VOLUME III

TRANSPORT PLANNING AIDS and METHODS for CAIRO URBAN AREA

VOLUME III
PART II

ANALYSIS and CASE STUDIES

PREFACE

This report is one of a series of publications which describe various studies undertaken under the sponsorship of the Technology Adaptation Program at the Massachusetts Institute of Technology.

The United States Department of State, through the Agency for International Development, awarded the Massachusetts Institute of Technology a contract 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. This particular study describes research conducted in conjunction with Cairo University, Cairo, Egypt.

In the process of making the TAP supported study some insight has been gained into how appropriate technologies can be identifies and adapted to the needs of developing countries per se, and it is expected that the recommendations developed will serve as a guide to other developing countries for the solution of similar problems which may be encountered there.

This research is carried out by Cairo University/M.I.T. Technological Planning Program, under the auspices of the M.I.T. Technology Adaptation Program, which is funded by the United States Agency of International Development (USAID), Cairo, Egypt. The view and opinions expressed in this report, however, are those of the authors and do not necessarily reflect those of the sponsors.

ACKNOWLEDGEMENTS

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Introduction :

Since 1977, Cairo University (CU) and the Massachusetts Institute of Technology (MIT) have worked cooperatively in a multi-faceted technology adaptation program addressing research needs of Egypt. One component of this program has been the urban transportation system in Cairo; within this component, a wide range of research topics was examined. Before detailing methods and findings of these topics, it is useful to first review the goals of the Urban Transportation Research Project. This cooperative effort between MIT and transportation professionals in Cairo is designed to:

- Improve and broaden capabilities of academic and planning institutions concerned with transportation in Egypt.
- Establish a comprehensive and reliable data base that can be used in transportation studies and that can be periodically tested and updated by appropriate governmental agencies.
- Adapt and calibrate those transport planning models and methods most suitable for Cairo.
- Formulate and test the sensitivity of transportation behavior and performance to alternative transportation investment, traffic management, and government policies.

These broad goals lead to a rather varied research agenda, covering many aspects of transportation operations, decision making, planning, and programming. Volume III describes the achievements made in developing transport planning aids and methods as part of this research agenda.

There are five major sections to this volume, each of which is described briefly below :

Basic Data Elaboration, Volume III, Part (1)

Two traffic surveys - a 1977 survey of private transport in Cairo and a 1978 survey of public transport use - form the basis for much of the

research in this project. The survey results are stored on magnetic tapes, and a complete documentation of these two surveys and their results is available in the Department of Civil Engineering, Faculty of Engineering, Cairo University. Data elaboration for speed/volume/travel time relationships, socio-economic variables for the traffic zones and parking supply and use are among the subjects covered in Part one of this report.

Travel Demand Forecasting, Volume III, Part (2)

An important methodological foundation of urban transportation planning is the development of an analytical capability to model future transport supply and demand relationships. Toward this end, trip generation, distribution and assignment models were calibrated for the Cairo region; requisite investigations to obtain required input data for these models (such as car occupancy rates, peak hour factors, trip information) were also undertaken in order to facilitate model calibration. With these models, forecasts of travel demand in Greater Cairo by different transport modes and for different trip purposes are obtained. The forecast travel demand is then assigned to the future transport network in the city, and system performance is evaluated. These subjects are covered in Part two of this report.

Auto Ownership, Volume III, Part (2)

The dramatic increase in the number of private cars in Cairo (about a 40% increase between 1976 and 1978) significantly contributes to the problems of congestion, safety, and pollution (both air and noise) in Cairo. The purpose of this auto ownership study was to develop a suitable methodology for estimating future increases in car ownership for the

whole of Egypt, as well as for the different traffic zones in Greater Cairo in particular. The scope and findings of the auto ownership study are described in Part three of this report.

Parking, Volume III, Part (2)

Like most cities of its size, Cairo faces important questions about the future role of parking facilities and policies. This research element sought to develop a model which accurately portrays the interaction between parking supply (by type and location) and vehicular traffic operating on the urban street network in the CBD. Such a model is very useful in evaluating different parking policies in the city center and outlying areas of Cairo. Part four of this report reviews this phase of the research.

Case Studies, Volume III, Part (2)

Following these four methodological parts of the report, case studies are presented to illustrate the applications of the data base and the analytical tools developed in the course of the project to date. The first case study shows how the data and planning aids presented in parts one and two of this report can be used in project programming. The second case study investigates the impact of the regional underground line on surface public transport services in the city center.

As can be seen from this description of work effort, considerable energy has gone into making this research a success. Future research will benefit from the time and effort spent in establishing the solid foundation that the research activities described in this report represent.

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CHAPTER II

TRAVEL DEMAND FORECASTING

1. Introduction

Travel demand forecasting is the stage of Urban Transportation Planning in which mathematical models are calibrated to represent the functional relationships between base year travel demand and both the existing planning parameters and the features of the existing transport system. The calibrated models are then used for forecasting future travel demands in the study area. Three types of model were calibrated and tested during this phase of the project as set out below:

a. Trip Generation
b. Trip Distribution Models
c. Traffic Assignment Models

Once calibrated, these models were used for forecasting future travel demand and traffic flows in Greater Cairo. In calibrating the above models, several techniques were considered; those which most suited the nature of the study area, as well as the available data set, were chosen for use. A total of 40 internal reports were produced in which the background, progress, and problems faced in the development and calibration of models were described in detail. It should be noted, therefore, that in this report an outline of the work done in travel demand forecasting is presented first, followed by the main results obtained. Detailed analysis and results are not included, and so the reader may wish to refer to the list of internal reports given in section 9 for additional information on specific topics. Fig. (II-1) shows a simplified flow chart of the analysis procedure followed in the travel demand forecasting stage of the project.

Finally, modal split analysis was omitted from the modeling sequence for two main reasons. First, there is a lack of sufficient data with

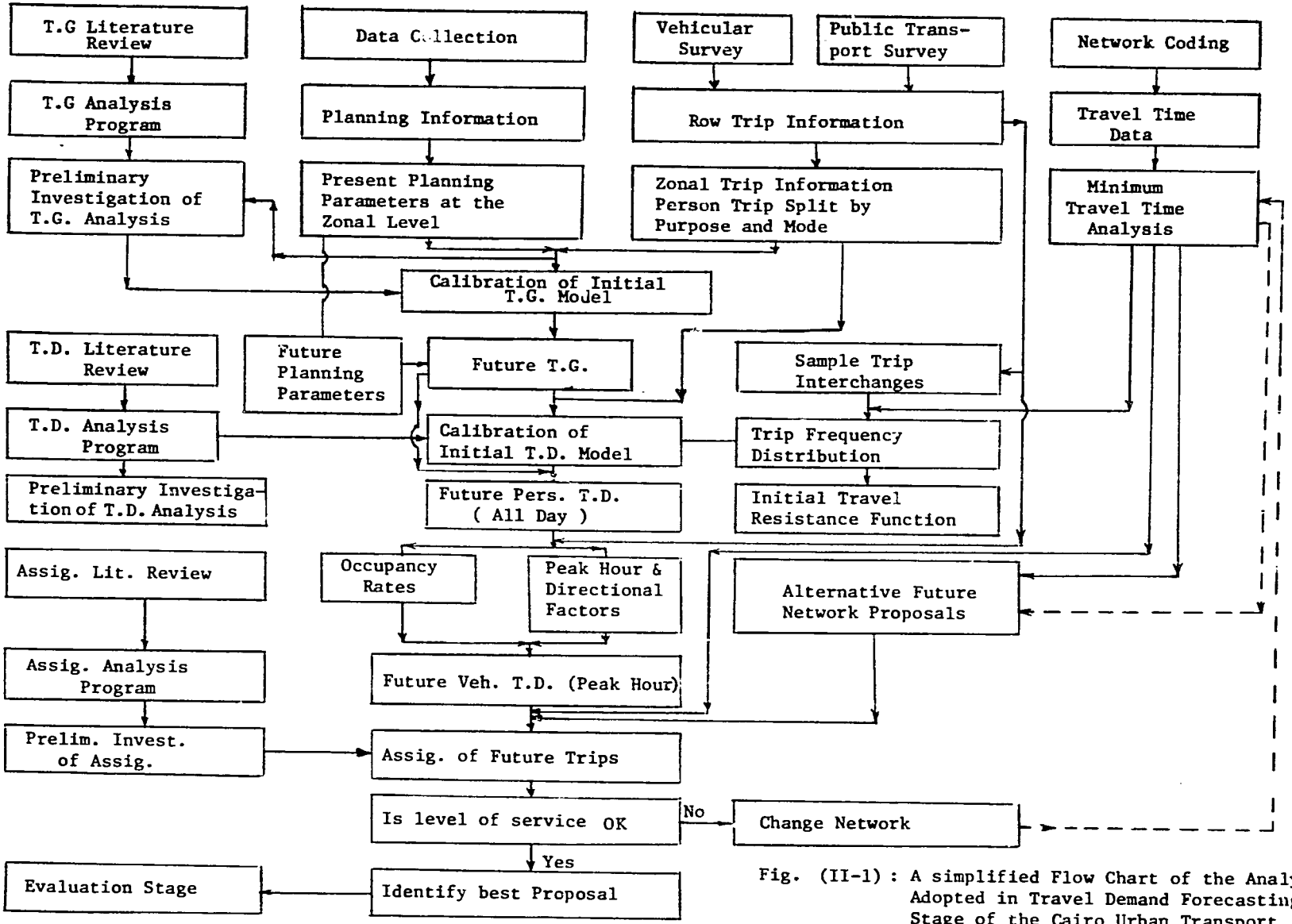

Fig. (II-1) : A simplified Flow Chart of the Analysis Adopted in Travel Demand Forecasting Stage of the Cairo Urban Transport Project.

which to undertake such an investigation properly. Second, since car owners rarely use public transport because of the low level of service, it is clear that no modal choice actually occurs; those who use public transport do so not out of choice, but out of necessity.

1.1 Objectives

The main objectives of travel demand forecasting (TDF) activities of the project included:

1. To calibrate trip generation, distribution, and assignment models for Greater Cairo.
2. To investigate different modeling techniques for each of the above mentioned models and to recommend the most suitable ones to be used considering local conditions.
3. To develop suitable computer programs and packages through which to undertake travel demand forecasting procedures and modeling.

1.2 Limitations

As in any transportation study, some limitations were imposed on the analysis of travel demand forecasting in Greater Cairo. These limitations are briefly discussed here.

First, the 1977 (1) & 1978 (2) travel surveys were not undertaken with the objective of enabling detailed sophisticated modeling. As a consequence, they did not permit the calibration of certain TDF models. Secondly, splitting trips by purpose was limited to three main categories (home based work, home based other, and non-home based) although 10 different trip purpose classifications were available from the interview results. This was done to increase sample size for each purpose type.

Thirdly, the available trip information represented only 10 hours of typical working days, hence the established trip generation and distribution

models corresponded to those 10 hours. No socio-economic data were gathered at the household (or individual) level during the 1977 and 1978 surveys and hence disaggregate modeling was not possible. Furthermore, no data were available for formulation of a generalized cost function. Hence, the trip distribution gravity model (as well as traffic assignment) was based on minimum travel times only.

Finally, the socio-economic data set has some limitations, including the difficulties of establishing some variables at the traffic zone level with a reasonable degree of accuracy and of predicting some variables (such as income).

The above mentioned limitations are not very different from those usually faced in typical urban transport studies, especially in developing countries. Nonetheless, every effort was made to minimize the impact of such limitations on the analysis of travel demand forecasting in this pioneer study, the first of its nature to be undertaken in Greater Cairo.

2. Travel Characteristics in Greater Cairo

2.1 General Trip-Making Statistics

The Urban Transportation Project offered the first opportunity to carry out a comprehensive survey of person trips in metropolitan Cairo and to collect information to form a sound data base indespensable for transport planners. This section summarizes some of the trip characteristics that were observed during the vehicular and public transport surveys (1, 2).

Table II-1 shows the total person movements on the different modes during the morning peak hour, which was found to be 8-9 a.m. The total number of person trips amounted to 438,400, of which 44.1% used private modes of transport* and the remaining 55.9% used public transport. Seventy-five percent of the public transport passengers use buses; the Nile ferry accounts for 1% of the public transport passengers; the remaining 4 modes (namely tram, trolley, metro, and urban railway) have approximately equal shares of the remaining 24% of the passenger market.

The flexibility of the public transport bus, the size of its network and fleet, as well as the operational difficulties encountered by other public transport modes (power cuts, non-insulated track, etc.) make the bus a more "attractive" mode of transport overall. Table II-2 shows the number of lines and the number of vehicles of the different public transport modes.

Table II-3 shows an average all-day occupancy rate factor for the different private modes, classified according to two movement types:

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*Private modes consist of private cars, taxis, private micro buses, and private buses.

Table (II-1)

Total Passenger Movement by Mode at Hour 8 to 9 a.m.

Mode	Private Car	Taxi	Micro Bus	Private Bus	P.T.Bus	Tram	Trolly	Metro	Ferry	Railway	All Modes
Passenger Trips	71777	47972	17771	55875	185875	17008	10471	15070	2248	14333	438400
Percentage	16.4	10.9	4.1	12.7	42.4	3.9	2.4	3.4	0.5	3.3	100

Table (II-2)

Number of lines and Vehicles of the Different Public Transport Modes

Mode	P.T. Bus	Tram*	Trolly	Metro*	Ferry	Railway
No. of Lines	220	21	6	7	6	2
No. of Operating Vehicles	1439	156	74	45	18	28

* No. of Operating Units : A tram unit consists of 2 cars, a metro unit consists of 4 cars, and a train unit varies between 3 and 6 cars, depending on the time of day.

urban/urban and rural/urban. It was found that the occupancy rate for the latter movement is higher than for the former movement, except for the private bus.

The total passenger movement by trip purposes for the whole survey period is shown in Table II-4 split between private car, taxi, and public transport modes. It can be seen that the home-based trips constitute more than 50% of the trips on all modes. However, the non-home based taxi trips exceed the home based work taxi trips, as should be expected.

The hourly fluctuation factors for urban/urban and rural/urban movements for the different private transport modes are shown in Tables II-5-a) and b). For urban/urban movements, the peak period for private cars and taxis extends from 8-10 a.m., while most of the private micro-buses and private buses run between 7-8 a.m. as they generally serve schools and industrial companies that usually have an early start to the day. It is notable from these tables that, while private car and taxi users are spread more or less evenly all day long, micro-bus and private bus users are more concentrated during the morning and evening peaks (7-8 a.m. and 3-4 p.m.), i.e. during the starting and ending hours of a working day. Table II-5-c shows the hourly fluctuation for public transport passengers. The results shown in this table indicate that the volume of passengers using public transport modes is evenly distributed between the different hours of the day.

2.2 Socio-Economic Features of Traffic Zones

This section discusses the socio-economic and land use variables chosen for introduction into the trip generation models for Greater Cairo.

Table II-3

Occupancy Rates for Selected Modes in Cairo Metropolitan Area

Mode / Movement Type	Private Car	Taxi	Micro Bus	Private Bus
Urban / Urban	2.09	3.01	5.47	25.70
Rural / Urban	2.45	5.19	6.18	10.44

Table II-4

Passenger Trips by Trip Purpose and Mode in Cairo

Mode / Purpose	Private Car*		Taxi*		Public Transport**	
	Number	%	Number	%	Number	%
HBW	307085	45.4	151745	34.3	1106430	68.5
HBO	194537	28.7	102118	23.1	322795	20.0
NHB	175222	25.9	188594	42.6	186123	11.5
All Purpose	676844	100.0	442457	100	1615348	100

*Survey period for 10 hours (7 a.m. until 11 a.m.; 1 p.m. until 4 p.m.; 6 p.m. until 9 p.m.).

**Survey period for Publid Transport: 6 a.m. to 3 p.m.

Table II-5

a) Private Transport Hourly Fluctuation Factors for Urban / Urban Movement in Cairo

Mode \ Study Hour	7-8	8-9	9 -10	10-11	13 -14	14-15	15-16	18-19	19-20	20-21	All Survey period
Private Car	0.09	0.13	0.12	0.11	0.11	0.11	0.08	0.10	0.09	0.08	1.00
Taxi	0.15	0.12	0.13	0.10	0.09	0.07	0.08	0.12	0.09	0.07	1.00
Micro Bus	0.23	0.16	0.06	0.11	0.09	0.09	0.11	0.07	0.04	0.05	1.00
Private Bus	0.34	0.10	0.09	0.03	0.11	0.11	0.14	0.03	0.03	0.01	1.00

Table II-5

b) Private Transport Hourly Fluctuation Factor for Rural / Urban Movement in Cairo

Mode \ Study Hour	7-8	8-9	9-10	10-11	13-14	14-15	15-16	18-19	19-20	20-21	All survey period
Private Car	0.11	0.13	0.12	0.12	0.14	0.09	0.15	0.06	0.04	0.04	1.00
Taxi	0.09	0.10	0.11	0.13	0.11	0.09	0.13	0.09	0.10	0.06	1.00
Micro Bus	0.03	0.09	0.11	0.10	0.04	0.03	0.32	0.23	0.03	0.03	1.00
Private Bus	0.08	0.23	0.08	0.06	0.07	0.04	0.07	0.36	0.01	0.02	1.00

Table II-5

c) Hourly Fluctuation Factors for Public Transport Movement (Bus-Trolley-Tram-Ferry-Metro-Suburban Railway) in Cairo

Study Hour	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	All Survey period
Fluct Factor	0.06	0.12	0.13	0.13	0.12	0.11	0.12	0.11	0.10	1.00

Each variable was subjected to statistical analysis to show its variability among different traffic zones of the study area, its frequency distribution, and the geographical categorization of its zonal values (3).

A total of 12 variables was selected from the set of 36 variables for Greater Cairo traffic zones (4); see also chapter I, section (1.6). The selection was made on the basis of the variable's logical importance in influencing zonal trip generation (productions and attractions) for different trip purposes. Table II.6 lists the chosen variables.

Table II.7 lists the main statistics of each of the selected 12 variables. In addition, histograms for each variable were drawn. These histograms are presented and discussed in detail in reference (4). Some pertinent comments concerning the selected variables are mentioned here.

Firstly, variability between zonal rates such as POP/HH, POP/ROOM, and INCOME/HH was low if compared with the remaining 9 variables in Table II.7. Furthermore, average family size of all analysis zones was 4.6 persons/household, a high value compared with metropolitan areas of the developed world. It also appears from Table II.7 that the average number of persons per room in each zone (POP/ROOM) was 1.758 with a relatively narrow range. This reflects the severe housing problem in Cairo.

In addition, it is clear from Table II.7 that among all of the 12 variables considered, JO, RTSL5, EMPWTE, and TE are distinguished by the great variability between zones (coefficients of variation $>$ 1.0). This means, in the case of JO, that work places were not evenly distributed among traffic zones. This is logical since great concentrations of jobs occurred in separate locations within the city. Similar conclusions apply to the cases of RTSL5, EMPWTE, and TE. However, it is interesting

Table II.6

Chosen Socio-Economic and Land Use Variables for Trip Generation Analysis

No.	Variables*	Units	Abbreviation
1	Population		POP
2	Household		HH
3	Total labor force & total students		TLF + TST
4	Household size		POP / HH
5	People per room		POP/Room
6	Average income per household	L.E./HH	INCOME/HH
7	Population density	Persons/km^2	POP/RAREA
8	Rooms		ROOM
9	Jobs offered		JO
10	Retail sales	10^3 L.E.	RTSL5
11	Employment in whole trade establishments		EMPWTE
12	Trading establishments		TE

* Detailed definition for every variable is found in report TDF17/TG4 (4).

Table II-7

Summary Statistics for the Zonal Planning Variables

No.	Abb. of variable	No. of obser-vations	Mean ($\bar{X}$)	Standard deviation (S)	Coef. of variation C.V. = ($\frac{S}{\bar{X}}$)
1	POP	120	57,635	57,340	0.995
2	HH	107	11,905	11,720	0.982
3	TLF + TST	107	29,413	28,326	0.963
4	POP/HH	107	4.685	0.398	0.085
5	POP/ROOM	107	1.758	0.533	0.303
6	INCOME/HH	107	689.54	285.53	0.414
7	POP/AREA	106	36,618	34,739	0.959
8	ROOM	107	29,329	24,348	0.830
9	JO	117	7,464	10,089	1.352
10	RTSL5	99	796	1,869	2.348
11	EMPWTE	99	232	379	1.634
12	TE	99	1,615	1,731	1.072

to note that the highest coefficient of variation, 2.348, was obtained for RTSL5. One of the reasons may be the concentration of trading activities in Cairo's central business district (CBD), the triangle of Tahrir, Ramsis, and Ataba squares, with only two or three other trading centers scattered around the city.

Each variable was classified into 5 categories (as given in Table II.8) with the zones relevant to each category given the same color on a zoning system map. A total of 12 maps corresponding to each of the variables given in Table II.6 are presented and discussed in reference (4). However, the main comments on the geographical distribution of some selected varaibles are given below.

Nearly all the very low population zones were located in the east and south peripheral zones of the city. In fact, these zones were located in the newly developed residential area of Greater Cairo. Heavily populated zones were mainly concentrated in the extreme north on both sides of the river Nile. It should be noted, however, that these zones were characterized by a very large residential area and, accordingly, total population in each of these zones was expected to be high.

As far as the zones of low and medium categories were concerned, they were mainly located within Cairo boundaries (i.e., the 66 zones of the enlarged CBD (ECBD)) with the low population zones to the west of the Nile and the medium zones mainly located to the east. A few exceptions occur, such as zones (21 001) and (21 003) which were characterized by a high number of households, even though the population in these zones is medium. Similar exceptions are zones (21 802), (21 701) and (21 702) where the above trend applies. Furthermore, zones (21 801), (20 802)

(21 201) and (22 501) were among the few very low population zones located within the 66 zones of ECBD. It is notable that the above mentioned four zones are considered to be the zones with the highest standard living in the capital.

As far as the distribution of job opportunities is concerned (i.e. variable JO), it can be concluded that three of the zones with very high job opportunities were (10 600), (10 501), and (11 409). These are the main industrial zones in the Greater Cairo region. Zones with a very high number of jobs are in and around the CBD area. The majority of the remaining zones of the ECBD belonged to the medium category. Zones located at the southeast peripherals generally offered few jobs.

Zones having high and very high values of the the number of TE were found around the CBD, with the remaining zones of ECBD having mostly medium values. Peripheral zones generally belonged to the low category, whereas most of the southern zones had a medium values of TE.

The main concentration of EMPWTE is located in the eastern side of the CBD. These were heavily occupied by wholesale trade establishments, including zones (21 001), (21 602), and (21 401).

Comparing the two variables POP/RAREA and INCOME/HH, an inverse correlation appears to exist between them. Zones which had high values of POP/RAREA had low values of INCOME/HH and vice versa. This is a logical finding since heavily populated areas are expected to have a low standard of living. Generally, zones around the CBD had high values of POP/RAREA and low values of INCOME/HH and this corresponds well with the patterns of urban structure in large metropolitan areas. It can also be noted that low residential density zones were scattered around peripheral zones of the study area. The increase in POP/ROOM is associated with a decrease in household income.

Table II-8

Categories for the Zonal Planning Variables

No.	Variable Abb.	Ranges of Categories				
		1	2	3	4	5
		Very Low	Low	Medium	High	Very High
1	POP	< 14,999	15,000-59,999	60,000-179,999	180,000-269,999	≥ 270,000
2	HH	< 3,999	4,000-10,999	11,000- 25,999	26,000- 33,999	≥ 34,000
3	TLF + TST	< 5,999	6,000-29,999	30,000- 83,999	84,000- 95,999	≥ 96,000
4	POP/HH	< 3.199	3.7 - 4.499	4.5 - 4.899	4.9 - 4.999	≥ 5.0
5	POP/ROOM	< 1.09	1.1 - 1.59	1.6 - 2.09	2.1 - 2.49	≥ 2.5
6	INCOME/HH	< 349	350 - 509	510 - 869	870 - 1069	≥ 1070
7	POP/AREA	< 11,999	12,000-31,999	32,000- 79,999	80,000- 99,999	≥ 100,000
8	ROOM	< 9,999	10,000-29,999	30,000- 69,999	70,000- 94,999	≥ 95,000
9	JO	< 1,499	1,500- 2,999	3,000- 4,999	15,000- 39,999	≥ 40,000
10	RTSL5	< 200	200-800	800-1800	1800-2500	≥ 2500
11	EMPWTE	< 149	150-299	300- 899	900- 1,499	≥ 1,500
12	TE	< 299	300-599	600- 2,699	2,700-6,299	≥ 6,300

2.3 Public Transport Trip Generation Features of Traffic Zones

This section discusses zonal trip generation characteristics of Greater Cairo (5). Data from each trip type were subjected to statistical analysis showing its variability between different traffic zones of the study area and its frequency distribution. The geographical categorization of zonal trip rates was also analyzed.

A set of 14 zonal variables was selected to represent trips made for different purposes as well as two percentages of zonal trips and zonal trip rates. Table II-9 lists the zonal trip variables and the two trip per-entages while Table II-10 lists the 16 zonal trip rate variables. The follwoing points should be noted concerning the definitions of trip types;

1. Home based work trips included work, business, and education trips.

2. Home based other trips included all home based trips for purposes other than work, business, education and shopping.

3. Home based other and shopping trips included all home based trips other than work, business and education.

4. Only trips with both origin and distribution in Greater Cairo (but excluding intra-zonal trips) were considered.

5. All trips for different purposes were aggregated to represent the available 10 hours (6 a.m. to 4 p.m.) of 1978 survey (1).

6. All trips for different purposes represented all public transport modes (i.e. bus, ferry, Heliopolis metro, and rail rapid transit).

Tables II-11 and II-12 list the main statistics for each of the 14 zonal total variables, the 2 percentage varaibles and the 16 zonal trip rates defined above. Histograms for the variables were drawn and are presented along with a detailed discussion and comments on the tables,

Table II-9

Zonal Trip and Trip Percentage Variables Used in Public Transport Trip Generation Analysis

No.	Variable	Notation
1	Production home based work	PHBW
2	Production home based other	PHBO
3	Production home based shopping	PHBS
4	Production home based other and shopping	PHBOS
5	Production total home based	PTHB
6	Production non-home based	PNHB
7	Production total purposes	PTOT
8	Attraction home based work	AHBW
9	Attraction home based other	AHBO
10	Attraction home based shopping	AHBS
11	Attraction home based other and shopping	AHBOS
12	Attraction total home based	ATHB
13	Attraction non-home based	ANHB
14	Attraction total purposes	ATOT
15	Home based work trip production/total trip productions (%)	(PHBW/PTOT)%
16	Home based work trip attraction/total trip attractions (%)	(AHBW/ATOT)%

Table II-10

Zonal Trip Rate Variables Used in the Public Transport Trip Generation Analysis

No.	Variable	Notation
17	Production home based work per household	PHBW/HH
18	Production home based other per household	PHBO/HH
19	Production home based shopping per household	PHBS/HH
20	Production home based other shopping per household	PHBOS/HH
21	Production total home based per household	PTHB/HH
22	Production non-home based per household	PNHB/HH
23	Production total purposes per household	PTOT/HH
24	Attraction home based work per jobs offered	AHBW/JO
25	Attraction home based other per jobs offered	AHBO/JO
26	Attraction home based shopping per jobs offered	AHBS/JO
27	Attraction home based other and shopping per jobs offered	AHBOS/JO
28	Attraction total home based per jobs offered	ATHB/JO
29	Attraction non-home based per jobs offered	ANHB/JO
30	Attraction total purposes per jobs offered	ATOT/JO
31	Attraction home based shopping per trading establishments	AHBS/TE
32	Attraction home based other and shopping per trading establishments	AHBOS/TE

Table II-11

Summary Statistics of the Zonal Public Transport Trip and Trip Percentage Variables

No.	Variable	No. of observations	Mean ($\bar{X}$)	Standard deviation (S)	Coeff. of Variation $CV=(\frac{S}{\bar{X}})$
1	PHBW	119	9091.9805	9406.0352	1.03450
2	PHBO	119	2294.4297	2270.2813	0.98950
3	PHBS	119	411.8887	355.6165	0.86338
4	PHBOS	119	2659.0278	2598.6213	0.97728
5	PTHB	119	11497.9290	11451.2814	0.99594
6	PNHB	119	1644.9897	1652.0532	1.00430
7	PTOT	119	13381.3164	13086.8086	0.97790
8	AHBW	119	9091.9805	11280.9414	1.24076
9	AHBO	119	2294.4297	3109.3638	1.35518
10	AHBS	119	411.8887	951.2983	2.30960
11	AHBOS	119	2659.0278	3899.92[illegible]	1.46667
12	PTHB	119	11497.9290	14676.1711	0.78344
13	ANHB	119	1644.9897	1876.4255	1.14069
14	ATOT	119	13381.3164	16538.0703	1.23591
15	(PHBW/PTOT)%	119	64.8759	11.5645	0.18442
16	(AHBW/ATOT)%	119	67.5100	12.6600	0.18753

Table II-12

Summary Statistics of Zonal Public Transport Trip Rate Variables

No.	Variable	No. of obser. vations	Mean ($\bar{X}$)	Standard deviation (S)	Coeff. of Variation $CV=(\frac{S}{\bar{X}})$
17	PHBW/HH	107	1.01940	0.96050	0.94222
18	PHBO/HH	107	0.25350	0.28290	1.11590
19	PHBS/HH	107	0.43100	0.04040	0.93735
20	PHBOS/HH	107	0.30140	0.28220	0.93630
21	PTHB/HH	107	1.32170	1.23500	0.93440
22	PNHB/JO	99	0.45550	0.68705	1.50830
23	PTOT/HH	107	1.61750	1.59400	0.98550
24	AHBW/JO	99	3.26573	9.09393	2.78470
25	AHBO/JO	99	0.63408	0.72847	1.14890
26	AHBS/JO	99	0.05887	0.08162	1.38640
27	AHBOS/JO	99	0.60753	0.70770	1.16488
28	ATHB/JO	99	3.63143	9.59429	2.64200
29	ANHB/JO	99	0.36580	0.38680	1.05740
30	ATOT/JO	99	3.89334	10.28600	2.64220
31	AHBS/TE	99	0.31865	0.64602	2.02737
32	AHBOS/TE	99	3.12821	4.44580	1.42119

in reference (5). However, some general comments on Tables II-11 and II-12 and the histograms are as follows:

- The mean of the trip rate PHBW/HH is approximately 1.0. This means that on average every household made only one work trip daily[1] on public transport modes. The mean of AHBW/JO = 3.3 means that on average about 3 public transport trips were made daily for each job offered. This high value may result from factors that affect AHBW trips other than JO, e.g., education available in each zone and the existence of jobs which necessitate more than two trips to the place of work (i.e., work places which close 4 hours during lunch and open again in the evening). Other means in Tables II-11 and II-12 appeared to be reasonable for the variables they represent.

- All coefficients of variation had high values.

- All histograms had approximately the same shape, being skewed to the left.

- There was correlation between home based trip production for different purposes. This was clear from the coefficient of variation of the percentage PHBW/PTOT, which had a low value. This conclusion also applies to trip attractions.

- Variability of the zonal aggregates AHBO, A BS and AHBOS were very high--especially AHBS, which had the high st value of coefficient of variation in Table II-11. Histograms for these variables had a common shape, with one tail and the mode shifted to the left. However, there were some zones which deviated far from the mean to the left-hand side. Thus, both the range and coefficient of variation for this variable were very high. One of the reasons behind this finding may be the concentration of major trading activities in Cairo's CBD with one or two more trading centers scattered around the city. Excluding these main shopping zones may reduce the coefficient of variation to a great extent. Those zones with extreme values of AHBS do not affect AHBOS because AHBS has a low percentage of AHBOS; (AHBS/AHBOS = 13.7%).

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(1) Note that only 10 hours of the day are taken into consideration as mentioned earlier, and that the word daily hereafter should be taken to mean the 10 hours period of the 1978 survey (2).

Each variable was classified into 5 categories with zones relevant to each category given the same color on a zoning system map. Limits of these categories are given in Tables II.13 and II.14. These maps are presented and discussed in details in reference (5). However, some pertinent comments on these maps are set out below.

- Variables PHBW, PHBO, PHBS, PHBOS, PTHB and PTOT:

Most of the zones with low values of PHBW, PHBO, PHBS, PHBOS, PTHB and PTOT were located in the eastern peripherals of the city. In fact, these zones were located in the newly developed residential area of Greater Cairo which also had low values of population. Zones located in the south peripherals of the city (excluding zone 11409, Helwan) had low and very low values. Other peripheral zones of the city had roughly medium values. Zones which had a high population also had high values of all trips under consideration. High standard of living zones (such as 20801, 20802 and 21101) had low and very low values because their residents may have used private transport rather than public transport modes. CBD zones were divided into 2 groups. The first group contained zones (21201, 21203, 21204 and 21207) in which the main city squares were located, namely Tahrir, Ataba, Falaki and Ramsis. These zones were considered from the most accessible zones and almost all of these zones had medium values. The second group contained zones (21202, 21205 and 21206) which were less accessible than zones of the first group and mainly had low values. These zones were mainly shopping zones. Zones located around CBD, and within the enlarged area, generaly had medium values.

