ENERGY EFFICIENCY IN TRANSPORT

PROCEEDINGS OF A SEMINAR
HELD ON 15 FEBRUARY 1991

Natural Resources, Energy & Science Authority of Sri Lanka

1991

ENERGY EFFICIENCY IN TRANSPORT

Proceedings of a Seminar organised by the Working Committee on Energy, and held at NARESA on 15 February 1991

Edited by
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FOREWORD

The transport sector is the major consumer of oil in Sri Lanka and accounts for over 50% of petroleum products consumed. Sri Lanka has to import her entire requirement of oil, which cost the country over 14 billion rupees in 1990.

For these reasons NARESA's Working Committee on Energy felt that the subject of energy efficiency in the transport sector had been a somewhat under-explored area, and decided to organise a seminar to discuss various aspects of energy use in transport, and suggest possible ways to minimise wastage and increase efficiency.

I wish to thank the Energy Working Committee for organising the seminar; Prof. K.K.Y.W. Perera, Chairman of the Committee, for chairing the sessions; and Mr Eardley de Silva for editing the proceedings for publication.

It is hoped that the information made available at the seminar will reach a much wider public to whom this publication will now become available. Suitable follow up action by the authorities on the recommendations made at the seminar may help to ease the burden of the rising oil prices.

Director-General

Natural Resources, Energy & Science Authority
47/5 Maitland Place
Colombo 7.

2 October 1991

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Seminar on Energy Efficiency in Transport

Date : 15 February 1991
Venue : Conference Hall, NARESA

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Participants

	Name	Institution
1.	Dr A.G.K.de S. Abeysuriya	Open University
2.	Mr Noel Amarasinghe	Cooperative Wholesale Establishment
3.	Mr J.W. Chandrasekera	Transport & Highways Ministry
4.	Mr D.A.U. Daranagama	Energy Conservation Ministry
5.	Mr M.A.T.de Silva	NARESA
6.	Mr K.G.D.D. Dheerasinghe	Central Bank of Sri Lanka
7.	Mr H.P. Dharmasena	Sri Lanka Railways
8.	Dr G. Dharmawardene	NARESA Working Committee on Energy; Radio-isotope Centre, Univ. of Colombo
9.	Mr K.S. Fernando	NARESA Working Committee on Energy; Ceylon Electricity Board
10.	Mr M.T. Fernando	Central Environmental Authority
11.	Mr D.M. Jayasekera	National Planning Department
12.	Mr Hemantha Jayasundera	Urban Development Authority (UDA)
13.	Mr N. Jayawardene	Transportation Consultant
14.	Mr T. Kanagasingham	Colombo Municipal Council (CMC)
15.	Capt. V.B. Karunaratne	Mahaweli Engineering & Construction Agency
16.	Mr M.J. Koniotes	W.S. Atkins International Ltd.

17.	Dr A.N.S. Kulasinghe	NARESA Working Committee on Energy; National Engineering Research & Development Centre
18.	Mr Victor Mendis	State Development & Construction Corporation (SD & CC)
19.	Mr Tilney Peiris	Motor Traffic Department
20.	Mr G.L. Perera	Greater Colombo Economic Commission (GCEC)
21.	Prof. K.K.Y.W. Perera	NARESA Working Committee on Energy; Univ. of Moratuwa
22.	Mr T. Perinpanayagam	Police Department
23.	Prof. Hema Ranasinghe	Dept. of Geography, Univ. of Colombo
24.	Mr Denzil Senanayake	Road Development Authority (RDA)
25.	Mr Sarath Seneviratne	Engineering Faculty, Univ. of Peradeniya
26.	Mr M. Watson	NARESA
27.	Mr Nihal Wickramaratne	Colombo Municipal Council (CMC)

POLICIES FOR ENERGY EFFICIENT TRANSPORT

D.M. Jayasekera
National Planning Department

(1) The Nature and the Magnitude of the Problem

Sri Lanka depends heavily on imported fuel for her commercial energy needs. Petroleum accounts for approximately 70 percent of the total commercial energy consumed in the country. The share of Electricity is about 30 percent. It is important to note that approximately 25 percent of electricity is generated in thermal plants based on petroleum products.

The total value of petroleum products imported in 1989 and 1990 amounted to approximately 10 percent of the total imports during the two years. The annual import bill accounts for nearly 20 percent of the country's total export earnings. Therefore, energy supply has severe balance of payments implications. Moreover it is observed that the domestic consumption of petroleum products is increasing steadily despite the increase in cost. With the recent sharp increase in international prices of oil and the possibility of increasing it further due to the Gulf crisis, the country is faced with a serious problem of making this vital source of energy available to the economy in sufficient quantities, without restricting the import of other essential goods or commodities.

The sector which accounts for the largest share of domestically used petroleum products is transport. According to available statistics the transport sector accounts for over 50 percent of the net domestic consumption of petroleum products. For example in 1987, out of 1,033,000 tons of petroleum products consumed in the country, the transport sector claimed 669,000 tons. Therefore it is very clear that if any meaningful steps are to be taken to conserve and rationally utilize petroleum products and thereby contain the demand and stabilise imports, attention has to be focussed on energy efficient machanism within the transport sector which is dependent 100 percent on petroleum products. The dilemma faced by the planners as well as by the decision makers is how to contain the consumption of fuel and at the same time expand and improve transportation which is vital for an expanding economy. The way out is by improving energy efficiency or in simple terms by getting more kilometres per litre.

