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  - The General Director of CTA Operation, Eng, Nabil El Mazny.
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  - The Chairman of Alexandria Passenger Transport Authority, **General Eng. Mohamed Salah El-Din Abd El-Moneim.**
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1. Introduction

During the last decade light rail transit (LRT) systems have been gradually reintroduced to many cities in Europe (e.g. Lile, Groneble, London, Manchester, Nanttes...). This has occurred after years of negletion since many systems were withdrawn from service in the 1950's. Reasons are many but perhaps most important are energy conservation and the possibility with the advanced technology of the late 20^{th} Centuary to eliminate LRT adverse impacts on traffic and on the image of the modern city. In 1991 the TRL started a pioneer work in cooperation with Institut National de Recherche sur les Transports et leur Securite (INRETS) of France to investigate the potential of LRT systems in developing countries cities and how the existing systems can perform in more acceptable efficient way. This work comes after the completion of two successive studies by TRL on metros and bus performance in developing countries (1,2). Hence the study on LRT performance in those countries completes this series of research work. It focuses on studying existing LRT systems in a set of East European and developing countries cities.

Cairo and Alexandria are two of the selected cities, each having two LRT systems that operated successively since the late 19^{th} and the early 20^{th} centuries. TRL (Overseas Unit), therefore, decided to cooperate with the Transportation Programme of DRTPC in conducting the part of the study in Cairo and Alexandria. The objective is to investigate the performance of the related LRT Systems, to know more about the operation environment and to detect the faced problems and the relevant successes. The scope of work concentrates on carrying out performance surveys on 4 selected corridors one for each of the 4 LRT systems of both Cairo and Alexandria.

2. General Features of Cairo and Alexandria Transit Systems

Greater Cairo (GC) is the largest metropolis in Africa and the Middle East with a population of more than 12 m. in 1990 and Alexandria (Alex) is the second largest city of Egypt and one of the major south Mediterranean ports. Its population reached 3.5 m. in 1991. However, during the summer months the resort is yearly visited by about 1 m. persons from allover the country and abroad. The gross area of GC is 2600 sq.km. but only 10% of which is inhabited whereas the area of Alex. is 27 sq.km. The transit modes are heavily used by the dwellers of the two cities and their visitors. Formal transit in Cairo includes in addition to bus, minibus, metro and ferry, two LRT systems; the tram and Heliopolis metro. In Alexandria two LRT systems exist; El-Ramel(Raml) and El-Madina (Madina), in addition to the other formal modes; the bus and minibus. Informal transit in the two cities consists of the shared taxi microbus vehicles running on licensed routes. Furthermore, the Egyptian National Railways (ENR) operates a suburban train line between Alex and Abu Keer. No information was gathered on this service in the course of the present study.

Table 1 summarises main features of formal transit systems in GC and Alex based on the available statistics of 1990/1991 (3,4,5,6,7 and 8). It is clear from this table that the bus system in GC is very important as it carries 70% of yearly passengers with a huge fleet of 2157 vehicles running on almost 5000 km. network. Whereas, in Alex where no metro exists the LRT system plays an important role carrying 67% of the yearly passengers with only 33% on the bus. LRT in GC looks of a minor importance as on 24 lines it carries merely 12% of yearly travel running third after metro which carries 18% on a single corridor. In absence of data on Alex total all modes daily travel it was only possible to say that formal transit is believed to be the main system for its dwellers. In GC however, the latest data shows that 46% of daily motorized trips are made by formal transit (9).

Table 1: General features of Greater Cairo and Alexandria transit systems*, (based on references 3 to 8).

Mode	City	Lengths of lines (km)	No. of lines	Fleet	% of yearly passengers
Metro	GC	42.7	1	100	18
	Alex	none			
Bus and Minibus	GC	5065	368	2157	70
	Alex	1869	115	301	33
LRT	GC	271	24	202	12
	Alex	110	21	170	67

* - Statistics of the period July 1990 to July 1991.
- Data on Alex do not include statistics on the suburban rail line Alex-Abu Keer.

3. Characteristics of LRT systems in Cairo and Alexandria

This section is based on the global information given in the available annual statistics and references of the operators (4,5,6,7 and 8).

3.1 Cairo LRT Systems

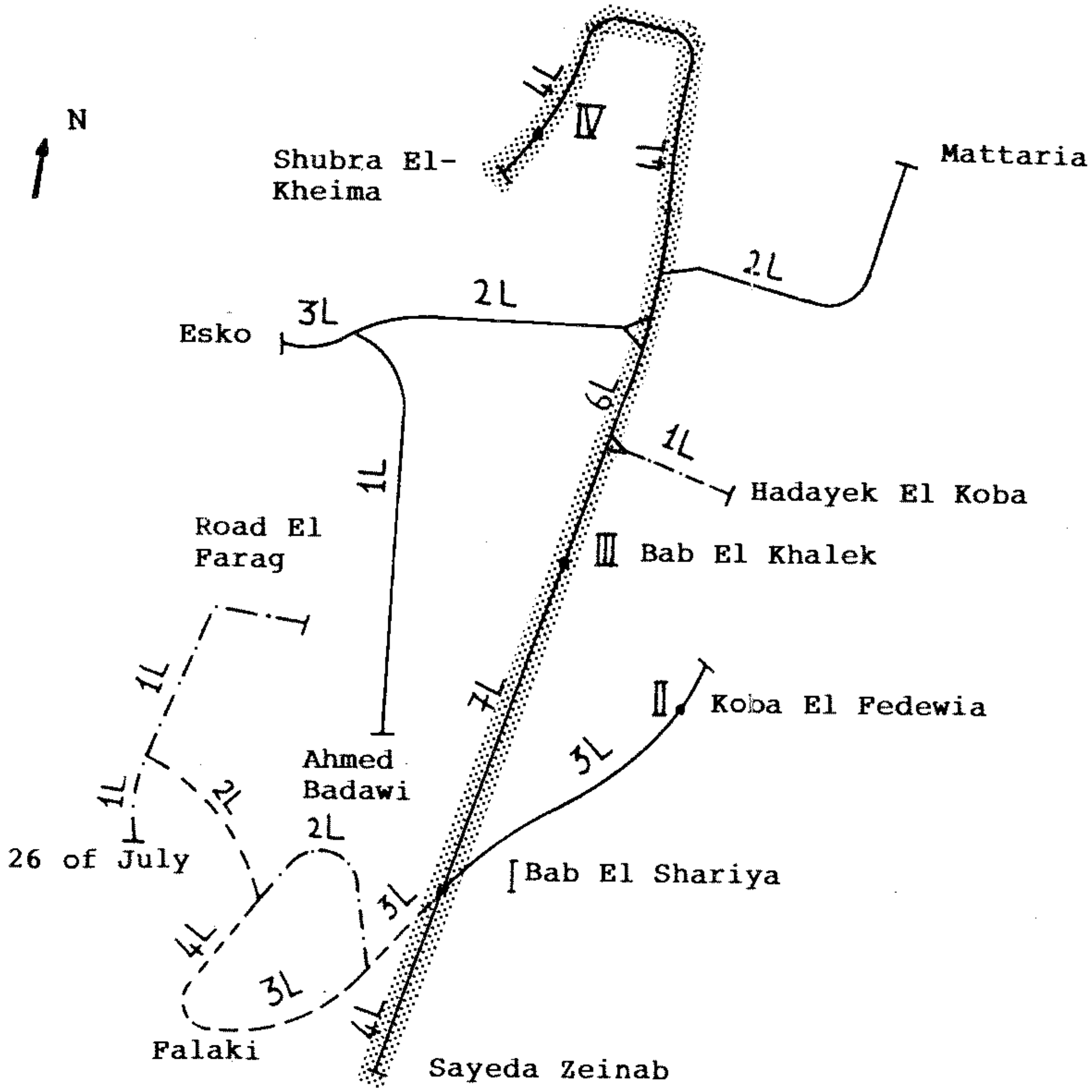
Two systems exist, the Tram (T) and Heliopolis Metro (HM). It was only in Dec. 1991 when the two systems were integrated under the Cairo Transit Authority (CTA) direction, which in addition is responsible of bus, minibus and ferry services. HM since its opening in 1910 had been operating under the Heliopolis Company for Housing and Redevelopment. The T system started 2 years earlier in 1908 with the objective of serving dwellers of Cairo and Giza cities (5). The network since the late 1950's has underseen elimination of routes and lines as local authorities started to worry about the space occupied by the track in the light of the increased vehicular traffic. Whereas the HM system which was built to serve the then newly suburb of Cairo (Heliopolis) expanded over the years. After integration under one operator the two systems will be able to use each others facilities and the routes will be integrated along some corridors.

Figures 1 and 2 show the T and HM existing networks, respectively and Table 2 gives the main features of the 2 systems. It should be noted that the information given in Table 2 are related to the period July 1990 to July 1991 (based on references 4 and 6)and before elimination of some of the T systems lines and tracks. The eliminated tracks are marked on Figure 1. It is clear from Table 2, however, that HM system in the above mentioned period carried about 47% of LRT passengers on 7 lines extending over 95 kms, whereas the T system carried the remaining 53% on a network of nearly double the HM one reaching 176 kms of lines lengths. Furthermore, the commercial speed of the HM system was about 1.3 times that on the T system. Here, it should be noted that the great majority of the HM system run on separate track that is fully devoted to the units. The T system, however, although in many sections run on fixed track, yet as a result of traffic congestion the track is not at all fully reserved for the units. Many interference occurs by vehicles and crossing pedestrians.

Table 2: Main operation features of the LRT systems in Cairo, July 1990 to July 1991 (based on references 4,6).

LRT system	Lines	Lines Lengths (km)	Fleet	Commercial speed (km/hr)	Daily Passengers* No.	%
Tram(T)	17	176	95	12.2	121134	53
Heliopolis Metro (HM)	7	95	107	16.1	105995	47

* Ticket and pass passengers.