Table II-13

Categories of the Public Transport Zonal Trip and Trip Percentage Variables

No.	Variable	Ranges of Categories				
		1	2	3	4	5
		Very low	Low	Medium	High	Very high
1	PHBW	< 2000	2000-8000	8000-24000	24000-38000	≥ 38000
2	PHBO	< 400	400-1600	1600- 6000	6000- 8400	≥ 8400
3	PHBS	< 80	80- 320	320- 1200	1200- 1440	≥ 1440
4	PHBOS	< 700	700-2800	2800- 7000	7000- 9800	≥ 9800
5	PTHB	< 2000	2000-6000	6000-14000	14000-22000	≥ 22000
6	PNHB	< 500	500-1500	1500- 4000	4000- 6000	≥ 6000
7	PTOT	< 3000	3000-12000	12000-36000	36000-51000	≥ 51000
8	AHBW	< 2500	2500-5000	5000-27500	27500-45000	≥ 45000
9	AHBO	< 800	800-1600	1600- 6400	6400-112000	≥ 112000
10	AHBS	< 100	100- 200	200- 1000	1000- 1400	≥ 1400
11	AHBOS	< 700	700-1400	1400- 8400	8400-13300	≥ 13300
12	ATHB	< 4000	4000-8000	8000-12000	12000-24000	≥ 24000
13	ANHB	< 500	500-1000	1000- 4500	4500- 6500	≥ 6500
14	ATOT	< 4000	4000-8000	8000-40000	40000-56000	≥ 56000
15	(PHBW/ PTOT)%	< 55	55-65	65-70	70-80	≥ 80
16	(AHBW/ ATOT)%	< 60	60-65	65-70	70-80	≥ 80

Table II-14

Categories of the Public Transport Zonal Trip Rate Variables

No.	Variable	Ranges of Categories				
		1	2	3	4	5
		very low	low	medium	high	very high
17	PHBW/HH	0-0.60	0.6 -1.00	1.00-1.4	1.40- 3.00	3.00- 5.2
18	PHBO/HH	0-0.15	0.15-0.25	0.25-0.30	0.30- 0.60	0.60- 1.30
19	PHBS/HH	0-0.03	0.03-0.06	0.06-0.08	0.08- 0.11	0.11- 0.21
20	PHBOS/HH	0-0.18	0.18-0.36	0.36-0.42	0.42- 0.72	0.72- 1.44
21	PTHB/HH	0-0.80	0.80-1.40	1.40-1.80	1.80- 3.20	3.20- 6.63
22	PNHB/HH	0-0.20	0.20-0.40	0.40-0.60	0.60- 1.00	1.00- 6.00
23	PTOT/HH	0-1.00	1.00-1.50	1.50-2.00	2.00- 4.00	4.00- 9.00
24	AHBW/JO	0-0.20	0.20-0.40	0.40-1.30	1.30- 2.60	2.60- 4.40
25	AHBO/JO	0-0.20	0.20-0.40	0.40-1.30	1.30- 2.60	2.60- 4.40
26	AHBS/JO	0.0.02	0.02-0.04	0.04-o.10	0.10- 0.18	0.18- 0.52
27	AHBOS/JO	0-0.20	0.20-0.40	0.40-1.20	1.20- 1.80	1.80- 4.80
28	ATHB/JO	0-1.00	1.00-2.00	2.00-8.00	8.00-12.00	12.00-93.75
29	ANHB/JO	0-0.10	0.10-0.20	0.20-0.70	0.70- 1.00	1.00- 5.10
30	ATOT/JO	0-1.00	1.00-2.00	2.00-8.50	8.50-14.00	14.00-99.50
31	AHBS/TE	0-0.05	0.05-0.15	0.15-0.65	0.65- 1.55	1.55- 4.15
32	AHBOS/TE	0-1.00	1.00-2.00	2.00-7.00	7.00-11.50	11.50-30.85

- Variables PNHB, AHBW, AHBO, AHBS, AHBOS, ATHB, ANHB, and ATOT

The category of trip attractions and non-home based trip productions was similar in many zones. Nearly all zones in the eastern and southern peripheral zones of the city had low or very low values. The first group of CBD zones (21201, 21203, 21204, and 21207) had very high values, while the group of CBD zones (21202, 21205, and 21206) had low or very low values. Zones around the CBD had high and medium values, and those in the peripheral zones of the enlarged CBD had low or very low values As for AHBS, it was shown that shopping zones in the CBD had very high values of this trip type, as might be expected. Other zones having medium values were almost all located around the CBD.

- (PHBW/PTOT)%

CBD zones, and some surrounding zones had low values of (PHBW/PTOT)% because of the large number of non-home based trips. Also, high-standard-of living zones (such as 21801, 21802, and 21101) had very low values because the residents of these zones were able to make a higher percentage of shopping and other trips. The highest values were found outside the enlarged CBD zones because these zones were less accessible by public transport. Hence, the residents of these zones were expected to make a higher percentage of work trips. In general, zones located within the enlarged CBD had low values, while those located outside the enlarged CBD had high values.

- (AHBW/ATOT)%

Almost all enlarged CBD zones had low or very low values; those located outside CBD had high or very high values; and zones around the

river Nile, within the enlarged CBD, had medium values. Industrial zones (such as 11409, 11411, 10600, and 11413) had high or very high values, as expected.

- PHBW/HH, PHBO/HH, PHBS/HH, PHBOS/HH, PTHB/HH and PTOT/HH

There were some similarities among the geographical distributions of these six variables. For instance, the first group of CBD zones had high and very high values, while the second group had medium to very low values. High-standard-of-living zones (such as zones 20801, 20802, 21101, and 20401) had low and medium values because the residents in these zones could use private transport. Almost all the zones' values ranged between low and very low categories, but there were many zones with extreme values. This indicated that there was some correlation between the trip values (i.e., PHBW, PHBO, PHBS, PHBOS, PTHB, and PTOT) and the number of households in each zone (HH).

- PNHB/JO, AHBW/JO, AHBO/JO, AHBS/JO, AHBOS/JO, ATHB/JO, ANHB/JO and ATOT/JO

There was also similarity among the geographical distributions of these variables. The highest trip attraction zones were nearly all located east of the city while the zones south of the city had high and medium values. Zones beside the river Nile had medium values. Nearly all zones in the north of the city had low and very low values. In general, zones in the enlarged CBD had lower values than zones outside this sector. CBD zones which had high values in the case of zone total trips had, in the case of zonal trip rates (per JO), medium to very low values.

2.4 Private Transport Trip Generation Features of Traffic Zones

This section discusses private transport trip generation features in Greater Cairo (6). Each trip type was subjected to statistical analysis showing its variability among different traffic zones of the study area and its frequency distribution. The geographical classification of zonal trip rates was also analyzed.

A set of 12 zonal variables representing total trips made for different purposes by private car and taxi was selected. Table II-15 lists zonal total variables, and Table II-16 lists the 12 zonal trip rate variables. The following points concerning different types of trips are noted.

1. Home based work trips included work, business and education trips.

2. Home based other trips included all home based trips for purposes other than work, business and education.

3. All trips for different purposes were aggregated to represent the available 10 hours (7-11 a.m., 11 a.m.-4 p.m. and 6-9 p.m.) of 1977 survey (1).

4. Only trips with both origin and destination in Greater Cairo (but excluding intra-zonal trips) were considered.

5. Only private car and taxi trips were selected for anlaysis from among the available trip data on other private transport modes, such as private bus.

Table II-15

Zonal Trip Variables Used in the
Private Transportation Trip Generation Analysis

No.	Variables	Notation
1	Home based work private car trip production	PHBWC
2	Home based other private car trip production	PHBOC
3	Non-home based private car trip production	PNHBC
4	Home based work private car trip attraction	AHBWC
5	Home based other private car trip attraction	AHBOC
6	Non-home based private car trip attraction	ANHBC
7	Home based work taxi trip production	PHBWT
8	Home based other taxi trip production	PHBOT
9	Non-home based taxi trip production	PNHBT
10	Home based work taxi trip attraction	AHBWT
11	Home based other taxi trip attraction	AHBOT
12	Non-home based taxi trip attraction	ANHBT

Table II-16

Zonal Trip Rate Variables Used in the
Private Transport Trip Generation Analysis

No.	Variables	Notation
13	Home based work private car trip production per houshold	PHBWC/HH
14	Home based other private car trip production per houshold	PHBOC/HH
15	Non-home based private car trip production per jobs offered	PNHBC/JO
16	Home based work private car trip attraction per jobs offered	AHBWC/JO
17	Home based other private car trip attraction per jobs offered	AHBOC/JO
18	Non-home based private car trip attraction per jobs offered	ANHBC/JO
19	Home based work taxi trip production per household	PHBWT/HH
20	Home based other taxi trip production per household	PHBOT/HH
21	Non-home based taxi trip production per jobs offered	PNHBT/JO
22	Home based work taxi trip attraction per jobs offered	AHBWT/JO
23	Home based other taxi trip attraction per jobs offered	AHBOT/JO
24	Non-home based taxi trip attraction per jobs offered	ANHBT/JO

Tables II-17 and II-18 summarize the main statistics of each of the 12 zonal aggregate total variables and the 12 zonal trip rates. In addition, histograms for each variable were drawn and are given in reference (6). General comments on Tables II-17 and II-18 and the said histograms are as follows:

- Average values of trip rates PHBWC/HH and PHBWT/HH are 0.58 and 0.20 for car and taxi, respectively. This means that, on average, for every two households in Greater Cairo, about one work trip by car is made per day,* whereas every five households make one daily work trip by taxi on average. The corresponding figure on public transport is about one home based work trip per household per day.#

- Average values of trip rates AHBWC/JO and AHBWT/JO are 0.84 and 0.33 for car and taxi, respectively. The corresponding figure in case of public transport modes is 3.30 trips per job per day #. Therefore, it may be concluded that, in general, every job offered in Greater Cairo generated about 4 trips daily# on all transport modes. This figure, of course, should only be taken as a rough indicator of potential trip generation and not as an exact design value.

- All histograms had approximately the same shape with one tail and the mode shifted to the left side of the mean.

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*Note that only 10 hours of the day are taken into consideration in 1977 survey (1), as mentioned earlier, and that the word "daily" here corresponds to the whole survey period.

#Note the difference in time periods between 1978 public transport survey (2) and 1977 private transport survey (1).

Table II-17

Summary Statistics of Zonal Private Transport Trip Variables

No	variable	No. of observations (n)	Mean ($\bar{X}$)	Standard deviation (S)	Coef. of variation C.V=(S/$\bar{X}$)
1	PHBWC	80	3838.56	4076.32	1.06
2	PHBOC	80	2431.71	2794.78	1.15
3	PNHBC	80	2190.28	1848.89	0.84
4	AHBWC	79	3887.15	3998.33	1.03
5	AHBOC	80	2431.71	3279.99	1.34
6	ANHBC	79	2218.00	2339.96	1.05
7	PHBWT	79	1920.82	3435.00	1.79
8	PHBOT	78	1309.20	1417.92	1.08
9	PNHBT	80	2357.43	1954.66	0.83
10	AHBWT	80	1896.81	2752.23	1.45
11	AHBOT	77	1326.20	1300.11	0.98
12	ANHBT	78	2417.87	2951.97	1.22

Table II-18

Summary Statistics of Zonal Private Transport Trip Rate Variables

No	variable	No. of observations (n)	Mean ($\bar{X}$)	Standard deviation (S)	Coef. of variation C.V=(S/$\bar{X}$)
13	PHBWC/HH	72	0.58	0.76	1.29
14	PHBOC/HH	72	0.49	0.88	1.80
15	PNBCO/JO	72	0.38	0.58	1.53
16	AHBWC/JO	77	0.84	2.08	2.49
17	AHBCO/JO	78	0.62	1.02	1.65
18	ANHBC/JO	77	0.40	0.56	1.40
19	PHBWT/HH	71	0.20	0.33	1.66
20	PHBOT/HH	70	0.19	0.28	1.46
21	PNHBT/JO	72	0.30	0.51	1.[illegible]1
22	AHBWT/JO	78	0.33	0.63	1.90
23	AHBOT/JO	75	0.29	0.38	1.33
24	ANHB/JO	76	0.36	0.55	1.53

- All the coefficients of variation for all the zone trip totals had high values except the variable PHBWT, which had a very high value. The shape of the histogram of this variable had one tail with mode shifted to the left of the diagram, but there were some zones which deviated far from the mean to the right hand side. Thus, both the range and the coefficient of variation of this variable were very high. One of the reasons for this characteristic may be the variation in the amount of taxi service provided from one zone to another. On the other hand, the coefficients of variation for all the zonal trip rates were very high, especially AHBWC/JO and AHBWT/JO.

Each variable was classified into 5 ranges of value and coded by color on a zoning system map. Limits of these categories are shown in Tables II-19 and II-20. The corresponding maps are presented in reference (6), but the main observations about the maps are given here:

Most of the zones with very low or low values of PHBWC, PHBOC, PNHBC, AHBWC, AHBOC, and ANHBC were located in the north, mid-north, northwest and southeast zones of Greater Cairo. Zones with high or very high values were located primarily in the northwest and southwest peripheral zones of the city. Furthermore, it appeared that center zones attracted very high work and non-home based trips by car.

Some of the high income zones (such as 20802) had the lowest values of private car trips; this may have occurred due to the low number of people living there. This zone (20802) was always in the high range in terms of car trip production rates per household for different trip purposes. It is also interesting to note that zones (10800 and 10200) always had high or very high trip totals by car and taxi for different

Table II-19

Categories of the Zonal Private Transport Trip Variables

No.	Variable	Ranges of Categories				
		1	2	3	4	5
		very low	low	medium	high	very high
1	PHBWC	< 1600	1600-3599	3600-6399	6400-8799	≥ 8800
2	PHBOC	< 800	800-1999	2000-4399	4400-7199	≥ 7200
3	PNHBC	< 800	800-1799	1800-3399	3400-6199	≥ 6200
4	AHBWC	< 1200	1200-3199	3200-6799	6800-11999	≥ 12000
5	AHBOC	< 800	800-1999	2000-3999	4000-6399	≥ 6400
6	ANHBC	< 800	800-1799	1800-3399	3400-6399	≥ 6400
7	PHBWT	< 800	800-1399	1400-2799	2800-4799	≥ 4800
8	PHBOT	< 400	400-999	1000-2399	2400-2599	≥ 3600
9	PNHBT	< 1000	1000-1999	2000-4399	4400-5999	≥ 6000
10	AHBWT	< 600	600-1199	1200-2599	3600-6199	≥ 6200
11	AHBOT	< 600	600-1199	1200-2399	2400-3799	≥ 3800
12	ANHBT	< 1000	1000-1799	1800-3999	4000-6599	≥ 6600

Table II-20

Categories of the Zonal Private Transport Trip Rate Variables

No.	Variable abb.	Ranges of Categories				
		1	2	3	4	5
		very low	low	medium	high	very high
13	PHBWC/HH	< 0.15	0.15-0.499	0.5-1.249	1.25-1.749	≥ 1.75
14	PHBOC/HH	< 0.05	0.05-1.99	0.20-0.849	0.85-1.349	≥ 1.35
15	PNHBC/JO	< 0.1	0.1 -0.249	0.25-0.549	0.55-0.999	≥ 1.0
16	AHBWC/JO	< 0.15	0.15-0449	0.45-1.149	1.15-1.849	≥ 1.85
17	AHBOC/JO	< 0.1	0.1 -0.249	0.25-1.049	1.05-2.299	≥ 2.3
18	ANHBC/JO	< 0.1	0.1 -0.349	0.35-0.749	0.75-1.599	≥ 1.6
19	PHBWT/HH	< 0.07	0.07-0.147	0.15-0.449	0.45-0.949	≥ 0.95
20	PHBOT/HH	< 0.05	0.05-0.099	0.1 -0.449	0.45-0.949	≥ 0.95
21	PNHBT/JO	< 0.1	0.1 -0.299	0.25-0.599	0.6 -0.899	≥ 0.9
22	AHBWT/JO	< 0.07	0.07-0.199	0.2 -0.599	0.6 -1.049	≥ 1.05
23	AHBOT/JO	< 0.07	0.07-0.199	0.2 -0.749	0.749-1.399	≥ 1.4
24	ANHBT/JO	< 0.15	0.15-0.299	0.3 -0.549	0.55-1.099	≥ 1.1

trip production and attraction purposes. This may be due to the existence of the Pyramids of Giza and the Sphinx in zone (10200), to which thousands of tourists and workers in tourist-based businesses travel daily. As for zone (10800), it included the high income district of El-Nuzha and is very close to Cairo International Airport.

Looking at trip production rates per household (PHBWC/HH, PHBOC/HH, PHNBC/HH, PHBWT/HH, and PHBOT/HH), most of the Greater Cairo zones, especially those located around the city center and extending to the north and southeast peripheral zones, were either low or very low. This is quite reasonable because people living in these zones are mainly of low and medium income and depend on public transport rather than private transport.

3. Trip Generation Analysis

The trip generation analysis started with a review of modeling techniques (7), after which different trip generation methods were investigated (8). In view of the available data, a specific program was selected (9). This section of the report briefly outlines the efforts undertaken in implementing the above mentioned program (9) and the results obtained.

3.1 Public Transport Trip Generation Models

Based on the available data set, it was only possible to calibrate two trip generation models at the aggregate level; namely, the regression model and the cross classification model. A detailed description of the analysis methodology is given in references (10, 11, & 12).

As given in Table II-21, 14 trip types were selected as dependent variables of the trip generation regression model and 17 trip types for cross classification analysis.

The dependent variables given in Table II-21 were classified into two groups. The first consisted of all home based trip productions while the second contained trip attractions and non-home based trip productions. These are listed in Table II-22, together with the set of planning parameters (i.e., explanatory or independent variables) which are expected to affect the trips of each type in each group.

Several forms of trip generation models were calibrated; those presented in the following section are the most accurate and reliable obtained (10, 11, & 12).

Table II-21

Trip Types used in Public Transport Trip Generation Model

Type of Analysis	No.	Dependent Variables	Notations
Regression	1	Production home based work	PHBW
	2	Production home based other	PHBO
	3	Production home based shopping	PHBS
	4	Production home based other and shopping	PHBOS
	5	Production total home based	PTHB
	6	Production non-home based	PNHB
	7	Production total purposes	PTOT
	8	Attraction home based work	AHBW
	9	Attraction home based other	AHBO
	10	Attraction home based shopping	AHBS
	11	Attraction home based other and shopping	AHBOS
	12	Attraction total home based	ATHB
	13	Attraction non-home based	ANHB
	14	Attraction total purposes	ATOT
Cross Classification	1	Production home based work per household	PHBW/HH
	2	Production home based other per household	PHBO/HH
	3	Production home based shopping per household	PHBS/HH
	4	Production home based other shopping per household	PHBOS/HH
	5	Production total home based per hosehold	PTHB/HH
	6	Production non-home based per household	PNHB/HH
	7	Production total purposes per household	PTOT/HH
	8	Attraction home based work per job offered	AHBW/JO
	9	Attraction home based other per job offered	AHBO/JO
	10	Attraction home based shopping per job offered	AHBS/JO
	11	Attraction home based other shopping per job offered	AHBOS/JO
	12	Attraction total home based per job offered	ATHB/JO
	13	Attraction non-home based per job offered	ANHB/JO
	14	Attraction total purpose per job offered	ATOT/JO
	15	Attraction home based shopping per trading establishment	AHBS/TE
	16	Attraction home based other and shopping per trading establishment	AHBOS/TE
	17	Production non-home based per job offered	PNHB/JO

Table II-22

Independent Variables Used In
Public Transport Trip Generation Analysis

Type of Analysis	Group No.	Dependent Variables (trip types)	Independent Variables (planning parameters)
Regression	1	PHBW, PHBO, PHBS, PHBOS, PTHB, and PTOT	POP, MLF, FLF, TLF, JO, HH, ROOM, INCOME, MSIT, MST, FST, and TST
	2	AHBW, AHBO, AHBS, AHBOS, ATHB, ATOT, PNHB, & ANHB	POP, MLF, FLF, TLF, JO, HH, ROOM, INCOME, MSIT, TE, EMPTE, RTE, EMPRTE, WTE, EMPWTE, RTE5, EMPRTE5, MST, FST, and TST.
Cross Classification	1	PHBW/HH, PHBO/HH, PHBS/HH, PHBOS/HH, PTHB/HH, PNHB/HH and PTOT/HH	POP/HH, INCOME/HH (TLF+TST)/HH, POP/ROOM and FLOOR/RB
	2	AHBW/JO, AHBO/JO, AHBS/JO, AHBOS/JO, ATHB/JO, ANHB/JO, ATOT/JO, PNHB/JO, AHBS/TE and AHBOS/TE	JO/HH, (JO-TLF)/HH, TE/HH, JO/TLF, JO/(TB-RB), RTSL5 INCOME/HH, JO/AREA, and EMPWTE/AREA

3.1.1 Regression Models

Tables II-23 and II-24 give the trip generation regression models together with supporting statistics for trip productions and attractions, respectively. Although these models yielded results difficult to confidently interpret, those results were the best obtained. Details of these models are discussed in reference (10 & 12).

3.1.2 Cross Classification Models

Many cross-classification models corresponding to different trip production purposes were produced based on one or more independent variables. Each model was produced in several forms according to the number of categories or cross categories and/or the limits of different intervals in the model with the same independent variable(s). Eventually, a short list of cross-classification models was selected for final examination in order to choose the best model to be used in prediction. After careful examination of these models, the one given in Table II-25 was selected using POP/ROOM as the independent variable. The details of the cross-classification analysis can be found in reference (11, 12). No reasonable model was obtained for trip attractions.

3.2 Private Transport Trip Generation Models

Only zonal regression analysis was tried in calibrating private transport trip generation models. Two separate models were developed--one for car trips and the other for taxi trips since the majority of private transport trips occur by these two modes.

Bearing in mind the available data set, the 12 trip types listed in Table II-26 were selected as dependent variables of the trip generation models.

Table II-23

Public Transport Zonal Trip Production Regression Equations

Model No.		Regression Equation	R^2	F	(S.E./$\bar{Y}$)%	(Const./$\bar{Y}$)%	No. of Observations
1 PHBW	equ. α β	1163 + 0.274 ROOM 0.001 0.6799	0.4623	88	79	13	104
2 PHBO	equ. α β	420 + 0.0651 ROOM 0.001 0.6680	0.4463	82	75	19	104
3 PHAS	equ. α β	75 + 0.0099 ROOM 0.001 0.6675	0.4455	82	72	21	104
4 PHBOS	equ. α β	495 + 0.075 ROOM 0.001 0.6750	0.4556	85	74	19	104
5. PTHB	equ. α β	2674 + 0.349 ROOM 0.001 0.6804	0.4629	88	77	24	104
6. PNHB	equ. α β	731.2 + 0.0523JO + 0.9655EMPWTE 0.001 0.001 0.4835 0.3244	0.4676	38	62	55	90
7. PTOT	equ. α β	1659 + 0.37 ROOM 0.001 0.6607	0.4365	79	75	13	104

α : Level of significance

β : The beta coefficient

All F Values significant at α = 0.001

Table II-24

Public Transport Zonal Trip Attraction Regression Equations

Model No.		Regression Equation	R^2	F	(S. E./$\bar{Y}$)%	(Const./$\bar{Y}$)%	No. of Observations
8 AHBW	equ.	5076 + 0.5165 JO - 0.1040 MLF	0.5099	45	67	69	90
	α	0.001 0.01					
	β	0.7737 - 0.2172					
9 AHBO	equ.	1162 + 0.1025 JO	0.3387	47	78	61	93
	α	0.001					
	β	0.582					
10 AHBS	equ.	42 + 0.0345 JO	0.4230	67	144	15	93
	α	0.001					
	β	0.6504					
11 AHBOS	equ.	1204 + 0.1370 JO	0.3937	59	80	55	93
	α	0.001					
	β	0.6504					
12 ATHB	equ.	6361 + 0.6580 JO - 0.1120 MLF	0.464	43	68	67	90
	α	0.001 0.05					
	β	0.7578 - 0.1799					
13 ANHB	equ.	643 + 0.0584 JO + 1.0432 EMPWTE	0.4872	41	68	50	90
	α	0.001 0.001					
	β	0.4996 0.324					
14 ATOT	equ.	7091 + 0.7304 JO - 0.1093 MLF	0.4890	42	67	65	90
	α	0.001 0.1					
	β	0.7477 - 0.1560					

α : Level of significance β : The beta coefficient

All F values significant at α = 0.001

Table II-25

Cross-Classification Model for Public Transport Trip Production Rates

Grouping Category no.	POP/ROOM	Average trip production rate for each purpose							HH% from the total HH of all used zones	No. of zones
		PHBW/HH	PHBO/HH	PHBS/HH	PHBOS/HH	PTHB/HH	PNHB/HH	PTOT/HH		
1	<1.2	1.145	0.298	0.043	0.341	1.487	0.335	1.82	0.039	12
2	1.2-1.399	1.117	0.273	0.041	0.314	1.431	0.176	1.607	0.063	10
3	1.4-1.599	1.042	0.243	0.041	0.284	1.326	0.198	1.524	0.061	15
4	1.6-1.799	0.919	0.215	0.033	0.248	1.167	0.114	1.281	0.192	15
5	1.8-1.999	0.856	0.214	0.034	0.248	1.104	0.132	1.236	0.216	12
6	2.0-2.199	0.654	0.190	0.030	0.220	0.875	0.090	0.965	0.192	14
7	≥2.2	0.535	0.134	0.027	0.162	0.750	0.082	0.779	0.215	18
8 *	-	2.809	0.818	0.077	0.895	3.704	1.613	5.316	0.012	3
9	-	0.556	0.172	0.015	0.187	0.744	0.657	1.401	0.009	4

* The two groups of the CBD zones mentioned earlier, (see section 2.3).

Table II-26

Zonal Trip Variables Used in Private Transport Trip Generation Model

Mode	No.	Variables	Notation
Car	1	Home based work private car trip production	PHBWC
	2	Home based other private car trip production	PHBOC
	3	Non-home based private car trip production	PNHBC
	4	Home based work private car trip attraction	AHBWC
	5	Home based other private car trip production	AHBOC
	6	Non-home based private car trip production	ANHBC
Taxi	7	Home based work taxi trip production	PHBWT
	8	Home based other taxi trip production	PHBOT
	9	Non-home based taxi trip production	PNHBT
	10	Home based work taxi trip attraction	AHBWT
	11	Home based other taxi trip attraction	AHBOT
	12	Non-home based taxi trip production	ANHBT

The following socio-economic and land use variables were examined as independent variables: POP, MLF, HH, JO, ROOM, and CAR. These variables are defined in Table II-6, except for the last variable, CAR, which is the number of private cars owned by residents of each traffic zone. Values of this variable for base year and zonal projections were obtained from the anlaysis of car ownership activity of the project (see Part III of this report).

Several forms of trip generation models were calibrated (13), and the best models are presented in Tables II-27 and II-28, together with key statistics for private car and taxi respectively. Although some of the calibrated equations showed poor explanatory power, they were all statistically significant.

3.3 Projections of Planning Parameters in Greater Cairo (1980 - 2000)

This section gives a brief review of the methodology, the availability of data, the assumptions, and the considerations underlying the projections of socio-economic variables in Greater Cairo, 1980 to 2000. The consistency of the results is then generally discussed. The projected variables were predicted for the same traffic zones as defined below. The 120 traffic zones of Greater Cairo were divided into 3 groups as follows:

- Group A includes those zones which lie within the boundaries of Greater Cairo and have reached saturation with respect to buildings (i.e., do not contain land area for additional buildings. New buildings would only be cases of substitution).
- Group B includes those zones lying within the boundaries of Greater Cairo, but still having land area on which additional buildings might be constructed.

Table II-27

Private Car Zonal Trip Generation Regression Equations

Model No.		Regression Equation	R^2	F	(S.E/$\bar{Y}$)%	(Const./$\bar{Y}$)%	No. of observation
1 PHBWC	eq. α β	1501 + 1.54 CAR 0.001 0.8172	0.668	129	46	43	66
2 PHBOC	eq. α β	1350 + 0.4279 CAR 0.005	0.16	11	N.A.	69	60
3 PNHBC	eq. α β	277 + 0.11 JO + 0.676 CAR 0.001 0.001 0.5788 0.5515	0.506	31	59	13	63
4 AHBWC	eq. α β	3040 + 0.2834 JO - 0.1026 MLF 0.001 0.001 0.6208 -0.376	0.41	21	86	79	63
5 AHBOC	eq. α β	686 + 1.1153 CAR 0.001 0.8487	0.71	165	48	32	66
6 ANHBC	eq. α β	399 + 0.11 JO + 0.518 CAR 0.001 0.005 0.4701 0.3394	0.266	11	92	19	63

α : Level of significance

β : The beta coefficient

All F values significant at α = 0.1

Table II-28

Taxi Zonal Trip Generation Regression Equations

Model No.		Equation	R^2	F	$(S.E/\bar{Y})\%$	$(Const./\bar{Y})\%$	No. of observation
1 PHBWT	eq.	349 + 0.038 HH + 0.284 CAR	0.384	19	61	28	65
	α	0.001 0.001					
	β	0.4943 0.429					
2 PHBOT	eq.	647 + 0.1937 CAR	0.164	11	N.A	71	59
	α	0.005					
	β						
3 PNHBT	eq.	1110 + 0.0655 JO + 0.2368 CAR	0.161	6	74	56	63
	α	0.005 0.1					
	β	0.3802 0.2183					
4 AHBWT	eq.	-212 + 0.533 CAR + 0.105 JO	0.127	4	183	-16	57
	α	0.05 0.1					
	β	0.325 0.2358					
5 AHBOT	eq.	167 + 0.273 CAR + 0.062 JO	0.440	20	54	16	63
	α	0.001 0.001					
	β	0.5799 0.4930					
6 ANHBTO	eq.	207 + 0.485 CAR + 0.084 JO	0.444	21	58	13	55
	α	0.001 0.001					
	β	0.6363 0.4078					

α : Level of significance

β : The beta coefficient

All F vales significant at $\alpha = 0.1$

- Group C includes those zones at the boundaries of Greater Cairo which are likely to extend more.

A list of these groups is given in Appendix I of reference (14).

Data on socio-economic variables were originally given in Report TDF 18/TG6 (4) and were available only for one date, 1976. For the sake of projections, the data should ideally be available for at least two dates. An attempt to determine the variables for the 120 zones from the results of 1960 population census of Egypt proved very laborious because the data in these two censuses were classified by administrative districts and Shiakhats. As a consequence, a process of redistribution by the 120 traffic zones was necessary, taking into consideration the new boundaries of districts and Shiakhats in 1976. This was done for only a few variables, namely:

- Total population (POP)
- Male labor force (MLF)
- Number of households (HH)
- Number of rooms (ROOM)
- Jobs offered (JO).

Adjustments to the boundaries of the 1960 and 1966 zones were made to match those of 1976 as given in reference (14).

The general assumptions used for projecting each variable are set out below:

- The rates of change in each variable were to be determined according to the differentials between the three groups of zones--A, B, and C defined earlier (14).

- After 1975, the rate of migration to the Cairo Governorate started a marked decline, indicating that Greater Cairo had reached a saturation point in the late seventies.

- The new towns around Cairo, Sadaat - 10 Ramadan - 6 October - El Amel etc., are expected to attract about 4 million people by 2000 from the whole of Egypt. Two millions of those are expected to come from Greater Cairo.

Accordingly, the total population of Greater Cairo in the year 2000 will be less than past projections by government agencies or by other institutions. These estimates place the year 2000 population of Greater Cairo at roughly 15 million.

3.3.1 Projection of Total Population

The most reasonable model for projecting variables such as population is the Ratio Model, consisting of the following elements:

Notation

For each zone i (i = 1, 2, 3, ..., 120), define:

x_i = the value of the variable x for zone i

P_i = proportion (%) of x_i from the summation of x over all zones:

$$= \frac{x_i}{\Sigma x_i} \times 100, \qquad \text{this gives } \Sigma P_i = 100$$

$\left.\begin{matrix} t_1 \\ t_2 \\ t_3 \end{matrix}\right\}$ = dates at which data are available (census dates 1960, 1966, and 1976)

r_1 = annual rate of change in P_i during the period (t_1, t_2)

$$= \left[\frac{P_i(t_2)}{P_i(t_1)}\right]^{1/n} - 1, \text{ assuming a geometric change model}$$

r_2 = annual rate of change in P_i during the period (t_2, t_3).

Procedure

The following procedure was used in projecting the variable x_i:

a) Calculate P_i for all zones to find the distribution of x_i among zones in t_1, t_2, and t_3.