(2) Structure of the Transport Sector

Transport sector in this country is principally dual mode, i.e. road and rail. The road sector commands a market share of over 85 percent. The railway accounts for less than 15 percent. Other modes such as coastal shipping, non-motorised transport which operate in selective markets are insignificant. Road transport is more dynamic compared to railway and is expanding fast as evident from the growing fleet of all types of vehicles.

Both railway and road transport depend entirely on petroleum products. As this sector is growing at the rate of 4 to 5 percent per annum, fuel supply has to keep pace with the growing demand. Currently there is no project or programme under implementation to diversify energy in the transport sector.

(3) Specific Policies for Energy Efficient Transport

Energy efficiency is part and parcel of systems efficiency be it transport, industry or service. In other words, efficiency in the use of fuel which is a vital basic input, cannot be overlooked in achieving operational efficiency.

Systems efficiency, with particular emphasis on optimum use of energy, can be achieved through

(a) appropriate specific or general policy guidelines
(b) 'in-house' adjustment.

The two are, however, closely inter-related and inter-dependent. Macro-level policy adjustments will have only limited or partial impact if the required micro-level adjustments for performance improvement are not systematically carried out.

(4) Current Policy

(i) Deregulation of Road Passenger Transport Industry

The Government has taken a policy decision to deregulate the road passenger transport services as a major element of restructuring the transport sector. Deregulation entails complete delinking of state involvement in management and supply of public road transport services. This will ensure the conversion of road passenger transport industry to a hundred percent private sector activity similar to road haulage. The overall objectives of this policy are to promote optimum utilization of existing resources,

facilitate efficient management and attract capital and skills, in a competitive free enterprise situation. Energy efficiency is expected to be a major benefit of this policy.

(ii) Fare Deregulation and Realistic Pricing

As a matter of policy the government is moving away from the practice of administrative pricing, particularly in respect of products and services rendered by state sector enterprises. The objective is to pave the way for the determination of prices, fares or tariffs on the basis of resource cost and in relation to supply and demand. Appropriate pricing of vital inputs whether imported or locally produced such as petroleum products, will result in savings and economic use of scarce resources.

Realistic pricing of petroleum products, in a situation of free competition devoid of barriers for supply and factor mobility, will compel the transport industry to move towards a higher level of efficiency in service delivery and in resource use resorting to appropriate fare setting, factor substitution and effective management. Energy efficiency, in this context, becomes a highly rewarding pursuit.

(iii) Development and Strengthening of Railway

The aim of policy guidelines is to identify a viable economic role for the railway and promote those services which have distinct national or socio-economic cost advantages over road transport.

The focus of attention on railway with the anticipation that it could turn around, if placed on the correct track built on commercial principles and sound management, has the objective of diversifying inland passenger and goods transportation without resorting to deliberate traffic assignment. It is also backed by the widely current notion that railway can provide, at least in selected markets, cost efficient particularly energy efficient, transportation. Two identified markets are, (a) long distance and bulk goods haulage and (b) urban sector mass transportation. Electrification of sub- urban railway can provide a very efficient mass transit system for Grreater Colombo Area.

(iv) Fiscal and other Incentives to promote Efficient Transport Services

Several elements of the Government's overall policy to encourage and develop employment creation (primary and secondary) with efficient and viable industrial and service enterprises, have a direct bearing on the promotion of energy efficient transport services. Tax and duty concession on the import of new equipmen and credit facilities at reasonable terms are some of the key elements of Government policy to promote the establishment of efficient low cost services to the public. Promoters of low cost energy efficient means of transport such as light motorised and even non-motorised forms of land transport, coastal shipping etc. can benefit from the incentive package.

(5) Future Needs

The above mentioned policy guidelines assume the continuation of the existing structure with improvement both in terms of resource use and modal split. They do not anticipate far reaching technological change leading to significant energy substitution.

This is because according to current perception the line separating energy efficiency and energy conservation is very thin to the extent of taking one for the other.

Energy efficiency and energy conservation are two different aspects. For example energy conservation can be achieved by reducing or completely cutting down services. Energy efficiency on the other hand refers to providing better or expanded service with reduced energy input. "Reduced energy input" refers not only to the reduced quantum of energy but to reduced domestic resource cost of that input. What it means is the extent to which imported fossil fuel could be replaced with hydro electric power; hydro electric power from the national grid with small scale thermal electric power and thermal power with solar power etc.

Obviously such transformation can be achieved only in the medium or long term. In the mean time short term efficiency measures even though they be primarily energy saving mechanisms, have to be pursued. The main concern, however, is that the long term objectives should not be undermined or discounted in the process of giving priority to short term objectives. Under these circumstances it is very necessary that policy guide lines to encourage and facilitate technological innovations leading to significant energy substitution in transport, should be spelled out as a matter of priority.

TRAFFIC LOAD IN COLOMBO CITY

Prof. P.C.H. Ranasinghe
Dept. of Geography, Univ. of Colombo

Urban Travel Trends in Sri Lanka

According to the Sri Lanka Transport Sector Planning Study (1987), GDP growth of the island would vary from 3.0% to 7.5% per year upto 1996 (three scenarios-base case, an optimistic and a pessimistic scenarios). Overall freight growth is expected to be 3.8% per year over the next 10 years in the Base Case, while passenger flows are expected to grow at 7% per year.

