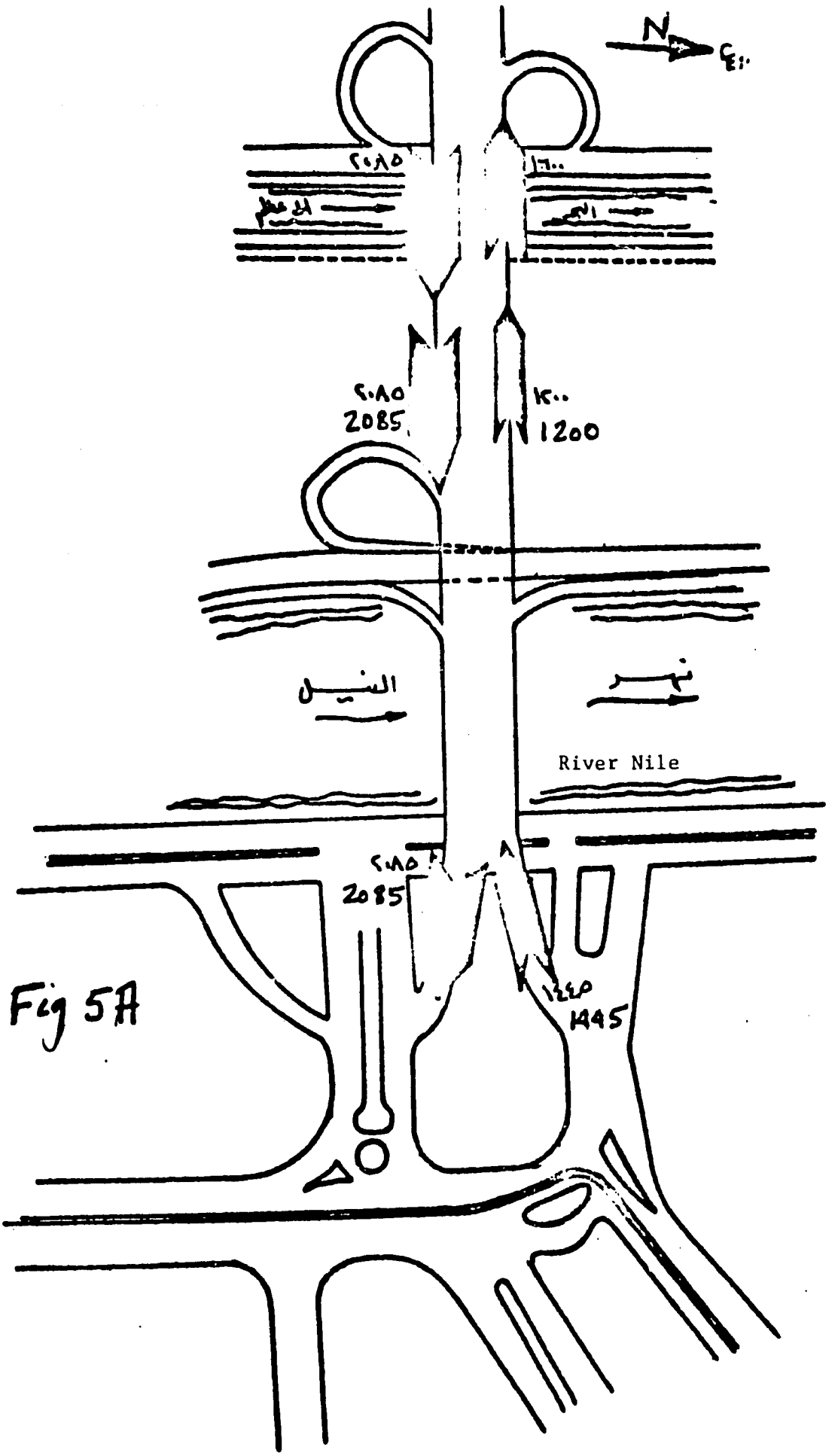
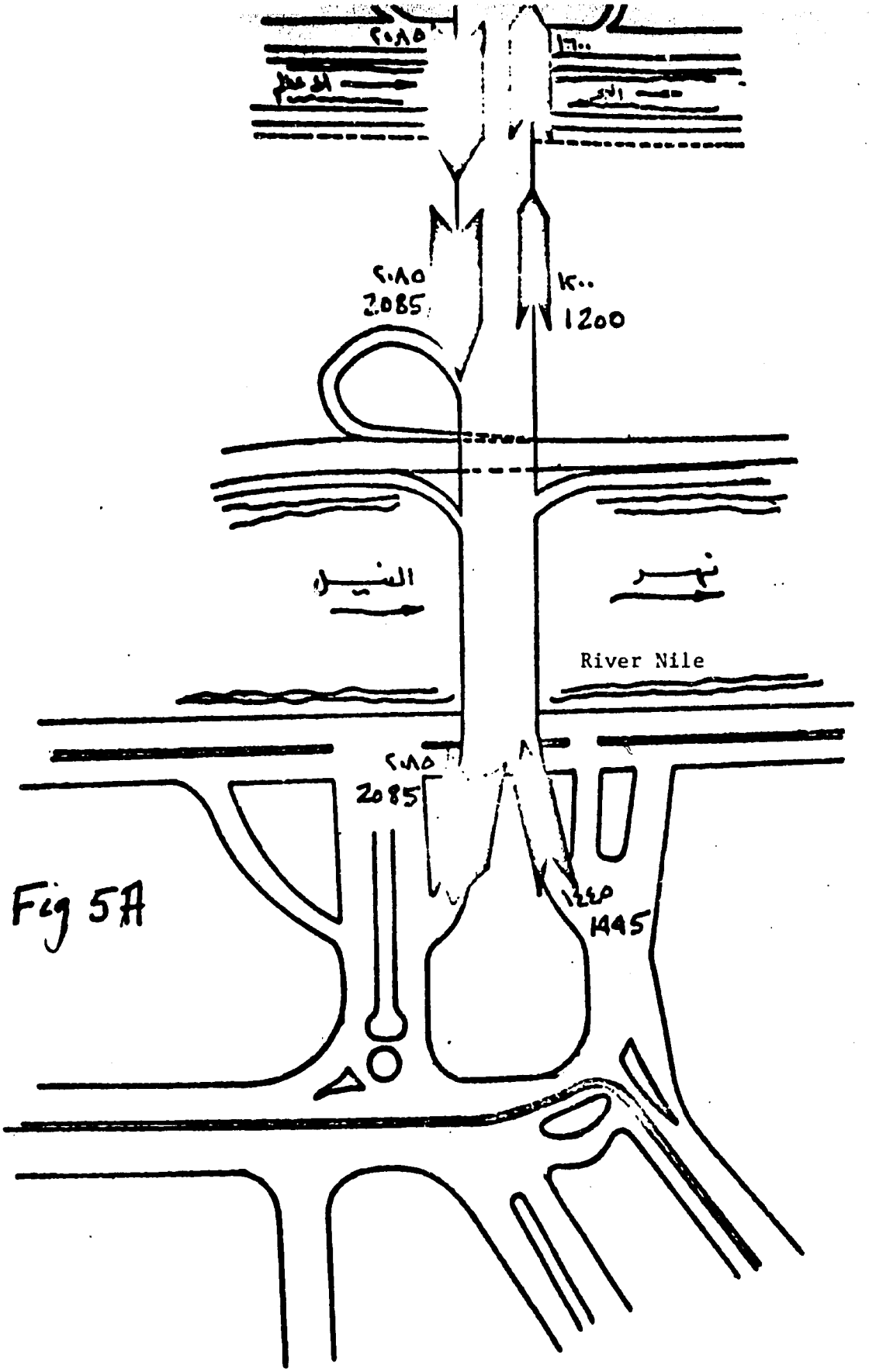
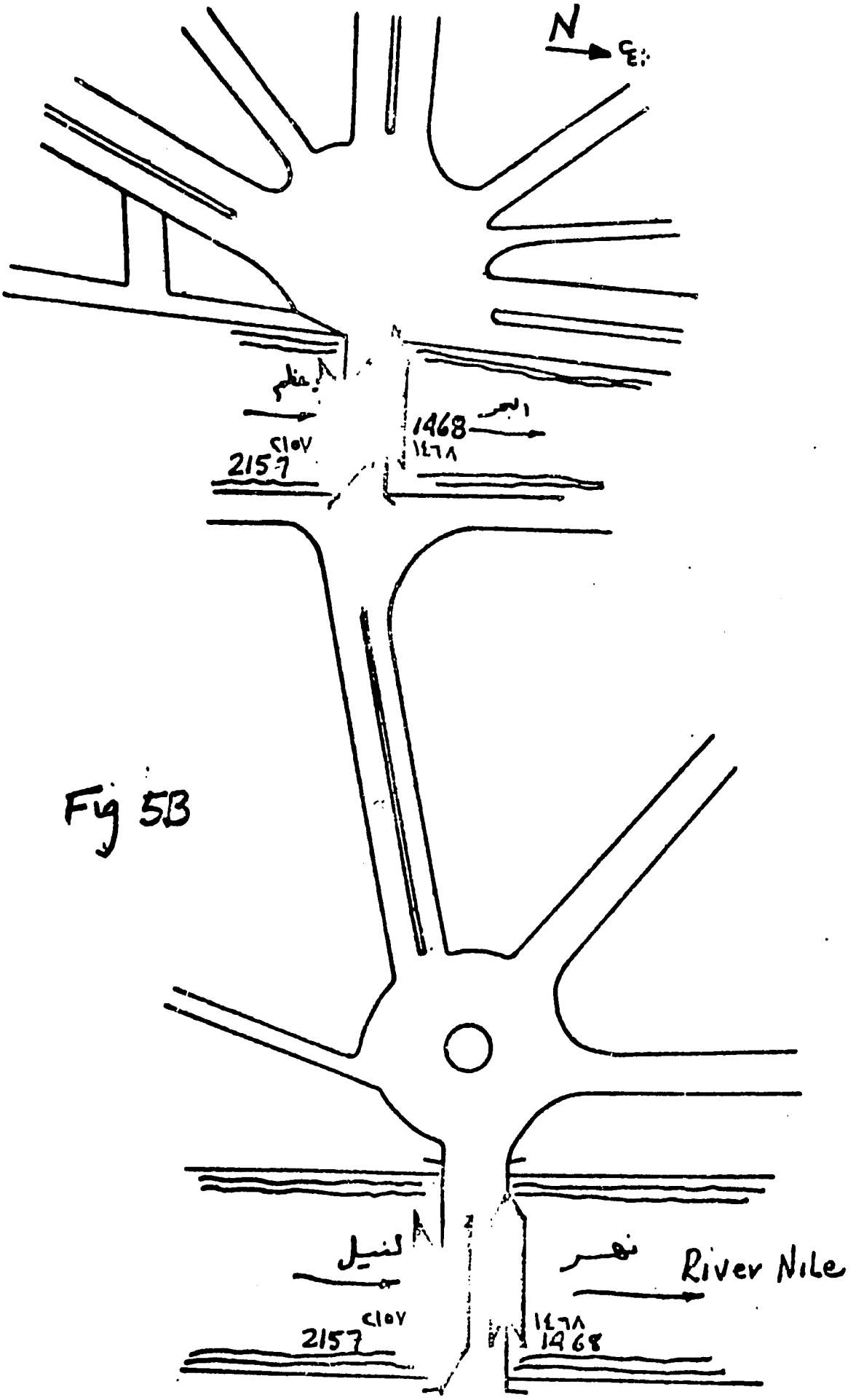

N
٢٠٨٥
١٦٠٠
٢٠٨٥
2085
١٢٠٠
1200
النيل
نهر
River Nile
٢٠٨٥
2085
١٤٤٥
1445

Fig 5A



شكل (٥-أ) حجم المرور على كوبرى ٦ أكتوبر فى حالة تشغيله فى الاتجاهين (الاقتراح الثالث)

Figure 5A - Traffic Volume on 6 October Bridge - (3rd Proposal)



شكل (٥-ب) حجم المرور على الجلاء والتحرير في حالة تشغيلها على الاتجاهين (الاقتراح الثالث)

Figure 5B - Traffic Volume on Galaa Bridge and Tahrier Bridge (3rd Proposal)

3) In accordance with this proposal, A. Riad Square would require replanning. This will be discussed later in the analysis.

4-6. Fourth Proposal

The traffic flows according to this proposal would be in the following directions:

- 6th of Ocotber Bridge - two directions in the Zone from the Agricultural Museum to the off-ramp on to Sarai Guezireh St. (using the other ramp for traffic coming from Cairo across the Tahrir Bridge to Giza). The remaining part of the 6th of Ocotber Bridge axis to A.Riad Square would be one-way for traffic from Cairo to Giza.
- Galaa Bridge and Tahrir St. to Saad Zaghlool Square would be one way for traffic from Giza to Cairo.
- Tahrir Bridge Axis - both directions.

Table 7, shows the traffic flow assigned in each direction according to the Fourth Proposal:

Table 7: Assignment of Traffic Flows in Accordance with Proposal Four.

First: Traffic flowing east to west across the Nile

From Zone	To Zone	6th of October Bridge Axis	Galaa Bridge Axis	Tahrir Bridge Axis
1	2	325	-	325
1	4	-	-	175
1	6	50	-	-
3	2	-	-	600
3	4	-	-	83
3	6	65	-	65
5	2	695	-	-
5	4	220	-	220
5	6	90	-	-
		1445		1468

Second: Traffic Flowing West to East across the Nile

From Zone	To Zone	6th of Ocotber Bridge Axis	Galaa Bridge Axis	Tahrir Bridge Axis
2	1	730	730	1460
2	3	-	410	410
2	5	865	-	865
4	1	-	765	765
4	3	-	2	2
4	5	-	375	375
6	1	215	-	215
6	3	150	-	150
6	5	-	-	-
		1960	2282	4242

Figures 6A, 6B show traffic volumes on the different links of each of the axes.

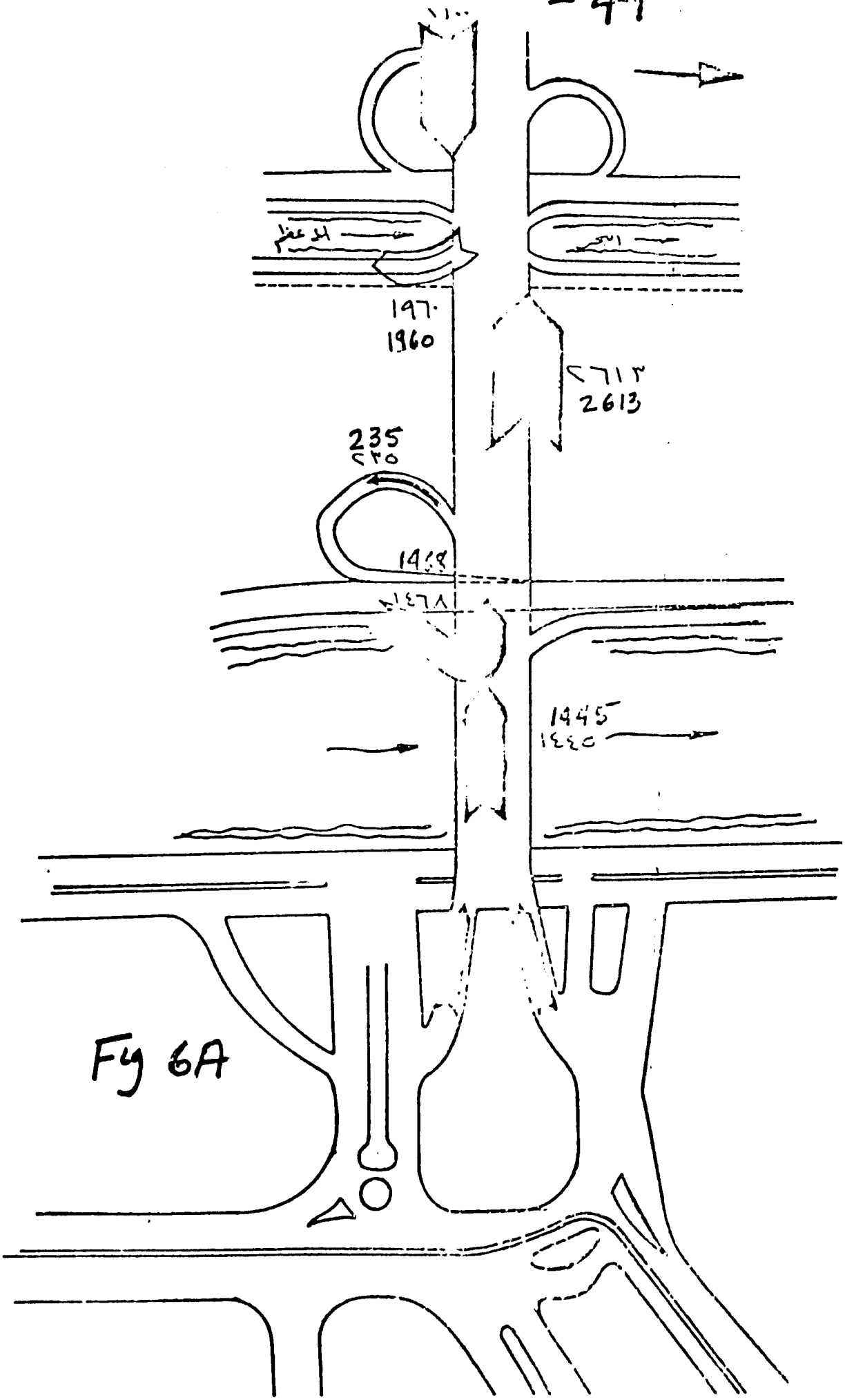
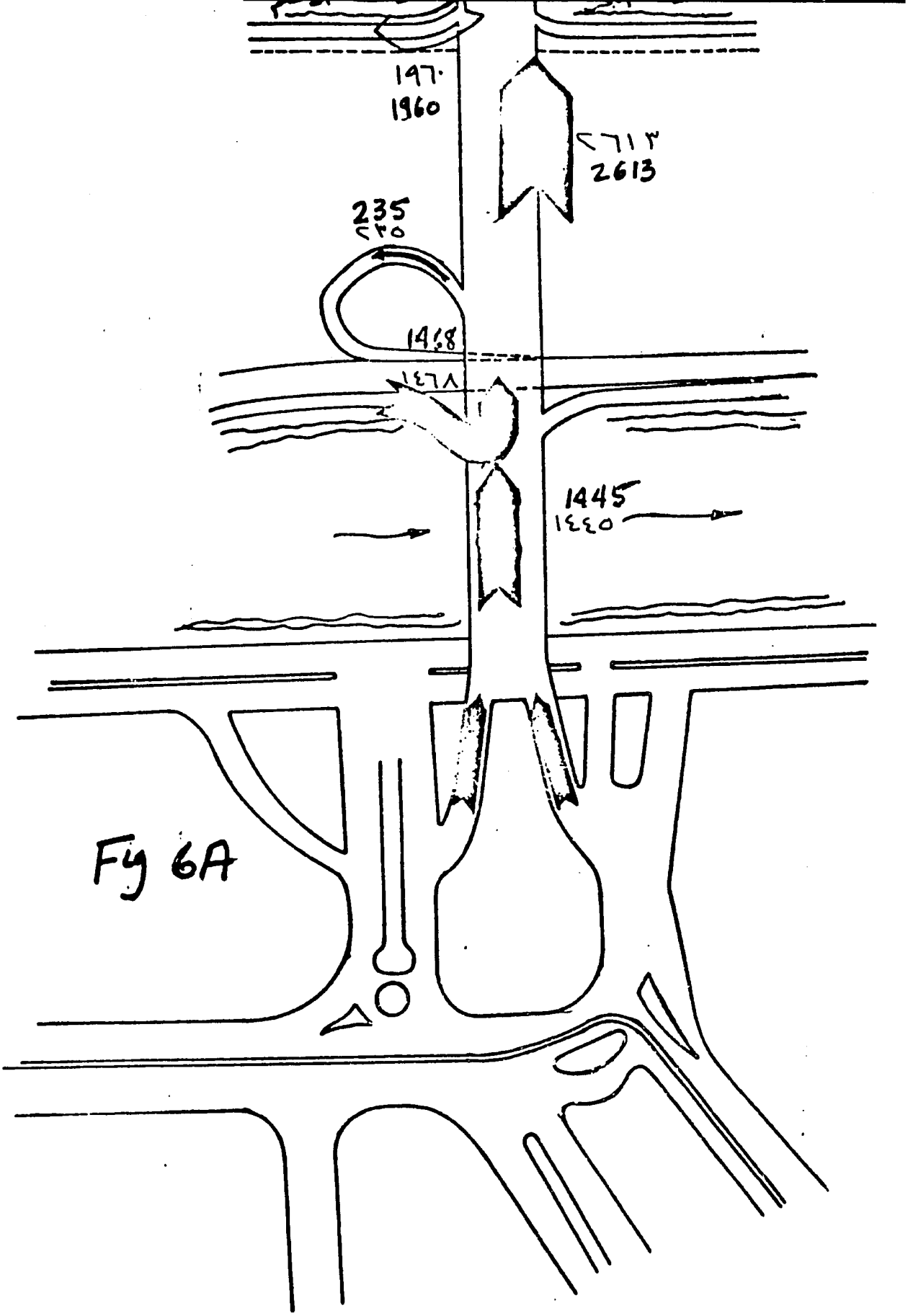


Fig 6A



شكل (٦-أ) حجم المرور على محور كوبري ٦ أكتوبر [الاقتراح الرابع]

Figure 6A - Traffic volume on 6 October Bridge (4th Proposal)

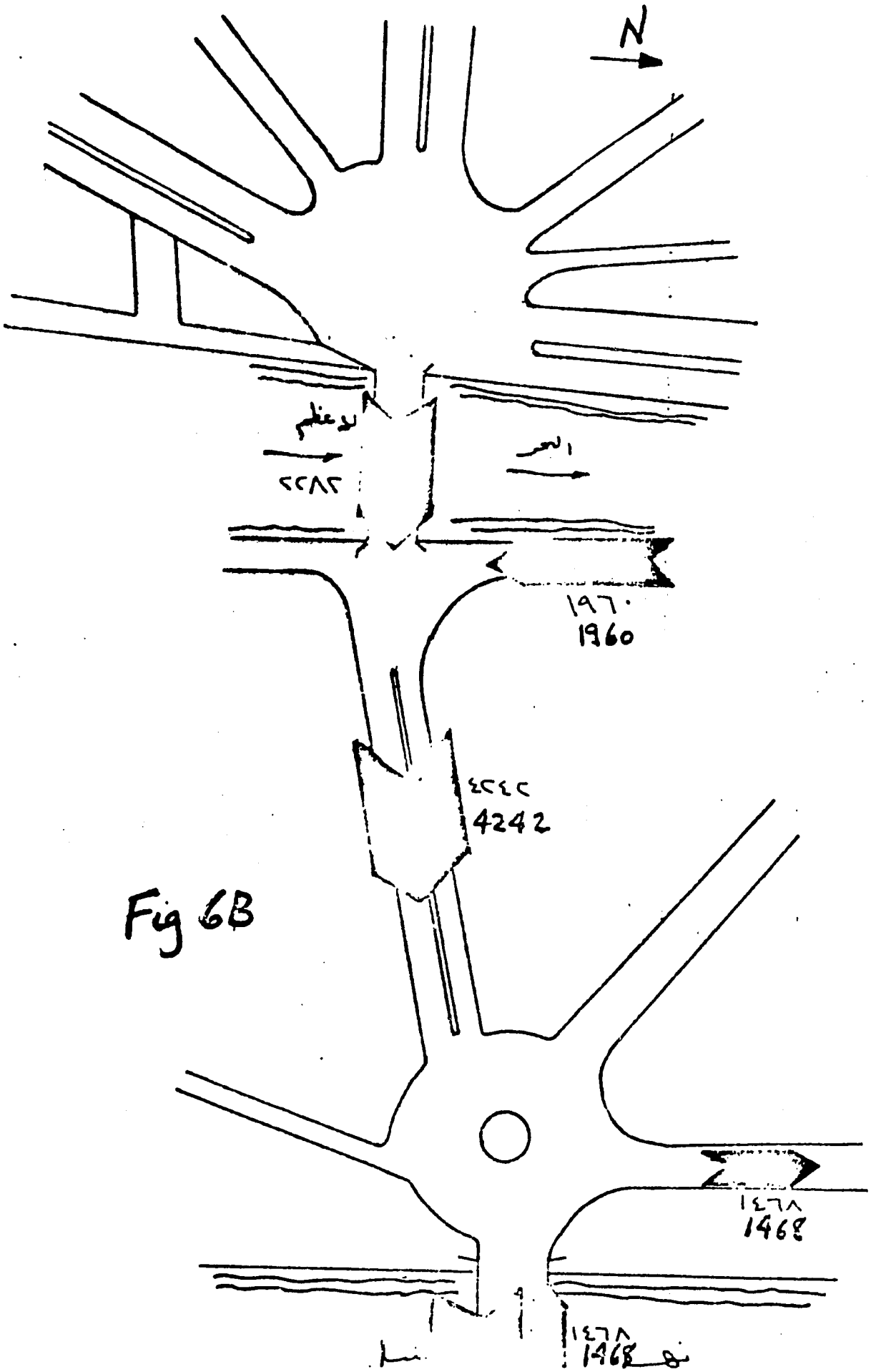
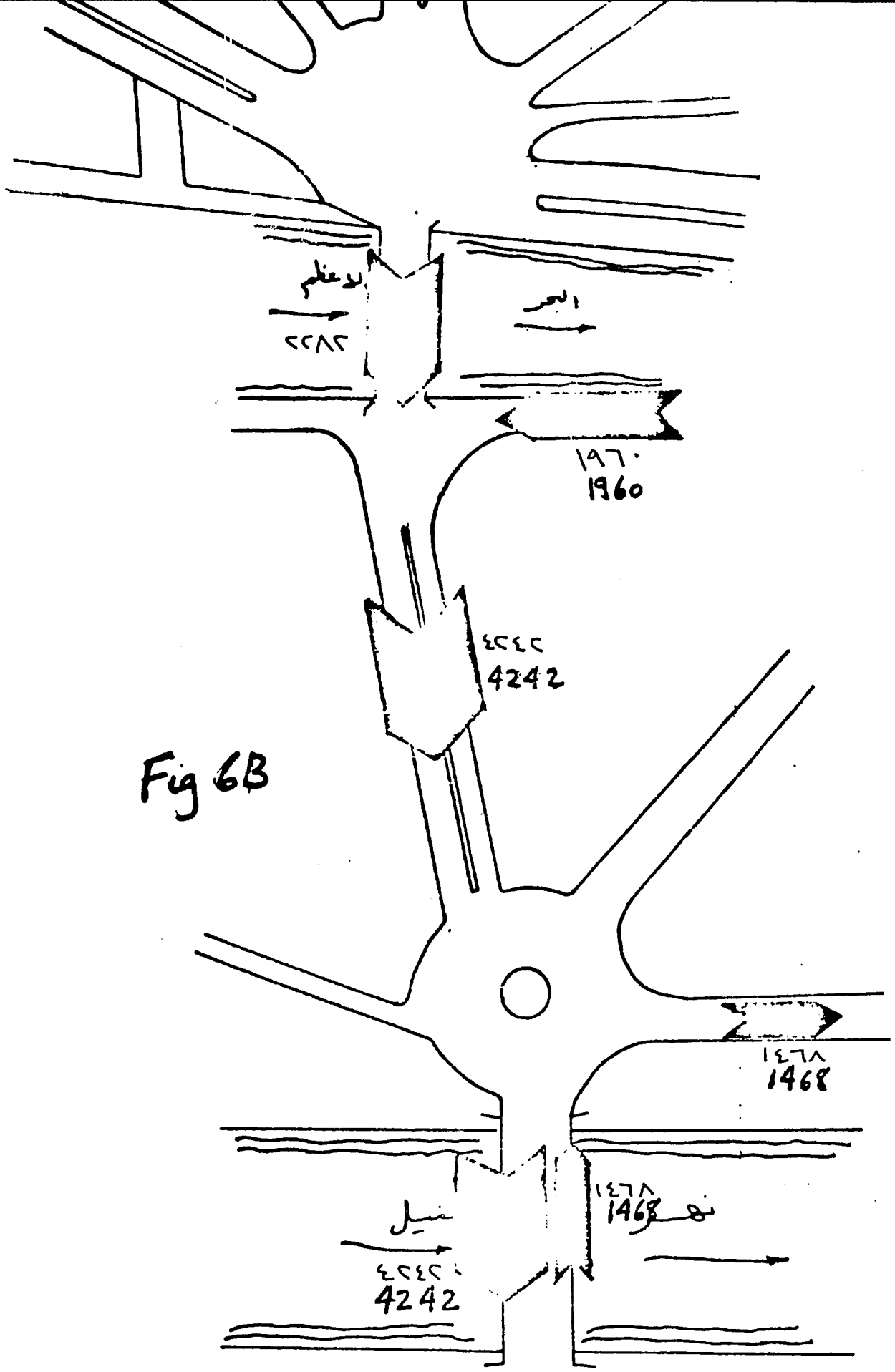


Fig 6B



شكل (٦-ب) حجم المرور على محور الجلاء والتحرير [الاقتراح الرابع]

Figure 6B - Traffic Volume on Galaa & Tahrier Bridge (4th Proposal)

The conclusions to be drawn from the above are:

1) Traffic volume entering the Galaa Bridge would drop from 4242 to 2282, thus largely reducing the existing delays in Galaa Square.
2) Traffic volume on Tahrir Bridge would be the same as presently exists.
3) Traffic moving west to east across the Nile would take the shortest route utilizing already complete highway facilities on the western end of the 6th of October Bridge, in its normal setting of permanent operation .
4) The off-ramp from the 6th of October Bridge (its connection with Guezireh St.) would be used as an on ramp for traffic coming from the Tahrir Bridge, and would be loaded with volumes similar to the present.
5) No change would be made in traffic volume or direction in A.Riad Square, making replanning of the Square unnecessary.
6) The on-ramp from Guezireh St. would be used as an off-ramp for traffic from west of the Nile travelling to the Zamalek Zone, thus reducing pressure on the Zamalek Bridge. The Guezireh Club intersection would require alteration to accept the contra-flow traffic.

To insure safer traffic flow at the east end of the Galaa Bridge and at Saad Zaghlool Square, the fourth proposal recommends the removal of the median island on Tahrir St. and also a minimizing of the Radius of the planted area around the Saad Zaghlool Statue.

4-7. Replanning of Martyr Abdel-Moneim Riad Square

Proposal 1, 2, and 3 would require the replanning of A. Riad Square, as the temporary ramps there would be operated in the opposite directions. The ramp from Galaa St. would carry traffic moving from Cairo to Giza, the other ramp from Marafek Square would carry traffic moving from Guiza to Cairo.

The proposal replanning primarily involves the conversion of traffic coming from Ramses St. and Galaa St. to the north of Galaa St. slope then to Cornish St., again to A. Riad Square, south of Marafek Square slope, then to Mariet or M. Bassiouni St.

The replanning of A. Riad Square as necessitated in the first three proposals would require the following:

A. The alternative operation of a part of Cornish St. as one-way, and another part as two-ways. This operation has the following disadvantages:

- Road users are unfamiliar with such a system.
- Traffic officers would find it difficult to implement this system due to a lack of clear vision of vehicles coming from Ramses and Galaa St. Bridge piers create visuals hazards here.
- Traffic flowing in the sector during peak hour would include 307 public and private buses.

B. The traffic volume which would be converted to Cornish St. (where first one-way and then two-ways traffic directions would exist) would be 2917 (P.C.U'S) in addition to the normal traffic on Cornish St. This would cause delays; again, it should be determined whether this part of the intersection would not produce traffic obstruction or stoppage in A. Riad Square.

C. Traffic travelling from Giza to Cairo and utilizing the temporary Marafik ramps would amount to 2000 (P.C.U'S) in peak hour. This level of traffic volume in the intersection would present the following difficulties:

- The traffic flow in A. Riad Square is controlled by a signal. Thus, the queue at the stop line in front of the signal would be about 470 meters long $(\frac{2000}{60} \times 2 \times 7)$.

  This queue may not be positioned either on the bridge or on the ramp itself. Positioning of the queue on the ramp is less than ideal from the standpoint of safety.

- Some delay might occur within the intersection, resulting from the acceleration time of trams coming from Galaa St. to Mariet St. and due to its intersection with the queue mentioned above.

In addition, as mentioned previously in the three proposals traffic volume on the southern ramp (from Giza to Cairo) would exceed its capacity is limited because of the narrow width of the ramps, the existence of a sharp opposite curve, and the steep slope of the ramp.

Conclusions

- The 6th of October Bridge on and off ramps are now completed on the west side of the Nile, thus permitting their use according to their original design. This is particularly important because the western end of the bridge lies in an area which generates many trips.
- Delay at the Galaa Square intersection during peak hours is unacceptable.
- Tahrir St. between the Galaa Bridge and Saad Zaghlool Square has additional capacity in the form of unused lanes.
- Traffic travelling on Zamalek Bridge from Giza to Zamalek encounters some bottlenecks.
- The operation of Galaa Bridge in both directions would not create an improvement in delay time at this intersection.
- Changes in the operation of A.Riad Square would create additional bottlenecks to those already encountered.
- The operation of the temporary Southern ramp for traffic travelling from Guiza to Cairo would generate traffic volume which would far exceed its capacity, and additionally create the risk of traffic queuing on the ramp.

The optimal proposal for improved traffic flow at present, on the 6th of October, Galaa, and Tahrir Bridges axes is as follows:

- Traffic be permitted to travel on the 6th ofOctober Bridge in both directions from the Agricultural Museum to the on ramp from Sarai Guezireh St. the ramp to be used as an off ramp for traffic from Giza to Zamalek the remaining part of the Bridge to the two temporary ramps on the eastern end to be used for one-way traffic coming from Cairo to Giza or to Zamalek.

- Traffic be permitted to move one-way on Galaa Bridge axis and Tahrir St. up to Saad Zaghlool Square, for traffic from Giza or from the 6th of October Bridge via the Sarai Guezireh ramp, and one-way to Gabalaya St. Cairo.
- Traffic be permitted to move in both directions on Tahrir Bridge.
- One-way operation of Gabalaya St. between Exhibition St. and Tahrir St. for traffic moving to the Tahrir Bridge.

In accordance with this proposal:

1. a section of the planted area surrounding the Saad Zaghlool statue should be removed to allow the smoother flow of traffic going to Tahrir Bridge.

2. a removal of 150 meters of the median island of Tahrir St. between Galaa and Tahrir Bridges, and channelizing this part to facilitate the merging of traffic prior to its arrival in Saad Zaghlool Square.

3. rechannelizing the Tahrir Bridge to allow 3 lanes for traffic moving from Guiza to Cairo, and 2 lanes for traffic moving in the opposite.

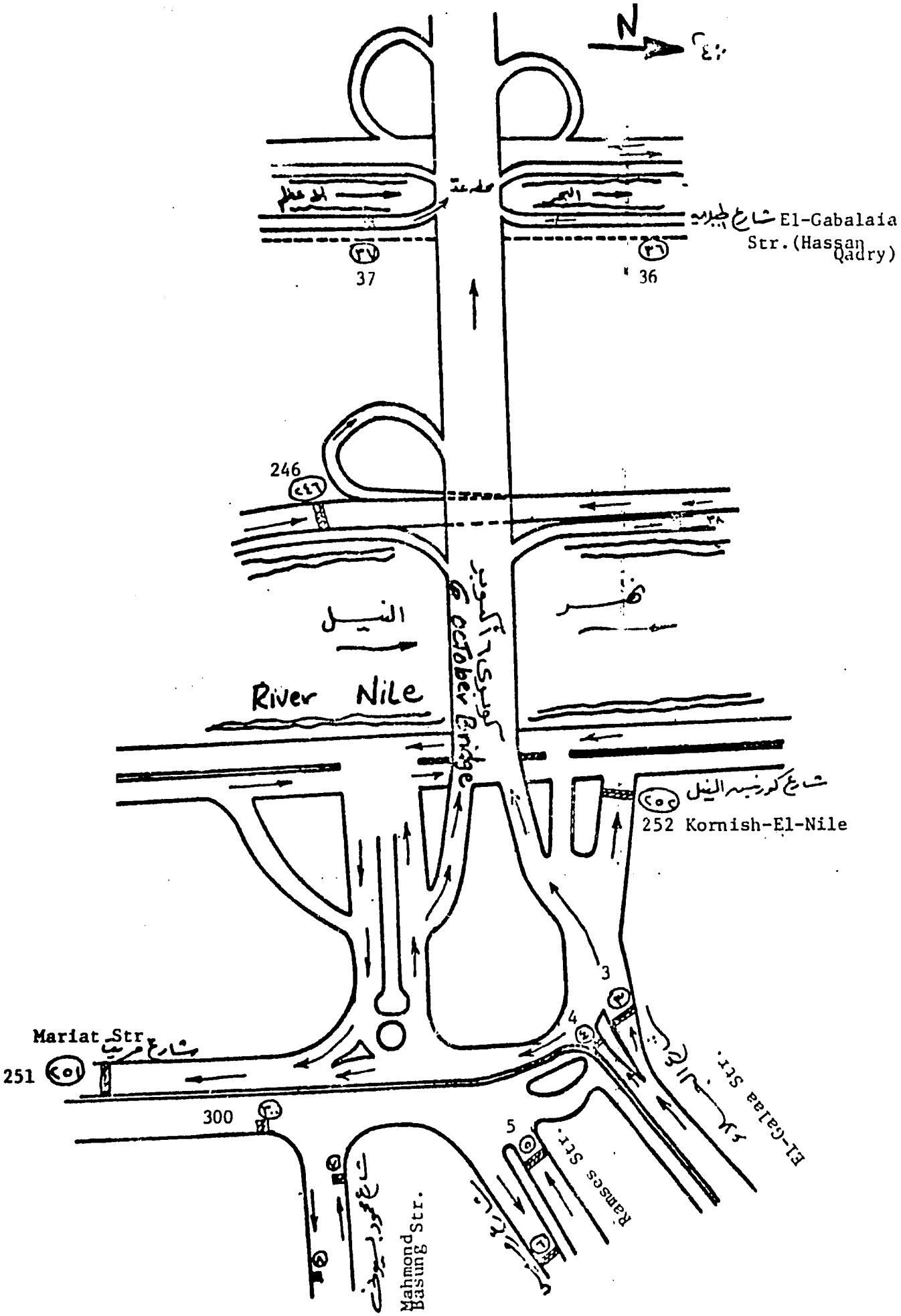


Figure shows study area and location of stations

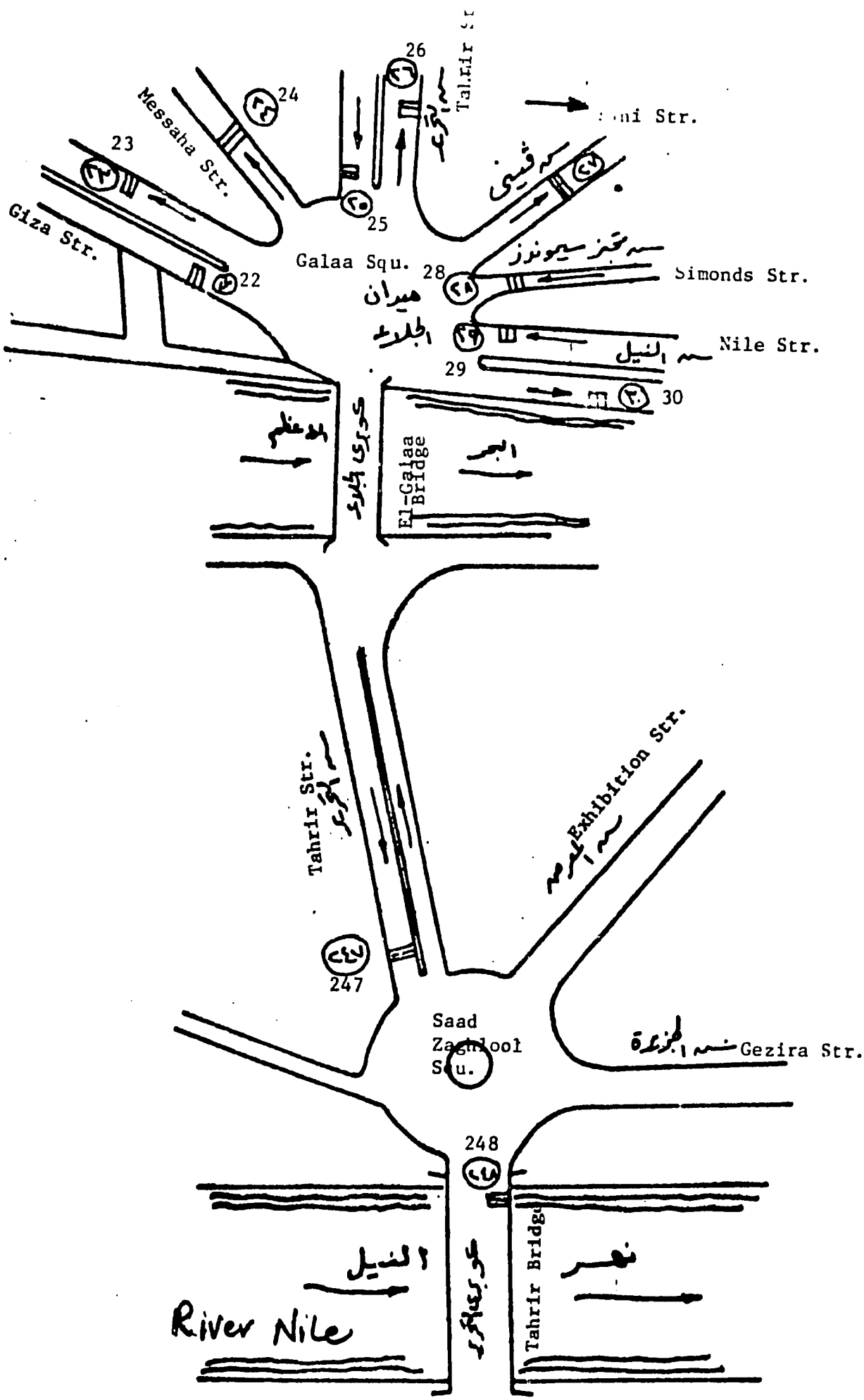


Figure shows station numbers (contd.)

Interzonal Flow Matrix (after expansion) between the Various Zones.

Station 3

O \ D	1	2	3	4	5	6
1	14	14		14		
2		27				
3						
4						
5	68	135		81		14
6	14			14		

Expansion Co-efficient = $\frac{331}{29}$ = 13.5

Station 4

O \ D	1	2	3	4	5	6
1	10		31	21	10	
2	42			10		
3						
4						
5	143	10	92	21	10	
6						

Expansion Co-efficient = 10.2

Station 5

O \ D	1	2	3	4	5	6
1	143	191		24		24
2		48				
3						24
4						
5	311	430	96	191	24	
6						

Expansion Co-ef.= $\frac{1507}{36}$ = 41.86

Station 6

O \ D	1	2	3	4	5	6
1			22	22	19	
2	108				324	
3	130				194	
4	86				108	
5	65	22				
6	22					

Expansion Co-ef. = 21.6

Station 7

O \ D	1	2	3	4	5	6
1	190	177	24	24	142	35
2	58	35			12	
3		35	12	23	12	24
4					12	
5	188	106		35	23	12
6						

Expansion Co-ef. = 11.9

Station 8

O \ D	1	2	3	4	5	6
1	135		51		17	
2	338		51		34	
3	51	17	17		17	
4	17					
5	85	34	51	17	17	
6	51					

Expansion Co-ef. = $\frac{1072}{59}$ = 16.9

Station 22

O \ D	1	2	3	4	5	6
1	35	87				
2	248	158	35		52	
3		280	18	18		18
4	385	315	18	52	158	315
5	18	35				
6						

Expansion Co-ef. = 17.5

Station 23

O \ D	1	2	3	4	5	6
1		29	29	19		
2		145		405	58	
3				29		
4	29	29		58		
5		29	87	58	29	
6				58		

Expansion Co-ef. = $\frac{1009}{29}$ = 28.9

Station 24

O \ D	1	2	3	4	5	6
1	9	17		9		
2		17				
3		9				
4						
5	9	26		52		
6						

Expansion Co-ef. = $\frac{179}{19}$ = 8.7

Station 25

O \ D	1	2	3	4	5	6
1						
2	1096	188	250		501	
3	31				31	
4	66			66	31	
5			31			
6						

Expansion Co-ef. = 31.3

Station 26

O \ D	1	2	3	4	5	6
1	6	36			3	
2	9	42	3	3	9	3
3	3	18				
4	3	3				
5	6	36			6	
6		6		3		

Expansion Co-ef. = 4.25

Station 27

O \ D	1	2	3	4	5	6
1	23	92				
2		138			23	
3		115				
4		23				
5		69		23	23	
6						

Expansion Co-ef. = 23

Station 28

O \ D	1	2	3	4	5	6
1		6				
2	56	25	19	67	16	3
3						
4	3	3	3			
5						
6	3		3			

Expansion Co-ef. = 3.1

Station 29

O \ D	1	2	3	4	5	6
1	48		48			
2	952		146	48	146	
3		48	48			
4	95					
5	48	95	48	48		
6	146		146			

Expansion Co-ef. = $\frac{2094}{44}$ = 47.6

Station 30

O \ D	1	2	3	4	5	6
1		49				33
2		147			33	
3		49		33		49
4		82				82
5						
6						

Expansion Co-ef. = 22.8

Station 36

O \ D	1	2	3	4	5	6
1	31	61				
2	245	612	153	153	61	
3		31	31			
4						
5	31	120		31		
6						

Expansion Co-ef. = $\frac{1498}{51}$ = 30.6

Station 37

O \ D	1	2	3	4	5	6
1		99				
2	7	52				
3		86		20		13
4		7				7
5		106	7	7		
6						

Expansion Co-ef. =6.6

Station 246

O \ D	1	2	3	4	5	6
1	22	215		43		
2		22				
3		194				22
4		22				
5	22	172		43		43
6						

Expansion Co-ef. $\frac{816}{38}$ = 21.5

Station 251

O \ D	1	2	3	4	5	6
1	187		94			
2	93		47			
3						
4						
5	796		374			
6	47		47		47	

Expansion Co-ef. = 46.8

Station 300

O \ D	1	2	3	4	5	6
1	34	34			106	
2	34				106	
3	137				239	34
4	68					
5	34					34
6					34	

Expansion Co-ef. = 34.2

جامعة القـــاهرة - معهـــد ماساتشوستس للتكنولوجيـــا

برنامج التخطيط التكنولوجى

CAIRO UNIVERSITY - MASSACHUSETTS INSTITUTE OF TECHNOLOGY

TECHNOLOGICAL PLANNING PROGRAM

CONFERENCE ON

TRANSPORTATION PLANNING POLICY

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III.8

ROAD NETWORK ANALYSIS

BY

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SUMMARY

This paper describes and documents an analytic model--the Road Investment Analysis Model--for use in evaluating alternative design, construction, and maintenance strategies on low volume roads at either the link or network level. The focus of the model is on project-level engineering decisions and their implications for total transport costs. The types of decisions which are within the scope of the model include the choice of alignment, geometric standard, surface type, maintenance policy, and construction and maintenance methods. The costs considered include total construction costs; labor, equipment, materials, overhead, and total maintenance costs; normal and generated traffic vehicle operating and travel time costs; and exogenous costs; all described in financial, economic, and foreign exchange terms. The model may be used at both the prefeasibility and feasibility stages of project evaluation, and has been structured so that it provides information useful in both budgetary and economic planning of low-volume roads, as well as the impacts of foreign exchange requirements and network configurations.