Zone	P_i		
	t_1	t_2	t_3
1	-	-	-
2	-	-	-
120	-	-	-
ΣP_i	100	100	100

b) Analyze the trend of P_i in each zone from the above table resulting in two cases:

1) P_i either increased or decreased in both periods, (t_1, t_2)&(t_2, t_3).

2) P_i increased in (t_1, t_2) and decreased in (t_2, t_3), or vice versa.

c) In case (1), r_1 and r_2 were calculated and the numerically smaller was assumed to represent the annual rate of change in P_i in 1977. In case (2), r_2 was calculated and half of its value assumed to represent the rate of change in P_i in 1977.

d) The proportion P_i for years after 1976 would change on the assumption that the annual rate of change in P_i will decline linearly reaching zero sometime in the future. This time is the date at which pull and push factors relevant to the variable x_i would balance. This time was determined according to economic projections on one hand and by professional judgment on the other. In similar studies for estimating future population in each state of the United States, this time was estimated as 50 years, which is generally accepted to be a reasonable assumption.

e) After estimating P_i for each zone i for the years after 1976, the total value of x_i (Σx_i) is projected from 1976 to 2000. For example, if x_i represents the population, it is projected by the exponential formula:

$$N_t = N_o e^{rt}$$

f) The projected total is allocated to zones in the years of projection using the estimated values of proportions P_i.

3.3.2 Male Labor Force Projections

Bearing in mind the three groups of Greater Cairo traffic zones (A, B, and C) defined previously, the following assumptions were made:

- For group A, it was assumed that the activity rate in each zone would remain constant during the period (1976 - 2000) at its 1976 level.

- For group B, it was assumed that the activity rate in each zone would remain constant during the period (1976 - 1987) at its 1976 level, and then increase gradually to reach the value 30% in the year 2000.

- For group C, it was assumed that the activity rate in each zone would increase gradually during the period 1976 - 1990. During the period 1990 - 2000, the increase in the rate would continue but with lower slope until the activity rate reaches 40% in the year 2000.

The data of 1960 were used with the data of 1976 to calculate the annual change in activity rates (A.R.) during the period 1960-76 as indicators of the speed of increase in the rates in groups A and B. Some of the available data given for 1976 were not reliable and were adjusted, such as:

Zone	Observed A.R.	Adjusted A.R.
10300	0.0879	25%
11403	0.0525	23%

3.3.3 Households Projections

For the projection of households, the mean size of the household in each group of zones was estimated taking into consideration trends found in different studies which had been carried out in Egypt (15). These estimates are:

Group of zones \ Year	1980	81	83	87	90	95	2000
A	4.80	4.80	4.80	4.60	4.40	4.20	4.00
B	4.80	4.80	4.60	4.40	4.20	4.00	3.80
C	3.40	3.40	3.50	3.54	3.60	3.66	3.73

Using the population estimated for these years by zones, the number of households in each zone was estimated.

3.3.4 Projection of the Number of Rooms

The ratio Pop/Room was calculated in 1960 and 1976. The trend in this ratio in the period 1980 - 2000 was estimated using the following assumptions:

- In group A this ratio was assumed to decrease very slowly up to 2000 at the same rate of its annual decrease in 1960-76.
- In group B it was assumed that the ratio would decrease in 1980-2000 at an annual rate less than that of the perios 1960-76.
- In group C the rate of decrease in the ratio was assumed to be much less than that of 1960-76 (see Appendix III of reference (14).

3.3.5 Projections of Jobs Offered

The ratio Pop/Job was calculated for the year 1976 for all zones and the frequency distribution of the ratio was as follows:

Pop./JO	Number of zones
.0-1	3
2-5	22
6-10	32
11-20	41
21-40	15
>41	7
Total	120

The mode of this ratio is in the interval 11-20 meaning that most of the zones have the ratio of population to jobs of between 11 and 20. In fact, most of these zones were in groups B and C. Zones of group A had ratios of less than 11 because these zones are saturated and employment had reached the level required to serve the zone. However, zones with new buildings, like Nasr-City, have not yet reached the employment required to serve it. In this last case, the current ratio Pop/Jo is greater.

The ratio of Pop/Jq was estimated for the period 1980-2000 and jobs were calculated using the projected population given in section 3.3.1.

3.3.6 Projections of Planning Parameters

Projections of planning parameters are given at the 120 traffic zone level for years 1980, 1981, 1983, 1987, 1990, 1995, and 2000 in Appendix IV of reference (14).

3.3.7 Consistency of Results

The following table gives the projections of the 5 variables under consideration for Greater Cairo as a whole. Some measures of consistency are derived in the same table.

Variables and Measures of Consistency (1980-2000)

	1980	1990	2000
		(In Thousands)	
POP	8,465	10,716	13,257
MLF	2,044	2,863	3,992
EH	1,877	2,580	3,432
ROOM	4,818	6,495	7,858
JO	0,995	1,059	1,098
MLF/POP (%)	24%	27%	30%
JO/POP.(%)	12%	10%	8%
POP/ROOM	1.8	1.6	1.7
Household size(persons)	4.5	4.2	3.9

Some important remarks about these data are as follows:

- It is shown that the MLF/POP rate gradually increases from 24% in 1980 to 30% in 2000. This is due to the expected change in the age structure of the population. Fertility is expected to decrease, leading to a smaller proportion of children age 15 or under and consequently, to a greater proportion of persons between 15 and 65, the source of the labor force.

- JO/POP rate will decrease from 12% in 1980 to 8% in 2000. This means that the number of jobs offered will decrease from 12 jobs for each 100 individuals in 1980 to 8 jobs for each 100 individuals in 2000. This is because in 2000 it is expected that a large proportion of new buildings will exist in many zones. In these zones, the number of workers in establishments would not have reached the maximum level.

- POP/ROOM is decreasing because the rate of growth of rooms will be faster than the rate of growth of the population.

3.4 Trip Generation Forecasts

Trip generation forecasts were produced at the zonal level for public transport trips as well as car and taxi trips for the target years 1981, 1983, 1987, 1990, and 2000. Results are documented in reference (16).

4. Trip Distribution

Several methods have been used previously in calibrating trip distribution models (17). It was initially decided to concentrate our efforts on two types of model, namely the BPR (Bureau of Public Roads) gravity model (18, 19) and the growth factor model. The former was to be used for long-term forecasting and the latter for short-term and rural forecasting. Later, however, the analysis focussed on the BPR model due to resource limitations, although some progress was made in preparing a computer program which performs growth factor methods. It is recommended that this effort should continue if any future work in trip distribution is to take place. Thus, this section of the report concentrates on only describing the calibration of gravity models of trip distribution.

4.1 Calibration and Testing of the BPR Gravity Model of Trip Distribution

The BPR gravity model of trip distribution was chosen for two main reasons. First, it is relatively easy to calibrate, and second, it has been used successfully in several other transport studies (17, 18, 19, 20, and 21).

The BPR gravity model of trip distribution is formulated as follows (18):

$$T_{ij} = \frac{O_i D_j K_{ij} F_{ij}}{\sum_j D_j K_{ij} F_{ij}}$$

where,

T_{ij} = Trip interchanges between zones i and j

O_i = Trip production from zone i

D_j = Trip attraction to zone j

K_{ij} = Socio-economic adjustment factor applied to movements between zones i and j

F_{ij} = Travel friction factor between zones i and j.

The calibration procedure for this model is described in project report TDF 28/TD 5 (22). A special computer program which performs the calibration procedure was developed at Cairo University and the details of this program are given in references (22, 23, 24, and 25).

4.2 The Calibrated Models

Six gravity models of trip distribution were calibrated according to trip purpose and travel mode as follows:

a) Car Trips

Model 1 - Home based work (HBW)
Model 2 - Home based other (HBO)
Model 3 - Non-home based (NHB)

b) Taxi Trips

Model 4 - Home based work (HBW)
Model 5 - Home based other (HBO)
Model 6 - Non-home based (NHB).

The calibrated travel friction function for each model took the following form:

$$F_{ij} = \alpha \cdot e^{-\beta t_{ij}} \cdot t_{ij}^{\gamma}$$

where:

F_{ij} = Travel friction factor between zones i and j

t_{ij} = Travel time (min.) between zones i and j

α, β, γ = Calibration constants

e = Exponential constant

This form was not imposed a priori during calibration. Seven different friction function forms were tried during the calibration of each model (see references 22, 23, & 24) and the best function among them chosen. Incidentally, it happened that the best function in all cases was that described by the above equation. This result shows some consistency in the reaction of Cairo travelers to travel time, regardless of the trip purposes, both for car trips and taxi trips. However, the constants of the travel friction function (i.e. values of α, β, γ in the equation) varied among the six models as given latter.

The introduction of K_{ij} factors did not improve the calibrated models and hence no K_{ij} values appear in the final fourmulations. Furthermore, in some models, relatively big differences appeared between survey and model values of River Nile crossings. Due to time limitations, it was not possible to pursue investigation of these two issues, but it is strongly recommended to do so in any future research about trip distribution in Greater Cairo.

Nevertheless, all six models gave results very similar (at level of significance $\alpha = .001$) to the survey trip length frequency distribution. Furthermore, all the fitted friction functions were statistically significant at .001 level. Full details of the calibrated model appear in reference (26) and Table II-29 gives the constants of the six calibrated models.

Figs. II-2 to II-7 show survey and model trip length frequency distributions for each of the six calibrated models.

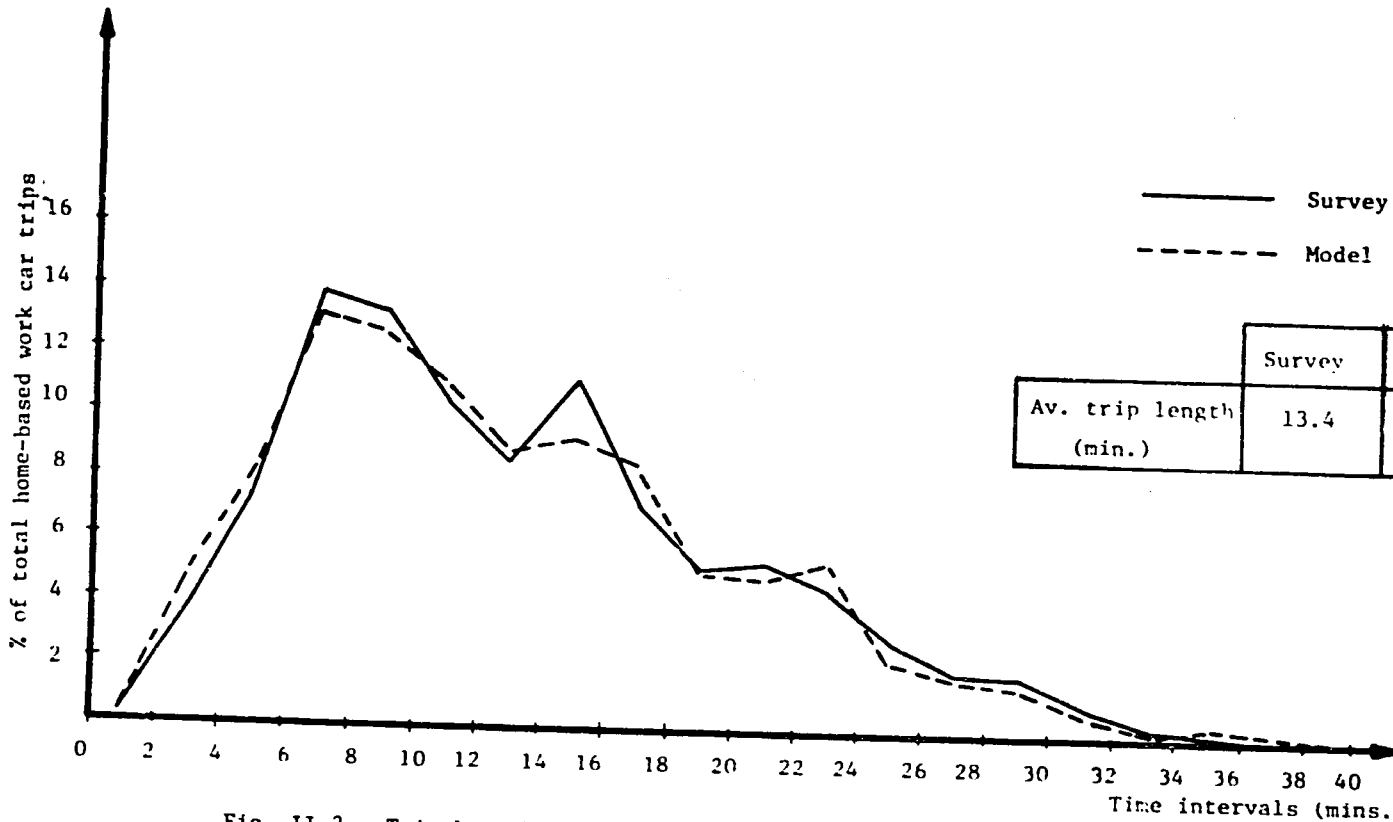
Table II-29

Constants of the Gravity Model of Trip Distribution

Model No.	Travel Mode	Trip* Purpose	α	β	γ
1	Car	HBW	4.169333	.067119	.134718
2		HBO	19.750020	.047360	-.265157
3		NHB	4.368551	.060060	0.239456
4	Taxi	HBW	9.735188	.156931	.522134
5		HBO	2.357711	.132692	.636944
6		NHB	4.415479	.142161	.709309

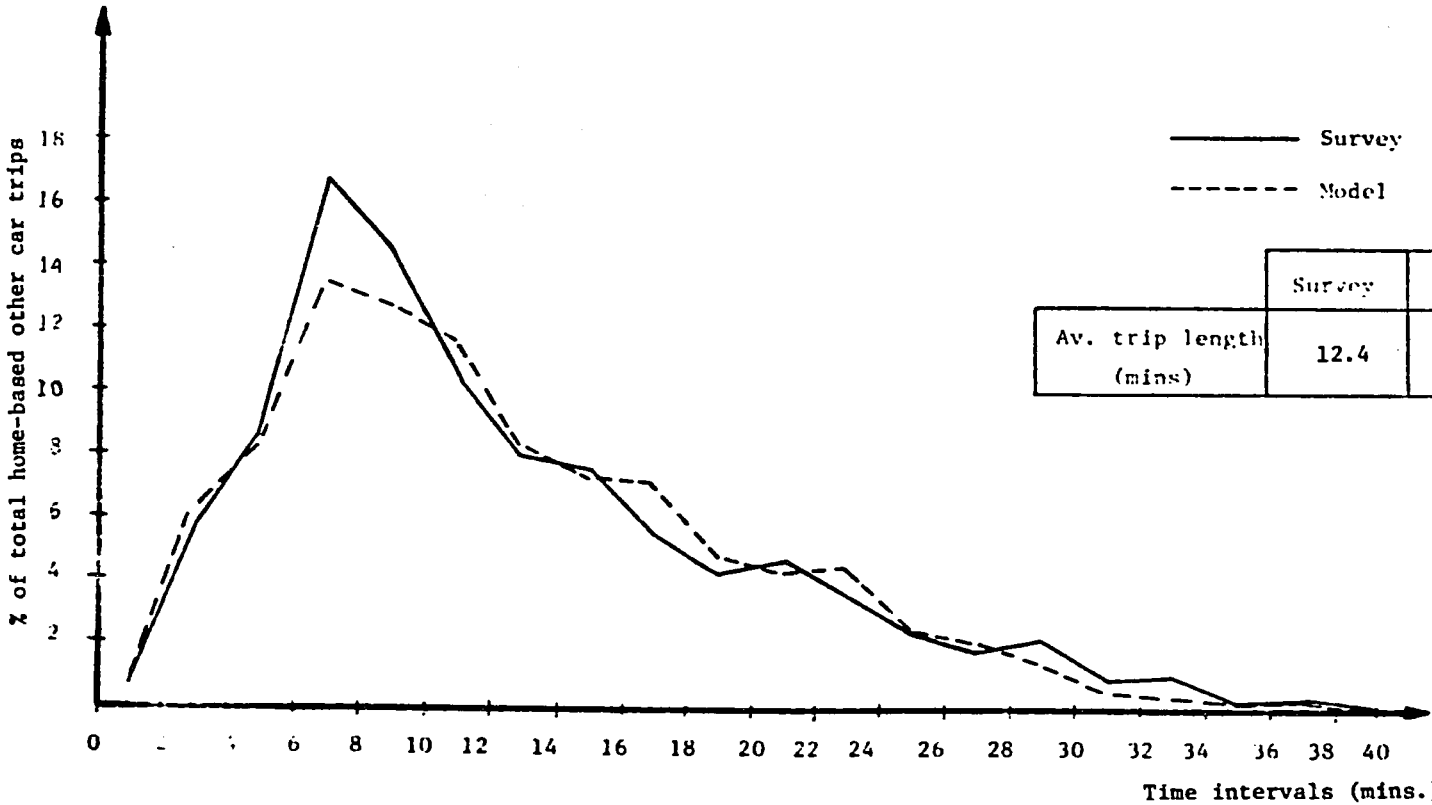
*HBW = home based work trips NHB = non-home based trip

HBO = home based other trips



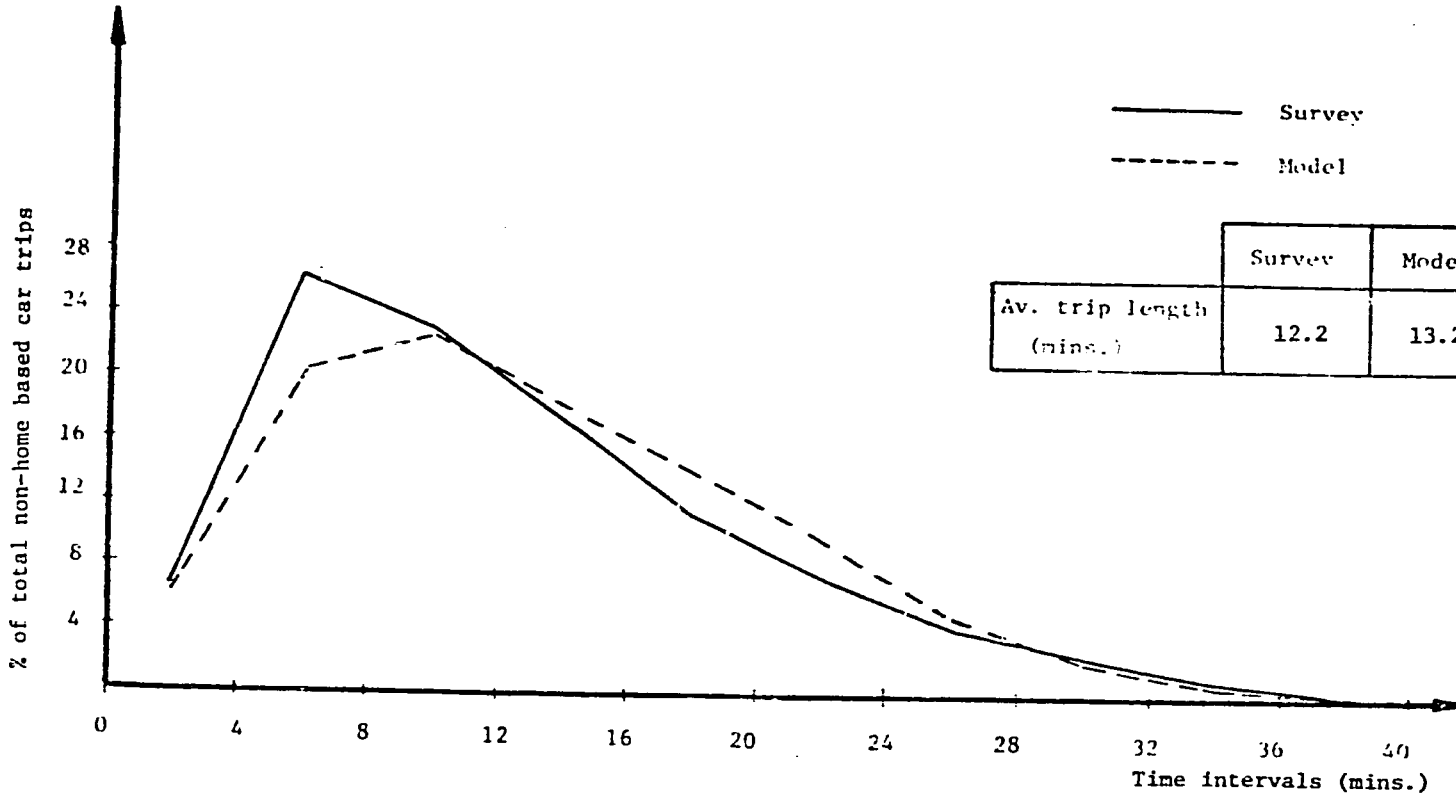
	Survey	Model
Av. trip length (min.)	13.4	13.2

Fig. II.2-- Trip Length frequency distribution for home-based work car trips



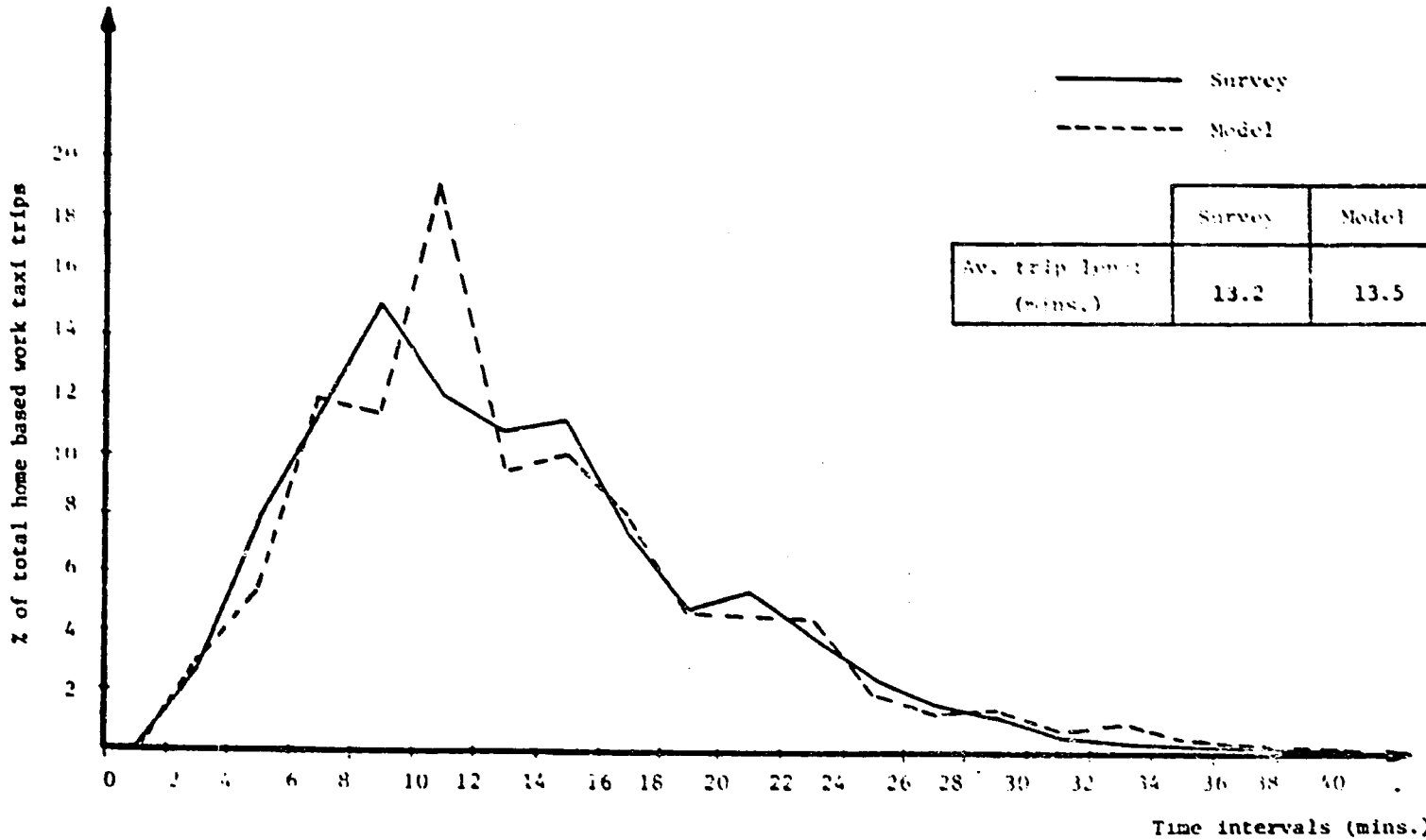
	Survey	Model
Av. trip length (mins)	12.4	12.8

Fig. II-3--Trip length frequency distribution for home-based other car trips



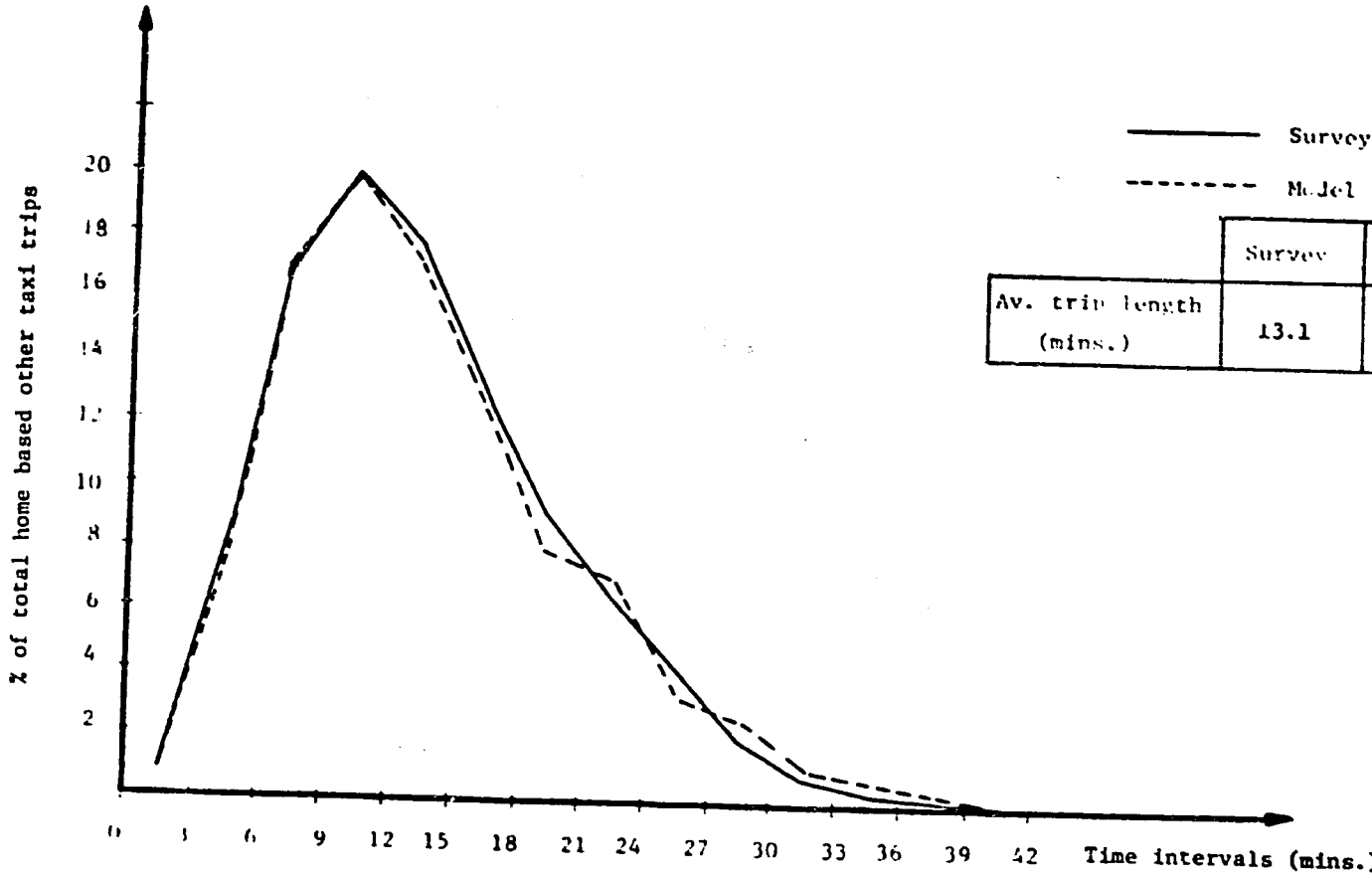
	Survey	Model
Av. trip length (mins.)	12.2	13.2

Fig. II-4--Trip length frequency distribution for non-home based car trips



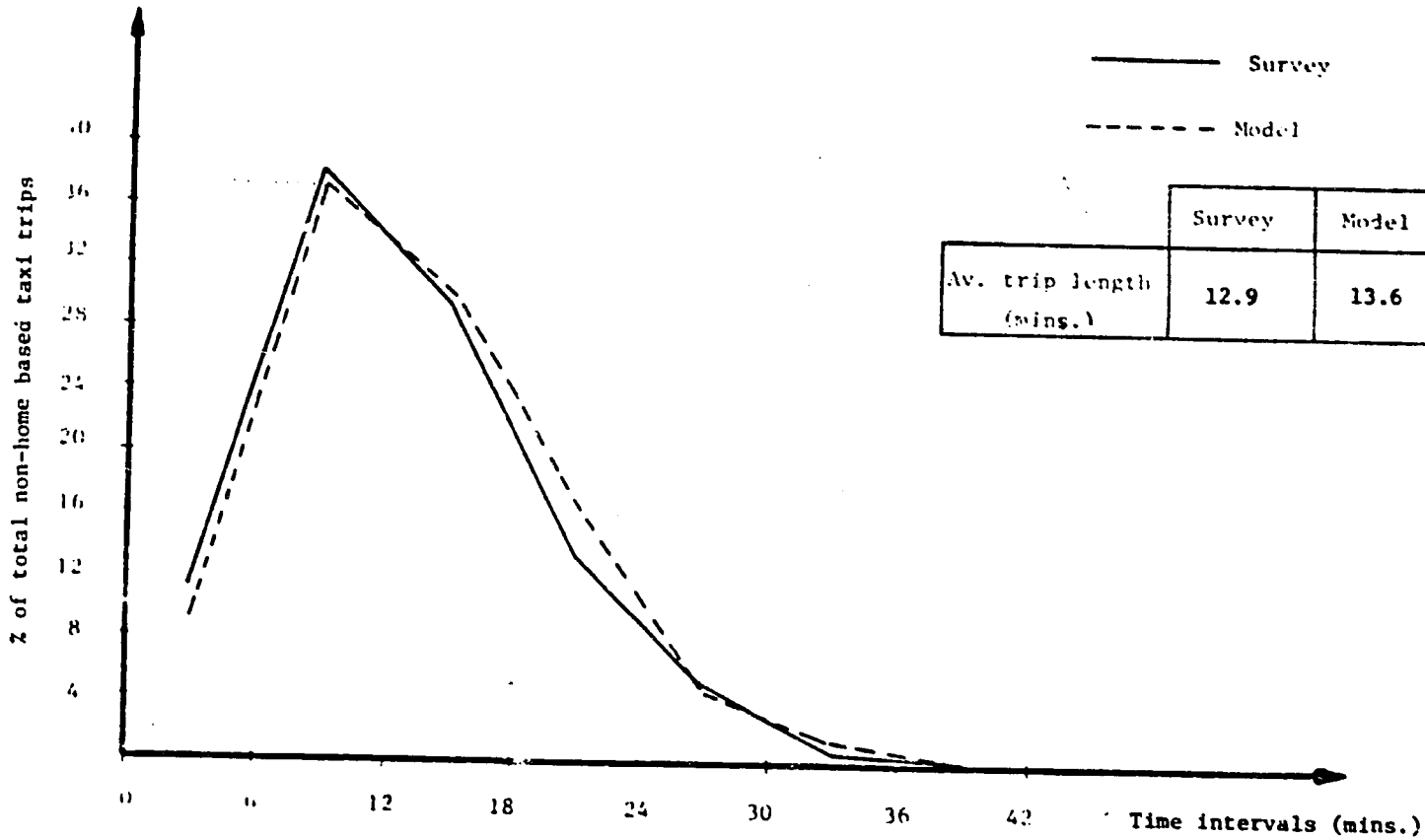
	Survey	Model
Av. trip length (mins.)	13.2	13.5

Fig. II-5--Trip length frequency distribution for home based work taxi trips



	Survey	Model
Av. trip length (mins.)	13.1	13.3

Fig. II-6--Trip length frequency distribution for home based other taxi trips



	Survey	Model
Av. trip length (mins.)	12.9	13.6

Fig. II-7--Trip length frequency distribution for non-home based taxi trips

5. Traffic Assignment

The importance of the assignment model lies in its results which were used to evaluate projects from a technical and economic point of view (27 & 28). Furthermore, different parking policies in and around the CBD can be tested using the assignment model to determine the effect of each policy on the network configuration (29).

Different computer packages were used to assign present and future O/D matrices to the Cairo network. Packages previously used in the developed countries showed some deficiencies in handling the transportation problems in developing countries and so a special package "The Cairo University Assignment Package" was developed.