Total intercity passenger trips are expected to grow from 121 million in 1986 to 272 million by 1996, under the Base Case, and 194-340 million as the pessimistic and optimistic ranges. Inter-Zonal or district freight flows are expected to grow from 9.5 million tons to 14.9 million tons under the Base Case, with a possible +25% variation for the other scenarios.

Roads and road transport have become the most dominant mode of transport in the island and it can be expected that the road sector will continue to dominate the transport scene in the years to come. (Table 1)

Vehicle ownership invariably will continue to increase in the future even at a lower rate than at present. Thus, the overall trend in road traffic levels could be anticipated to be upward for both passenger and freight movements. It can be visualized, based on the present pattern, that more vehicles would be concentrated in the city.

TABLE 1

The Dominance of Road Transport in Sri Lanka

	1984		1996 (Estimated)	
Freight (000 tons)				
Rail	1,591	(16%)	2,090	(14%)
Road	8,361	(84%)	13,392	(86%)
Freight (Million ton-Km)				
Rail	263	(19%)	302	(13%)
Road	1,100	(81%)	1,975	(87%)
Passengers (000 trips)				
Rail	43,779	(39%)	43,890	(23%)
Road	68,707	(61%)	211,604	(77%)

Passengers (Million px Km)				
Rail	1,631	(22%)	997	(06%)
Road	6,306	(87%)	16,724	(94%)

(Note: Figures for public transport interzonal flows only, under normal political conditions)

Source: Transport Sector Study (1987). Table E 3-4.

Greater Colombo

Colombo is the nerve centre of the island for administration, banking, commerce, communication, industry and culture, which has a considerable 'impact' upon activities throughout the rest of the island. Its immediate hinterland encompasses the entire Western Province consisting of the Colombo, Kalutara and Gampaha Districts, which together is known as the Colombo Metropolition Area or Greater Colombo. The "City of Colombo" is demarcated by the Municipal Council boundaries. Greater Colombo contains more than 26% of the island's population whereas it has only 5.6% of the land area.

Within Greater Colombo there are about 5,293 Km of paved roads and 4,261 Km of unpaved roads. The City of Colombo has nearly 50 Km of trunk roads and 430 Km of other paved streets.

There are some 66 major bridges carrying roads and railways, over rivers and other waterways within the Greater Colombo Area, and of these there are twenty road/waterway bridges and six road/railway bridges within the Colombo Municipality.

There are seven level crossings within the Municipal boundary where the rail network intersects major roads. Two road/rail intersections are located on either side of the Slave Island station, on the Coastline Railway, two othes are on the main line meeting the Baseline Road and Avissawella Low levelRoad and the other three are on the narrow guage line with crossings at Baseline Road, Cotta Road and State Drive.

Road Passenger Transport in Colombo Urban Area

Among motorised travel, bus transport is the predominant means of passenger transport in Sri Lanka. It has accounted for more than 80% of total passenger kilometers in 1985, and the balance shared equally between the railway and private automobile.

Sri Lanka Transport Board Buses (Presently in the process of peoplisation)

The increase of travel can be examined in relation to the mode of travel or vehicles. The Sri Lanka Transport Board had the primary obligation of providing mobility to the nation. The SLTB experienced a dramatic increase in the travel demand from about 15 million passenger kilometers in 1977 to over 19 million in 1980. During the decade 1975 to 1985, the statistics also show a steep increase in passenger kilometers, except in the years of stiff fare increases. In 1986 the SLTB had operated 4,880 buses daily with a seat kilometerage of 20,255. The total number of buses belonging to SLTB was 5955 out of which Colombo North depot had 1062 buses.

TABLE 2

Region	Long distance	Other services	Total buses
Colombo South	36	1236	1272
Colombo North	46	1016	1062
Central	107	830	937
Uva	80	495	575
Northern	56	195	251
Eastern	55	158	213
North Central	49	257	306
North Western	48	704	752
Southern	39	548	587
Total	516	5439	5955
Colombo Metropolitan	82 (16%)	2252 (41%)	2334 (39%)

Source: Sri Lanka Transport Board.

Sri Lanka Transport Board operations for 1986 show that 16% of the long distance services and 41% of the other services were operated within the Colombo Metropolitan Region. Out of the total number of buses operated in the island 39% were operated within the Colombo Urban Zone.

Private Passenger Buses

The distribution of bus operations by districts and the number of routes operated in each district can be considered as indications of the extent of urban transport demand in the island.

TABLE 3

PRIVATE BUS OPERATIONS 1986

District	Buses Registered	Buses Operated	Operational Routes	Performance Vehicle Km/Day
Colombo	3,954	3,163	313	648,415
Gampaha	1,555	1,244	208	255,020
Kalutara	884	707	121	141,935
Total	6,393	5,114	642	1,048,370
Sri Lanka	11,001	8,800	1,818	1,804,000
% in 3 districts	58%	58%	35%	58%

Source: Ministry of Private Omnibus Services.

The private bus operations have increased considerably by the year 1989. Out of the registered number of 15,895 private buses, 80% were in effective operation, and 58% of these were in the Colombo Metropolitan Region. Although only 35% of the private bus operational routes are in this area, it has accounted for 58% of the vehicle kilometers operated per day. This well illustrates the density of road traffic in Colombo and its hinterland.