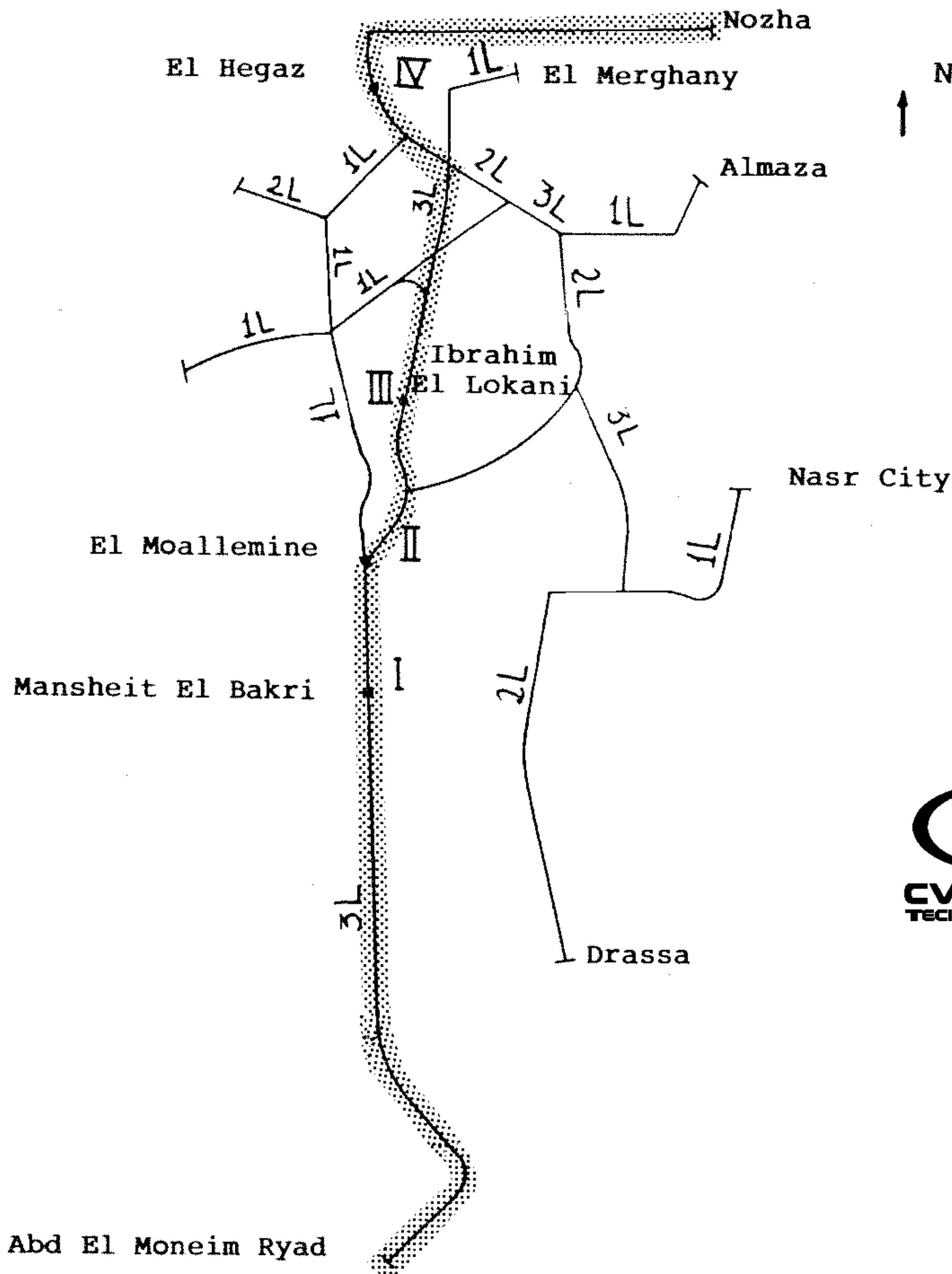


Key & notes:

- Survey points (I to IV), see Fig. 14 for details
- 3L = 3 Lines
- The studied corridor
- ------ Eliminated part before July 1990
- _._._. Eliminated part after July 1991
- ——— Existing track till July 1992

Only selected tram stops/stations are shown.

Figure 1: Cairo Tram (T) network, (not to scale), Cairo based on CTA maps 1990/1991.



<u>Key & notes:</u>

—•— Survey points (I to IV), see Fig. 15 for details

4L = 4 Lines

░ The studied corridor

Only selected tram stops/stations are shown

Figure 2: Heliopolis metro (HM) network, Cairo (not to scale), based on Heliopolis metro technical division maps, 1990/1991.

3.2 Alexandria LRT Systems

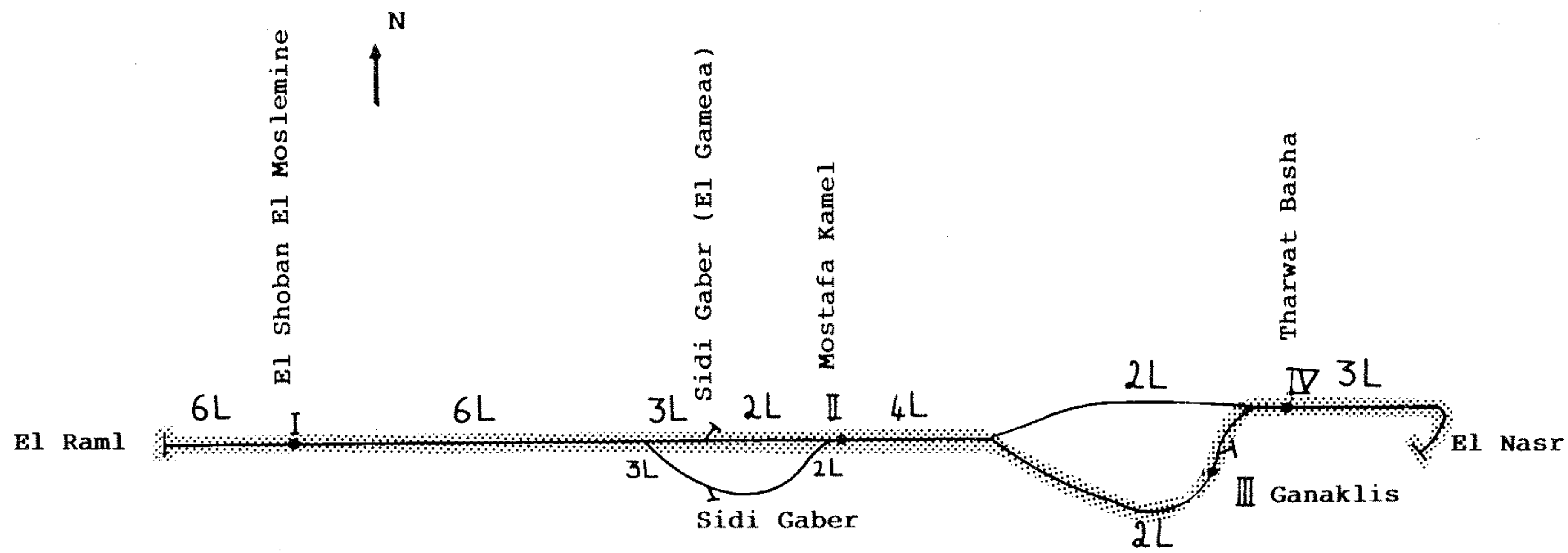
Two systems also exist in Alex, namely El-Ramel (R) and El-Madina (M). Both are operated by the Alexandria Passengers Transport Authority (APTA) which also operates the rest of Alex formal transit systems (bus and minibus). The R system has a long history as it was opened in Sept. 1862 as a horse-drawn light rail on a 6 km section of the very existing corridor of today. One year latter, steam engined trams started on the same track, which lasted till 1904 when the line was extended to 10 kms length and was totally electrified. And latter the M tram network was gradually introduced. For additional details refer to reference (7).

Figures 3 and 4 show the networks of R and M tram systems, respectively, and Table 3 gives the main operation features. It is clear from Figure 3 that the R system is operating on a single corridor of 10.5 km with two loops in the middle. The corridor is fully segregated with a respected right of way. The M tram system however operates mixed with traffic on the streets of the old city with an extended network. Table 3 indicates that the M system is larger than the R system in terms of line lengths, number of lines and the fleet of trains. However, both systems carry slightly different no. of passengers. Commercial speeds on the M system are much lower since trams run mixed with traffic contrary to the R system which operates on a reserved track.

Table 3: Main operation features of the LRT system in Alex, July 1990 to July 1991 (based on references 7,8).

LRT system	Lines	Lines lengths (km)	Fleet	Commercial speed (km/hr)	Daily Passengers* No.	%
Ramel(R)	6	48.5	36	20	274577	42
Madina(M)	15	61.5	134	10	356200	58

* tickets and pass passengers.



Key & notes:

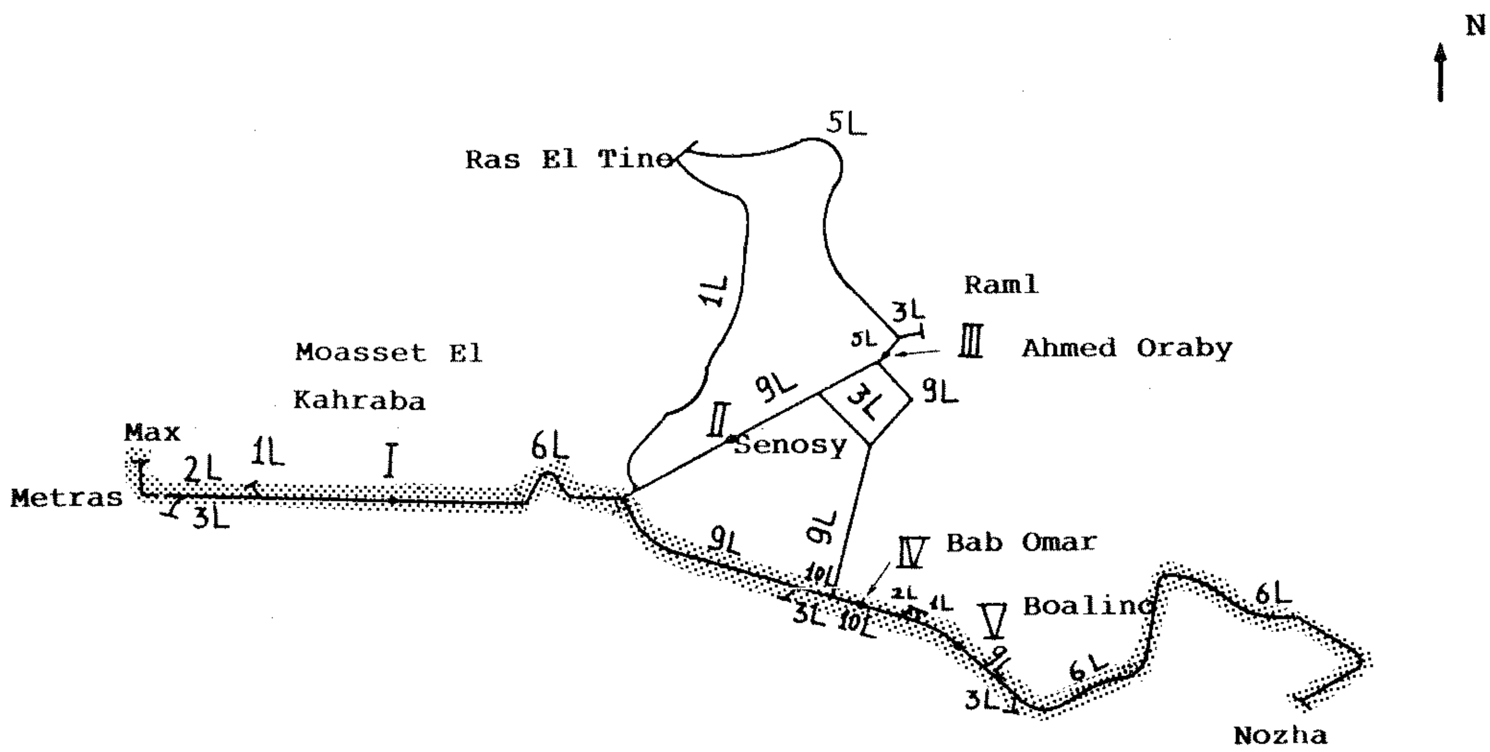
Survey points (I to IV), see Fig. 16 for details

6L = 6 lines

The studied corridor

Only selected tram stops/stations are shown

Figure 3: El-Raml tram (R) network, Alexandria (notto scale), based on APTA maps 1990/1991.



Key & notes:

—•— Survey points (I to V), see Fig. 17 for details

2L = 2 Lines

The studied corridor

Only selected tram stops/stations are shown

Figure 4: El-Madina tram (M) network, Alexandria (not to scale), based on APTA maps, 1990/1991.

4. Surveys Outline.

4.1 Objectives

It was out of the scope of the current work to undertake a comprehensive study of the 4 systems in consideration. Hence, it was decided to select a main corridor from each system to undertake performance surveys. The objectives of the surveys are:

- to measure the commercial speeds and journey times.
- to determine reasons and duration of delays en route.
- to observe roughly the loading features on vehicles.
- to determine the performance of trams on selected sections each including a stop.

4.2 Methodology

The selected corridors are as given below and as marked on Figures 1, 2, 3 and 4 for T, HM, R and M systems, respectively.

- for T system - Port Said Corridor, (Cairo 1).
- for HM system - El-Nozha Corridor, (Cairo 2).
- for R system - Raml Corridor, (Alex 1).
- for M system - Nozha-Max via Sherif St. Corridor, (Alex 2).

For each corridor 4 types of survey were performed namely,

- General inventory.
- On Vehicle Delay (OVD) survey.
- Tram Flow (TFL) survey.
- Occupancy At Stop (OAS) survey.

4.2.1 The General Inventory

This was meant to be just a general identification exercise that gives the main features of each corridor registering the length, type of track, number and location of major and minor junctions, type of traffic control for each junction and finally the major land marks along each corridor. Figure 5 shows the track categories and the inventory key.

4.2.2 OVD survey

Here the observers were asked to ride on a tram line on the corridor from terminal to terminal and back during the a.m. and p.m. peaks. They would register departure and arrival times from terminal to terminal, delay reasons and duration as well as the approximate no. of passengers boarding/alighting at each station in the first vehicle of the tram unit. Three observers worked on 3 successive trams starting 7.00 a.m. to 9.00 a.m. and 1 p.m. to 3 p.m. Each observer was standing in the driver cabin. The OVD survey was carried out during 12 days to achieve 6 readings for each corridor. The OVD form is given in Figure 6.

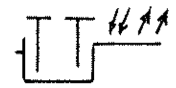
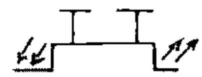
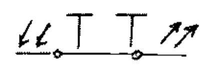
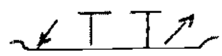
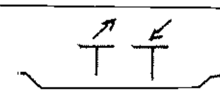
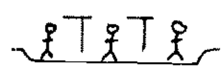
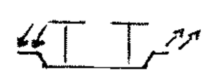
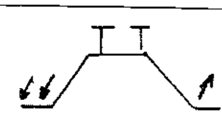
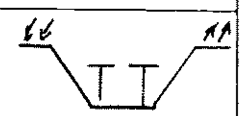
4.2.3 TFL survey

In this survey 2 observers were stationed one at each of 2 intermediate positions on each corridor during the morning (7-9 a.m.) and the afternoon (1-3 p.m.) peaks. The observer was asked to record the following information for each tram unit that passed in front of him in the predominant direction (and in the other direction whenever possible) of passenger traffic as given by the operators:

- no. of the tram.
- no. of the line.
- time of observation.
- degree of occupancy of each vehicle.

Fig. 7 gives the TFL survey form and Fig. 8 gives the degrees of occupancy ranging from "1/3 seated" to "Crushed" conditions. The locations of the TFL points of observation are marked on Figures 1, 2, 3 and 4 for T, HM, R and M systems selected corridors, respectively. Table 4 gives the estimated number of passengers in each tram car corresponding to each

Track Category

A	Fully Segregated, not drivable by traffic	
B	Segregated by high kerbs, cars can use in emergency	
C	Segregated only by white line or low kerb and police control	
D	Not segregated, traffic has one or more lanes	
E	Fully mixed, trams and traffic must share same space	
F	Pedestrian street, trams and peds. share same space	
G	Segregated	
H	Segregated, not drivable by traffic	
L	Segregated, not drivable by traffic	
M	Segregated, not drivable by traffic	

Inventory Key

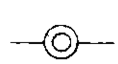
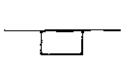
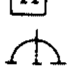
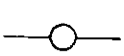
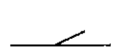
N	North		Big Junction
	Station	U	Uncontrolled Junction
	Big Station	C	Controlled by a policeman
	Informal Station	S	Traffic Signal
[A]	Track Category	SP	Survey point
	Terminal	CBD	Centre
	Junction		Branching

Figure 5: Track Categories and the inventory key.

DRTPC - Cairo University										(OVD Form)

City :
Surveyor :
Date :
No.of Cars :

Line No. :
Direction :
Origin Pt. :
Destination PT.:

Location	Stop Time			Pax.		Departure			Reasons of Delay or Comments
	Hr.	Min.	Sec.	On	Off	Hr.	Min.	Sec.	

P:Passengers (boarding/alighting).
S:Traffic signal.
C:Junction controlled by a policeman
U:Vehicles crossing the track.
T:Vehicles moving on the track.
X:Pedestrian crossing.

Figure 6: OVD survey form.

DRTPC - Cairo University (TFL Form)

City :
Surveyor :
Date :
Watch No. :

Station :
Direction :
Comments :

Car No.	Line No.	Observation Time			Occupancy		
		Hr.	Min.	Sec.	1	2	3

Figure 7: TFL survey form.

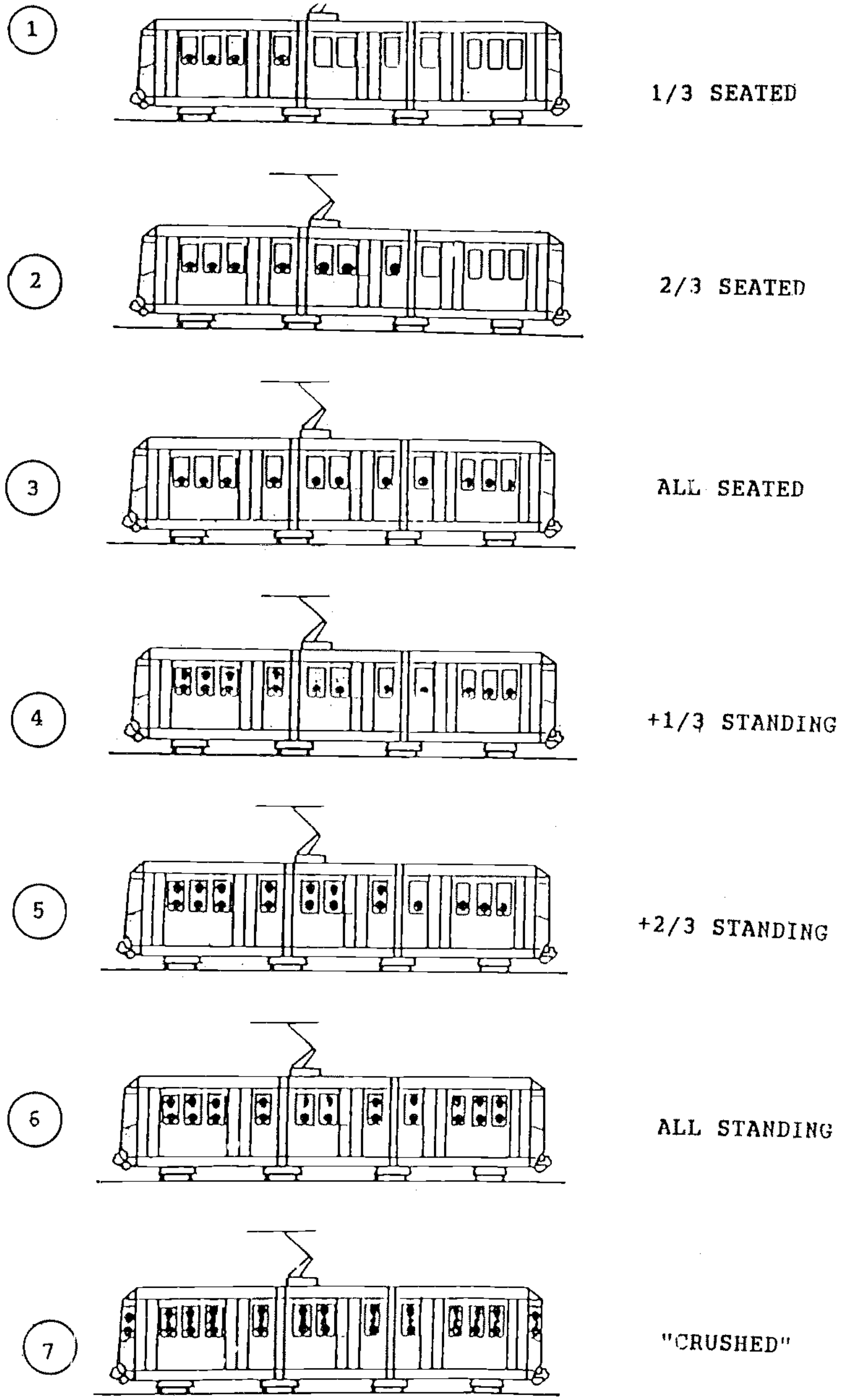


Figure 8: Degree of occupancy of tram cars.