CHAPTER I. INTRODUCTION

While the concepts of project evaluation are fairly well understood and the techniques for their application well developed, the outcome of any one particular evaluation is still highly dependent upon, and often sensitive to, the degree of accuracy and oversimplification involved in assessing the various costs and benefits associated with the project, and even to the objectives of the project itself. Therefore, in preparing or evaluating proposals for low-volume roads, project analysts must address a variety of issues, foremost among them being to identify the objectives of the project and the extent to which these objectives are achieved by a specific proposal.

Among the objectives most frequently cited as justifying investments in low-volume roads are: (i) the provision of administrative and social services to isolated regions (national unity); (ii) access to areas with development potential (economic integration); (iii) increased transport capacity (economic expansion); and (iv) reduced transport costs (economic efficiency). A second area of concern to the analyst may be to evaluate the role of a particular link in the development and performance of the overall network; this type of analysis is of particular importance where a road will compete with other roads or other modes of transport--now or in the future. A third area of concern may be to fit the project into an overall development program, both in terms of the various financial and human resources which it will require, and in terms of its overall objectives. A fourth concern may be to study the impacts of the investment program on such broad social and political issues as migration of population; the elimination of poverty; provision of basic services in health care, education, and nutrition, etc.

The above issues constitute some of the broad range of topics which are generally considered in the planning and evaluation of low-volume road investments. Normally, they are considered in such a way that a variety of alternatives, together with their most relevant implications, are analyzed and presented to the ultimate decision-makers. This framework of issues spans a spectrum from the more or less detailed effects resulting from the construction of the road itself to the very broad social and economic changes resulting from the provision of basic access. At the technical extreme of this spectrum are the impacts arising from the actual construction and maintenance of the roads; the use of local construction materials and abundant

unskilled labor; and the establishment of local capabilities in construction skills and quality control, for example.

1.2 BACKGROUND

Within the above framework of issues there is an important subset which has generally been ignored by social and transportation planners, but which is of particular importance to road authorities--the selection of appropriate design and maintenance standards. While the choice of standards is sometimes obvious, as in the construction of an unimproved track to provide basic access to an isolated and undeveloped region, there appears to be a broad range of projects where planners provide little or no guidance, and for which the choice of engineering standards has important budgetary and economic implications.

For example, in deciding whether to improve an existing gravel road in order to reduce vehicle operating costs, planners may compare the costs of using and maintaining the existing road against the costs and benefits of constructing, maintaining, and using the new paved road. If the economic return from paving the road is high enough, the project will be recommended.

At a more detailed level, however, the road authority may be interested in the following issues: Should the road be surface-treated or paved with asphalt-concrete? What should be the thickness of the base, subbase, and surface courses, and what types of materials should be used? How long will the road last before improvements are required, and what will be the nature of these improvements? Can the life of the road be extended through improved maintenance? Each of the possible alternatives implies a different stream of construction and maintenance expenditures, and a different salvage value for the road at some specified future date. In addition, if the project is to be financed externally the different alternatives may result in a different allocation of costs between the road authority and the lending agency. Similarly, if the road is allowed to deteriorate, there will be a shift in costs from the road authority (if deterioration is the result of low maintenance) or the lending agency (if deterioration is the result of an initial low design standard) to the road users. The extent of this shift will depend on how well the pavement was designed originally, and on the specified level of maintenance; the costs involved may, however, vary over a considerable range.

Tradeoffs similar to those described above may exist on other types of projects. For example, within new road construction it may be possible to vary geometric standards within a relatively broad range to achieve different tradeoffs between initial construction expense and the future costs of using the road. Each time a low standard is considered, the designer is effectively shifting costs from the road authority to transporters, and, through increased tariffs, to the public. At some point there should be an overall minimum--but whether or not this is the standard which is actually selected will depend upon whether there are sufficient available funds for construction and, more generally, upon the manner in which government decision-makers choose to allocate costs between different parties in order to achieve social objectives.

Unfortunately, the practical difficulties of undertaking the above types of analysis on a comprehensive, project-by-project basis are enormous. Until recently, relatively little has been known about the relationship between design and maintenace standards, or their implications for maintenance and user costs. And while considerable attention has been focused on the problem of estimating construction costs, the resulting methods have been either simple and inaccurate, or overly detailed. In short, there hasn't been any practical way of analyzing a large number of engineering alternatives, or of accurately assessing their implications.

In summary, there appears to be a broad range of projects for which engineering solutions will have different implications for the timing and magnitude of project costs and benefits, and for the allocation of these costs and benefits among different groups--including the road authority, lending agencies, transporters, and the population of the region to be served by the road. Unfortunately, road authorities have had relatively little guidance in, and have lacked the analytic methods for, making rational choices between different engineering possibilities. One of the major objectives in developing the Road Investment Analysis Model is to provide a sound basis for making these choices.

Network Evaluation

There is another important subject within the overall spectrum of issues which has generally been ignored by planners but which is of particular interest to road authorities--investment in the development and upgrading of a low-volume road network, either through new network components, upgrading or reconstructing parts of existing network links, or maintaining existing and future facilities. Since changes in one part of a network modify the costs and benefits not only of the modified component or link, but also the economics of the network as a whole, decisions on investment alternatives should be based on an evaluation of the integrated operation of the entire network.

This is a rather complex problem, usually solved on a highly simplified basis in a manner which automatically generates an "optimal" solution. Such an approach does not provide the planners with sufficient technical data and alternatives for the integration of social and political factors with the economic forecasts. In addition, since it does not utilize the accuracy and detail which exist in a variety of evaluation tools useful for comparing investment alternatives for a single link, it does not provide the road authority with sufficient engineering and resource consumption data necessary for evaluation of various district design standards or maintenance policies.

For example, in deciding which of several proposed network investment alternatives should be implemented, planners may compare the costs of using and maintaining the existing road system against the costs and benefits of constructing, maintaining, and using each of the proposed alternatives. If an optimization approach is used, only that alternative with the maximal value is determined, even though other alternatives may be extremely close to the maximum value and rank higher in non-quantifiable values such as regional distribution, provision of new access, or distribution of costs among the various parties involved. So an evaluation or ranking methodology is required bore so than an optimization methodology.

At a more detailed level, the road authority may be interested in the following issues: Do the proposed alternatives predict realistic maintenance requirements for the system? Is there any radical change in the traffic flow pattern which would require modifications to the proposed maintenance

standards? Do the road investments last for their design lifetimes? Is the maintenance requirements pattern consistent with existing district organization, resources, and standards? Are sufficient material resources available at the indicated prices, or will scarcities arise? Each of the possible alternatives will have different implications for appropriate maintenance standards and organization, and, hence, for future maintenance financing, whether internal or external.

Tradeoffs similar to those described above may exist in conjunction with the timing or scaling of the proposed projects, or with the resultant traffic flow patterns. For example, a construction program which would tend to keep the link volumes in much the same ratios as the relative link structural numbers should result in the most uniform deterioration pattern, and hence be the most predictable in terms of maintenance requirements and schedulings.

1.2 ANALYTIC FRAMEWORK

The basic function of the Model is to estimate construction, maintenance, exogenous, and user costs for a system of roads which are to be designed, constructed and maintained to specific standards, and subject to known traffic demands and ancillary investments. This is done by simulating the life of each road from initial construction, through periodic upgrading, and through the annual cycle of use, deterioration, and maintenance. The basic structure of the Model is shown in Figure 1-1.

The simulation is accomplished by determining construction and maintenance activities to be performed, and by estimating road conditions, traffic volumes, ancillary investments, and all associated costs on a year-by-year basis throughout the analysis period. The specific operations undertaken in each year are as follows:

A construction submodel schedules projects, allocates a percentage of construction costs to the current year, and updates the status of the link and activates generated traffic and/or exogenous cost/benefits (if any) as projects are completed. The various types of construction projects which may be undertaken include new construction, overlaying, pavement reconstruction, widening, widening and reconstruction, realignment, and removal from service.

Figure 1-1

DATA REQUIREMENTS

National or Regional Parameters

Design Standards
- Geometric standards
- Pavement sections
- Material characteristics

Maintenance Standards
- Routine Maintenance Criteria for Earth Gravel and Paved Roads
- Resurfacing Criteria

Highway Program Parameters

Construction Unit Costs
Maintenance Unit Costs
Basic Vehicle Ownership and Operating Costs

Project Parameters

Traffic
Exogenous Costs/Benefits
Physical Characteristics of the Alignment
Specific Design and Maintenance Standards to be Studied
Schedule for Implementation

SIMULATION OF A LINK-ALTERNATIVE

For each year in analysis period:

↓

Estimate costs for road construction or upgrading based on design standards and construction unit costs

↓

Update the status of the road based on project completions

↓

Assign this year's traffic

↓

Assign this year's exogenous costs/benefits

↓

Estimate road deterioration, effects of maintenance, costs, and average surface conditions

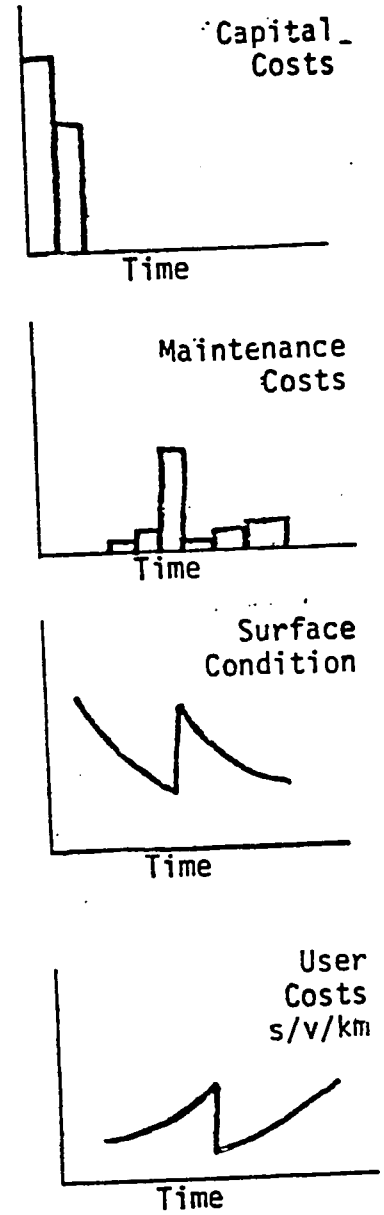
↓

Estimate user costs based on geometric standards, surface type and surface condition

↓

Store results for evaluation phase

RESULTS



Updating of the road includes the opening of sections to traffic and the abandonment of older sections. All costs are input by the User, in financial, economic, and foreign exchange terms.

A road deterioration and maintenance submodel estimates the average and final surface conditions for the year as a function of the initial design standard, last year's surface conditions, the volume and composition of the traffic during the current year, the local environment, and the specified maintenance policy. Surface deterioration may be estimated for both paved and unpaved roads. A range of typical maintenance activities may be specified for each surface type on either a scheduled or demand responsive basis; these are priced in financial, economic, and foreign exchange terms according to the amount of maintenance which is actually performed. The condition of the road is expressed in terms of roughness and rut depth (all roads), cracking and patching (paved roads), and looseness and moisture content (unpaved roads).

A User cost submodel estimates the costs of operating vehicles over each road as a function of surface type and condition, environment, design geometrics (grade, curvature, and width), and vehicle characteristics. The components of vehicle operating costs include running costs (fuel, oil, tires, maintenance parts, and maintenance labor), annual fixed costs (depreciation, interest, crew costs, and overhead costs), and travel time costs (passenger time and cargo holding costs). Cost estimates are prepared for a fleet of vehicles representative of those which will actually be using the road, by vehicle type, in financial, economic, and foreign exchange terms.

A traffic submodel estimates the current year's traffic volumes based on the previous year's traffic and the anticipated growth, by vehicle type, for both normal and generated traffic. If the network option is used, the origin-destination demands are assigned to the system using a stochastic user-equilibrium approach. Both the actual and perceived costs of travel are then recorded in financial terms, to measure the consumer surplus of the system.

An exogenous costs benefits submodel estimates the current year's exogenous net costs based on the previous year's costs and benefits and anticipated growth, in financial, economic, and foreign exchange terms.

The results of the simulation include a record of the expenditures incurred by the Highway Authority for capital improvements and maintenance; a record of the costs incurred by road users, both normal and generated; a detailed history of the status and deterioration of each road; and a history of the traffic volumes and ancillary investments. All estimates, other than construction and ancillary investments, are made in terms of physical quantities, from which total costs are obtained by applying the appropriate unit rates. The Model is therefore not dependent on the use of a particular monetary system, nor is it affected by changes in relative prices. All costs are estimated in financial, economic, and foreign exchange terms.

The User cost relationships are based on the TRRL results from Kenya (1) and reflect free flowing conditions, driver behavior, and the types of vehicles typical of East Africa. These relationships do not include the effects of congestion or of non-motorized traffic on vehicle operations, nor do they incorporate the traffic interaction effects of single lane roads. In addition, the results are applicable for gravel and paved roads only.

The paved road deterioration and maintenance relationships are based on the AASHO road tests (2) and on the results of the TRRL studies in Kenya (3). As such, their direct applicability is limited to high standard asphalt concrete roads (modified structural number greater than 3.0) and to bituminous treated, cement stabilized base roads (modified structural numbers between 2.5 and 4.0) which are subject to a limited range of traffic conditions and maintenance policies. The gravel road relationships are based on the TRRL results, and are limited in applicability to relatively well-constructed gravel roads.

While the Model can be used outside the range of conditions described above, results which are obtained in these situations should be critically evaluated and used with caution.

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(1) Hide, H., et al. The Kenya Road Transport Cost Model: Research on Vehicle Operating Costs. Department of the Environment, TRRL Report LR672, Crowthorne, 1975 (Transport and Road Research Laboratory).

(2) American Association of State Highway and Transportation Officials, "AASHTO Interim Guide For Design of Pavement Structures," Washington, D.C., 1972.

(3) Hodges, J.W., et al. The Kenya Road Transport Cost Study: Research on Road Deterioration. Department of the Environment, TRRL Report LR673. Crowthorne, 1975 (Transport and Road Research Laboratory).

CHAPTER 2. ROAD CONSTRUCTION

The key functions of the construction submodel are to allocate construction costs by cost component (financial, economic, and foreign exchange) on a year-by-year basis over the duration of the project, to modify the physical characteristics of the link as projects are completed, and to activate generated traffic and generated exogenous costs/benefits sets to the link (if any) as projects are completed. Key features of the model are as follows:

Projects may be scheduled for any year in the analysis period, and may consist of new construction, pavement reconstruction, widening, and so on. Projects may also be scheduled sequentially, as in staging; that is, a link may be constructed to a low standard initially, followed at a future date by pavement reconstruction, widening, realignment, or some other form of upgrading. Each project may affect any or all sections of the link, each having its own physical characteristics and design standards.

Construction costs are input by the User in financial, economic, and foreign exchange terms, along with salvage values, and the time distribution of these costs over the project duration.

Generated traffic sets and/or generated exogenous costs/benefits sets are activated and assigned to the link upon completion of the project, if any have been defined by the User as generated by this project.

2.1 DATA REQUIREMENTS

The data requirements of the road construction submodel consist of the cost of the project, in financial, economic, and foreign exchange terms; the distribution of costs over the project duration; its salvage values; and the type of improvement and physical characteristics of the alignment, on a section by section basis. The projects considered range from new construction to various forms of road improvement, with data requirements summarized in Table 2-1.

2.2 DESCRIPTION OF THE SUBMODEL

The construction submodel operates on all projects in one of three ways, depending upon the project status in the current year. The three status conditions which any project may experience in any year are: (a) not active

TABLE 2-1

DATA REQUIREMENTS FOR VARIOUS TYPES OF IMPROVEMENTS

Data Item	New Construction	Overlay	Pavement Reconstruction	Widen	Widen and Reconstruct	Realignment	Remove From Service
Location							
Length	X					X	
Start Station	X					X	
End station	X					X	
Subgrade CBR	X					X	
Geometry							
Rise	X					X	
Fall	X					X	
Curvature	X					X	
Width	X			X	X	X	
Surfacing							
Surface type	X	X	X		X	X	
Surface thickness	X	X	X		X	X	
Shoulder type	X	X	X		X	X	
Shoulder thickness	X	X	X		X	X	
Structural number	X	X	X		X	X	
Deterioration type	X	X	X		X	X	
Condition							
Serviceability	X	X	X	X	X	X	
Roughness	X	X	X	X	X	X	

(either not yet scheduled or already completed); (b) ongoing, or (c) opening to traffic.

Inactive projects are ignored by the model in the current year. Ongoing projects, but projects not opening to traffic in this year, are processed to determine the costs incurred during the current year, by cost component (financial, economic, and foreign exchange). Salvage values are also computed, by cost component, for use in the last year of the economic analysis period. The costs for this project are added to the totals for the link being analyzed, by cost type. Projects opening to traffic in the current year cause the physical characteristics of the affected link to be modified to reflect the completed construction activities. The modifications made to the link are dependent upon the type of construction which has occurred.

For sections where the pavement structure is being modified (those experiencing new construction, overlay, reconstruction, widening and reconstruction, or realignment) the following data items are modified: pavement name, carriageway type, carriageway thickness, shoulder type, shoulder thickness, structural number, serviceability, roughness, and deterioration model type. In addition, the pavement age, axle history, cracking, and patching are set to zero.

For sections where the pavement cross-section is being modified (all types except overlay and reconstruction) the carriageway and shoulder widths are modified.

For sections where the alignment is being modified (new construction or realignment) the following data items are modified: start chainage, end chainage, geometric standard, length, rise, fall, curvature, and subgrade CBR.

For sections which are being removed from service, the section status is modified to "inactive."

In addition, if the project is to generate any traffic and/or exogenous cost/benefit sets, then the status of these sets is modified to active in the current year.

CHAPTER 3. ROAD DETERIORATION AND MAINTENANCE

The maintenance-deterioration model computes two types of information essential to the successful operation of the total cost model: maintenance resources and costs and the condition of road surface. These are computed for each link under each alternative for each year of the planning horizon. The maintenance cost is added directly to the total highway cost, while the condition of the road surface is used as an input to the user cost submodel for estimating road user costs. Thus, the surface condition predicted by the maintenance mode affects the total highway cost indirectly, but very importantly, through its effect on road user costs.

The four basic types of variables that affect the maintenance cost and surfact condition are: the environment, the traffic demand, the characteristic of the constructed highway, and the proposed maintenance standards and unit costs. The exact nature of a set of inputs needed to adequately describe each situation will depend upon the type of design under construction. A gravel road, for instance, will require a different set of parameters to define maintenance policy than a paved road.

Output from the maintenance submodel is of the same form regardless of the design. Maintenance costs are originally computed as the quantities of labor, equipment, and materials required. These are converted to monetary costs based on the applicable factor prices. The costs predicted by this submodel are for actual maintenance activities, plus supervision and overhead, in financial, economic, and foreign exchange terms. The results may be expressed either as a discounted economic summary of the analysis period on a link-alternative basis, providing the total discounted expenditure and resources consumed by each maintenance activity, along with the percentage breakdown in terms of labor, equipment, materials, and overhead; or as an annual undiscounted economic summary of a requested link for a requested year on a section-by-section basis, providing physical quantities performed and total economic and foreign exchange costs.

Roadway surface condition is computed by the maintenance submodel, and described in terms of roughness and rut depth (all roads), patching (paved roads only), and surface looseness depth (unpaved roads only). Also provided are the modified structural number of the section and the years since major

maintenance was last performed. The surface condition parameters are computed for two subdivision or seasons of each year: the dry season (when earth and gravel roads are dusty) and the wet season. These parameters are used within the user cost submodel, along with curvature, grade, etc., to compute road user costs for each year.

3.1 DESCRIPTION OF THE SUBMODEL

Maintenance-deterioration estmates are made for the following categories of maintenance activities: paved surface maintenance; unpaved surface maintenance; and other maintenance, which includes shoulder maintenance, drainage maintenance, and vegetation control. The emphasis in this discussion is placed on the problem of surface maintenance. This emphasis coincides with the distribution of costs for maintaining low-volume roads, as surface maintenance is usually responsible for over half of the maintenance cost and in some extreme cases can account for practically all of the expenditures. A second reason for concentrating on surface maintenance is the obvious tradeoff potential with construction and user costs. Other types of maintenance also provide the opportunity for tradeoff, but usually involve smaller amounts of resources.

3.11 Paved Roads Surface Deterioration

The deterioration of paved roads is handled in one of two ways, depending upon whether the base is flexible or stabilized. For flexible pavements with granular bases, the general AASHO Road Test (1) results are used, with some modifications. For flexible pavements with stabilized bases, the TRRL Kenya (2) results are used. In either case, the traffic composition is converted into standard equivalent single axle loads of 18,000 lbs. (8,200 kg). The equations used in the RIAM are those suggested by the TRRL Kenya work (2,3).

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(1) Highway Research Board, "The AASHO Road Test," Special Report 61E, Publication No. 954, Washington, D.C., National Research Coundil, 1962.

(2) Robinson, R., et al. A road transport investment model for developing countries. Department of Environment TRRL Report LR 674, Corwthorne, 1975, (Transport and Road Research Laboratory).

(3) Hodges, J.W., et al. The Kenya Road Transport Cost Studies research on road deterioration. Department of the Environment, TRRL Report LR 673, Crowthorne, 1975, (Transport and Road Research Laboratory).

Modified Structural Number

In the analysis of pavement performance a convenient index of pavement strength is needed. This index must satisfy the condition that two pavements of the same type having the same index will perform identically. The concept of structural number developed during the AASHO Road Test satisfies this requirement, provided that the strength of the subgrade, the impact of the environment, and the drainage characteristics of the base and sub-base are incorporated, establishing a moddified structural number. The structural number of a pavement is defined by an empirical linear relationship in which the thickness and strength of each pavement layer are combined together as follows:

$$SN = \sum_{i=1}^{n} a_i D_i \qquad (3\text{-}1)$$

where a_i is the strength coefficient of the ith layer
D_i is the thickness of the ith layer, in inches.

The most satisfactory way of taking into account the strength of the subgrade, the environmental impact, and the drainage characteristics of the base and subbase is to modify the structural number of the pavement so that it is equal to the structural number of a road of the same type which behaves in the same way, but which was built in a standard environment on a standard subgrade with standard drainage characteristics. This has been done in one of two ways, depending upon whether the base is flexible or stabilized.

The TRRL Kenya study of road deterioration (1) assumed Kenya to be the standard environment and standard subgrade, including only the effect of subgrade strength in the modification of structural number, producing the following relation:

$$\overline{SN} = SN + 3.51 \, Log_{10}CBR - 0.85(Log_{10}CBR)^2 - 1.43 \qquad (3\text{-}2)$$

where $\overline{SN}$ is the modified structural number,
SN is the structural number of the pavement and
CBR is the California Bearing Ratio of the subgrade

(1) Ibid.

To allow direct comparisons with the AASHO Road Test, the most convenient standards to use are the AASHO conditions themselves, (1) producing the following equation for the modified structural number of granular base pavements:

$$(1 + \overline{SN}) = (1 + SN) * (REGFAC)^{-0.10684} \left(\frac{CBR}{CBR_0}\right)^{0.14744} \qquad (3\text{-}3)$$

where: REGFAC is the regional-and-drainage factor

CBR_0 is the CBR of the AASHO subgrade (=2.69)

and the other parameters are as in Equation (3-2).

A higher regional-and-drainage factor indicates a weaker effective pavement. The values of REGFAC range from 0.1 in a frozen subgrade condition to 5.0 in a saturated subgrade condition.

Deterioration of Flexible Pavements With Granular Base

Paved surface performance for roads with granular bases is analyzed in the submodel by a routine which simulates the cycle of deterioration and repair. Deterioration is predicted as a function of equivalent axle loads and modified structural number. The equations used to predict this deterioration are of the form of the general AASHO equation as presented in the "Interim Guide." (2) Deterioration is initially predicted in terms of AASHO concept of serviceability --PSI. This serviceability measure is related to three measurable characteristics of the surface: slope variance (SV), rut depth (RD), and the amount of cracking and patching (CP) by the equation (3):

$$PSI = 5.03 - 1.91 \, Log_{10}(1 + SV) - 0.01 \sqrt{10CP} - 1.38 \, RD^2 \qquad (3\text{-}4)$$

Deterioration is predicted as a drop in AASHO servicability, PSI, for each year of the analysis period. The equation for estimating deterioration is the general AASHO equation: (illustrated in Figure 3-1).

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(1) American Association of State Highway and Transportation Officials, "AASHTO Interim Guide for Design of Pavement Structures," Washington, D.C., 1972.

(2) Ibid.

(3) Carey, W.N. Jr., and Irick, P.E., "Performance of Flexible Pavements in the AASHO Road Test," International Conference on the structural Design of Asphalt Pavement, Proceedings, University of Michigan, 1962.

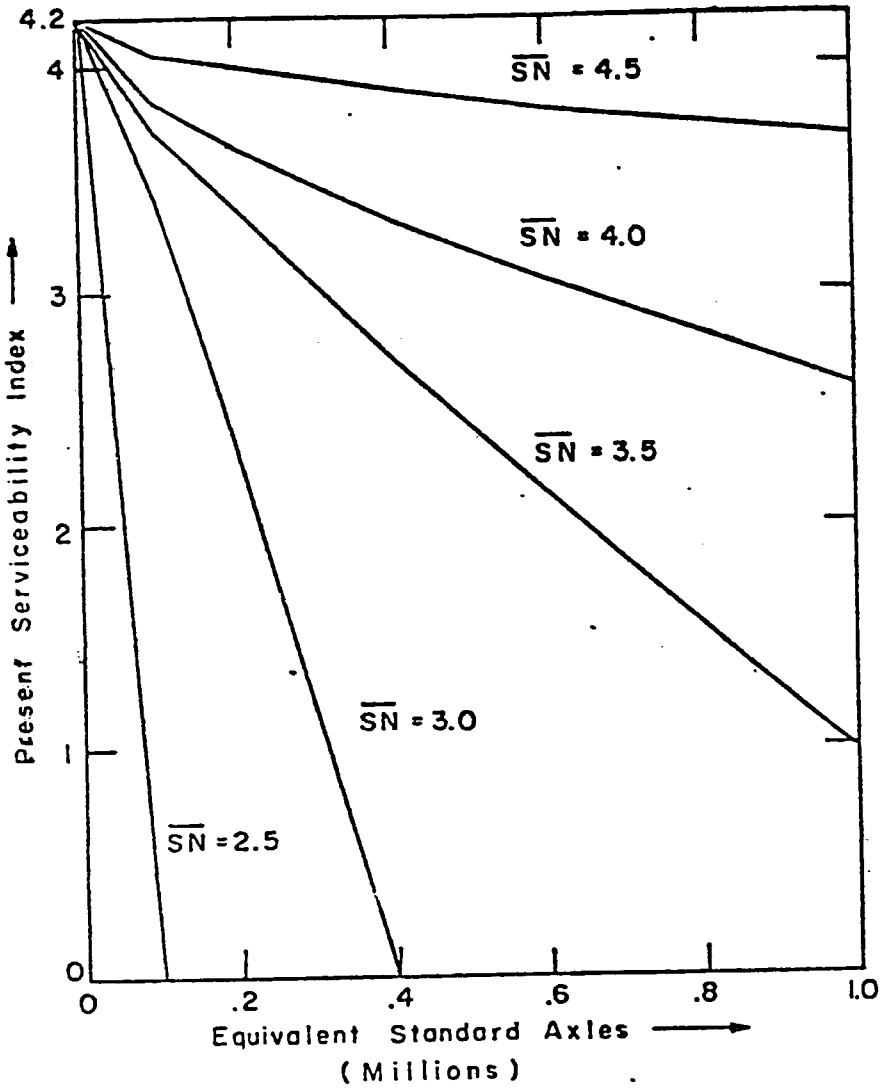

Figure 3-1 AASHO Serviceability Equation

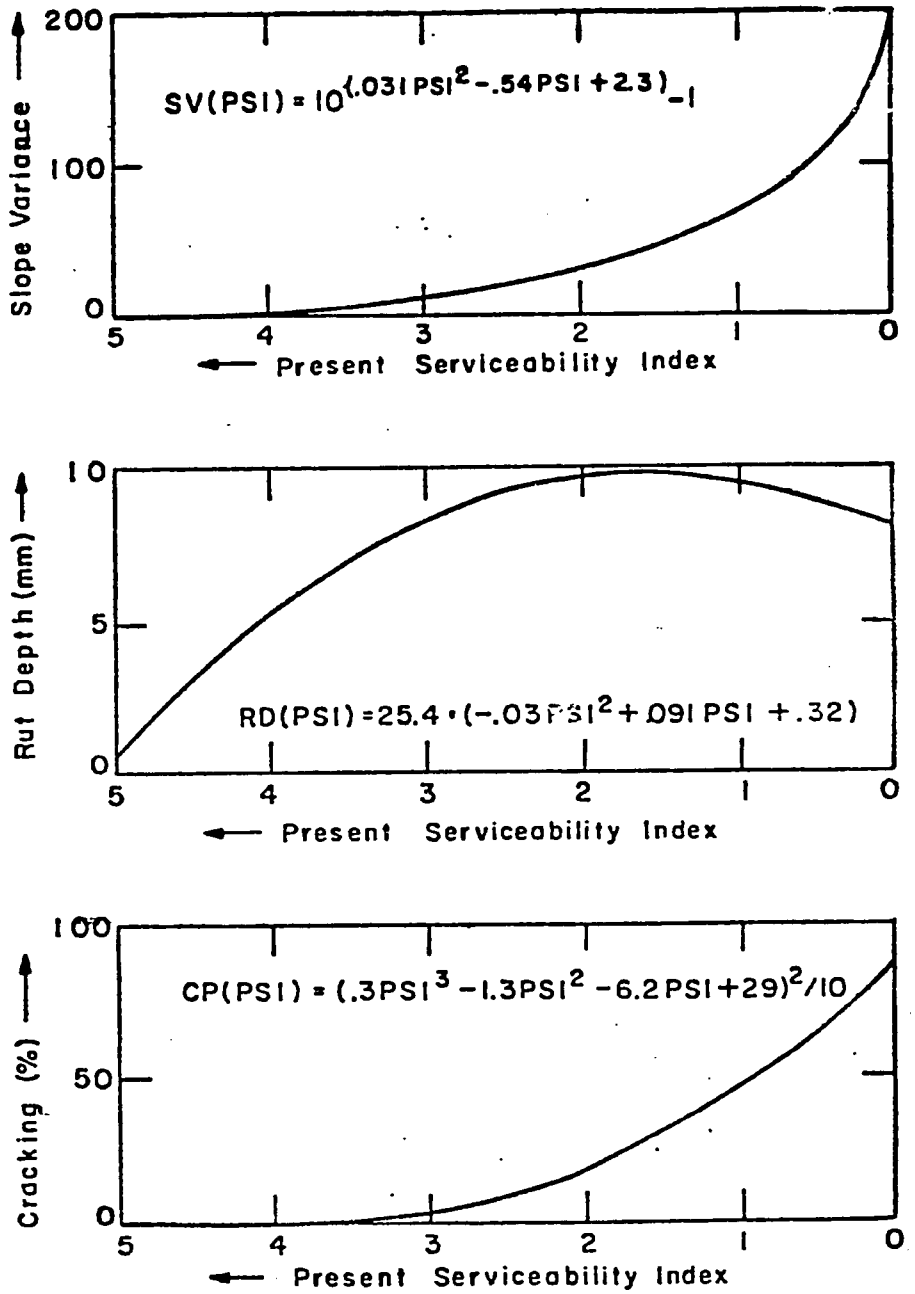

Figure 3-2 Damage Indicators vs. Serviceability

$$PSI(V,\overline{SN}) = 4.2 - 2.7(1.58V(1 + \overline{SN})^{-9.36})^{exponent} \quad (3\text{-}5)$$

where exponent = $0.40 + 1094(1 + \overline{SN})^{-5.19}$

V is the cumulative volume of equivalent standard axles

$\overline{SN}$ is the modified structural number

From this, the deterioration caused by an equivalent traffic volume of ΔV ensuing after a previous total equivalent volume of V would be

$$PSI(V,\Delta V, \overline{SN}) = PSI(V,\overline{SN}) - PSI(V + \Delta V,\overline{SN}) \quad (3\text{-}6)$$

in which PSI is the deterioration due solely to the equivalent traffic volume ΔV.

Using this new level of serviceability, the degree of deterioration measured in terms of slope variance (SV), rut depth (RD), and amount of cracking and patching (CP) is found using the relationships (1) which are illustrated in Figure 3-2. The roughness of the road is calculated from the slope variance, assuming a normal distribution of the slopes to yield (2):

$$ROUGH(mm/km) = 636.62\sqrt{SV} \quad (3\text{-}7)$$

Deterioration of Flexible Pavements with Stabilized Bases

The deterioration of pavements with stabilized bases is based on the TRRL Kenya research on road deterioration (3), with little additional information being available. All the deterioration relationships included in this model are in the form of polynomial equations relating a surface condition variable to traffic loading for a range of modified structural numbers, which were further regressed in terms of the modified structural number.

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(1) Alexander, J.A., "An Approach for Integrating Highway Maintenance into the Design Process," Unpublished PhD dissertation, Massachusetts Institute of Technology, August, 1970.

(2) Moavenzadeh, F., et al. The Highway Cost Model: General Framework. Technology Adaptation Program Report Number 75-4, Massachusetts Institute of Technology, Cambridge, Ma., September, 1975.

(3) Hodges, J.W., et al. The Kenya Road Transport Cost Study: research on road deterioration. Department of the Environment, TRRL Report LR 673, Crowthorne, 1975, (Transport and Road Research Laboratory).

Roughness. The relationships used are derived from the Kenya data in conjunction with Road Note 31 (1). They are illustrated in Figure 3-3 and given below.

$$\begin{aligned} \overline{SN} \leq 2.5 \quad & R = R_o + 320N \\ \overline{SN} = 3.0 \quad & R = R_o + 483N \\ \overline{SN} = 3.5 \quad & R = R_o + 159N \\ \overline{SN} \geq 4.0 \quad & R = R_o + 119N \end{aligned} \qquad (3\text{-}8)$$

In these equations

- R is the roughness measured in mm/km by a fifth-wheel bump integrator towed at 30km/hr;
- R_o is the roughness when the road was new;
- N is the total cumulative traffic loading in millions of equivalent (8200 kg) standard axles per lane

The above equations were further regressed over structural number to yield:

$$R = R_o + 1250N/[10^{a^{1/3} - b^{1/3} - 1.3841}] \qquad (3\text{-}9)$$

where $a = \sqrt{0.20209 + 23.1318C^2} - 4.8096C$,

$b = \sqrt{0.20209 + 23.1318C^2} + 4.8096C$, and

$c = 2.1989 - \overline{SN}$

which is valid for $\overline{SN} > 2.2$

Rut Depth. The maximum mean rut depth measured on any of the test sections in Kenya was about 8mm, and the majority of measurements were between 3mm and 5mm regardless of traffic (2). The maximum mean rut depth which is

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(1) Transport and Road Research Laboratory, A guide to the structural design of bitumen-surfaced road in tropical and sub-tropical countries. Proposed revision of Road Note 31, Crowthorne, 1974 (unpublished).

(2) Hodges, J.W., et al. The Kenya Road Transport Cost Study: research on road deterioration. Department of the Environment, TRRL Report LR 673, Crowthorne, 1975, (Transport and Road Research Laboratory).

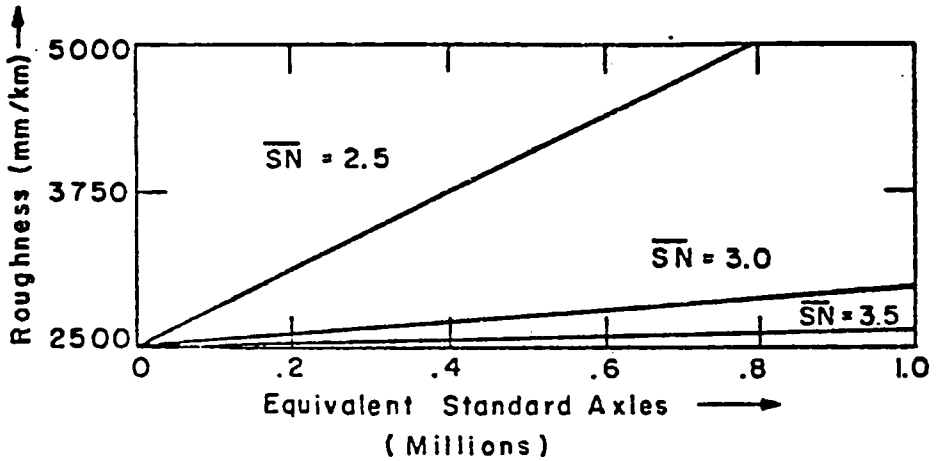

Figure 3-3 TRRL Roughness Relation

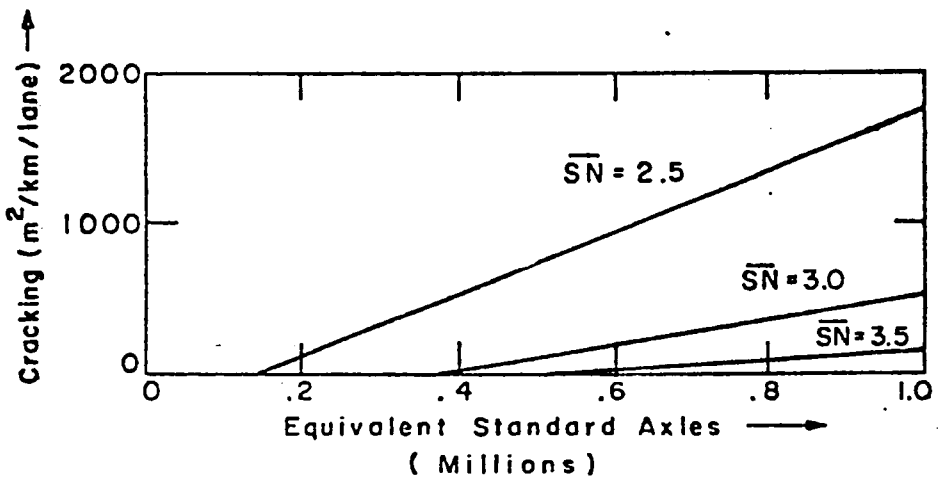

Figure 3-4 TRRL Cracking Relation

TABLE 3-1

Maintenance activities and units

Unpaved Road Sections	
Dry Season Grading	kilometers
Wet Season Grading	kilometers
Spot Regravelling	cubic meters
Gravel Resurfacing	cubic meters
Miscellaneous routine maintenance	kilometers
Paved Road Sections	
Patching	square meters
Surface Dressing	square meters
Overlaying	cubic meters
Rehabilitation	kilometers
Miscellaneous routine maintenance	kilometers

tolerable before reconstruction becomes necessary is usually about 20mm for this type of pavement; therefore, it is unlikely that failure will occur through excessive rutting. Rut depth was also shown to have no measurable effect on vehicle operating costs, and therefore rut depth relationships have not been included in the model for this type of pavement.

Cracking. The estimation of pavement cracking is necessary to determine the maintenance requirement of a road. Two aspects of cracking must be predicted, namely the mean level of cracking in the wheeltracks and the total pavement area where severe local cracking occurs. The traffic loadings which were necessary to produce mean levels of cracking of $1m/m^2$ and $3m/m^2$ on the test sections in Kenya have been regressed (1) to yield:

$$\overline{SN} < 4.0 \qquad CP = 300\,\overline{SN} - 1200 + \frac{21600N}{(\overline{SN})^{\overline{SN}}} \qquad (3\text{-}10)$$

$$\overline{SN} \geq 4.0 \qquad CP = \frac{21600N}{(\overline{SN})^{\overline{SN}}}$$

where CP is the total area of cracking plus patching per km in one traffic lane. These results are illustrated in Figure 3-4.

Deterioration of Other Types of Paved Roads

Relationships for other types of pavements may be included in the model when further research has been carried out; but, in the meantime, it is assumed that either paved deterioration option used will predict similar types of deterioration, especially when compared with earth and gravel roads. However, care must be used in determining a realistic regional-and-drainage factor for the AASHO-based relationships when applying them to tropical and sub-tropical situations.

Paved Surface Maintenance. Maintenance activities are the same for flexible pavements, regardless of base type, although the component costs may vary depending on surface type. The maintenance activities included in the model for paved surface are: patching, surface dressing, overlaying, rehabilitation, and miscellaneous.

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(1) Robinson, R., et al. A road transport investment model for developing countries. Department of Environment TRRL Report LR 674, Crowthorne, 1975, (Transport and Road Research Laboratory).

Sealing cracks and filling ruts have not been included in the model as maintenance options because, although used occasionally to rectify premature pavement failures, the techniques are not in general use for routine maintenance. Excessive cracking is best dealt with by the application of a surface dressing, and excessive rut depth, being indicative of pavement fatigue, by an overlay.

The amount of maintenance work to be done during the year is determined by the deterioration parameters and the specified maintenance policy. Table 3-1 gives a review of the maintenance activities and their units which are included in the model.

3.13 Deterioration of Unpaved Roads

There are many combinations of construction materials which are used frequently in highway construction, but which were not studied in the AASHO Road Test or by TRRL in Kenya. As it is not practical to incorporate a large number of deterioration relationships into a computer model, it is the responsibility of the Model User to choose that set of relationships described below which most closely approximates the design under study.

Most of the deterioration relationships for unpaved roads were derived from the Kenya field data reported by TRRL (1). Traffic volumes were measured in terms of the total number of vehicles using the road since grading, so that no equivalence factors are employed in this part of the Model. Also, pavement strength, the essential feature of the paved road deterioration relationships, cannot be used as an index for unpaved roads, as material is constantly being lost from the surface. The roads have therefore been broadly classified according to gravel type or earth type as described below.

Deterioration of Gravel Roads

The essential requirement of gravel roads is that they be properly engineered with adequate drainage. The deterioration rates used in the Model will certainly not apply if these conditions are not met. It is assumed that gravel roads are passable during the whole year, and all deterioration is measured from the last blading.

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(1) Hodges, J.W., et al. The Kenya Road Transport Cost Study: research on road deterioration. Department of the Environment, TRRL Report LR 673, Crowthorne, 1975, (Transport and Road Research Laboratory).

Surface Roughness. Traffic volumes and gravel type were found to be the most important determinants of surface roughness (1). The two relationships used within the Model to predict surface roughness are illustrated in Figure 3-5.

Rutting. Traffic volume and gravel type were again found to be the most important variables determining rutting. The relationships used within the Model to predict rutting are illustrated in Figure 3-6.

Surface Looseness. Two relationships from the Kenya data have been incorporated into the Model and are illustrated in Figure 3-7. The Model uses the above information to calculate the mean looseness between each grading.

Gravel Loss. The quantity of gravel lost from the pavement surface depends on annual rainfall, traffic volume, traffic speed, gravel type, and road geometry. It was not possible for the TRRL Kenya study to quantify the effects of traffic speed, but they produced a single equation relating the other variables (2), illustrated in Figure 3-8, which has been incorporated within the Model:

$$GL_A = F(\text{gravel type})(4.2 + 3.5\ RL^2 + 0.094\ (RS + F) + 0.092T_A)T_A^2/(50 + T_A^2) \qquad (3\text{-}11)$$

where GL_A is the annual gravel loss, in mm

RL is the annual rainfall, in meters

RS is the road rise, in m/km

F is the road fall, in m/km

T_A is the annual traffic volume in both directions, in thousands of vehicles

F is the function of gravel type, and has the value of 0.94 for lateritic gravels, 1.1 for quartzitic gravels, 0.7 for volcanic gravels, and 1.5 for coral gravels.

TRRL also concluded that the frequency of grading had no noticeable effect on annual gravel loss.

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(1) Ibid.

(2) Ibid.