TABLE 4

COORDINATED SERVICES - RTB AND PRIVATE BUSES

Region	Private buses	RTB buses	Number of Routes	Total buses
Colombo South	579	203	42	800
Colombo North	635	209	21	844
Central	696	334	74	1030
Southern	551	294	59	845
North Western	387	173	35	560
North Central	53	23	09	76
Uva	3	12	04	15
Total	2992	1248	224	4170
Colombo Metropolitan Region	1232	412	63	1644
	41%	33%	28%	39%

Source: Sri Lanka Transport Board.

Urban Traffic Density

Out of the estimated all island passenger kilometres of 14,495 covered by SLTB in 1985, 24% were within the Colombo hinterland, while out of the estimated passenger kilometers of 14,060 covered by private buses, 51% were in the Colombo hinterland. Total estimated bus passenger kilometers were 28,555 million: out of which 37% was in the Colombo hiterland. This illustrates the heavy traffic concentration withir the urban zone.

Vehicle density is a good indicator to illustrate the urban development and associated traffic problems. For example as far back as 1983 the districts of Colombo and Gampaha together had 211 vehicles per square kilometer and 45 vehicles per 1000 population; while the island's density was 3.5 vehicles per square kilometer and 2.8 vehicles per 1000 population.

TABLE 5

COMPARATIVE STATISTICS (1986) FOR REGIONS

Region	Area $(km)^2$	Population ('000)	Road (km)	Vehicles ('000) (registered)
Colombo Municipality	37	585	480	
Colombo District	625	1,809	700	175,350
Colombo Metropolitan	3,659	4,140	3,217	
Sri Lanka	64,628	16,117	20,766	587,515

Source: Department of Census and Statistics.

TABLE 6

AS A PERCENTAGE OF ISLAND'S TOTAL (1986)

Region	Area	Population	Roads	Vehicles
Colombo Municipality	0.057	3.63	2.3	
Colombo District	0.96	11.22	3.37	29.84
Colombo Metropolitan	5.65	25.68	15.49	
Sri Lanka	100.00	100.00	100.00	100.00

TABLE 7

TOTAL NUMBER OF MOTOR VEHICLE REVENUE LICENSES ISSUED IN THE COLOMBO DISTRICT - (ACTIVE VEHICLE POPULATION)

CLASS OF VEHICLE	1983	1984	1985	1986	%	Sri Lanka Total	Cbo. Dis.(%)
Motor cars	47821	50981	51470	58400	33.0	155972	37
Motor cycles	41253	43796	40250	48950	28.0	186843	26
Lorries	27701	32239	34924	39300	22.0	93350	42
Tractors/Trailer	6761	6593	5685	6550	4.0	76449	8
SLTB buses	5000	5000	5000	5100	5.0	5100	100
Private coaches	61	987	580	950	0.5	3675	25
Hiring buses	2175	3670	5450	6600	4.0	21572	31
Hearses	79	81	15-	15-	0.08		
Govt. vehicles	5400	5465	6300	9350	5.0		
Total active vehicles in Colombo District	136251	148722	149827	175350	100.0		
Sri Lanka (Registered)	439666	478104	522607	561403			

Source: Commissioner of Motor Traffic.

Road Traffic Growth

A rapid growth of traffic in the city roads is witnessed, especially since 1977. The Transport Sector Planning Study has measured an average growth of 5.2% of traffic per year on principal roads, with the largest increases in private buses and motor cycles. Over the last seven years an even higher growth rate, ranging from 3.5% to 10.5% per year, had been observed.

TABLE 8

FORECAST OF TRAFFIC GROWTH RATES, PER YEAR

Vehicle	Forecast GR per year	Probable Range
Cars, Vans & taxis	3.5%	2 - 5%
Motor cycles	6.5%	5 - 8%
Private buses	5.0%	3 - 8%
Commercial vehicles	4.0%	2 - 6%

Source: Sri Lanka Transport Sector Planning Study 1987.

Private Automobile

The registration of motor cars in the island shows an upward trend during recent years. For instance, the year 1973 recorded 89,771 motor cars and in 1983 this had increased to 136,857 adding over 4,700 cars within an year. In 1986 there were 155,311 private cars in the island with an average increase of over 6,000 cars per year between 1983-86. Although overall car travel has not increased due to the high cost of fuel, there is a significant increase of car traffic in Colombo roads.

The recorded 97,010 cars at the end of 1979 represents 7 cars per thousand people as island's average. This has increased to 10 cars per thousand people by 1986. The annual growth rate of car population is expected to be around 2.5%. Out of the total car population in the island, about 66% are registered in the Western Province and 63% are registered in the Colombo District. Out of the revenue licenses issued in 1986, 37% are issued in Colombo District. Out of the total traffic entering the city of Colombo during a normal working day 55% - 65% are formed by motor cars. During a normal working day about 51,000 cars enter the city limits. In Sri Lanka private car as a mode of transport is essentially urban. However, the proportion of travel by car measured in person - miles is only about 5% - 6% of the total.

Rising Motor Cycle Population

The average annual registration of motor vehicles in the island had been around 35,000. The total registration of motor vehicles in 1987 was 46,884, out of which 7,695 were private cars and 29,041 were motor cycles.