5.1 The ICL Package

The assignment package developed by ICL (30) to be run on the 1900 series computer was used with the relevant Cairo data. The main difference between this package and conventional assignment models rests with the network coding and the simulation of traffic volume approaching or leaving a zone. The network is divided into sections, each of which is given a unique number which is used to describe how the sections are interconnected. Every section is represented by its centroid, and hence a section forms part of a zone if its centroid falls within that zone. Furthermore, flows originating from and attracted to each section are considered to emanate from these centroids, resulting in an evenly spread assignment.

The data required to run the package were collected, coded, punched, revised, and stored on a magnetic tape. Details about the modifications of the package to suit local conditions can be found in Reference (31).

The package ran successfully for a limited time with the actual data but stopped with an execution error not identified because the source code was not available.

5.2 The Urban Transportation Planning System (UTPS) Package

The assignment model of the UTPS package was tried next. The capacity restraint formula incorporated in this package adjusts the link travel time according to the function:

$$T = T_o \left[1 + 0.15 \left(\frac{V}{C}\right)^4\right]$$

where,

T = estimated link time at volume V

T_o = free flow link time

V = link volume

C = practical capacity of the link.

The factors of 0.15 and 4, known more generally as α and β, are constants calibrated for U.S. traffic characteristics. However, these factors were calibrated to suit the local conditions in Cairo in a separate study, (see section 1-5 in Chapter I), and values of α and β for various area type/facility type combinations were determined.

The network was represented in terms of links and nodes. Zone centroids were enumerated serially. In the case of Cairo, enumeration goes from 1 to 108. In order to avoid any confusion between this enumeration and the existing node enumeration on the link/node map, the same node enumeration was used by adding the figure of 1000 to each number. Thus, a node enumerated "1" on the key map was coded as "1001" for the program.

The maximum allowable number of links approaching one node was 4. In case this condition did not hold, dummy nodes were added to the network and connected to the actual nodes by "zero" links. A full description of the coding of Cairo street network can be found in Reference (32).

Several runs of the UTPS package were carried out at M.I.T. Analysis of these runs showed that the accuracy of the model was constrained for two main reasons.

1) The program neglected the impact of public transport on the network.

2) The program did not take into consideration the time spent at the intersections as a result of severe congestion (a case which probably did not occur on the day of the travel time survey).

Details of the analysis of these runs can be found in Ref. (33).

5.3 Cairo University Assignment Package

As mentioned earlier, the impact of public transport on the network should be carefully modeled, especially in a developing country where it plays a central role. This led the Cairo University team to develop a computer program initally based on work by Hassan (34) to take this factor into consideration. This was achieved by calculating for each link an initial load that consisted of public transport and commercial vehicles running along that link during the period under consideration, using the appropriate passenger car equivalent (P.C.E.) conversion factors. This measure would have the effect of simulating the congested network characterized by a high percentage of public transport and commercial vehicles.

In order to avoid confusion that might be caused by giving the same node different coding numbers, a new enumeration system was developed. Zone centroids were given numbers from 1 to 108, and the actual nodes given serial numbers starting from 109. Zone centroids were connected to the actual network through centroid connectors. The maximum number of links approaching any node was raised to five, with dummy nodes and zero links catering for nodes with more than five links.

The data input to the program is described in detail in Reference (35). The program consisted of:

1. A master segment that:

   - o Reads the different data sections
   - o Prints out the data for visual inspection
   - o Calculates the impedance of each link according to the capacity restraint formula.
   - o Calls subroutine "Minimum Route"
   - o Outputs the results.

2. Subroutine "Minimum Route"

This is a standard routine that calculates and prints out the shortest path between all O/D pairs according to link impedance. It then assigns to this path the O/D volume determined for this step. Initially, the Moore algorithm (36) was used to build the minimum trees. However, dynamic programming (37) was subsequently used to improve the model performance. The necessary alterations to the main program to incorporate this subroutine were carried out and are described in Ref. (38).

The following outputs can be produced by the model:

i) All input parameters and network data
ii) The impedance of each link, i.e., link travel time after last iteration of the capacity restrained loading process.
iii) The minimum route between each O/D pair after the last iteration
iv) The assigned volume on each link
v) The minimum impedance matrix between all O/D pairs
vi) Important statistics that reflect the network performance (V/C ratios and aggregate vehicular travel (veh-hr/hr).

A simplified flow chart of the program is shown in Fig. II.9 and the description of the program is given in section 6.2 of this chapter.

5.4 Evaluation Procedure :

In order to evaluate the impact of the different network configurations it was decided to calculate two measures : volume/capacity ratio and the aggregate vehicular travel time (p.c.e.hr/hr). An evaluation program was developed to carry out the following steps:

i) Calculate the link capacity according to its area type, facility type and number of lanes.

ii) Calculate the volume/capacity ratio for real links only by dividing the load on the link obtained after the last iteration by its capacity obtained from step (i).

iii) Classify the volume/capacity ratios into 10% increments and print a frequency table.

iv) Calculate the aggregate vehicle travel time by summing the product of the travel time along each link after the last assignment step and the respective volume on the link.

6. Development of Computer Programs

6.1 Trip Distribution Program

Figure II.8 shows a simplified flow chart of the different steps of the trip distribution program; a brief description of the required subprograms is presented below. Full details of the trip distribution program are given in references (22, 24, & 25).

Subprogram 1 - Sample O/D Matrix

This subprogram prepares sample O/D matrices for different trip purposes in a non-directional form. It also calculates row and column summations of each matrix, and determines necessary factors for transferring non-directional matrices into directional ones for use before assignment.

Subprogram 2 - Minimum Travel Time Matrix

This subprogram prepares travel time matrices in the right format. It also provides the possibility of determining generalized cost matrices, should the appropriate function exist.

Subprogram 3 - Fitting Travel Friction Function

This subprogram begins by calculating initial travel friction factors and fits the initial travel friction function using the least squares method.

Subprogram 4 - Plotting Trip Length Frequency Distribution

The main objective of this subprogram is to plot a trip length frequency distribution given an O/D matrix and a minimum travel time matrix.

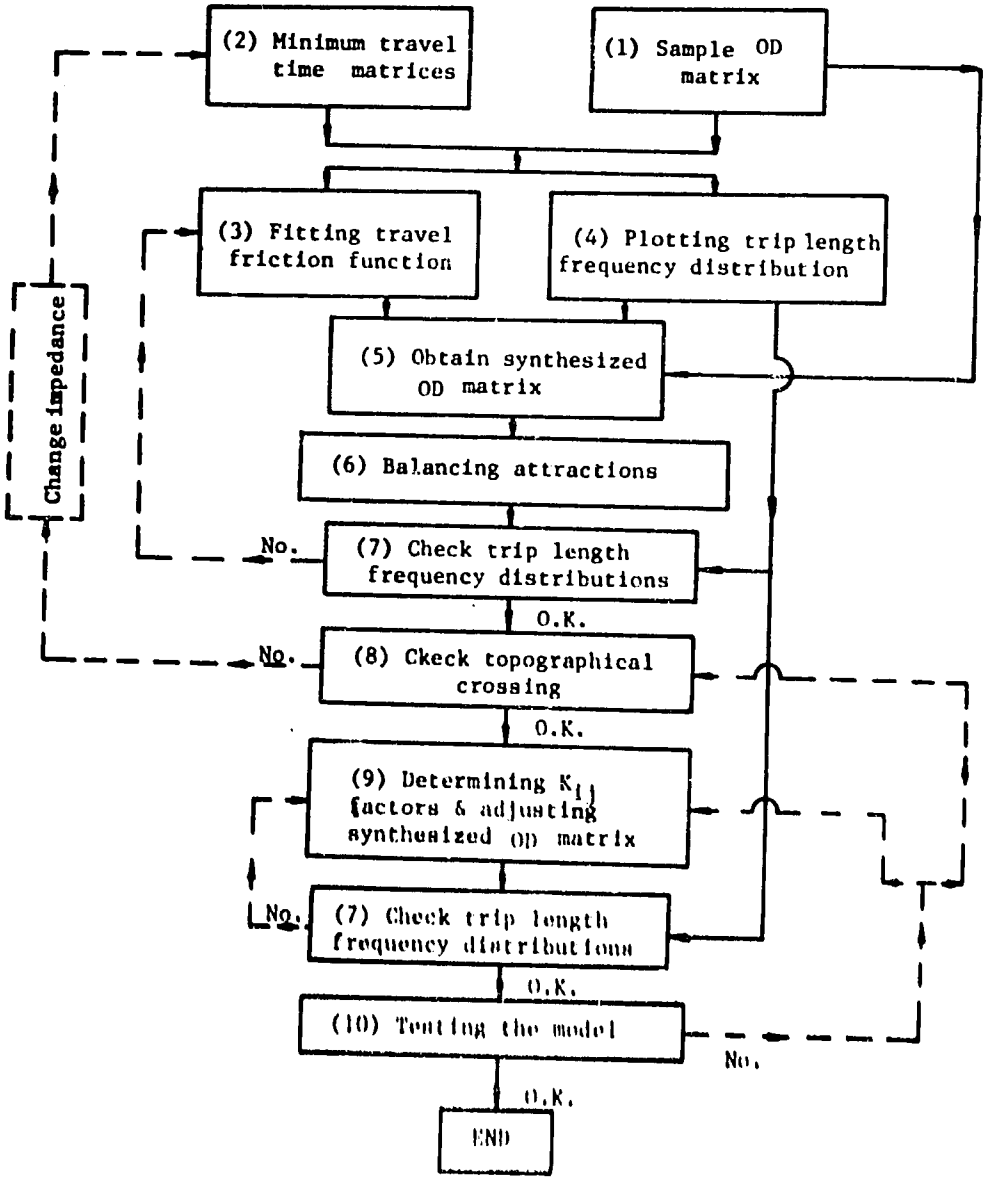


Fig. II.8 : Simplified Flow Chart of the Suggested Program for Calibration and Testing the BPR Gravity Model of Trip Distribution.

Subprogram 5 - Obtaining Synthesized O/D Matrix

This subprogram produces a synthesized O/D matrix, using a given travel friction function and setting zone to zone adjustment factors to unity.

Subprogram 6 - Balancing Attractions

This subprogram balances column summations (attractions) using an iterative procedure. An acceptable level of accuracy is specified in order to stop the procedure (i.e., $\sum_i T_{ij} = D_j \pm \gamma$, where γ is to be given by program user).

Subprogram 7 - Check Modeled Against Observed Trip Length Frequency Distributions

This subprogram compares the observed and estimated trip length frequency distributions, using the χ^2 statistical test. Sample O/D matrix obtained by subprogram 1, as well as synthesized O/D matrix obtained by subprogram 6, were inserted into subprogram 4, together with the minimum travel time matrix. The resulting trip length frequency distributions (i.e., observed and estimated) are the two distributions to be compared. If the results of the χ^2 test were not satisfactory according to a prescribed level of significance (to be specified by the user) the subprogram was then to proceed as follows. First, it calculates new travel friciton factors, then it calls subprogram 3 in order to fit the new travel friction function.

Subprogram 8 - Check Topographical Crossings

This subprogram calculates all movements crossing any topographical barrier that may exist in the study area (such as a river), given an O/D matrix and the identification of the grouping of zones in each side of the barrier. This subprogram should be applied first to the sample O/D

matrix and then to the modeled matrix. It will then compare survey and model crossings and detect any unacceptable differences according to a prescribed value $\tilde{\theta}$ (i.e., survey crossings = model crossings ± $\tilde{\theta}$) specified by the user. If the differences are not acceptable, the subprogram would so indicate to the user who could change travel impedances (e.g., time) on certain links of the network (e.g., bridges) if appropriate.

Subprogram 9 - Determining K_{ij} Factors

This subprogram determines K_{ij} factors. It then inserts these factors into the gravity model and produces a new adjusted synthesized O/D matrix. Then, the subprogram calls subprogram 7 in order to check the new adjusted trip length frequency distribution against the surveyed one. If the results are not acceptable, it will give a message to the user in order to adjust K_{ij} factors.

Subprogram 10 - Testing the Model

This subprogram performs the statistical tests described in reference (22). If the outcome of the test is not satisfactory, the subprogram will give a message to the user who can decide which step he should start for reiteration of the process, i.e. to go back to subprograms 8 or 9 for final adjustments.

6.2 Assignment Program

Figure II.9 shows a simplified flow chart of the assignment program and a brief description of the required subprograms are presented below:

Subprogram 1 - Validation

This subprogram checks the validity of the coded network and the initial load according to predetermined validation rules.

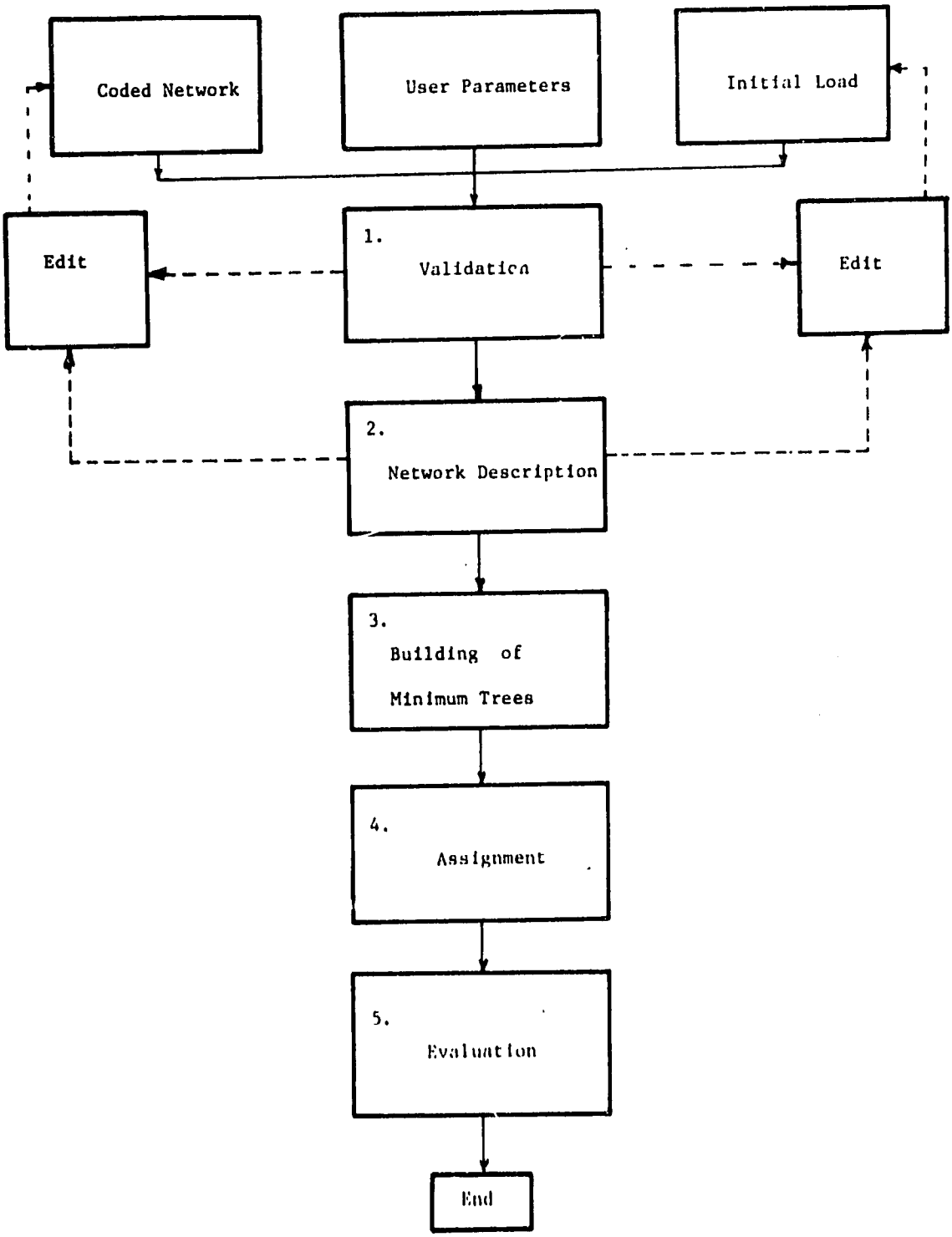


Fig. II.9 : Simplified Flow Chart of the Assignment Program

It produces a list of errors which is used by the user to edit and correct the network or the initial load.

Subprogram 2 - Network Description

This subprogram produces a printout of the network configuration in a readable form for visual inspection.

Subprogram 3 - Building of Minimum Trees

This subprogram is used to build minimum trees, i.e. the shortest path between each O/D pair of the coded network. The shortest path calculation is based on:

a. Initial travel time of links, assuming we are going to build minimum trees under free flow conditions, or alternatively,

b. Impedance calculations. The impedance calculation formula is discussed in Chapter I.

Subprogram 4 - Assignment

This subprogram assigns the trips moving between each O/D pair to the links of the shortest path between that pair.

A loaded network is the final output of this subprogram.

Subprogram 5 - Evaluation

This subprogram produces the final evaluation reports of the assignment program, they are as follows:

a. Minimum travel time matrix
b. List of minimum routes
c. Final load on each link
d. Final travel time on each link
e. Final volume/capacity on each link
f. The aggregate vehicle travel time of the network measured vehicle hr/hr.

7. Recommendations for Further Work

In view of the limitations of the data sets mentioned before, and bearing in mind the different activities of travel demand forecasting carried out in the project, some recommendations for further work are summarized in this section:

7.1 Trip Generation Analysis

Perhaps the most important recommendation in this area is to perform trip generation analysis at the disaggregate level (household or individual). This sort of behavioral modelling may shed more light on the trip making of Cairo residents. It should be noted, however, that there is no guarantee that this type of disaggregate analysis will produce "better" models than those obtained at the aggregate level during this project. Nevertheless, this analysis will make it possible to compare the accuracy and validity of each type of analysis in Greater Cairo. For instance, such disaggregate analysis enables the study of the variation in trips and socio-economic parameters that occur between and within traffic zones. Accordingly, validity of aggregate trip generation models will be investigated in more detail. Furthermore, the disaggregate analysis should consider a wide range of trips by purpose, such as work, education, shopping, recreation, social, and other trips. Effort can also be directed towards establishing more logical and accurate planning parameters that can be more easily predicted. In addition, the influence of accessibility on trip generation should be investigated, especially for public transport trips, given the zonal regression results obtained in this study. Incorporation of accessibility and/or variables that reflect the supply side may add to the explanatory power of the equations.

7.2 Modal Split Analysis

Although modal split analysis was not included in the travel demand forecasting activities of the project, it is important to undertake such an anlaysis in the future. This type of analysis should be undertaken at the disaggregate level, incorporating a wide range of mode choice variables , and should initially focus on submodal split analysis (i.e., mode choice within public transportation modes).

7.3 Trip Distribution

As mentioned in reference (39) a broad program of trip distribution analysis was initiated. However, ultimately only the BPR gravity model (19 & 26) was applied due to time and other constraints. These limitations led also to shortening the analysis of the calibration of the BPR model. Therefore, the following issues warrant further investigation:

1. Extension of the analysis of the six gravity models calibrated and presented in this report to cover:

    a. A discussion and comments on the calibrated travel friction functions

    b. Wider investigation of the effect of introducing socio-economic adjustment factors into the models

    c. Adjustment of travel friction assigned to the bridges in order to close the gap between the survey and model results for River Nile crossings that appeared in the calibrated models

    d. Undertake the procedure of testing the six calibrated models as illustrated in subprogram 10 of report TDF28/TD5 (22).

2. Enhancement of the developed computer program so as to be easily operated by any user.

3. Calibration of different trip distribution models such as entropy maximizing models, opportunity models and so on. This would allow comparison between different models and deciding more confidently which of them is most suitable for local conditions.

4. Using generalized cost instead of travel time in gravity model calibrations. This, of course, requires another analysis in order to establish a generalized cost function for Greater Cairo.

5. Studying the nature and form of travel friction function suitable for gravity model calibration in different size urban areas. This study will pave the way for trip distribution modeling to be used in different urban areas in Egypt.

6. Finalizing the computer program developed for growth factor methods. This program has already been written and tried on a test run. However, time limitations did not allow its finalization or use. Such a program would be useful in short term forecasts and in rural area studies.

7.4 Assignment Program

a) Enhance the program to be more efficient

b) Develop an assignment program to include the effect of public transport passengers

c) Develop a more comprehensive evaluation procedure. In such development, the economic impact of the different network configurations is mainly reflected in the overall travel time savings for both private and public road users. The assignment model could calculate these savings according to the following functions:

a) Private Transport Users

$$T_i^j = n \sum_{C=1}^{3} AO_c \sum_{\ell=1}^{m} \cdot \sum_{h=1}^{24} x_{\ell h} \cdot i_{\ell h} \cdot t_{\ell h}$$

where,

T_i^j = total travel time for private road users for year i if project set j is implemented

n = number of working days in a year (assumed to be 300 days)

AO_c = auto occupancy which could be classified by area type into 3 classes. Links within a certain area type could be given the auto occupancy value of this class. Values of AO could be obtained by dividing the total number of passengers by the total number of P.C.E.'s.

m = total number of links in the network

$x_{\ell h}$ = final load on link ℓ in P.C.E.'s/hr after the last increment is assigned during the peak hour

$f_{\ell h}$ = ratio of the volume for the hth hour to the peak hourly volume. The use of such a factor will overcome the need to run the assignment model for the non-peak hours.

$t_{\ell h}$ = travel time along link ℓ during hour h. The value of t_h for the peak hour is output from the assignment model. However, for the off-peak hours this value could be extracted from the appropriate volume/delay curves ($T = T_o\ (1 + \alpha(x_{\ell h} \cdot f_{\ell h}/C)^{\beta})$).

b) Public Transit Users

$$T_i^{'j} = n \sum_{\ell=1}^{m} \sum_{h=1}^{24} \sum_{k=1}^{p} \alpha_{\ell k} \cdot F_{kh} \cdot C_{kh} \cdot t_{\ell h}$$

where,

$T_i^{'j}$ = total time for public transport users for year i if project set j has been implemented

$\alpha_{\ell k}$ = binary parameter for each link = 1 if line (k) uses link (ℓ) and zero otherwise

F_{kh} = bus frequency for line (k) during hour (h). CTA generally uses two frequencies one for the peak and one for the off peak periods

C_{kh} = average vehicle occupancy on line (k) during hour (h). It is proposed to use 120 and 80 passenger/hr during peak and off peak hours respectively.

$t_{\ell h}$ = same as mentioned above, and could be increased by an average of Z minutes dwell time at each stop along the link.

In order to transform the savings in travel time and operating costs into monetray terms, values suggested by Jameson Mackay & Parkers (40) could be used for public and private road users independently.

7.5 Development of TDF Computer Package

As mentioned above, different computer programs were developed in the project for the calibration and testing of various models of travel

demand forecasting. It is recommended to integrate these programs into one package which could be used by transport planners in Cairo. The existing package makes a good starting point for developing another one which would be suitable not only for Cairo but also for other metropolitan areas in developing countries. Such a package is considered a necessary tool which can bring together in a usable format all modelling and programming efforts of the project team during the last four years. Figure II.10 shows a proposed simplified flow chart of components of such a package and reference (41) gives more detail and discussion about the proposed package and its importance.

7.6 Related Research Topics

Other research topics that are worth considering in the future include the following:

a. Formulation of generalized cost function that is suitable for local conditions in Greater Cairo

b. Investigating the validity and usefulness of calibrating combined models such as generation/distribution, distribution/modal split and generation/distribution/modal split models.

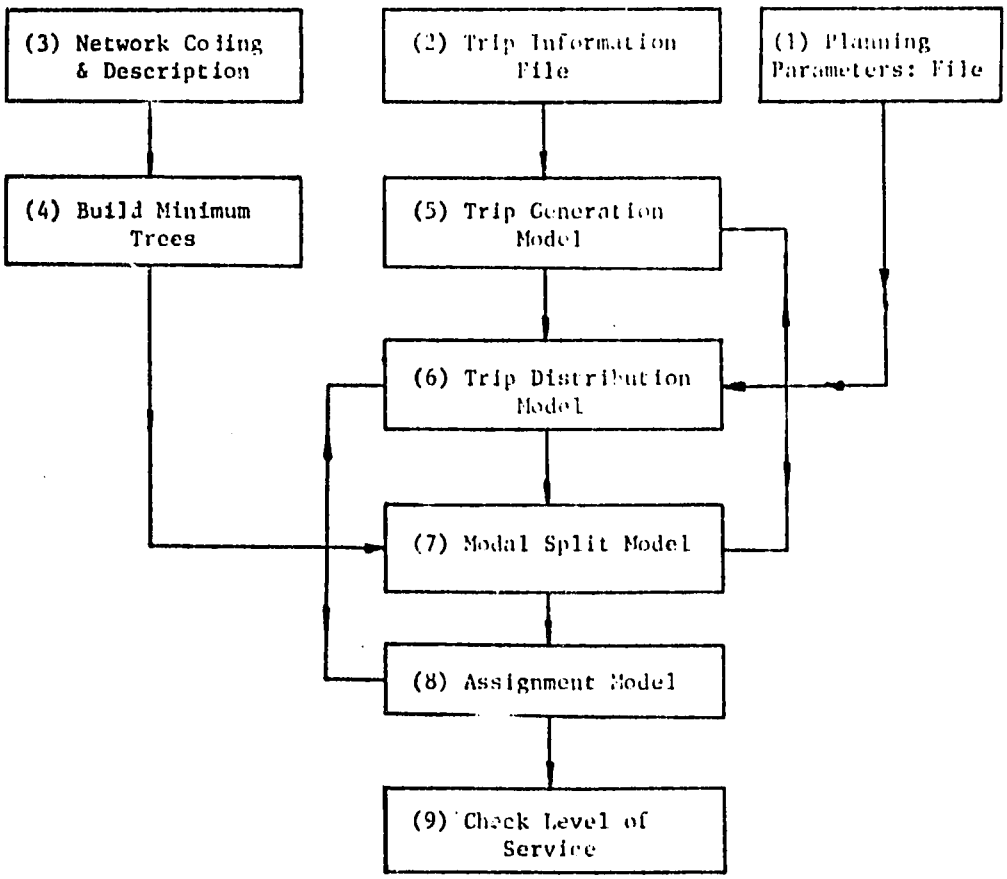


Fig. II.10

Flow Chart of the Proposed Forecasting Package

8. List of Project Papers and Reports in Travel Demand Forecasting

Serial No.	Title	Author(s)	Date	Area Code	Library Code
1	The ICL Traffic Assignment Package Progress Report	T. El-Reedy	1978	-	21/3
2	Urban Traffic Patterns and Trip Generation Rates in Cairo	M. El-Hawary M.S. El-Hawary	Oct. 1978	TDF1/TC1	21/8
3	Trip Generation Rates	M. El-Hawary M. S. El-Hawary	Oct. 1978	TDF2/TC2	21/9
4	Functional Evaluation	D. Keller	Nov. 1978	-	21/6
5	Travel Demand Forecasting, Options	D. Keller	Nov. 1978	-	21/10
6	Notes on the Preparation of Data for Analysis of Trip Generation Rates	D. Keller	Dec. 1978	TDF3	
7	The Trip Generation Model Review of Analysis Techniques	A.S. Huzayyin	Dec. 1978	TDF4/TG1	21/1
8	Coding of the Street Network in Cairo to apply "U road" Assignment Model	M. Hassan	1978	-	21/7
9	UTPS Vol. 0 - UTPS Introduction - UTPS Reference Manual - UTPS Users Guide Vol. 1 - U Logit Users Guide	F. Bouthelier	Dec. 1978	-	21/47

Serial No.	Title	Author(s)	Date	Area Code	Library Code
	- Demand Model Selection Manual - General Purpose Subroutines and Utility Programs Vol. 2 - Characteristics of Urban Transportation Systems - Network Development Manual. Vol. 3 - Software Systems Development Manual				
10	Estimation of hourly traffic volume in the missing 6 hours of 1977 Cairo Traffic Survey	A.S. Huzayyin	Jan. 1979	TDF5/TC3	21/96
11	The effect of changing shop opening hours in Cairo on traffic patterns in the city centre	M. El-Hawary A.S. Huzayyin	Feb. 1979	TDF6/TC4	60/2
12	Travel Demand in Cairo Projections with the Matrix-Factor-Method	D. Keller	Feb. 1979	-	21/73
13	A Review of Trip Distribution	M.K. Amin	Feb. 1979	TDF7/TD1	21/94
14	Some Observations on the Private Vehicular Trip Rates in Cairo	D. Keller	Feb. 1979	TDF10.1/ TC5.1	21/72

Serial No.	Title	Author(s)	Date	Area Code	Library Code
15	Trip Generation Model for Cairo, Analysis Programme	A.S. Huzayyin	Mar. 1979	TDF8/TG2	21/95
16	Progress Report on Travel Demand Forecasting	A.S. Huzayyin	Apr. 1979	TDF9	21/91
17	Comments on the analysis of trip rates	T.M. El-Hakim	Apr. 1979	TDF10.2/ TC5.2	21/92
18	Frequency distribution of some socio-economic variables of the 66 traffic zones of the enlarged C.B.D. area	T.M. El-Hakim	Apr. 1979	TDF11/ TG3	21/116
19	Trip distribution model for Cairo, analysis program	M.K. Amin	Apr. 1979	TDF12/ TD2	21/93
20	Comments on the paper of D. Keller concerning projection of travel demand using the uniform growth factor method	M.K. Amin	Apr. 1979	TDF13/ TD3	21/98
21	Occupancy Rates of Private Cars and Taxis in Greater Cairo	S. El-Hawary	Apr. 1979	TDF14	21/97
22	I) Trip information required for trip generation and trip distribution models (private transport)	A.S. Huzayyin T.M. El-Hakim	May 1979	TDF15.1	21/320
23	II) Details of computation steps necessary for	T.M. El-Hakim	May 1979	TDF15.2	21/321

Serial No.	Tiltle	Author(s)	Date	Area Code	Library Code
	determining the required trip information descibed in TDF15.1				
24	Trip information required for the analysis of travel demand forecasting	A.S. Huzayyin	July 1979	TDF16.1	21/142
25	Computational guidlines for determining the required trip information for the analysis of travel demand forecasting	T.M. El-Hakim	July 1979	TDF16.2	21/176
26	Documentation of Greater Cairo Zonal sosio-economic and land use characteristics	T.M. El-Hakim	July 1979	TDF17/ TG4	21/177
27	Preliminary investigation of the cross classification tabulation of zonal trip generation rates	A.S. Huzayyin T.M. El-Hakim	July 1979	TDF18	21/178
28	Preliminary investigation into the nature of travel friction factors in Greater Cairo	A.S. Huzayyin	July 1979	TDF19/ TD4	21/143
29	Present and proposed future activities on travel demand forecasting	A.S. Huzayyin	Aug. 1979	TDF20	21/144
30	Comments on "Documentation of Greater Cairo zonal socio-economic & land use variables (Report TDF18/TG6)	A.M. Hardman	Sept. 1979	-	21/152

Serial No.	Title	Author(s)	Date	Area Code	Library Code
31	Latent demand for public transit service in Cairo	H. Mahmassani	Nov. 1979	-	21/198
32	Usage of UTPS Package for Modelling the Assignment of Vehicular Traffic to the Road Network in Cairo, Background & Status of Pre-Present Work	M. Hassan	Nov. 1979	-	21/197
33	Operating UTPS in Egypt	M.H. El-Sherif	1979	-	21/356
34	Summary of methodology used in regression and cross classification analysis of public transport trip generation modelling	T.M. El-Hakim	Apr. 1980	TDF21/ TG6	21/253
35	The effect of error in public transport enlargement factors on trip productions and attractions used in trip generation analysis	T.M. El-Hakim	Apr. 1980	TDF22/ TG7	21/313
36	Vol. 1 - Traffic Assignment model Vol. 2 - Appendix A : Test Run(Computer Print) Vol. 2 - Appendix B : The effect of changing the initial loading of the network on the derived min. route	T. El-Reedy T. Hashem	Apr. 1980	-	21/255

Serial No.	Title	Author(s)	Date	Area Code	Library Code
	Vol. 4 - Appendix C : The effect of changing the interzonal volumes.				
37	Transit User Survey (1978) Data	A. Hardman	June 1980	-	21/284
38	Vol. 1 - Shortest path Algorithms for Assignment Model.	H. Mahmassani	July 1980	-	21/277
	Vol. 2 - A Computation Analysis of Alternative Algorithms & Labeling techniques for finding shortest path tress	R. Dial F. Glover D. Karney D. Klingman			
39	Comments on the remarks about public transport trip rates mentioned in A. Hardman's report titled "Characteristics of Cairo Transit Users", June 1980	T.M. El-Hakim	July 1980	TDF23/ TG8	21/268
40	Cairo Land Use and Population Characteristics by zones	A. Hardman	July 1980	-	21/282
41	The Cairo University Assignment Model	T. El-Reedy T.M. Hashem	July 1980	-	21/280
42	Assessment of network Dependent economic impacts	H. Mahmassani	Sept. 1980	-	21/331

Serial No.	Title	Author(s)	Date	Area Code	Library Code
43	Characteristics of Greater Cairo traffic zones sosio-economic variables	T.M. El-Hakim	Nov. 1980	TDF24/ TG9	21/334
44	Public transport trip generation characteristics of Greater Cairo traffic zones	T.M. El-Hakim	Nov. 1980	TDF25/ TG10	21/348
45	Public transport trip generation regression models for Greater Cario	T.M. El-Hakim	Nov. 1980	TDF26/ TG11.	21/360
46	Traval demand forecasting package for developing countries (TDFPDC)	A.S. Huzayyin	Nov. 1980	TDF27	21/303
47	Computer Program for calibration of trip distribution gravity model	A.S. Huzayyin	Nov. 1980	TDF28/ TD5	21/304
48	Preliminary report on the analysis of the impact of changing shop opening hours in Greater Cairo on traffic characteristics and travel demand forecasting in the Capital	M. El-Hawary A.S. Huzayyin	Nov. 1980	TDF29/ TG6	21/305
49	Proposal of the methodology for projecting zonal planning variables in Greater Cairo (1976 - 2000).	S. Zaghloul N. Gheita	Nov. 1980	TDF30/ TG12	21/306
50	Progress Report on the Assignment Package	T. El-Reedy T. Hashem	Nov. 1980	-	21/298

Serial No.	Title	Author(s)	Date	Area Code	Library Code
51	Assessment of non-network economic impacts	A. Hardman	Dec. 1980	-	21/332
52	Multicriteria Evaluation in the Revised Programming Procedure	H. Mahmassani	Dec. 1980	-	21/324
53	Operationalisation of the network economic impacts	T. El-Reedy	1980	-	21/358
54	Testing of gravity model, calibracion procedure and computer program	M.M. Shouman A.S. Baiumy	Mar. 1981	TDF31/ TD6	21/364
55	Computational procedure of gravity model calibration	A.S. Huzayyin A.S. Baiumy M.M. Shouman	Apr. 1980	TDF32/ TD7	21/365
56	Public transport trip generation cross-classification maodel for Greater Cairo	T.M. El-Hakim	May 1981	TDF33/ TG13	21/366
57	Private transport trip generation characteristics of Greater Cairo traffic zones	T.M. El-Hakim	June 1981	TDF34/ TG14	21/367
58	Private transport trip generation regression model for Greater Cairo	T.M. El-Hakim	July 1981	TDF35/ TG15	21/368

Serial No.	Title	Author(s)	Date	Area Code	Library Code
59	Projection of zonal planning parameters in Greater Cairo (1980-2000).	S. Zaghloul N. Gheita	July	TDF36/ TG16	21/369
60	Comparison between trip genration regression and cross classification models for prediction of public transport trips in Greater Cairo	T.M. El-Hakim	July	TDF37/ TG17	21/370
61	Future zonal trip genration in Greater Cairo	T.M. El-Hakim	Aug. 1981	TDF38/ TG18	21/371
62	System specifications of gravity maodel calibration program	T. Hashem A. Rashad	Aug. 1981	TDF39/ TD8	21/372
63	Gravity model of trip distribution for Greater Cairo	A.S. Huzayyin	Aug. 1981	TDF40/ TD9	21/373

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CHAPTER III

PRIVATE CAR OWNERSHIP

1. Introduction

Car ownership forecasting is of foremost significance in the formulation of future transportation policies. At the national level, the number of private cars in Egypt is increasing at a rate greater than the rate of increase of population (see Table III.1). Using the time series of the motorization index (MI),* A. Gazarin (1) has derived three trend projections of demand up to 1985 (see Fig. III.1). Table III.2 shows the most likely of these estimates (Estimate 2). The Netherland Engineering Consultants (NEDECO), working in Egypt have developed a regression model relating passenger car ownership in Egypt to the gross domestic product (GDP) per capita in constant prices of 1977 L.E. (2). This model (with $R^2 = 0.7$) has the form:

$$MI = -8.2 + 0.088 \text{ (GDP per capita in constant 1977 L.E.)}.$$

The increasing auto-ownership in Greater Cairo (Table III.3) contributes significantly to the problems of congestion, accidents, air, and noise pollution.