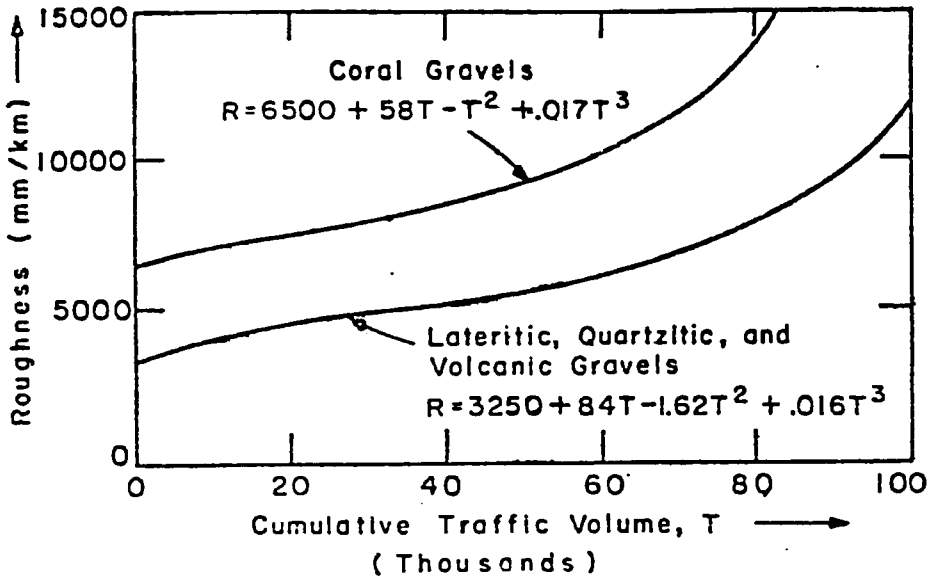

Figure 3-5 Gravel Roughness

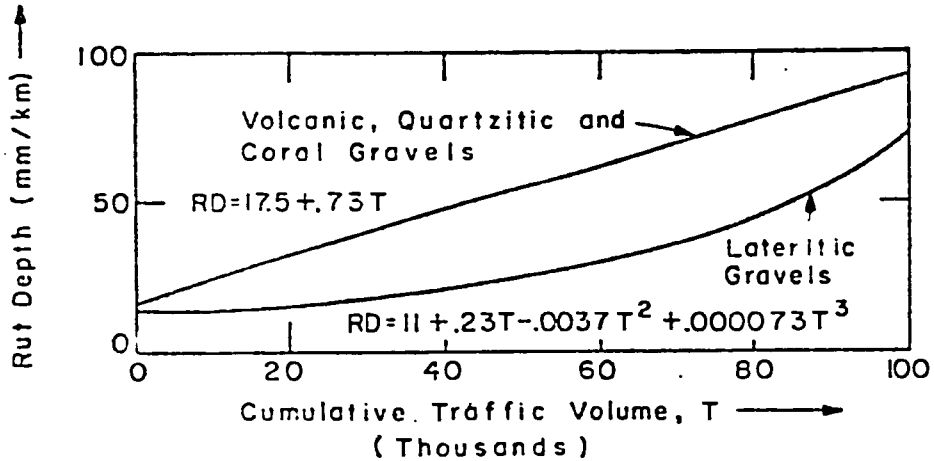

Figure 3-6 Gravel Rut Depth

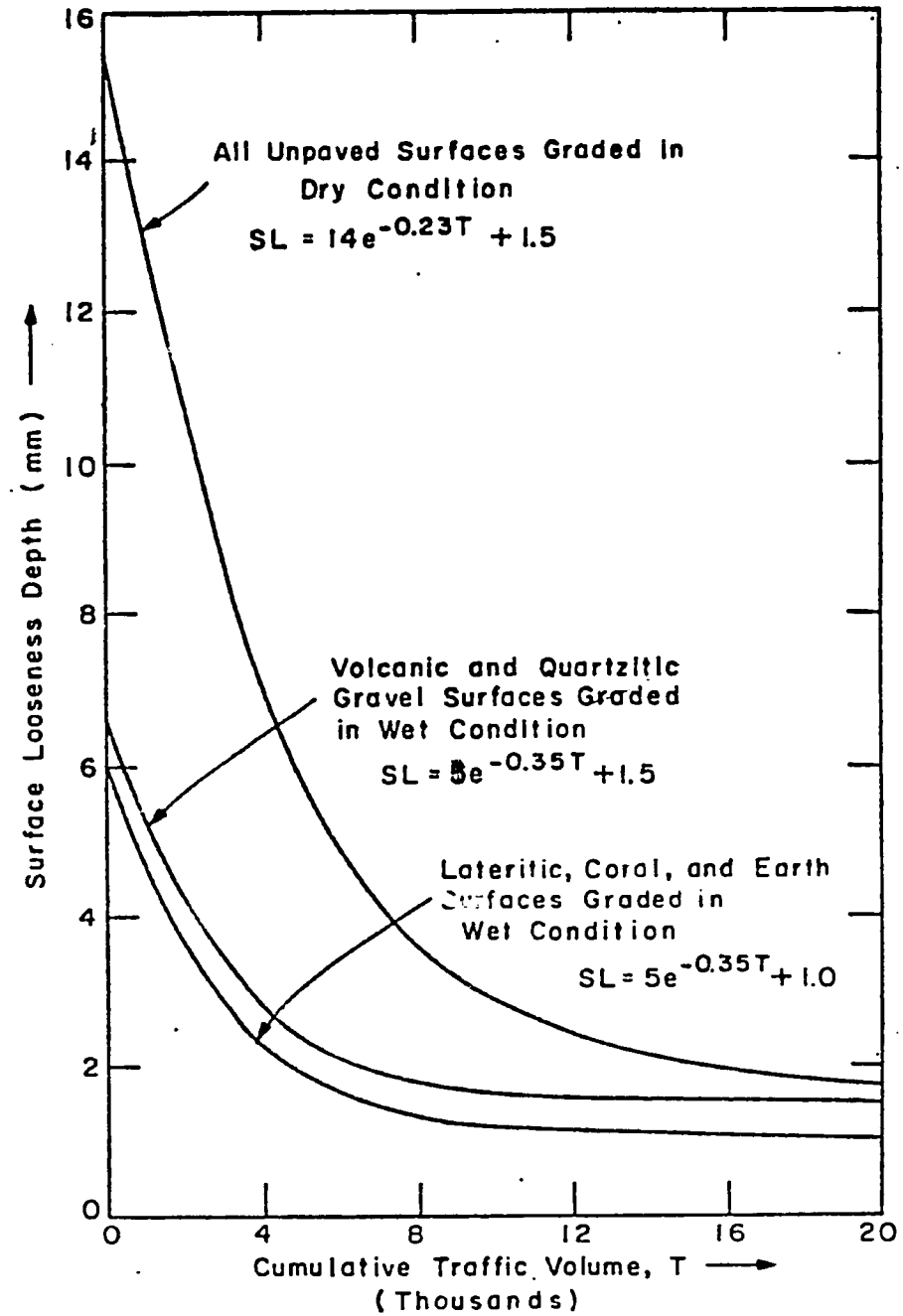

Figure 3-7 Unpaved Surface Looseness

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Deterioration of Earth Roads

The relationships used in the Model to estimate the deterioration of earth roads are extremely rough approximations, and caution should be exercised whenever the predicted benefits associated with upgrading an earth road to a gravel road are small. The data obtained in Kenya only extended to a total traffic loading of 20,000 vehicles, and none of the test sections were impassable at that point. The Model User must specify the number of months per year for the dry season, when earth and gravel surfaces are dusty, and the wet season. Also, the User must specify the frequency of grading in the dry and wet seasons.

Surface Roughness. The data obtained in Kenya (1) were very scattered, and the only conclusion that could be drawn was that roads for which the pavement material was classified as clay displayed lower levels of roughness than roads for which the pavement material was classified as sand.

The average and maximum surface roughness are illustrated in Figure 3-9.

Rutting. For earth roads, the TRRL applied linear regression to all rut depth measurements (2), deriving the relation illustrated in Figure 3-10.

Surface Looseness. The relations used in the model to estimate the depth of loose material for earth roads in wet and dry conditions are identical for those for lateritic and coral gravels graded in wet and dry conditions.

Unpaved Surface Maintenance. The maintenance activities included in the model for unpaved surfaces are: dry season grading, wet season grading, spot regravelling, gravel resurfacing, and miscellaneous. The amount of maintenance work to be done during the year is determined by the deterioration parameters and the maintenance policy specified. Table 3-1 gives a review of the maintenance activities which are included in the model, along with their units.

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(1) Ibid.

(2) Ibid.

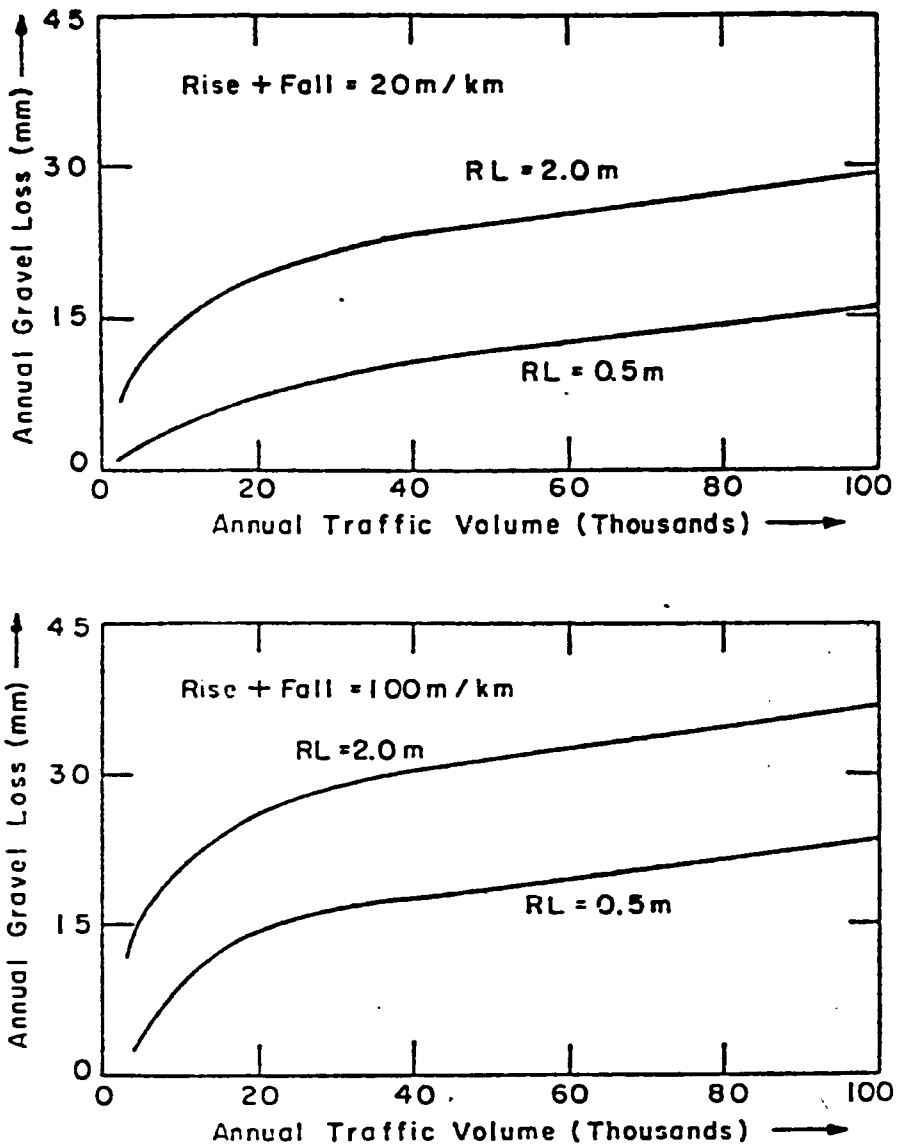

Figure 3-8 Annual Gravel Loss Relation

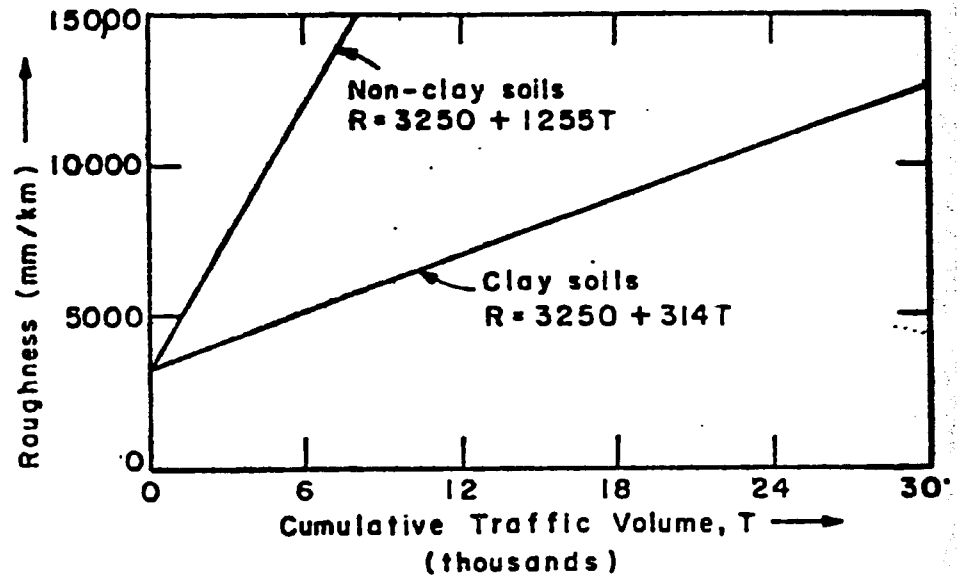

Figure 3-9 Earth Road Roughness

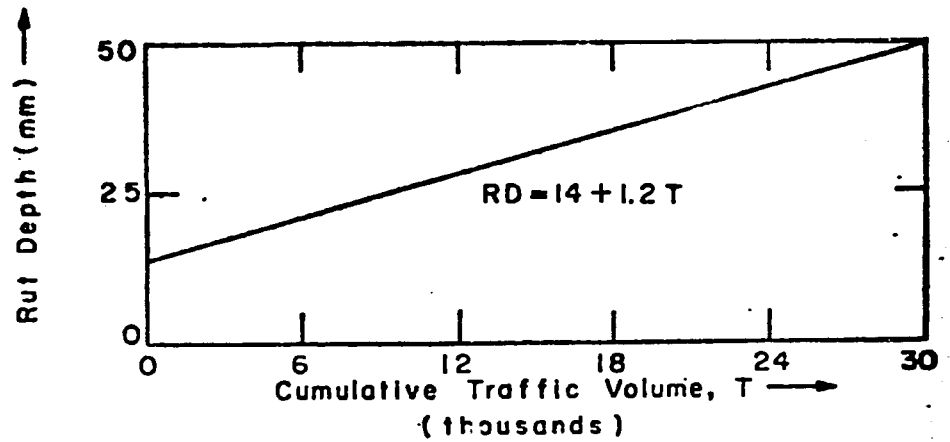

Figure 3-10 Earth Road Rut Depth

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3.2 MAINTENANCE ACTIVITIES

The Model has incorporated four maintenance activities for both paved and unpaved roads into its structure, each of which may be scheduled or responsive in any given maintenance standard; and miscellaneous routine maintenance for both paved and unpaved roads, which are strictly scheduled at once per year. Scheduled maintenance activities are done at specific times, regardless of the state of roadway deterioration, while responsive maintenance activities are done when the roadway has deteriorated to a specific condition, regardless of the time at which that condition is reached.

Maintenance activities on unpaved roads include dry and wet season grading, spot regravelling, gravel resurfacing, and miscellaneous routine maintenance. Dry and wet season grading may be scheduled as days between gradings; or responsive as thousands of vehicle passes (both directions) between gradings, subject to minimum and maximum days between gradings constraints. Spot regravelling may be scheduled as cubic meters per kilometer per year to be replaced; or responsive as the percentage of annual gravel loss to be replaced, subject to a maximum cubic meters per kilometer per year constraint. Gravel resurfacing may be scheduled as number of years between resurfacings; or responsive as the minimum tolerable gravel thickness, subject to minimum and maximum years between resurfacings constraints. In addition, gravel resurfacing, whether scheduled or responsive, may be subjected to a last analysis year to consider resurfacing constraint. Miscellaneous routine maintenance is strictly scheduled at one time per year.

Maintenance activities on paved roads include patching, surface dressing (seal coating), overlaying, rehabilitation, and miscellaneous routine maintenance. Patching may be scheduled as square meters per kilometer per year to be patched, but not to exceed the area requiring patching; or responsive as the percentage of cracked area to be patched, subject to a maximum square meters per kilometer constraint. Surface dressing may be scheduled as the number of years between surface dressings; or responsive as the maximum tolerable percentage cracking, subject to minimum and maximum years between surface dressings constraints. Overlaying may be scheduled as the number of years between overlays; or responsive as the maximum tolerable roughness before overlay, subject to minimum and maximum years between overlay constraints.

Rehabilitation may be scheduled as the number of years between rehabilitations; or responsive as the maximum tolerable roughness before rehabilitation, subject to minimum and maximum years between rehabilitations constraints. In addition, surface dressing, overlaying, and/or rehabilitation, whether scheduled or responsive, may be subjected to a last analysis year to consider surface dressing, overlaying, and/or rehabilitation constraint, respectively. Miscellaneous routine maintenance is strictly scheduled at one time per year. Table 3-2 gives an explanation of the activities and their scheduling options.

3.3 MAINTENANCE COSTS

The costs of maintenance operations in each year are estimated based on the quantities of maintenance performed and appropriate unit costs. These unit costs provide the breakdown of activity costs into labor, equipment, materials, and overhead components. Each of these components is further broken down into financial, economic, and foreign exchange costs. These costs are intended to represent national averages for the various activities. However, since actual costs per unit of activity may vary depending on region, terrain, activity frequency, level of activity, and/or other factors, each activity of each standard may be weighted by a cost adjustment factor which modifies the national unit costs for that activity.

TABLE 3-2

Maintenance activities and scheduling options

(S = Scheduled Maintenance R = Responsive Maintenance)

Unpaved Road Sections**

1. Surface grading--dry season

   S = days/grading R = 1000 vehicles/grading

   subject to min-max days/grading constraints

2. Surface grading--wet season

   S = days/grading R = 1000 vehicles/grading

   subject to min-max days/grading constraints

3. Spot regravelling of gravel road section

   S = cubic meters/km/year R = percent annual loss to be replaced

   subject to max m^3/km/yr constraint

4. Gravel resurfacing of gravel road sections

   S = years/resurfacing R = minimum tolerable gravel thickness (mm)

   subject to min-max years/resurfacing constraints

   Subject to last applicable analysis year constraint*

   Desired gravel thickness after resurfacing*

   Type of gravel being placed*

5. Miscellaneous routine maintenance

   S = one km/km/yr

TABLE 3-2 (continued)

Paved Road Sections**

1. Patching--weighted average of skin and deep patches

   S = square meters/km R = maximum tolerable % cracking & patching

   subject to max unpatched cracks constraint subject to max square meters/km constraint

2. Surface dressing (seal coating)

   S = years/surface dressing R = maximum tolerable % cracking & patching

   subject to min-max yrs/surface dressing constraints

   Subject to last applicable analysis year constraint*

3. Overlaying

   S = years/overlaying R = maximum tolerable roughness

   subject to min-max yrs/overlaying constraints

   Subject to last applicable analysis year constraint*

   Thickness and material type of overlay*

4. Rehabilitation

   S = years/rehabilitation R = maximum tolerable roughness subject

   subject to min-max yrs/rehabilitation constraints

   Subject to last applicable analysis year constraint*

   Resultant modified structural number*

   Resultant deterioration model type*

*Applies to both scheduled and responsive options

**In addition, a separate cost adjustment factor may be applied to each activity

CHAPTER 4. VEHICLE OPERATING COSTS

This chapter describes the methods used to estimate vehicle operating costs, which reflect the geometric standards to which the road was constructed, the type of surface, and the current surface condition as determined through the interactions of pavement design, environment, maintenance policy, and the volume and composition of traffic. Operating costs are estmated by first determining the amount of resources consumed in vehicle operation, and then by applying appropriate factor prices. The output from the submodel consists of vehicle operating and travel time costs for the year, broken down by type of vehicle and cost category.

The four basic types of variables that effect vehicle costs are: road geometrics, environment, surface type and condition, and vehicle characteristics and costs. The exact nature of required inputs for any given situation will depend upon the type of surface under consideration, as some environmental and condition data elements are required for unpaved but not for paved roads.

Vehicle operating costs are a function of road geometry, environment, surface type and condition, and the characteristics of the vehicles using the road. Because road gradients differ in each direction, the costs of vehicle operation per kilometer are computed for both directions of travel and then averaged. In addition, because surface conditions on unpaved roads may vary on a seasonal basis, the costs of operation on unpaved roads are computed for each season and weighted by the season length to produce the average cost per kilometer. The surface conditions used in the vehicle operating cost relationships represent the average conditions for each season (unpaved roads) or year (paved roads).

Costs are calculated in two categories: operating costs and travel time costs. Operating costs are those costs incurred through owning and operating the vehicle, and include fuel, oil, tires, maintenance parts and labor, depreciation, interest, overhead, and crew costs. Travel time costs are related to the time value of persons and cargo holding costs. Costs are computed in financial, economic, and (in some cases) foreign exchange terms. Financial costs represent the actual costs incurred by owning and operating vehicles over the road. Economic costs represent the real costs to the economy of that ownership and operation. Foreign exchange costs represent

the real costs to the economy which must be provided for in foriegn currencies. The outputs of the submodel are vehicle operating and travel time costs, total costs, and speeds, by road section and vehicle type.

4.1 DESCRIPTION OF THE SUBMODEL

Cost and quantity estimates are made for the following elements of total vehicular costs: fuel consumption, oil consumption, tire consumption, spare parts, maintenance labor, depreciation, interest charges, overhead, crew costs, passenger time costs, and cargo holding costs.

Data Requirements

The data requirements of the submodel consist of road geometry, environment, surface type and condition, and vehicle characteristics and costs. The specific variables required are as follows (see Table 4-1).

Road Geometry is specified in terms of the rise and fall of the road (m/km), horizontal curvature (°/km), and road width (m). These variables reflect the geometric standards of the road as it exists in the current year.

Environmental input to this submodel is the mean elevation of the road section, in meters above sea level.

Surface Type is either unpaved (earth or gravel) or paved (bituminous treated or asphalt concrete). Surface conditions are described in terms of surface roughness (mm/km) and rut depth (mm) for all roads, and also surface looseness (mm) and moisture content (%) for unpaved roads.

Vehicle Characteristics and Costs are defined for the traffic using the road which may be represented by up to seven different vehicle types. The required characteristics of each of these representative vehicles are summarized in Table 4-1.

4.2 COSTS OF OPERATION

The various components of vehicle operating and travel time costs are summarized in Table 4-2. The specific relations used to estimate these costs are described below, following a discussion of vehicle speed and age.

Vehicle Speed

The average operating speeds of vehicles using the road are needed in order to estimate fuel consumption and travel time, which is used to apportion

TABLE 4-1

DATA REQUIREMENTS

	Coding or Units
Road Geometry	
1. Road Rise	meters per kilometer
2. Road Fall	meters per kilometer
3. Curvature	degrees per kilometer
4. Road Width	meters
Environment	
5. Elevation	meters
Surface Type and Condition	
6. Surface Type	paved or unpaved
7. Roughness	millimeters per kilometer
8. Rut depth	millimeters
9. Looseness	millimeters
10. Moisture Content	percent
Vehicle Characteristics and Costs	
11. Vehicle Classification	TRRL category
12. Fuel Type	petrol or diesel
13. Brake Horsepower	BHP
14. Gross weight	metric tons
15. Equivalent Axle Factor	*
16. Cost of New Vehicle (F,E,X)	per vehicle
17. Tire Cost (F,E,X)	per tire
18. Fuel Cost (F,E,X)	per litre
19. Oil Cost (F,E,X)	per litre
20. Maintenance Labor Wage (F,E,X)	per hour
21. Crew Cost (F,E,X)	per hour
22. Value of Time (F,E)	per passenger hour
23. Overhead Costs (F,E,X)	annual or percent of operating costs
24. Interest Rate (F,E)	percent
25. Cargo Holding Costs (F,E,X)	per truck hour
26. Spare Parts Price Ratio (E/F, X/E)	percent
27. Average Number of Passengers	integer
28. Annual Crew Hours	hours per year
29. Annual Operating Hours	hours per year
30. Annual Kilometers Driven	kilometers per year
31. Average Vehicle Life	years
32. Age Distribution	percent
33. Annual Fleet Growth Rates	percent

*See Section 3.11

TABLE 4-2

COMPONENTS OF OPERATING COSTS

	Financial	Economic	Foreign Exchange
A. Running Costs			
1. Fuel	yes	yes	yes
2. Oil	yes	yes	yes
3. Tires	yes	yes	yes
4. Maintenance Parts	yes	yes	yes
5. Maintenance Labor	yes	yes	yes
B. Annual Fixed Costs			
6. Depreciation	yes	yes	yes
7. Financing Charges	yes	yes	no
8. Crew Costs	yes	yes	yes
9. Overhead Costs	yes	yes	yes
C. Travel Time Costs			
10. Passenger Time Costs	yes	yes	no
11. Cargo Holding Costs	yes	yes	yes

the annual fixed costs and determine the value of time savings. The speed prediction relations used in the model are based on the work of TRRL in Kenya, and were developed from 130,000 observations of speeds for different vehicle types, road geometrics, and surface conditions over a two year period (1). These relations are of the following general form:

$$\text{SPEED} = F(\text{RISE, FALL, CURVATURE, ELEVATION, WIDTH, ROUGHNESS, MOISTURE CONTENT, RUT DEPTH}) \quad (4\text{-}1)$$

The actual coefficients for TRRL's multiple linear regression analysis are shown in Table 4-3. The relationships do not account for vehicle interaction from congestion or speed cycle changes, but do reflect the small effects of reduced road width (below 5 meters). The TRRL equations were developed for passenger cars, light goods vehicles, medium and heavy goods vehicles (in one category), and buses, for both paved and unpaved roads.

Vehicle Age Spectrum

The age distribution of the vehicle fleet using a road affects maintenance, depreciation, and financing costs. One aspect of TRRL's work was therefore to develop a vehicle age distribution function for the Kenya vehicle fleet.

While the form of this function is generally applicable, the data base on which the function is based is strictly Kenyan, and as such can be said to model only the Kenyan situation. Since no generally valid function is available at present, the Model allows the User the option of choosing one of four age spectrum relations, with differing implications for depreciation, annual kilometrage, and cumulative kilometrage. These are the TRRL (2), DeWeille (3), constant age spectrum, and MIT (4) relations.

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(1) Hide, H., et al, The Kenya Road Transport Cost Study: research on vehicle operating costs, Department of the Environment, TRRL Report LR 672, Crowthorne, 1975 (Transport and Road Research Laboratory).

(2) Robinson, R., Road Transport Investment Model: draft user manual. Department of the Environment, TRRL Supplementary Report 224 UC, Crowthorne, 1976 (Transport and Road Research Laboratory).

(3) DeWeille, Jan, Quantification of Road User Savings, International Bank for Reconstruction and Development, World Bank Staff Paper No. 2, Washington, D.C.

(4) Moavenzadeh, F., et al. The Highway Cost Model: General Framework. Technology Adaptation Program Report Number 75-4, Massachusetts Institute of Technology, Cambridge, Ma., September, 1975.

TABLE 4-3: COEFFICIENTS FOR SPEED EQUATIONS

	α_0 (Constant)	α_1 Rise	α_2 Fall	α_3 Curvature	α_4 Altitude	α_5 Roughness	α_6 Moisture	α_7 Rut Depth	α_8 Width
1. Passenger Cars									
Paved	105.27	-0.37243	-0.07599	-0.11056	-0.00491	-0.00089	N/A	N/A	7.31
Unpaved	84.19	-0.20947	-0.06977	-0.11812	N/A	-0.00089	-0.13481	-0.18584	4.32
2. Light Load Commercial									
Paved	89.75	-0.41810	-0.04962	-0.07376	-0.00278	-0.00095	N/A	N/A	7.31
Unpaved	81.23	-0.31708	-0.05925	-0.09664	N/A	-0.00095	-0.29296	-0.19657	4.32
3. Buses									
Paved	72.40	-0.52558	0.06663	-0.06611	-0.00417	-0.00036	N/A	N/A	3.29
Unpaved	62.58	-0.49172	-0.01022	-0.04628	N/A	-0.00036	-0.16327	-0.09054	6.36
4. Medium & Heavy Load Commercial									
Paved	49.80	-0.51892	0.02989	-0.05807	-0.00042	-0.00060	N/A	N/A	3.29
Unpaved	49.20	-0.43342	0.00445	-0.06098	N/A	-0.00060	-0.22111	-0.26535	6.36
Variable Units	------	meters/km	meters/km	°/km	meters	mm/km	%	mm	meters
Safe Range of Variable Validity									
Paved	-----	0-85	0-85	0-200	0-2500	2000-5000	-----	-----	-----
Unpaved	-----	0-80	0-80	0-250	------	2000-14000	0-30	0-75	-----

GENERAL FORM OF EQUATIONS

$$\text{SPEED} = \alpha_0 + \alpha_1\text{RISE} + \alpha_2\text{FALL} + \alpha_3\text{CURVATURE} + \alpha_4\text{ALTITUDE} + \alpha_5\text{ROUGHNESS} + \alpha_6\text{MOISTURE} + \alpha_7\text{RUT DEPTH}$$

If road width is less than 5.0 meters, SPEED = SPEED - α_8(5.0 - ROAD WIDTH)

TABLE 4-4: COEFFICIENTS FOR FUEL CONSUMPTION EQUATIONS

	α_0 (Constant)	α_1 Speed	α_2 Speed	α_3 Rise	α_4 Fall	α_5 Roughness	α_6 Looseness	α_7 GVW	α_8 BHP/GVW
1. Passenger Cars									
Paved	53.66	498.6716	0.0058	1.5936	-0.8539	N/A	N/A	N/A	N/A
Unpaved	46.90	614.0499	0.0079	1.7235	-1.0657	0.0011	0.8218	N/A	N/A
2. Light Load Commercial									
Paved	74.70	1150.5988	0.0131	2.9058	-1.2774	N/A	N/A	N/A	N/A
Unpaved	72.78	844.2944	0.0137	2.8283	-1.3062	0.0011	1.7565	N/A	N/A
3. Medium Load Commercial									
Paved	105.43	902.5266	0.0143	4.3616	-1.8335	N/A	N/A	N/A	-2.3955
Unpaved	121.99	795.8916	0.0150	4.1760	-2.2200	0.0014	1.9688	N/A	-2.6192
4. Buses & Heavy Load Commercial									
Paved	-48.60	902.5266	0.0143	4.3616	-1.8335	N/A	N/A	69.2	-2.3955
Unpaved	-32.00	795.8916	0.0150	4.1760	-2.2200	0.0014	1.9688	69.2	-2.6192
Variable Units	-----	km/hr	km/hr	m/km	m/km	mm/km	mm	MT	HP/MT
Safe Range of Variables									
Paved	-----	see limits as defined in Table 4-3		0-85	0-85	2000-5000	-----	8.5-40	5-40
Unpaved	-----	"		0-80	0-80	2000-14000	0-20	8.5-40	5-40

$$\text{Fuel Consumption} = \alpha_0 + \alpha_1/\text{SPEED} + \alpha_2\text{SPEED}^2 + \alpha_3\text{RISE} + \alpha_4\text{FALL} + \alpha_5\text{ROUGHNESS} + \alpha_6\text{LOOSENESS} + \alpha_7\text{GVW} + \alpha_8\frac{\text{POWER}}{\text{GVW}}$$

4.21 Resource Consumption

Running costs consist of those costs which are incurred as a direct result of vehicle usage, and include the costs of fuel, oil, tires, and maintenance parts and labor. Generally speaking, they vary with vehicle class and age, surface type (paved and unpaved) and condition, design geometry, vehicle speed, and driver habits. The major source of new primary data on resource consumption relationships for the various components of running costs is the TRRL Kenya Study (1). Although the study was not complete in every respect, it serves as the primary source for the relationships used in the Model. The specific components of running costs are computed as follows.

Fuel Consumption: The general form of the fuel consumption relations used in the Model is:

$$\text{FUEL} = (\text{FUEL TYPE FACTOR})\ \text{FL} \qquad (4\text{-}2)$$

where:

FL	is f(SPEED, RISE, FALL, ROUGHNESS, LOOSENESS, GVW, PWR)
FL	is fuel consumption at constant speed in liters/1000km
GVW	is Gross vehicle weight, in metric tons
PWR	is Power to weight ratio (horsepower/GVW)
FUEL TYPE FACTOR	is Increased fuel consumption ratio due to speed cycle changes (1.08 for petrol engines, 1.13 for diesel engines)

The equations were developed by TRRL using multiple linear regression techniques on the results of experiments conducted with (i) passenger cars using a Ford Cortina estate wagon, (ii) light goods vehicles using a Land Rover, and (iii) buses and medium and heavy goods vehicles using a 7-ton Bedford diesel truck and a varying payload.

Since the fuel consumption data for buses and medium and heavy goods vehicles were obtained using the Bedford Lorry, the experimental results were compared by TRRL with survey data. The incorporation of a gross vehicle weight factor into the relationship gave good correlation, as follows:

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(1) Hide, H., et al, The Kenya Road Transport Cost Study: research on vehicle operating costs. Department of the Environment, TRRL Report LR 672, Crowthorne, 1975 (Transport and Road REsearch Laboratory).

$$\Delta FUEL = FUEL - FUEL_E = 69.2\sqrt{GVW} - 154 \qquad (4\text{-}3)$$

In this equation:

FUEL = the actual fuel consumption in liters/1000 kms

$FUEL_E$ = the estimated fuel consumption calculated from the equation for medium good vehicles

GVW = the gross vehicle weight in metric tons

Using this result, the equation for medium goods vehicles was extrapolated to include heavier vehicles. The resulting equations together with the equations for cars and light goods vehicles are summarized in Table 4-4.

On unpaved roads, TRRL was able to relate two surface condition variables--roughness and looseness--to fuel consumption. However, for paved roads, surface condition did not affect fuel consumption within the range of conditions studied. In order to extend the paved road relation to include roughness, the Model allows the User the option of utilizing the relationships developed by Claffy (1).

These relationships are in the form of a matrix of fuel consumption multipliers for speeds between 16 and 80 km/hr and roughness between 1800 and 5000 mm/km for all vehicle classes, save heavy goods commercial vehicles. The multiplier outside these ranges is unity. The matrix is shown in Table 4-5.

Oil Consumption: The consumption of oil represents about 1% of the total cost of vehicle usage and, as such, there has been very little research in relating oil consumption rates to either geometry, surface condition, or vehicle age. The oil consumption rates are shown in Table 4-6.

Tire Consumption: From their survey of operators, TRRL was able to develop two equations for estimating tire consumption:

a) Passenger cars and light goods vehicles

$$\begin{aligned} TC &= (-83 + 0.058R)10^{-3} && R \geq 2000 \\ &= .03 && R < 2000 \end{aligned} \qquad (4\text{-}4)$$

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(1) Claffey, P.J., "Running Costs of Motor Vehicles as Effected by Road Design and Traffic," NCHRP Report 111, Washington, D.C., 1971

b) Medium and heavy goods vehicles and buses

$$TC = (83 + .0112R)GVW\ 10^{-4} \qquad R \geq 1500$$
$$= GVW \cdot 10^{-2} \qquad R < 1500 \qquad (4\text{-}5)$$

where: TC = the number of tires consumed per 1000 kilometers

GVW = the gross vehicle weight in metric tons

R = the roughness in millimeters per kilometer, which ranged from 1500-7500 in the conditions analyzed.

Maintenance Spare Parts Consumption. The TRRL survey of operators showed maintenance spare parts consumption to be a function of road roughness and the vehicle age in kilometers. This consumption rate is expressed as a percentage of the new financial cost of the vehicles per 1000 kilometers. The relations are as given in Table 4-7.

Maintenance Labor Hours: The general functional form specified by TRRL for predicting hours of maintenance labor required per 1000 kilometers of vehicle operation is

$$\text{LABOR HOURS} = f(\text{PC, ROUGHNESS}) \qquad (4\text{-}6)$$

where PC is the maintenance parts consumption rate as determined in the previous section. The relations are as given in Table 4-8.

4.22. Costing of Resource Consumption

Consumed resources are costed in financial economic, and foreign exchange terms, as described below.

Fuel: The fuel consumption costs are computed per kilometer as the fuel resources consumed (liters per thousand kilometers) times the appropriate unit cost component (cost per liter in financial, economic, and foreign exchange terms) divided by one thousand.

Oil: The oil consumption costs are computed per kilometer as the oil resources consumed (liters per thousand kilometers) times the appropriate unit cost component (cost per liter in financial, economic, and foreign exchange terms) divided by one thousand.

Tires: The tire consumption costs are computed per kilometer as the tires consumed (tires per thousand kilometers) times the appropriate unit cost component (cost per tire in financial, economic, and foreign exchange terms) divided by one thousand.

TABLE 4-5

CLAFFEY'S MULTIPLIERS FOR FUEL CONSUMPTION ON ROUGH PAVED ROADS

	Roughness = 1800 mm/km			Roughness = 5000 mm/km		
Speed (km/hr)	Pass Car	Light Goods	Bus & Medium Goods	Pass Car	Light Goods	Bus & Medium Goods
16	1.0	1.0	1.0	1.01	1.00	1.03
32	1.0	1.0	1.0	1.05	1.00	1.06
48	1.0	1.0	1.0	1.20	1.01	1.07
64	1.0	1.0	1.0	1.34	1.06	1.08
80	1.0	1.0	1.0	1.50	1.16	1.20

Notes: (1) If velocity is less than 16 km/hr, roughness less than 1800/mm/km, or vehicle is heavy goods, then the multiplier is unity.
(2) Speeds over 80 km/hr are treated as 80 km/hr, and roughness over 5000 mm/km is treated as 5000 mm/km
(3) Interpolate linearly between ranges as necessary

TABLE 4-6

OIL COMSUMPTION RATES (LITRES PER 1000 KM)

	PAVED ROADS	UNPAVED ROADS
Passenger Car	1.2	2.4
Light Goods	1.8	3.6
Buses & Medium & Heavy Goods	4.0	8.0

TABLE 4-7

MAINTENANCE SPARE PARTS CONSUMPTION (PER 10[illegible] KM)

	α_0	α_1	α_2
Passenger Cars and Light Goods Vehicles	-2.03	0.00180	1.0
Medium and Heavy Goods	0.48	0.00037	1.0
Buses	-67.00	0.06000	0.5

Spare Parts = $(\alpha_0 + \alpha_1 \text{ROUGHNESS})(\text{CUMULATIVE KM})^{\alpha_2} \cdot 10^{-8}$

TABLE 4-8

MAINTENANCE LABOR HOURS (PER 1000 KM)

	α_0	α_1
Passenger Cars and Light Goods Vehicles	851	-0.078
Medium and Heavy Goods	2975	-0.078
Buses	2640	-0.078

Maintenance Labor Hours = ($_0$ + $_1$ROUGHNESS) · (Spare Parts Rate)

Note: if Roughness >6000, Roughness = 6000

Spare Parts: The spare parts consumption costs in financial terms are computed per kilometer as the parts consumed (fraction of new vehicle financial price per thousand kilometers) times the financial price of the new vehicle divided by one thousand. In economic terms, it is computed as the financial spare parts cost times the economic to financial spare parts cost ratio. The reason for this difference in methodology is that in many countries the vehicle is dutied at a different rate than are spare parts. In foreign exchange terms, it is computed as the economic spare parts cost times the foreign exchange to economic spare parts cost ratio.

Maintenance Labor: The maintenance labor costs are computed per kilometer as the maintenance hours consumed (maintenance hours per thousand kilometers) times the appropriate unit cost component (cost per hour in financial, economic, and foreign exchange terms) divided by one thousand.

4.23 Annual Fixed Costs

The annual fixed costs of vehicle operations include depreciation, interest, crew, and overhead costs. The total costs of these items are assumed as fixed within reasonable ranges around the average annual kilometrage driven, but their allocation on a per kilometer basis will vary with the number of kilometers actually driven during a year, which generally increases with road improvements.

Depreciation: The costs of vehicle depreciation depend upon the vehicle age spectrum option. All options compute the financial costs of vehicle depreciation in the same manner on a per kilometer basis as a vehicle depreciation factor times the new financial vehicle price divided by the average annual kilometrage.

The TRRL and DeWeille Relations for economic vehicle depreciation are identical on a per kilometer basis, being computed as a vehicle depreciation factor times the new economic vehicle cost divided by the average annual financial kilometrage. The MIT Relations and the Constant Age Spectrum Relation are identical on a per kilometer basis in that annual economic depreciation cost is calculated as a periodic payment to a sinking fund. Using the economic rate of interest (ERI), a stream of N equal annual payments (where N is the vehicle of life expectancy) is calculated whose present value after discounting is equal to the economic cost of the new vehicle. This annual payment is the

annual economic depreciation cost. The formula for this is:

$$\text{Annual Depreciation, Economic} = \left[\frac{\text{Economic Cost}}{\frac{1}{1 + ERI}} \; \frac{[1 - \frac{1}{1 + ERI}]}{[1 - (\frac{1}{1 + ERI})^N]} \right] \qquad (4\text{-}7)$$

The TRRL and DeWeille Relations for foreign exchange vehicle depreciation are identical on a per kilometer basis, being computed as a vehicle depreciation factor times the new foreign exchange vehicle cost divided by the average annual kilometrage. The MIT and Constant Age Spectrum Relations are identical on a per kilometer basis in that the annual foreign exchange depreciation cost is calculated as a periodic payment to a sinking fund. Using the economic rate of interest discussed above, a stream of equal annual payments is calculated whose present value after discounting is equal to the foreign exchange cost of the new vehicle, using an equation of the same form as Equation (4-7).

Financing Costs: In purchasing a passenger car or truck the owner either borrows money or must lose the interest on the money that could have been saved or used elsewhere. The annual financial cost is the market money rate times one-half of the financial cost of the new vehicle, prorated over the financial kilometrage to obtain a per kilometer financial interest cost. The one-half represents, once again, the assumption that all vehicles have on the average aged halfway.

The economic financing charges are zero for the DeWeille and Constant Age Spectrum Relations. For the TRRL and MIT Relations, they are computed as the economic rate of capital times one-half the economic cost of the new vehicle, prorated over the financial kilometrage to obtain a per kilometer economic interest cost.

The foreign exchange financing charges are zero for all vehicle age spectrum options.

Crew Costs: The Model treats crew costs as a fixed annual expense. The costs are computed as the annual crew hours times the appropriate cost component (crew cost per hour in financial, economic, and foreign exchange terms) divided by the appopriate annual kilometrage (financial, economic, and foreign exchange).

Overhead Costs: The overhead costs of vehicle operation may be calculated in one of two ways, at the option of the User, by the vehicle type: (i) as average absolute overhead costs in financial, economic, and foreign exchange terms) prorated over the annual kilometrage (in financial, economic, and foreign exchange terms); or (ii) as an annual percentage of vehicle operating costs (in financial, economic, and foreign exchange terms).

Travel Time Costs: Travel time costs are assumed to consist of the value of consumed passenger time and of cargo holding costs. Passenger travel time costs are computed in financial and economic terms as the average number of passengers per vehicle times the hourly value of time per passenger (in financial or economic terms), times the average travel time for the road section divided by the length of the section to obtain the prorated financial and economic travel time costs for passengers on a per kilometer basis. No account is made of the foreign exchange value of passenger travel time.

Cargo holding costs are computed as the travel time over the road (hours per kilometer) times the appropriate cargo holding cost component (cost per hour in financial, economic, and foreign exchange terms) divided by the road length, to obtain the proper financial, economic, and foreign exchange cargo holding costs per kilometer. This hourly cost will vary depending upon the type of cargo being carried--higher for perishable goods cargo and goods that will be placed in service or otherwise used as soon as they arrive, and lower for other goods.

CHAPTER 5. TRAFFIC ASSIGNMENT AND EXOGENOUS COSTS/BENEFITS

This chapter describes the methods used within the Model to assign and grow traffic volumes and exogenous costs/benefits on the links currently under analysis.

5.1 LINK ANALYSIS

Up to twenty distinct sets of traffic may be defined by the User, with any combination of sets being assigned to each link alternative. Each set must be either normal or generated traffic.

5.11 Normal Traffic

Normal Traffic is that traffic which would use the link regardless of any road improvements, with benefits being calculated as the reduction in operating and travel time costs. The forecasts of normal traffic volumes may be given in either of two ways in each of up to three periods of the analysis horizon:

a) The User may specify an annual percentage growth rate for each vehicle class at which this traffic will grow during the period being defined.

b) The User may alternatively specify a constant annual increment for each vehicle class at which this traffic will increase each year during the period being defined.

Whichever options are used in any or all of the traffic periods, the base year average daily traffic for each vehicle class is provided by the User. In addition, different growth rates or annual increments may be specified for each of the vehicle calsses and in each traffic period. Normal traffic is then aggregated over all normal traffic sets which are active on this link in the current year, by vehicle class.

5.12 Generated Traffic

Generated traffic is that traffic which is drawn to the link due to changes in the travel costs of this link and/or neighboring links. In this sense, the term generated traffic includes both "generated" and "diverted" traffic, and benefits are calculated as one-half the reduction in operating and travel time costs. The forecasts of generated traffic volumes may be given in one of three ways in each of up to three periods of the analysis horizon:

a) The User may specify an annual percentage growth rate for each vehicle class at which this traffic will grow during the period being defined.

b) The User may alternatively specify a constant annual increment for each vehicle class at which this traffic will increase each year during the period being defined.

c) The User may alternatively specify a percentage of current normal traffic for each vehicle class at which this generated traffic will increase each year during the period being defined. Care should be taken if this option is used for long periods because it may predict an unrealistically large traffic growth rate. We recommend that this option be used only in the initial year of the generated traffic set, and that either (a) or (b) be used subsequently.

For generated traffic sets, no base year average daily traffic is provided by the User, since the year of generation may be tied to completion of construction projects. Similarly to normal traffic, different growth rates, annual increments, or percentages of current normal traffic may be specified for each vehicle class in each traffic period. Generated traffic is then aggregated over all generated traffic sets which are active on this link in the current year, by vehicle class.

5.2 NETWORK ANALYSIS

The traffic assignment model assigns the origin-destination (O-D) flows to the links of the network, based on the operating and travel time costs of the relevant paths and the vehicle diversion parameters. It also grows the traffic O-D demands for the current year. The most recent vehicle operating costs and travel times over the various links will be used in conjunction with the origin-destination demands and the network data (available paths) to predict the link volumes. These volumes will be measured as vehicles per day, for use in the construction and unpaved roads deterioration models, and as equivalent single axle loads per day, for use in the paved roads deterioration models. Each link's volume (vehicles per day) will be used by the construction model to trigger demand responsive projects. Each link's volume, its characteristics, and the exercised maintenance will be used by the deterioration models to calculate the maintenance costs incurred and the condition of the link at the end of the year. This information will be used to calculate the level of service (road users' costs and travel times) of the link. The financial users' costs and travel times will be part of the generalized price used by the assignment procedure to load the network flows in the successive year, while the economic costs will be stored for later use in the economic analysis of the investment alternative.

The inputs to the submodel are the following:

1) Network description--available paths between all origin-destination pair
2) Traffic demands--base volumes and growth projections and load factors for all origin-destination pairs
3) Previous levels of service--operating costs and travel times for all links of the network
4) Assignment parameters--diversion intensities and elasticity parameters

The outputs from the assignment submodel are the link flows, in vehicles per day by vehicle type, both normal and generated, and the equivalent axle loads per day. In addition, the perceived and actual financial costs and travel times are computed for each link.

5.21 Description of the Submodel

The traffic assignment algorithm incorporated into the Model is stochastic, as human behavior is much more realistically modelled stochastically than deterministically. Thus, we have a procedure that will predict the probabil of choosing any given path out of the set of possible alternative paths betwen any given origin-destination pair.

To formalize the problem, we assume that each path is associated with some travel disutility that is distributed according to some probability law:

$$U_i \sim F_{U_i}(u_i) \tag{5-1}$$

According to the utility maximization principle, the probability P_i of choosing path i between an arbitrary origin-destination pair for an arbitrary motorist out of the set A of all available paths between this origin and destination is given by:

$$\begin{aligned} P_i &= \Pr(\text{choose } i|A) = \Pr(U_i \le U_j;\ \forall\, j \epsilon A) \\ &= \Pr(U_i = \min_{j \epsilon A} \{U_j\}) \end{aligned} \tag{5-2}$$

where U_i denotes the disutility associated with travelling over path i.