In 1973 motor cycle population which remained at 22,134 shot up dramatically, making it to 121,845 in 1983 and 187,717 in 1986. In 1987 the total motor cycles in the island were 213,441.

Out of the revenue licenses issued for motor cycles 26% are issued in the Colombo District. Out of the total revenue licences issued for all motor vehicles in the island, 28% are issued for motor cycles.

Commercial Vehicles

Since the liberalization of the economy there has been a substantial growth in the commercial vehicle fleet. In 1977 there were 17,000 commercial vehicles which has increased to 70,000 in 1985. The major population of the commercial vehicles are based in Colombo.

An overall traffic growth of 4% per year, on average, is expected with plus or minus growth rates in some areas, subjected to population increase and intensification of economic activities. Thus, within the next 10 years a 48% growth of traffic is expected.

Traffic Condition

The traffic density on the road network near the City is most intense with an average of 10,000 vehicles per day which thins out as one proceeds to the suburban areas. Negombo and Kandy roads within the Greater Colombo area show high traffic density. It is reported that 162,000 vehicles pass through the Colombo Municipal boundary during a 12 hour period of a weekday. The congestion in the city is further aggravated by the fact that these vehicles have to find access to the city through nine major entries in the City limits, which impose restraining pressure on some corridors.

Trip Movement Patterns

The city of Colombo acts as the principal commercial and business centre of the island and as such has a major impact on the traffic pattern of the island. Trunk Roads of A1, A2, A4 and A5 along with Main Roads of B1, B2 and B5 radiate from Colombo thereby facilitating the drawing of commuters to the City. The Central Business District (CBD) formed by Pettah and Fort provides 100,000 job opportunities andthe estimated daytime population of CBD is around 550,000. Not only as the major employment centre but also as the chief wholesale and retail centre, the CBD attracts a large number of people daily with consequent effect on traffic.

Regional distribution of population in the Greater Colombo Area and the spatial concentration of job opportunities in the city have created a traffic pattern which is superimposed by the radial structure of the transport routes centred round the City of Colombo. Job opportunities within Greater Colombo Area are estimated to be 1.09 million in 1984 and 37% of this is found within the Colombo Municipality. Outside the City towards the north, Colombo Airport and the Free Trade Zone exert a major influence on travel patterns. It is estimated that 200,000 job opportunities are available in the coastal area towards the north of the City. In addition, the Galle Road corridor between Dehiwela and Kalutara attracts large numbers of work and business trips. Thus, the employment and commercial attractions are concentrated in the City of Colombo and along the Galle Road while the population is distributed evenly throughout the Greater Colombo Area.

The freight flow is similarly structured by the radial routes and the location of the Colombo Port. Major export commodities and imports are carried between the dockyard area

on the north side of the City and all parts of the island by road and rail.

Colombo Port handles over 90% of the total freight shipped to the island, in addition to transhipment traffic. The two container terminals in the Port are linked to 16 inland terminals which are located in the North East of Colombo. It is estimated that the average daily vehicle trips in and out of Port is about 8000 and 95% of all freight handled by the Port travels by road, including almost all container traffic.

Traffic Volumes in the City

Traffic volume within Greater Colombo reflects the radial routes converging at the City. As one would expect the traffic volumes get heavier towards the CBD and thins out with the increasing distance from the Colombo Municipality. It has been estimated that about 180,000 vehicles cross the MC boundary daily while it reduces to 22,500 at the Greater Colombo border. This demonstrates well the increased level of economic and commercial activity towards the CBD. This trend is particularly prominent for private vehicles which are heavily concentrated in and around Colombo.

Road passenger flows at the CMC cordon are 4.5 times those at the Greater Colombo boundary, also reflecting regional patterns of the distribution of economic activity.

Central Business District (CBD)

PETTAH
Pettah is the market area bounded by two of the major radial roads into Fort - viz. Reclamation Road and Olcott Mawatha. Two main activity centres in the City are located in Pettah, viz. Central Bus Stand and the Railway Terminal. The road network within Pettah is a maze of rectangularly spread narrow streets. These streets are often blocked and congested by pedestrians, street hawkers and parked cars and commercial vehicles.

Olcott Mawatha which acts as a radial route to Fort penetrates through Pettah. This route is heavily used by buses and pedestrians. Recent traffic counts show that almost 30% of the vehicles on Olcott Mawatha are buses. Due to passenger interchanges between Fort Railway Station and Pettah Bus Stand pedestrian activity is concentrated along Olcott Mawatha between Gasworks Street and Front Street.

Fig. 1 & 2 show the trip volumes of the mid - day peak period (12 noon to 1.30 p.m.). This period is identified as that of maximum demand within the central districts of the city, by shopping and business trips, journeys home for lunch and trips to collect children from school.

The Transport Sector Study has established that 67% of all trips within Greater Colombo have an origin or destination within CMC. Within the CMC boundary 20% of all trips have origin and destination in Fort and Pettah. Thus, one may be able to identify two separate trip patterns - one originating/ending in CBD and the other originating/ending in Colombo Municipality.

Traffic Zones Outside the City

Outside the city, a traffic zone can be identified immediately to the north of the Municipal boundary and extending north-wards to Negombo, which accounts for 8% of trip ends; zones immediately to the south and extending along the coastal strip to Panadura account for 10%. Kotte and Nawala together make up a further 5% of trip ends. The balance 10% of trip ends are spread thinly to the remaining areas both within Greater Colombo and beyond.