degree of occupancy. It should be noted that the 6th and 7th degrees of occupancy are based on the number of normal and maximum standing passengers; 6 pax/m^2 and 7 pax/m^2, respectively, as given by the HM operator. Since, this information was not available for the other three systems it was assumed that the percentage of increase of number of passengers for the 7th degree of occupancy is the same as for HM system. In case of Cairo 1 it was found that 3 types of tram are in operation, with different capacities. Hence, an average figure of capacity was considered.

Table 4: Assumed no. of passengers in each tram car corresponding to the degrees of occupancy.

System	Tram		Heliopolis Metro			Raml			Madina*	
Occ. degree	Car1	Car2	Car1	Car2	Car3	Car1	Car2	Car3	Car1	Car2
1	13	13	13	21	13	11	11	11	12	12
2	27	27	27	27	43	21	21	21	23	23
3	40	40	40	64	40	32	32	32	35	35
4	77	77	79	96	79	92	103	92	69	69
5	115	115	118	107	118	153	173	153	103	103
6	152	152	157	159	157	213	244	213	137	137
7	179	179	185	180	185	251	288	251	161	161

* The units are operated in 1 or 2 cars.

4.2.4 OAS survey

Two major tram stops on each corridor were selected. The influence section of each stop was then defined as shown in the following illustration sketch.

Point A: is the point at which the tram starts to decelerate for stopping.
Point B: is the point at which the tram reaches normal speed.
A-B : the influence section of the stop.
Point O: is the point of observation.

Illustrative sketch of the OAS survey point section.

At point O two observers were stationed. One would keep an eye on the stop watch and the other would fill the following information in the survey form for the main direction of traffic.

- the same information as in the TFL form.
- time of arrival at point A.
- time of each stoppage between A and B.
- approximate no. of boarding and alighting passengers.
- time of each starting again between A and B.
- time of final departure from point B.
- reason of each stoppage.

The OAS form is given in Fig. 9 and the locations of the OAS observation locations are marked on Figures 1, 2, 3 and 4 for T, HM, R and M systems selected corridors, respectively. Sketches of the OAS survey locations on each of the 4 corridors are given in the Appendix.

4.3 Management of Surveys

The surveys were undertaken in full cooperation with the operators. A team of young civil engineering graduates from Cairo University was appointed. They firstly attended lecturing periods on the study objectives, the surveys nature, the forms and the expected output after data processing. Then they went to the field to investigate the predetermined points of observation. A series of pilot surveys were undertaken. The observers were then asked to manually process the data from the pilot surveys forms and to produce the expected output manually. During these activities lecturing sessions were arranged to answer any questions and to unify the work performance. Then, after obtaining necessary permissions from operators and the traffic police the real work started between 19 December 1991 and first June 1992. All the team was insured against field accidents before undertaking the pilots and for all the surveys period, and the surveys went on as planned. However, in 4 occasions the work had to be totally repeated. Once because a major traffic acci-

DRTPC - Cairo University (OAS.FORM)

City :
Surveyor (1) :
Surveyor (2) :

Date :
Station :
Direction:

Watch No. :
Comments :

Car No.	Line No.	Arrival Time			Occupancy			Stop Time		Pax.		Move Time		Departure		Reasons of Delay or Comments
		Hr.	Min.	Sec.	1	2	3	Hr.	Min.	On	Off	Min.	Sec.	Min.	Sec.	

P:Passengers (boarding/alighting)
S:Taffic signal.
C:Junction controlled by a policeman.
U:Vehicles crossing the track.
T:Vehicles moving on the track.
X:Pedestrian crossing.
O:Others.

Figure 9: OAS survey form.

dent interrupted traffic flows on the Alex 2 and 3 times because of unusual heavy rain that disrupted tram flows on the Alex 2 and the Cairo 1. It should be noted that the work was undertaken on the 4 corridors successively in the following order Cairo 1, Cairo 2, Alex 1, Alex 2 and no observations were undertaken during the month of Ramadan as flow patterns naturally change.

4.4 Data Checks and Processing

Several checks were undertaken as follows and before data processing.

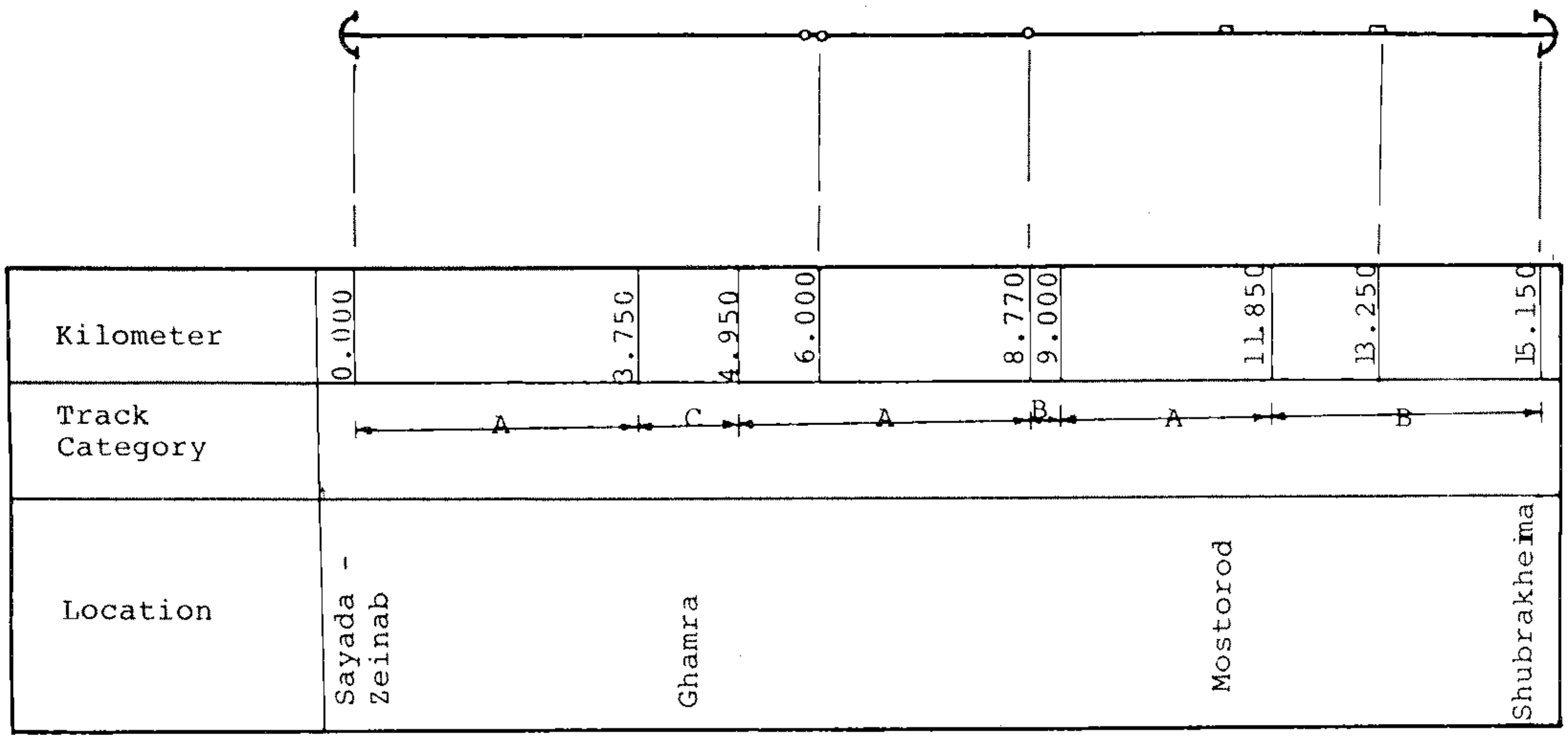
- each form was checked after each day of field work; by each observer.
- any problem during work was reported to the office; the appropriate advice was given.
- before data entry on the LOTUS 123 software the forms were checked again by the office engineer; any unclear matter was clarified by the concerned observer.

Then data entry on the computer took place, and a manual check on a sample of surveys forms was done to make sure that the LOTUS package would produce the needed results. Print outs of the entered data were checked manually and the needed corrections were made.

5. Analysis of Results

5.1 Inventory Survey Results and Operators Data

Figures 10,11,12, and 13 show sketches of the general features of Cairo 1, Cairo 2, Alex 1 and Alex 2, respectively, and Table 5 summarizes the results of the inventory of the selected 4 corridors. The main comments are set out below in a comparative manner.