Given this criterion of path choice, the Stochastic User Equilibrium (1) can

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(1) Wardrop, J.G. "Some Theoretical Aspects of Road Traffic Research," Proceedings, Institute of Civil Engineers, London, Part II, Volume 1, 1952.

be formalized on the basis of the law of large numbers:

$$P_i = Pr(U_i \leq U_j;\ \forall_j \epsilon A) = \frac{x_i}{\sum_j x_j} \qquad (5\text{-}3)$$

where x_i = the traffic flow over path i

$\sum_j x_j$ = the total number of trips between the origin and destination under consideration

This equation states that, at equilibrium, the fraction of flow choosing path i equals the probability of choosing this path.

A Logit-Based Model of Path Choice

It is generally assumed that the disutilities associated with the set of alternatives are linear in the parameters with additive disturbance term (1). We assume that each alternative path's disutility is composed of a deterministic, measurable part, termed the "generalized price" (GP_i) and an additive disturbance term Σ_i:

$$U_i = GP_i + \Sigma_i \qquad (5\text{-}4)$$

We further assume that the generalized price is a linear combination of travel time and travel cost:

$$GP_i = \alpha(\text{Travel Time}) + \beta(\text{Travel Cost}) \qquad (5\text{-}5)$$

where α and β are parameters to be estimated from observed path choice situations.

To obtain the Logit model of choice among alternatives, we assume that the disturbances, or error terms, are independently and identically distributed Gumbel variates, i.e.:

$$Pr(\xi_i \leq \omega) = \exp(e^{(a+\omega)}) \qquad (5\text{-}6)$$

for any real value of ω.

Using this distribution, McFadden (2) demonstrated that Equation (5-2) can be written as:

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(1) Manski, C. "The Structure of Random Utility Models," Working Paper, School of Urban and Public Affairs, Carnegie-Mellon University, 1975.

(2) McFadden, D. "Conditional Logit Analysis of Qualitative Choice Behavior," appeared in P. Zarembka, (ed.). Frontiers in Econometrics, Academic Press, New York.

$$P_i = e^{-U_i} / \left(\sum_{j \in A} e^{-U_j} \right) \tag{5-7}$$

For path choice problems, we rewrite the above equation as:

$$P_i = e^{-\theta GP_i} / \sum_j e^{-\theta GP_j} \tag{5-8}$$

Note that when the model is expressed in this way, the measurable portion of the disutility functions can be written in terms of θ and a new parameter VT:

$$\theta GP_i = \theta[(\text{Travel Cost}) + VT(\text{Travel Time})] \tag{5-9}$$

which is equivalent to Equation (5-5) but has a more intuitive appeal, since θ can be interpreted as the diversion intensity parameter and VT as the value of time. Thus we modify the definition of generalized price to:

$$GP_i = (\text{Travel Cost}) + VT(\text{Travel Time}) \tag{5-10}$$

and the path choice criterion is given by Equation (5-8), which is the basis of the assignment model.

In order to find the proper measure of the network performance, and formalize it, we denote the set of feasible alternative paths for an arbitrary tripmaker going from origin i to destination j by A^{ij}. Each alternative path k is associated with a perceived disutility U_k^{ij}, and we assume that an individual selects that member of A^{ij} which minimizes his perceived disutility. The disutilities are assumed to be random variables, and the choice set A^{ij} is assumed to include N^{ij} members (alternative paths) which are, by definition, mutually exclusive and collectively exhaustive.

Since each individual selects the alternative which is perceived as minimum, the perceived travel cost $\overline{U}^{ij}$ becomes:

$$\overline{U}^{ij} = \min_{k \in N^{ij}} \{U_k^{ij}\} \tag{5-11}$$

However, since the GP_i^{ij} are random variables, this value is not measurable, and the quantity to be used becomes the expectation of the above expression, i.e.

$$\overline{GP} = E[\min_{k \in A^{ij}} (GP_k^{ij})] \tag{5-12}$$

The expected value of the minimum perceived generalized price (disutility) has two properties that are highly desirable in traffic assignment:

1) It is monotonically increasing with respect to the mean (measured) disutility of each alternative path (i.e., the generalized price).
2) It is monotonically decreasing with respect to the size of the choice set.

The first property implies that when any link of the network is improved (its generalized price decreases), the expected minimum perceived cost decreases as well. Sheffi and Daganzo (1) prove that the marginal expected minimum disutility with respect to the mean disutility (the generalized price) on any path equals the probability of using that path:

$$\frac{\partial E[\bar{U}^{ij}]}{\partial GP_k^{ij}} = P_k^{ij} \tag{5-13}$$

Since P_k^{ij} is the probability of choosing path k, it is always non-negative, and thus the first property above holds. Substituting Equation (5-8) into Equation (5-13) yields:

$$\frac{\partial E[\bar{U}^{ij}]}{\partial GP_k^{ij}} = \frac{e^{-\theta GP_k^{ij}}}{\sum_m e^{-\theta GP_m^{ij}}} \tag{5-14}$$

which, upon integration, produces

$$E[\bar{U}^{ij}] = -\frac{1}{\theta} \ln \sum_m e^{-\theta GP_m^{ij}} \tag{5-15}$$

The constant of integration is shown to be zero by introducing the boundary condition:

$$E[\bar{U}^{ij}] = GP^{ij} \text{ for } N^{ij} = 1 \tag{5-16}$$

The second property of the expected minimum disutility implies its reduction when any new alternative route is provided. A general proof of this property is offered by Williams (2), which is not restricted to any specific model.

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(1) Sheffi, Y. and C. Daganzo, "Another Paradox of Traffic Flow," to appear in Transportation Research 11, No. 5.

(2) Williams, H., "On the Formation of Travel Demand Models and Economic Evaluation Measurement of User Benefits," Environment and Planning 9, pp. 285-344.

Economic Interpretation

The attractiveness of the new measure of benefits, $E[\bar{U}]$, would have been limited had it not had an appealing economic interpretation. Using a binary choice example, consider the share of motorists that will choose path 2, P_2, as a function of the generalized price over path 2, as GP_1 remains constant:

$$\frac{x_2}{x_1 + x_2} = P_2(GP_2) = \frac{e^{-\theta GP_2}}{e^{-\theta GP_1} + e^{-\theta GP_2}} \tag{5-17}$$

Where x_i is the number of users choosing path i. This function represents the demand for the use of path 2, and is plotted in Figure 5-1. Now consider an investment in upgrading path 2 which decreases the generalized price over it from GP_2' to GP_2''. The consumer surplus in the first situation is given by:

$$-GP_2'P_2' + \int_0^{P_2'} (GP_1 + \frac{1}{\theta} \ln \frac{P_1}{P_2})\, dP_2 \tag{5-18}$$

and after the investment, the total consumer surplus in the system is given by:

$$-GP_2''P_2'' + \int_0^{P_2''} (GP_1 + \frac{1}{\theta} \ln \frac{P_1}{P_2})\, dP_2 \tag{5-19}$$

The increase in the consumer surplus, ΔCS, is the difference between the above quantities, or the integral:

$$\Delta CS = -GP_2''P_2'' + GP_2'P_2' + \int_{P_2'}^{P_2''} GP_2\, dP_2 \tag{5-20}$$

which corresponds to the shaded area in Figure 5-1. However, as evidenced by the figure, the same area can be calculated by integrating $P_2(GP_2)$ along the generalized price axis. The change in consumer surplus gained by lowering the generalized price from GP_2' to GP_2'' is:

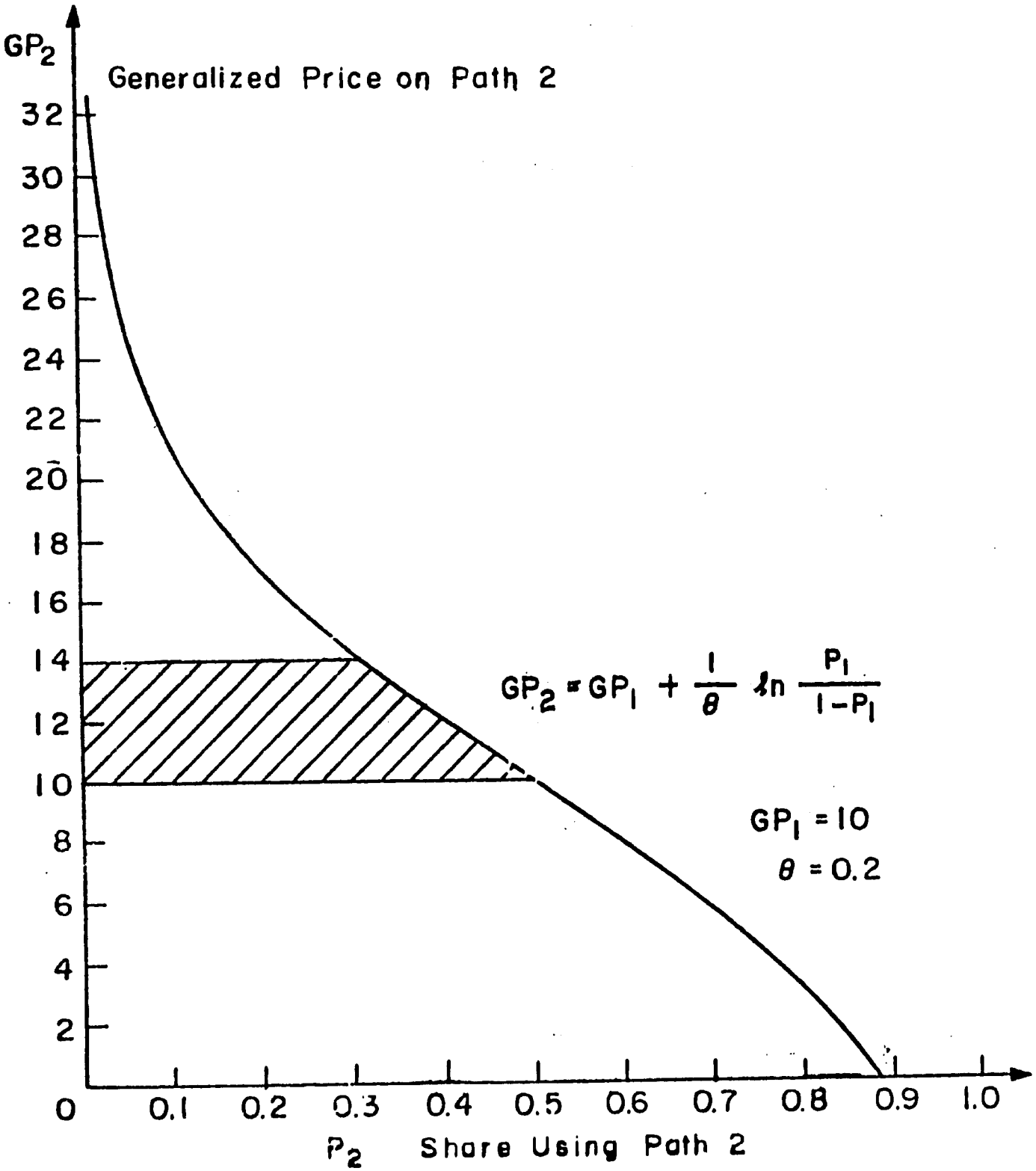

FIGURE 5-1 DEMAND CURVE FOR THE USE OF PATH 2

$$\Delta CS = \int_{GP_2'}^{GP_2''} P_2(GP_2)dGP_2 \tag{5-21}$$

Upon substituting the first property of the expected minimum disutility (Equation 5-13), the change in the consumer surplus becomes:

$$\Delta CS = E[\bar{U}] \Big|_{GP_2=GP_2''} - E[\bar{U}] \Big|_{GP_2=GP_2'} \tag{5-22}$$

which result extends directly to the miltinomial case. For the demand curve in Figure 5-1, the change in consumer surplus is;

$$\Delta CS = \frac{1}{\theta} \ln(e^{-\theta GP_2'} + e^{-\theta GP_1}) - \frac{1}{\theta} \ln(e^{-\theta GP_2''} + e^{-\theta GP_1}) \tag{5-23}$$

Thus, the difference between the expected minimum disutilities of two network configurations exactly equals the amount of consumer surplus gained by the change.

The above formula is also the proper measure of network performance for all O-D pairs and all vehicle types. When comparing two network configurations, the metric is given by:

$$E[\bar{U}'] - E[\bar{U}''] = -\frac{1}{\theta} \ln \sum_j e^{-\theta GP_j'} + \frac{1}{\theta} \ln \sum_j e^{-\theta GP_j''} \tag{5-24}$$

This difference can be shown to equal the difference in total consumer surplus in the system between the two configurations, and the total consumer surplus for a given configuratton ts given by:

$$E[\bar{U}] = -\frac{1}{\theta} \sum_{\substack{\text{all}\\ \text{users}}} \sum_{\substack{\text{all}\\ \text{O-D}\\ \text{pairs}}} \ln \sum_{\substack{\text{all}\\ \text{paths}\\ j}} e^{-\theta GP_j} \tag{5-25}$$

5.3 CONGESTION

The relationships used in the model to predict vehicle speeds and fuel consumptions were developed under almost free-flow conditions (1) where the only constraints on speed were the physical characteristics of the road and the characteristics of the vehicles, and they are therefore not valid when traffic interaction takes place. A knowledge of the relationship between speed and traffic flow is of fundamental importance in many aspects of traffic engineering, and much research has been undertaken in developed countries on this subject. During the simulation of the life of the road, it is possible that the vehicle flows will increase until critical levels of hourly flow and average daily traffic are reached, causing traffic interaction and its resultant reductions in vehicle speeds.

5.4 EXOGENOUS COSTS/BENEFITS

Exogenous costs and benefits sets are regarded as the parallel of traffic sets, in that the forces which give rise to traffic are often the same forces which give rise to production, and hence to exogenous costs and benefits. Accordingly, the structure of this submodel is analogous to that of traffic described in section 5.1. The User may define exogenous cost/benefit "sets" as streams of costs and benefits applicable to specific links, with the streams being either normal or generated.

Normal Exogenous Costs/Benefits are the costs and benefits streams which would occur in the vicinity of the link regardless of any road improvements and which are not directly related to the road itself (construction or maintenance) such as the cost and benefit streams associated with the installation and operation of an irrigation system in an area already having raod access. The forecasts of normal exogenous cost and benefit streams may be provided in one of three ways:

a) The User may specify a one-shot lumb sum amount which would apply during the period being defined.

b) The User may alternatively specify a constant annual increment at which costs or benefits will increase each year during the period being defined.

c) The User may alternatively specify an annual percentage growth rate at which costs or benefits will grow during the period being defined.

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(1) Hide, H., S.W. Abaynayaka, I. Sayer, and R.J. Wyatt. The Kenya Road Transport Cost Study: research on vehicle operating costs. Department of the Environment, TRRL Report LR 672. Crowthorne, England, 1975 (Transport and Road Research Laboratory).

Normal costs/benefits sets are defined as applicable to only one link, due to their localized nature, and would be applied to that link as scheduled in the link-alternative. Costs and benefits are then aggregated over all normal cost/benefit sets active on the link in the current year.

Generated Exogenous Costs/Benefits are those cost and benefit streams which occur due to construction activities on the link, such as increased agricultural production and marketing caused by provision of an all-weather access road. The forecasts of generated exogenous cost and benefit streams may be provided in the same manner as for normal cost/benefit sets. Generated costs and benefits are then aggregated over all generated cost/benefit sets active on the link in the current year, and added to the normal cost and benefit totals to produce the total costs and benefits by cost component (financial, economic, and foreign exchange).

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III.9

AN APPLICATION OF THE ROAD INVESTMENT ANALYSIS MODEL TO THE EVALUATION OF THE REHABILITATION AND MAINTENANCE PROGRAM OF THE EGYPTIAN ROAD AND WATERWAY AUTHORITY

BY

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CHAPTER 1. INTRODUCTION

1.1 BACKGROUND

The road network in Egypt comprises over 26,000 kilometers of roads with approximately 12,000 km paved and 14,000 km unpaved. Intercity highway transportation is undoubtedly the predominant mode for freight transport, with estimates placing its share in 1975 at more than 80 percent of total freight tonnage and about 75 percent of ton-kilometers (1). This present predominance is caused, in part, by capacity limitations on both the railways and inland waterways and is expected to decrease in the medium term; nevertheless, highways will remain the principal means for freight transportation. Roads also dominate in intercity passenger transport, carrying around 56 percent of all passengers and 75 percent of all passenger - kilometers (1); this situation is expected to continue over the next decade.

The road system is on the average in relatively good condition (1), to a large extent due to the favorable climatic conditions throughout most of Egypt. Recent partial appraisal reports by independent consultants (1) have concluded that around 75 percent of the roads surveyed were in fair and fair - to - good condition, with about equal shares of 10 percent in good and poor condition, (the poorer conditions being concentrated in the less heavily trafficked paved roads). However, no exact specifications were presented by the consultants as to which parts of the road network were surveyed or the standards and methodology used in the evaluation, and the capabilities of the Egyptian Ministry of Transport to maintain the present system or expand the paved network in the coming decades has not been sufficiently addressed. The relative importance of the various links comprising the primary, secondary, tertiary, and feeder road networks to the overall performance of the road transport network are not well understood, nor is there agreement on the appropriate design and maintenance standards for the various classifications of links and upon criteria for

upgrading.

Aspects of the highway system deserving closer analysis include:

- Although pavement conditions are, on the average, relatively good, significant deterioration can be observed in heavy traffic areas and specific points such as railroad crossings, canal crossings, etc.
- Although all paved roads were originally furnished with rather wide shoulders of around 3m, subsequent "wear and tear" caused by agricultural and animal erosion has resulted in a considerable reduction of the usable surface, which is further complicated in some areas by the fact that trees have been planted on the shoulders of the older roads. Lack of maintenance has often caused the level of the shoulder to be considerably lower than that of the carriageway, causing crumbling of the pavement edges, deep furrows, and general unevenness. As a result, the shoulders of many roads have become practically unusable and broken down vehicles simply remain on the carriageway.
- Contrary to the pavement situation, road signalization and safety installations are generally highly inadequate, increasing hazard conditions and making reasonably safe night driving virtually impossible.
- Although rural roads provide, in general, year-round all-weather access to agricultural areas, exceptions are found in the Northern Delta Region where higher precipitation on soils of high plasticity can cause serious difficulties to traffic for one or two months each year.
- The unpaved components of the road system are currently not maintained at all, and therefore present considerable variability in surface conditions, which further complicates the decision on which links to upgrade through paving.
- Although the road system appears, in general, to provide sufficient capacity for the present and expected near - future volumes of traffic, attention should be called to the fact that the relatively

low value of road/population density (0.5 kilometers per 1000 inhabitants (1)) might determine some capacity limitations in the longer run, as rising standards of living and higher motorization ratios increase the demand for road space.

Given the above considerations and the limited resources available for road transportation investments, either in construction of new facilities, or the maintenance and upgrading of existing facilities. There is a growing need within the Egyptian Ministry of Transport for a hierarchy of analytic techniques capable of evaluating the capital budgeting and programming of alternative scenarios for major investments in expanding or upgrading the network; of analyzing the various interdependencies between alternative projects and maintenance policies of a road system; and of evaluating the economic consequences of alternative design, construction, and maintenance standards. The present Egyptian techniques for evaluation of transport investments and corresponding data inventories are rather inadequate for the application of analytic models for road investment evaluation.

1.2 ANALYTIC FRAMEWORK

While the concepts of project evaluation are fairly well understood and the techniques for their application well developed, the outcome of any one particular evaluation is still highly dependent upon, and often sensitive to, the degree of accuracy and oversimplification involved in assessing the various costs and benefits associated with the project, and even to the objectives of the project itself. Therefore, in preparing or evaluating proposals for road investments, project analysts must address a variety of issues, foremost among them being to identify the objectives of the project and the extent to which these objectives are achieved by a specific proposal. Among the objectives most frequently cited as justifying investments in roads are: (i) the provision of administrative and social services to isolated regions (national unity); (ii) access to areas with development potential (economic integration); (iii) increased transport capacity (economic expansion); and (iv) reduced trans-

port costs (economic efficiency). (2). A second area of concern to the analyst may be to evaluate the role of a particular link in the development and performance of the overall network; this type of analysis is of particular importance where a road will compete with other roads or other modes of transport -- now or in the future. A third area of concern may be to fit the project into an overall development program, both in terms of the various financial and human resources which it will require, and in terms of its overall objectives. A fourth concern may be to study the impacts of the investment program on such broad social and political issues as migration of population; the elimination of poverty; provision of basic services in health care, education, and nutrition, etc. The above issues constitute some of the broad range of topics which are generally considered in the planning and evaluation of road investments. Normally, they are considered in such a way that a variety of alternatives, together with their most relevant implications, are analyzed and presented to the ultimate decision-makers.

1.2.1. Network Evaluation

There is an important subject within the overall spectrum of issues which has generally been ignored by planners but which is of particular interest to road authorities -- investment in the development and upgrading of the road network, either through new network components, upgrading or reconstructing parts of existing network links, or maintaining existing and future facilities. Since changes in one part of a network modify the costs and benefits not only of the modified component or link, but also the economics of the network as a whole, decisions on investment alternatives should be based on an evaluation of the integrated operation of the entire network (3).

For example, in deciding which of several proposed network investment alternatives should be implemented, planners may compare the costs of using and maintaining the existing road system against the costs and benefits of constructing, maintaining, and using each of the proposed

alternatives. At a more detailed level, the road authority may be interested in the following issues; Do the proposed alternatives predict realistic maintenance requirements for the system? Is there any radical change in the traffic flow pattern which would require modifications to the proposed maintenance standards? Do the road investments last for their design lifetimes? Is the maintenance requirements pattern consistent with existing district organization, resources, and standards? Are sufficient material resources available at the indicated prices, or will scarcities arise? Each of the possible alternatives will have different implications for appropriate maintenance standards and organization, and, hence, for future maintenance financing, whether internal or external.

Tradeoffs similar to those described above may exist in conjunction with the timing or scaling of the proposed projects, or with the resultant traffic flow patterns. For example, a construction program which would tend to keep the link volumes in much the same ratios as the relative link structural numbers should result in the most uniform deterioration pattern, and hence be the most predictable in terms of maintenance requirements and schedulings.

1.2.2. Link Evaluation

Another important subset which has generally been ignored by social and transportation planners, but which is of particular importance to road authorities is the selection of appropriate design and maintenance standards. While the choice of standards is sometimes obvious, as in the construction of an unimproved track to provide basic access to an isolated and undeveloped region, there appears to be a broad range of projects where planners provide little or no guidance, and for which the choice of engineering standards has important budgetary and economic implications (4).

For example, in deciding whether to imporve an existing gravel road in order to reduce vehicle operating costs, planners may compare

the costs of using and maintaining the existing road against the costs and benefits of constructing, maintaining, and using the new paved road. If the economic return from paving the road is high enough, the project will be recommended.

At a more detailed level, however, the road authority may be interisted in the following issues: Should the road be surface-treated or paved with asphalt-concrete? What should be the thickness of the base, subbase, and surface courses, and what types of materials should be used? How long will the road last before improvements are required, and what will be the nature of these improvements? Can the life of the road be extended through improved maintenance? Each of the possible alternatives implies a different stream of construction and maintenance expenditures, and a different salvage value for the road at some specified future date. In addition, if the project is to be financed externally, the different alternatives may result in a different allocation of costs between the road authority and the lending agency. Similarly, if the road is allowed to deteriorate, there will be a shift in costs from the road authority (if deterioration is the result of low maintenance) or the lending agency (if deterioration is the result of an initial low design standard) to the road users. The extent of this shift will depend on how well the pavement was designed originally, and on the specified level of maintenance; the costs involved may, however, vary over a considerable range.

Tradeoffs similar to those described above may exist on other types of projects. For example, within new road construction it may be possible to vary geometric standards within a relatively broad range to achieve different tradeoffs between initial construction expense and the future costs of using the road. Each time a lower standard is considered, the designer is effectively shifting costs from the road authority to transporters, and, through increased tariffs, to the public. At some point there should be an overall minimum -- but whether or not this is the standard which is actually selected will depend upon whether there are sufficient available funds for construction and, more generally,

upon the manner in which government decision-makers choose to allocate costs between different parties in order to achieve social objectives.

Unfortunately, the practical difficulties of undertaking the above types of analysis on a comprehensive, project-by-project basis are enormous. Until recently, relatively little has been known about the relationship between design and maintenance standards, or their implications for maintenance and user costs. And while considerable attention has been focused on the problem of estimating construction costs, the resulting methods have been either simple and inaccurate, or overly detailed. In short, there hasn't been any practical way of analyzing a large number of engineering alternatives, or of accurately assessing their implications.

In summary, there appears to be a broad range of projects for which engineering solutions will have different implications for the timing and magnitude of project costs and benefits, and for the allocation of these costs and benefits among different groups -- including the road authority, lending agencies, transporters, and the population of the region to be served by the road. Unfortunately, road authorities have had relatively little guidance in, and have lacked the analytic methods for, making rational choices between different engineering possibilities.

1.3 PURPOSE AND SCOPE OF THE STUDY

The purpose of this research is to demonstrate the application of an existing analytic framework, the Road Investment Analysis Model, to road transport investment decisions in Egypt, to develop the necessary procedures for its modification to local Egyptian conditions, and to strengthen the Egyptian institutional capabilities for the analysis, planning, and programming of highway investments. Emphasis has been placed on the identification and resolution of the major issues confronting the establishment of appropriate maintenance and upgrading standards for Egypt.

Specifically, the work is building upon the recently completed MIT effort in Ethiopia by applying the developed framework and methodology to the following issues:

1) Economic evaluation of proposed projects (both new construction and upgrading of existing links
2) Economic evaluation of design and maintenance standards in the context of the larger road network
3) Development of projections of future maintenance requirements and traffic patterns
4) Recommendation of equipment required to develop and maintain the data inventory of the network condition and maintenance activities. This report describes the completed first phase of this work.

– The scope of the research effort during its first phase was restricted to the evaluation of road transport in a zone comprising roughly one-fourth of the paved road network of the Delta. Five reconstruction and subsequent maintenance policy alternatives were analyzed on each of twenty-five links independently. The five alternatives included do-nothing; a premix overlay followed by either scheduled or demand-responsive maintenance; and a double (asphalt over premix) overlay followed by either scheduled or demand-responsive maintenance. For each alternative and on each link economic analysis of net present value, first year benefits, and internal rate of return were performed against the do-nothing alternative. Where data were lacking or unreliable, surveys were undertaken or engineering judgments were used.

1.4 OUTLINE OF THE REPORT

Chapter Two presents an overview of the analytic framework, the Road Investment Analysis Model, used in the work. It summarizes its technical contents and capabilities, and highlights the assumptions, relationships, and data requirements of the various submodels used for construction, road deterioration and maintenance, vehicle operating costs,

traffic, and exogenous costs and benefits.

Chapter Three provides a summary of the data sources and collection techniques utilized for obtaining the parameters required by the analytic framework. The study area is defined and the reasons for its selection outlined. The results of existing design practice are presented for construction items; proposed maintenance unit costs and standards are developed; the results of vehicle operating cost surveys are given; and traffic count data and projections are developed.

Chapter Four presents the analysis which was performed and the results obtained. The economic indicators for the twenty-five link-evaluation applications of the Road Investment Analysis Model are presented, and their implications for estimation of appropriate design and maintenance standards analyzed. A discussion of the effects of uncertainty in the input parameters, especially the AASHO Regional Factor, is given. Four classes of link behavior under the proposed strategies are developed.

Chapter Five presents the conclusions obtained from the analysis of the preceeding chapter as regards the appropriateness of the construction standards and subsequent maintenance standards evaluated. The uncertainty of key data items is examined, and their effects on the results described. The implications of these analysis on the directions of future work conclude this result.

CHAPTER 2. OVERVIEW OF THE ROAD INVESTMENT ANALYSIS MODEL

2.1 INTRODUCTION

Initial development of the Road Investment Analysis Model (RIAM) was conducted at MIT starting in 1969, under the aegis of the World Bank's Highway Design Standards Study. This program, which was completed in 1971,[5] resulted in an integrated framework for relating construction, maintenance, and road user costs to proposed design and maintenance standards. A major conclusion of the study, however, was that there was very little empirical data available confirming either the hypothesized patterns of deterioration for different road surfaces, or the hypothesized relationships between design standards, surface condition, and road user costs. Subsequently, the Transportation and Road Research Laboratory (TRRL) in conjunction with the World Bank program, agreed to develop these relationships through extensive field studies in Kenya.[6,7] The specific objectives of the TRRL project were to measure the deterioration characteristics of low design standard roads, and the costs incurred in using these roads. This work was completed in 1974.

The deterioration relationships used in the current version of the RIAM incorporate the TRRL results from Kenya and modified relationships based on the AASHO Road Test.[8] The user cost relationships are based on the Kenya results and reflect free-flowing conditions, driver behavior, and the vehicle types typical of East Africa. In addition, the validity of the relationships is limited to well-engineered gravel roads and high-strength paved roads (modified sturctural number greater than 2.5)* To test these assumptions and limitations, the model will be applied to the Egyptian road network.

2.2 TECHNICAL CONTENT AND CAPABILITIES

The basic function of the Road Investment Analysis Model is to estimate construction, maintenance, and user costs for a road which is to be designed,

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* Modified structural number is a measure of pavement and subgrade strength. See section 2.4.1.

constructed, and maintained to specific standards, and subject to known traffic volumes and ancillary investments. This is done by simulating the life of the road from initial construction, through periodic upgrading, and through the annual cycle of use, deterioration, and maintenance. The basic structure of the model is shown in Figure 2-1. The simulation is accomplished by determining construction and maintenance activities to be peformed, and by estimating road conditions, traffic volumes, ancillary investments, and all associated costs on a year-by-year basis throughout the analysis period. The specific operations undertaken in each year are as follows:

- A construction submodel schedules projects, allocates a percentage of construction costs to the current year, and updates the status of the link and activates generated traffic and/or exogenous costs/benefits (if any) as projects are completed.

- A road deterioration and maintenance submodel estimates the average and final surface conditions for the year as a function of the initial design standard, last year's surface conditions, the volume and composition of the traffic during the current year, the local environment, and the specified maintenance policy. Surface deterioration may be estimated for both paved and unpaved roads.

- A user cost submodel estimates the costs of operating vehicles over the road as a function of surface type and condition, environment, design geometrics (grade, curvature, and width), and vehicle characteristics. Cost estimates are prepared for a fleet of vehicles representative of those which will actually be using the road.

- A traffic submodel estimates the current year's traffic volumes based on the previous year's traffic and the anticipated growth, by vehicle type, for both normal and generated traffic.

- An exogenous costs/benefits submodel estimates the current year's exogenous net costs based on the previous year's costs and benefits and their anticipated growth.

The results of the simulation include a record of the expenditures incurred by the road authority for capital improvements and maintenance; a record of the costs incurred by road users, both normal and generated; a detailed history of the status and deterioration of the road; and a history of the traffic volumes and ancillary investments. All estimates, other than for construction and ancillary investments, are made in terms of physical quantities, from which total costs are obtained by applying the appropriate unit rates. The model is, therefore, not dependent upon the use of a particular monetary system; nor is it affected by changes in relative prices. All costs are estimated in financial, economic, and foreign exchange terms.

An economic evaluation submode produces the requested annual reports for maintenance quantities and costs, user costs, and road conditions. In addition, it performs the economic evaluation of the requested alternatives, producing cost stream histories and economic indicators (net present value, rate of return, and first-year benefits) for each comparison.

The various submodels are described more fully in the following sections.

2.3 ROAD CONSTRUCTION

Projects may be scheduled for any year in the analysis period, and may consist of new construction, pavement reconstruction, widening, and so on. Projects may also be scheduled sequentially, as in staging, that is, a link may be constructed to a low standard initially, followed at a future date by pavement reconstruction, widening, realignment, or some other form of upgrading. Each project may affect any or all sections of the link, each having its own physical characterisitcs and design standards.

Construction costs are input by the User is financial, economic, and foreign exchange terms, along with salvage values, and the time distribution of these costs over the project duration. Generated traffic sets and/or generated exogenous costs/benefits sets are activated and assigned to the link upon completion of the project, if any have been defined by

Figure 2-1

DATA REQUIREMENTS

National or Regional Parameters

Design Standards
- Geometric standards
- Pavement sections
- Material characteristics

Maintenance Standards
- Routine Maintenance Criteria for Earth Gravel and Paved Roads
- Resurfacing Criteria

Highway Program Parameters

Construction Unit Costs
Maintenance Unit Costs
Basic Vehicle Ownership and Operating Costs

Project Parameters

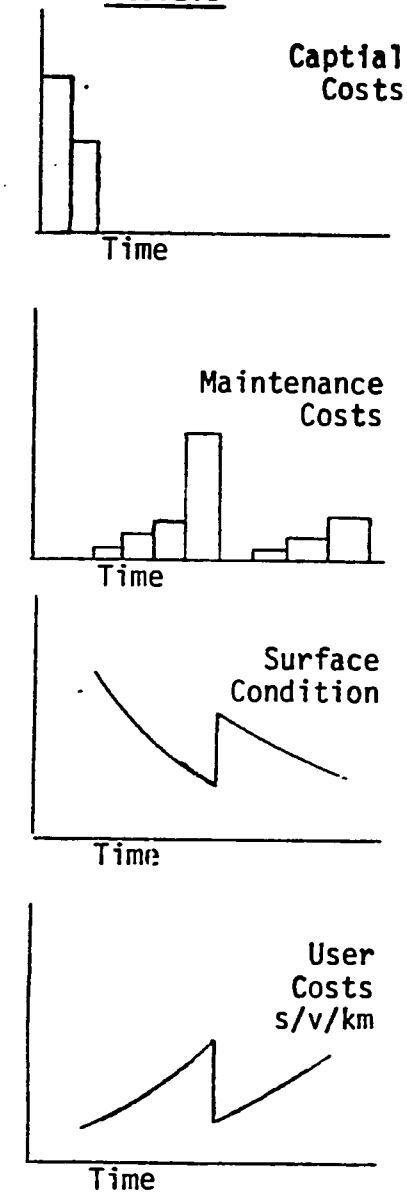
Traffic
Exogenous Costs/Benefits
Physical Characteristics of the Alignment
Specific Design and Maintenance Standards to be Studied
Schedule for Implementation

SIMULATION OF A LINK-ALTERNATIVE

For each year in analysis period:

- Estimate costs for road construction or upgrading based on design standards and construction unit costs
- Update the status of the road based on project completions
- Assign this year's traffic
- Assign this year's exogenous costs/benefits
- Estimate road deterioration, effects of maintenance, costs, and average surface conditions
- Estimate user costs based on geometric standards, surface type and surface condition
- Store results for evaluation phase

RESULTS



the User as generated by this project.

The data requirements of the road construction submodel consist of the cost of the project, in financial, economic, and foreign exchange terms; the distribution of these costs over the project duration; its salvage values; and the type of improvement and physical characteristics of the alignment, on a section-by-section basis.

2.3.1 Types of Improvement

The projects considered range from new construction to various forms of road improvement. The general characteristics of each project type are as follows, with data requirements summarized in TABLE 2-1:

a) New Construction: the construction of a road where none currently exists or where the only existing road is an unimproved earth road.

b) Pavement Overlay: a construction operation consisting only of placing additional material on the surface of the existing pavement and shoulders.

c) Pavement Reconstruction: includes the removal of part or all of the existing pavement structure, and the construction of new base and pavement layers.

d) Widening: includes additional site clearing and earthworks, and the extension of culverts and the pavement structure.

e) Widen and Reconstruct: involves a combination of pavement reconstruction and widening described above.

f) Realignment: consists of the construction of a new section of road to correct excessive curvature or grade in an existing alignment. Widening and/or pavement reconstruction may also be incorporated into this operation.

g) Abandonment: the removal of the road section from service.

2.3.2 Physical Features of the Alignment

Topography, climate, geology, and soil types jointly influence the choice of the most economical design, and the pattern of construction,

TABLE 2-1

DATA REQUIREMENTS FOR VARIOUS TYPES OF IMPROVEMENTS

Data Item	New Construction	Overlay	Pavement Reconstruction	Widen	Widen and Reconstruct	Realignment	Remove From Service
Location							
Length	X					X	
Start Station	X					X	
End Station	X					X	
Subgrade CBR	X					X	
Geometry							
Rise	X					X	
Fall	X					X	
Curvature	X					X	
Width	X			X	X	X	
Surfacing							
Surface type	X	X	X		X	X	
Surface thickness	X	X	X		X	X	
Shoulder type	X	X	X		X	X	
Shoulder thickness	X	X	X		X	X	
Structural number	X	X	X		X	X	
Deterioration type	X	X	X		X	X	
Condition							
Serviceability	X	X	X	X	X	X	
Roughness	X	X	X	X	X	X	

maintenance, and user costs incurred over the life of a road. Since individual characteristics may change, particularly over a long alignment, the model allows the project analyst to break each link into sections each with its own physical characteristics. The length of each section will roughly correspond to the distance over which all characteristics are reasonably similar. The specific variables relevant to the construction submodel are as follows:

a) Soil Support: soil strength is expressed as the California Bearing Ratio of the compacted subgrade.

b) Geometry: geometric features of the alignment include rise, fall, curvature, and width. Rise and fall are in m/km, curvature in ^{o}/km, and width in meters.

c) Surfacing: surfacing features are specified in terms of material type and thickness for the carriageway and shoulders, the pavement strength, and the deterioration type. The basic types of surfaces which may be considered include earth, gravel, asphaltic concrete, and bituminous treated roads. Material thicknesses are in millimeters, and pavement strength as structural number.

d) Condition: consists of initial roughness and, in the AASHO deterioration types, initial serviceability for paved roads only. Roughness is measured in millimeters per kilometer as measured by a fifth-wheel bump integrator towed at 30 km/hr (6) and serviceability is as defined by the AASHO Road Test (8).

2.3.3 Description

The construction submodel operates on all projects in one of three ways, depending upon the project status in the current year: (a) not active (either not yet scheduled or already completed); (b) ongoing, or (c) opening to traffic.

a) Inactive Projects: are ignored in the current year.

b) Ongoing Projects: are processed to determine the costs incurred during the current year, by cost component (financial, economic

and foreign exchange).

c) Projects Opening to Traffic: the physical characteristics of the affected link are modified to reflect the completed construction activities. The modifications which are made to the various sections of the link are dependent upon the type of construction which has occurred. In addition, if the project is to generate any traffic and/or exogenous cost/benefit sets, then the status of these sets is modified to "active" in the current year.

2.4 ROAD DETERIORATION AND MAINTENANCE

The road deterioration and maintenance submodel estimates the average and final surface conditions for the year as a function of the initial design standard, last year's surface conditions, the volume and composition of traffic during the current year, the local environment, and the specified maintenance policy. Surface deterioration may be estimated for paved and unpaved roads. A range of typical maintenance activities may be specified for each surface type on either a scheduled or demand responsive basis; these are priced in financial, economic, and foreign exchange terms according to the amount of maintenance which is actually performed. The maintenance cost is added directly to the total road cost. The condition of the road surface is used as an input to the user cost submodel for estimating road user costs. Thus, the surface condition predicted by the maintenance model affects the total road cost indirectly, but very importantly, through its effect on road user costs.

The four basic types of variables which affect the maintenance cost and surface condition are:

1) Environment

2) Traffic volume and composition

3) Characteristics of the constructed roadway

4) Proposed maintenance standards and unit costs

The costs of maintenance in each year are estimated based on the amount of maintenance performed and the appropriate unit costs, which reflect expenditures for labor, equipment, materials, and overhead.

Roadway surface condition is described in terms of roughness, rut depth, cracking and patching (paved roads only), and surface looseness depth (unpaved roads only). Also provided are the modified sturctural number of the section and the years since major maintenance was last performed. The surface condition parameters are computed for two subdivisions or seasons of each year: the dry season (when earth and gravel roads are dusty) and the wet season (when earth and gravel roads are not dusty). These parameters are used by the user cost model, along with curvature, grade, etc., to compute road user costs for each year.

Maintenance-deterioration estimates are made for the following categories of maintenance activities: paved surface maintenance; unpaved surface maintenance; and other maintenance, which includes shoulder maintenance, drainage maintenance, and vegetation control. The emphasis of the next sections is on paved surface deterioration and maintenance, as this is the area of primary interest in Egypt.

2.4.1 Paved Surface Deterioration

The deterioration of paved roads in handled in one of two ways, depending upon whether the base is granular or stabilized. For flexible pavements with granular bases, the general AASHO Road Test (9) results are used, with some modifications. For flexible pavements with stabilized bases, the TRRL Kenya (6) results are used. Since the AASHO design method is in use in Egypt, the AASHO deterioration relations are also used. These are described below.

Deterioration is predicted as a function of equivalent axle loads and modified structural number. The equations used to predict this deterioration are of the form of the general AASHO equation (8). Deterioration is initially predicted in terms of the AASHO concept of serviceability -- PSI. This serviceability measure is related to three quantifiable characteristics of the surface: slope variance (SV), rut depth

(RD), and the amount of cracking and patching (CP) by the equation (10):

$$PSI = 5.03 - 1.91 \, Log_{10} (1+SV) - 0.01 \sqrt{10 \cdot CP} - 1.38 \, RD^2 \qquad (2\text{-}1)$$

Deterioration is predicted as a drop in AASHO serviceability, PSI, for each year of the analysis period. The equation for estimating deterioration is the general AASHO equation (illustrated in Figure 2-2):

$$PSI(V,\overline{SN}) = 4.2 - 2.7 \, (1.58V \, [1 + \overline{SN}]^{-9.36})^{\text{exponent}} \qquad (2\text{-}2)$$

Where: $\text{exponent} = 0.40 + 1094 \, (1 + \overline{SN})^{-5.19}$

V = cumulative volume of equivalent standard axles

$\overline{SN}$ = modified structural number *

Using this predicted level of serviceability, the degree of deterioration measured in terms of slope variance, rut depth, and amount of cracking and patching is found using the relationships (illustrated in Figure 2-3) (11):

$$SV \left(\frac{mm^2}{m^2}\right) = 10^{(0.031 \, PSI^2 - 0.54 \, PSI + 2.3)} - 1 \qquad (2\text{-}3)$$

$$RD \, (mm) = (-0.03PSI^2 + 0.091 \, PSI + 0.032) \cdot 25.4 \qquad (2\text{-}4)$$

$$CP(\%) = [(0.3 \, PSI^3 - 1.3 \, PSI^2 - 6.2 \, PSI + 29)^2]/10 \qquad (2\text{-}5)$$

The roughness of the road is calculated from the slope variance, assuming a normal distribution of slopes, to yield (12):

$$ROUGH \, (mm/km) = 636.63 \sqrt{SV} \qquad (2\text{-}6)$$

*Modified sturctural number incorporates the effect of climate, drainage conditions, and subgrade support (as measured by the California Bearing Ratio). Two relations are available, one from the TRRL Kenya work:

$$\overline{SN} = SN + 3.51 \, Log_{10} \, CBR - 0.85 \, (Log_{10} \, CBR)^2 - 1.43$$

and the other from the AASHO Road Test:

$$(1 + \overline{SN}) = (1 + SN) * (REGFAC)^{-0.10684 + (CBR/2.69)^{0.14744}}$$

where REGFAC is the AASHO Regional Factor.