Time Variations

Morning peaks are high in the inbound direction, representing journeys to work and school. A small midday peak period is noticeable with journeys home for lunch and trips to school. The afternoon is a reversal of the morning situation. However, the afternoon peak is less concentrated than the morning peak since the closing of offices and shops extends through from 4.00 p.m. to 5.30 p.m.

As one moves out of the city the concentration of traffic reduces with the increasing distance towards the suburbs.

A survey done by CTRRP reveals -

" * that 57% - 58% of the total inbound morning peak are mostly journey to work trips.
* Outbound homebased work trips are less than 20%.
* Business trips are more concentrated in the inner area of the city and are heaviest during midmorning and at midday; and constitute 50% of the trips into and out of Fort."

Traffic Composition

* Cars and vans account for about 50% of the total flow within the CMC falling to 30% towards the limit of Greater Colombo.
* Private buses together with SLTB buses form 20% of the total volume of traffic on the road. This has become the major form of transport in the urban and suburban areas.
* Motor cycles constitute 10% of the total traffic on the roads, in urban areas.
* Within Colombo, commercial vehicles account for 6% of the flow on strategic routes but varies according to the

direction and location. For example Prince of Wales Avenue carries over 3000 commercial vehicles per 12 hr day representing 11.5% of total traffic, while Galle Road carries 1500 commercial vehicles accounting for 5% of the total traffic.

Traffic Congestion

The major radial routes into the city of Colombo are:

* Galle Road from the south
* Highlevel Road/Havelock Road from the east and southeast
* Kotte Road from Jayewardenepura to the east
* Kandy Road/Prince of Wales Avenue from the northeast
* Negombo Road from the north

Thus, the traffic movement pattern within Greater Colombo is essentially radial centred on the city as the nucleus of business and commercial activity. Inbound traffic flow increases strikingly towards the CMC border making the roads immediately approaching the city congested especially during morning peak hours.

However, it can be established that much of the congestion throughout Greater Colombo is associated with poor road use rather than capacity limitations due to:

* indiscriminate and irresponsible vehicle parking,
* insufficient laying out of junctions,
* inadequate and non-existence of lane demarcations,
* inconsiderate behaviour of road users,
* pedestrian interference with traffic,
* slow moving vehicles,
* use of roadway to activities other than transport.

MAIN CONSTRAINTS

1. The radial pattern of strategic highway routes within the Greater Colombo and the lack of supportive concentric links. Traffic entering the City has less opportunities for diversion.

2. The high density of job opportunities and inadequate traffic management in the Central area which are responsible for congestion of the existing road network in the City centre (Fig.2)

3. Access to Colombo Area from the north is through the Victoria and Kelani bridges and from the south through Moratuwa bridge. Thus, all traffic in a north/south direction has to pass the City centre.

4. Existence of a number of level crossings which interfere with the road capacity and the safety of road operations. Traffic flow is interrupted by rail crossings at 7 places within the CMC boundary.

5. Insufficient parking facilities resulting in vehicle parking on the main roads, thus reducing the road capacity. It has been estimated that between 11.30 a.m. and 12.00 noon the peak demand for parking is about 1,800 vehicles in Fort itself, out of which 15% are Commercial vehicles and the balance private cars. There is a 400 spaces of shortfall during the peak hour resulting in indiscriminate parking in footways and other prohibited areas.

6. Traffic is constrained to run at low average speed because the carriageway availability is frequently restricted to a single lane in each direction by bus stops, turning traffic, pedestrians and other activities on the road. In addition, vehicle breakdowns and accidents cause queues to build-up rapidly and result in significant delays.