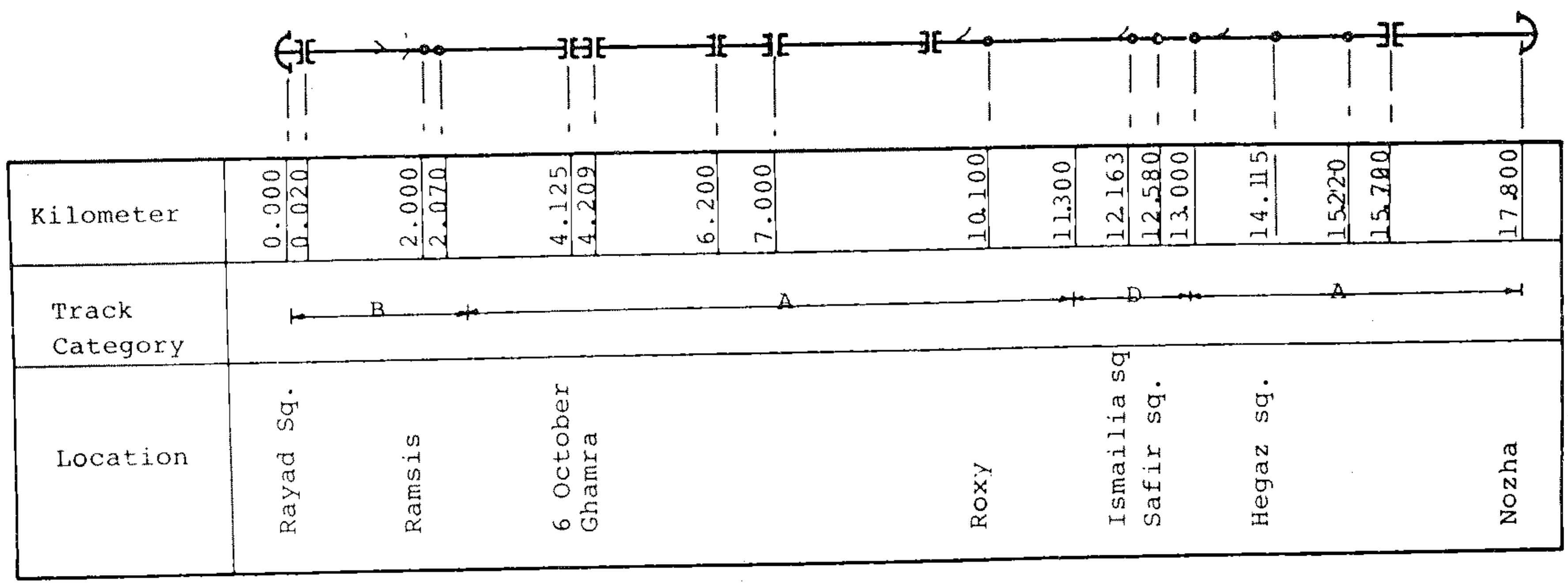


Key & notes:

- Big station.
- Big junction.
- Terminal.
- Fly over
- Branching

See Figure 5 for track categories key.

Figure 10: Sketch of the main results of Cairo 1 inventory.



Key & notes:

Big station.

Big junction.

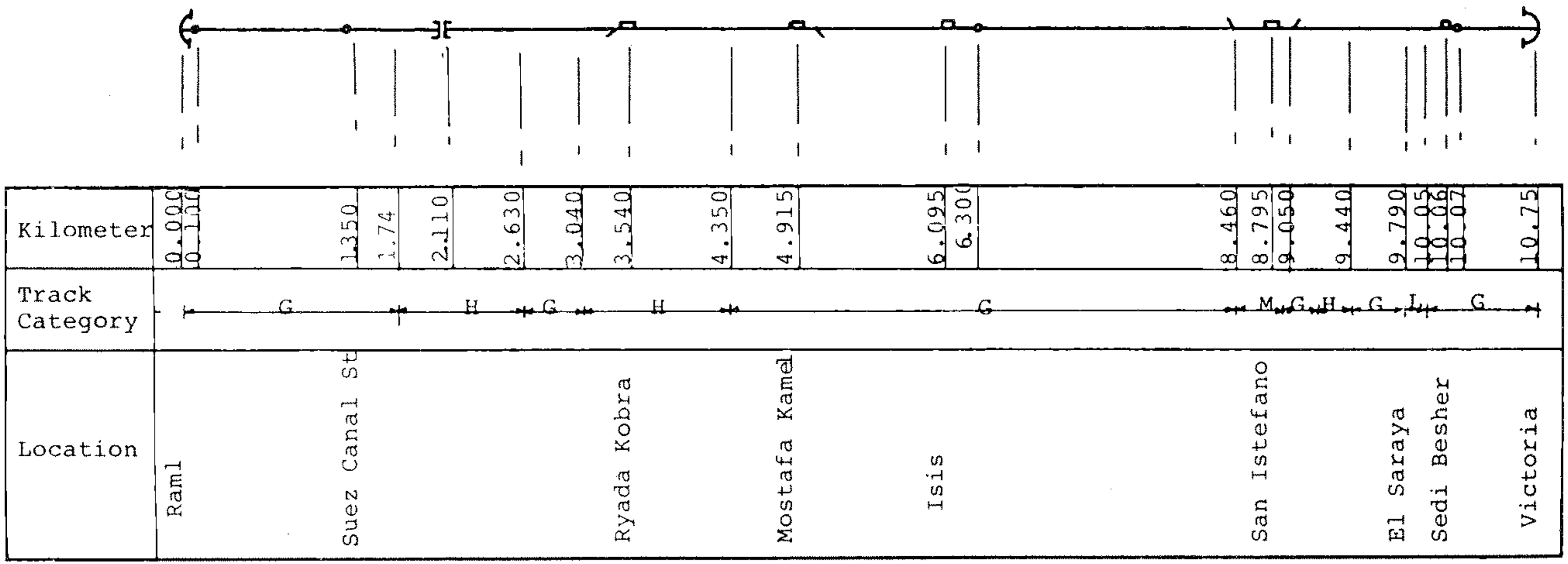
Terminal.

See Figure 5 for track categories Key

Fly over

Branching

Figure 11: Sketch of the main results of Cairo 2 inventory.

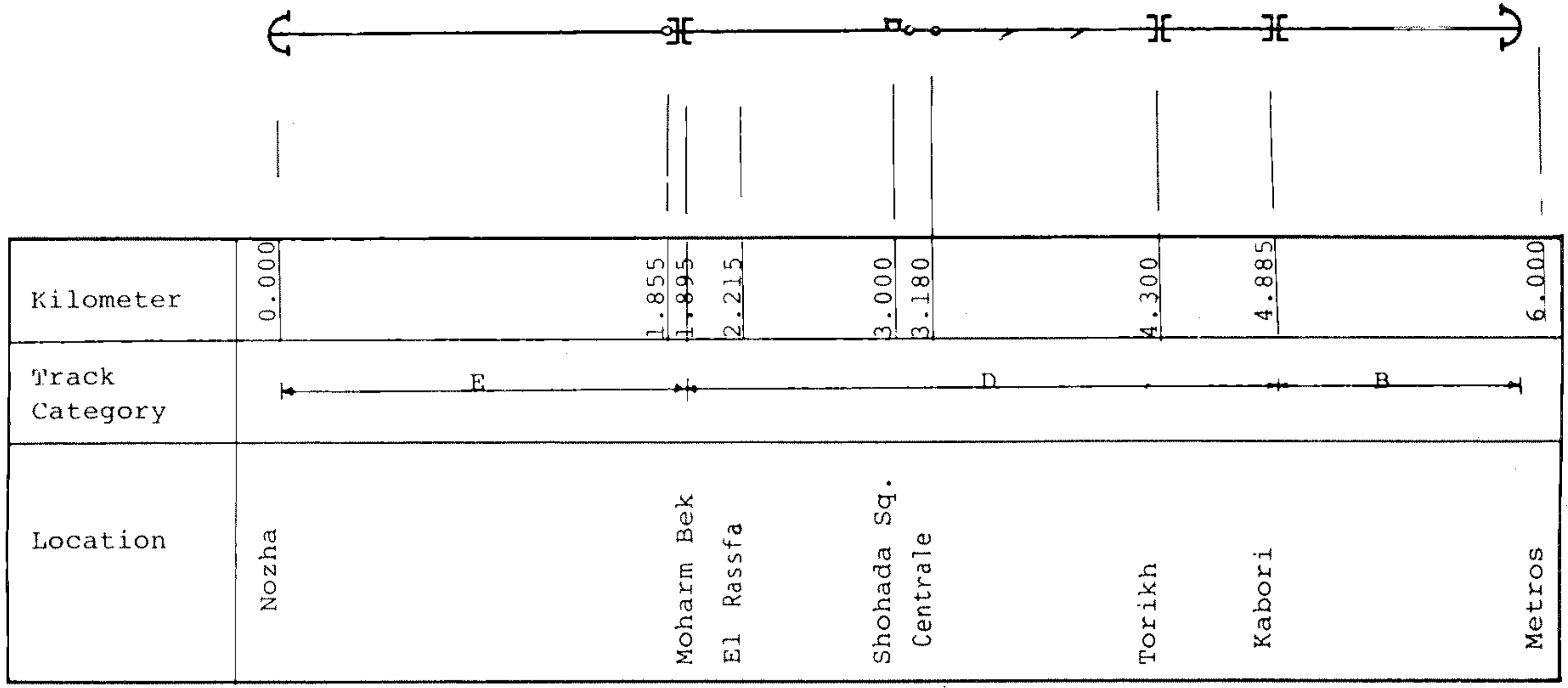


Key & notes:

- Big station.
- Big junction.
- Terminal.
- Fly over
- Branching

See Figure 5 for track categories key.

Figure 12: Sketch of the main results of Alex 1 inventory.



Key & notes:

- Big station.
- Big junction.
- Terminal.
- Fly over
- Branching

See Figure 5 for track categories key.

Figure 13: Sketch of the main results of Alex 2 inventory.

Table (5): Summary of the main features of the selected corridors.