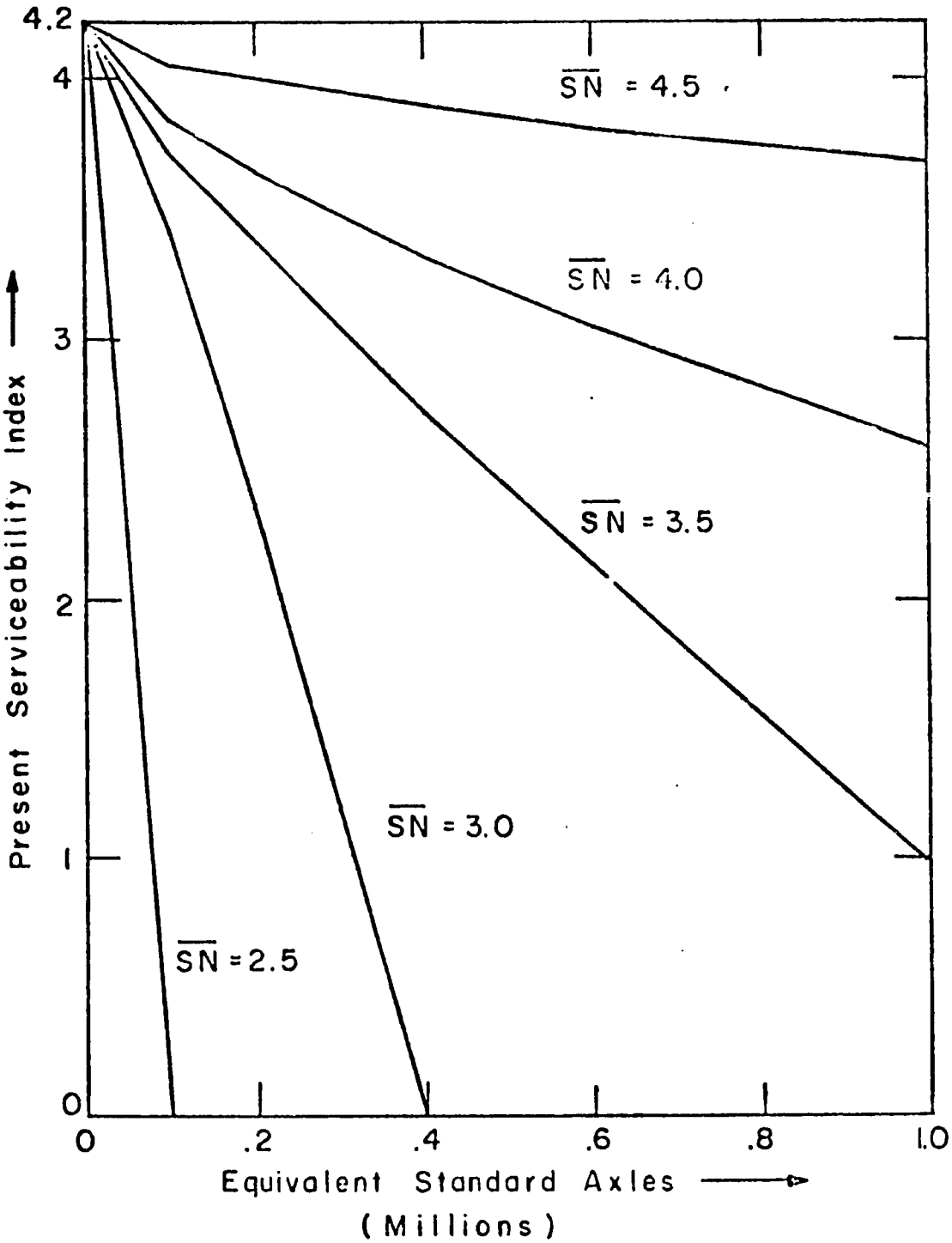


Figure 2-2 AASHO Serviceability Equation

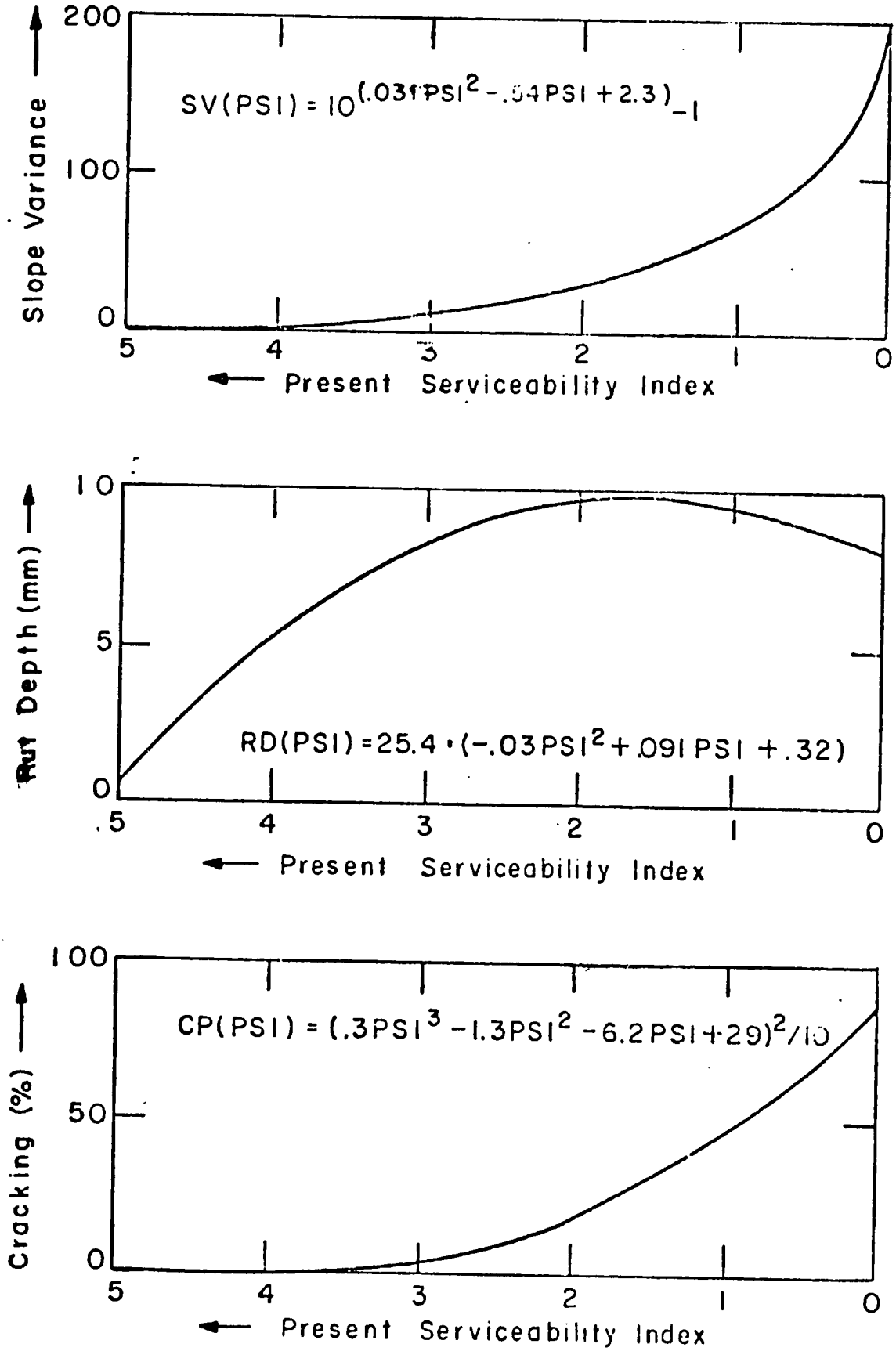


Figure 2-3 Damage Indicators vs. Serviceability

The deterioration of pavements with stabilized bases is based on the TRRL Kenya research on road deterioration (6) with little additional information being available. All the deterioration relationships are in the form of polynomial equations relating a surface condition variable to traffic loading for a range of modified structural numbers, which were further regressed in terms of the modified structural number.

2.4.2 Unpaved Surface Deterioration

Most of the deterioration relationships for unpaved roads were derived from the Kenya field data reported by TRRL (6). Traffic volumes were measured in terms of the total number of vehicles using the road since grading, so that no equivalence factors are employed. Also, pavement strength as measured by structural number, the essential feature of the paved road deterioration relationships, cannot be used as an index for unpaved roads, as material is constantly being lost from the surface. The roads have therefore been broadly classified according to gravel or earth type. All deterioration is measured from the last blading.

2.4.3 Maintenance Activities

Maintenance activities are the same for flexible pavements, regardless of base type, although the component costs may vary depending upon surface type. The maintenance adtivities included in the model for paved surfaces are:

1) Patching
2) Surface dressing
3) Overlaying
4) Rehabilitation
5) Miscellaneous

The maintenance activities included in the model for unpaved surfaces are:

1) Dry season grading
2) Wet season grading

3) Spot regravelling

4) Gravel resurfacing

5) Miscellaneous

The amount of maintenence work to be done during the year is determined by the deterioration parameters and the maintenance policy specified. TABLE 2-2 gives a review of the maintenance activities, and their units, which are included in the model.

2.5 VEHICLE OPERATING COSTS

The methods used to estimate vehicle operating costs reflect the geometric standards to which the road was constructed, the type of surface, and the current surface condition as determined through the interactions of pavement design, environment, maintenance policy, and the volume and composition of traffic. Operating costs are estimated by first determining the amount of resources consumed in vehicle operation, and then by applying appropriate factor prices. The output from the submodel consists of vehicle operating and travel time costs for the year, broken down by type of vehicle and cost category.

The four basic types of variables that effect vehicle operating costs are:

1) Road geometrics

2) Environment

3) Surface type and condition

4) Vehicle characteristics and costs

Vehicle operating costs are a function of road geometry, environment, surface type and condition, and the characteristics of the vehicles using the road. Because road gradients differ in each direction, the costs of vehicle operation are computed for both directions of travel and then averaged. In addition, because surface conditions on unpaved roads may vary on a seasonal basis, the costs of operation on unpaved roads are computed for each season and weighted by the season length to produce the average cost per kilometer. The surface conditions used represent the average conditions for each season (unpaved roads) or year (paved roads).

TABLE 2-2

Maintenance activities and units

Unpaved Road Sections	
Dry Season Grading	kilometers
Wet Season Grading	kilometers
Spot Regravelling	cubic meters
Gravel Resurfacing	cubic meters
Miscellaneous routine maintenance	kilometers
Paved Road Sections	
Patching	square meters
Surface Dressing	square meters
Overlaying	cubic meters
Rehabilitation	kilometers
Miscellaneous routine maintenance	kilometers

Costs are calculated in two categories: operating costs and travel time costs. Operating costs are those costs incurred through owning and operating the vehicle, and include fuel, oil, tires, maintenance parts and labor, depreciation, interest, overhead, and crew costs. Travel time costs are related to the time value of passengers and cargo holding costs. Costs are computed in financial, economic, and (in some cases) foreign exchange terms. Financial costs represent the actual costs incurred by owning and operating vehicles over the road. Economic costs represent the real costs to the economy of that ownership and operation. Foreign exchange costs represent the real costs to the economy which must be provided for in foreign currencies.

The outputs of the submodel are vehicle operating and travel time costs, total costs, and speeds, by road section and vehicle type.

2.5.1 Data Requirements

Cost and quantity estimates are made for the following elements of total vehicular costs: fuel consumption, oil consumption, spare parts, maintenance labor, depreciation, interest charges, overhead, crew costs, passenger time costs, and cargo holding costs. The specific variables required are as in TABLE 2-3. The various components of vehicle operating and travel time costs are summarized in TABLE 2-4. The specific relations used to estimate these costs may be found in Reference (4).

2.6 TRAFFIC

Up to twenty distinct sets of traffic estimates may be defined, with any combination of sets being assigned to a link. Each set must be either "normal" or "generated." Traffic is aggregated over all traffic sets which are active on the link in the current year, by vehicle class.

2.6.1 Normal Traffic

Normal traffic is that traffic which would use the link regardless of any road improvements. The forecasts for normal traffic volumes may be given in either of two ways in each of up to three periods of the analysis horizon:

TABLE 2-3

DATA REQUIREMENTS

	Coding or Units
Road Geometry	
1. Road Rise	meters per kilometer
2. Road Fall	meters per kilometer
3. Curvature	degrees per kilometer
4. Road Width	meters
Environment	
5. Elevation	meters
Surface Type and Condition	
6. Surface Type	paved or unpaved
7. Roughness	millimeters per kilometer
8. Rut depth	millimeters
9. Looseness	millimeters
10.- Moisture Content	percent
Vehicle Characteristics and Costs	
11. Vehicle Classification	*
12. Fuel Type	petrol or diesel
13. Brake Horsepower	BHP
14. Gross weight	metric tons
15. Equivalent Axle Factor	*
16. Cost of New Vehicle (F,E,X)	per vehicle
17. Tire Cost (F,E,X)	per tire
18. Fuel Cost (F,E,X)	per litre
19. Oil Cost (F,E,X)	per litre
20. Maintenance Labor Wage (F,E,X)	per hour
21. Crew Cost (F,E,X)	per hour
22. Value of Time (F,E)	per passenger hour
23. Overhead Costs (F,E,X)	annual or percent of operating costs
24. Interest Rate (F,E)	percent
25. Cargo Holding Costs (F,E,X)	per truck hour
26. Spare Parts Price Ratio (E/F, X/E)	*
27. Average Number of Passengers	integer
28. Annual Crew Hours	hours per year
29. Annual Operating Hours	hours per year
30. Annual Kilometers Driven	kilometers per year
31. Average Vehicle Life	years
32. Age Distribution	*
33. Annual Fleet Growth Rates	percent

*See Appendix A

TABLE 2-4

	Financial	Economic	Foreign Exchange
A. Running Costs			
1. Fuel	yes	yes	yes
2. Oil	yes	yes	yes
3. Tires	yes	yes	yes
4. Maintenance Parts	yes	yes	yes
5. Maintenance Labor	yes	yes	yes
B. Annual Fixed Costs			
6. Depreciation	yes	yes	yes
7. Financing Charges	yes	yes	no
8. Crew Costs	yes	yes	yes
9. Overhead Costs	yes	yes	yes
C. Travel Time Costs			
10. Passenger Time Costs	yes	yes	no
11. Cargo Holding Costs	yes	yes	yes

a) Annual percentage growth rate, by vehicle type.

b) Constant annual increment, by vehicle type.

The base year average daily traffic for each vehicle class must also be provided.

2.6.2 Generated Traffic

Generated traffic is that traffic which is drawn to the link due to changes in the travel costs of this link and/or neighboring links. In this sense, the term generated traffic includes both "generated" and "diverted" traffic, and benefits are calculated as one-half the reduction in operating and travel time costs. The forecasts of generated traffic volumes may be given in one of three ways in each of up to three periods of the analysis horizon:

a) Annual percentage growth rate, by vehicle type.

b) Constant annual increment, by vehicle type.

c) Percentage of current normal traffic, by vehicle type.

For generated traffic sets no base year average daily traffic is provided, since the year of generation may be tied to completion of construction projects. Therefore, the initial traffic period for generated traffic sets must be either option (b) or (c) above.

2.7 EXOGENOUS COSTS/BENEFITS

Exogenous costs and benefits sets are regarded as the parallel of traffic sets in that the same forces which give rise to traffic are often the same forces which give rise to production, and hence to exogenous costs and benefits. The User may define exogenous cost/benefit "sets" as streams of costs and benefits applicable to specific links, with the streams being either normal or generated. Costs and benefits are aggregated over all sets active on the link in the current year.

2.7.1 Normal Exogenous Costs/Benefits

Normal exogenous costs/benefits are those costs and benefits streams which would occur in the vicinity of the road regardless of any road

improvements, and which are not directly related to the road itself (construction or maintenance), such as the cost and benefit streams associated with the installation and operation of an irrigation system in an area already having road access. The forecasts of normal exogenous cost and benefit streams may be provided in one of three ways:

a) One-shot lump sum amount, by cost component.

b) Constant annual increment, by cost component.

c) Annual percentage growth rate, by cost component.

The base year costs and benefits are provided for each cost component (financial, economic, and foreign exchange).

2.7.2 Generated Exogenous Costs/Benefits

Generated exogenous costs/benefits are those cost and benefit streams which occur due to construction activities on the link, such as the increased agricultural production and marketing caused by provision of an all-weather access road. The forecasts of generated exogenous cost and benefit streams may be provided in the same manner as for normal cost/benefit sets. The base year costs and benefits are zero for generated sets, implying that the first period for generated costs and/or benefits cannot be percentage increase [type (c) above].

CHAPTER 3. DATA AVAILABILITY AND COLLECTION

3.1 DEFINITION OF THE STUDY AREA

The area chosen for study is flat, mainly cultivated land lying to the north of Cairo, which contains the Monofia and Qalubia Governorates road network (see Figure 3-1). This area was chosen for the study zone for the following reasons:

1) Availability of records concerning construction and maintenance of the road network.

2) Physical homogeneity of the link characteristics.

3) Diversity of traffic volumes and compositions providing a cross-section of the spectrum of traffic conditions found on the Egyptian road network.

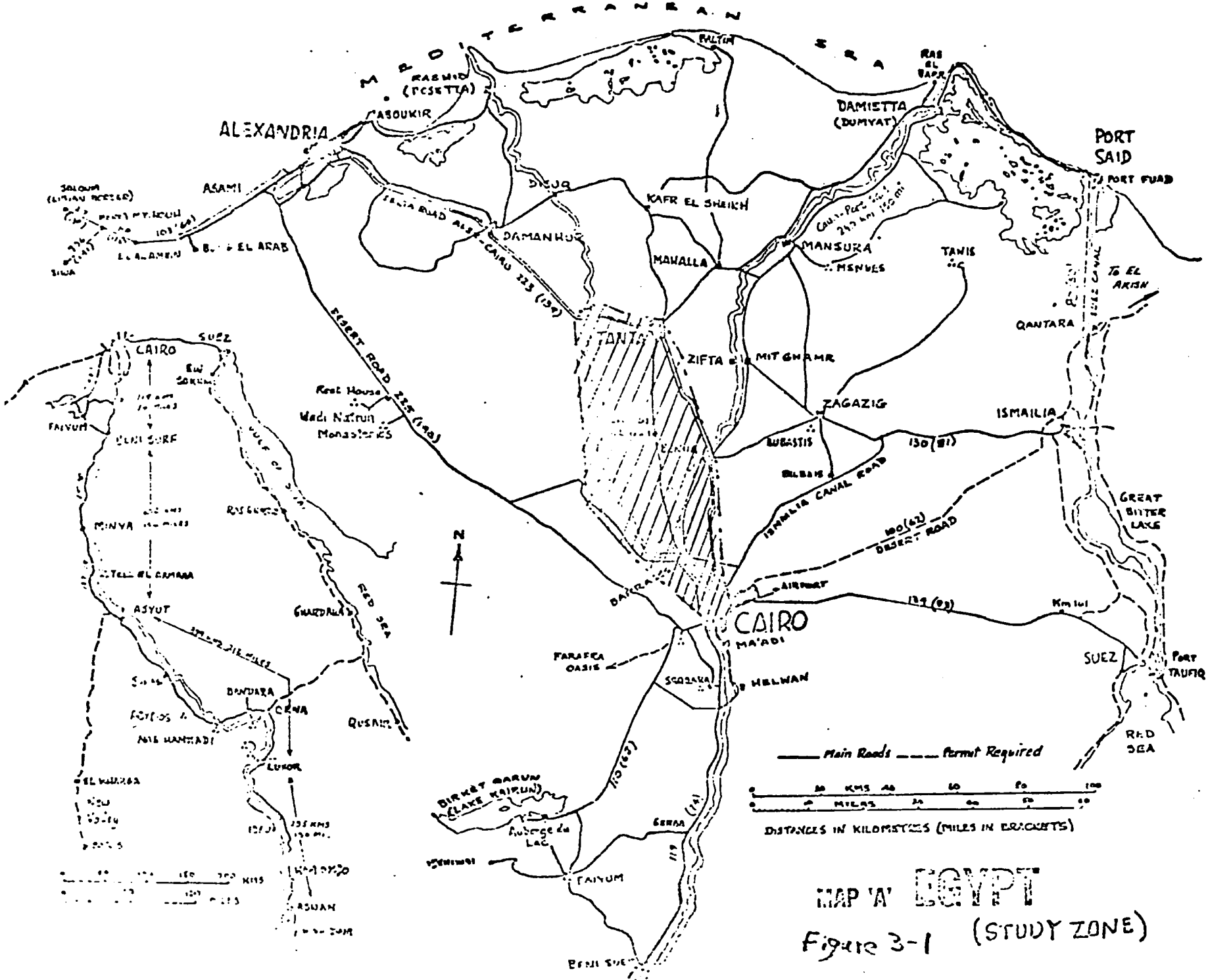
4) Possibility of a route-choice study, since the zone contains the Monofia highway, which parallels the Cairo-Alexandria agricultural expressway, and numerous perpendicular connecting links.

5) Economic importance of the road network to the highway authority in Egypt.

In order to produce a study of manageable size, given the time and resource constraints of this research effort, the study zone has been abstracted into the major links in the area bounded on the west and south by the roads on the west bank of the Rasheid Branch of the Nile between the towns of Tawfikieh, Tamaly, Khatatba, and Kanater, and on the east and north by the Cairo-Alexandria agricultural expressway, between the cities of Qalub (immediately north of Cairo) and Tawfikieh. The resulting network, comprising twenty-five links, is close to the maximum size which the model is capable of analyzing at present. Specific constraints considered in the choice of the links in this zone include:

1) The physical boundaries facilitate the definition of an external zoning system for the origin-destination flows;

2) The time and manpower requirements needed for data collection, which necessitated the elimination of unpaved roads from the



MAP 'A' EGYPT (STUDY ZONE)

Figure 3-1

study network;

3) The model's capabilities to analyze a specific number of links.

The idealized road network to be analyzed consists of the following links, which have been arranged in order of decreasing life-expectancy to facilitate the presentation of results:

1) Qalub -- Touck (QB-TK)
2) Touck -- Banha (TK-BN)
3) Tanta -- Tawfikieh (TN-TW)
4) Banha -- Quesna (BN-QS)
5) Quesna -- Berket-el-Saab (QS-BS)
6) Berket-el-Saab -- Tanta (BS-TN)
7) Quesna -- Shibean-el-Koam (QS-SH)
8) Bagour -- Tamaly (BG-TM)
9) Qalub -- Kanater (QB-KN)
10) Kanater -- Tamaly (KN-TM)
11) Kanater -- Biltan (KN-BL)
12) Biltan -- Touck (BL-TK)
13) Biltan -- Banha (BL-BN)
14) Ashmoon -- Santriss (AS-SN)
15) Shohda -- Babel (SD-BB)
16) Berket-el-Saab -- Shibean-el-Koam (BS-SH)
17) Babel -- Tanta (BB-TN)
18) Kanater -- Santriss (KN-SN)
19) Santriss -- Bagour (SN-BG)
20) Bagour -- Shibean-el-Koam (BG-SH)
21) Shibean-el-Koam -- Kom-el-Akder (SH-KM)
22) Kom-el-Akder -- Babel (KM-BB)
23) Banha -- Bagour (BN-BG)
24) Kom-el-Akder -- Shohda (KM-SD)
25) Tamaly -- Tawfikieh (TM-TW)

3.2 DATA ON EXISTING LINK CONDITIONS

Personnel within the Ministry of Transport gathered all data required to describe the existing link characteristics, the various items of which were obtained from the following sources:

1) Geometric data (road rise, road fall, horizontal curvature, and road length) were collected from field surveys and existing design drawings;

2) Soil data (subgrade CBR) were taken from previous tests executed during road construction;

3) Weather data (annual rainfall, dry and wet season lengths) were taken from the Department of Meteorology information;

4) Pavement data (surface type, shoulder and carriageway width and thickness, initial condition, structural number) were developed from construction records, measurements, and visual inspections.

5) AASHO Regional factors were assumed as unity except on the Cairo-Alexandria agricultural expressway, where they were taken as 0.55 to reflect the slower deterioration of the four-lane road (the model is calibrated to two-lane roads). In addition, three representative links in the secondary and tertiary classes were given regional factors of 0.55 to study the sensitivity of this parameter on road performance (see section 4.2.5).

The data collected were for road contition, road inventory, and geometric standard, and were dependent on the following:

1) Actual information taken from the field surveys and laboratory tests.

2) Adoption of the AASHO Interim Guide (9) methods for calculation of both the Equivalent Single Axle Load Factors and the Structural Number.

3) AASHO Road Test Results applied to pavement design in Illinois.

In determining the structural number (SN), the following equation was used:

$$SN = a_1D_1 + a_2D_2 + a_3D_3 \qquad (3\text{-}1)$$

where a_1, a_2, and a_3 are coefficients of relative strength of the surface, base, and subbase, respectively, and D_1, D_2, and D_3 are the thickness (in

inches) of the surface, base, and subbase, respectively, of the pavement structure. For the coefficients a_1, a_2, and a_3 the following tables were used:

- AASHO Interim Guide coefficients (TABLE 3-1)
- AASHO Road Test Results applied to pavement design in Illinois (TABLE 3-2).

For converting the traffic count data into equivalent 18-kip single-axle load applications, TABLE 3-3, taken from the AASHO Interim Guide was used.

The relevant data items for existing link conditions are summarized in TABLE 3-4.

3.3 CONSTRUCTION PROJECT DATA

Data on construction costs have been taken from recently completed highway project contract awards. Two construction projects were considered as applicable on all links: a premix overlay of sixty millimeters, and a double overlay consisting of a premix overlay of sixty millimeters followed by an asphalt concrete overlay of fifty millimeters. The quality control of the overlays was taken to be moderately poor, resulting in roughness measures after the overlays of 3500 mm/km for the premix overlay and 3000 mm/km for the asphalt concrete overlay. The duration of the projects were taken as one and two years, respectively. Economic costs were assumed to be ninety percent of financial costs, with foreign exchange costs twenty-two percent of economic costs. Salvage values were taken as sixty percent of the premix overlay costs and seventy percent of the double overlay costs. Costs for the double overlay are assumed to be distributed sixty percent in the first year and forty percent in the second year. The premix overlay resulted in an increase in pavement strength (structural number) of 0.80, while the double overlay added 1.68. The projects were scheduled to begin in 1980. The relevant data items are summarized in TABLE 3-5.

3.4 MAINTENANCE DATA

Maintenance data consists of maintenance policies, standards, and unit costs. The costs of maintenance operations in each year are estim-

TABLE 3-1

COEFFICIENTS OF RELATIVE STRENGTH OF PAVEMENT COMPONENTS

PAVEMENT COMPONENT	COEFFICIENT (3) a_1	a_2	a_3
Surface course:			
Road mix (low stability)	0.20		
Plantmix (high stability)	0.44 (4)*		
Sand asphalt	0.40		
Base course:			
Sandy gravel		0.07 (2)	
Crushed stone		0.14	
Cement treated (no. soil cement);			
650 psi or more (1)		0.23 (2)	
400 psi to 650 psi		0.20	
400 psi or less		0.15	
Bituminous treated:			
Course graded		0.34 (2)	
Sand asphalt		0.30	
Lime treated		0.15-0.30	
Subbase:			
Sandy gravel			0.11 (4)*
Sand or sandy-clay			.05-0.10

1. Compressive strength at 7 days
2. This value has been estimated from AASHO Road Test data, but not to the accuracy of those factors marked with an asterisk.
3. It is expected that each state will study these coefficients and make such changes as their experience indicates necessary. (Sources AASHO 127, P, 22)
4. After AASHO ROAD TEST Equation

TABLE 3-2

MINIMUM COEFFICIENTS FOR PAVEMENT STRUCTURE MATERIAL

MATERIALS	Min, Strength Requirements			Coefficients		
	MS	CBR	PSI	a_1	a_2	a_3
Bituminous surface subclass						
B-1, B-2; B-3 and B-4	300			0.2		
B-5 and I-1	900			0.3		
I-11	1,700			0.4		
Base Course						
Granular						
Gravel, Grade 7		50			0.10	
Gravel, Grade 9		70			0.12	
Crushed stone, Grade 8		90			0.13	
Water bound macadam		110			0.14	
Selected soil stabilized W/P6			300[c]		0.15	
Granular material stabilized W/PC plant mix			1450[c]		0.20	
			650[c]		0.23	
Granular material stabilized W/lime flyash			450[c]		0.20	
			650[c]		0.23	
Granular material stabilized W/bit materials						
Emulsified asphalts	300				0.16	
Liquid asphalts	400				0.18	
Paving asphalts	600				0.20	
	900				0.24	
PC concrete (new)	1,700		2,500[c]		0.50	
Subbase						
Gravel						
Grade 11		30				0.11
Grade 7		50				0.12
Grade 4		70				0.13
Crushed stone						
Grade 8		90				0.14

TABLE 3-3

AXLE LOAD EQUIVALENCY FACTORS

AXLE LOAD	Equivalent Factors *	
	Single Axles	Tandem Axles
2000 - 8000	0.0006	———
8000 - 16000	0.18	0.02
16000 - 20000	1.00	0.08
20000 - 24000	2.35	0.17
24000 - 30000	5.80	0.42
30000 - 34000	12.00	0.83
34000 - 38000	20.00	1.38
38000 - 44000	33.00	2.40
44000 - 48000	———	3.5
Passenger Cars	0.0002	

* Serviceability index expected to be reached at the end of the design period: 2.0.

The following assumptions have been adopted in calculating the number of equivale axle loads for each vehicle type:

Type of Vehicle	No. of Axles	Axle Load (lbs)	Equivalency Factor	
Private Cars	2	2000 - 8000	0.0012	
Inter-City Taxi	2	2000 - 8000	0.0012	
Buses	2	8000 - 16000	0.36	
Trucks	2	8000 - 16000	0.36	
Trucks with Trailer	4 { 2	8000 - 16000	0.36	1.20
	2 (tandem)	24000 - 30000	0.84	

Further study is needed to more accurately determine the average number of axles per vehicle and the average equivalency factors.

TABLE 3-4

EXISTING LINK CONDITIONS

No.	Link	Length (km)	Curve °/km	Carriage-way Width (m)	Shoulder Width (m)	Carriage-way Thick-ness (mm)	Shoulder Thickness (mm)	CBR	SN	Regional Factor	$\overline{SN}$
1	QB-TK	20	6	15	3	735	215	3	6.96	.55	7.62
2	TK-BN	15	6	15	3	710	215	3	5.08	.55	5.88
3	TN-TW	26	20	15	3	700	215	3	5.14	.55	5.65
4	BN-QS	12	18	15	3	675	215	3	4.62	.55	5.09
5	QS-BS	12	0	15	3	675	215	3	4.62	.55	5.09
6	BS-TN	20	0	15	3	675	215	3	4.62	.55	5.09
7	QS-SH	12	0	6	3	370	120	3	4.34	1	4.40
8	BG-TM	23	15	6	3	310	0	8	1.76	.55	3.20
9	QB-KN	9.6	12	7	3	380	0	3	2.80	1	2.90
10	KN-TM	56	8	6	3	350	170	5	.82	1	2.53
11	KN-BL	21.9	5	6	1	300	1	3	1.3	1	2.33
12	BL-TK	4	5	6	3	300	0	3	1.3	1	2.33
13	BL-BN	9.1	2	6	1	300	0	3	1.3	1	2.33
14	AS-AN	9	0	6	2	250	0	5	1.37	1	2.30
15	SD-BB	17	33	6	3	250	0	3	1.37	.55	2.25
16	BS-SH	12	36	6	3	250	0	3	1.37	1	2.05
17	BB-TN	11	0	6	3	200	0	3	1.62	.55	1.90
18	KN-SN	18	2	6	3	200	0	3	1.62	1	1.80
19	SN-BG	14	14	6	3	200	0	3	1.62	1	1.80
20	BG-SH	13	23	6	3	200	0	3	1.61	1	1.80
21	SH-KM	5	0	6	3	200	0	3	1.61	1	1.80
22	KM-BB	9	0	6	3	200	0	3	1.61	1	1.80
23	BN-BG	18	45	5	3	200	0	3	1.37	1	1.80
24	KM-SD	19	10	6	3	260	0	3	.82	1	1.80
25	TM-TW	36	8	6	3	310	170	5	1.37	1	1.60

TABLE 3-5

CONSTRUCTION DATA

	Premix Overlay (60 mm)	Double Overlay (110 mm) Premix(60mm)	AC(50mm)	Total
Cost per cubic meter in place: (L.E.)				
Financial	83.33	83.33	50.00	68.1[illegible]
Economic	75.00	75.00	45.00	61.36
Foreign Exchange	16.50	16.50	9.90	13.50
Project Duration (Years)	1	1	1	2
Cost Distribution	100	60	40	100
Salvage Value (%)	60		70	
Initial Roughness	3500		3000	
Incremental Structural Number	0.80		1.68	

ated based on the quantities of maintenance performed and the appropriate unit costs. These unit costs provide the breakdown of activity costs into labor, equipment, materials, and overhead components. Each of these components is further broken down into financial, economic, and foreign exchange costs. These costs are intended to represent national averages for the various activities, and were derived by Road and Waterway Authority personnel from existing maintenance records. The unit costs are summarized in TABLE 3-6.

Maintenance standards are composed of activity frequency schedules applicable to a specific surface type and traffic range (such as patching 50 sq.m/km/yr on an asphalt road). The model has incorporated four maintenance activities for both paved and unpaved roads into its structure, each of which may be scheduled or responsive in any given maintenance standard; and miscellaneous routine maintenance for both paved and unpaved roads, which is strictly scheduled at once per year. Scheduled maintenance activities are done at specific times, regardless of the state of roadway deterioration, while responsive maintenance activities are done when the roadway has deteriorated to a specific condition, regardless of the time at which that condition is reached.

Maintenance activities on paved roads include patching, surface dressing, overlaying, rehabilitation, and miscellaneous routine maintenance. Patching may be scheduled as square meters per kilometer per year to be patched, but not to exceed the area requiring patching; or responsive as the percentage of cracked area to be patched, subject to a maximum square meters per kilometer constraint. Surface dressing may be scheduled as the number of years between surface dressings; or responsive as the maximum tolerable percentage cracking, subject to minimum and maximum years between surface dressings constraints. Overlaying may be scheduled as the number of years between overlays; or responsive as the maximum tolerable roughness before overlay, subject to minimum and maximum years between overlay constraints. Rehabilitation may be scheduled as the number of years between rehabilitations; or responsive as the maximum tolerable roughness before rehabilitation, subject to minimum and maximum years between rehabilitations constraints. In addition, surface dressing

TABLE 3-6

MAINTENANCE UNIT COST

[Costs Per Application (not annual costs) in L.E.]

Maintenance Operation			Maintenance Unit Costs in Egyptian Pounds				
Description	Unit	Cost Type	Labor	Equipment	Materials	Overhead	Total
PATCHING	SQ.M.	Financial	00.30	0.70	0.90	0.10	2.00
		Economic	0.30	0.35	0.81	0.10	1.56
		Foreign Ex.	0.0	0.14	0.0	0.0	0.14
SURFACE DRESSING	SQ.M.	Financial	0.02	0.08	0.09	0.01	0.20
		Economic	0.02	0.04	0.81	0.01	0.15
		Foreign Ex.	0.0	0.02	0.0	0.0	0.02
OVERLAYING	CU.M	Financial	6.0	14.00	18.80	1020.00	40.00
		Economic	6.0	7.00	16.92	1020.00	31.12
		Foreign Ex.	0.0	5.60	0.0	0.0	5.60
REHABILITATION	KM	Financial	6400.0	11200.00	13440.00	960.00	32000.00
		Economic	6400.0	5600.00	12096.00	960.00	25056.00
		Foreign Ex.	0.00	4480.00	0.0	0.0	4480.00
ROUTINE MAINTENANCE PAVED ROAD	KM	Financial	1000.00	300.00	600.00	100.00	2000.00
		Economic	1000.00	90.00	540.00	100.00	1730.00
		Foreign Ex.	0.0	60.00	0.0	0.0	60.00

overlaying, and/or rehabilitation, whether scheduled or responsive, may be subjected to a last analysis year constraint. Miscellaneous routine maintenance is strictly scheduled at one time per year. Also, since actual costs per unit of activity may very depending upon region, terrain, activity frequency, level of activity, and/or other factors, each activity of each standard may be weighted by a cost adjustment factor which modifies the national unit costs for that activity.

Five maintenance standards were defined for analysis, as follows:

1) The existing standard (CAEX), consisting of routine patching of 10 sq.m./km/yr with surface dressing every two years;

2) A scheduled premix standard (HPMX), consisting of medium level patching of 50 sq.m/km/yr, surface dressing every two years, and overlay every ten years;

3) A scheduled asphalt concrete standard (HDAC), consisting of low level patching of 10 sq.m/km/yr, surface dressing every five years, and overlay every fifteen years;

4) A responsive premix standard (HRPM), consisting of patching 80% of new cracks, surface dressing when 8% of the roadway is cracked, and overlay at a roughness of 3500 mm/km;

5) A responsive asphalt concrete standard (HRAC), consisting of patching 80% of new cracks, surface dressing when 5% of the roadway is cracked, and overlay at a roughness of 3000 mm/km.

The cost adjustment factors for the activities of the various standards reflect engineering judgements. These five standards were grouped into three maintenance policies: existing (CAEX), scheduled (HSCH), and responsive (HRSP). The maintenance standards are summarized in TABLE 3-7.

3.5 VEHICLE CHARACTERISTICS DATA

The available data items regarding vehicle characteristics and costs were initially derived from the Berger-Dorsch Egypt National Transport Study, Phase I, interim report (1). The vehicle classification scheme of the RIAM proposes five different vehicle categories to be distributed among up to seven vehicle types: Passenger cars, Light goods vehicles,

TABLE 3-7

MAINTENANCE STANDARDS

Standard ID: CAEX

1. Surface type: EXIS

This standard applies to Traffic range 0 - ***** ADT.

No.	Maintenance Activity	Unit	Standard	Cost Adjustment Factor
6	Patching	SQ.M.	Patch 10 SQ.M/KM/YR	1.10
7	Surface Dressing	SQ.M.	Surface dressing every 2 years but not after analysis year 18	0.20
10	Routine Maintenance Paved Road	KM	Includes drainage, vegetation, shoulder, and miscellaneous activity	1.00

MAINTENANCE STANDARDS

Standard ID: HPMX

2. Surface type: HPMX

This standard applies to Traffic range 0 - ***** ADT.

No.	Maintenance Activity	Unit	Standard	Cost Adjust-Ment Factor
6	Patching	SQ.M.	Patch 50 SQ.M/KM/YR	1.00
7	Surface Dressing	SQ.M.	Surface dress every 2 years but not after analysis year 19	1.00
8	Overlaying	CU.M.	Overlay every 10 years but not after analysis year 18 using ashpalt paving of 40. MM	1.00
10	Routine Maintenance Paved Road	KM	Includes drainage, vegetation shoulder, and miscellaneous activity	1.00

TABLE 3-7 (cont'd)
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MAINTENANCE STANDARDS

Standard ID: HDAC

3. Surface type: HQAC
This standard applies to Traffic range 0 - ***** ADT.

No.	Maintenance Activity	Unit	Standard	Cost Adjustment Factor
6	Patching	SQ.M.	Patch 10 SQ.M/KM/YR	1.00
7	Surface Dressing	SQ.M.	Surface dress every 5 years but not after analysis year 19	1.00
8	Overlaying	CU.M.	Overlay every 15 years but not after analysis year 17 using asphalt paving of 40.MM	1.00
10	Routine Maintenance Paved Road	KM	Includes drainage, vegitation, shoulder, and miscellaneous	1.00

MAINTENANCE STANDARDS

Standard ID: HRPM

4. Surface type: HPMX
This standard applies to Traffic range 0 - ***** ADT.

No.	Maintenance Activity	Unit	Standard	Cost Adjustment Factor
6	Patching	SQ.M.	Patch 80% of unpatched cracks but not more than 150 SQ.M/KM/YR	1.00
7	Surface Dressing	SQ.M.	Surface dress when C+P exceed 8% but not less than 1 years/dressing; but not more than 5 years/dressing; but not after analysis year 18	1.00
8	Overlaying	CU.M.	Overlay when roughness exceed 3500 MN/KM. But not less than 5 years/overlay; but not more than 10 years/overlay; but not after analysis year 18 using asphalt paving of 40.MM	1.00
10	Routine Maintenance Paved Road	KM	Includes drainage, vegetation, shoulder, and miscellaneous activity	1.00

TABLE 3-7 (cont'd)
Page 3.

MAINTENANCE STANDARDS

Standard ID: HRAC

5. Surface type: HQAC
This standard applied to Traffic range 0 - ***** ADT.

No.	Maintenance Activity	Unit	Standard	Cost Adjustment Factor
6	Patching	SQ.M.	Patch 80%of unpatched cracks but not more than 50 SQ.M/KM/YR	1.00
7	Surface Dressing	SQ.M.	Surface dress when C+P exceeds 5% but not less than 1 years/ dressing; but not more than 5 years/dressing; but not after analysis year 19	1.00
8	Overlaying	CU.M.	Overlay when roughness exceeds 3000 MM/KM but not less than 5 years/overlay, but not more than 10 years/overlay, but not after analysis year 18, using asphalt paved of 40.MM	1.00
10	Routine Maintenance Paved Road	KM	Includes drainage, vegitation, shoulder and miscellaneous activity.	1.00

Buses, Medium good vehicles, and Heavy goods vehicles. In view of the nature of the different types of vehicles operating on the road network in Egypt, the following classification was introduced.

A. Passenger cars

The passenger cars under the proposed RIAM scheme include passenger vehicles seating not more than nine passengers. Estate cars, taxis, and hired cars are also included, but not "Land-Rover" or mini-bus types of vehicles. The data provided by the Berger report, however, illustrates some basic differences between the operating characterisitcs of private cars and inter-city taxi cabs (ICTC). This is primarily due to the annual kilometrage of each type, which was estimated to be over 100,000 km for ICTC, whereas for private cars this would normally not exceed 15,000 km. Hence, it was considered appropriate to include two types of passenger cars in the analysis:

(i) Private cars: includes all passenger vehicles having a plate number with "P" registration.

(ii) Inter-city taxi cabs: includes all non-metered taxis operating outside urban areas.

B. Light goods vehicles

The Berger report indicates that this category of vehicles does not represent any appreciable percentage of the Egyptian vehicle fleet. This type was not, therefore, considered in the present study.

C. Buses, Medium goods, and Heavy good vehicles

These vehicle types were analyzed in accordance with the requirements of the RIAM classification.

3.5.1 Operating Costs

As previously mentioned, the preliminary data concerning the vehicle operating costs were taken directly from the Berger report. As the

accuracy of these data limited model application, the Transport Planning Authority decided to carry out a detailed study, whose objective was the achievement of realistic figures concerning the operating costs of the different vehicle types.

The first phase of this investigation was directed towards the operating costs of the inter-city taxis, followed by surveys of inter-city freight transport lorries and inter-city passenger transport buses. The results are summarized in TABLE 3-8. Surveys of the remaining vehicle types are currently being planned. Detailed results of the surveys may be found in Appendix B.

The data as it was presented to the analysis is as shown in TABLE 3-9 for all five vehicle types.

3.6 TRAFFIC DATA

Traffic counts have been carried out on all links in the study zone for a period of one week. The results of this survey have been converted to annual daily traffic volumes for each of the five vehicle classes representative of the Egyptian fleet:

1) 1.2 Liter Car
2) 2 Liter Inter-city Taxi
3) 42 Passenger Bus
4) 9 Ton Truck
5) 20 Ton Truck with Trailer

The resulting link volumes and compositions are presented in TABLE 3-10, along with their projected growth rates.

TABLE 3-8

FINANCIAL OPERATING COST/VEHICLE (L.E./YEAR)

Item	Inter-City Taxi	Lorry	Bus
Fuel	732.0	787.5	750.0
Oil	13.3	250.0	105.0
Lubrication	28.0	100.8	20.0
Tires	311.9	2363.0	900.0
Batteries	—	72.0	72.0
Spare Parts	250.0	2100.0	2600.0
Service Parts	—	210.0	—
Driver	500.2	1368.0	1200.0
Helper	—	504.0	—
Conductor	—	—	864.0
Operation and Traffic	—	—	456.0
Maintenance Labor	332.0	564.0	2184.0
Administration	154.8	684.0	1008.0
Non-skilled Labor	—	—	456.0
Overheads	316.8*	945.0	1000.0
Insurance	—	600.0	640.0
License	120.0	616.0	260.0
Depreciation	856.0	3662.5	4050.0
Interest	291.0	1360.0	1742.5
TOTAL	3906.0	16086.8	18307.5
Annual kilometers	(70,180)	(70,000)	(100,000)
Cost per/km	.056	.230	.183

* Includes fines, garage, and parking costs

TABLE 3-9

VEHICLE CHARACTERISTICS AND COSTS

Costs in Egyptian Pounds

A. VEHICLE DESCRIPTION

NAME	1.2L-CAR	2L-INTC	42P-BUS	9TTR	20TTT
Vehicle Type Code	1	1	3	4	5
Fuel Type	gasoline	gasoline	diesel	diesel	diesel
Brake Horsepower	50.00	100.00	280.00	260.00	520.00
Gross Veh. Wght. (Metric ton)	1.5	3.00	10.00	10.00	18.60
Axel Equivalency Factor	0.01	0.01	0.36	0.36	1.20

B. FINANCIAL COSTS (L.E.)

New Vehicle	3400.00	7000.00	24000.00	20500.00	27700.00
Cost/tire	25.00	38.00	85.00	96.00	96.00
Maintenance Labor Cost/Hr	0.40	0.40	0.40	0.40	0.40
Crew Cost/Hr	0.0	0.20	0.60	0.52	0.68
Value of time/Hr	0.0	0.0	0.0	0.0	0.0
Annual Overhead Costs. (Tot.)	0.0	0.0	0.0	0.0	0.0
Annual Overhead Costs % of Operating Costs	3.0	5.00	25.0	20.0	20.0
Interest Rate (%)	8.5	8.5	8.5	8.5	8.5

Fuel & Lubricants (Cost/litres)

Petrol = 0.08

Diesel fuel = 0.02

Engine oil = 0.27

TABLE 3-3 (cont'd)
Page 2.

C. ECONOMIC COSTS

NAME	1.2L-CAR	2L-INTC	42P-BUS	9TTR	20TTT
New Vehicle	1530.00	3500.00	19200.00	15200.00	20500.00
Cost/tire	17.50	25.00	60.00	69.00	69.00
Maintenance Labor Cost/Hr	0.40	0.40	0.40	0.40	0.40
Crew Cost/Hr	0.0	0.20	0.60	0.52	0.68
Value of time/Hr	0.0	0.0	0.0	0.0	0.0
Annual Overhead Costs (tot.)	0.0	0.0	0.0	0.0	0.0
Annual Overhead Costs % of Operating Costs	0.0	2.0	20.00	15.00	15.00
Interest Rate (%)	12.0	12.0	12.00	12.00	12.00
Ratio of Spare Parts to New Vehicle Costs	0.8	0.8	0.8	0.8	0.8

Fuel and Lubricants (cost/liter)

Petrol = 0.04
Diesel fuel = 0.02
Engine oil = 0.27

D. FOREIGN EXCHANGE COMPONENT OF ECONOMIC COSTS

New Vehicle	1350.00	3500.00	19200.00	13500.00	18500.00
Cost/tire	5.00	6.00	18.0	21.00	21.00
Maintenance Labor Cost/Hr	0.0	0.0	0.0	0.0	0.0
Crew Cost/Hr	0.0	0.0	0.0	0.0	0.0
Annual Overhead Costs (tot.)	0.0	0.0	0.0	0.0	0.0
Annual Overhead Costs % of Operating Costs	0.0	0.0	0.0	0.0	0.0
Ration of Spare Parts to New Vehicle Cost	0.90	0.90	0.90	0.90	0.9

Fuel and Lubricants (cost/liter)

Petrol = 0.0
Diesel fuel = 0.0
Engine oil = 0.0

TABLE 3-9 (cont'd)
Page 3.