This section of the report describes models for estimating the future increase in private car ownership in Egypt and in each traffic zone in Greater Cairo. After reviewing previous efforts in this field and also the available data (3), a zonal regression analysis technique was used to develop two models:

a. The Egypt Model

This is a regression model at the national level developed from data collected in different time periods. It gives the relationship between

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*MI: number of autos per 1000 population

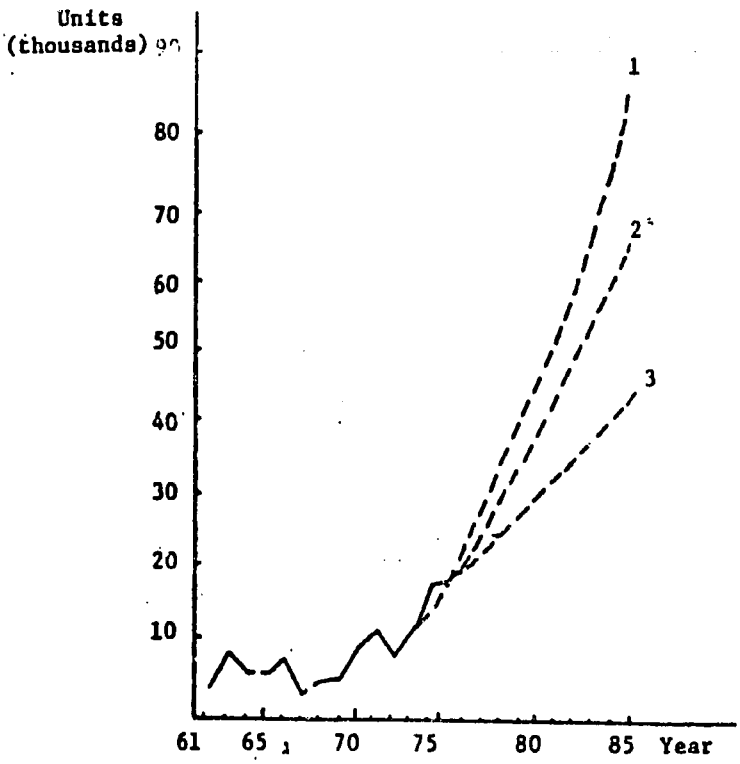

Fig. (III.1)

Automobile Demand Forecasts Up to 1985

Table III.1

Car Ownership in Egypt

Year	Population* (thousands)	Private Cars**	Private Cars per 10,000 Capita
1964	28659	77721	27.12
1965	29389	82034	27.91
1966	30139	89042	29.54
1967	30835	89964	29.18
1968	31547	96548	30.50
1969	32276	101973	31.59
1970	33022	108130	32.74
1971	33785	115908	34.31
1972	34565	123259	35.61
1973	35363	128868	36.44
1974	36130	138334	38.26
1975	37016	153734	41.53
1976	37870	175523	46.35
1977	38745	207684	53.60
1978	41000	245293	59.83

* Source : CAPMAS

** Source : Traffic Agency

Table (III.2)

An Estimation of Motorization Index (up to 1985)

Year	Private Car Demand (000)	Private Car Total (000)	Motorization Index (Cars / 1000 pop.)
1972	8.6	141.5	3.9
1973	12.0	151.0	4.1
1974	15.0	164.0	4.4
1975	19.0	180.0	4.8
1976	23.0	200.0	5.2
1977	27.0	224.0	5.7
1978	32.0	252.0	6.3
1979	36.0	285.0	7.0
1980	40.0	321.0	7.7
1981	45.0	382.0	8.4
1982	50.0	406.0	9.3
1983	55.0	458.0	10.2
1984	62.0	515.0	11.2
1985	67.0	576.0	12.3

Table (III.3)

Car Ownership in Greater Cairo

Year	Population (estimated)	Private cars	Private Cars per 10,000 Capita
1966	6113032	60671	99.25
1967	6282577	63994	101.86
1968	6452122	69170	107.21
1969	6621667	73367	111.40
1970	6791212	75484	111.15
1971	6960756	78549	112.85
1972	7140301	81285	113.84
1973	7299846	83807	114.81
1974	7469391	88229	118.12
1975	7638936	95558	125.09
1976	8000133	110730	138.41

Source : Traffic Agency

the number of private cars per thousand inhabitants in Egypt and the main variables affecting auto ownership.

b. The Cairo Zonal Model

For each of the 66 traffic zones of the study area in Greater Cairo (4) defined in Part I of this report, private car ownership data and socio-economic parameters were collected and processed and a cross-sectional zonal regression model was developed. The traffic data were obtained from the traffic survey discussed in Part I, section 1.1, and also from the Central Traffic Agency. The socio-economic data were collected from the Central Agency for Public Mobilization and Statistics (CAMPAS). The data required to estimate car prices were collected from El-Nasr Car Company (NASCO).

2. The Egypt Model

2.1 Model Form

The dependent variable (Y) is the number of private cars per 10,000 capita, while the independent variables were chosen as follows:

X_1 = Average annual per capita income (in constant 1970 L.E.)

X_2 = Average car price (in constant 1970 L.E. ÷ 100)

X_3 = Annual Transport investment per capita (in constant 1970 L.E. X 10)*

X_4 = Number of workers leaving Egypt annually ÷ total population (X 10,000)

The model to be estimated is a time series linear regression model in the form:

$$Y = b_o + \sum_i b_i X_i .$$

The computer program used for estimation is based on the abbreviated "Doolittle Method" (3).

A sequence of four models was estimated with the results of each model summarized below.

2.2 The First Model

For the period 1969-1977, the following model was developed with X_1, X_2, X_3, and X_4 as independent variables:

$$Y = -5.45 + 0.23X_1 + 0.90X_2 + 0.11X_3 + 0.07X_4 .$$

The bivariate correlation coefficients are as follows:

---

*A lag of one year is introduced to take into account the completion time of projects.

Variable	X_1	X_2	X_3	X_4
X_2	0.2519			
X_3	0.8986	-0.1316		
X_4	0.8978	0.5341	0.6982	
Y	0.9531	0.4414	0.7987	0.9507

The multiple correlation coefficient = 0.98

The residual SS = 14.07

Standard Error of Estimate = SEE = 3.5

$$\frac{SEE}{\bar{Y}} = 0.09, \quad \frac{b_o}{\bar{Y}} = 0.14.$$

For testing the significance of each variable, the F-test is used with the critical value F 0.9 (1,4)* = 4.54.

Hypothesis	$b_0 = 0$	$b_1 = 0$	$b_2 = 0$	$b_3 = 0$	$b_4 = 0$
F	3878.253	105.3997	5.0223	0.7702	0.8414

From the F-test, it seems that X_3 and X_4 are insignificant, so they were excluded in the second model.

---

* 0.9 = 1 - α; α is the level of significance = 0.1
(1.4) are the degrees of freedom (ν_1, ν_2) for the F-test.

2.3 The Second Model

For the period 1967-1977 (excluding 1968 which is a special case) and with X_1, X_2 as independent variables, the model takes the form:

$$Y = -20.21 + 0.61X_1 + 0.46X_2;$$

with the following correlation matrix:

Variable	X_1	X_2
X_2	0.1298	
Y	0.9499	0.2379

RMULT = 0.95696

RSS = 41.6012

SEE = 5.9430

$\frac{SEE}{\bar{Y}}$ = 0.15655

$\frac{b_o}{\bar{Y}}$ = 0.53238

F 0.9 (1,7) = 3.59

Hypothesis	$b_o = 0$	$b_1 = 0$	$b_2 = 0$
F	2424.752	74.995	1.112

In this model, X_2 is insignificant. So the third model has X_1 as the only independent variable.

2.4 The Third Model

$$Y = -15.05 + 0.6187X_1$$

RMULT = 0.94994

RSS = 48.2076

SEE = 6.0260

$\frac{SEE}{\bar{Y}}$ = 0.15874

$\frac{b_o}{\bar{Y}}$ = -0.39645

F0.9 (1,8) = 3.46

Hypothesis	$b_o = 0$	$b_1 = 0$
F	2391.385	73.963

2.5 The Fourth Model

In this model (X_2/X_1) was taken as the independent variable for the period 1965-78 excluding 1968. It has the form:

$$Y = 64.34 - 1.64 \left(\frac{X_2}{X_1}\right).$$

RMULT = 0.54165

RSS = 888.6799

SEE = 74.0567

$\frac{SEE}{\bar{Y}}$ = 1.97857

$$\frac{b_o}{\bar{Y}} = 1.71897$$

F 0.9 (1.12) = 3.18

Hypothesis	$b_o = 0$	$b_1 = 0$
F	1598.003	502.932

In this model, either current prices or fixed prices may be used, since the independent variable is a ratio, and is not affected by inflation. But its disadvantage is the small RMULT relative to the other models.

2.6 Forecasts of Auto Ownership in Egypt

Each of the preceeding models could be used to predict auto ownership, but with different levels of reliability. The third model appears to be the best among the ones tested and is also the simplest one as it has only one independent variable to be predicted.

In order to estimate future private car ownership on the national level using the third model, the per capita income must be forecasted for the analysis period. In doing this, it was noticed that the rate of increase of per capita income was very low and nearly constant before the year 1973, while rapid growth occurred after the 1973 war (see Fig. III.2). If the per capita income continues to increase at this high rate, it will lead to a very high level of car ownership (Est. 1). On the other hand, if the rate of increase is as before 1973, it will lead to a lower

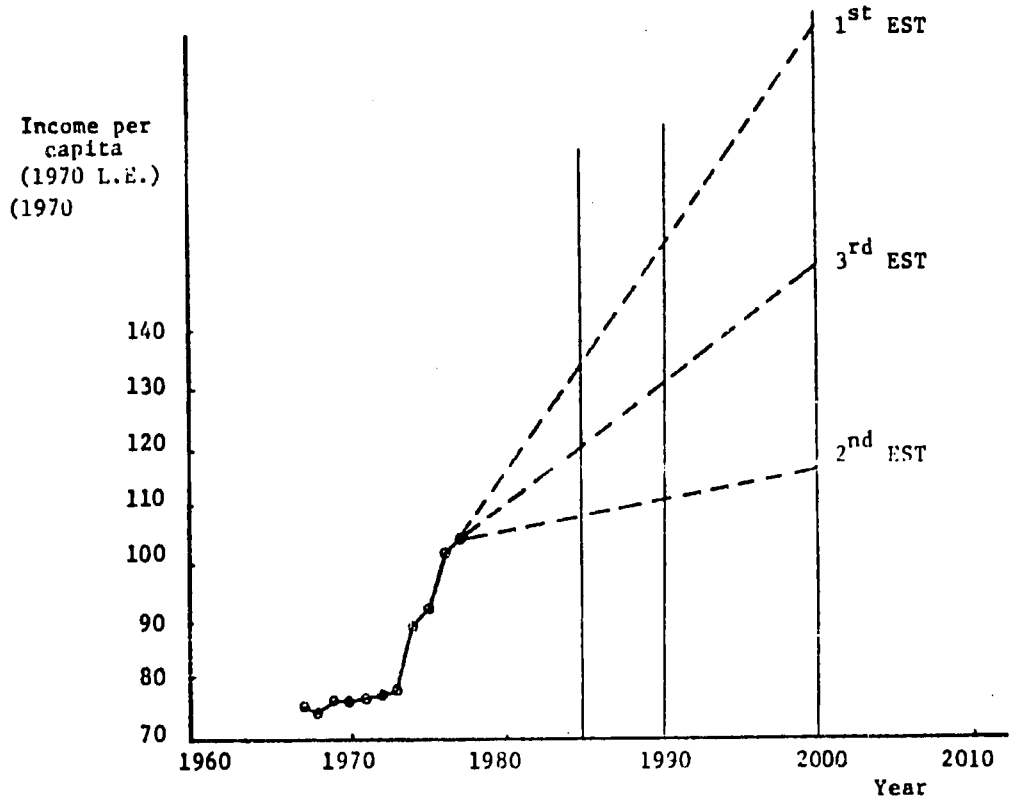

Fig. (III.2) PER CAPITA INCOME FORECASTS

estimate of car ownership (Est. 2). A third estimate which is the average of these low and high estimates is considered to be the most reasonable, taking into account the probability of changing economic conditions over long periods (Est. 3). The estimated private car ownership according to these income trends are shown in Table III.4.

To check the estimates given in Table III.4, the cross-section UN countries' regression model (5) is used. This model has the form:

Total number of private cars = $\alpha(GNP \cdot 10^6)^\beta$;

GNP = Gross National Product in U.S. dollars

Using 1970 as the base year:

$\alpha = 0.1189$, $\beta = 0.7958$

The population given in Table III.5 is based on a rate of increase of 2% per year (see Bulletin of Statistics UN Estimation). If we assume US \$ = 0.7 L.E., then the estimated car ownership figures will be as shown in Table III.5

The results of Table III.5 are obtained by using the estimates of income of Table III.4. However, the UN model gives decreasing values of auto ownership per capita over time, which is an unreasonable result. The estimates for the far future (the year 2000), however, do not vary too much from those shown in Table III.4. It should also be noted that the relationship between the purchasing power of L.E. and the US dollar may vary with time; so a more detailed economic study is required to use the UN model with confidence.

Table (III.4)

Forecasts of Auto-ownership

Year	Per Capita Income (1970 L.E.)			Private Car Ownership (Cars/10,000 Capita)		
	1st Est.	2nd Est.	3rd Est	1st Est.	2nd Est.	3rd Est.
1985	136	110	123	69.3	53.2	61.3
1990	154	113	133.5	80.4	55.0	67.7
2000	186	119	152.5	100.3	58.7	79.5

Table (III.5) : Estimates of Population and Auto-ownership

Year	Population (millions)	Total Number of Cars (1000 Cars)			Private Car Ownership (Cars/10,000 Capita)		
		1st Est	2nd Est.	3rd Est.	1st Est.	2nd Est.	3rd Est.
1985	45.850	469	396	433	102.3	86.4	94.4
1990	50.622	518	404	462	102.3	79.9	91.3
2000	61.708	601	421	514	97.5	68.3	83.3

3. The Cairo Zonal Model

3.1 Model Form

The following eight zonal variables were identified as likely to affect private car ownership:

X_1 = average per capita income (L.E./year)

X_2 = average percent of per capita income spent on transportation and communication

X_3 = number of people per room

X_4 = % of population employed (6 years and older)

X_5 = % of population educated (10 years and older who can read and write)

X_6 = % of population who are highly educated (10 years and older)

X_7 = % of population of age 12-65 years

X_8 = No. of garages per 1,000 capita.

The estimate of the number of private cars owned in each traffic zone was based on the survey carried out in April 1977 (see Part 1, section 1.1). Through this survey, we obtained the number of vehicles parked at night in each traffic zone. Using the following notation:

y_i = private cars parked by night in zone (i) (in the sample),

Y_i = estimated private cars owned in the zone (i).

Then, Y_i can be estimated as:

$$Y_i = y_i \times \frac{\text{Total private cars registered in Greater Cairo (1976)}}{\text{Total sample size}}$$

$$Y_i = y_i \times \frac{110730}{49100} = 2.255\ y_i$$

This formula seems to give a good estimate for private car ownership since nearly every car owner parks his car close to his home.

So for each traffic zone the dependent variable in cars per thousand is:

$$\frac{Y_i}{\text{Population of traffic zone (i)}} \times 1000$$

Tables of the independent and dependent variables for each traffic zone are given in reference (3).

As for the Egypt model, the model is a cross-sectional linear regression model of the form:

$$y = b_o + \sum_i b_i X_i$$

The same computer program used in the Egypt model is also applied here.

3.2 The First Model

For the 66 zones and the 8 independent variables, the regression coefficients are:

b_0 = 85.2671; b_1 = 0.2249

b_2 = 11.2837 b_3 = - 42.9134

b_4 = - 0.9780 b_5 = - 0.8869

b_6 = 8.3237 b_7 = 0.4365

b_8 = - 0.9390, the correlation matrix has the form :

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
X_2	0.6486							
X_3	-0.6557	-0.6184						
X_4	0.2394	0.3623	-0.4058					
X_5	-0.2803	-0.2229	0.2647	0.1429				
X_6	0.7999	0.6775	-0.7815	0.4102	-0.2388			
X_7	0.3216	0.3243	-0.3582	0.3705	-0.1414	0.3280		
X_8	0.6750	0.6551	-0.6767	0.2891	-0.2890	0.9223	0.2235	
y	0.5173	0.5828	-0.6038	0.2859	-0.2050	0.6469	0.2636	0.5999

The multiple correlation coefficient:

RMULT = 0.69042

RSS = 326140.0831

SEE = 5721.7558

$\frac{SEE}{\bar{Y}}$ = 103.19 , $\frac{b_o}{\bar{Y}}$ = 1.54 .

For testing the significance of variables, the F-test is used with the critical value F 0.9 (1,57) = 2.80.

Hypothesis	$b_o = 0$	$b_1 = 0$	$b_2 = 0$	$b_3 = 0$	$b_4 = 0$
F	35.4616	29.1475	11.4950	7.1489	0.0108

Hypothesis	$b_5 = 0$	$b_6 = 0$	$b_7 = 0$	$b_8 = 0$
F	0.0579	3.9968	0.0343	0.0301

From the F-test it seems that X_4, X_5, X_7, X_8 are not significant. Also, from the bivariate correlation matrix, X_1 is highly correlated with X_2, X_3, and X_6; and it has a correlation coefficient with y which is less than that of X_2, X_3 and X_6 with y. So in the second run X_6, X_3, X_2 are the independent variables included in the model based on their bivariate correlation coefficient with y and their significance.

3.3 The Second Model

It takes the form :

$$y = 47.4125 + 5.9486\ X_6 - 43.7479\ X_3 + 10.1084\ X_2$$

with the same bivariate correlation coefficients and with

RMULT = 0.68693

RSS = 329137.8185

SEE = 5308.6745

$\frac{SEE}{\bar{Y}}$ = 95.75

$\frac{b_o}{\bar{Y}}$ = 0.85510

F 0.9 (1,62) = 2.79

Hypothesis	$b_o = 0$	$b_6 = 0$	$b_3 = 0$	$b_2 = 0$
F	38.2210	49.1246	2.9107	3.3613

It is noticed that these 3 independent variables are significant.

3.4. Forecasts of Auto-ownership at Cairo Zonal level :

It is clear from the statistical tests that the second model could be used to forecast car ownership at Cairo zonal level with the same accuracy as the first model. The advantage of the second model is that forecasts for only three socio-economic variables are required:

-- % of population who are highly educated (X_6)

-- No. of people per room (X_3)

-- Average percent of per capita income spent on transportation and communication per year (X_2).

The accuracy of the chosen model can be seen in the difference between the observed and estimated (Y) values as presented in Table III.6 for selected zones.

3.4.1 Projecting the Percentages of Highly Educated People

The number of highly educated people is increasing in Egypt as shown in Table III.7.

Table III.6

Application of the Zonal Model for Car-ownership

to Three Traffic Zones

Zones	Administrative District (Kism)	X_6	X_3	X_2	Y	Y	Diff.
21002	El-Khalifa	3.1	2.02	2.50	1.83	7.753	-0.923
21201	Abdin Kasr El-Nile	8.5	1.50	12.00	125.50	139.095	-13.595
20102	Bolak El-Sayeda-Zinab Abdin	4.2	1.9	3.09	23.95	20.510	3.440

Table III.7

Annual Rate of Increase of Percentage

of Highly Educated People

Year	Highly Educated*	Population	% Population who are highly educated	Annual rate of increase of X_6
71/72	26558	34565	0.077	
72/73	29598	35363	0.084	0.007
73/74	37574	36180	0.104	0.020
74/75	41916	37016	0.132	0.028
75/76	55430	37870	0.146	0.014
76/77	63853	38745	0.165	0.019

*Source: Annual Statistical Book CAMPAS 1978

The average rate of increase in X_6 is 0.018/year. Three estimates are considered for the traffic zones:

Est. (1) Annual rate of increase of $X_6 = R_6 = 0.018$ (the same as the whole of Egypt)

Est. (2) Expecting a high rate of increase of X_6 for Cairo, $R_6 = 5(0.018) = 0.09$

Est. (3) Which lies between the previous two estimates, i.e. $R_6 = 0.054$

Thus, in any year n of the analysis period:

$$[X_6]_n = [X_6]_0 + [R_6]\ (i) \qquad (1)$$

where $[X_6]_n$ = value of X_6 at the year (n)

$[X_6]_0$ = value of X_6 at the base year (1976)

(i) = (n) - (1976)

3.4.2 Projecting Number of People per Room

Noting both that the population is increasing at an annual rate of 2% and that there is a policy of encouraging construction of the new cities outside Cairo, the following three estimates for the annual rate of increase of X_3 (denoted by R_3) were used:

Est. (1) : $R_3 = 0.02$ (the increase in population)

Est. (2) : R_3 = zero (people per room will remain unchanged)

Est. (3) : 0.01 (medium estiamte).

Thus, in any year (n)

$$[X_3]_n = [X_3]_0\ [1 + R_3]^i \qquad (2)$$

3.4.3 Projecting Percent of per Capita Income Spent on Transportation

X_2 is increasing by a rate of about 0.05 per year, for the country as a whole. Thus, in Greater Cairo, rate R_2 may be estimated as:

Est. (1): $R_2 = 0.05$ (the same as the whole of Egypt).

Est. (2): $R_2 = 5(.50) = 0.25$ as the percent of the individual expenditure on transportation is expected to increase at a higher rate than the average (more trips, higher increase of auto-owning, increasing price of petrol,... etc.)

Est. (3): $R_2 = 0.15$ the average of the figure of Est. (1) and Est. (2)

Hence, in any year n:

$$[X_2]_n = [X_2]_0 + [R_2] \text{ (i)} \qquad (3)$$

3.4.4 Estimation of Auto Ownership

The preceeding estimates for the independent variables lead to three estimates of auto ownership for each traffic zone, namely low (Est. 1), high (Est. 2), and medium (Est. 3) for each projection year.

The results are shown in Table III.8 for the same three zones shown in Table III.7. The low (Est. 1) seems to be unreasonable, as it gives car ownership the decreasing with time and there are many negative values due to the negative regression coefficient of X_3. Est. (2) gives high estimates for future auto ownership, for which there is a remote likelihood. The most reasonable estimate appears to be Est. (3), which is the medium one, based on presently anticipated trends and future economic conditions.

Table III.8

Estimates for Auto Ownership in three Traffic Zones

Zone No.	Year	X_6			X_3			X_2			Y		
		Est.(1)	Est.(2)	Est.(3)	Est.(1)	Est.(2)	Est.(3)	Est.(1)	Est.(2)	Est.(3)	Est.(1)	Est.(2)	Est.(3)
21002	1985	3.26	3.91	3.59	2.4	2.02	2.2	2.95	4.75	3.85	- 8.2	30.7	11.8
	1990	3.35	4.36	3.86	2.7	2.02	2.3	3.20	6.0	4.6	-18.7	46.4	16.4
	2000	3.53	5.26	4.40	3.3	2.02	2.6	3.70	8.5	6.1	-38.6	76.7	21.5
21201	1985	8.66	9.31	8.99	1.8	1.5	1.6	12.45	14.25	13.35	145.9	180.8	165.9
	1990	8.75	9.76	9.26	2.0	1.5	1.7	12.7	15.5	14.1	139.4	196.4	171.4
	2000	8.93	10.65	9.80	2.4	1.5	1.9	13.2	18.0	15.6	128.5	226.8	180.7
20102	1985	4.36	5.01	4.69	2.3	1.9	2.1	3.54	5.34	4.44	8.3	48.2	28.3
	1990	4.45	5.46	4.96	2.5	1.9	2.2	3.79	6.59	5.19	2.9	63.9	32.9
	2000	4.63	6.36	5.50	3.1	1.9	2.4	4.29	9.09	6.69	-18.1	94.2	43.1

4. List of Project Papers and Reports in Part III:

Serial No.	Title	Author(s)	Date	Area Code	Library Code
1	Policy Frame for Private Auto-Ownership	R. Gakenheimer	1977	-	21/55
2	Summary of Framework of Auto-Ownerships study in Cairo	H. Shishido	1978	-	21/11
3	Car Ownership	N.S. Ghaly	1978	-	21/12
4	Linear Programming Model of Estimating Auto-Ownership	H. Shishido	Apr. 1979	-	21/82
5	Some Prespectives on Auto-ownership.	H. Shishido	Apr. 1979	-	21/81
6	Car - Ownership	N.S. Ghaly	Apr. 1979	-	21/77
7	Linear Programming Model for Estimating the Number of Passenger Autos for the Auto-Ownership Study	H. Shishido	June 1979	-	21/103
8	Data obtained for Auto-Ownership Study (Linear Programming)	H. Shishido	June 1979	-	21/121
9	Data obtained for Auto-Ownership Study	N.S. Ghaly	July 1979	-	21/126
10	The Basic Salary of foreman in Nasr Car Company	N.S. Ghaly	July 1979	-	21/135
11	Auto-Ownership Study	N.S. Ghaly	July 1979	-	21/138

Serial No.	Title	Author(s)	Date	Area Code	Library Code
12	Private Car-Ownership in Egypt	N.S. Ghaly	Aug. 1979	-	21/139
13	Proposal for Future Study on Auto-Ownership (Macro-aspect Side)	H. Shishido	Aug. 1979	-	21/169
14	Auto-Ownership Study from Supply Side	H. Shishido	Aug. 1979	-	21/170
15	Consideration on the Egyptian Automative Market	A.H.El-Salmawy	Dec. 1979	-	21/183
16	Auto-Ownership Study from Supply Side - A Revision -	H. Shishido	Dec. 1979	-	21/189
17	Auto-Ownership Study from Demand Side	H. Shishido	Dec. 1979	-	21/230
18	Consideration on the Egyptian automotive market	A. Hardman	1979	-	21/99
19	Data obtained for Auto-Ownership Study	N.S. Ghaly	1979	-	21/352
20	Private Car Ownership in Egypt and for the zones of Greater Cairo	N.S. Ghaly	1980	-	21/302
21	Appendix A : Table of socio-economic Data Used for Building up the Auto-Ownership Models	N.S. Ghaly	1981	-	21/363

5. List of References

(1) A. Gazarin " Considerations on the Egyptian Automotive Market"

(2) Netherlands Engineering Consultants and Ministry of Transportation " Passenger Car Ownership " Report 1980.

(3) Nashaat S.Ghaly " Private Car Ownership in Egypt and for the zones of Greater Cairo". M. Sc. Thesis Cairo University, June 1981.

(4) Cairo University, Ministry of Transport and Ministry of Interior Affairs (traffic sector) "Cairo Urban Transportation Project-Traffic Survey " November 1977.

(5) Bulletin of Statistics UN Estimation

CHAPTER IV
THE PARKING STUDY

1. Introduction

The parking problem in the Cairo central business district (CBD) area creates a serious traffic problem that greatly reduces the performance of the street network in the heavily used downtown area. During most of the daytime hours, one-half hour or more of searching is required to find an available legal parking space, sometimes with no success. This results in added congestion to the already crowded streets, attendant increases in delay and accidents, and reduced system capacity.

The severity of the problem has become more pronounced as the population and number of cars have markedly increased (3% and 17% per annum, respectively) without a corresponding increase in either the capacity of parking facilities or the level and frequency of public transport service. Furthermore, a considerable increase has occurred during the last few years in most working, shopping, and recreational activities in the CBD area. This implies additional increases in the number of vehicular trips in the already overcrowded CBD street network.

Illegal parking in the downtown Cairo area is currently widespread. Naturally, this is a direct result of the large deficiency in both on and off-street parking facilities, low monetary penalties imposed on violating parking laws, and low enforcement policies.

The existing conditions and the expected future increase in parking demand require a sound parking management scheme that views the parking facilities in the Cairo CBD as an integral part of the total urban transportation system.

1.1 Study Objectives and Limitations

This study seeks to develop a model that differs from conventional parking models by considering the interaction between parking supply (by type and location), parking demand, and vehicular traffic assigned to the urban street network. The study also uses the developed model to investigate and evaluate the effect of different parking policy options (e.g., increase of tariffs, elimination of some on-street free parking, construction of multi-level garages) on the traffic pattern along the Cairo CBD street network.

The model uses the O/D traffic volume matrices developed in the CU/MIT Urban Transportation Project (see Part I, section 1.1) as input data. Changes in these O/D traffic volumes, due to implementation of a particular parking policy option, were considered beyond the scope of this study.

2. Network Description

The street network was defined in terms of nodes and links with a link being a one-way connection between two intersections (nodes). A two-way street, for example, was described as two links, one for each direction.

The network under consideration was categorized according to area type. Five area types were identified for this purpose:

1. CBD
2. Fringe
3. Residential
4. Outer CBD (small CBD on periphery of large metropolitan area)
5. Rural.

The links of the network were classified into two main groups; real links and imaginary links.