Corridor	Length (km)	No.of lines	Stops*			Stops per km.	Junction*		Junction per km.	Junc. control**			Track***			Area+ zone
			M	N	I		M	N		S	P	U	type	%	% not driveable	
Cairo 1	15.15	5	3	35	--	2.5	3	32	2.3	-	13	22	A B C	69 23 8	92	1,2&3
Cairo 2	17.79	7	3	32	--	2.0	7	19	1.5	16	-	10	A B D	76 14 10	90	1,2&3
Alex 1	10.75	6	7	22	--	2.7	4	18	2.0	17	3	2	A G H L M	4 70 5 16 5	100	2
Alex 2	6.00	14	4	29	1	5.7	4	18	3.5	1	-	21	B D E	22 46 32	22	2

* M= Major N= Minor I= Informal
** S= Signal P= Policeman U= Uncontrolled
*** see Fig. 5 for key of track types.
\+ 1 = CBD 2 = Middle 3 = Outer suburb

- The Alex 2 though having the least length of 6 kms it carries 14 tram lines which is by far the highest number of lines among the 4 corridors.
- The Cairo 2 has 2.0 stops/km which is the lowest and the Alex 2 has the highest figure of 5.7 stops/km.
- 35 junctions are extended over the length of the Cairo 1 with a rate of 2.3 junctions/km. Nearly the same rate occurs at the Alex 1 which has 22 junctions over its total length of 10.75 kms. The Cairo 2 has the least no. of junctions per km reaching only 1.5 with the maximum rate of 3.5 junctions/km exist along Alex 2.
- The great majority of junctions on the Cairo 2 and Alex 1 are signalized whereas most of those on Cairo 1 and Alex 2 are uncontrolled either by a signal or a traffic policeman.
- Alex 1 though has 5 different track types along its corridor, yet they are all segregated from traffic (i.e. 100% of its length are not driveable by traffic). Cairo 1 and Cairo 2 has 92% and 90% of there total lengths not driveable by traffic, respectively.
- On the other hand Alex 2 has only 22% of its length not driveable by traffic.
- The two Alex corridors pass totally in zones of middle types, i.e. neither CBD nor suburban. Whereas the 2 corridors of Cairo run through the three area types suburban, middle and CBD.
- Based on the above general features, it may be said that the Cairo 2 of HM system is that which offers the highest level of service followed by the Alex 1. Whereas the Alex 2 and Cairo 1 are less superior. They are both confronted with uneasy operation environment basically because Alex 2 operates in a mixed with traffic fashion, and Cairo 1 though run in segregated track yet it lacks many technical and management requirements. In addition, the Alex 2 is passing through heavily congested street system in a very high population density areas. Hence, it may be very difficult for the operator to increase level of service on this corridor. Finally, it is believed that reaching

definite conclusions on levels of service of the 4 corridors would certainly need a wider data collection effort leading to an in depth analysis.

Information on operation of tram lines on each of the selected 4 corridors are given in the Appendix as derived from operators statistics.

5.2 OVD Survey Results

Table 6 gives measured journey times and calculated commercial speeds on the selected 4 corridor based on the OVD survey results. The main comments are given below.

- Cairo 2 offers the highest commercial speeds regardless of the peak period, reaching 17 and 14 km/hr for a.m. and p.m. peaks, respectively. It is important to note, however, that for Alex 1 the commercial speed may have been reduced because of repeated tram stoppage due to the many intersections with vehicular traffic. This is natural as Alex is a linear city and the corridor is extending along the eastern part of the city parallel to major arterials and hence intersected by many crossing roads.
- Trams on the Alex 2 operate with very low commercial speeds of 6 and 5 km/hr for the a.m. and p.m. peaks, respectively. This confirms the results obtained from the corridors inventory as given earlier.
- The Cairo 1 is characterized by consistent journey times over the 2 peak periods and the 2 directions of travel as the relevant coefficient of variation is merely 0.07. This means that operation features along this corridor is almost unchanged during the 2 peaks and in both directions.

Table 7 gives a comparison between average journey times measured during a.m. and p.m. peaks in both directions of travel for each corridor and scheduled ones as given in the operators

Table (6): Journey times and commercial speeds on each of the selected 4 corridors based on OVD survey results.

Corridor	O/D	Length (km)	Peak	Journey time (min)	(a) cv	Comm. Speed (b) km/hr a.m.	Comm. Speed (b) km/hr p.m.
Cairo1	Shourba/Sayda	15.15	a.m. p.m.	83* 91	0.07	11	11
	Sayda/Shoubra		a.m. p.m.	** 79*			
Cairo2	Tahrir/Nozha	17.79	a.m. p.m.	65* 78	0.13	17	14
	Nozha/Tahrir		a.m. p.m.	61 80*			
Alex1	Victoria/Ramel	10.75	a.m. p.m.	57* 55	0.10	12	11
	Ramel/Victoria		a.m. p.m.	49 63*			
Alex2	Nozha/Mitras	6.00	a.m. p.m.	60* 65	0.13	6	5
	Mitras/Nozha		a.m. p.m.	63 79*			

* heaviest direction passenger traffic
** could not be obtained
(a) coefficient of variation for all of the journey times of each corridor
(b) average of each peak in both directions

statistics. Though the comparison would have been more effective if the two time periods were the same, yet some useful comments can be observed as given below.

- For Cairo 2 and Alex 2 the 2 averages are very close. Hence, it may be said that operation conditions during peaks along the 2 corridors are not very much different from those prevailing along the day.
- For Cairo 1 and Alex 1 the 2 averages are quite different with the scheduled journey times much lower than the measured ones. Thus, it may be said that operation conditions unexpectedly change than planned along these 2 corridors especially during peaks.

Table (7): Average journey times on the 4 corridors during peaks compared to scheduled ones during operation hours.

Corridor	Cairo1	Cairo2	Alex1	Alex2
Avg. journey time during a.m. & p.m. peaks for both directions (min.)*	84	71	56	67
Scheduled average journey time (min.)**	53	66	32	64

* based on OVD survey results
** based on operators statistics

Table 8 gives the percentage of delay reasons along each corridor resulting from the OVD survey. The main comments are set out below.

- By far the most important reason for delay on the 4 corridors is the stoppage for allowing passenger boarding/alighting, which is quite reasonable. However, it remains to investigate whether the time spent for this reason is optimum or not. It is, therefore, recommended that the operators investigate this question. Accordingly, there could be a good chance to reduce delay via efficient passenger management at stops if it appears to be warranted.

Table (8): Percentage of delay reasons along the 4 selected corridors based on OVD survey results.

Delay Reason	Cairo 1		Cairo 2		Alex 1		Alex 2	
	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M
P	62	64	85	68	65.0	93	93	64.8
S	--	--	7	10	5.5	--	--	5.6
C	6	7	--	1	4.0	--	--	--
U	3	3	1	3	--	1	0.7	4.4
T	1	1	--	3	10.0	3.0	2.6	9.6
CR	16	18	1	3	3.5	2.5	1.2	3.4
O	12	7	6	12	12.0	0.5	2.5	12.2

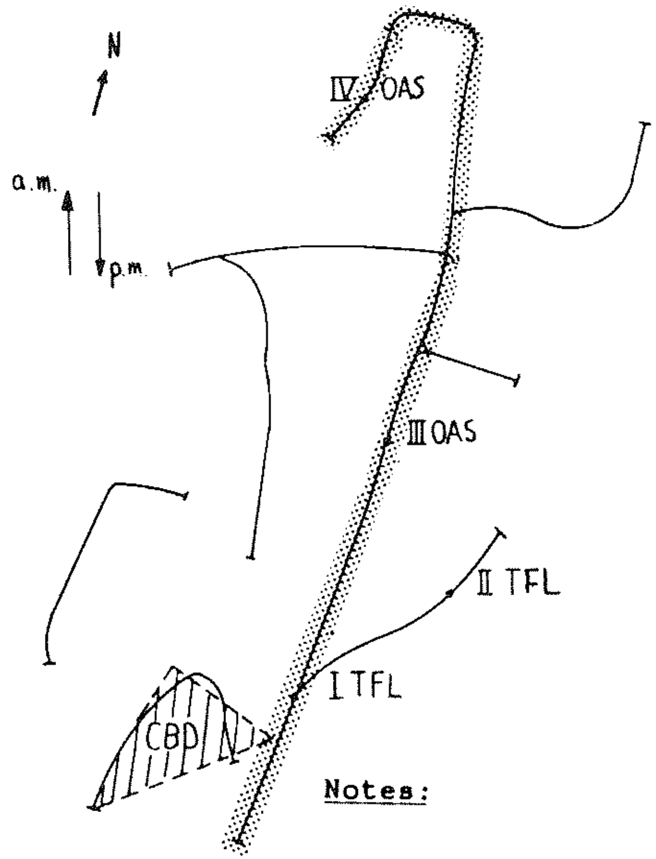
P= Passengers (boarding/alighting) U= vehicles crossing the track
S= trafficsignal T= vehciles moving on the track
C= junction controlled by traffic policeman
CR= combined reasons (i.e. P+S,P+C,..etc.)
O= others (e.g. change of crew, in front tram is stopping, driver talk with inspector or maintenance workers, power failure, driver buying food, etc.).

- In some instances the "other" reasons of delay (e.g. change of crew, in front tram is stopping, driver talk with inspector or maintenance workers, power failure, driver buying food, etc.) are relatively high. These reached 12% in 4 cases of a.m. or p.m. peaks on the 4 corridors. Some of these reasons should be eliminated via tighter control on driver behavior. Yet some others like power failure may be out of hand unless technical improvements are introduced.

5.3 TFL Survey Results

As mentioned in section 4 the OAS survey form included a part in which TFL information is also recorded. It is felt more convenient to present the results of this part together with those of the TFL survey. Table 9 summarizes the TFL data obtained at survey points of the 2 surveys. The table gives averages of headways (min.) and tram unit occupancies (pax) on each survey point in both directions and in the predominant direction of travel, for a.m. and p.m. peaks. It should be noted that these averages, are for all the observations of all the tram units passing at each survey point regardless of the tram line number. Documentation of TFL results from both surveys by tram line are given in the Appendix. The results can be affected by the location of the survey points which are shown on Figures 14,15,16 and 17 for the Cairo 1, Cairo 2, Alex 1 and Alex 2, respectively, (see also Figures 1,2,3 and 4). For instance, some TFL points are located on a corridor branching from the one under consideration. On some locations, furthermore, some lines terminate before reaching a TFL survey point. This will be, therefore, referred to during the following comments on Table 9.

- For the Cairo 1 average pax per tram unit in the p.m. peak are nearly twice those in the a.m. peak for points of observation I, II and III. Headways are increased on points II and IV as a result of branching.