E. VEHICLE UTILIZATION

NAME	1.2L-CAR	2L-INTC	42P-BUS	9TTR
Average No. of Passengers per Vehicle	3	6	37	0
Annual Crew Hours	0	2500	2000	2000
Annual Operating Hours	700	2000	1200	1200
Annual Kilometers Driven	12500	70180	60000	55000
Average Vehicle Life (Years)	12	8	10	11

F. VEHICLE AGE DISTRIBUTION

	VEHICLE TYPE			
AGE (Yrs)	CARS	LIGHT COMMERCIAL	BUSES	HEAVY GOODS
1	18.2	18.2	15.4	15.4
2	16.4	16.4	14.1	14.1
3	14.5	14.5	12.8	12.8
4	12.7	12.7	11.5	11.5
5	10.9	10.9	10.3	10.3
6	9.1	9.1	9.3	9.0
7	7.3	7.3	7.7	7.7
8	5.5	5.5	6.4	6.4
9	3.6	3.6	5.1	5.1
10	0.0	0.0	3.8	3.8
11	0.0	0.0	2.6	2.6
12	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0

TABLE 3-10

BASE YEAR VOLUMES (1977) AND ANNUAL GROWTH RATES

LINK NO.	I.D.	CAR	INTC	BUS	TRUCK	TRUCK & TRAILER
1	QB-TK	12949	7962	1008	4240	1828
2	TK-BN	13152	7775	1008	4240	1828
3	TN-TW	5951	4766	564	2998	1484
4	BN-QS	5978	3713	552	2194	820
5	QS-BS	8174	4556	552	2124	820
6	BS-TN	6183	4477	552	2124	820
7	QS-SH	996	465	337	499	90
8	BG-TM	582	387	157	350	111
9	QB-KN	861	320	153	285	34
10	KN-TM	357	128	44	309	442
11	KN-BL	1354	153	82	512	386
12	BL-TK	362	41	32	622	172
13	BL-BN	1354	153	82	512	386
14	AS-SN	932	197	138	472	121
15	SD-BB	396	58	73	203	32
16	BS-SH	388	447	259	663	145
17	BB-TN	756	443	153	285	34
18	KN-SN	2149	370	469	537	175
19	SN-BG	1898	622	469	537	175
20	BG-SH	382	611	154	265	145
21	SH-KM	756	443	153	285	34
22	KM-BB	756	443	153	285	34
23	BN-BG	132	198	103	195	81
24	KM-SD	434	62	73	203	32
25	TM-TW	319	160	182	718	601

ANNUAL GROWTH RATES (%)

YEAR	PASSENGER CAR	INTC	BUS	TRUCK	TRUCK & TRAILER
1977-1987	6	6	6	4	4
1988-1997	8	8	8	5	5

CHAPTER 4. ANALYSIS AND RESULTS

4.1 ANALYSIS

Five alternatives were analyzed for each of the twenty-five links in the study zone. These were:

1) No construction and the existing maintenance policy, EXIS: (low patching, surface dressing every 2 years);
2) A 60mm premix overlay in 1980 followed by a scheduled premix maintenance policy, PMXS: (medium patching, surface dressing every 2 years, and overlay every 10 years);
3) A 110mm double overlay (asphalt concrete over premix) in 1980-81 followed by a scheduled asphalt concrete maintenance policy, HACS: (Low patching, surface dressing every 5 years, and overlay every 15 years);
4) A 60mm premix overlay in 1980 followed by a responsive premix maintenance policy, PMXR (patching 80% of new cracks, surface dressing when 8% of the roadway is cracked or patched, and overlay at a roughness of 3500 mm/km); and
5) A 110mm double overlay (asphalt concrete over premix) in 1980-81 followed by a responsive asphalt concrete maintenance policy, HACR: (patching 80% of new cracks, surface dressing when 5% of the roadway is cracked or patched, and overlay at a roughness of 3000 mm/km).

Traffic on the links was as given in Table 3-10. No exogenous costs or benefits were included in the analysis. The existing maintenance policy was assumed to hold until completion of the construction activities (1981 for the premix overlay, 1982 for the double overlay) in all cases. The analysis horizon was 19 years, from 1977 to 1995.

4.2 RESULTS

The economic results of these alternatives are summarized in Table 4-1, which presents the construction, maintenance, vehicle operating, and

total economic costs for each link-alternative, discounted to 1977 at 12% (the nominal social cost of capital in Egypt). The net present values of the various alternatives are obtained as the difference between the total costs of the existing option (EXIS) and the various overlay options.

Inspection of Table 4-1 suggests that the study zone contains four classes of links (with respect to the proposed alternatives). These are:

1) Links for which the proposed investments may be postponed;
2) Links for which the proposed investments are adequate;
3) Links for which the proposed investments are marginal; and
4) Links for which the proposed investments are inadequate.

These are examined in depth below.

4.2.1 Links with Postponable Overlays

These seven links, which represent the structurally strongest links in the study zone (as measured by modified structural number), at first glance at Table 4-1 appear to have responded extremely favorably to the proposed investments, since reductions in total costs for the various overlay options are quite large. However, as may be seen from Figure 4-1, it is not the construction overlays which make for the majority of these savings, but rather the savings produced by future overlays done through maintenance. Figure 4-1 presents the total net benefits for the four alternatives (discounted to 1977 value at 12%) on a year-by-year basis for a typical link in this group, Tanta-Tawfikieh (TNTW). From this figure, one can see that the proper timing of any overlay is dependent on its cost, and the road surface conditions before and after the overlay. The present worth difference between the asphalt concrete and premix operating benefits is 2 million Egyptian pounds in 1982 (the first year in which both overlays would be open to traffic) which reflects a roughness difference of 500 mm/km between the two surfaces. As the present worth of the construction cost differences is roughly one-fourth this amount, the initial asphalt concrete overlay will always be superior to the initial premix overlay for links within this group. The best alternative will of course depend upon the subsequent

TABLE 4-1
ECONOMIC COST SUMMARY
(Million Egyptian Pounds Discounted at 12%)

No.	Link	Alt.	Construction Costs	Maintenance Costs	Vehicle Operating Costs	Total Costs	Net Present Value*
1	QBTK	EXIS	0.000	0.330	201.138	201.468	0.000
		PMXS	0.843	0.494	220.365	221.702	-20.234
		HACS	1.174	0.338	210.866	212.379	-10.911
		PMXR	0.843	0.502	196.842	198.187	3.281
		HACR	1.174	0.460	185.832	187.467	14.001
2	TKBN	EXIS	0.000	0.247	214.446	214.694	0.000
		PMXS	0.632	0.371	178.124	179.128	35.566
		HACS	0.881	0.254	165.775	166.910	47.783
		PMXR	0.632	0.409	155.996	157.038	57.655
		HACR	0.881	0.349	145.514	146.745	67.949
3	TNTW	EXIS	0.000	0.423	245.286	245.710	0.000
		PMXS	1.096	0.642	202.263	204.002	41.708
		HACS	1.526	0.433	188.298	190.258	55.452
		PMXR	1.096	0.700	177.817	179.614	66.096
		HACR	1.526	0.597	166.440	168.564	77.146
4	BNQS	EXIS	0.000	0.198	86.087	86.285	0.000
		PMXS	0.506	0.297	67.781	68.585	17.700
		HACS	0.705	0.203	63.610	64.518	21.767
		PMXR	0.506	0.327	59.574	60.407	25.878
		HACR	0.705	0.279	55.988	56.971	29.314
5	QSBS	EXIS	0.000	0.198	98.047	98.244	0.000
		PMXS	0.506	0.297	76.098	76.900	21.343
		HACS	0.705	0.203	71.199	72.106	26.138
		PMXR	0.506	0.327	66.424	67.256	30.987
		HACR	0.705	0.279	62.207	63.190	35.054
6	BSTN	EXIS	0.000	0.330	153.521	153.851	0.000
		PMXS	0.843	0.495	119.154	120.492	33.358
		HACS	1.174	0.338	111.419	112.932	40.919
		PMXR	0.843	0.545	103.864	105.252	48.599
		HACR	1.174	0.464	97.193	98.831	55.020
7	QSSH	EXIS	0.000	0.184	15.355	15.538	0.000
		PMXS	0.202	0.227	12.965	13.394	2.144
		HACS	0.282	0.186	12.144	12.611	2.927
		PMXR	0.202	0.230	12.180	12.612	2.926
		HACR	0.282	0.215	10.949	11.445	4.093

TABLE 4-1 (cont'd)

Page 2.

No.	Link	Alt.	Construction Costs	Maintenance Costs	Vehicle Operating Costs	Total Costs	Net Present Value*
8	BGTM	EXIS	0.000	0.348	33.150	33.498	0.000
		PMXS	0.388	0.432	28.025	28.845	4.653
		HACS	0.540	0.355	23.862	24.758	8.741
		PMXR	0.388	0.551	23.408	24.347	9.151
		HACR	0.540	0.416	21.671	22.627	10.872
9	QBKN	EXIS	0.000	0.146	11.588	11.734	0.000
		PMXS	0.162	0.188	8.686	9.035	2.699
		HACS	0.225	0.149	8.156	8.530	3.204
		PMXR	0.162	0.206	7.565	7.933	3.801
		HACR	0.225	0.178	7.464	7.867	3.867
10	KNTM	EXIS	0.000	0.845	93.986	94.830	0.000
		PMXS	0.944	1.030	93.939	95.914	-1.084
		HACS	1.315	0.859	90.856	93.029	1.801
		PMXR	0.944	1.177	92.284	94.405	0.425
		HACR	1.315	1.249	82.051	84.614	10.216
11	KNBL	EXIS	0.000	0.327	46.920	47.248	0.000
		PMXS	0.369	0.394	46.721	47.485	-0.237
		HACS	0.514	0.332	46.437	47.284	-0.036
		PMXR	0.369	0.447	45.785	46.602	0.646
		HACR	0.514	0.454	41.521	42.490	4.758
12	BLTK	EXIS	0.000	0.060	5.251	5.311	0.000
		PMXS	0.067	0.074	5.228	5.369	-0.058
		HACS	0.094	0.061	5.147	5.303	0.008
		PMXR	0.067	0.085	5.056	5.209	0.102
		HACR	0.094	0.086	4.468	4.648	0.663
13	BLBN	EXIS	0.000	0.137	19.577	19.713	0.000
		PMXS	0.153	0.165	19.494	19.811	-0.098
		HACS	0.214	0.139	19.375	19.727	-0.014
		PMXR	0.153	0.187	19.103	19.443	0.270
		HACR	0.214	0.190	17.323	17.726	1.987
14	ASSN	EXIS	0.000	0.136	13.375	13.511	0.000
		PMXS	0.152	0.166	13.369	13.687	-0.176
		HACS	0.211	0.138	12.279	12.629	0.882
		PMXR	0.152	0.189	13.089	13.430	0.081
		HACR	0.211	0.197	9.995	10.403	3.108
15	SDBB	EXIS	0.000	0.256	9.825	10.081	0.000
		PMXS	0.287	0.314	9.248	9.849	0.233
		HACS	0.399	0.261	8.274	8.934	1.147
		PMXR	0.287	0.375	7.944	8.606	1.475
		HACR	0.399	0.317	6.874	7.590	2.491

TABLE 4-1 (cont'd)

Page 3.

No.	Link	Alt.	Construction Costs	Maintenance Costs	Vehicle Operating Costs	Total Costs	Net Present Value*
16	BSSH	EXIS	0.000	0.181	24.440	24.620	0.000
		PMXS	0.219	0.221	24.429	24.869	-0.248
		HACS	0.305	0.184	23.922	24.411	0.210
		PMXR	0.219	0.255	23.532	24.006	0.614
		HACR	0.305	0.256	20.164	20.725	3.895
17	BBTN	EXIS	0.000	0.166	14.495	14.661	0.000
		PMXS	0.186	0.203	13.079	13.468	1.193
		HACS	0.258	0.169	11.578	12.006	2.655
		PMXR	0.186	0.243	10.773	11.202	3.459
		HACR	0.258	0.205	9.241	9.705	4.956
18	KNSN	EXIS	0.000	0.272	47.059	47.330	0.000
		PMXS	0.304	0.331	47.043	47.678	-0.348
		HACS	0.423	0.276	45.194	45.892	1.438
		PMXR	0.304	0.383	45.244	45.931	1.400
		HACR	0.423	0.394	37.373	38.190	9.140
19	SNBG	EXIS	0.000	0.211	39.680	39.892	0.000
		PMXS	0.236	0.258	39.667	40.161	-0.270
		HACS	0.329	0.215	38.022	38.565	1.326
		PMXR	0.236	0.298	38.052	38.587	1.305
		HACR	0.329	0.306	30.991	31.626	8.266
20	BGSH	EXIS	0.000	0.196	21.282	21.477	0.000
		PMXS	0.219	0.239	20.981	21.439	0.038
		HACS	0.305	0.199	19.343	19.847	1.630
		PMXR	0.219	0.284	19.237	19.740	1.737
		HACR	0.305	0.278	14.521	15.104	6.374
21	SHKM	EXIS	0.000	0.075	6.588	6.664	0.000
		PMXS	0.084	0.092	6.450	6.627	0.037
		HACS	0.117	0.077	5.700	5.895	0.769
		PMXR	0.084	0.109	5.670	5.864	0.800
		HACR	0.117	0.103	4.263	4.484	2.180
22	KMBB	EXIS	0.000	0.136	11.860	11.995	0.000
		PMXS	0.152	0.166	11.611	11.928	0.067
		HACS	0.211	0.138	10.261	10.610	1.385
		PMXR	0.152	0.196	10.207	10.555	1.440
		HACR	0.211	0.185	7.674	8.071	3.925
23	BNBG	EXIS	0.000	0.269	14.418	14.687	0.000
		PMXS	0.304	0.320	14.297	14.920	-0.233
		HACS	0.423	0.273	13.283	13.979	0.708
		PMXR	0.304	0.373	13.186	13.862	0.825
		HACR	0.423	0.365	10.325	11.113	3.574

TABLE 4-1 (cont'd)

Page 4.

No.	Link	Alt.	Construction Costs	Maintenance Costs	Vehicle Operating Costs	Total Costs	Net Present Value
24	KMSD	EXIS	0.000	0.284	11.258	11.542	0.000
		PMXS	0.320	0.337	11.205	11.863	-0.321
		HACS	0.446	0.288	11.022	11.757	-0.215
		PMXR	0.320	0.384	10.770	11.475	0.067
		HACR	0.446	0.382	9.269	10.098	1.444
25	TMTW	EXIS	0.000	0.543	97.642	98.184	0.000
		PMXS	0.607	0.662	97.591	98.861	-0.676
		HACS	0.845	0.522	95.596	96.993	1.191
		PMXR	0.607	0.756	95.866	97.229	0.955
		HACR	0.845	0.793	88.148	89.787	8.398

*Net Present Value is with respect to alternative EXIS

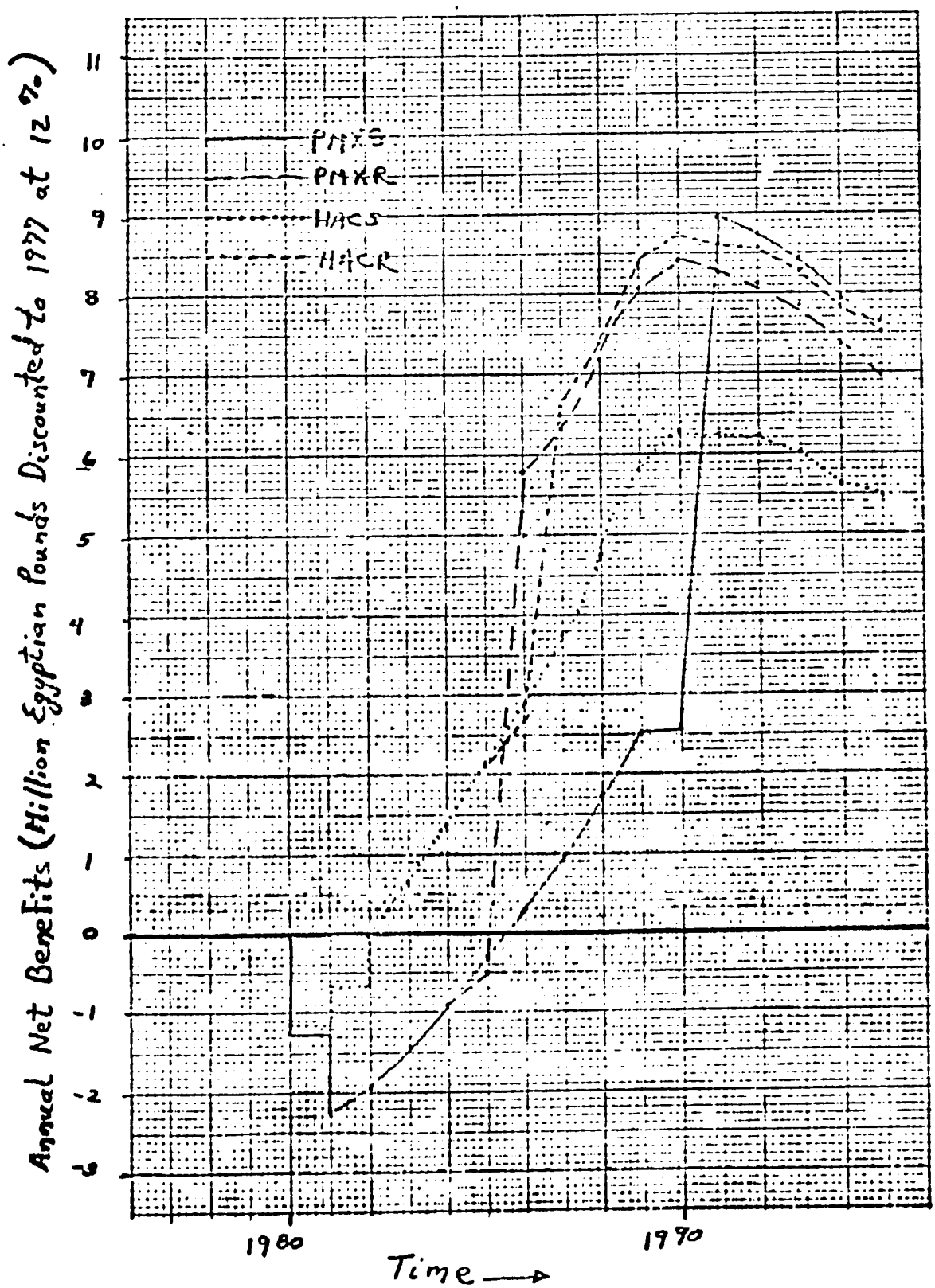

Figure 4-1. Annual Net Benefits for a Typical Link in the Group with Postponable Overlays, TNTW.

maintenance policy, also.

Table 2-4 presents the economic indicators computed for the links in this group, discounting to 1977 at 12%. These include the total cost, net present value, first year benefits, and internal rate of return. In most cases, the first year benefits, which are often used to determine the appropriate timing of an investment, are extremely large and negative. Their largeness reflects the great potential of the investments, but the negativity is more confusing: the surface is in worse condition after the overlay than previously. The situation was produced by the strict scheduling of the construction for 1980, regardless of surface conditions, and by the slow deterioration pattern and excellent initial conditions of the links in this group. However, it is also due in large part to the assumed moderately poor quality of the overlays themselves, suggesting that the quality of the finished surface is of great importance to links with these high traffic volumes.

Table 4-3 presents a summary of the predicted existing conditions and operating costs for the links within this group, while Figure 4-2 shows the relationships between surface conditions (roughness) and unit vehicle operating costs for the representative vehicle types. It is these relationships between surface conditions and operating costs which allow maintenance and construction investments to produce such high economic returns upon these heavily trafficked roads.

For all of the links in this group, greater economic returns to investment could be made by postponing the proposed overlays for several years and/or improving the surface quality produced by the overlays. Also, the recommended subsequent maintenance policy is the asphalt concrete responsive policy, which was the most intensive policy analyzed. Indications are that even higher levels of maintenance investment on these links would be justified, but their relative priority cannot be determined from single link analyses.

4.2.2 Links for Which the Overlays are Adequate

Two links showed an immediate need for the proposed investments, yielding good returns to the overlays and maintenance policies analyzed.

TABLE 4-2
ECONOMIC INDICATORS* FOR LINKS WITH POSTPONABLE OVERLAYS
(Millions of Egyptian Pounds Discounted at 12%)

No.	Link	Alternative	Total Cost	Net Present Value	First Year Benefits	Internal Rate of Return
1	QBTK	EXIS	201.468	0.000	------	----
		PMXS	221.702	-20.234	-569.3	1.8
		HACS	212.379	-10.911	-227.5	-2.8
		PMXR	198.187	3.281	-569.7	13.8
		HACR	187.467	14.001	-227.5	23.3
2	TKBN	EXIS	214.694	0.000	------	----
		PMXS	179.128	35.566	-347.3	31.9
		HACS	166.910	47.783	-25.1	75.6
		PMXR	157.038	57.655	-347.8	45.8
		HACR	146.745	67.949	-25.2	82.3
3	TNTW	EXIS	245.710	0.000	------	----
		PMXS	204.002	41.708	-200.2	34.2
		HACS	190.258	55.452	0.1	72.3
		PMXR	179.614	66.096	-200.6	47.9
		HACR	168.564	77.146	0.0	77.7
4	BNQS	EXIS	86.285	0.000	------	----
		PMXS	68.585	17.700	-132.5	39.5
		HACS	64.518	21.767	13.6	72.0
		PMXR	60.407	25.878	-132.9	51.9
		HACR	56.971	29.314	13.5	76.5
5	QSBS	EXIS	98.244	0.000	------	----
		PMXS	76.900	21.343	-151.5	41.2
		HACS	72.106	26.138	18.8	78.4
		PMXR	67.256	30.987	-152.0	54.1
		HACR	63.190	35.054	18.7	82.7
6	BSTN	EXIS	153.851	0.000	------	----
		PMXS	120.492	33.358	-146.4	40.4
		HACS	112.932	40.919	16.0	75.8
		PMXR	105.252	48.599	-146.8	53.1
		HACR	98.831	55.020	15.9	80.3

TABLE 4-2(cont'd)
Page 2.

No.	Link	Alternative	Total Cost	Net Present Value	First Year Benefits %	Internal Rate of Return %
7	QSSH	EXIS	15.538	0.000	------	----
		PMXS	13.394	2.144	-63.4	29.2
		HACS	12.611	2.927	-4.4	42.4
		PMXR	12.612	2.926	-63.8	35.4
		HACR	11.445	4.093	-4.4	47.4

*Economic indicators are with respect to alternative EXIS.

TABLE 4-3
PREDICTED EXISTING CONDITIONS AND VEHICLE OPERATING COSTS
FOR LINKS WITH POSTPONABLE OVERLAYS

No.	Link	Modified Structural Number, SN	Roughness mm/km	Vehicle Operating Costs--LE/km				
				Car	Taxi	Bus	9 Ton Truck	Truck/ Trailer
1	QB-TK	7.6	1604	0.028	0.027	0.073	0.130	0.178
2	TK-BN	5.6	1856	0.029	0.035	0.075	0.136	0.188
3	TN-TW	5.3	1936	0.030	0.038	0.076	0.137	0.192
4	BN-QS	5.1	1970	0.030	0.039	0.076	0.138	0.193
5	QS-BS	5.1	1975	0.030	0.039	0.076	0.138	0.193
6	BS-TN	5.1	1972	0.030	0.039	0.076	0.138	0.193
7	QS-SH	4.4	2030	0.030	0.041	0.077	0.140	0.195

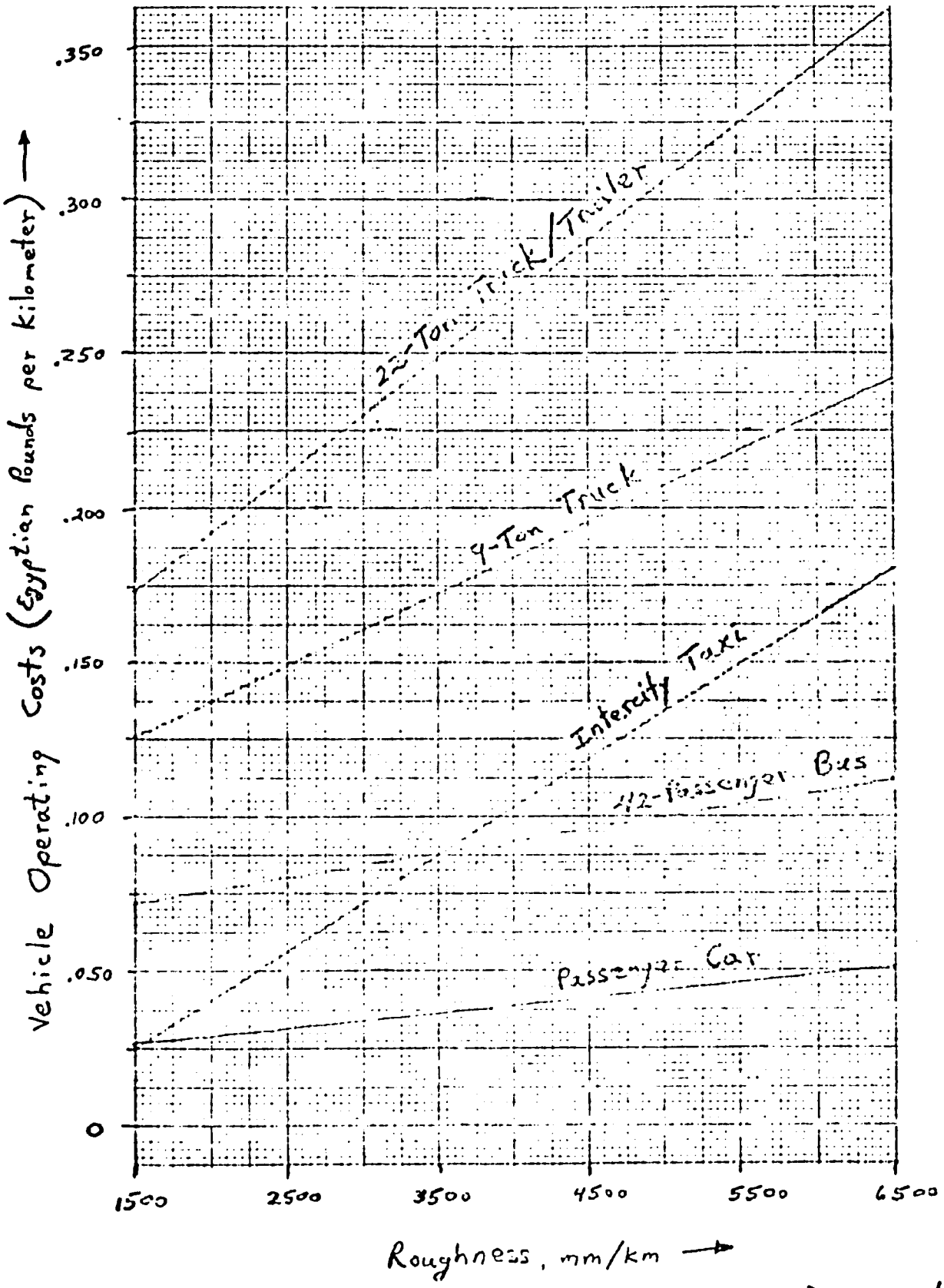

Figure 4-2. Vehicle Operating Costs versus Road Surface Condition

Table 4-4 summarizes the economic performance of the various alternatives, from which it can be seen that alternative HACR (the double overlay followed by responsive maintenance) provides the superior economic return in all cases. These links have modified structural numbers only around 3.0, but the traffic, particularly heavy vehicles, is not so high.

Since the first year benefits are extremely large and positive for all alternatives on both links in this group, the overlays should be performed even earlier than 1980, if possible. However, one should note that this last point is quite sensitive to the initial conditions assumed, which in this case were extremely bad.

Figure 4-3 presents the total net benefits for the four alternatives (discounted to 1977 value at 12%) on a year-by-year basis for a typical link in the group, Bagour-Tamaly (BGTM). Similar results would be obtained for Qalub-Kanater (QBKN). From this figure, one can see that the premix overlay fails in 4 years, while the asphalt concrete overlay performs adequately throughout the analysis. However, the superior alternative is again the asphalt concrete-responsive maintenance alternative, the most intensive of the options analyzed.

The predicted initial roughness for the links in this group was more than four times those of the previous group (links with postponable overlays), resulting in vehicle operating costs roughly twice as high, and nearly six times for inter-city taxis.* Thus, extremely large savings resulted from improving the riding surface of the links in this group.

4.2.3 Links for Which the Overlays are Marginal

Seven links responded marginally to the proposed overlays, with marginality being defined as the failure of the initial double overlay in from 5 to 14 years. A first glance at Table 4-5, which summarizes the economic performance of the various alternatives, would seem to indicate that the returns on investment were quite good, and this is indeed the case. However, the concern of this analysis is to place the limited

*This large fluctuation in intercity taxi cab operating costs is partly due to the high average kilometrage of these vehicles and the extreme roughness of the road, both of which values are beyond the range of vehicle cost regression date represented in the Road Investment Analysis Model.

TABLE 4-4
ECONOMIC INDICATORS* FOR LINKS RESPONDING WELL TO OVERLAYS**
(Millions of Egyptian Pounds Discounted at 12%)

No.	Link	Alternative	Total Cost	Net Present Value	First Year Benefits %	Internal Rate of Return %
8	BGTM	EXIS	33.498	0.000	-----	----
		PMXS	28.845	4.653	250.4	>100
		HACS	24.758	8.741	185.8	>100
		PMXR	24.347	9.151	245.9	>100
		HACR	22.627	10.872	185.7	>100
9	QBKN	EXIS	11.734	0.000	-----	----
		PMXS	9.035	2.699	215.0	>100
		HACS	8.530	3.204	157.0	>100
		PMXR	7.933	3.801	214.0	>100
		HACR	7.867	3.867	156.9	>100

*Economic indicators are with respect to alternative EXIS.

**These are links on which the asphalt concrete overlay performs satisfactorily for at least 15 years.

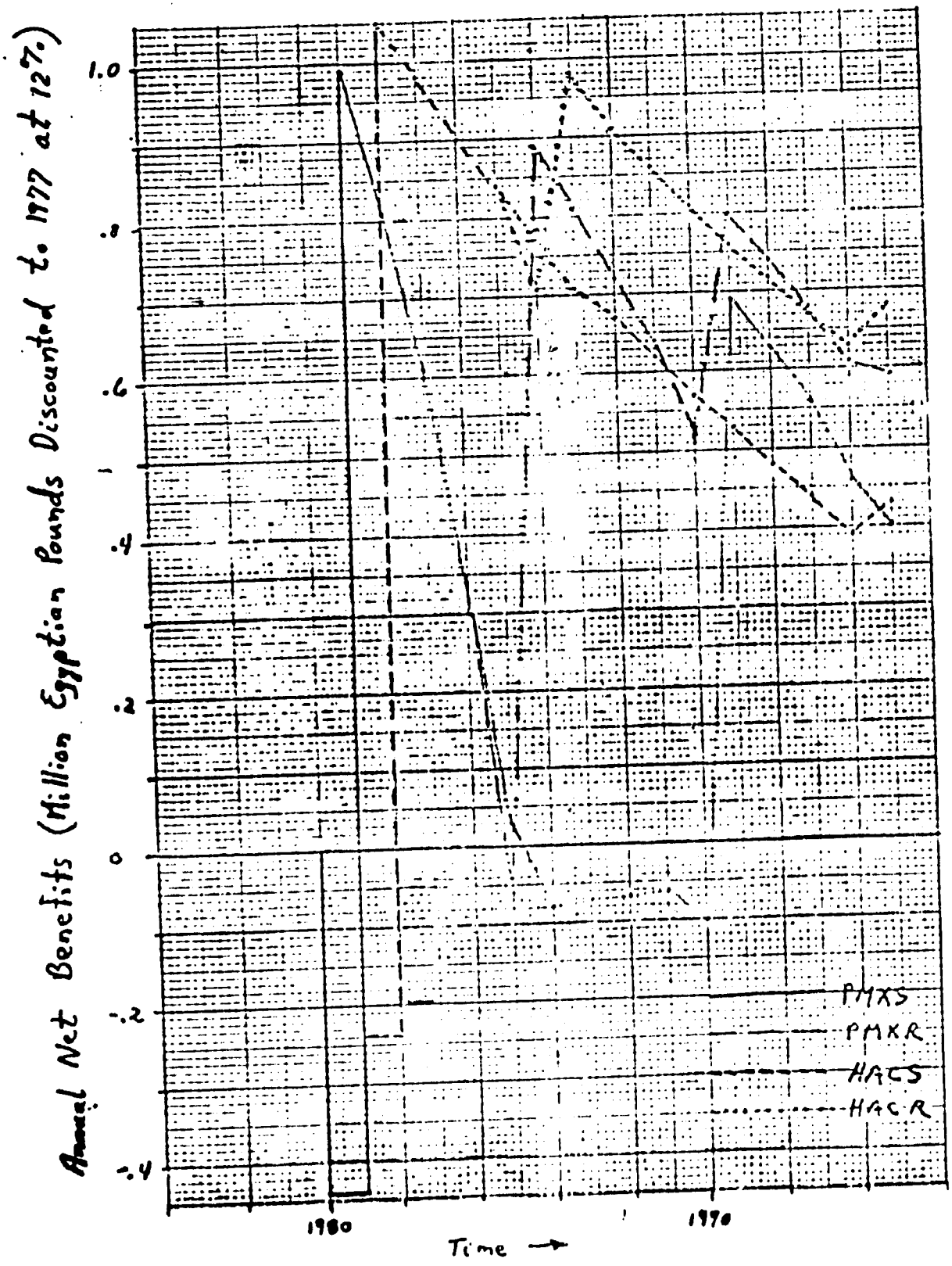

Figure 4-3. Annual Net Benefits for a Typical Link in the Group Responding Well to the Overlays, BGTM

TABLE 4-5
ECONOMIC INDICATORS* FOR LINKS RESPONDING MARGINALLY TO OVERLAYS**
(Millions of Egyptian Pounds Discounted at 12%)

No.	Link	Alternative	Total Cost	Net Present Value	First Year Benefits	Internal Rate of Return
14	ASSN	EXIS	13.511	0.000	-----	----
		PMXS	13.687	-0.176	111.8	-11.6
		HACS	12.629	0.882	172.3	>100.0
		PMXR	13.430	0.081	107.3	19.8
		HACR	10.403	3.108	172.0	>100.0
15	SDBB	EXIS	10.081	0.000	-----	----
		PMXS	9.849	0.233	51.7	17.6
		HACS	8.934	1.147	66.9	53.6
		PMXR	8.606	1.475	47.2	36.6
		HACR	7.590	2.491	66.8	57.5
17	BBTN	EXIS	14.661	0.000	-----	----
		PMXS	13.468	1.193	209.1	>100.0
		HACS	12.006	2.655	178 6	>100.0
		PMXR	11.202	3.459	204.6	>100.0
		HACR	9.705	4.956	178.5	>100.0
20	BGSH	EXIS	21.477	0.000	-----	----
		PMXS	21.439	0.038	140.5	13.8
		HACS	19.847	1.630	217.6	-18.8
		PMXR	19.740	1.737	136.0	55.8
		HACR	15.104	6.374	217.3	>100.0
21	SHKM	EXIS	6.664	0.000	-----	----
		PMXS	6.627	0.037	114.1	15.9
		HACS	5.895	0.769	178.2	>100.0
		PMXR	5.864	0.800	109.6	53.3
		HACR	4.484	2.180	178.0	>100.0
22	KMBB	EXIS	11.995	0.000	-----	----
		PMXS	11.928	0.067	114.1	15.9
		HACS	10.610	1.385	178.2	>100.0
		PMXR	10.555	1.440	109.6	53.3
		HACR	8.071	3.925	178.0	>100.0

TABLE 4-5(cont'd)

Page 2

No.	Link	Alternative	Total Cost	Net Present Value	First Year Benefits %	Internal Rate of Return %
23	BNBG	EXIS	14.687	0.000	-----	----
		PMXS	14.920	-0.233	63.1	1.9
		HACS	13.979	0.708	98.0	60.5
		PMXR	13.862	0.825	59.1	29.9
		HACR	11.113	3.574	97.8	MANY***

*Economic indicators are with respect to alternative EXIS.

**These are links on which the apshalt concrete overlay performs satisfactorily for 5-14 years.

***More than one discount rate between -20 and 100 percent produced an NPV of zero.

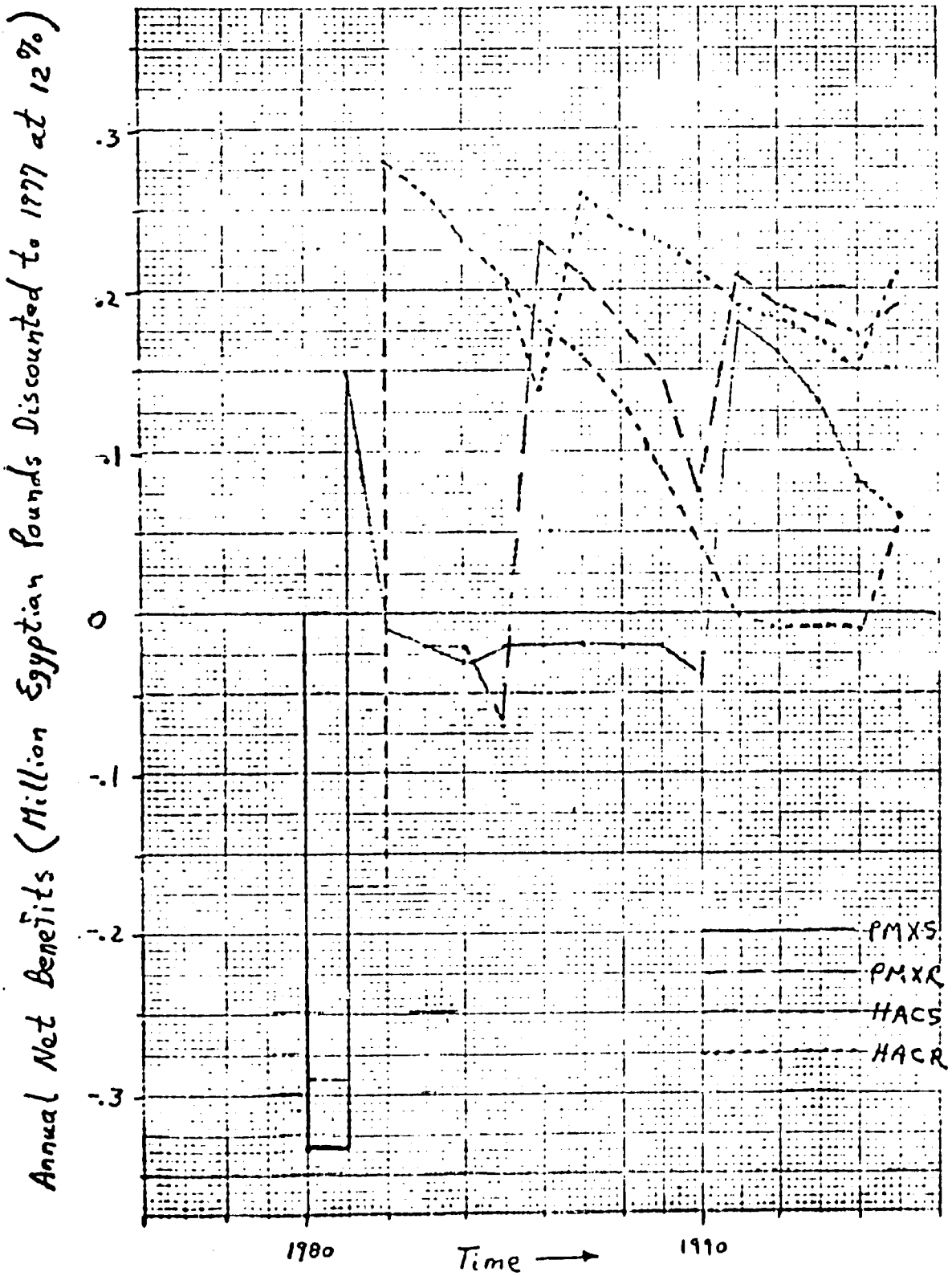

Figure 4-4. Annual Net Benefits for a Typical Link in the Group Responding Marginally to the Overlays, SDBB

number of options studied into an adequacy framework, thus indicating where in relation to the options in hand the optimum might lie.

Figure 4-4 presents the total net benefits for the four alternatives (discounted to 1977 value at 12%) on a year-by-year basis for a typical link in this group, Shohda-Babel (SDBB). Similar plots would be obtained for the other links in this group. From the figure, one can see that the premix overlay is completely inadequate, with failure occuring in 2 years. The double asphalt concrete over premix overlay fails in 10 years. Of all the options studied again the most intensive one, HACR: asphalt-concrete-maintenance, was superior. This however required an overlay in the fifth year after construction, which may be operationally difficult for the Highway Authority to implement. For links within this group an even higher initial investment, in terms of structural strength or riding quality, may be preferable.

4.2.4 Links for Which the Overlays are Inadequate

Nine links responded inadequately to the proposed investments, with none of the overlays surviving for even five years. A first glance at Table 4-6, which summarizes the economic performance of the various alternatives, would again seem to indicate that the returns on investment were quite good, at least for the responsive maintenance options. But again, these returns are not coming from the initial construction overlays, but from subsequent maintenance overlays.

Figure 4-5 presents the total net benefits for the four alternatives (discounted to 1977 value at 12%) on a year-by-year basis for a typical link in this group, Kom-El-Akder--Shohda (KMSD). Similar plots would be obtained for the other links in this group. From the figure, one can see that the premix overlay is completely inadequate, with failure occurring in 2 years, and subsequent maintenance overlays failing in 3 and 4 years, respectively. The asphalt-concrete double overlay lasts only 3 years, but the subsequent overlay under the responsive policy survives for almost five years. Thus, the pavements within this group are just too weak to perform well under the proposed alternatives and traffic levels, with the best alternative, again the most intensive, requiring overlays every five years. The best solution here would be a much larger initial invest-

TABLE 4-6

ECONOMIC INDICATORS* FOR LINKS NOT RESPONDING TO OVERLAYS**

(Millions of Egyptian Pounds Discounted at 12%)

No.	Link	Alternative	Total Cost	Net Present Value	First Year Benefits %	Internal Rate of Return %
10	KNTM	EXIS	94.830	0.000	-----	----
		PMXS	95.914	-1.084	109.7	-11.1
		HACS	93.029	1.801	163.1	MANY***
		PMXR	94.405	0.425	105.2	18.7
		HACR	84.614	10.216	160.7	83.9
11	KNBL	EXIS	47.248	0.000	-----	----
		PMXS	47.485	-0.237	146.8	3.1
		HACS	47.284	-0.036	175.8	MANY***
		PMXR	46.602	0.646	142.6	37.5
		HACR	42.490	4.758	173.6	71.9
12	BLTK	EXIS	5.311	0.000	-----	----
		PMXS	5.369	-0.058	92.3	-0.2
		HACS	5.303	0.008	133.9	MANY***
		PMXR	5.209	0.102	87.8	26.0
		HACR	4.648	0.663	131.5	59.6
13	BLBN	EXIS	19.713	0.000	-----	----
		PMXS	19.811	-0.098	147.4	3.1
		HACS	19.727	-0.014	176.6	MANY***
		PMXR	19.443	0.270	143.2	37.7
		HACR	17.726	1.987	174.4	72.2
16	BSSH	EXIS	24.620	0.000	-----	----
		PMXS	24.869	-0.248	149.1	-13.7
		HACS	24.411	0.210	217.0	MANY***
		PMXR	24.006	0.614	144.9	38.6
		HACR	20.725	3.895	214.8	MANY***
18	KNSN	EXIS	47.330	0.000	-----	----
		PMXS	47.678	-0.348	193.9	NONE
		HACS	45.892	1.438	292.0	-6.2
		PMXR	45.931	1.400	189.4	57.6
		HACR	38.100	9.140	289.7	>100.0

TABLE 4-6 (cont'd)

Page 2.

No.	Link	Alternative	Total Cost	Net Present Value	First Year Benefits %	Internal Rate of Return
19	SNBG	EXIS	39.892	0.000	-----	----
		PMXS	40.161	-0.270	222.0	NONE
		HACS	38.565	1.326	334.7	-5.9
		PMXR	38.587	1.305	217.5	76.2
		HACR	31.626	8.266	332.3	>100.0
24	KMSD	EXIS	11.542	0.000	-----	----
		PMXS	11.863	-0.321	44.1	-2.3
		HACS	11.757	-0.215	65.3	-5.2
		PMXR	11.475	0.067	40.2	14.1
		HACR	10.098	1.444	63.3	34.7
25	TMTW	EXIS	98.184	0.000	-----	----
		PMXS	98.861	-0.676	178.5	-15.2
		HACS	96.993	1.191	255.0	-0.7
		PMXR	97.229	0.955	174.0	42.4
		HACR	89.787	8.398	252.6	>100.0

*Economic indicators are with respect to alternative EXIS.

**These are links on which the asphalt concrete overlay failed in less than five years.

***More than one discount rate between -20 and 100 percent produced an NPV of zero.

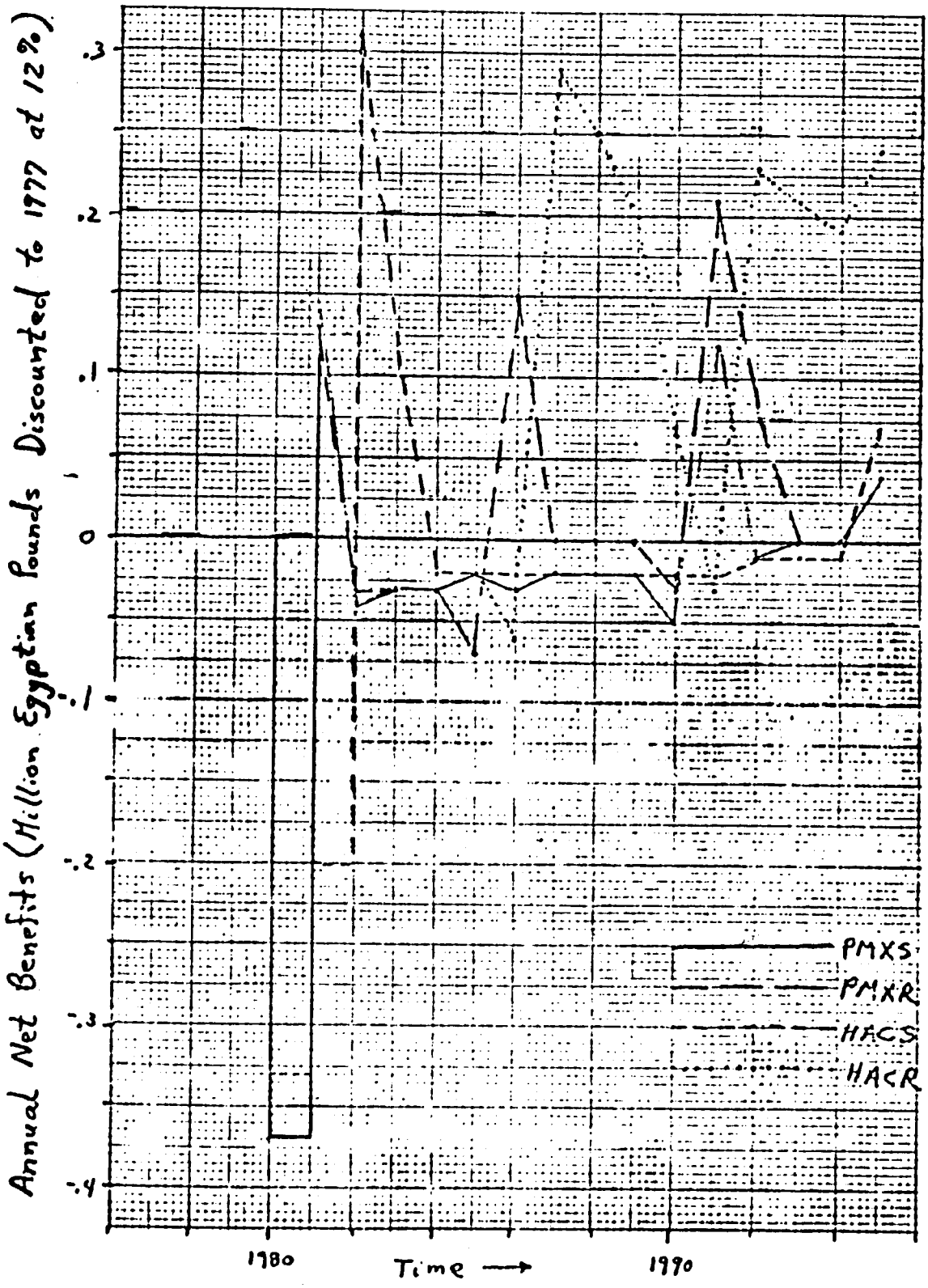

Figure 4-5. Annual Net Benefits for a Typical Link in the Group Responding Poorly to the Overlays, KMSD

ment, principally in increasing the structural strength of pavements within this group.