2.1 Real Links

These links represented the existing street network of the study area and were categorized according to the facility type. Five facilities were defined for this purpose, namely:

1. One-way arterial with no parking
2. One-way arterial with parking both sides
3. One-way arterial with one-side parking
4. Two-way arterial with parking both sides, and
5. Two-way arterial with no parking

2.2 Imaginary Links

These links represented all parking-related facilities as well as centroid connectors. To simulate actual field conditions, the imaginary links were subdivided into the following categories:

2.2.1 Centroid Connectors

These imaginary links connected some selected nodes of the real network to the centroids of traffic zones in which the parking study was conducted.

2.2.2 Searching Time Links

These links represented the distance traveled by a car entering or leaving a parking place. When entering a zone, the driver spends a certain time looking for a place to park. This time is a function of the parked volume and the capacity of the parking facility. When a car leaves a parking facility, the minimum time spent on this link is set to a predetermined value. Searching time links are connected to the real network through some selected nodes at one end and to a parking link at the other end. The choice of these nodes depends solely upon the user's field experience of the network under study.

2.2.3 Parking Links

Parking links are places where vehicles are parked and were divided into four categories according to type and location, as follows:

1. On-street free parking
2. On-street metered parking
3. On-street illegal parking
4. Off-street parking lot or garage.

Each of the above four parking types was classified according to a direction. The volume attracted to the respective parking facility was defined as positive and the volume emitted as negative. The centroid of an illegal parking facility was assumed to coincide with the centroid of the on-street free parking facility and its capacity was assumed to be approximately equal to the capacity of that on-street parking facility.

Parking links are connected to the respective searching time links at one end and to a pedestrian link at the other end.

2.2.4 Pedestrian Link

These are used by the motorists afterparking their vehicles to reach their final destinations (zone centroids). Two types of pedestrian links

were defined in the network structure. The first type of pedestrian link connected the zone centroid to a parking link within the same zone. The second type connected the zone centroid to a parking link in a zone adjacent to the one considered. This structure has the advantage of simulating the actual field conditions. Some trip-makers actually park their vehicles in a zone near their destination due to either deficiency of supply or high parking cost in the zone to which they are heading. They then walk to their final destinations.

2.2.5 Parking Counter

The imaginary parking counter, one in each zone where a parking policy is considered, was used together with illegal parking to indicate the deficiency in parking supply. This imaginary parking counter was not loaded until all the parking supply in all the study zones was completely exhausted. Including such a facility in the network description provided a means of using the model to simulate the case where the actual parking demand exceeded the available supply.

According to this network structure, all vehicles generated from a zone where the parking policy was studied should leave the zone centroid through a pedestrian link, followed by a parking link, and finally by a searching time link that led to the actual network. Similarly, all vehicles attracted to a zone where parking policy was employed would enter the zone from a reasonable node of the actual network through a seraching time link, followed by a parking link, and finally by a pedestrian link. In all other zones, the zone centroid was connected to the real links through the centroid connectors. These different conditions can be seen in Figure IV.1.

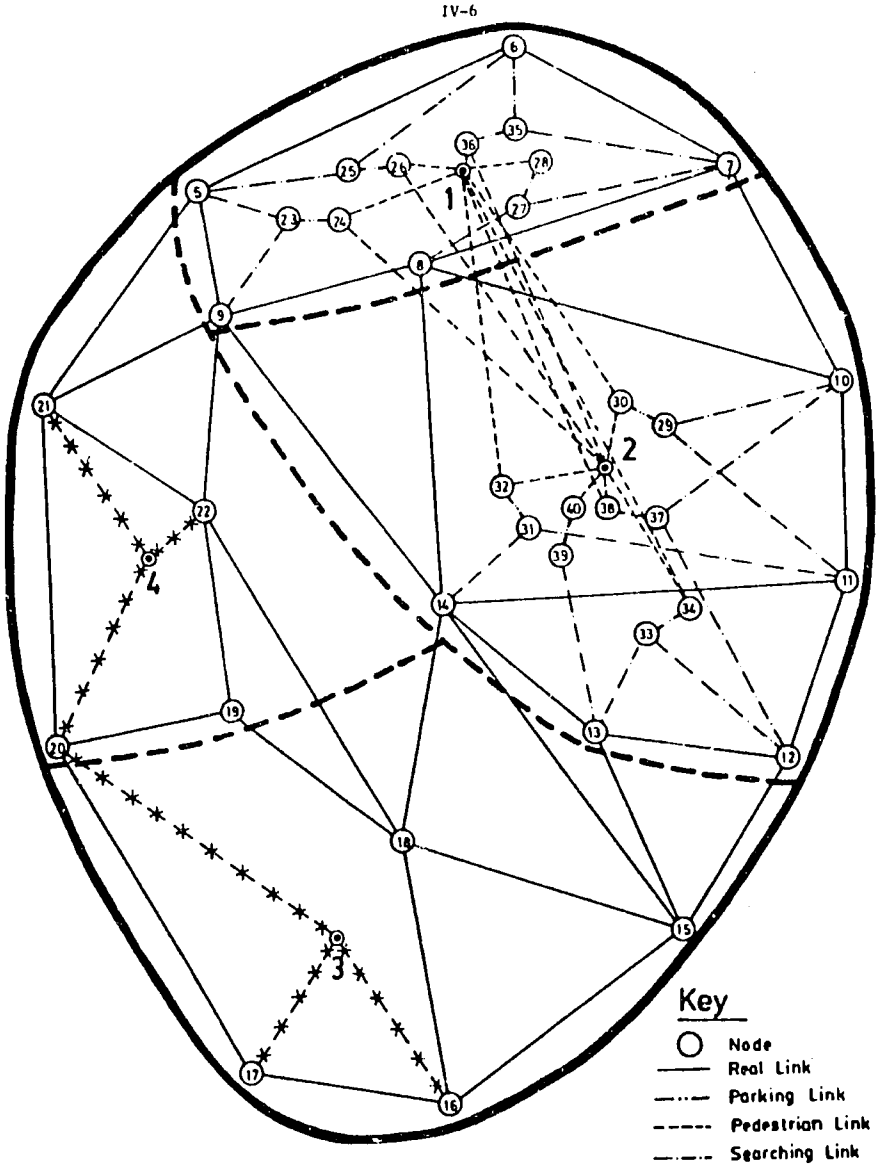

Fig. IV-1 A : Network Description

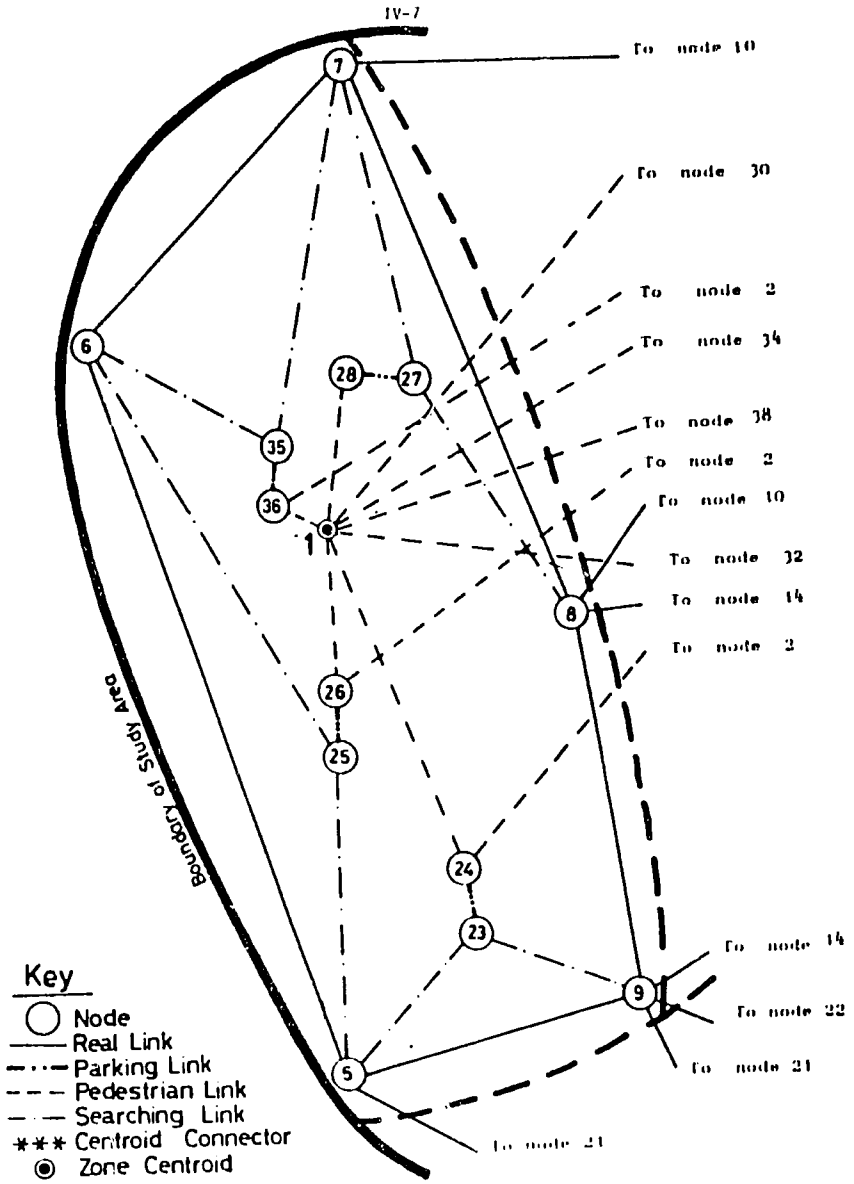

Fig.IV-1.B: Detailed Network Description for Zone 1

3. Model Description

In order to satisfy the study objectives, the model was structured to include the following components:

3.1 Generalized Cost Function

This function was used to calculate the impedance to travel between any pair of zones. The cost of travel on each link was calculated by multiplying the time consumed on this link by a reasonable monetary value (λ), depending upon the area type/facility type combination of the respective link. The following two cost functions were used for real and imaginary links, respectively:

3.1.1 Cost Function for Real Links

The model used the capacity-restrained formula developed by the U.S. Department of Transportation (1) and included in the Urban Transportation Planning System (U.T.P.S.) model. This formula was stated as follows:

$$T = T_o \left[1 + \alpha (Q_l / C_l)^{\beta}\right]$$

where:

T = Travel time in minutes for a given traffic volume

T_o = Travel time in minutes corresponding to the free flow conditions

α and β = Calibration parameters

Q_l = Traffic volume on the link under consideration, P.C.E./hr

C_l = Capacity of the link under consideration, P.C.E./hr

The parameters α and β were calculated for the Egyptian conditions (see section 1.5 of Part I of this report).

3.1.2 Cost Functions for Imaginary Links

A. Searching Time Links

Delays on searching time links were expressed as follows:

$$T = \frac{A_o}{1-Q_2/C_2} + T_1$$

where:

A_o = minimum time spent by a motorist looking for an on-street parking space under free flow conditions or in an empty car park, in minutes.

Q_2 = number of parked cars in a certain area type/facility type combination

C_2 = number of parking spaces available within an area type/facility type combination

T_1 = length of the searching time link divided by the free flow speed (Vo), in minutes.

The parameter T_1 in the above relationship was used to prevent the vehicular traffic from using the searching time link as a part of the real network. The application of the above relationship in a case where the parked volume is zero gives a searching time value equal to the constant $(A_o + T_1)$. However, as the parked volume approaches the capacity of the parking facility in connection with the searching time link, delays on the latter approach infinity.

B. Parking Links

The parking cost associated with the parking links is simply the out-of-pocket cost to park a vehicle in a certain area type/facility type combination. It should be noted that the model recognized a linear relationship between parking duration and parking cost, unless the parking link was classified as on-street-free-of-charge.

In order to prevent assigning vehicles to an at-capacity parking link, its mpedance was increased by an extremely high value (1000 monetary units). Therefore, during the next assignment step, such links would have no chance of being selected in the route choice stage.

C. Pedestrian Links

The time spent on a pedestrian link was calculated assuming a walking speed that varied according to the area type in which the pedestrian link was located.

The total cost will, therefore, be the summation of all costs between two zone centroids.

3.2 Route Choice

Having calculated the impedance to travel along each link, the model searches for the minimum route between every pair of zones. This was achieved using standard algorithms (see Part II of this report). However, a minor alteration was introduced to suit the nature of the problem under consideration. This alteration consisted of loading the reasonable links with an initial load that was equal to the volume of all vehicles other than private cars during the time period considered. As for parking links, they were initially loaded with the volume parked prior to the beginning of the simulation time.

3.3 Traffic Assignment

Once the network was loaded with other-than-private vehicles (the initial loading), the origin/destination matrix of private cars was assigned to the shortest route between every O/D pair. This was achieved by assigning increments of the O/D matrix under consideration and recalculating the minimum route between zones after each increment. The

minimum route is very likely to change after each loading step, as it is a function of the volume/capacity ratio on each link. Increments should be as small as possible in order to reduce the possibility that the volume assigned to a particular parking facility is greater than its capacity.

To implement the model where acute illegal parking problems exist, a "capacity-correction" formula was included. This correction depended on the on-street illegal volume/legal capacity ratio. When this ratio exceeded a predetermined value, the capacity of the link under consideration was multiplied by a corresponding reduction factor.

Conventional assignment runs are usually done for a specific peak hour using the corresponding hourly matrix. However, the highest demand for parking generally occurs an hour or two after the morning peak hour. The model is, therefore, preferable run for a period long enough to reflect the interaction between parking supply and volume of traffic during the different hours. A facility was included in the model to update the initial loading and parking volume at the end of each hour before assigning the private car matrix of the following hour.

3.4 Model Structure

3.4.1 Input Data

The input data to the model were as follows:

1. The road network described in a node and link system.

2. Description of the link characteristics for use in the capacity-restrained formula, which included the area type/facility type and number of lanes in each link.

3. The capacity-restrained calibrationparameters (α,β) of the normal link delay/volume relationship. These parameters varied according to the area type/facility type combination of each link.

4. The practical capacity per lane used in the dealy/volume relationship. This capacity varied according to the area type/facility type combinations

5. The free-flow travel time of each real and pedestrian link (T_o).

6. Monetary value of time (λ) which varied according to the area type/ facility type combination.

7. Free-flow travel time (A_o) on the searching-time links. This time was defined as the time required by a motorist to park his car under free-flow conditions assuming no accumulation of parked cars.

8. Original parking volume (i.e., cars parked before the first study hour) at the zones considered for the parking study.

9. Origin-destination traffic volume matrices from the first to the last study hours.

10. The initial load of other-than-private cars on every link for every study hour (e.g., public transport vehicles, taxis, trucks, etc.).

11. Parking cost, if any, for every study hour.

3.4.2 Output of the Model

The model is capable of giving the following output after each assignment step:

1. Data for each link as input to the model.

2. The impedance of each link.

3. The minimum route between origin and destination zones.

4. The minimum impedance matrix between origin and destination zones.

5. The assigned volume on each link.

6. Zoanl parking volume to capacity ratios.

7. Saturated links by zone.

8. Number of vehicles parked in zones other than their final destination zones.

9. A warning sign to indicate if the total parking demand is greater than the parking supply at any zone.

10. Parking deficiency (needed additional parking spaces).

4. Program Description

The program was divided into three segments as shown in Figure IV.2 which is a simplified flow chart for the program. The detailed flow diagram is included in reference (1).

4.1 The Master Segment

1. Reads the different parameters required for computation.
2. Prints out the input data for visual inspection.
3. Calculates the incremental volume for each O/D pair to be assigned at each step.
4. Calculates the impedance of each link using its appropriate formula at the end of each iterative step.
5. Calls subroutine "Minimum Route."
6. Prints out the minimum impedance matrix, as well as the total volume of traffic on each link at the end of each hour. It also outlines all links at or exceeding capacity.
7. Prints out the following statistics:
   - Volume/capacity ratio for each parking zone
   - Number of saturated links in each zone
   - Number of vehicles parked in zones other than their final destination.

All the above steps were repeated for each iteration and each hour.

4.2 Subroutine "Minimum Route"

1. Calculates the minimum route between each O/D pair for each increment.
2. Calls subroutine "Assign."

4.3 Subroutine "Assign"

Assigns every increment of traffic load on every link of the minimum route identified by the previous segment.

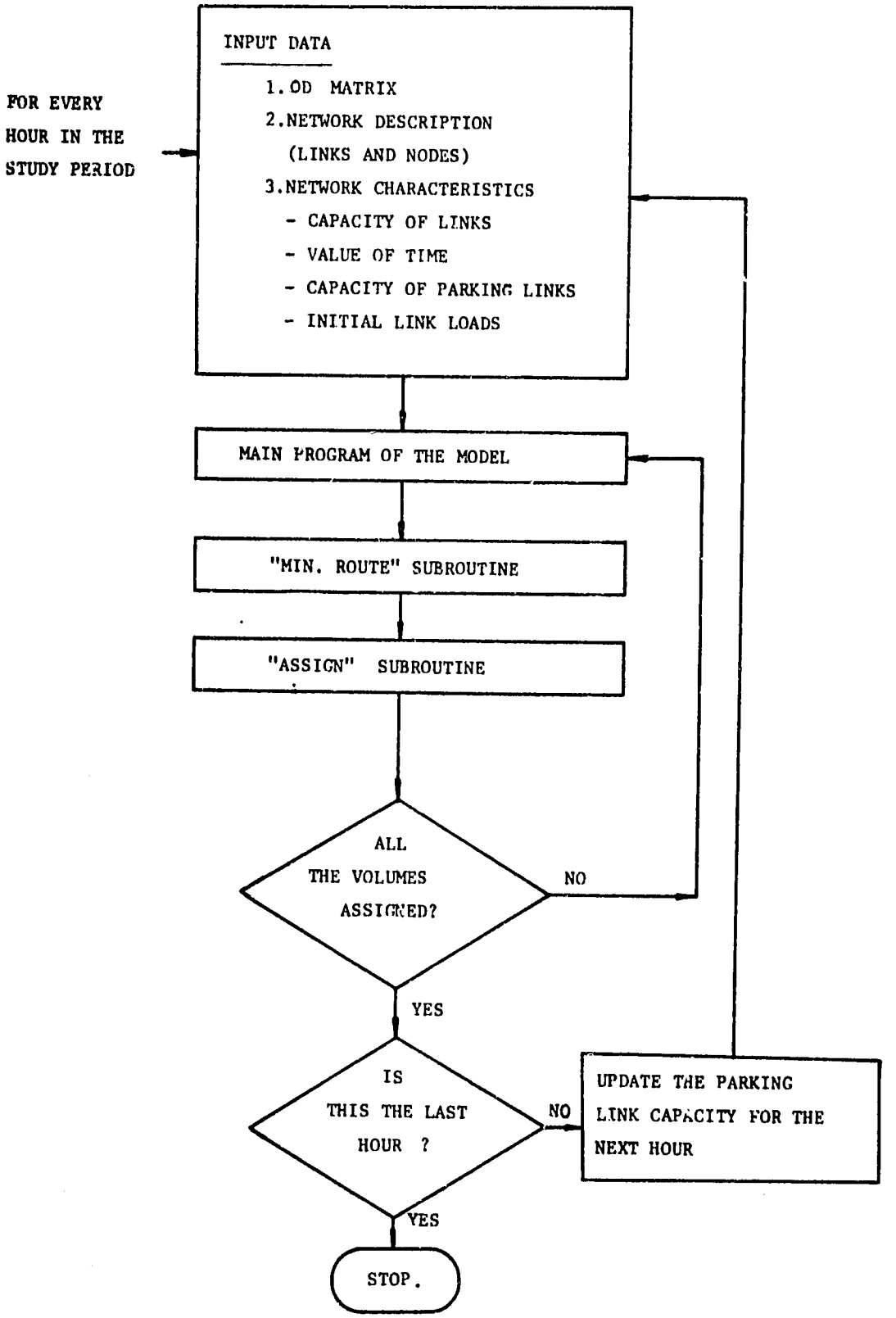

Fig. IV-2: Simplified Flow Chart of the Program

4.4 Options for Use of the Computer Package

The computer package can be used with the following options:

1. Assignment of one origin-destination matrix, using the all-or-nothing without capacity-restrained technique. Minimum route trees are built in this case according to the chosen link impedance.

2. Assignment of one or more origin-destination matrices, by the all-ro-nothing with capacity-restrained technique, in a time stepwise form. Minimum route trees are built in this case according to the chosen link cost as variable with travel time.

3. Assignment of one or more origin-destination matrices, by the all-or-nothing with capacity-restrained technique and parking capacity restrained, time stepwise form. Minimum route trees are built similar to No. 2 above.

4.5 Specific Points Considered in Developing the Assignment Technique

The following are some of the key points considered in the computer package for implementation of the options described above.

1. Centroid connectors to real nodes were given an imaginary cost of 1000 units to prevent any transfer within the imaginary links. The computer program subtracted these exaggerated costs from the minimum routes to avoid the inclusion of artificial costs.

2. Numeration of the network nodes, including the zone centroids, had to be in a serial form. Zone centroids were numbered successively beginning with 1.

3. The assignment started at 7:00 a.m. and the volume at each parking facility was updated at the beginning of each hour, i.e. volume

at a particular hour = volume at previous hours + volume assigned at the previous hour - volume leaving at the previous hour . Also, number of spaces available was updated on an hourly basis.

4. At any particular hour, volume leaving a zone should not come from an empty parking facility. This feature was provided by raising its impedance at the route choice stage.

5. Parking facilities were given a priority criterion. For instance, on-street free parking was filled first, then on-street metered parking and so forth.

6. Travel time on an inlet link was calculated as the searching time from the capacity-restrained formula: $T = \frac{A_o}{1 - Q_2/C_2} + T_1$; on the other hand, travel time at an outlet was considered as the minimum parking time $A_o + T_1$.

7. Differentiation was made between zones containing parking facilities to be analyzed (such as CBD zones), and zones with parking facilities but not analyzed.

8. All parking links were connected to the same reasonable nodes on the real network through more than one searching time link.

9. The links were classified according to zone number.

10. The capacity values of the real links were corrected for the presence of illegal parking. If the illegal parking volume in any zone was greater than or equal to 40% of the legal parking volume, one lane from each real link in the same zone was eliminated.

11. The imaginary parking counter was given an assumed high capacity of 5000 vehicles.

12. The imaginary parking counter was given a moderately high impedance (500 monetary units) to serve a dual purpose. Firstly, to

prevent assigning vehicles to the parking counter links before exhausting the total parking supply in all zones, as this artificial impedance value is higher than that of the other parking links. Secondly, the impedance of the parking counter, being less than that of at-capacity parking links, will ensure assigning vehicles to the former when the total supply of all zones is consumed.

13. The maximum number of links connected to any node was four. For nodes that had more than four links, one dummy node (or more if needed) was created.

5. Collection of Input Data

Various input data were required before exercising the model. The main advantage of this model was its capacity to use the origin-destination traffic volume data, previously described in Part I of this report. This model used the calibration parameters of the capacity-restraint formula (α and β), practical capacities of the links, and free-flow speeds corresponding to different area type/facility type combinations, also described in Part I. Reasonable assumptions based on available data were made for the monetary values of different types of travel time on different link types.

5.1 Zoning

Zone boundaries for the study area were those determined in section 1.1 of Part 1, with eleven zones included in the parking study, based on the considerations discussed in the parking surveys (section 1.3 of Part I).

5.2 Origin/Destination Traffic Flows

Two methods for determining the hourly origin/destination traffic volumes (for each hour of the morning period 7:00 to 11:00 and for the whole morning period using the hour fluctuation factors) were proposed in Part I of this report. Table IV-1 gives the vehicular trips up to 11:00 a.m. obtained from the two methods. The two methods are consistent with almost no variation in the accumulated vehicular traffic by the end of the morning period (11:00 a.m.). As the parking volume and capacity of each link were updated by the end or each hour in the described model, the accumulated traffic determined in method 1 was assumed more appropriate for this study.

Table IV.1

Comparison Between Method 1 and Method 2 for Hourly Zonal Traffic Flows

Study Hour / Zone Name	Method 1					Method 2					Acc. Method 1 / Acc. Method 2
	7 - 8*	8 - 9*	9 - 10*	10 - 11*	Acc.**	7 - 8*	8 - 9*	9 - 10*	10 - 11*	Acc.**	
Garden City	+ 915	+ 65	+ 448	+ 206	+ 1634	+ 343	+ 494	+ 444	+ 429	+ 1710	104.7
Area of Ministries	+ 312	+ 612	+ 334	+ 181	+ 1439	+ 288	+ 418	+ 379	+ 361	+ 1446	100.5
El-Tahrir	+ 945	+ 1371	+ 881	+ 610	+ 3807	+ 774	+ 651	+ 1006	+ 971	+ 3401	89.3
Talaat Harb	+ 627	+ 1150	+ 485	+ 162	+ 2469	+ 517	+ 751	+ 675	+ 651	+ 2594	105.6
Attaba	+ 241	+ 1052	+ 986	+ 583	+ 2862	+ 580	+ 840	+ 754	+ 726	+ 2900	101.3
Abdin	+ 31	+ 19	+ 124	+ 1145	+ 1319	+ 248	+ 357	+ 322	+ 309	+ 1236	93.7
Klot Beik	- 19	- 252	+ 105	- 40	- 205	- 36	- 53	- 49	- 47	- 185	90.2
Tawfikia	+ 387	+ 875	+ 301	+ 1613	+ 3176	+ 612	+ 882	+ 789	+ 759	+ 3042	95.8
Ramsis	+ 871	+ 807	+ 982	+ 1187	+ 3847	+ 782	+ 1132	+ 1015	+ 978	+ 3907	88.9
Azhar	+ 140	+ 414	+ 396	+ 642	+ 1592	+ 311	+ 452	+ 404	+ 386	+ 1553	97.6
Bab El Sheria	- 107	- 1860	- 6	+ 295	- 2268	- 453	- 677	- 584	- 562	- 2276	100.4
Total	+ 4388	+ 4253	+ 5039	+ 5992	+ 19672	+ 3966	+ 4491	+ 5155	+ 4961	19328	98.3

* The difference between emmission and attraction per hour for each of the parking zones in the study area

** The summation of the previous differences for each zone.

5.3 Selection of the Study Hours

Study hours were chosen based on the maximum accumulation of parked vehicles in the study area, as determined from the origin/destination traffic flow matrices. Table IV.2 shows this accumulation in each zone for the critical 10 hours of the day. It is clear that the maximum accumulation of parked vehicles occurs between 7:00 a.m. and 11:00 a.m. so this period was selected for the study.

5.4 Link Data

The physical conditions of each link in the study area were obtained from the 1977 street inventory updated in 1981; see section 1.4 of Part I.

5.5 Initial Load on the Network

The traffic counts performed in 1977 as a part of the CU/MIT Urban Transportation Project and presented in section 1.1 of Part I were based on 267 stations chosen on 260 links of the study area. This number of links represents 14% of the total links in the study area. Thus, it was assumed that the ratio between public transport and commercial vehicles to the total traffic volume on links without counting stations is equal to that on links with counting stations having the same area type/facility type combination. To calculate the volume of public transport and commercial vehicles on real links, the following steps were followed:

1. From the traffic count survey and for each individual station, the initial load of public transport and commercial vehicles was determined.

2. For each link, the practical capacity was determined.

3. The initial load of public transport and commercial vehicles on each link with a counting station calculated in step (1) was divided by its capacity.

Table IV.2

Accumulated Volume of Private Cars at Each Zone

Period / Zone Name	1 * (7:00 a.m. to 11:00 a.m)	2(From 13:00 p.m. to 16:00 p.m.) ***				3(From 18:00 p.m. to 21:00 p.m.) ***			
		13 - 14	14 - 15	15 - 16	Accumulated **	18 - 19	19 - 20	20 - 21	Accumulated
Garden City	+ 1634	+ 275	+ 275	+ 225	+ 775	+ 225	+ 200	+ 175	+ 600
Area of Ministries	+ 1439	- 28	- 28	- 23	- 79	- 23	- 20	- 18	- 61
El-Tahrir	+ 3807	+ 456	+ 456	+ 373	+ 1285	+ 373	+ 331	+ 290	+ 994
Talaat Harb	+ 2469	- 315	- 315	- 258	- 888	- 258	- 229	- 201	- 688
Attaba	+ 2862	+ 633	+ 633	+ 518	+ 1784	+ 518	+ 460	+ 403	+ 1381
Abdin	+ 1319	+ 182	+ 182	+ 149	+ 513	+ 149	+ 132	+ 116	+ 397
Klot Beik	- 205	- 86	- 86	- 70	- 242	- 70	- 63	- 55	- 188
Tawfikia	+ 3176	+ 345	+ 345	+ 282	+ 972	+ 282	+ 251	+ 219	+ 752
Ramsis	+ 3847	+ 863	+ 863	+ 706	+ 2432	+ 706	+ 627	+ 549	+ 1882
Azhar	+ 1592	+ 126	+ 126	+ 113	+ 365	+ 113	+ 91	+ 80	+ 284
Bab El Sheria	- 2268	- 451	- 451	- 369	- 1271	- 369	- 328	- 287	- 984
Total	+ 19672	+ 2000	+ 2000	+ 1646	+ 5646	+ 1645	+ 1452	+ 1271	+ 4369

* Determined from the hourly matrices of vehicular trips (see table IV.1)

** The summation of the differences between emmission and attraction for each of the parking study zones.

*** Determined from the all-day matrix of vehicular trips and fluctuation factors (section (2) of chapter I).

4. The ratios determined in step (3) were classified according to their area type/facility type combinations. Then, the average of the ratios for the different area type/facility type combinations were calculated as given in Table IV-3.

5. Values obtained in step (2) were multiplied by the corresponding value calculated in step (4) to get the public transport and commercial vehicles loads on links with no counting stations.

5.6 Speed/Volume Characteristics

Values of the calibration parameters (α and β) of the capacity-restrainted formula are shown in section 1.5 of Part I of this report.

5.7 Trip Cost

The trip cost is one of the most important parameters which affect the output of the model. The components of the trip cost considered in this study were:

1. Private car operating costs.
2. Value of time for work and non-work trips.
3. Parking charge.

5.7.1 Operating Cost for Private Cars

Vehicle operating costs can be divided into two groups:

1. Variable (fuel, lubricants, tires, and maintenance)

2. Fixed (capital costs, insurance, taxes, etc.)

The basic assumptions made in this study were:

1. Interest rate (r) = 8%

2. Price of fuel = 130 millims/litre

3. Average price of private car = 4250 L.E.

4. Capital cost $= \dfrac{\text{Average price of vehicle} \times 0.95 \times \text{CRF}}{\text{Annual mileage}}$

where CRF is the Capital Recovery Factor.

Table IV-3

Average Initial Load/Capacity Ratios (%)

1st. Hour : 7.00 - 8.00 a.m.

Facility Type / Area Type	Two-Way No. Parking	Two-Way Park. both sides	One-Way No Parking	One-Way Park. one side	One-Way Park.both sides
CBD	22.296	18.158	21.695	7.993	10.388
Fringe	27.556	21.677	18.948	10.567	
Residential	23.494	24.549	11.909	10.084	
Outer CBD	33.590	16.869	6.485	8.857	
Rural	23.210	28.702	6.785		

2nd Hour : 8.00 - 9.00 a.m.

Facility Type / Area Type	Two-Way No Parking	Two-Way Park. both sides	One-Way No. parking	One-Way Park. one side	One-Way Park. both sides
CBD	20.824	16.435	18.195	8.975	9.017
Fringe	25.780	22.762	19.025	14.600	
Residential	24.203	24.759	9.727	15.532	
Outer CBD	22.564	15.051	9.515	9.643	
Rural	25.972	27.619	2.785		

Table IV-3

Average Initial Load/Capacity Ratios (Cont.)

3rd. Hour : 9.00 - 10.00 a.m.

Facility Type / Area Type	Two-Way No. Parking	Two-Way Park. both sides	One-Way No Parking	One-Way Park. one side	One-Way Park.both sides
CBD	23.838	18.448	20.857	10.217	9.721
Fringe	25.073	26.423	18.365	16.500	
Residential	23.494	25.983	9.939	15.869	
Outer CBD	22.667	19.798	9.939	15.966	
Rural	32.410	29.905	8.560		

4th Hour : 10.00 - 11.00 a.m.

Facility Type / Area Type	Two-Way No Parking	Two-Way Park. both sides	One-Way No. parking	One-Way Park. one side	One-Way Park. both sides
CBD	26.800	19.730	21.729	9.957	12.950
Fringe	27.678	25.929	19.274	15.533	
Residential	24.959	25.890	10.697	13.691	
Outer CBD	22.615	22.828	10.303	15.286	
Rural	30.872	32.833	8.537		

Table IV-4 illustrates the effect of speed on fuel consumption, annual mileage, lifetime, and lifetime mileage (2).

Table IV-5 shows the vehicle operating costs adopted in the National Transport Study by NEDECO as related to speed (2).