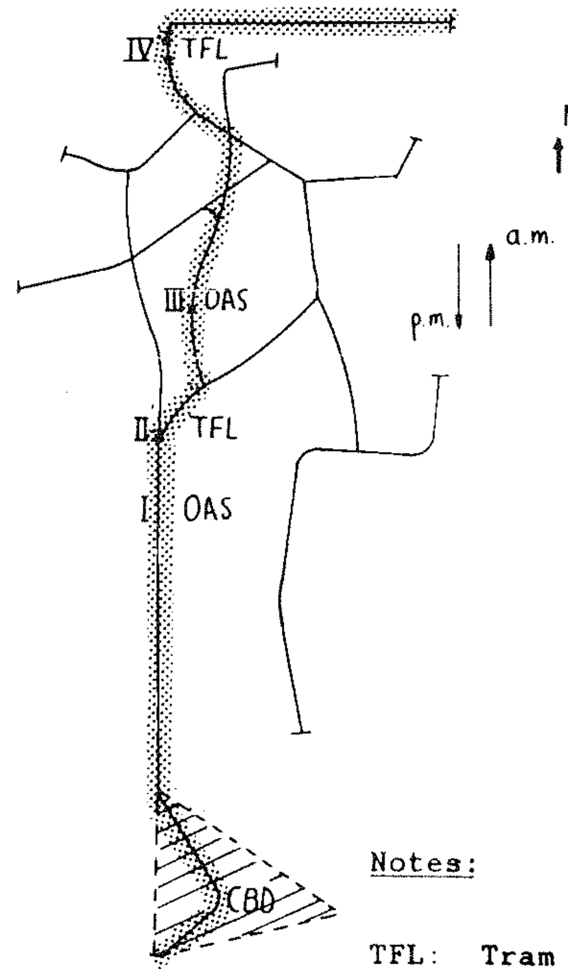
Notes:

TFL: Tram flow survey

OAS: Occupancy at stop survey

↑ : Predominant direction (a.m./p.m.)

Figure 14: Location of TFL and OAS survey points for Cairo 1 (PORT SAID Tram Corridor - Cairo, not to scale).



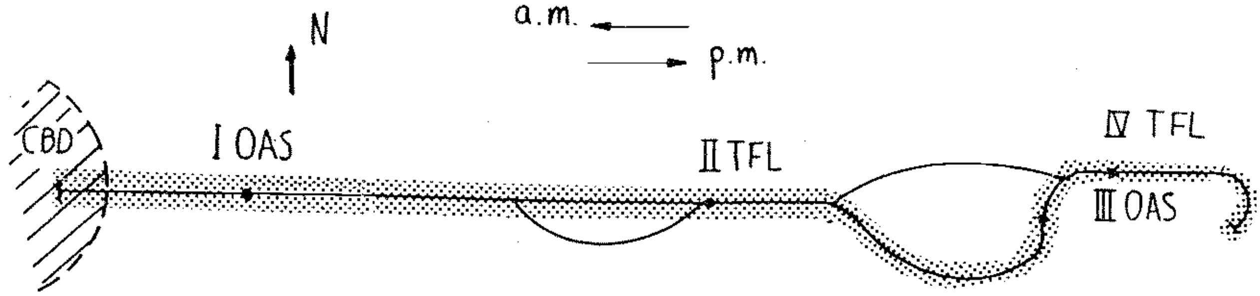
Notes:

TFL: Tram flow survey

OAS: Occupancy at stop survey

↑ : Predominant direction (a.m./p.m.)

Figure 15: Location of TFL and OAS survey points for Cairo 2(Nozha Corridor of Heliopolis Metro - Cairo, not to scale).



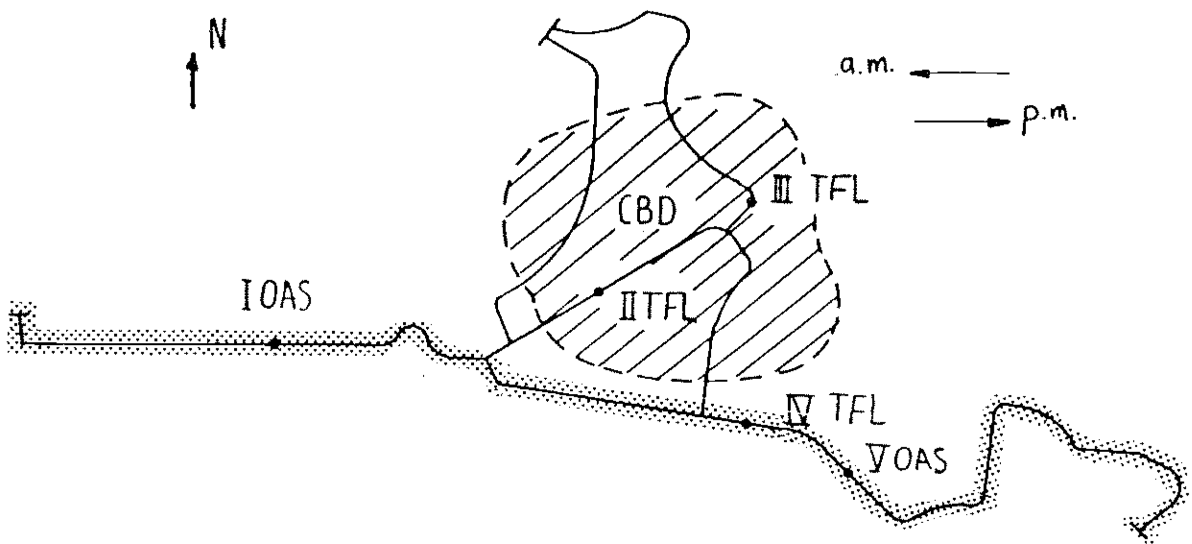
Notes:

TFL: Tram flow survey

OAS: Occupancy at stop survey

——→ : Predominant direction (a.m./p.m.)

Figure 16: Location of TFL and OAS survey points for Alex 1 (EL Raml Corridor - Alexandria, not to scale).



Notes:

TFL: Tram flow survey

OAS: Occupancy at stop survey

——→ : Predominant direction (a.m./p.m.)

Figure 17 : Locations of TFL and OAS survey points for Alex 2 (Nozha - Max via Sherif St. Corridor of El Madina Tram-Alexandria, not to scale).

Table 9: Average tram unit occupancies and average headway at survey points during a.m. and p.m. peaks for the 4 selected corridors (TFL results).

Corridor	Survey point	Direction of travel									
		At survey point				Direction+		In P. direction			
		Avg.Occ.(pax)		Avg.Headway				Avg. pax		Avg.Headway	
		a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.
Cairo 1	I	65	110	1.7	2.3	T	F	96	138	2.9	4.2
	II*	63	121	4.8	5.2	T	F	45	80	8.0	9.9
	III	72	132	3.0	3.5	T	F	79	163	5.3	7.5
	IV	71	71	5.3	7.5	T	F	99	91	9.3	10.6
Cairo 2	I	320	394	5.4	7.3	F	T	376	359	11.0	13.2
	II	293	425	5.3	8.5	F	T	383	425	9.8	11.4
	III	273	297	9.8	14.0	F	T	282	287	19.4	14.2
	IV	155	157	16.0	21.0	F	T	162	173	29.0	29.0
Alex 1	I	**	**	**	**	T	F	437	587	3.8	4.2
	II	424	445	2.2	2.4	T	F	620	544	4.5	4.3
	III	**	**	**	**	T	F	318	332	4.8	4.6
	IV	281	325	3.3	2.2	T	F	432	205	4.5	4.3
Alex 2	I	**	**	**	**	F	T	58	95	3.4	4.7
	II*	71	145	2.3	7.6	F	T	70	113	3.0	10.3
	III*	121	205	3.6	5.4	F	T	92	214	3.6	7.3
	IV	130	120	**	**	T	F	130	120	1.1	2.0
	V	**	**	**	**	T	F	100	89	1.6	1.8

Notes:
- survey points are shown in Figures 14 to 17.
- average occupancy is determined for all units passing at the survey point
- Headway is defined as the time interval (min.) between 2 tram units passing successively at the survey point regardless of the tram line number.

\+ T = to CBD direction - and F = from CBD direction.

* out of corridor

** No observations at the non-predominant direction were possible to obtain.

- On the Cairo 2 average pax. per tram unit are nearly equal during a.m. and p.m. peaks particularly for points I, III and IV showing a balance in tram crowdness during peaks. In general, occupancies on points I and II are higher than on points III and IV which can be attributed to branching of lines prior to these latter 2 points. Headways at points I and II are, therefore, lower than those at the other 2 points.
- As for headways on the Alex 1 it appears that they are nearly equal for the 2 peak periods especially in the predominant direction which may indicate a stable travel pattern on the corridor.
- For the Alex 2, point I during the a.m. peak has the lowest tram unit occupancy. This can be related to the location of this point on a section dominated by warehousing and light industries rather than heavy populated as the sections of points II, IV and V. On points IV and V the lowest headways occur even among all other points of observation on all the 4 corridors. This may be a result of the locations of these 2 points where many, tram lines pass throughas can be seen from Figure 4. Furthermore, it is interesting to note that, at points II and III, relatively a great variation in the observed headways between a.m. and p.m. peaks occurs.
- A general observation on Table 9 show that the Cairo 1 occupancy of tram units is the least among all other corridors. This may reflect the uneconomic operation on the corridor and the unpopularity of trams running on it as a result of its low level of service.
- In addition, it is clear that average pax per tram units on the Alex 1 is the highest among all other cases regardless of the peak period. This may be due to the high capacity of the tram units operating on this corridor.

5.4 OAS Survey Results

This section gives the main results of the OAS survey except those related to its TFL part which are already presented and discussed in section 5.3.

Table 10 gives the percentage of the main reasons of tram stoppage along the influence section at each of the selected 2 tram stops for each of the 4 corridors under consideration. The main comments are given below.

- For the Cairo 1 along the section of point IV, the tram units are delayed mainly due to passengers handling which reached 95% of the delay reasons.
- For the Cairo 2 the main reasons of delay along point III section were on/off passengers at the station and stopping at the traffic signal. Since section I did not include a traffic signal the main reason for delay was on/off passengers at the stop.
- For the Alex 1 along points I and III sections the main reason for delay was the traffic signal. On/off passengers did not cause significant delay. This reflects how this corridor is affected by the existance of many signalized junctions along its path which do not give priority to the tram.
- On the Alex 2 the main reason for delay along the section of point I is a combined reason of "on/off passengers" and "uncontrolled junctions". Along point V section it is interesting to note that 30% of the delay occurred because of traffic vehicles running on the track and 29% occurred because of a combined reason of "on/off passengers" and "vehicles on the track". Thus, it is clear that operation conditions are difficult.