4.2.5 Effects of AASHO Regional Factor

The regional factors used on the various links are presented in Table 3-4. For links BBTN and KMBB, both of which are classified as being in the marginal group, all factors other than length and regional factor were identical. After normalizing for length, the economic indicators are summarized in Table 4-7. From the table, one can see that the increase in net present value per kilometer due solely to the value of the regional factor ranges from a low of 15,000 1977 Egyptian pounds for the asphalt concrete-responsive maintenance option to a high of 154,000 1977 Egyptian pounds for the premix-responsive maintenance option.

Figure 4-6 presents the undiscounted net benefits per kilometer for the responsive policies. The impact of the regional factor can be clearly seen in Figure 4-6A, which shows the net benefits produced from the slower deterioration history of the lower regional factor (0.55 for BBTN as opposed to 1.0 for KMBB) for the premix overlay. No net benefits accrue during the years 1983-85, as the pavement has failed under both regional factor values. The lower net benefits of 1990 as opposed to 1989 indicate that the subsequent 1985 maintenance overlay is also near failure. After the second, 1990 maintenance overlay, the slower deterioration pattern due to the lower regional factor is clearly shown. The uncertainty for this option due to regional factor is 154,000 1977 Egyptian pounds per kilometer, or, in other terms, 395 percent of per kilometer construction and maintenance costs. The importance of an accurate regional factor cannot be understated.

In figure 4-6B, which presents the net benefits for the double asphalt concrete over premix overlay, one perceives the smaller net benefits produced by the more similar deterioration patterns of the stronger pavement (modified structural numbers after the construction are 3.7 and 3.4 for the double overlay versus 2.7 and 2.5 for the premix overlay; see Figure 2-2 for deterioration patterns). Thus, the effects of structural number are more gradual on higher strength pavements. We can see that, in this case, the slightly higher deterioration

TABLE 4-7
ECONOMIC INDICATORS* PER KILOMETER FOR LINKS WITH DIFFERING AASHO REGIONAL FACTORS
(Millions of Egyptian Pounds Discounted at 12%)

No.	Link	Alternative	Total Cost	Net Present Value	First Year Benefits %	Internal Rate of Return %
17	BBTN **	EXIS	1.333	0.000	-----	-----
		PMXS	1.224	0.108	209.1	>100.0
		HACS	1.091	0.241	178.6	>100.0
		PMXR	1.018	0.314	204.6	>100.0
		HACR	0.882	0.451	178.5	>100.0
22	KMBB ***	EXIS	1.333	0.000	-----	-----
		PMXS	1.325	0.007	114.1	15.9
		HACS	1.179	0.154	178.2	>100.0
		PMXR	1.173	0.160	109.6	53.3
		HACR	0.897	0.436	178.0	>100.0

*Economic indicators are with respect to alternative EXIS. The total cost and net present values have been normalized from Table 4-5 by the length of each link (BBTN = 11km, KMBB = 9km).

** Regional factor = 0.55

*** Regional factor = 1.00

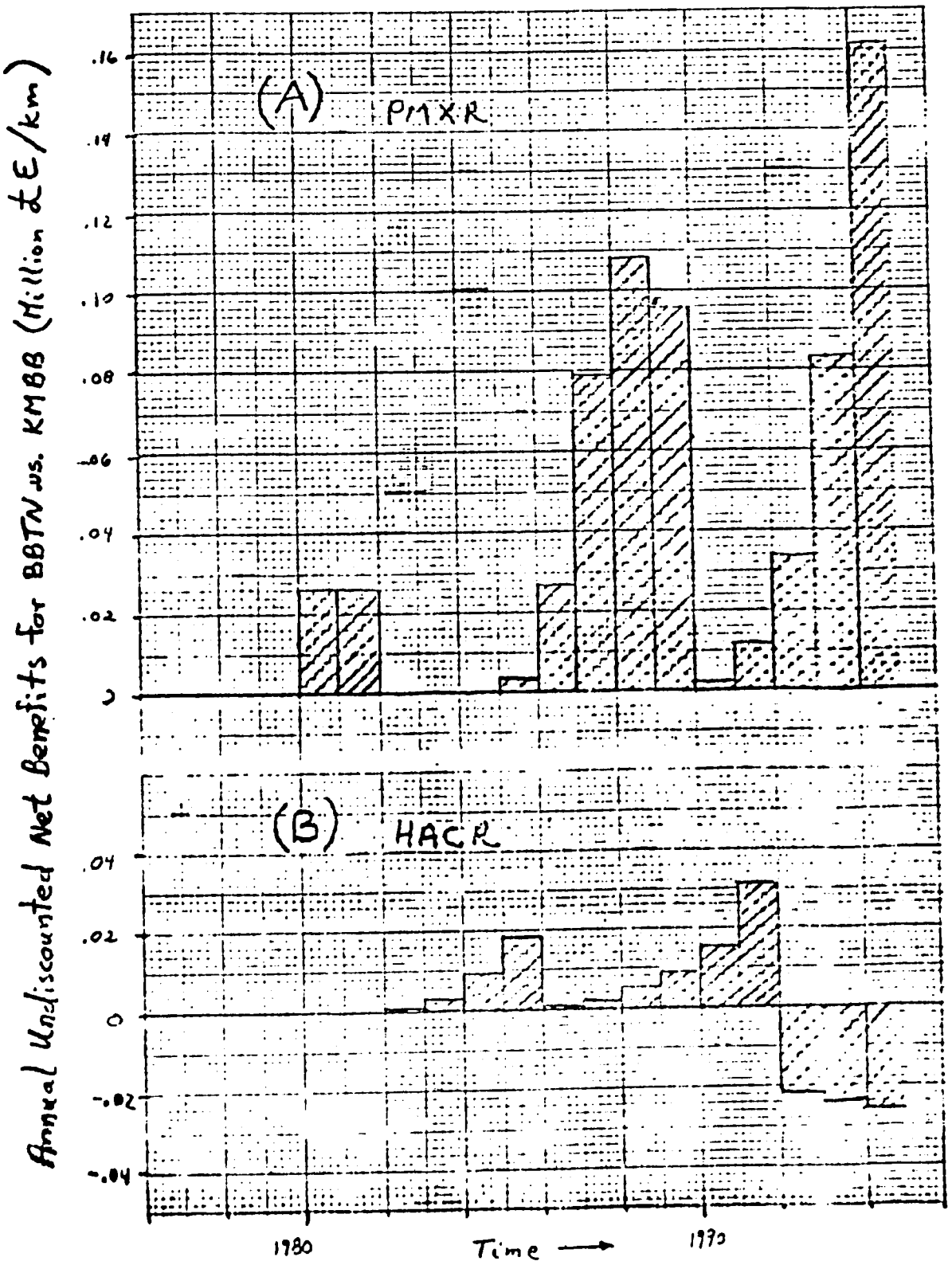

Figure 4-6. Annual Per Kilometer Net Benefits for Similar Links Having Different Regional Factors, BBTN - KMBB

rate of the higher regional factor produced a second maintenance overlay in 1992. Thus, the regional factor can have implications not only for the net benefits of a given policy, but also on the maintenance resource requirements of that policy. In this case, the uncertainty due to regional factor is 15,000 1977 Egyptian pounds per kilometer, or, in other terms, 35% of per kilometer construction and maintenance costs.

CHAPTER 5. CONCLUSIONS AND SUMMARY

5.1 CONCLUSIONS

The conclusions drawn from the analyses of the links within the Egyptian study zone concern the areas of appropriate construction standards, as regards both structural capacity and riding quality; appropriate maintenance standards, both qualitative and quantitative; and data availability and reliability. The implications of these conclusions leads to the recommendations made below.

5.1.1 Construction Standards

The results of these applications of the Road Investment Analysis Model indicated that there were four classes of link performance under the proposed structural overlays. These classes were the following:

a) Links in excellent present conditions for which the proposed investments may be postponed:

1) QBTK Qalub--Touck
2) TKBN Touck--Banha
3) TNTW Tanta--Tawfikieh
4) BNQS Banha--Quesna
5) QSBS Quesna--Berket-el-Saab
6) BSTN Berket-el-Saab--Tanta
7) QSSH Quesna--Shibean-el-Koam

b) Links in poor present condition for which the proposed investments produce good results:

8) BGTM Bagour--Tamaly
9) QBKN Qalub--Kanater

c) Links in poor present condition which respond marginally to the proposed investments and which require heavy subsequent maintenance investments, for which heavier initial investments should be considered:

14) ASSN Ashmoon--Santriss
15) SDBB Shohda--Babel
17) BBTN Babel--Tanta
20) BGSH Bagour--Shibean-el-Koam
21) SHKM Shibean-el-Koam--Kom-el-Akder
22) KMBB Kom-el-Akder--Babel
23) BNBG Banha--Bagour

d) Links of weak structural strength and poor present condition which respond poorly to the proposed investments and where all of the net benefits accrue from subsequent maintenance investments, for which heavier initial investments or reconstruction must be considered:

10) KNTM Kanater--Tamaly
11) KNBL Kanater--Biltan
12) BLTK Biltan--Touck
13) BLBN Biltan--Banha
16) BSSH Berket-el-Saab--Shibean-el-Koam
18) KNSN Kanater--Santriss
19) SNBG Santriss--Bagour
24) KMSD Kom-el-Akder--Shohda
25) TMTW Tamaly--Tawfikieh

The locations of these links are shown in Figure 5-1.

The precise construction standard which should be applied to each link is dependent upon three major factors: the cost of the overlay, the improvement in surface condition achieved, and the reduction in the rate of future deterioration or increment in structural strength. For the two construction overlays studied, the costs were determined by the volume of material placed; the resulting surface conditions were given; and the structural numbers of the pavements were increased by a specific amount.

The large net present values produced on those links in group a) above resulted not from the construction projects significantly

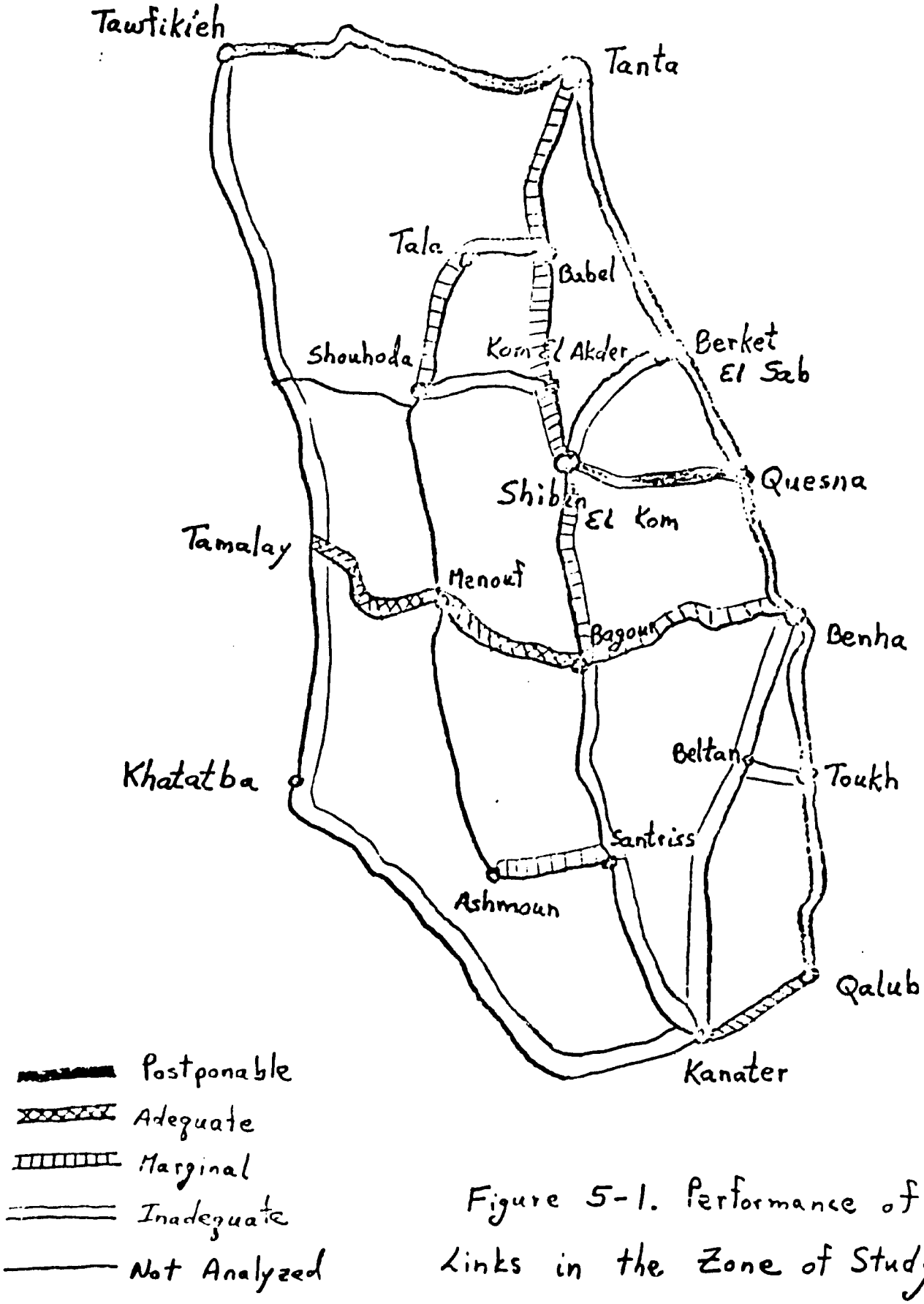

Figure 5-1. Performance of the Links in the Zone of Study

reducing the rate of future deterioration, but rather through an improvement in the road surface condition produced by subsequent maintenance overlays which are assumed by the model to be of high quality. In reality, the majority of these overlays would have been postponed until these links had reached a more deteriorated condition. However, the results indicate that extremely large benefits may be obtained by minimizing the roughness on these links, so that higher quality overlays should be considered in the future.

For the two links in group b) above, the selection of proper construction standard is dominated by the large improvement in surface condition and reduction in the rate of future deterioration, in that the structural strengths of the overlaid pavements seem well suited to the traffic volumes carried. The uncertainty in the investment decision, then, is in the reliability of the existing road conditions and structural capacities.

For the links in group c) above, which performed marginally under the proposed investments, the choice of design standards should consider higher initial investments than those analyzed here. If, however, the existing structural strengths have been underestimated, the proposed investments may indeed be appropriate. For these links, an accurate measure of structural capacity is of greater importance than are measures of existing surface conditions, since even the overlaid pavements subsequently require substantial maintenance investments.

For the links in group d) above, which responded poorly to the proposed investments, a choice of upgrading standards cannot be properly made without verification of the accuracy of the data on their existing structural strengths. Although some of these links are in an existing failed state, others are not. However, given the structural strengths and traffic volumes on these links, the existing conditions are almost irrelevant, as the model predictions are that these links, even if upgraded through the proposed investments, will almost immediately fail.

5.1.2 Maintenance Standards

Four maintenance policies were proposed for the links after the overlays, the significant differences between which were in the performing of asphaltic concrete overlays of 40mm thickness. These policies were dependent on the type of construction overlay performed, as follows:

a) Premix overlay
   --a scheduled overlay in 1990 (PMXS)
   --responsive overlays whenever the roughness exceeds 3500 mm/km, but not more frequently than every 5 years nor less frequently than every 10 years (PMXR)

b) Double (asphalt concrete over premix) overlay
   --no scheduled overlays (HACS)
   --responsive overlays whenever the roughness exceeds 3000 mm/km, but not more frequently than every 5 years nor less frequently than every 10 years (HACR)

In addition, the policies varied as to patching and surface dressing standards, but these did not contribute significantly to the outcomes of the analysis.*

Of these maintenance policies, the one most overlay-intensive, HACR, dominated the economic analysis on all links, independently of the effectiveness of the original double overlay, which was the more extensive of the two construction options analyzed. Thus, on all links studied, the heaviest construction and maintenance investments provided the greatest economic benefits. From Table 4-1, one can see that, in almost all cases, the net present values increase as the investments increase, the exceptions being the ranking of alternatives HACS and PMXR, the merits of which are dependent on the quality assumed for the construction and maintenance overlays.

Since this trend of greater returns to greater investments held across all links, which varied tremendously in their conditions, traffic

*The Road Investment Analysis Model does not relate the level of cracking to vehicle operating costs, so these items contributed only to maintenance costs.

volumes, and structural capacities as well as in the reliability of these data items, we can conclude that maintenance and upgrading investments will be economically justifiable at considerably higher levels than we have analyzed in this study.

5.1.3 AASHO Regional Factor

The validity of the above conclusions is dependent upon a number of conditions, primarily that:

a) the roughness/vehicle operating cost relationships shown in Figure 4-2 are valid;

b) the roughness histories predicted by the Road Investment Analysis Model are valid; and

c) the number and damaging effects of the vehicles in the traffic projections are valid.

Verification of point a) above would require a time and manpower commitment beyond the resources of the current study, and so this data must be treated as the best currently available, if not completely valid. For point c), the current number and damaging effects of the vehicles on the links can be enhanced by small-scale traffic count, classification, and axle load surveys, which are planned for the coming period. The future growth rates must, of necessity, be handled through engineering and economic judgment and sensitivity analyses. Point b) requires accurate data on existing road conditions and structural capacities, as well as the effects of the overlays on these parameters. Surface conditions must be developed from field inventories, both visual and mechanical, while structural capacities may be obtained from layer thicknesses, subgrade support, and the regional factor. Of these, the regional factor is the most significant, since its value is known with the least accuracy.

The regional factor is an empirical correction factor used to explain the different behavior of otherwise similar pavements in varying drainage and climatic conditions. The importance of having an accurate estimate of its value when using empirical deterioration relations

developed in other parts of the world has been demonstrated in section 4.2.5, where a 45% change in its value produced a 395% change in the resulting economic return on investment. We do not know whether the Egyptian regional factor is 0.55 or 1.0, or 1.55 for that matter; however, we suggest that an accurate value of this parameter is of critical importance in maximizing the economic return on Egyptian road investments. A study is planned for the coming period for its determination.

5.1.4 Data Availability and Reliability

The recommendations and conclusions drawn in the preceding sections depend, of necessity, on the implicit assumption of accurate input data. Of them all, we can feel most confident in the conclusion that greater investments have proportionately even greater returns, at least up through the largest investments analyzed, as this conclusion was verified on all links regardless of the quality of their performance under the proposed investments. However, greater confidence in all of the above conclusions could be derived if the data base could be more adequately and accurately developed. Specific concerns in this area are outlined below.

For construction or maintenance overlays, the key item is the quality of the subsequent riding surface. This together with the riding quality before the overlay and the traffic volume determines the first year returns which are often used to schedule improvements. Of lesser concern is the increment of structural strength added, as it can be fairly accurately determined from overlay thickness and layer coefficients.

For existing road conditions, the items of primary importance are the roughness, structural capacity, and regional factor. These items should be the core of any road inventory which is to be developed. However, these are also items which should be measured mechanically, and their determination will require the acquisition of certain road measurement equipment. Of these, the most difficult to obtain will be the AASHO regional factor, as it must be derived from comparisons of predicted versus actual deterioration (roughness) under known traffic volume

and structural strength (structural number). Hence, it cannot be known more accurately than the least certain of the other items.

For the average equivalency factors of the representative vehicles used to characterize the Egyptian traffic fleet, uncertainty here is equivalent to uncertainty in the regional factor. Thus, these values should be determined as accurately as possible through classification and axle load surveys.

For the roughness/vehicle operating cost relationships shown in Figure 4-2, a rederivation for Egyptian conditions of the physical relationships incorporated in the Road Investment Analysis Model is beyond the scope and resources of the current study. However, the validation of the required input data items, particularly the maintenance parts and labor costs for intercity taxis, should be performed. Additional surveys of vehicle types not yet studied are currently being performed.

5.1.5 Congestion and Safety

Recommendations in this concern are directed primarily at those links in group (a), for which the proposed investments may be postponed (links 1-6). These links represent parts of the Cairo-Alexandria Agricultural Expressway, which is the busiest route in Egypt. These links showed good riding surface conditions and would perform well under routine maintenance until around 1985 (depending on the link). Meanwhile, these links carry a large volume of traffic involving very different vehicle speeds.

Police records showed a high number of accidents on this route in recent years, indicating efforts should be concentrated on improving capacity and safety aspects. Some traffic engineering operational measures which might be enhanced include:

--access control
--traffic signs (information, warning, and prohibition)
--channelization and lane marking
--traffic signals at or near inhabited areas
--shoulder improvements for both capacity and safety
--segregation of non-motorized traffic

5.2 SUMMARY

The results of the twenty-five link-evaluation applications of the Road Investment Analysis Model indicated that there were four classes of link performance in the study zone under the proposed structural overlays and subsequent maintenance standards. These classes were the following:

i) links in excellent condition for which the proposed investments may be postponed;

ii) links in poor present conditions for which the proposed investments produce good results, in that the heavier structural overlay performs satisfactorily for the entire analysis period requiring no major subsequent maintenance investments;

iii) links in poor present conditions which performed marginally under the proposed investments, in that the heavier structural overlay failed in from 5-14 years requiring major subsequent maintenance investments, and for which heavier initial investments should be considered; and

iv) links of weak structural strength and poor present condition which performed poorly under the proposed investments, in that both of the proposed structural overlays failed in less than 5 years and where all of the net benefits accrue from major subsequent maintenance investments, and for which heavier initial investments or reconstruction must be considered.

Precise pronouncements of the appropriate strategy could not be made on a link by link basis, due to the preliminary nature of much of the data used. However, a tentative general finding which held true on all links analyzed was that, of the four alternative strategies the one which was largest in the present value of construction and maintenance investments produced the greatest net present value. Since this trend of proportionately greater returns to greater investments held true across all links, which varied widely in their conditions, traffic volumes, and structural capacities as well as in the reliability of these data items, we can conclude that maintenance and upgrading investments will be economically justifiable at even higher levels than we have analyzed in this study.

This and the above performance classification are being reviewed in light of the assumptions made during data collection, the data availability and reliability discussed in section 5.1.4 above, and the requirements for additional surveys and acquisition of road evaluation equipment.

5.3 RECOMMENDATIONS FOR FUTURE WORK

The work in the next phase (January through June, 1978) will be directed towards developing the network analysis capabilities, enhancing the Egyptian data base, and calibrating the deterioration relations to Egyptian conditions. These tasks will be conducted simultaneously by different members of the project team. The specific items of work are as follows.

The completion of the network analysis capabilities will involve the following activities:

1) to develop the network analysis case study data;
2) to use this data to debug and validate the model;
3) to calibrate the traffic assignment parameters; and
4) to perform and analyze the base runs and sensitivity runs.

Task 1) involves the coding of the origin-destination flows data produced by the survey, and incorporation of any changes deemed necessary by the project team, as well as the determination of the network maintenance policies to be used and construction program to be followed. Task 2) will involve several trial runs to verify the correctness of the coded data and the inner consistency of the model (for this assumed values of the traffic assignment parameters will be used). Task 3) will involve several iterative runs (for a one-year study only) to calibrate the predicted flows with the existing traffic counts. The installation of the network model on the Egyptian computer facility will be done in April, and the remaining period will be used for analysis of the runs and preparation of the final report.

Enhancement of the data base will involve two research efforts: a traffic count and axle load survey and a private car and light truck operating cost survey, both of which are required to fill gaps in the current inventories. In the analyses made to date, a very rough method was used to evaluate the vehicle load factors and the associated standard axle equi-

valencies. To improve upon these relations, a study will be made on three main roads:

1) Cairo - Alexandria (agricultural)
2) Cairo - Ismailia - Port Said
3) Cairo - Assiut

The study will involve the weighing of vehicles of all representative Egyptian classes except passenger cars. In addition to the axle load survey, traffic counts and classifications will be made for Upper Egypt, at the following sites:

1) Beni Suef
2) Faiyum
3) Menia
4) Assiut
5) Qena
6) Luxor
7) Aswan
8) Helwan - Saff
9) Saff - Zafferon

The classification will be done manually, while mechanical counters will be installed for total vehicle counts.

The vehicle operating cost survey will be directed towards calculating the costs for those vehicle types not previously examined, namely private cars and light to medium goods vehicles. Both types are operated almost entirely privately, and so there are no reliable published data concerning their operational characteristics. Another difficulty is the inter-relationship between the usage of the vehicles in urban and inter-city transport, emphasized by the fact that over 50% of the private cars have registration in urban governorates. Therefore, a more indirect survey form will have to be undertaken, utilizing mailed questionnaires rather than interviews.

The calibration of the deterioration relations to local conditions will involve a research investigation aimed at calculating the regional and drainage factors for Egypt. Five links in Lower Egypt have been

selected for this study, based on adequate history data and spanning a range of climatic, drainage, and subgrade soil conditions. These links are:

1) Kafr-el-Dauwar -- Abu Matamir (semi-arid, cultivated, sandy clay)
2) Damanhour -- Makmalay (semi-arid, cultivated, clay)
3) Cairo -- Alexandria desert road, km 30-40 (arid, desert)
4) Shibean-el-Koam -- Tanta (arid, cultivated, clay)
5) Mineadar -- Zagazig (arid, cultivated, clay)

In addition, two links from Upper Egypt will also be investigated. The tests made will include subgrade CBR (lab), soil classification, subsoil drainage conditions (moisture content, water table, height of embankment), cropping pattern, and condition rating (to be subjectively determined by a team of qualified engineers).

The objective of the study will be to match subjective present condition, axle history, and structural strength against predicted condition, to determine the AASHO Regional Factor for the various regions of Egypt. Subsequently, an analysis will be made to determine if the regional factor is separable into climatic and drainage factors.

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CAIRO UNIVERSITY - MASSACHUSETTS INSTITUTE OF TECHNOLOGY

TECHNOLOGICAL PLANNING PROGRAM

CONFERENCE ON

TRANSPORTATION PLANNING POLICY

JUNE 20-22, 1978

CAIRO, EGYPT

III.10

CALIBRATION OF AASHO DETERIORATION MODEL FOR EGYPT CONDITIONS

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I. INTRODUCTION

The basic AASHO equation for flexible pavement structures provides a relationship between drop in serviceability, traffic, and pavement thickness. In these equations loss in serviceability is expressed in terms of a drop of serviceability index, traffic is represented by equivalent 18-kip single axle-load applications, and pavement thickness is represented by a structural number (1).

The structural number of a pavement is defined by an emperical relationship in which the thickness and strength of the pavement layers are combined together as follows:

$$SN = \sum_{i=1}^{n} A_i D_i \qquad (1)$$

Where SN = structural number

A_i = strength coefficient of the ith layer

D_i = thickness of the ith layer in inches

and the summation is over all pavement layers

The structural number is then modified to take into account the strength of subgrade, environmental impact, and drainage characteristics of the base and sub-base differing from those at the AASHO road test site (1). Using this concept, the following equation for the modified (effective) structural number was produced:

$$(1+\overline{SN}) = (1+SN) * (REGFAC)^{-0.10684} * (CBR/CBR_0)^{0.14744} \qquad (2)$$

Where SN = Pavement structural number

$\overline{SN}$ = Modified (effective) structural number

$REGFAC$ = Regional and drainage factor

CBR = California bearing ratio of the subgrade

CBR_0 = CBR of AASHO subgrade = 2.69

Based on the preceding concepts, deterioration is predicted as a function of equivalent axle load applications and effective structural number. The equation for estimating deterioration is the general AASHO equation:

$$PSI\ (V,\overline{SN}) = 4.2 - 2.7\ (1.58\ V * (1+\overline{SN})^{-9.36\ \text{exponent}}) \qquad (3)$$

Where PSI = Present serviceability index

V = Cummulative volume of equivalent standard axles in the design lane

$\overline{SN}$ = Modified (effective) structural number

and exponent = $0.40 + 1094\ (1+\overline{SN})^{-5.19}$

Of the design parameters considered in the AASHO equations, the regional factor is probably the least well defined. In most cases, the selection of a proper regional factor value is based upon the local conditions of the highway in combination with engineering judgment. Several procedures have been used to estimate regional factors using one or more of the following parameters (2): Topography*, similarity to the AASHO road test site, rainfall*, temperature, groundwater table, subgrade type*, engineering judgment*, type of highway facility, and

*Indicates the most frequently used parameters.

subsurface drainage.* Even with the various guidelines presented, considerable judgment must still be exercised in selecting an appropriate regional and drainage factor for design. The regular use of a pavement rating system would provide valuable background data for determining a regional and drainage factor. When a regional and drainage factor of one (REGFAC = 1) was incorporated in the deterioration model as a part of the application of the Road Investment Analysis Model to the Egypt road network (based on a link-by-link analysis (3)), the predicted road conditions did not agree satisfactorily with the existing field conditions of the roadway links. This indicated the importance of calibrating the deterioration model to Egyptian conditions.

II. PURPOSE AND SCOPE

The main purpose of this study was to calibrate the AASHO deterioration model for Egyptian conditions. This included calibration of the modified (effective) structural number equations, together with evaluating the regional and drainage factor for local conditions. This evaluation is based on the climatic conditions (temperature and rainfall), subgrade soil type, drainage, pavement performance, and engineering judgment.

*Indicates the most frequently used parameters.

III. TECHNICAL APPROACH

Figure 1 presents the analysis system in flow chart form. The study consists mainly of two phases. Field and laboratory tests were conducted on the selected roadway links for the two phases.

Figure 1
The Evaluation Framework

Study of Climatic-Conditions

PHASE I
Preliminary Survey on Selected Roadway Sample
Field Evaluations
Laboratory Tests
Pavement Condition Surveys
Analysis and Results

PHASE II
Selection of Refined Study Area
Field Evaluations
Pavement Condition Surveys
Laboratory Tests
Evaluation and Calibration of the Model
Analysis, Results and Conclusions

III.1 Climatic Conditions

Although Egypt is located in the subtropical zone, owing to the extent of the country and the presence of deserts and sea borders,

some variations in climatic conditions occur.[4] For the purpose of the study the country has been divided into four representative climatic zones:

1. Mediterranean Coast (typified by Marsa Matrouh)
2. Northern Part of Nile Valley (typified by Cairo)
3. Southern Part of Nile Valley (typified by Luxor)
4. Red Sea Coast of Nile Valley (typified by Ghardaka)

The data have been obtained from "Climatological Normals for Egypt Arab Republic" up to 1960.

Temperature

The highest and lowest temperature are recorded for Luxor where the daily maximum averages 40.7^{o} C in June/July and the average lowest mean is 5.4^{o}C in January. Owing to their location near the sea, Marsa Matrouh and Ghardaka show smaller differences between average maximum and minimum temperatures. Table 1 presents the average minimum, maximum, and daily mean temperatures in ^{o}C per season for the four representative sites.

TABLE 1
Temperature Records for Representative Egyptian Conditions

	Summer (May-October Daily)			Winter (November-April)		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean (Daily)
Marsa Matrouh	28.0	18.4	23.0	20.5	10.2	15.8
Cairo	32.7	19.7	26.2	22.9	11.2	16.9
Ghardaka	30.9	22.8	27.2	23.1	12.6	18.6
Luxor	35.2	21.6	30.6	27.8	9.8	18.4

Rainfall

The highest annual rainfall is recorded along the Mediterranean coast (Marsa Matrouh receives 144 mm, with a maximum of 38 mm in December). The annual rainfall decreases slightly towards the east over the coastal area. The influence of the sea is still evident in Cairo (24 mm), but at Luxor rainfall is almost nil (1 mm).

At Marsa Matrouh 3 and 15 mm of rain are recorded during the months of May and October, and only 0.6 mm in the months in between. The Red Sea does not cause much precipitation. At Ghardaka it is 4 mm annually.

III.2 Phase 1: Preliminary Survey on Selected Roadway Links

Based on past experience and information provided by Road Research and Training Center personnel, six roadway links were selected from different parts of Egypt (Figure 2). The roadway link locations are as follows:

1.	Elghita - Abo Elmatameer	7.7 km	(Coastal Region)
2.	Damanhour - Elmahmoudia	18.0 km	(Coastal Region)
3.	Cairo - Alexandria (Desert Road)	20.0 to 30.0 km	(Desert Region)
4.	Shebin Elkom - Tanta	26.0 km	(Delta Region)
5.	Zakazik - Menia El Kamh	18.0 km	(Delta Region)
6.	Badrashin - Elaiaat	31.0 km	(Southern part of Nile Valley)

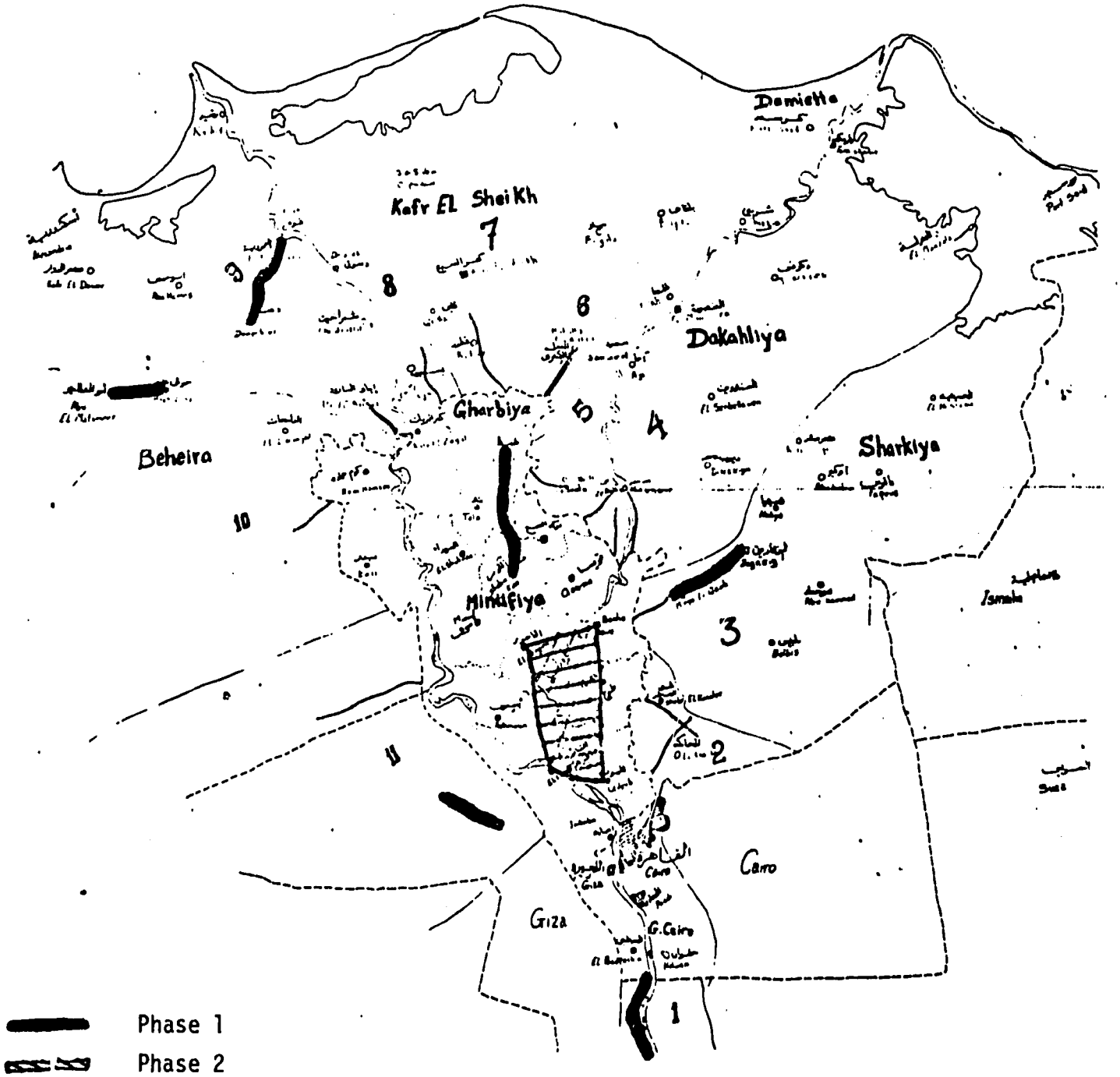

Figure 2: Location of Selected Roadway Links

Field Evaluation of Roadway Links

A survey team was assigned to collect the necessary field data for the six links. Each link was first traversed and test sections were selected within the link on level, tangent terrain. The following test data were obtained for each test section:

1. Pavement cores, to determine pavement components and thicknesses. The cores were taken at a distance of one meter from the pavement edge.

2. In situ CBR for the subgrate soil; this was obtained through the use of a portable penetrometer. The test was conducted on the shoulder area near the pavement-shoulder interface.

3. Moisture content of the subgrade was determined by standard procedure.

4. Material from the subgrade was sampled from under the pavement at the pavement-shoulder interface for laboratory testing.

5. Detailed cross-sections of the roadway were obtained, showing widths, formation of the surrounding area, drainage, and any other relevant information.

6. Surface condition of the roadway section, including cracks, patching and riding quality, was coupled together with a serviceability rating, which will be discussed later.

Laboratory Tests and Evaluation

Subgrade samples obtained from the field were subjected to the following tests:

1. Sieve analysis
2. Consistency limits
3. Compaction and CBR.

From the above tests, information about subgrade soil type (AASHO classification) and laboratory CBR was obtained.

Pavement Condition Survey

The condition survey was conducted for the purpose of determining the present condition of the pavement sections. Present serviceability ratings (PSR) were determined based on the average rating value of three team members. The present serviceability ratings were determined based on the surface condition, riding quality, surface smoothness, and cracking. This was coupled with typical descriptions and photographs for each section.

Analysis of Test Results for the Preliminary Survey

Table 2 presents the test results for the selected roadway links (Phase 1). In addition, Figure 3 shows typical roadway cross sections for links with and without adjacent canals.

The evaluation and analysis of data collected in the first phase of the study revealed a number of results:

1. Climatic conditions in Egypt are favorable relative to their effect on pavement performance, and no extreme climatic conditions are present.

2. The natural subgrade soils are mainly clay and silty clay in the Delta region and Nile Valley region. In the desert areas the subgrade is mainly sand, with some silt pockets.

3. Egypt could be divided into three regions having similar characteristics relative to climate, topography, and subgrade soil type. The three regions are: (a) Delta region and Northern part of the Upper Egypt Nile Valley until Banysweif; (b) Southern part of the Nile Valley of Upper Egypt; and (c) Desert areas and Red Sea Coast.

Table 2

Summary of Test Results (Phase 1)

	Length (km)	Test Location	Subgrade Characteristics: C.B.R. in Situ	C.B.R. in Lab	AASHO Soil Classification	T (cm)	SN	Date of Last Overlay or Recon.	Σ EAL Per Direction	PSR
Ghiah-Aboelmatameir	7.7	3 + 200	8	3.5	A-7-6	31.5	2.57	July, 1966	722,273	3.8
		6 + 200	9	7.5	A-4	33	2.44			3.5
Damnhour-El Mahmoudia	18	5 + 030	3	2.6	A-6	18	1.57	Beginning of 1967	693,127	1.5
		10 + 090	4	2	A-6	14	1.91			1.5
		15 + 800	5	1.5	A-7-6	13	1.12			1.1
Cairo-Alexandria Desert Road	10	22 + 200	>15	>15	A-2-6	20	4.33	End of 1972	673,260	3.8
		26 + 350	>15	5	A-2-4	32	3.1			3.2
Shebin el Kom Tanta	26	9 + 900	6	1.6	A-7-6	34	3.01	End of 1959	478,246	3.1
		16 + 970	5	2.6	A-6	33	2.89			2.7
		22 + 00	5	5.6	A-4	34	3.01			1.8
Zakazik Menia el-Kamh	18	7 + 000	6	3.7	A-7-6	36	3.31	Beginning of 1965	562,877	2.0
		elgadidah village	-	6	A-7-6	37.5	2.57			1.2
		15 + 700	5	5.5	A-7-6	37	3.37			2.0
Elbadrashine Elaiaat	31	11 + 000	-	3.0	A-7-6	30	3.71	July 1977	457,167	3.5
		el-aff	2.5	2.75	A-7-6	32	2.51			2.6

PSR = Present service ability rating
T = Total pavement thickness, in cm
SN = Structural number
EAL = Cumulative equivalent standard axle-loads

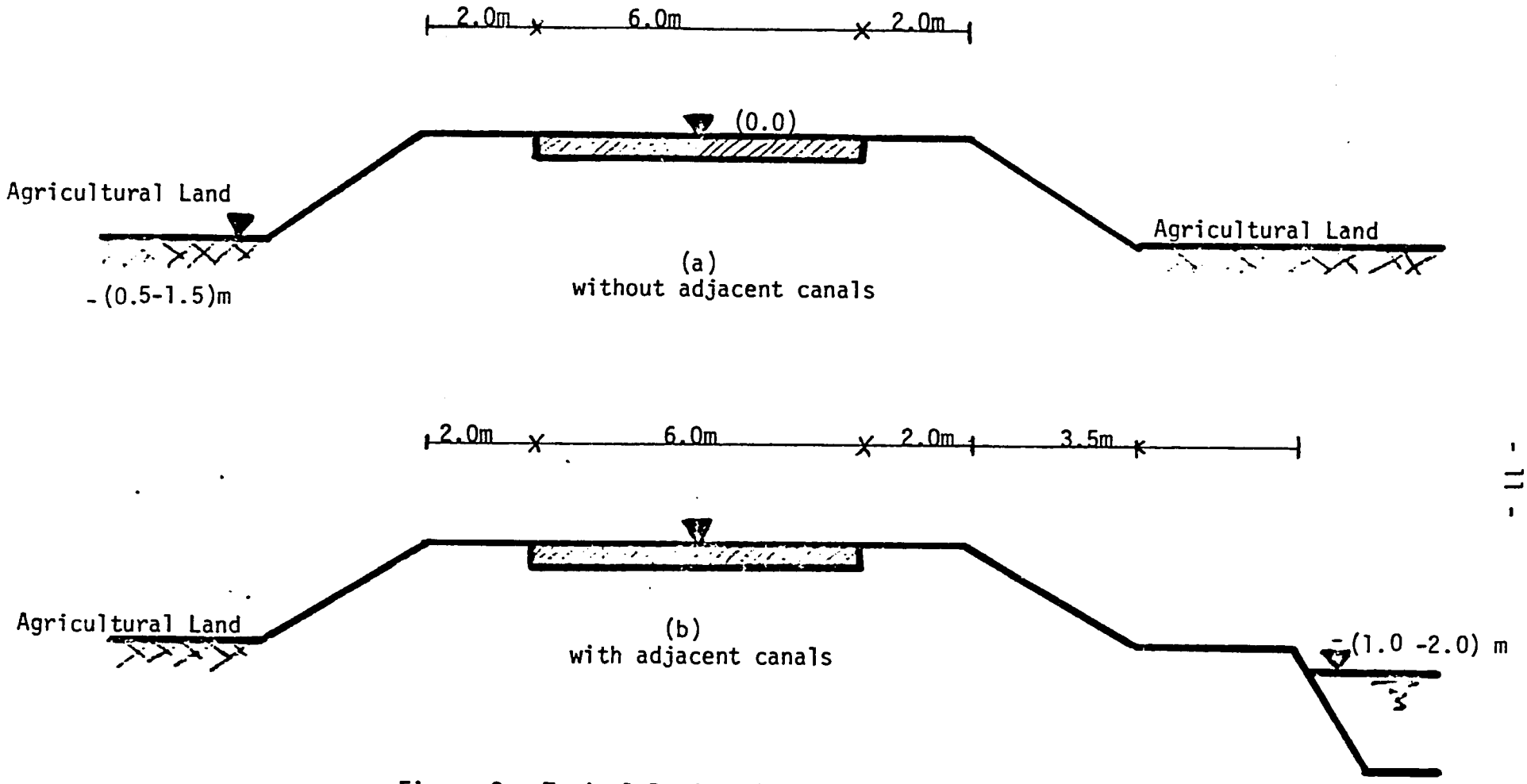

Figure 3: Typical Roadway Cross-Sections

4. Drainage is a main factor that affects the performance of pavement sections. In the same region and/or link different drainage conditions lead to different pavement performance. Drainage factors could be assigned based on the difference in elevation between roadway surface and surrounding farm land or highest water level on the area, whichever is closer to the roadway. The drainage factor (DRNFAC) is divided into three categories:

   1 - Good drainage (h* >100 cm) 1.0 DRNFAC

   2 - Fair drainage (h = 100-50 cm) 1.2 DRNFAC

   3 - Poor drainage (h < 50 cm) 1.4 DRNFAC

5. Table 3 presents a summary of the suggested values for the regional and drainage factor (REGFAC*DRNFAC) for the three regions (Phase 1).

Table 3
Suggested Environmental Factors

Region	Drainage Good	Fair	Poor
1-Delta region and Northern part of the Upper Nile Valley	0.80	1.00	1.15
2-Southern part of the Nile Valley of Upper Egypt	0.70	0.85	1.00
3-Desert Area and Red Sea Coast	0.60	0.75	0.85

6. By using the suggested regional and drainage factors in the deterioration models, the predicted roadway performance (PSI) was not adequate for explaining the field performance of Egyptian roadway links. This

* h = difference in elevation between roadway surface and surrounding land or highest water level, whichever is closer to the roadway.

provided the basis for Phase 2 of the study, since the deterioration model must be calibrated through the study of all parameters that are incorporated in it (structural number, deterioration CBR, and regional factor).

Phase 2: Approach to the Problem

Most of the pavement structural numbers for roadway links ranged from 1.5 to 3.0, which is outside the inference space of the AASHO deterioration models (SN $\geq$ 3).

The predicted roadway performance (Phase 1) was unsatisfactory; the field condition, however, proved to be relatively good. This implies that the embankment height, with relatively good climatic and drainage condition, plays an active role in the performance of pavement sections and has to be accounted for in estimating the structural number. Egypt's topography, in general, is flat and most of the roads are in agricultural areas with embankment height of 50 - 150 cm above the cultivated land and/or the level of water in the irrigation canals.