5.7.2 Value of Time

The values of time for home-based work trips and home-based other purpose trips were determined based on average wage rates in Egypt. For home-based work trips, the method followed to calculate the monetary value of time was reasonably straightforward. In contrast, a number of assumptions had to be made to calculate the monetary value of non-work trips.

From the data of CAPMAS, the national 1976 income was 246 LE/annum. However, when excluding agricultural workers, this increased to 355 LE/annum.

The following procedure was adopted to derive a 1981 average Greater Cairo income based on the 1976 average value for Egypt:

1. To recognize the trend of average income and inflation over the last four years, the figure was increased by 10% per annum giving 456 LE/year for 1981.

2. For those people employed in Cairo, an annual increase of 15% in the average income was assumed to be reasonable. This gave an average annual income for Cairo of 628 L.E.

To derive the value of time in this case, it is necessary to estimate the number of working hours per annum. This was estimated as 1602 hours (267 working days per year x 6 hours per day).

Table IV-4

Fuel Consumption, Annual Mileage, and Lifetime Mileage (2)

Speed (km/hr)	20	40	60	80	100
Fuel Consumption Lit/1000km	130	113.5	103	100	111.5
Annual mileage km (000)	12	18	22	25	28
Lifetime (year)	15	11.5	10.5	10	9.5
Lifetime mileage (000)	180	207	231	250	266

Table 5

Vehicle Operating cost L.E./1000 km.

Item \ Speed km/hr	20	40	60	80	100
Fuel	16.9	14.8	13.4	13.0	14.5
Engine Oil	3.4	2.8	2.8	2.8	2.8
Tires	0.9	1.8	3.1	4.2	4.8
Maintenance					
- Parts	4.9	4.1	4.1	4.3	4.7
- Labor	1.4	1.2	1.2	1.3	1.4
Total Variable Costs	24.1	21.7	21.9	23.0	25.3
Capital Costs	38.0	29.5	25.6	23.6	21.5
Other Fixed Costs	12.1	8.1	6.6	5.8	5.2
Total Fixed Costs	50.1	37.6	32.2	29.1	26.7
Total Operating Cost	77.6	62.3	56.8	54.7	54.9

The above values are transformed to monetary values of time utilizing the different speed classes as shown in Table (IV-6).

Table IV-6

Speed and Operating Costs

Speed(km/hr)	5	10	15	20	30	40	50	60	80	100
Operating Cost(Mill/Min)	13.85	17.80	21.75	25.87	33.70	41.53	49.17	56.80	72.93	91.50

To calculate the value of working time, the wage rate was increased by approximately 10% to allow for social security and other payments. Thus, the computed average income of 628 L.E. resulted in the following value of working time:

$$\text{Value of working time} = \frac{628 \times 1.1 \times 100}{1602} = 43.12 \text{ piaster/hour}$$

$$= 7.19 \text{ millime/min.}$$

Value of Time for Home-based Other Trips

Travel to and from work, and time spent in shopping, visiting friends, and general leisure is normally classified as non-working time. Clearly, the value to the individual of such time varies according to purpose, the travel time component (i.e., walking, waiting, or in-vehicle time), comfort, and convenience. Empirical evidence has shown that a reasonable approximation to the value of time for home-based other trips in the case of travel in Egypt is 40% - 50% of the value of working time.

Thus, the value of time for home-based other trips is calculated as:

$$\text{Unit Value} = \frac{628 \times 0.45 \times 100}{1602} = 17.64 \text{ piaster/hr}$$

$$= 2.94 \text{ millims/min.}$$

Average Value of Time for Home-based Work Trips and Home-based Other Purpose Trips

The following steps were followed to estimate the average value of time for home-based work and other purpose trips:

1. Vehicle occupancy rate was determined for private cars, as shown in Part I of this report.

2. The ratio of the work and other-purpose volume of trips to the total traffic volume was assumed as calculated for the base year (1977) and for different area types.

3. The weighted average values of time for all trips in the different area types were determined, as shown in Table IV-7.

The monetary values of time for real links were calculated as the sum of the operating cost of vehicle per unit time, according to the speed class (see Table IV-6), and the value of time for home-based work and other purpose trips (Table IV-7). For imaginary links, the value of time was calculated according to the respective area type/facility type combination. Values of time on pedestrian links were considered equal to that of the home-based work and other purpose trips. A reasonable assumption was made for the value of time on parking links.

Based on the above, monetary values calculated for trip times along imaginary links are shown in Table IV-8.

5.8 Parking Supply, Illegal Volume, and Overnight Volume

Data related to parking supply available in the study area zones together with illegal and overnight parking volumes are shown with the necessary details in section 1.3 of Part I of this report.

Table IV-7

Value of Time for Home-based Work and Other Purpose Trips

Area Type	Trip Purpose	Percentage of Total	Occupancy Rate	Average Value of Time millims/min.
C.B.D	Home-work Home-other	72.10 27.90	2.12	12.69
Fring	Home-work Home-other	74.60 25.40	2.12	12.93
Resid-ential	Home-work Home-other	70.66 29.34	2.12	12.57
Outer C.B.D.	Home-work Home-other	63.64 36.36	2.12	11.94
Rural	Home-work Home-other	74.17 25.83	2.12	12.88

Table IV-8

Monetary Value of Time for Imaginary Links

Facility Type / Area Type	Centroid Connector	On - Street			Off-Street	Searching Time	Pedestrian	Counter
		Free	Metered	Illegal				
1 CBD	34.64	0.83	1.00	1.67	1.67	34.64	12.69	3.33
2 Fringe	38.80	0.67	0.83	1.38	1.33	38.80	12.93	2.75
3 Residential	39.44	0.50	0.67	1.11	1.17	39.44	12.57	2.22
4 Outer CBD	37.81	0.67	0.83	1.38	1.33	37.81	11.94	2.75
5 Rural	38.75	0.33	0.50	0.83	1.00	38.75	12.88	1.67

6. Model Application

The proposed model was tested first on the Greater Cairo street network to assign the 1981 vehicular traffic and parking volumes on the respective links. Data collected were updated to 1981 using the appropriate enlargement factors (see section 5 of this Part and section 1.1, Part I).

The model was then used to test several transport and parking policy options for the future. Different scenarios were formulated for this purpose and each was tested separately to evaluate its effect on traffic patterns and parking volumes in the street network of the Cairo CBD area.

6.1 Existing Conditions

6.1.1 Updating the Collected Data

As the model was applied in June 1981, it was necessary to update some of the collected data to reflect the changes that had taken place since the date of the survey(s). The parking supply was increased by the 1,200 spaces that were provided in 1980 after the construction of the 6th October bridge. Seven hundred spaces were provided along El-Galaa Street and the other 500 spaces represent the 6th October parking lot. These spaces were added to the supply of the Ramsis and El-Tahrir zones, respectively.

Based on car registration data of the Central Traffic Agnecy, together with the results of the latest parking survey, Table IV-9 gives the growth factors for the period from the traffic count survey (April 1977) to the date of model implementation (May 1981). The table also shows the percent of each vehicle type in the total, as determined by the latest parking survey.

Table IV-9

Increase in Vehicle Registration from April 1977 until May 1981

Vehicle Type	Percent of Total	Growth Factors (April 77-May 1981)
Passenger Cars	90.15	82.9
Taxis	4.15	42.9
Micro Buses	4.50	57.0
Private Buses	1.20	57.0

The weighted average growth factor for this period (49 months) is 79.76%. To update the overnight and illegal parking volumes surveyed in January 1980, a growth factor of $79.76 \times \frac{17 \text{ months}}{49 \text{ months}} = 27.67\%$ was used. Tables IV-10 and IV-11 show the updated overnight and illegal parking volumes by zones.

6.1.2 Modifications in the Street Network

Modifications in the Street Network, since the road inventory survey of 1977, are shown in section 1.4 of Part I of this report.

6.1.3 Calculation of the Initial Loads on the Street Network

The following steps were followed to calculate the initial load:

1. The 1977 hourly initial load for public transport and commercial vehicles was updated to 1981, using a 6% annual rate of increase.

2. The person trips in the O/D matrices of the different vehicle types were converted to vehicular trips using the occupancy rate for each mode.

3. Vehicular trips were converted to P.C.E.'s using the appropriate conversion factors (passenger car = 1, taxi = 1, microbus = 1.25, and private bus = 2).

4. Vehicular P.C.E.'s matrices for the different modes were updated to reflect the traffic growth between April 1977 and May 1981 (as shown in section 6.1.1).

5. The hourly updated P.C.E.'s matrices for taxis, microbuses and private buses were added.

6. The matrix obtained in the above step was assigned to the street network, thus obtaining the final initial load for each hour.

6.2 Parking Policy Scenarios

Several parking options have been suggested for the Cairo CBD area (3,4,5). Based on these past efforts and taking into consideration the developments that have occurred in the Cairo CBD area during the last few years, two policy scenarios for the year 1983 were evaluated using the proposed model.

Table IV-10

Estimated Overnight Parking Volume in 1981

Zone Name \ Parking Facility	On - Street				Off - Street			Total
	Free	Metered	Illegal	Total	Garage	Lot	Total	
Garden City	1,374		152	1,526	1,259		1,295	2,821
Area of Ministries	2,210		626	2,836	579	108	687	3,523
El Tahrir	214		107	321	152	144	296	617
Talaat Harb	1,374	35	439	1,848	2,065	180	2,245	4,093
Attaba	498		184	682	497	46	543	1,225
Abdin	442		268	710	467		467	1,177
Kiet Bey	610		107	717	60	158	218	935
Tawfikia	862		36	898	341	36	377	1,275
Ramsis	366		262	628	714	47	761	1,389
Azhar and Gheria	378		77	455		101	101	556
Bab El Sheria	732		27	759	198	33	231	990
Total	9060	35	2,285	11,380	6,368	853	7,221	18,601

Table IV-11

Estimated Illegal Parking Volume (1981)

Zone Name	Illegal Parking Volume	% of Illegal to On-Street Parking Supply	% of Illegal To Total Parking Supply
Garden City	1,135	68.3	37.7
Area of Ministries	1,653	79.3	42.3
El-Tahrir	1,972	536.0	82.8
Talaat Harb	4,273	158.3	78.1
Attaba	1,771	340.6	97.6
Abdin	1,778	331.8	177.3
Klot Beik	628	79.7	47.5
Tawfikia	1,440	128.3	88.5
Ramsis	1,736	138.7	67.6
Azhar and Ghoria	1,865	506.8	176.4
Bab-El-Sheria	1,401	176.6	78.4
Total	19,652	159.4	75.7

6.2.1 Scenario One

The objective of scenario one was to reduce the problem of illegal parking in the core of the CBD area (zones 21201 to 21207) by applying the following measures:

1. Increase the parking violation penalty from 1 L.E. to 10 L.E.

2. Increase off-street parking supply in these seven zones from 13,758 to 19,308 spaces. This could be achieved by providing ten multi-story garages. Three of these garages are currently under construction (Kasr El Nile, Bank Misr, and Maroof) and two other garages (El Bostan and Midan Opera) were recommended in previous studies of Cairo governorate and proposed to be constructed in the near future. An average parking charge of 15 PT/hr. was suggested.

Table IV-12 shows the number of parking spaces either removed or added in the seven zones, and a summary of the overall parking supply by type, location, and zone is presented in Table IV-13. In addition, a summary of illegal parking by zone is shown in Table IV-14.

Figure IV-3 illustrates the traffic directions in the CBD streets and locations of the proposed multilevel garages.

6.2.2 Scenario Two

The objective of scenario two was to eliminate on-street free parking and to reduce the problem of illegal parking in the core of the CBD area (zones 21201 to 21207) as follows:

1. Increase on-street metered parking supply in these seven zones from 157 to 4,767 spaces; i.e., all on-street free parking becomes controlled on-street metered parking on the streets with high traffic volumes. Thus, the parking supply and illegal parking spaces in the CBD area would be decreased by 1,384 and 3,955 spaces, respectively. The parking charge for these meters would be 5.P.T./hr. (5).

Table IV-12

Estimated Parking Spaces in the Core of the CBD Area

Location	Number of parking spaces		
	Removed	Added	Net
1. Kasr El Nile (Private)		500	500
2. Bank Misr (Private)		275	275
3. Maarouf (public)		675	675
4. El Bostan (Public)	275	700	425
5. Midan Opera (Public)	650	1,850	1,200
6. Azbakia Garden Adjacent to El Gomhouria St. (Public)	75	300	225
7. Regional Taxi Station at Ahmed Helmy (Public)		800	800
8. Taxi Station at Kolaly (Public)		300	300
9. Midan El Tahrir at Nile Hilton (Public)		600	600
10. Sh. Fawala Behind Bank Misr (Public)		150	550
Total	1,150	6,700	5,550

Table IV-13

Suggested Parking Supply by Type, Location, and Zone (Scenario 1)

Parking Facility / Zone Name	On - Street		Off - Street			Total Off - Street	Total
			Garages		Lots		
	Free	Metered	Public	Private			
Garden City	1,661		1,030	229	87	1,346	3,007
Area of Ministries	2,087		426	153	1,246	1,825	3,912
El Tahrir	368		677	75	1,862	2,614	2,982
Talaat Harb	2,542	149	3,451	1,464	284	5,199	7,890
Attaba	512	8	2,610	37	73	2,720	2,240
Abdin	536		348	119	-	467	1,003
Kloot Beik	789		36	24	472	532	1,321
Tawfikia	1,122		118	223	164	505	1,627
Ramsis	1,252		1,574	240	603	2,417	3,669
Azhar and Ghoria	368		-	-	689	689	1,057
Bab El Sheria	793		198	-	796	994	1,787
Total	12,030	157	10,468	2,564	6,276	19,308	31,495

2. Increase off-street parking supply in the core of the CBD area from 13,758 to 19,308 spaces by providing ten multilevel garages as presented in scenario one.

Table IV-15 shows the proposed parking supply by type, location, and zone. In addition, a summary of illegal parking spaces by zone for scenario two is presented in Table IV-14.

Table IV-14

Illegal Parking Volume by Zone

Zone Name	Scenario 1	Scenario 2
Garden City	1,135	1,135
Area of Ministries	1,653	1,653
El Tahrir	1,972	1,744
Talaat Harb	4,273	2,750
Attaba	1,776	1,109
Abdin	1,778	1,323
Klot Beik	628	289
Tawfikia	1,440	902
Ramsis	1,736	1,526
Azhar and Ghoria	1,865	1,865
Bab-El-Sneria	1,401	1,401
Total	19,652	15,697

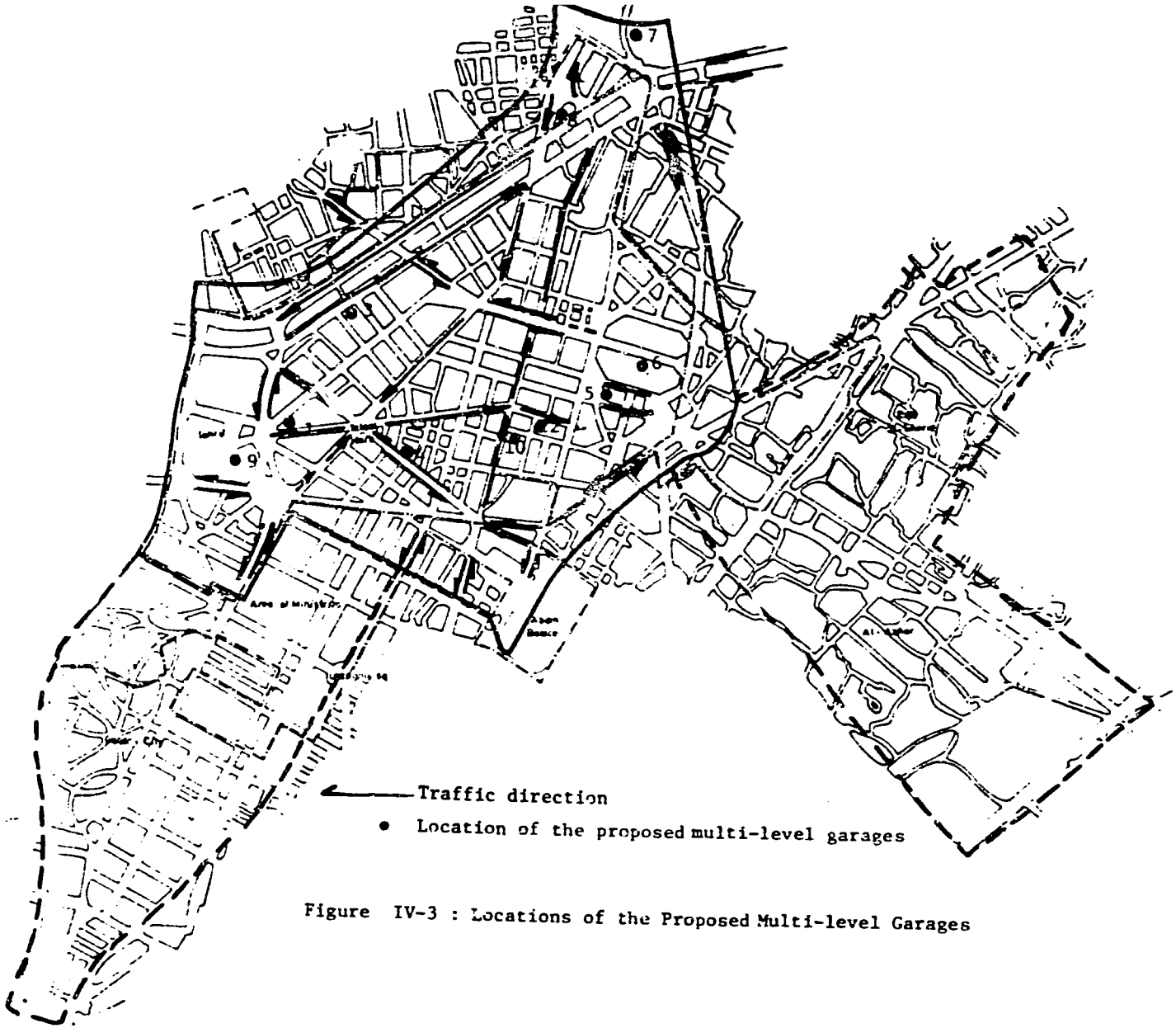

Figure IV-3 : Locations of the Proposed Multi-level Garages

Table IV-15

Suggested Parking Supply by Type, Location, and Zone (Scenario 2)

Parking Facility / Zone Name	On - Street		Off - Street				Total
	Free	Metered	Garage		Lots	Total Off - Street	
			Public	Private			
Garden City	1,661		1,030	229	87	1,346	3,007
Area of Ministries	2,087		426	153	1,246	1,825	3,912
El Tahrir	-	276	677	75	1,862	2,614	2,890
Talaat Harb	492	1,687	3,451	1,464	284	5,199	7,378
Attaba	112	308	2,610	37	73	2,720	3,140
Abdin	172	273	348	119	-	467	912
Klot Beik	80	532	36	24	472	532	1,144
Tawfikia	-	842	118	223	164	505	1,346
Ramsis	114	849	1,574	240	603	2,417	3,380
Azhar and Ghoria	368		-	-	689	689	1,057
Bab El Sheria	793		198	-	796	994	1,787
Total	5,879	4,767	10,468	2,564	6,276	19 308	29,954

7. List of Project Papers and Reports in Part (IV)

Serial No.	Title	Author(s)	Date	Area Code	Library Code
1	A research Proposal on the Parking Problem in the C.B.D. of Cairo	M.S. Nourel Din	May 1978	-	21/22
2	Parking in Cities, Bliblio-graphy prepared for Cairo Urban Transportation Pro-ject MIT/CU Technological Planning Program	A. Hardman	Aug. 1978	-	21/24
3	A Research Proposal on a Parking Demand Model for Cairo C.B.D. Area	F. Abdel-Bary M.S. Nourel Din H.K. Ismail	1978	-	21/20
4	The Parking Model	M.S. Nourel Din	March 1979	-	21/71
5	Survey of Parking Supply in Cairo CBD Area	M.S. Nourel Din	March 1979	-	21/74
6	The Parking Model (Pro-blem Statment)	M.S. Nourel Din H.K. Ismail	1979	-	21/75
7	A Combined Parking and Traffic Assignment Model	T. El-Reedy M.S. Nourel Din H.K. Ismail	Jan. 1980	-	21/279
8	Survey of Overnight Par-king	M.S. Nourel Din	Apr. 1980	-	21/251
9	Parking Study	M. Meyer	Apr. 1980	-	21/237
10	Parking Management as a component of Urban Trans-portation Policy in deve-	M. Meyer M.S. Nourel Din	Oct. 1980	-	21/288

Serial No.	Title	Author(s)	Date	Area Code	Library Code
	loping countries : the case of Cairo, Egypt				
11	Parking Model	H.K. Ismail	1980	-	21/246

8. List of References

(1) Khalid, Hamdy, "Traffic Assignment Programs for Greater Cairo" Ph. D. thesis submitted to Ain Shams University, Egypt, Cairo, 1981.

(2) NEDECO; Egypt National Transport Study, Ministry of Transport, TPA., 1981.

(3) RATP; SOFRETU of France "Greater Cairo Transportation Planning Study", Volumes A and C, Ministry of Transport, Arab Republic of Egypt, May 1973.

(4) Cairo Governorate Policy, "Parking in Cairo CBD area", Unpublished, 1979.

(5) Mackay, J. and Partners, "Cairo Urban Transportation Project", Volume one, Draft Final Report, Transportation Planning Authority, Ministry of Transport, Arab Republic of Egypt, April 1980.

CHAPTER V

CASE STUDIES

1. Introduction

As shown in the first four parts of this report*, a great deal of effort has been put into the development of planning tools for Greater Cairo. These tools will be useful in a wide range of transport planning and decision-making which will be required in Cairo in the coming years. While it would be futile to show the application of all the techniques developed in this research, it is useful to demonstrate how some of the methods can be used to tackle the types of problems currently existing in Cairo. Accordingly, in this part of the report two case studies will be presented to show the practical value of the analytical techniques. The first case study is of project programming in Greater Cairo and shows how the travel demand forecasting methods presented in Part II of this report can be used to investigate the value of alternative capital investment programs. The second case study shows how the impact of the new regional underground line on surface public transport services can be assessed using the travel demand forecasting methods presented earlier in this report.

It should be stressed that these two case studies are presented for illustrative purposes only and are not intended to make definitive recommendations on the topics addressed.

2. Project Programming

2.1 Objective

This case study demonstrates the use of transport planning aids and tools discussed in Parts I and II in the evaluation of system performance for different network configurations resulting from possible future

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* Cairo Urban Transport Project, Transport Planning Aids and Tools, Final Report, Volume III Part 1 and Part 2 .

capital investments. These applications are useful in the staging of slated projects for implementation.

2.2 Projects in Slate*

Projects considered to be in the slate are:

- Abu El-Ela Bridge, Zamalek Bridge
- Abbassis Bridge, 6th of October Elevated Road Extension to Ghamra
- King Faisal Bridge
- Helwan-Heliopolis autostrad
- 26th July elevated roadway
- Ramsis Street extension to Ghamra
- Sekket El Waili Bridge (Railways)
- Giza square flyover
- King Fisal Street
- Road El-Farag Bridge

2.3 Procedure

2.3.1 Travel Demand Forecasting

In order to determine the 1981, 1983, and 1987 hourly traffic volume matrices to be used in the assignment stages, the following steps were followed:

1. 1977 private car and taxi passenger (80X80) matrices were developed for Greater Cairo traffic zones and for the survey period (i.e., for 10 hours). This required some "smoothing" and filling in of the empty cells)see Part I of this report).

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*See Working Paper "Different Networks to be Tested with the Assignment Program" by T. Y. El Reedy, 1981, Project library, Cairo University.

2. 1977 private car and taxi passenger (108X108) matrices were developed for Greater Cairo and rural traffic zones for each of the morning survey hours (i.e. 7-8, 8-9, 9-10, and 10-11) after smoothing and filling the empty cells (see Part I).
3. 1977 hourly fluctuation matrices (80X80) were developed for private car passengers for Greater Cairo traffic zones by dividing the respective cell data from Step 2 by those obtained in Step 1. This was also done for taxi passengers.
4. Trip generation and distribution techniques discussed in Part II were used to produce (80X80) private car and taxi passenger matrices for the Greater Cairo Traffic zones for the 10 hours corresponding to the survey periods of 1977. These matrices were produced for the years 1981, 1983, and 1987. In the case study presented here, only one scenario for socio-economic development in Greater Cairo was assumed.
5. The results of step (3) were multiplied by the corresponding ones of step (4) to obtain the morning hourly passenger movements (80X80) matrices for private cars and taxis. Total internal passenger movements for Greater Cairo residents by private car and taxi were forecast (see results in Table V-1).
6. Morning hourly rural/urban movements for the Greater Cairo traffic zones for the year 1977 were obtained from results in step (2) for private car and taxi passengers.
7. Results from step (6) were multiplied by an assumed growth factor obtained from previous car and taxi registration trends to obtain rural/urban movements for the years 1981, 1983, and 1987. The

Table V-1 : Forecast Internal Total Passenger Movements in Greater Cairo

Hour / Year	7-8 A.M.		8-9 A.M.		9-10 A.M.		10-11 A.M.	
	Pri. Car	Taxi	Pri. Car	Taxi	Pri. Car	Taxi	Pri. Car	Taxi
1981	77 964	47 974	110 697	54 208	79 780	43 758	91 720	50 771
1983	82 041	50 291	115 808	56 733	84 521	46 586	95 283	52 286
1987	88 344	56 256	127 957	62 220	91 867	50 910	102 477	56 863

Table V-2: Forecast Rural/Urban Total Passenger Movements for Greater Cairo Region

Hour / Year	7-8 A.M.		8-9 A.M.		9-10 A.M.		10-11 A.M.	
	Pri. Car	Taxi	Pri. Car	Taxi	Pri. Car	Taxi	Pri. Car	Taxi
1981	7 282	12 205	8 016	13 581	8 327	15 383	7 530	15 771
1983	9 670	14 803	10 649	16 479	11 053	18 665	9 998	19 139
1987	12 030	17 476	13 243	19 464	13 745	22 037	12 446	22 597

Table V-3: Forecast Total Passenger Movements for Greater Cairo

Hour / Year	7-8 A.M.		8-9 A.M.		9-10 A.M.		10-11 A.M.	
	Pri. Car	Taxi	Pri. Car	Taxi	Pri. Car	Taxi	Pri. Car	Taxi
1981	85 246	60 179	118 713	67 789	88 107	59 141	99 250	66 542
1983	91 711	65 094	126 457	73 212	95 574	65 251	105 281	71 425
1987	100 374	73 732	141 209	81 684	105 612	72 947	114 923	79 460

annual increase in registrations was found to be 20.3% for private cars and 10.5% for taxis between 1977 and 1981. The estimated total rural/urban passenger movements for Greater Cairo are shown in Table V-2.

8. The results of step (7) were merged with those of step (5) to obtain the modal (108X108) hourly passenger matrices by model by mode for the years 1981, 1983, and 1987. Total estimated hourly passenger movements for private cars and taxis are shown in Table V-3.

9. Morning period trip matrices were obtained for passenger movements by minibuses and private buses for the years 1981, 1983, and 1987 by multiplying the corresponding 1977 matrices by a growth factor based on the increase in vehicle registration between the years 1977 and 1981. The increase per year was assumed to by 14% for both minibuses and private buses.

10. The hourly passenger matrices obtained in steps (8) and (9) were then converted to passenger car equivalent (P.C.E.) matrices using the following conversion factors:

Passenger Car Equivalent Factor

Mode	P.C.E.'s
Minibus	1.25
Private Bus	2.00

	Occupancy rates*	
Mode	Rural/Urban Trips	Urban/Urban Trips
Private Car	2.45	2.09
Taxi	5.19	3.01
Micro Buses	6.18	5.47
Private Buses	10.44	25.70

*See Part I of this report.

Table V-4: Estimated Total Passenger Car Equivalent Movements for Greater Cairo Region

Hour \ Year		1981	1983	1987
7-8 A.M.	Inter.	77 582	86 827	98 321
	Exter.	6 107	7 781	9 452
	Total	83 689	94 608	107 773
8-9 A.M.	Inter.	83 692	90 418	101 580
	Exter.	8 034	10 228	12 405
	Total	91 726	100 646	113 985
9-10 A.M.	Inter.	58 861	63 801	70 600
	Exter.	6 885	8 766	10 646
	Total	65 746	72 567	81 246
10-11 A.M.	Inter.	65 173	68 705	75 025
	Exter.	6 614	8 395	10 181
	Total	71 787	77 100	85 206

The maximum total P.C.E.'s movements was found to occur between 8-9 A.M. (see Table V-4) in the corresponding matrix which was used in the assignment stage.

2.3.2 Network Configuration and Assignment

The Cairo street network of 1977 was coded, revised, punched, checked, and stored on a magnetic tape. This network was subsequently used to test the assignment program with the 1977 O/D matrices by checking the assigned volumes with the measured volumes at selected stations (see Part I of this report).

The Cairo street network of 1981 was also coded, revised, punched, checked, and stored, incorporating the alterations already made to the 1977 network.*

The Cairo street network of 1983 then consists of the 1981 network plus the selected improvements,* including the King Faisal Bridge, King Faisal Street, Guiza Square flyover, Zamalek Bridge, 26th July flyover, Abbassia Bridge, Ramsis Street extension to Ghamra.

Three scenarios are examined for the 1987 network configuration:

* Scenario 1: "Do-nothing" alternative, i.e. the 1983 network without additions.
* Scenario 2: The Sekket El Wally Bridge, the 6th October elevated road extension to Ghamra, and the Abu El Ela Bridge added to the 1983 network.
* Scenario 3: Scenario 2 plus the Helwan-Heliopolis autostrade and the Road El Farag Bridge.

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* See Working Paper "Different Networks to be Tested with the Assignment Program" by T. Y. El Reedy, Project Library, Cairo University.

The assignment program is the main analysis tool for evaluation of the proposed configurations. Volume/capacity ratios for all network links are then used in an economic assessment. Details of the assignment program are found in Part II of this report.

2.4 Results

The morning rush hour (8-9 A.M.) PCE matrices were assigned to the corresponding network configurations defined in the previous section for the years 1981, 1983, and 1987. The Cairo University stepwise capacity restraint assignment was used for this exercise. An initial load for each link having public transport or commercial vehicle movement in 1977 was assumed for each year extrapolating past trends in public transport demand and vehicle registration. Corrections and adjustments were made for the changes which have taken place in the public transport networks and in the traffic regulations for routing commercial vehicles. These initial loads were also converted into PCE movements.

Results of these assignment runs yielded the following types of network link information:

- Total volume assigned (in P.C.E.s), travel time (in minutes), and the volume/capacity (V/C) ratio for each link in the network
- Number of links in the network having the same V/C ratio, i.e., roughly equivalent levels of service (see Table V-5).
- Total aggregate vehicle travel time (AVTT) on the whole network, estimated in P.C.E. travel hours per hour (see Table V-5).

Table V-6 shows the volumes assigned to each of the bridges connecting the western and eastern parts of Greater Cairo. The total traffic crossing the River Nile from West to East is estimated to be 20,287, 22,412, and 25,573 and from East to West 18,109, 19,961, and 23,172 for

Table V-5

Link Volume Capacity Ratios Summary

Class	Frequency
- 1 %	25
10 - 20%	21
20 - 30%	27
40 - 50%	91
50 - 60%	103
60 - 70%	85
70 - 80%	106
80 - 90%	87
90 - 100%	81
> 100 %	915
TOTAL	1639

Aggregate Vehicle Travel Time (AVTT) 124003.21 PCE.HR./HR.

the years 1981, 1983, and 1987 respectively (Scenario 1). The increase in total traffic crossing the River Nile in both directions compared with 1981 was found to be 10 percent for 1983 and 25 percent for 1987. From Table V-4 the increase of total traffic movements in the study area for the years 1983 and 1987 (again compared to 1981) were found to be 9 percent and 23 percent, respectively. The comparison between the corresponding traffic figures and also between the 1981 assigned volumes and those measured in April 1977 and February 1980 (given in Table V-6) tend to verify the consistency of the results of the assignment runs. However, the distribution of traffic on the bridges has changed dramatically, due to changes in traffic operation on the 6th October Bridge and the opening to traffic of the proposed Rod El-Farag and the ew Abu El-Ela Bridges.

Detailed operational and economic analysis for links and the whole network are needed according to the procedures presented in part (2) of volume III of the Project Final Report based on the results of the assignment runs. The construction of new bridges and their opening to traffic have significant effects on the traffic volumes assigned to the different links of the Greater Cairo enlarged downtown. Table V-6 presents also the volumes assigned to some important links. The 6th October elevated road, Ramsis, Salah Salem and Kornish Streets will have heavier traffic volumes (which means a low level of service) if Rod El-Farag and Abu El-Ela Bridges are not opened to traffic in 1987.