Table (10): Percentage of the main reasons of tram stoppage along the influence section of each of the 2 OAS selected stops by corridor in the predominant direction of passenger traffic.

Corridor	Survey* point	Delay reason***									
		P	S	U	T	O	X+C	P+S	P+U	P+O	P+T
Cairo 1**	IV	95.0	-	3	-	-	1.2	-	-	0.8	-
Cairo 2	I	89.2	-	-	-	10.8	-	-	-	-	-
	III	45.9	44.7	-	-	2.2	-	7.2	-	-	-
Alex 1	I	5.6	94.1	-	-	-	-	0.3	-	-	-
	III	3.5	88.1	-	-	-	-	8.4	-	-	-
Alex 2	I	12.0	-	-	-	-	-	-	88.0	-	-
	V	41.0	-	-	30	-	-	-	-	-	29

* Refer to Figures 14 to 17.
** It was very difficult during OAS survey at section I to obtain reliable results.
*** <u>Delay reasons:</u>

P = Passengers (boarding/alighting) U = vehicles crossing the track
S = traffic signal T = vehciles moving on the track
C = junction controlled by traffic policemen X = Pedestrian crossing
O = others (e.g. change of crew, in front tram is stopping, driver talk with inspector or maintenance workers, power failure, driver buying food, etc.).

Table 11 gives average travel time, delays and on/off pax along the OAS sections on each of the studied 4 corridors. The main comments on this table are set out below.

- Average on/off passengers at the LRT stops under consideration ranged between 9 and 40.
- Average time per on/off passenger ranged between 0.60 sec./passenger and 2.20 sec./passenger.
- Passenger boarding/alighting management along the Alex1 seems to be effective. The average time required for each boarding /alighting passenger was small for both I&III,reaching 0.80 sec. for the stop at section I and 0.60 sec. for the stop at section III.This is irrespective of the high on/off pax. at the stop on the former section. The well designed stops and platforms along this corridor may have partially attributed to this result.

Table 12 gives the percentage of delay to travel time and the percentage of delay reasons to total delay along the OAS sections for each of the 4 selected corridors. The main comments are given below.

- Sections delay ranged between 37% and 60% of travel time along the section in all the cases.
- The highest delay percentages of sectional travel time are spotted on the Alex1 reaching 60% and 50% for sections I and III, respectively.
- The lowest delay percentages of sectional travel time are observed on the Cairo 1 reaching 37% and 39% for sectionsIII and IV, respectively.
- The percentages of delay to sectional travel time due to handling on/off passengers at stops are generally higher than those for other reasons of delay.

In addition, the OAS data was used to plot 3 scatter diagrams for each survey section, namely:

- "on/off passengers" vs. "stopped wheel time for loading and unloading".
- "on/off passengers" vs "travel time along the section".

Table (11): Average travel time/delays and on/off pax. along the OAS influence sections of the selected stops on each corridor for the predominant direction of traffic during the a.m. and p.m. peaks.

Corridor	Section	Section travel time (sec.)	Avg. stopping time (sec.)			Avg. on/off pax. at the stop	Avg. time per on/off passenger (sec./pax.)
			On/off pax.	other* reasons	total		
Cairo 1	III	59	20	2	22	13	1.5
	IV	54	19	2	21	13	0.7
Cairo 2	I	79	39	1	40	40	1.0
	III	96	27	19	46	22	1.2
Alex 1	I	88	32	21	53	40	0.8
	III	141	6	65	71	10	0.6
Alex 2	I	53	20	1	21	9	2.2
	V	55	23	2	25	13	1.8

* reasons other than only for on/off pax.

Table (12): Percentage of delays to travel time along the OAS influence sections of the selected stops and percentages of delay reasons to total delay.

Corridor	Section	% delay to travel time			% delay reason to total delay	
		pax.	other	total	pax.	other
Cairo 1	III	34	3	37	92	8
	IV	35	4	39	90	10
Cairo 2	I	49	1	50	98	2
	III	28	20	48	58	42
Alex 1	I	36	24	60	60	40
	III	4	46	50	8	92
Alex 2	I	38	2	40	95	5
	V	42	4	46	92	8

- "on/off passengers" vs. "total stopped wheel time".

Accordingly, 6 plots were produced for each corridor. These sets of plots are given in the Appendix. However, it is interesting to note that examination of these plots did not reveal any dominant trend that can encourage undertaking curve fitting exercise.

6. Conclusions and Recommendations

This section presents the main conclusions of the study. These are based on the general characteristics of the 4 LRT systems under consideration given by the operators as discussed in section 3 and on the discussions of the results of the surveys performed on the 4 selected corridors as given in section 5.

- LRT systems in Alex play a very important role in public transport travel in the city which seems not to be the case in GC where the bus (and metro) dominates. LRT in Alex carry almost 67% of daily transit travel as compared to merely 12% in GC. It should be noted that the Alex-Abu Keer suburban rail that belongs to ENR is not included in the analysis as mentioned in section 2.
- Increasing ridership can yet be achieved on the 4 systems if operation conditions are improved. However, this naturally requires initial costs that may be difficult to achieve in the near future.
- If LRT systems ridership is increased especially in Cairo, the heavy burden put on the bus and minibus system (carrying 70% of daily transit trips) can be gradually relieved. This of course can exert positive impact on the global operation cost of the CTA as bus operation is more expensive than LRT bearing in mind the carrying capacity of each mode.

- Operation conditions of Cairo 1 are very difficult. It is clear that many improvements (technical and management) are needed in order to raise ridership and to reduce operation cost.
- Although the operation environment along the Alex 2 is very difficult with the tram units operating in a mixed with traffic fashion, thus reducing commercial speeds sharply, yet ridership levels are reasonably high on the corridor.
- The Alex 1 is a well established corridor on which demand is high and ridership on certain sections are accordingly very high. Yet this corridor on which trams run on a reserved track suffers from many interruptions by several crossings with traffic. It is therefore necessary to improve operation by introduction of priority schemes giving advantage to trams over vehicular traffic at least at certain points. This of course warrants specialized studies so as to achieve a balance between the 2 modes with preferably a bias towards the tram; to favour the concept of public transport. May be flyovers at certain crossings can help to achieve the needed solution. However,they still can have certain adverse impacts. Hence the whole matter needs to be studied in a comprehensive manner.
- The above also applies to the Cairo 2 which needs further protection from increased stopping at street junctions, particularly along its northern sections. However,the Cairo 2 offered the highest commercial speeds during peaks from amongst the studied cooridors. Thus, with introducing tram priority schemes the level of service can be increased further.
- Passenger boarding/alighting management need to be improved on the 4 systems in order to reduce en route delays. The surveys on the 4 selected corridors revealed that by far the major reason for tram delays is at stops to handle passengers boarding/alighting. However, the Alex 1 system seemed to offer a reasonable management of passengers along its well designed stops and reasonably high platforms.

- Reasonable reduction in journey delays can also be achieved by tighter control on drivers sticking to the roles.
- Tram stop spacing appears to be very low on the Alex 2. This could be very difficult to change as the tram run along a very crowded traffic corridor and stops repeatedly. The existance of several formal stops is then important for pedestrian safety.
- The tram(T) system in Cairo has been subjected to many eliminations in the past 3 years; about 50% of the track since 1989 as reported by the operator. The image of the system seems to be distorted by the negletion of introducing any improvements to raise operation levels. It is believed that the T system can yet play a more important role in Cairo transit market if it is given a chance through supporting the CTA to raise the levels of service provided. Such recommendation is pointed out by 2 leading studies in 1985 (10) and 1987 (11).

7. Closer

It is hoped that the present research study can draw the attention to the following points.

- LRT systems can play a highly effective role in urban public transport even when operation environment is difficult.
- LRT systems in Alex which carry 67% of daily travel on formal transit modes in the city need more support so as to increase the offered level of service and to maintain the role they play in the service of the public.
- LRT systems need the right operation conditions in order to prove its importance. It is unfair to neglect the basic technical/management needs of these systems and to start eliminating services.
- If the right operation conditions are facilitated such as track, fleet, power, management control and giving priority at traffic junctions, LRT systems can certainly prove supe-

riority. For instance ,one should always remember that the tram is a pollution free mode. Furthermore,although initial costs of improvements are high, yet on the long run LRT systems as an intermediate technology between the extremely expensive metros and the low capacity buses can be cost effective.

- LRT systems in Cairo, especially the T system, should be given the chance to increase its share in the transit market if the above requirements are gradually achieved. Some European cities that removed trams 50 years ago have been reintroducing them again.
- For cities which would like to introduce new LRT systems, besides many essential requirements the following are on top of the list. Firstly, the right demand on the potential corridor must exist. Secondly, the system should extend along a reserved track and be given priority at traffic junctions. The elimination or reduction of highly competitive alternative transit modes along the full length of the desired LRT corridor is a third element. This will maintain the expected ridership levels. In addition, the stops should be well spaced with carefully designed platforms so as to ensure efficient and safe passengers boarding and alighting. It is also necessary to take care of the system management aspects so as to ensure a reliable and sustainable level of service. The right type of rolling stock is to be operated. It should be suitable for the local conditions and the techno-economic capabilities of the operator especially in developing countries. In addition technical maintenance of the track, the rolling stock and all other elements of the system is also an essential requirement. Unfortunately, this is often neglected in developing countries. It ensures maintaining a good level of service and hence a stable ridership and revenues. Finally, a well designed transit fare policy that encourages LRT systems usage can play an important role in the success of the system.

Last but not least,it is clear from the present study that through simple field surveys at selected LRT corridors one can draw a general picture of operation conditions and can reach useful conclusions.It would have been even possible to undertake more specific analysis on each tram line on the studied corridors if such exercise was part of the objectives of the work. It is hoped therfore,that the study,draws the attention of operators of LRT systems to the fact that via limited inexpensive surveys they can reach more understanding of the system characteristics. This is particularly important in developing countries when budget constraints are many.

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