The term that represents subgrade strength in Equation (2) was assumed as unity. This was selected because of the following:

(1) Climatic and rainfall conditions will be very similar throughout the study zone;

(2) The effect of embankment height will be incorporated in the determination of the structural number of the pavement; and

(3) The study area will be limited to the Delta region within which the subgrade soil is roughly homogenous, having a CBR value close to the AASHO value (CBR = 2.69).

Study Area

The study area was selected in the Menofia and Qualubia Governorates (see Figure 2), which is mainly flat, cultivated land having roughly similar topographic, climatic, and soil conditions. Links in this pahse of study were chosen to have moderate structural numbers (between 1.5-3) and relatively good surface condition. These links were selected from previous study (3).

Table 4 presents the data obtained for the selected roadway links for this phase of the study.

Analysis of Test Data

The height difference between the bottom of the pavement structure and level of surrounding land was used as a pavement layer contributing to pavement strength (5,6).

Strength coefficients of 0.04, 0.05, and 0.06 for embankment height effect on the pavement structural number were studied to select the best strength coefficient for subgrade soils that provides consistent results.

The modified structural number, $\overline{SN}$, for each study section was computed (Equation(3)) as a function of PSR and V; the $\overline{SN}$ was then used as an input to Equation(2), where the adjusted structural number (SN*) was used instead of the pavement structural number (SN). The adjusted structural number (SN*) is computed as follows:

Table 4

Summary of Test Results (Phase 2)

Section		PSR	T (cm)	SN	H (cm)	ΣEAL since last overlay
Biltan-Touck -	1	2.6	20	1.69	100	660,222
	2	3.3	20	1.69	100	660,222
	3	2.9	20	1.69	125	660,222
Banha-Bagour	1	3.8	25	1.97	120	108,911
	2	3.8	22	1.80	80	108,911
Ashmoon-Santriss	1*	2.7	28	1.90	80	564,098
	2	3.4	24	1.68	120	564,098
Qalub-Kanater	1	2.6	19.5	2.22	50	224,378
	2**	1.8	20	2.22	400	224,378
Kanater-Santriss	1	3.0	24.5	2.35	90	883,158
Bagour-Shibean	1*	2.5	25	1.92	70	492,069
Santriss-Bagour	1	3.0	19.5	1.60	100	700,000

PSR = Present serviceability rating

T = Total pavement thickness, cm

SN = Structural number

H = Difference in elevation between roadway surface and surrounding land

V = Total cumulative traffic loadings (18 Kip) axles per lane.

* = These two sections have adjacent irrigation canals

** = Omitted from study due to extreme embankment height.

500

$$SN^* = SN + a_5 \cdot \Delta \qquad (4)$$

Where a_5 = strength coefficient of the subgrade soil

Δ = height difference between the bottom of pavement structure and the surrounding land.

Different values for the strength coefficient (0.04, 0.05 and 0.06) were used to determine the adjusted structural number. Different REGFAC were obtained through the use of Equation (2) for each link and different SN* (obtained through the use of different subgrade strength coefficient).

The best range of REGFAC values for the different roadway links was obtained when using subgrade strength coefficient of 0.05. The average REGFAC value was 0.4 (ten links provided a REGFAC ranging from 0.22 to 0.57).

Figure 4 shows the measured Δ for the 12 links against the predicted Δ. The predicted Δ's were obtained through the use of Equation (2) (REGFAC = 0.4, a_5 = 0.05).

The predicted Δ values were plotted as a function of pavement structural number (SN) (Figure 5). Regression analysis was employed to represent this relationship. The resulting regression equation was as follows:

$$\Delta = 3700\, e^{-2.24(SN)} \qquad (5)$$

With $R^2 = 0.81$

From these results, the adjusted structural number (SN*) could be

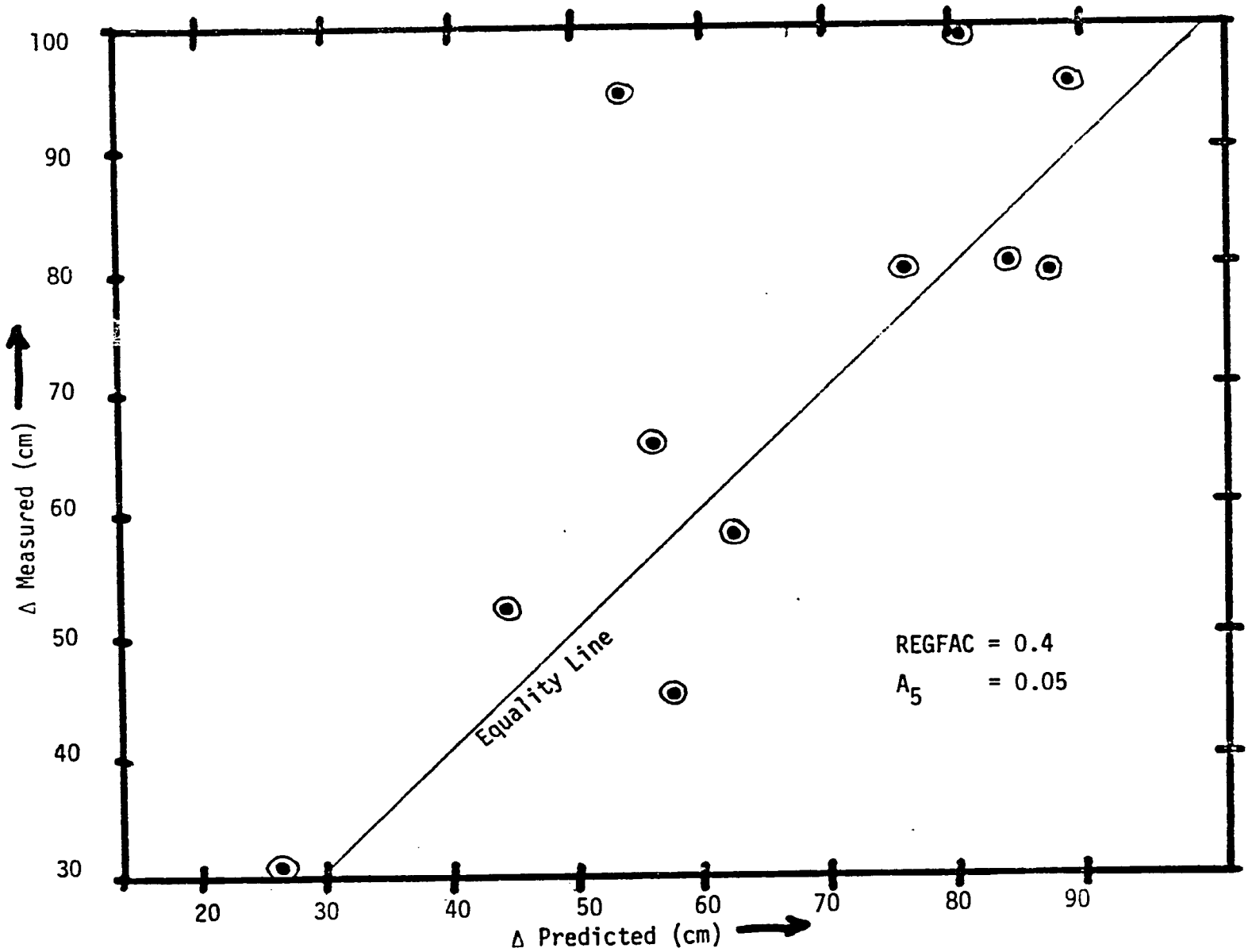

Figure 4: Predicted vs. Measured Δ Predicted (cm)

obtained through the use of the pavement structural number (SN) and the corresponding effective subgrade layer obtained from Equation (5). It has to be noted that pavement sections with structural number of 3 or more do not need any adjustment for the effective height of subgrade. SN = 3 lies within the AASHO range and the adjustment is needed only for SN outside this range as explained before.

To verify the adequacy of this calibration of the deterioration model parameters, the present serviceability rating was estimated (PSI) using Equations (2) and (3), together with V and SN' (kb of AS = 0.4, a_5 = 0.05). The results are shown in Figure 6, which indicates a good agreement between the predicted performance (PSI) and the field rating (PSR). However, two of the sections (indicated in Figure 6 by *) show relatively large variation from the equality line. This was mainly because the formation of the surrounding land in these two sections was different from the majority of links, as adjacent canals are present in those two sections.

Summary of Results and Conclusions

The study resulted in a number of significant results. However, it must be emphasized that the conclusions pertain to the constraints and inference conditions used in this study.

Justifiable extrapolation of the results should be made only after further studies. The following is a brief summary of the

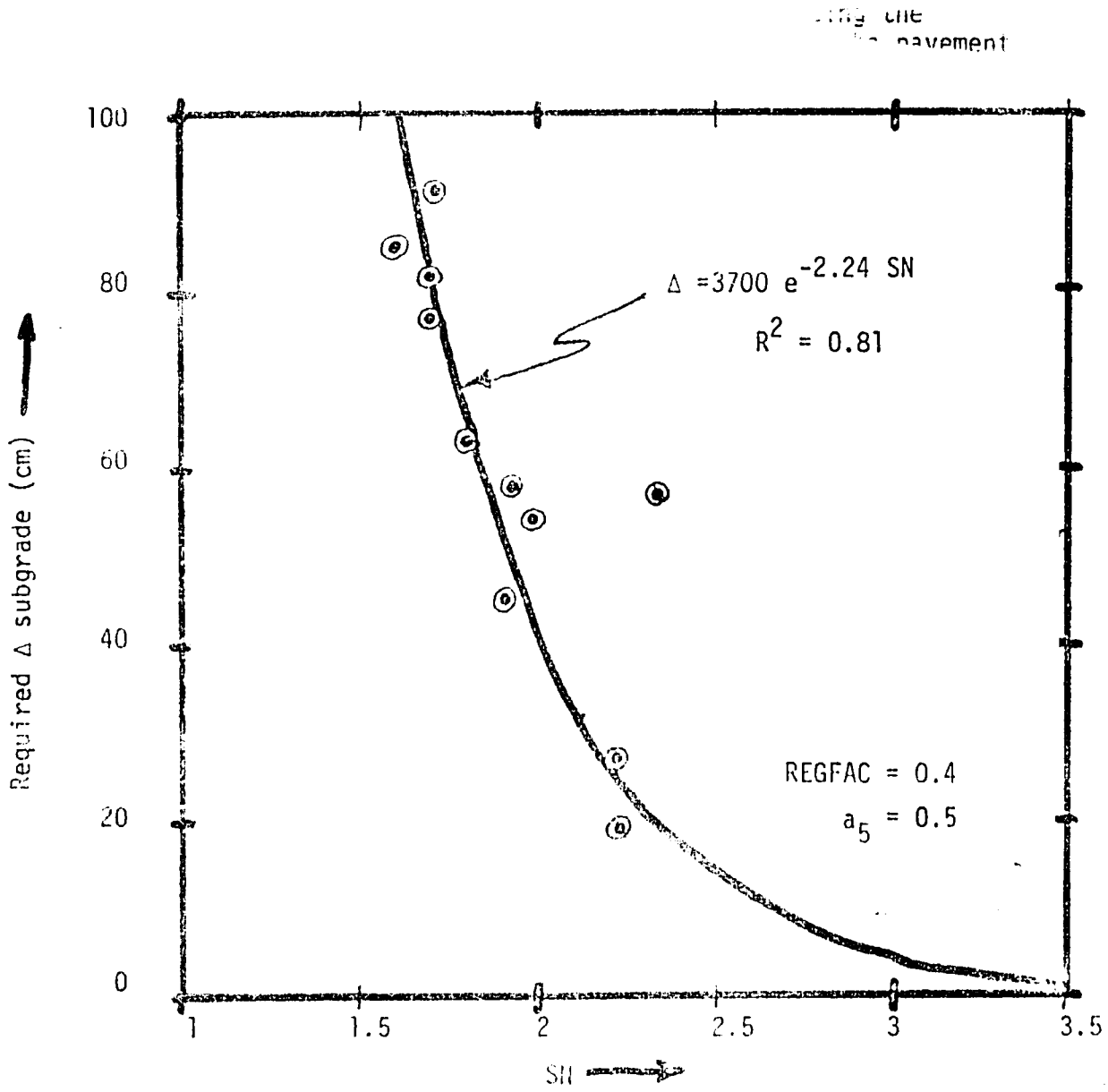

Figure 5: Relationship Between Pavement Structural Number (SN) and Required Effective Subgrade Height (Δ)

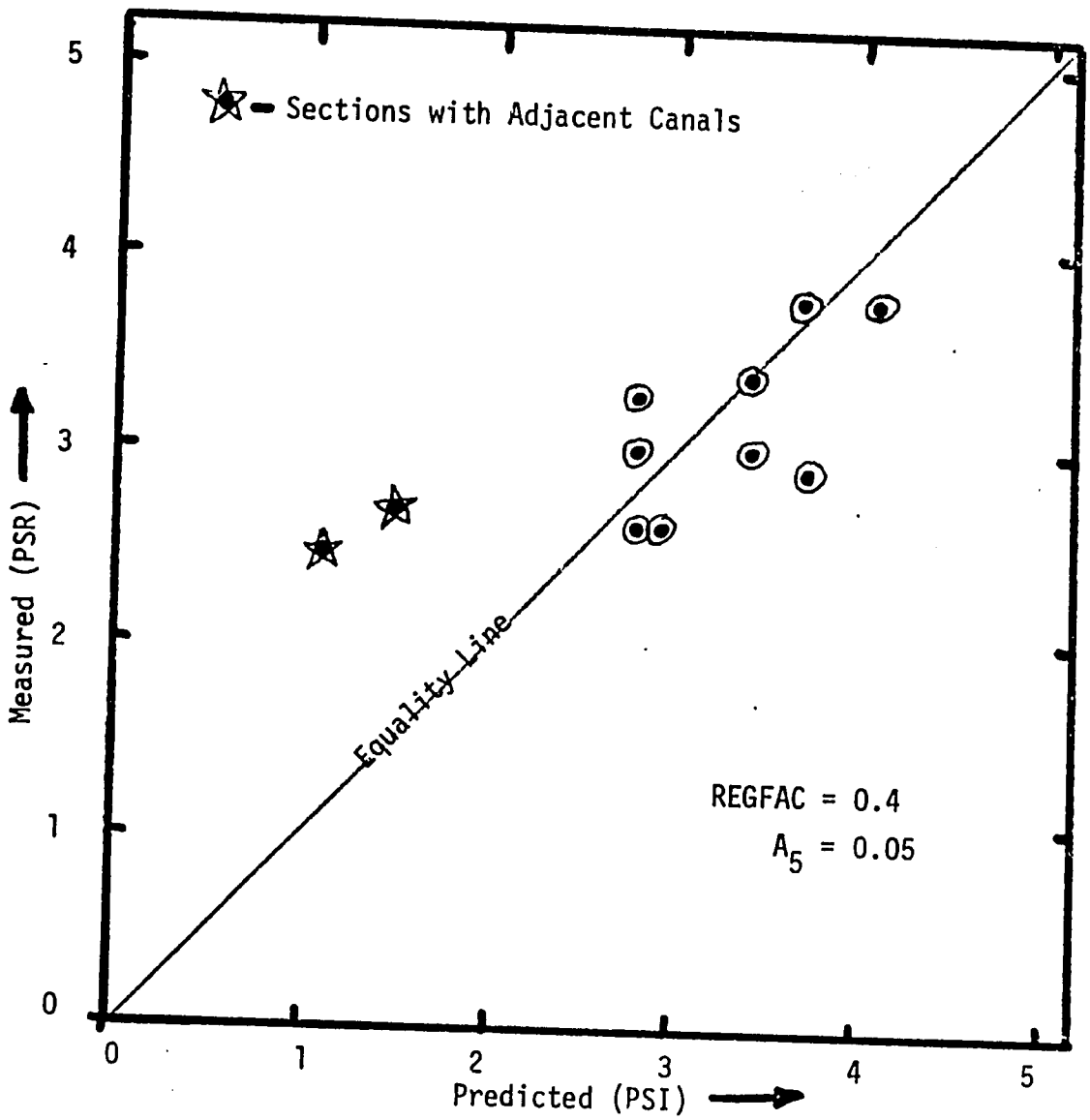

Figure 6: Present Serviceability Rating vs. Present Serviceability Index

significant findings of the study.

1. The best suited regional and drainage factor (REGFAC) for Egypt condition (Delta region and cultivated areas) is 0.4.

2. Pavement structural numbers (SN) that are less than 3 have to be adjusted by incorporating the effective subgrade layer as part of the pavement structure and using subgrade strength coefficient (a_5) of 0.05.

$$SN^* = SN + a_5 \Delta$$

Where SN^* = adjusted structural number

SN = pavement structural number

a_5 = subgrade strength coefficient

Δ = height difference between bottom of pavement structure and surrounding land in inches.

3. The inclusion of the effect of the subgrade layer in adjusting the pavement structural number, together with the fact that subgrade CBR values for the study area were about the same as the standard CBR_0, nullifies the effect of CBR on Equation (2). The $(CBR/CBR_0)^{0.14744}$ term has been considered as unity.

4. For pavement structural numbers (SN) of 3 or more, Equation (2) is used to estimate the modified (effective) structural number ($\overline{SN}$). However, for SN < 3 the equation will be:

$$(1+\overline{SN} = (1+SN^*) * (REGFAC)^{-0.10684}$$

and $(REGFAC) = 0.4$

therefore $(1+\overline{SN}) = 1.10\ (1+SN^*)$

Where $\overline{SN}$ = modified structural number

SN^* = adjusted structural number

These findings pertain to the following conditions:

1. These concepts are valid for roadway links located within the Delta region and cultivated areas. Desert roads are not incorporated in the study.

2. Roadway links do not have adjacent irrigation canals.

3. Embankment height ranges between 50 cm and 150 cm.

4. Pavement structural number range between 1.5 and 3.0.

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برنامج التخطيط التكنولوجي

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III.11

ROAD AXLE LOAD DISTRIBUTIONS IN EGYPT

BY

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I. INTRODUCTION

The amount of damage done to a road by a moving vehicle depends very strongly on the axle load of the vehicle. The relationship between this damage and the axle load is extremely important for the proper design of roads.

In Egypt, the axle load spectrum of the vehicle population has not been determined for use in modern pavement design. Surveys of the loads on separate axles of commercial vehicles have been conducted in a number of developing countries in Africa, the Middle East, the Far East and the Caribbean. Appendix A presents some of the findings of these surveys[1].

This paper presents the results of an axle-load weighing survey, which we initiated to provide adequate information on the pavement loads of commercial vehicles for use in the design and maintenance of highways in Egypt. The survey was carried out during February, 1978 and covered four sites on major highways; three of them are major approach highways to Cairo and the fourth is near Alexandria.

II. SURVEY STATIONS

The weighing survey was carried out at the following stations:

- Cairo - Alexandria Agriculture Highway (Cairo Entry)
- Cairo - Alexandria Agriculture Highway (Alexandria Entry)
- Cairo - Ismailia Desert Highway (km 21 from Cairo)
- Guiza - Badrashin Highway (Guiza Entry)

III. WORKING GROUP

The working group consisted of eight men, assigned jobs as follows:

- One for recording data;
- Four for weighing; (two weighing scales were used);
- Two for stopping vehicles and regulating traffic;
- One driver.

IV. EQUIPMENT

The equipment for the study consisted of a portable weighing bridge of size 75 cm x 30 cm x 15 cm. This meant that only one wheel (single or double tires) could be weighed at one time. As in many axle-load surveys, the small errors introduced by raising one wheel 15 cm can be ignored. Two scales were used in this operation, one for the right and one for the left wheel(s) of the same axle.

V. SURVEY PROCEDURE

Basically, the survey procedure is weighing each axle. This was carried out by weighing the wheel(s) of each axle at the same time. Meanwhile, the drivers were interviewed to get information about the empty load, payload and type of cargo.

In the interest of highway safety, only vehicles travelling in one direction were stopped for weighing and interviewing. To avoid inadequate and hazardous lighting conditions, weighing was carried out between 8 a.m. and 4 p.m.

VI. EQUIVALENCE FACTOR

The amount of damage done to a road by a moving vehicle depends very strongly on the axle loads of the vehicle. The relationship between this damage and axle load is extremely important for the proper designing of roads. Most of the information on this topic is derived from the AASHO Road Test[2]. The most widely used method for estimating the total damage from a sample of commercial vehicles is to express the damage caused by each axle load in terms of the damage that would be caused by a standard axle.

The equivalence factor of an axle is defined as the number of applications of an axle carrying a standard load which would cause the same damage to a road as one application of the axle in question. The standard load used in this paper is 18,000 lbs. (8,200 kg.). The equivalence factors depend, slightly, on the strength of the pavement and its present serviceability index[3]. The basic AASHO forms used for the damage relationships in this paper are:

$$\text{Equivalence Factor (single axle)} = \left(\frac{W + 0.46}{8.6}\right)^{4.79}$$

$$\text{Equivalence Factor (Dual in Tandem)} = 2^{-4.33}\left(\frac{W + 0.91}{8.6}\right)^{4.79}$$

Where: W = actual axle load in metric tons

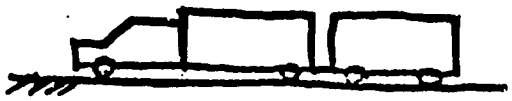
VII. ANALYSIS

In this analysis four vehicle types were considered. These are shown in the given diagramatic sketches, Figure (1).

Type 1: Truck
2 Single Axles
6 Tires

Type 2: Truck
1 Single Axle
1 Tandem Axle
10 Tires

Type 3: Truck with Trailer
4 Single Axles
14 Tires



Type 4: Truck with Trailer
3 Single Axles
1 Tandem Axle
18 Tires

Figure (1) - Truck Types Considered

The axle load equivalence factor was calculated using the damage relationship given before. Truck equivalence factors for each vehicle type were also calculated.

VIII. RESULTS

The results of the analysis will be presented for the following aggregate and disaggregate levels.

(a) All stations; all vehicles;

(b) Each station; all vehicles;

(c) Each station, considering different vehicle types.

Graphical representation of axle loads distributions are given in Appendix A.

DISTRIBUTION OF AXLE-LOADS AND DAMAGING POWER (ESA) FOR ALL STATIONS (ALL VEHICLES)

The total number of axle loads analyzed in this paper is 1163, corresponding to 384 commercial vehicles.

The results are as follows:

Axle Load (Above)	% Axles	% ESA (Equivalent Standard Axle)
2,000 kg	100.00	100.00
4,000 kg	83.89	99.98
6,000 kg	63.43	98.82
8,000 kg	44.09	94.90
10,000 kg	27.59	82.28
12,000 kg	13.06	59.09
14,000 kg	4.12	28.81
16,000 kg	1.03	8.71

Average Truck Factor = 6.64 (Standard axle/truck)

Average Axle Facotr = 2.19 (Standard axle/axle)

DISTRIBUTION OF AXLE-LOADS AND DAMAGING POWER (ESA) FOR EACH OF THE SURVEY STATIONS (all vehicles):

The following table gives the results of the analysis for each of the survey stations:

Station	Entry of Cairo-Alexandria Agricultural Road Alexandria Station		Entry of Cairo-Alexandria Agricultural Road Cairo Station		Ismailia Cairo Road		Guiza Badrashin Road	
Axle load	% Axles	%ESA	% Axles	%ESA	% Axles	%ESA	% Axles	%ESA
above 2000 kg	100	100	100	100	100	100	100	100
" 4000 kg	89.37	100	86.65	99.87	71.77	99.16	87.82	99.94
" 6000 kg	70.38	99.14	64.13	98.32	50.67	97.11	71.14	98.13
" 8000 kg	55.28	96.95	42.93	93.13	28.22	89.84	53.19	95.04
" 10000 kg	39.88	89.71	23.82	77.87	17.34	77.57	30.12	82.80
" 12000 kg	20.24	67.35	9.95	51.08	7.14	44.72	16.66	63.80
" 14000 kg	7.55	36.70	2.88	25.11	1.36	16.24	5.12	31.55
" 16000 kg	1.21	7.28	1.05	10.70	0.34	4.9	1.92	13.83
Total number of Vehicles in Survey	90		117		126		51	
Numbers of Axles	331		382		294		156	
Average Truck Factor	11.14		6.34		3.26		7.80	
Average Axle Factor	3.00		1.94		1.42		2.55	

DISTRIBUTION OF AXLE-LOADS FOR EACH STATION CONSIDERING DIFFERENT VEHICLE TYPES

Cairo-Alexandria Agriculture Road - (Alexandria Entry)

Vehicle Type	Truck		Truck with Trailer	
Axle-Load (above)	Two axles % Axles	Three axles % Axles	Four axles % Axles	Five axles % Axles
2,000 kg	100.00	100.00	100.00	100.00
4,000 kg	73.33	90.50	90.42	97.50
6,000 kg	40.00	76.20	75.84	57.50
8,000 kg	30.00	61.90	62.51	27.50
10,000 kg	20.00	57.20	44.18	20.00
12,000 kg	10.00	28.60	21.68	15.00
14,000 kg	6.66	14.30	6.68	10.00
16,000 kg	0.00	0.00	0.84	5.00
Number of Trucks in Survey	15	7	60	8
Number of Axles	30	21	240	40
Average Truck Factor	4.38	2.19	13.83	11.52
Average Axle Factor	2.19	0.73	3.46	2.31

C.2 Cairo-Alexandaria agriculture road (Cairo entry).

Vehicle type / Axle-Load	Truck		Truck with Trailer
	Two Axles	Four Axles	Five Axles
	% Axles	% Axles	% Axles
Above 2000 kg	100	100	100
" 4000 kg	73.96	89.00	100
" 6000 kg	44.78	68.25	82
" 8000 kg	33.38	41.15	70
" 10000 kg	21.98	20.40	44
" 12000 kg	9.48	8.10	20
" 14000 kg	2.08	2.15	8
" 16000 kg	1.04	0.85	2
No. of Trucks	48	59	10
No. of Axles	96	236	50
Average Truck factor	3.55	8.07	13.47
Average Axle factor	1.78	2.0	2.69

Cairo - Ismailia Desert Road
(km 21 from Cairo)

Vehicle Type	Truck	Truck with Trailer	
Axle-Load (above)	Two axles % Axles	Four Axles % Axles	Five axles % Axles
2,000 kg	100.00	100.00	100.00
4,000 kg	62.38	98.0	100.00
6,000 kg	40.38	78.85	80.00
8,000 kg	20.20	51.92	60.00
10,000 kg	11.00	30.78	55.00
12,000 kg	4.12	15.40	20.00
14,000 kg	0	5.78	5.00
16,000 kg	0	1.92	0.00
Number of Trucks in Survey	109	13	4
Number of Axles	218	52	20
Average Truck Factor	1.66	13.18	14.54
Average Axle Factor	0.83	3.27	2.91

Guiza - Badrashin Road (Guiza Entry)

Vehicle Type Axle-Load	Truck Two Axles % Axles	Truck with Trailer Four Axles % Axles	 Five Axles % Axles
(above) 2,000 kg	100.00	100.00	100.00
4,000 kg	76.00	90.00	100.00
6,000 kg	46.40	78.33	95.00
8,000 kg	32.10	61.67	70.00
10,000 kg	17.80	41.67	30.00
12,000 kg	7.10	30.00	10.00
14,000 kg	3.55	10.00	0.00
16,000 kg	0.00	5.00	0.00
Number of Trucks in Survey	28	15	8
Number of Axles	56	60	40
Average Truck Factor	2.94	16.64	8.27
Average Axle Factor	1.47	4.16	1.65

IX. GENERAL REMARKS AND CONCLUSIONS

1. Major differences have been found between the magnitudes of axle loads in different survey stations in Egypt similar to differences existing in various developing countries (Appendix A).

2. While axle loads above 8,000 kg are only 44%, they cause 95% of the damage to the roads. This shows that roads are being damaged at very high rates compared with the rate of damage experienced by pavements in Europe (Appendix A).

3. The axle loads above 8,000 kg represent 55% for Alexandria-Cairo Road, 53% for Guiza-Badrashin Road, 43% for Cairo-Alexandria Road, and 28% for Ismailia-Cairo Road. These give average equivalent standard axle factors of 3.00, 2.55, 1.94 and 1.42, respectively.

4. The Alexandria-Cairo Road results show the highest axle-load factor, due to trucks carrying heavy cargoes from Alexandria Harbor to all of Egypt.

5. In general, the average axle factor for vehicle type 2 (three axles) is the least value while the average axle factor for vehicle type 3 (four axles) is the largest value.

6. A significant percentage of trucks were found to be overloaded by factors up to 50 percent more than documented information giving tare weight and payload. This should be seriously considered when fixing a legal axle load, since the AASHO road tests have shown that, by doubling the axle load from 8 tons to 16 tons, the damaging effect on a highway is increased by over 20 times.

7. Average truck and axle-load factors for Egyptian highways determined by this weighing survey are as follows:

Vehicle Type	Truck		Truck with Trailer	
	Two Axles	Three Axles	Four Axles	Five Axles
Percentage of vehicle type in the weighing survey	52	2	38	8
Truck Factor	2.49	2.19	11.75	11.58
Axle Factor	1.25	0.73	2.94	2.32

REFERENCES

1. H.E. Bofinger, "Research into the Deterioration and Strengthening of Road Pavements in Developing Countries," Pan African Conference, Ghana, November, 1977.

2. Highway Research Board, The AASHO Road Test, Report 5 Pavement Research, Special Report 61-E, Washington, D.C. 1962.

3. F. Moavenzadeh, et al., The Highway Cost Model: General Framework, TAP Report 75-4, Massachusetts Institute of Technology, Cambridge, Massachusetts, September, 1975 (Technology Adaptation Program).

Results of Axle Load Surveys in Different Countries

Year	Country	Legal Axle Load Limit (Tonnes)	ESA per 100 axles	Average ESA per payload (Tonne)	Range of axle load distribution (Tonnes) > 8T	8.2T	10T	12T	14T	16T	18T
1976	Ethiopia	8.0	491	0.66	45%		34%	24%	15%		
1976	Ethiopia	8.0	233 (mean of 5 trunk routes)	0.45	28%		19%	12%	7%		
1975	Nigeria	10.0	389	0.62			30%	10%		4%	
1975	Turkey	8.2	57	0.21		28%	17%	7%	4%		
1974	Kenya	8.0	281 (33t)* Mombasa to Nairobi Road	0.75	67%		52%	30%	4%		
1974	Jordan	12.0	2 axle = 1100 3 axle = 1600 4 axle = 675	1.48 1.79 0.93	77%		58%	45%	28%	14%	
1971	Abu Dhabi	No Limit	127	0.49	23%		8%	4%	1%		
1970 1971	Qatar	No Limit	109	0.50	21%		13%	6%	2%	1%	
1970 1971	Qatar Selected Route	No Limit	452	1.08	43%		36%	27%	14%	13%	10%
1967	Malaysia	7.0	19	0.15	12%		4%	2%			
1964	United Kingdom M1 Motorway	10.0	46	0.19	7.5%		4%	3%	2%		
1963	Jamaica	7.0	36	0.33	13%		6%	2%			
1961	Rhodesia	7.0	5.9	-	1.5%						
1961	Malawi	7.0	3.6	-	2%						
	France RN10 Motorway	13.0	89	0.31	-						

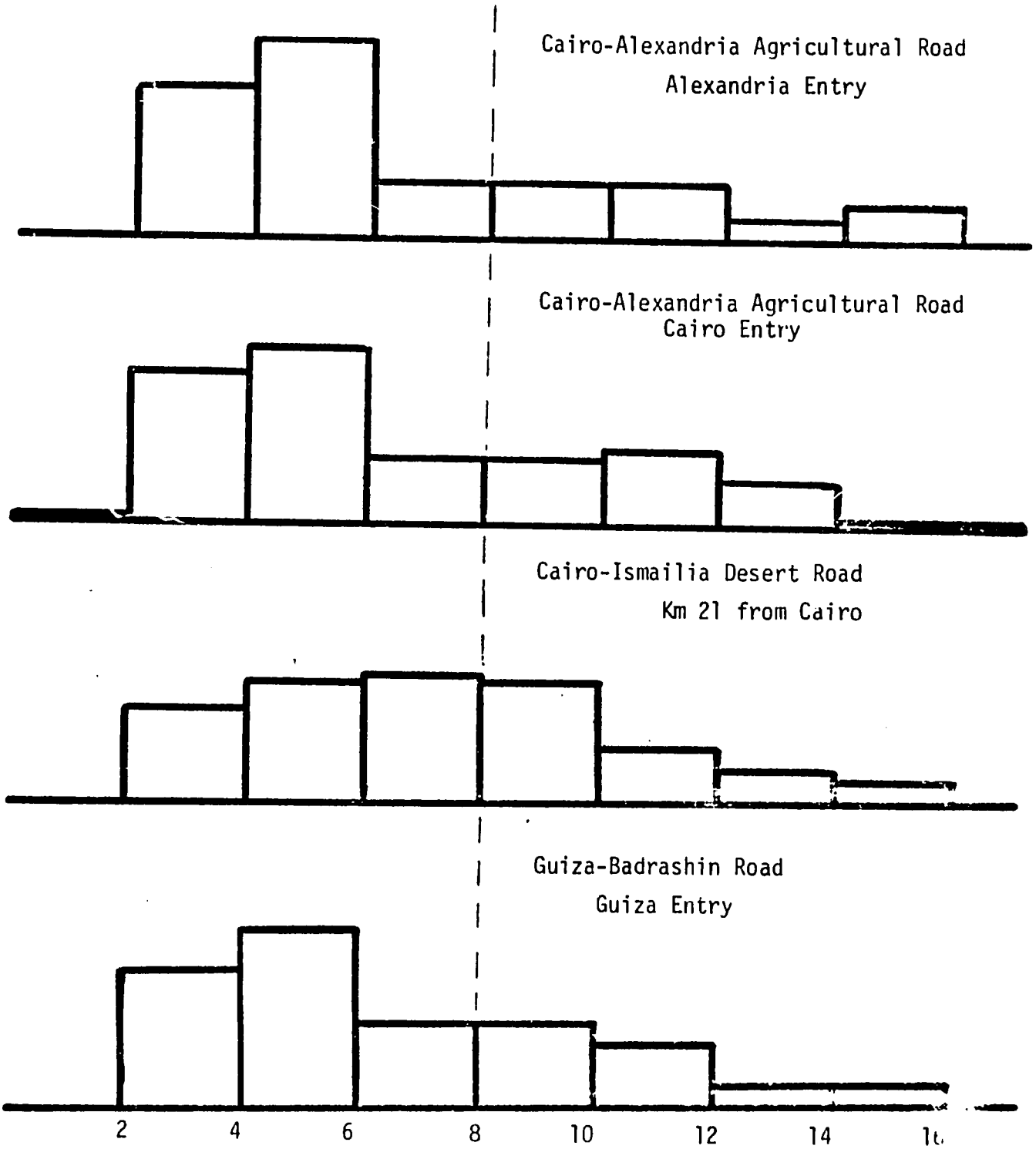
*heavy commercial vehicles only

Equivalence Factor

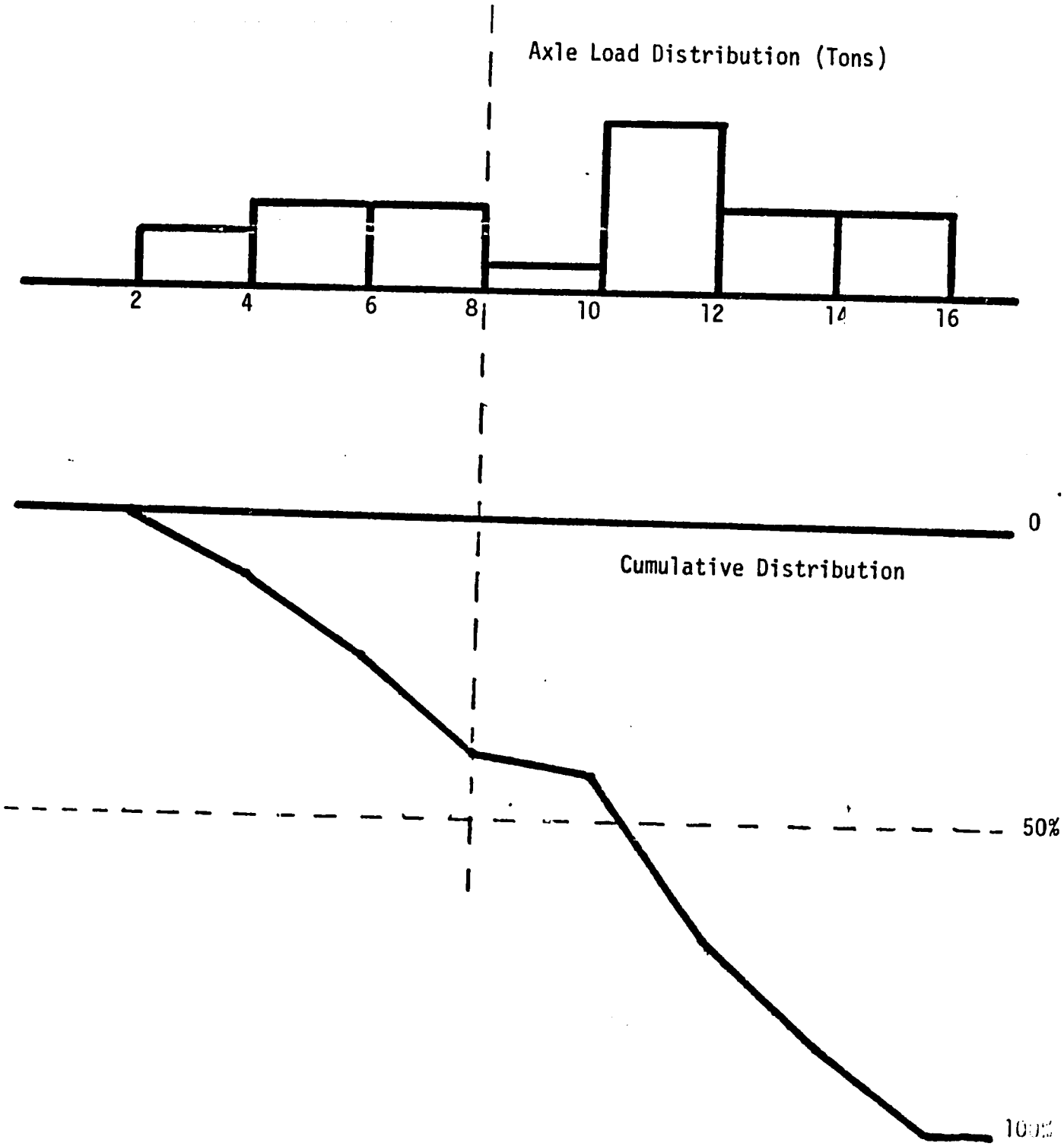
N.B.

8.2T = 1.00
10.0T = 2.47
12.0T = 5.69
14.0T = 11.52
16.0T = 21.20
18.0T = 36.48

APPENDIX A

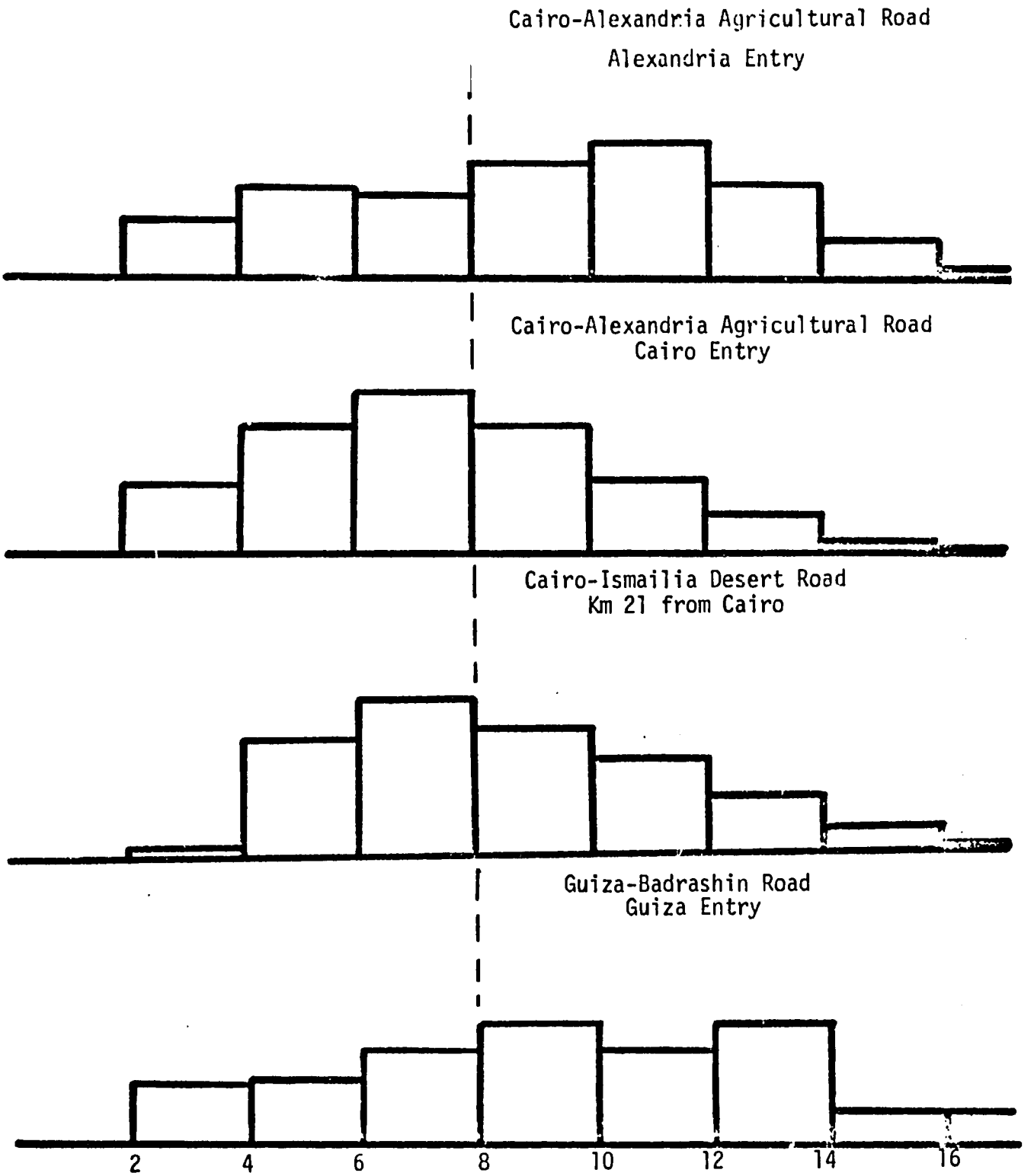


AXLE LOAD DISTRIBUTION (TONS) FOR VEHICLE TYPE 1: 2 AXLES

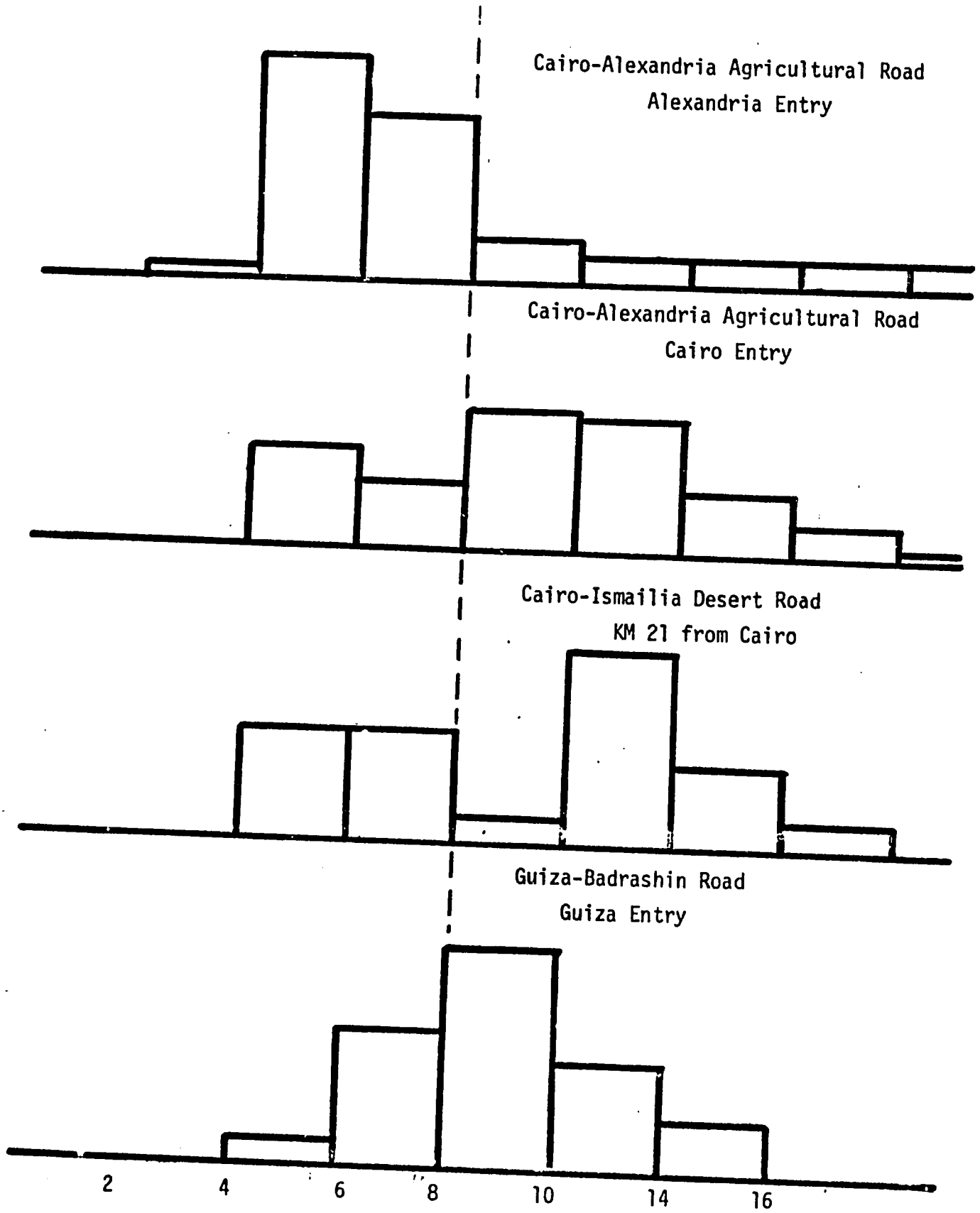


VEHICLE TYPE 2: 3 AXLES

CAIRO-ALEXANDRIA AGRICULTURAL ROAD - ALEXANDRIA ENTRY



AXLE LOAD DISTRIBUTION (TONS) FOR VEHILCE TYPE 3: 4 AXLES



AXLE LOAD DISTRIBUTION (TONS) FOR VEHICLE TYPE 4: 5 AXLES