Results of the overall operational evaluations of the performance of these networks in 1983 and 1987 compared to that of 1981 are given in Tables V-7 and V-8. Table V-7 shows that the number of links having a

V/C ratio more than 100 percent increases from about 43 percent for 1981 to 48 percent in the year 1983 and to 52 percent in the year 1987, even under Scenario 3, which includes Abu El-Ela and Rod El-Farag Bridges, as well as the Helwan Auto-Strade. An implication of this finding is that the total vehicle operating hours will increase from an estimated 69,288 in 1981 to 85,586 in 1983 and to 98,559 in 1987 measured in P.C.E. hours/hour in the morning rush hour. The increase in vehicle operating hours due to traffic delays was estimated to be 23 percent and 42 percent, respectively; these far exceed the increases in traffic volumes that were estimated to be 9 percent and 23 percent, respectively. A rough estimate of yearly monetary losses in vehicle operating costs due to the increased deterioration in the level of service (which does not include monetary losses of passenger travel time) is estimated to be 15 and 20 mill L.E. in 1983 and 1987, respectively. This finding indicates the importance of increasing street network capacity through additional roadway construction projects, traffic management schemes, and appropriate parking policy revisions designed to reduce street curb parking, especially on main arterial streets.

Table V-6

MEASURED AND ASSIGNED TRAFFIC VOLUMES ON THE NILE BRIDGES

(a) WEST TO EAST

BRIDGES	SURVEY COUNT		ASSIGNED TRAFFIC VOLUME				
	APRIL 1977	FEB. 1980	1981	1983	1987 S1	1987 S2	1987 S3
GIZA	1,711	2,680	3,451	3,870	4,946	4,807	4,795
GAMEA	1,869	2,832	2,503	3,031	3,148	2,833	2,805
TAHRIR	3,643	2,622	3,647	3,764	4,274	3,685	3,278
6th OCTOBER		4,261	7,971	9,695	10,790	8,293	7,317
ABU EL ELA	2,203	1,217	1,280	481	566	4,302	3,131
IMBABA	1,312	1,282	1,435	1,571	1,849	1,849	1,849
ROD EL FARAQ							3,524
TOTAL	10,738	14,894	20,287	22,412	25,573	25,769	26,699

Table V-6

MEASURED AND ASSIGNED TRAFFIC VOLUMES ON THE NILE BRIDGES

(b) EAST TO WEST

BRIDGES	SURVEY COUNT		ASSIGNED TRAFFIC VOLUME				
	APRIL 1977	FEB. 1980	1981	1983	1987 S1	1987 S2	1987 S3
GIZA	2,000	2,[illegible]	3,277	3,802	4,163	4,113	4,310
GAMEA	2,026	2,75[illegible]	2,550	3,116	3,862	3,836	3,518
TAHRIR	328	2,151	2,560	2,844	3,321	2,881	2,701
6th OCTOBER	2,158	3,088	6,259	7,654	8,832	7,052	5,358
ABU EL ELA	1,058	1,662	1,580	432	508	3,072	2,651
IMBABA	1,637	1,173	1,927	2,113	2,486	2,486	2,486
ROD EL FARAQ							3,609
TOTAL	9,207	13,109	18,109	19,961	23,172	23,440	24,63[illegible]

TABLE (V-6)a-MEASURED AND ASSIGNED TRAFFIC VOLUMES ON SOME IMPORTANT STREETS IN GREATER CAIRO ENLARGED DOWN TOWN IN MORNING RUSH HOUR

SERIAL NO.	LINK NAME	LINK DESCRIPTION	LINK DIRECTION	SURVEY COUNT		ASSIGNED TRAFFIC VOLUME				
				APRIL 1977	MARCH 1982	1981	1983	1987 S1	1987 S2	1967 S3
1	Ramsis Street	From Tharwat St. to Assaf Sq.	160-748	1,157		4,382	5,241	5,773	4,602	3,720
2		From Ramsis Sq. to Ghamra	791-782	765		4,175	5,803	6,673	4,920	4,605
3		From Ghamra to Ramsis Sq.	339-799 351-800 969-800	3,380		3,706	5,123	5,725	4,382	4,393
4		From Sarayat St. to Salah Salem St.	432-888	1,575		1,925	1,105	1,490	1,416	1,182
5		From Salah Salem St. to Sarayat St.	887-863	712		1,151	1,276	1,568	1,229	944
6	Galaa Street	From Shanen St. to Assaf Sq.	814-768	1,183		4,209	3,815	4,539	5,363	4,703
7	Geish Street	From Attaba Sq. to Bab el Sheria St.	736-398	1,764		962	1,447	1,305	1, 477	1,331
8		From Bab el Sheria St. to Attaba St.	398-736	1,752		2,796	3,690	4,183	3,120	3,184
9	Salah Salem Street	From Ramsis St. to Youssef Abbas St.	856-857	1,757		3,146	3,495	3,722	3,726	3,980
10		From Sayed Elsha St. to Sur-el-Eyoon	643-380	1,665		2,702	3,208	3,647	3,586	2,902
11	Shobra Street	To Galaa St.	818-140	2,875		6,111	6,301	6,219	7,464	6,430
12	Teresa Street	From Galaa St.	140-348	1,482		2,616	2,434	2,941	3,500	3,290
13	Ibrahim El Lakhany	From Roxi Sq.	460-481	651		1,102	1,210	1,361	1,398	1,360
14		To Roxi Sq.	481-480	841		1,542	1,656	1,849	1,771	1,907
15	Galaa Bridge	From Galaa Bride Sq. To Maarad	567-603	4,436		3,812	3,945	4,486	3,897	3,490
16		From Maarad To Galaa Bridge S.	268-568			2,756	3,193	3,678	3,190	3,348
17	6th October Elevated Rd.	Over Galaa To Ramsis Sq.	658-922			2,846	3,450	4,044	3,984	3,590
18		From Ramsis Street Sq.	921-687			2,566	3,238	3,433	3,655	3,463
19	Azhar Street	From Hussein To Attaba	390-388	2,332	2,030	2,908	2,592	2,925	2,455	2,503
20		From Attaba To Hussein	111-388	1,072	1,344	1,271	1,282	1,775	1,205	1,285
21	Talaat Harb Street	From Tahrir Sq.	208-207	1,730	1,597	1,649	1,960	2,179	1,776	1,765
22	Kasr El-Nil Street	To Tahrir Sq.	205-209	1,245	975	1,643	1,856	1,884	1,897	1,847
23	Kornish Street	Shobra-El-Mezallat to Imbaba Bridge	935-936	1,249	2,101	2,647	2,648	3,132	2,953	2,380
24		From Imbab Bridge to Shobra El Mezallat	930-931	1,786	1,372	2,523	2,771	3,223	3,557	1,813

Table V-7: Degree of Loading (V/C)

V/C % \ Study Year	1981		1983		1987 Scenario 1		1987 Scenario 2		1987 Scenario 3	
	No. of Links	%	No. of Links	%	No. of Links	%	No. of Links	%	No. of Links	%
0-10	32	1.98	28	1.71	25	1.52	28	1.67	29	1.70
10-20	30	1.86	23	1.40	21	1.28	21	1.25	25	1.46
20-30	47	2.91	32	1.95	27	1.65	27	1.61	26	1.52
30-40	172	10.64	160	9.76	91	5.55	100	5.96	113	6.61
40-50	105	6.50	102	6.22	98	5.98	101	6.00	93	5.39
50-60	109	6.74	105	6.41	103	6.28	100	5.96	104	6.08
60-70	120	7.43	116	7.08	85	5.19	113	6.73	118	6.90
70-80	113	6.99	110	6.71	106	6.47	117	6.97	106	6.20
80-90	89	5.51	73	4.45	87	5.31	88	5.24	113	6.61
90-100	108	6.68	96	5.86	81	4.94	93	5.54	91	5.32
> 100	691	42.76	794	48.45	915	55.83	891	53.07	892	52.21
TOTAL	1616	100	1639	100	1639	100	1679	100	1710	100

Table V-8: Vehicle Travel Time (AVTT)
Estimated into P.C.E. hr/hr. in
Morning Rush Hour

Year	1981	1983	1987 S1	1987S2	1987S3
AVTT	69,289	85,587	124,003	108,021	98,599

3. Impact of Cairo Regional Underground Line on Surface Public Transport Services

3.1 Background

It was recently decided to implement the regional line of the proposed Greater Cairo Underground urban rail network. Work has started, and construction of the regional line will connect the Helwan and Mataria suburban railway lines with a 4 km tunnel; thus, a 42-km rapid rail line will operate from Helwan in the south to El-marg in the north.

This long mass transit line will obviously be the backbone of public transport in the city. It is certain that this line will force dramatic changes in the size, level of use, and type of service offered by other transport modes operating in Greater Cairo. Using the data base and modeling techniques developed during the CU/MIT Cairo Urban Transport Project, it is possible to analyze the anticipated effects of the regional underground line on Cairo's surface public transport services. To do so within budget limitations, this task was assigned to senior Cairo University transport planning students in Civil Engineering as their B.Sc. degree project. Since the whole exercise had to be completed in four weeks, numerous assumptions and approximations were made, and as a result, the analysis presented here is of a general nature. The analysis presented here points toward directions of effects and "order of magnitude" quantitative assessments of various impacts, the new rail line is likely to have. The importance of undertaking a wider investigation of this topic in the very near future and before operating the line is a major conclusion of this preliminary analysis.

3.2 Objective and Scope

The main-objective of the investigation is to determine the nature of effects that a regional underground line will have on surface public transport services in Greater Cairo in 1987, with special focus on impacts in the city centre.

Due to the constraints mentioned above, the following restrictions were imposed on the analysis:

1. Only the street network was coded and stored on a magnetic tape. Therefore, some modifications and assumptions were made in order to make this network represents the public transport system as closely as possible.
2. No public transport assignment package was available. Accordingly, the street network assignment package with an "all or nothing" minimum travel time algorithm without capacity constraint was used in assigning public transport trips. No information was available about public transport transfer times; hence some plausible assumptions were made to meet this data need. The outcome of the analysis was then subject to alteration and corrections.

3.3 Procedure Outline

The analysis procedure adopted in this study was conditioned on the objectives and limitations mentioned above. The main steps of this procedure are summarized in the flow chart given in Fig. V-1. The year 1987, which is the official year for opening the whole regional line to traffic, was designated as the horizon year for this analysis.

3.3.1 Future Trip Generation

Based on the calibrated public transport trip generation models for Greater Cairo (see Chapter II), 1987 zonal trip productions and attractions were calcualted. The zonal trips were calculated for a period corresponding to that of the 1978 public transport survey (7 A.M. to 3 P.M. of a working day).

3.3.2 Public Transport Network 1978 and 1987

The 1977 street network and the 1978 public transport network were available (see Part I). However, only the 1977 street network was coded and stored on magnetic tape. To save time, it was decided to use this file after introducing the necessary adjustments to obtain a 1987 coded generalized public transport network. Major adjustments were:

a. All links having no public transport running on them were eliminated by assigning each a travel time of 99.00 minutes.

b. To change the coded private car travel time on each link to public transport travel time, link travel times for private car was multiplied by a factor depending on the area and facility type as shown in Table V-9.

c. Since the street network available for calculation of minimum travel time matrices was based on 80 zones, and knowing that the public transport zoning system has 120 zones, an aggregation process was applied to reduce the 120 public transport zones to 80. The 66 zones of the central area of Cairo were left unchanged and the 54 external zones of Greater Cairo were aggregated to the 14 zones defined in Part I. As a result of this aggregation, the travel time was increased to all centroid connectors of the 14 external zones.

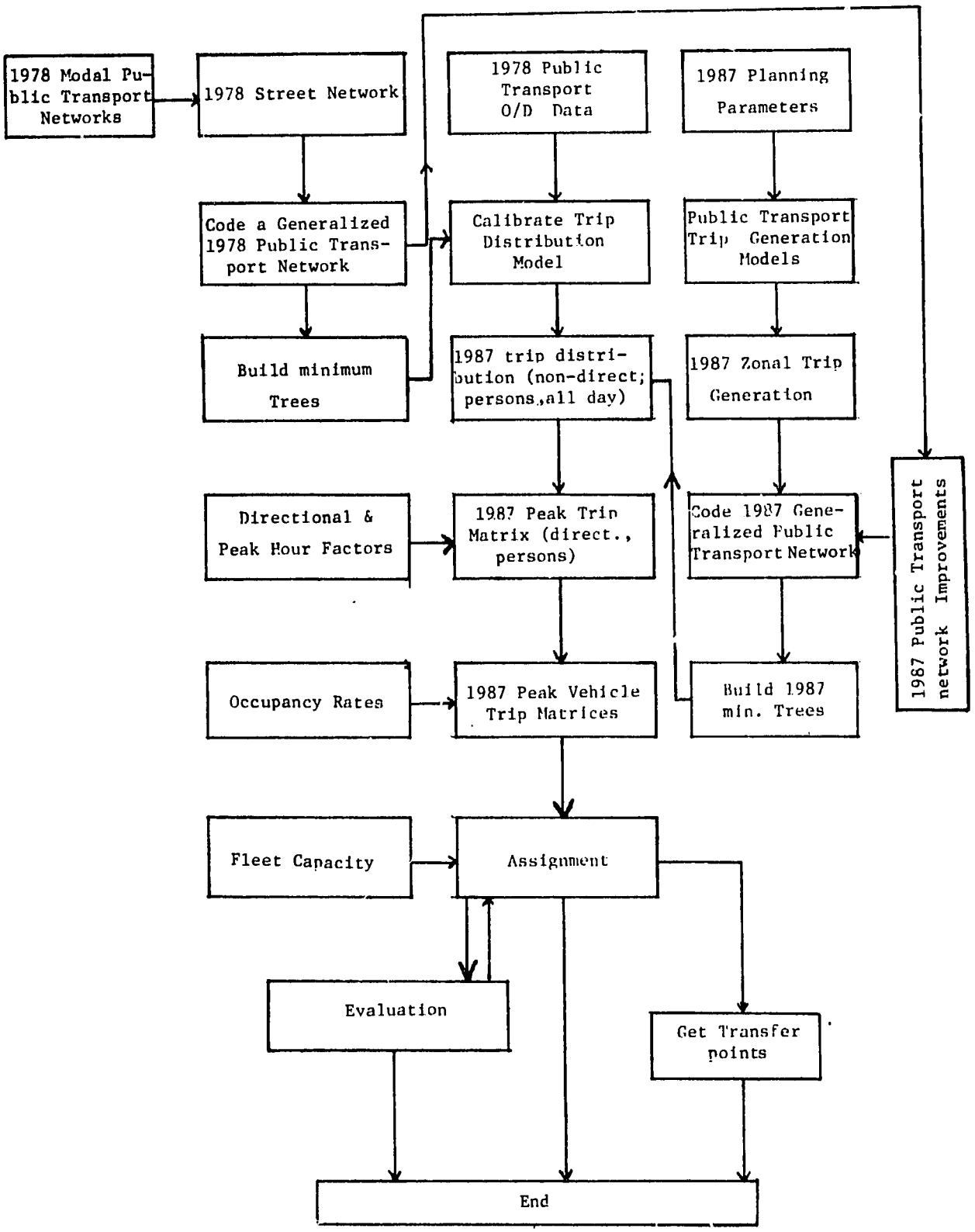

Fig. V-2 Procedure Used to Analyze Effects of Underground Rail Line

This "penalty" travel time also recognized the effect of transfers as well as the type of mode operating in each zone. Table V-10 gives the values of the penalty travel times.

The 1987 generalized public transport network took into consideration the plans of Cairo Transport Authority (CTA). The following assumptions were made to code the 1987 network.

a. New nodes and links for the underground regional line (U.G.) were included as well as the extension of the tramway network at the periphery of Greater Cairo.

b. U.G. average speed was assumed to be 35 km/hr.

c. In order to take the effect of the U.G. line on reducing journey time, link travel times were multiplied by reduction factors according to their distance from the U.G. line. These factors are presented in Table V-11

Table (V-9): Adjustment Factors to Convert Link Private Car Travel Time into Public Transport Travel Time

Area Type* \ Facility Type*	1	2	3	4	5	6
1. C.B.D.	1.48	1.85	1.33	1.48	1.33	1.85
2. Fringe	1.48	1.85	1.33	1.48	1.33	1.85
3. Residential	1.39	1.73	1.25	1.39	1.25	1.73
4. Outer C.B.D.	1.48	1.85	1.33	1.48	1.33	1.85
5. Rural	1.71	2.13	1.54	1.71	1.54	2.13

*See Part I for definition of facility and area types.

Table V-10 Penalty Travel Times for the 14 External Zones

Zone Number	Penalty travel time (min.)
10100	10
10200	10
10300	10
10400	10
10500	10
10600	10
10700	15
10800	10
10900	10
11000	10
11100	10
11200	10
11300	12
11400	15

Table V-11 Link Travel Time Reduction Factors Reflecting Effect of the U.G. Line on Journey Times

Distance of zone centroid on each side of the U.G. route (km)	Reduction Factor	Associated minimum travel time on each link (min)
≤.5	0.2	2.0
>.5 - ≤1.5	0.5	5.0
>1.5	0.8	7.0

3.3.3 Trip Distribution

Using the above assumptions, minimum travel time matrices were obtained. The trip distribution program developed in Chapter 11 was then used to calibrate three trip distribution models, one model for each trip purpose.

The trip distribution program resulted in three passenger trip matrices corresponding to 1987, one for each defined trip purpose. Since the matrices indicated non-directional person-trips for the nine hours between 7 A.M. and 4 P.M., it was necessary to apply three factors to obtain directional peak hour vehicle matrices. These factors were:

- directional factors
- vehicle occupancy rates
- peak hour factors.

Based on the 1978 public transport survey data, these factors were produced and stored in computer files. Accordingly, the required matrices were produced in the format ready for assignment applications. The trip distribution exercise was repeated twice, first using 1987 travel times that corresponded to the "do nothing" alternative, and the second, using travel times with the U.G. in service.

3.3.4 Assignment

With the results of the trip distribution process, assignment runs were made using the Cairo University computer package. An "all or nothing" method of assignment without capacity constraint was applied in the public transport runs. As a result of using the "all or nothing" assignment, it was found that some links were heavily loaded while other links had zero volume, an unrealistic condition. To correct such errors,

a reassignment process was developed giving a preference in loading to the underground until it reached its capacity. To achieve reliable results for the reassignment process, every mode was treated separately. Then, a combination of all modes was studied to determine the configurations for new lines in Greater Cairo with the regional underground line operating. The following points explain the steps of the correction process:

1. Correcting the loads on the links of the underground:

   The loads on links parallel to the underground links of any public transport mode were removed and reloaded on the corresponding links of the underground, taking into consideration the maximum capacity of the line (60,000 passengers/hour).

2. Correcting the loads on the links of the other modes:

   Considering the street capacities to carry bus passengers given in Table V-12 and also the fleet capacities of the tram and the metro of Heliopolis, the loads on all links of the Heliopolis metro, tram and buses were corrected by transferring loads from one mode to another.

3.4 Estimated Impact of the Underground

As mentioned earlier, two cases of assignment of peak hour public transport person trips expected in 1987 were obtained:

1. The "do nothing" case, (DN).
2. The "Underground in Operation" case (UGO).

A comparison between the results of these two cases was made in order to assess the impact of the underground line on public transport service in Greater Cairo.

Table V-12: Maximum Capacity by Road Class

Class No.	Classification	Peak Pass/hour
1	2 way - 2 lanes	3000
2	2 way - 3 lanes	4000
3	2 way - 4 lanes	5000
4	2 way - 5 lanes	6000
5	2 way - 6 lanea	7000
6	Divided - 2 lanes each direction	8000
7	Divided - 3 lanes each direction	12000
8	Divided - 4 lanes each direction	15000
9	Divided - 5 lanes each direction	18000
10	One way - 2 lanes	8000
11	One way - 3 lanes	12000
12	One way - 4 lanes	15000
13	One way - 5 lanes	10000
14	One way - 6 lanes	15000

Table V-13 gives the expected city center bus trips in the 1987 morning peak in the DN and UGO cases. It is clear from these data that the number of bus trips to and from the city centre is expected to be reduced dramatically (by about 70%) after implementing the regional underground line. In other words, the present high volumes of passenger transfer trips that take place in the city center will be markedly reduced. Transfer trips that occurred in the city center in 1978 accounted for about 30% of total trips in Greater Cairo, or the equivalent of one million trips.

Table V-13: Expected City Center Bus Trips in the 1987 Morning Peak.

	Do Nothing Case	Underground Case	Difference	% Change
Entering	73426	20366	53060	-72%
Leaving	74487	23264	51223	-69%
Total	147913	43630	104283	-70%

Accordingly, it is anticipated that the number of buses running in the city center streets can be dramatically reduced. Figure V-2 shows these estimated reductions for selected major streets in the city center. On average, a 36% reduction in bus flows is expected to take place on the selected 11 streets shown in Fig. V-2 during the 1987 morning peak. On some streets a massive reduction will occur, such as on Kasr El-Einy Street where the reduction will be 98%.

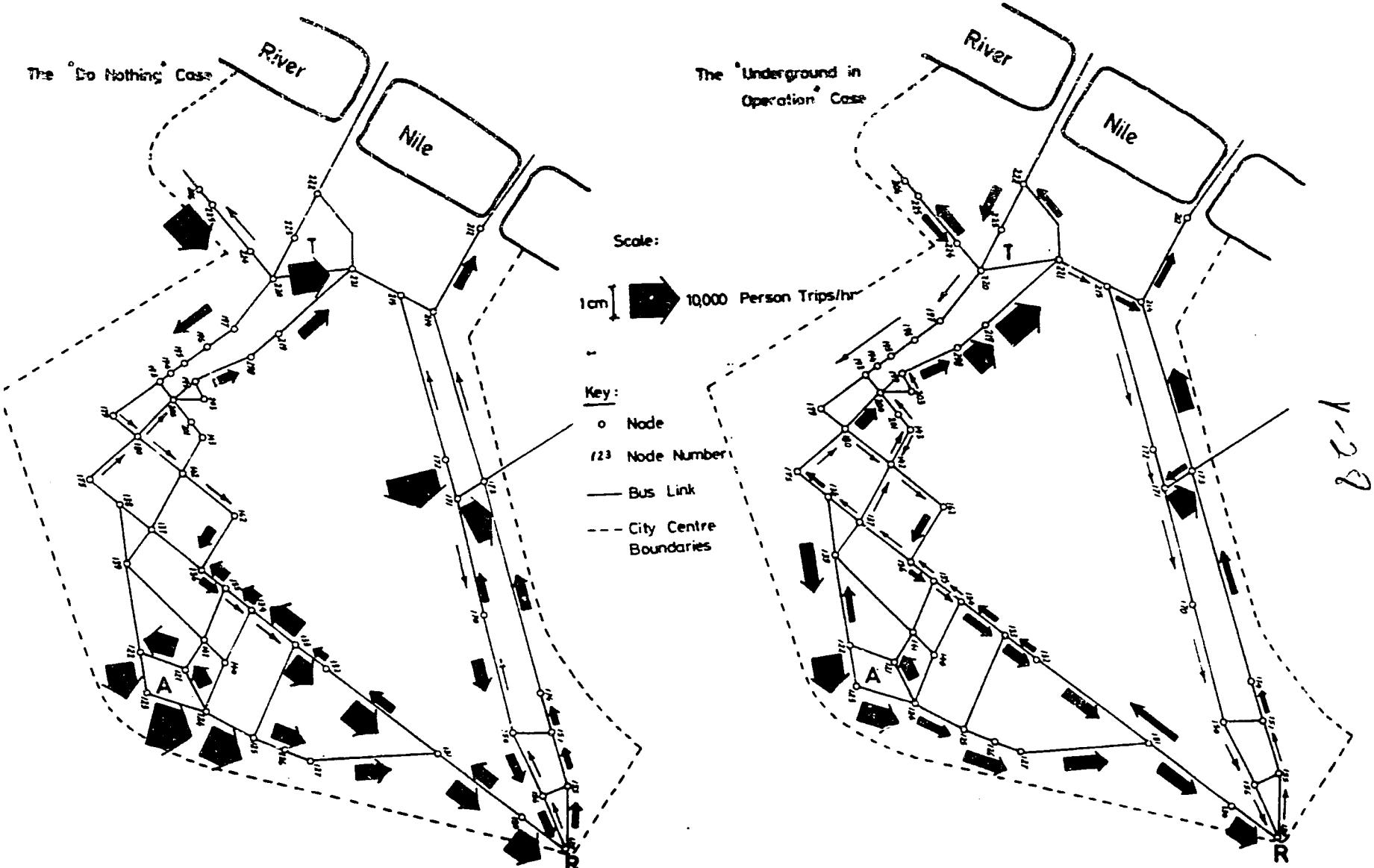

Fig. V-2 : Expected Impact of UG on Morning Peak Hour Bus Person Trips in Selected Major Streets of the City Centre in 1987

Furthermore, a great reduction in bus trip ends at the three major squares in the city center are also expected. Fig. V-3 and Table V-14 show that reductions of 81%, 57%, and 58% of peak hour trip ends by bus will take place at Tahrir, Ramsis and Attaba squares, respectively.

Table V-14: Bus Trip Ends in Major City Center Squares

Squares	1987 Total Trip Ends		1987 change	
	DN	UG	Trips	% Reduction
Tahrir	52000	10000	42000	-81%
Ramsis	42500	10375	32125	-57%
Attaba	48750	20500	28250	-58%
	143250	40875	103375	-72%

It is concluded that private and public transport operations in the city center of Cairo are expected to be much improved after implementation of the underground[1] in 1987. The endless chains of buses will largely vanish and, hence, traffic flow will become smoother. The large number of transfer trips will be eliminated, and so pedestrian/vehicle conflicts will be reduced.

Another output of the assignment runs was the total number of 1987 peak hour passenger travel time for the "DN" and the "UGO" alternatives. The results were as follows:

DN	143,046	passenger-hours
UGO	121,118	passenger-hours

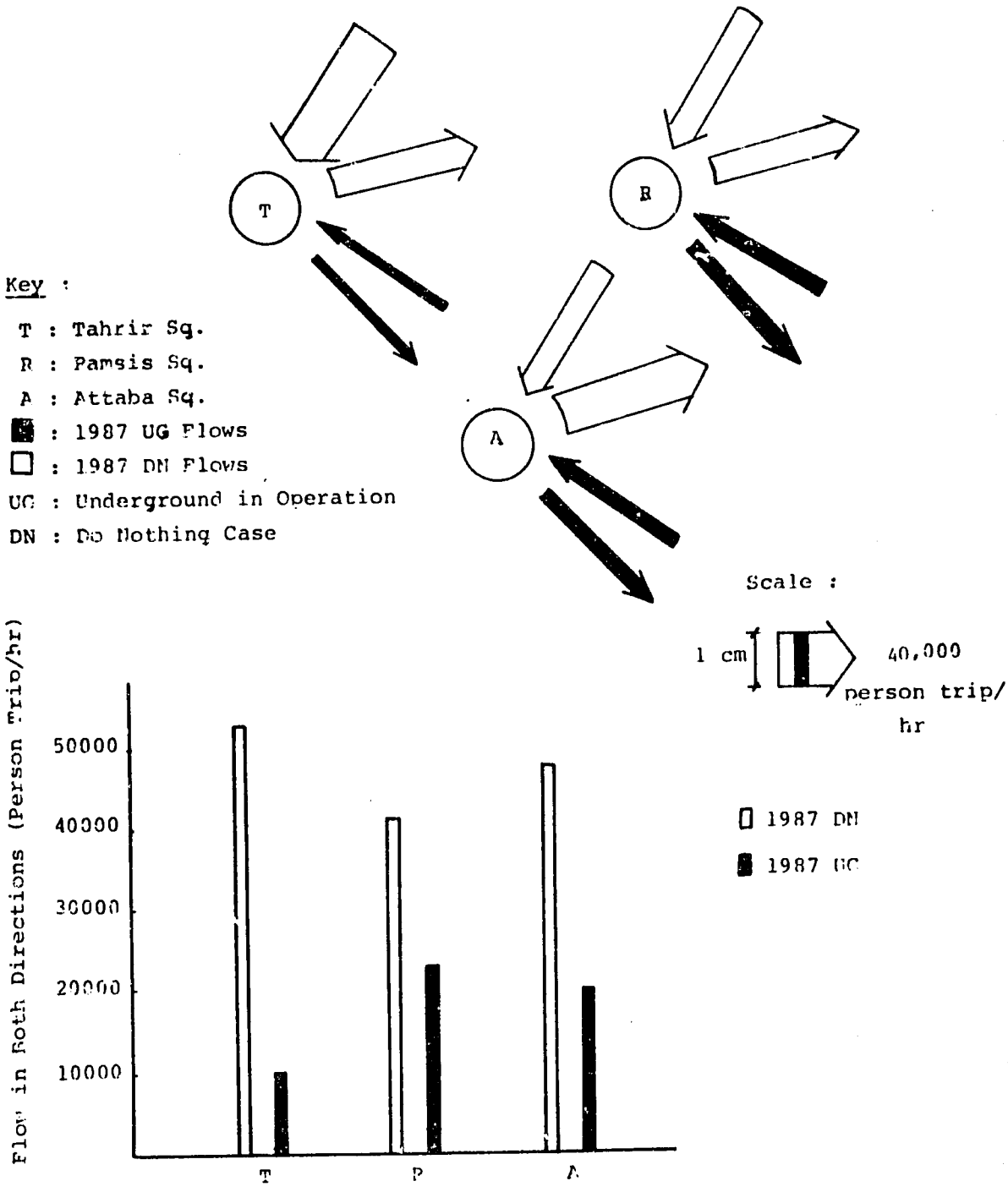

Fig. V-III : Expected Impact of UG on Peak Hour Bus Trip Ends in Major City Center Squares in 1987

The difference of 21,928 passenger-hours in the peak hour only is equivalent to annual savings of at least 30 million pounds using some sensible assumptions about traveler value of time.

Projected bus flows in Greater Cairo in 1987 were also plotted as flow bands for the DN and the UGO cases, showing the expected values of bus flows (passenger/hr) on bus routes in Greater Cairo. It appeared from these plots that most city streets will have low bus movements. However, some streets will experience heavy volumes, including Al-Ahram and the 26 July streets. These movements will be caused by the diversion of many trips to the underground route. This problem may be mitigated by introducing designated bus lane schemes or rerouting some lines to parallel streets.

Expected changes in public transport trip transfers were also calculated which showed that the major transfers will be Bus/UG and would take place at major UG stations along the regional UG line, with heavy transfers occurring in the city center as dictated by the existing public transport system.

To illustrate, consider a person who lives in Al-Ahram and works in Ismailia Square, Heliopolis. Currently, he must take a bus to Tahrir Square (in the city center) and transfer to another bus line which would take him to his destination. When the U.G. is in operation, this person will instead go directly from Al-Ahram to El-Malek El-Saleh underground station and take the U.G. to Kobry El-Kobba and then take a bus to Ismailia Square. However, the forecast transfers draw attention to the need for careful consideration of constructing UG stations of ample capacity with sufficient exits and entrances so as to avoid congestion inside the station and the station's vicinity.

3.5 Conclusions and Recommendations

It is concluded from this study that Cairo city center travel and traffic flow will be much improved after opening the regional UG line to service. Long chains of buses will be largely eliminated and traffic flow will be smoother. The large numbers of transfer trips will be significantly reduced and distributed along the UG route. In addition, there will be reduced public transport travel time, reduced street traffic delays (especially in the city center), and reduced accidents and pedestrian vehicle conflicts. However, it is also concluded from this study that some points should be taken into consideration in order to ensure the success of the UG service together with other public transport services in Cairo. These actions are briefly summarized in the following tentative recommendations:

1. Reduce the number of bus lines that terminate at Tahrir, Ramsis, and Attaba Squares.
2. Eliminate the Metro line between El-Demerdash and Ramsis Square because all its passengers could use the underground instead.
3. Due to the expected heavy transfer movements at stations along the underground route, it is important to take care in the design of the entrances to these stations and their connections to the surface transfer stations.
4. Increase and improve bus service that transport people between underground stations and different zones in the city. This, of course, can be achieved by different corridor analysis and route restructuring, as explained in other parts* of the final project report.

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* Cairo University/Massachusetts Institute of Technology, TPP, Bus Service Palnning, TAP Report No. 82-1, May 1982.

5. Introduce special bus lanes where appropriate, on streets that are expected to carry heavy volumes of bus trips (12000 passenger/hr and more) in 1987.

3.6 Recommendations for Further Study

The main objective of this investigation was to throw some light on the main impacts that are expected to take place on public transport service in Greater Cairo upon the operation of the regional U.G. line in 1987. Bearing in mind time, budget, and other constraints imposed on this study, the following recommendations for additional study are made:

1. The exercise described in this report should be repeated in a more comprehensive and refined way in order to improve the accuracy and reliability of the projected impacts.
2. Public transport corridor designs are necessary to coordinate the U.G. and other surface transport to get maximum benefit of the high investment in the U.G. These should be designed in detail.
3. Practical recommendations about the planning and design of major U.G. transfer stations and the related surface facilities should be developed after site and system studies are completed.