Fig 1

TRAFFIC COUNTS 1985 & 1990 (1200 – 1300 HRS.)
ON A WEEK DAY

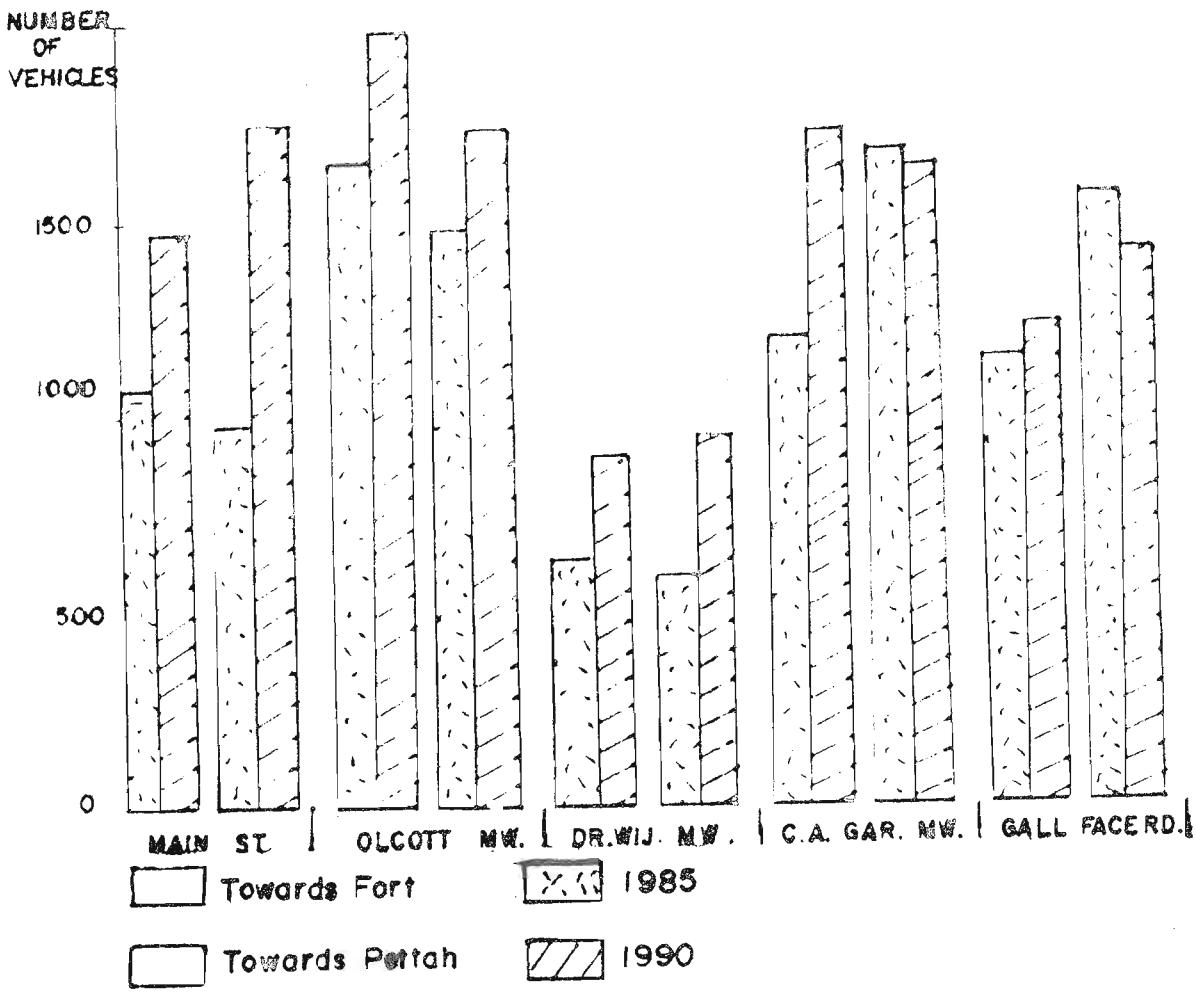
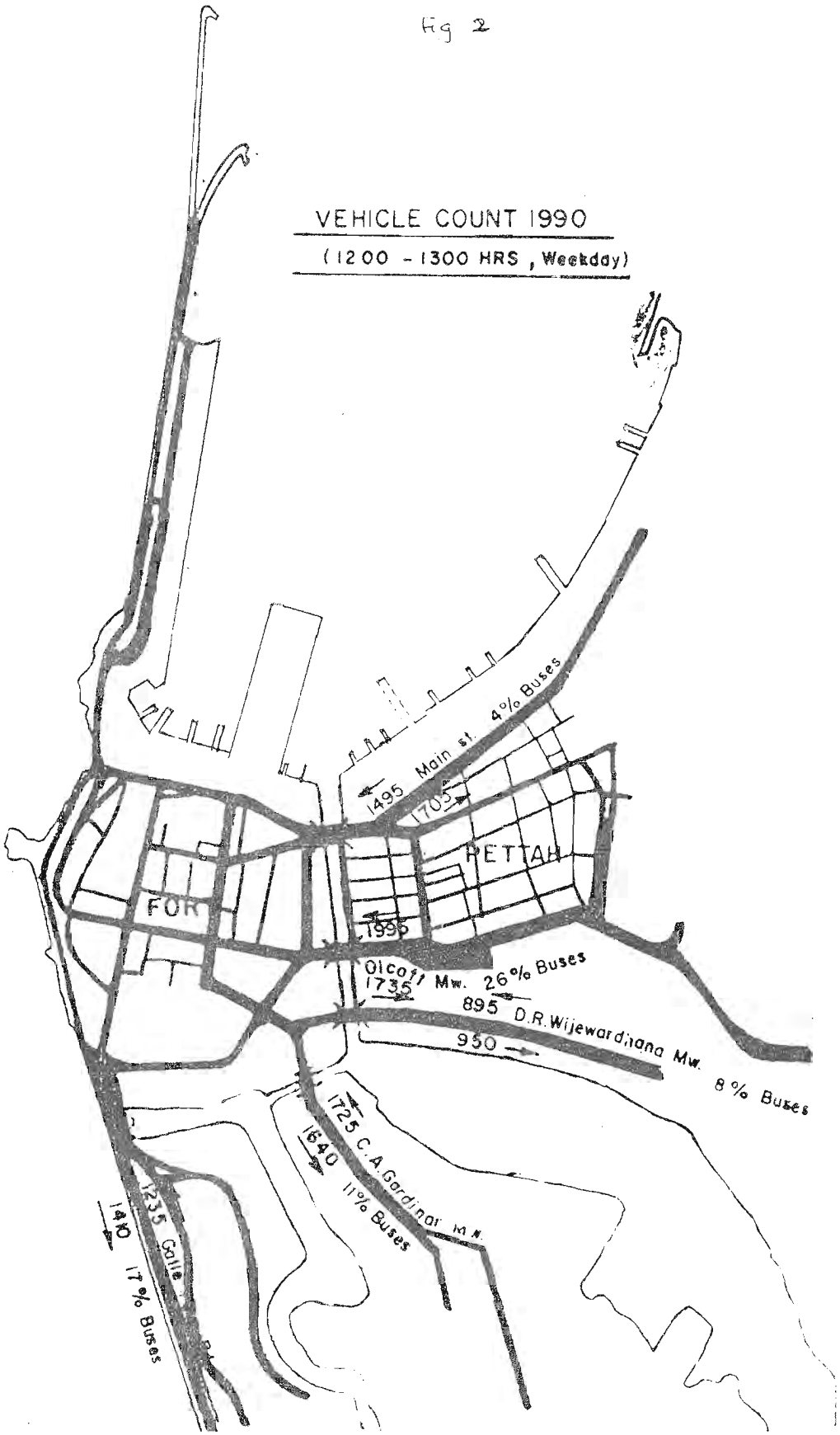
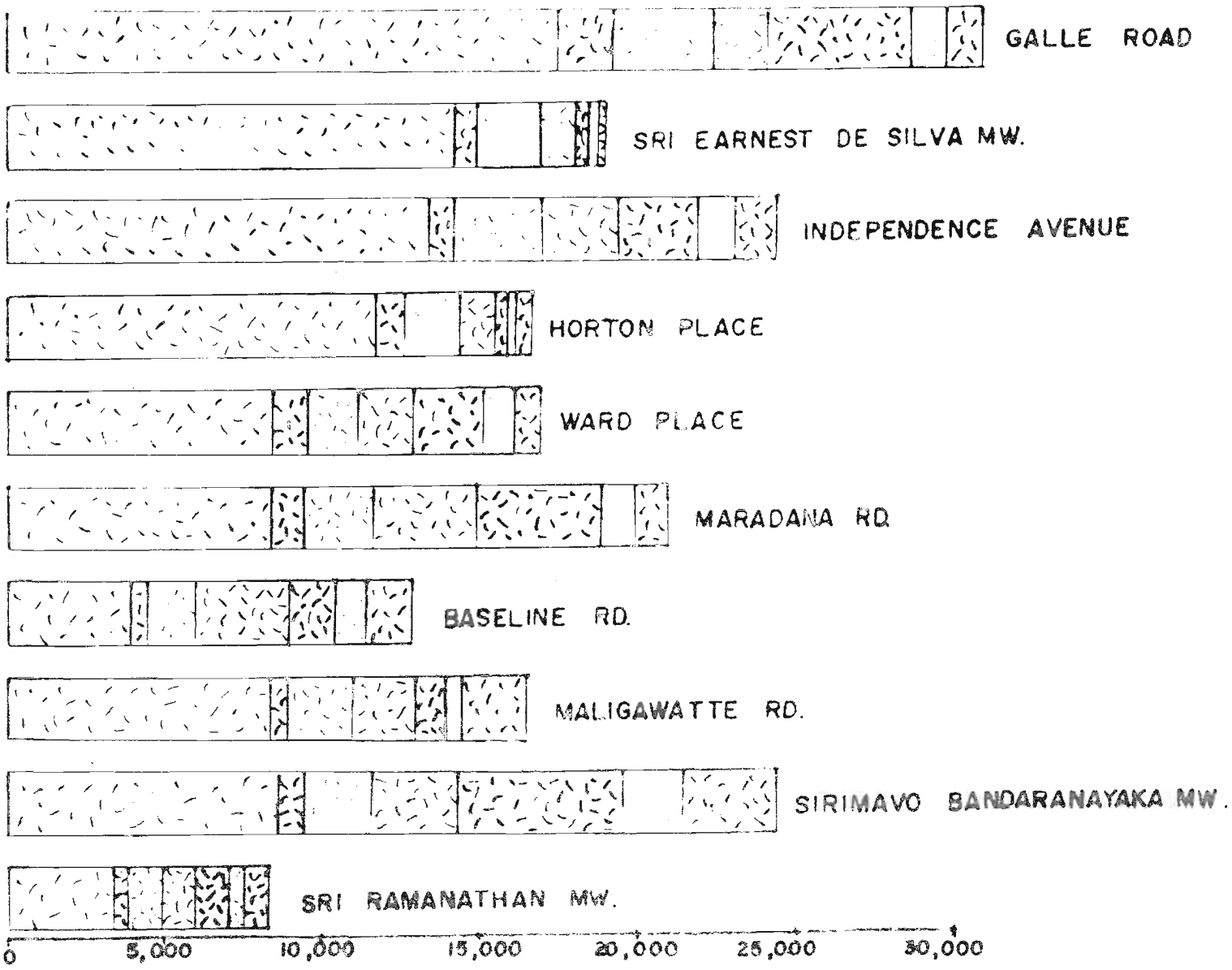


Fig 2


VEHICLE COUNT 1990
(1200 - 1300 HRS, Weekday)
1495 Main st. 4% Buses
705
PETTAH
FOR
1995
Olcott Mw. 26% Buses
1735
895
D.R.Wijewardhana Mw.
950
8% Buses
1725 C.A.Gardiner Mw.
1640
11% Buses
1235 Galle
1400
17% Buses

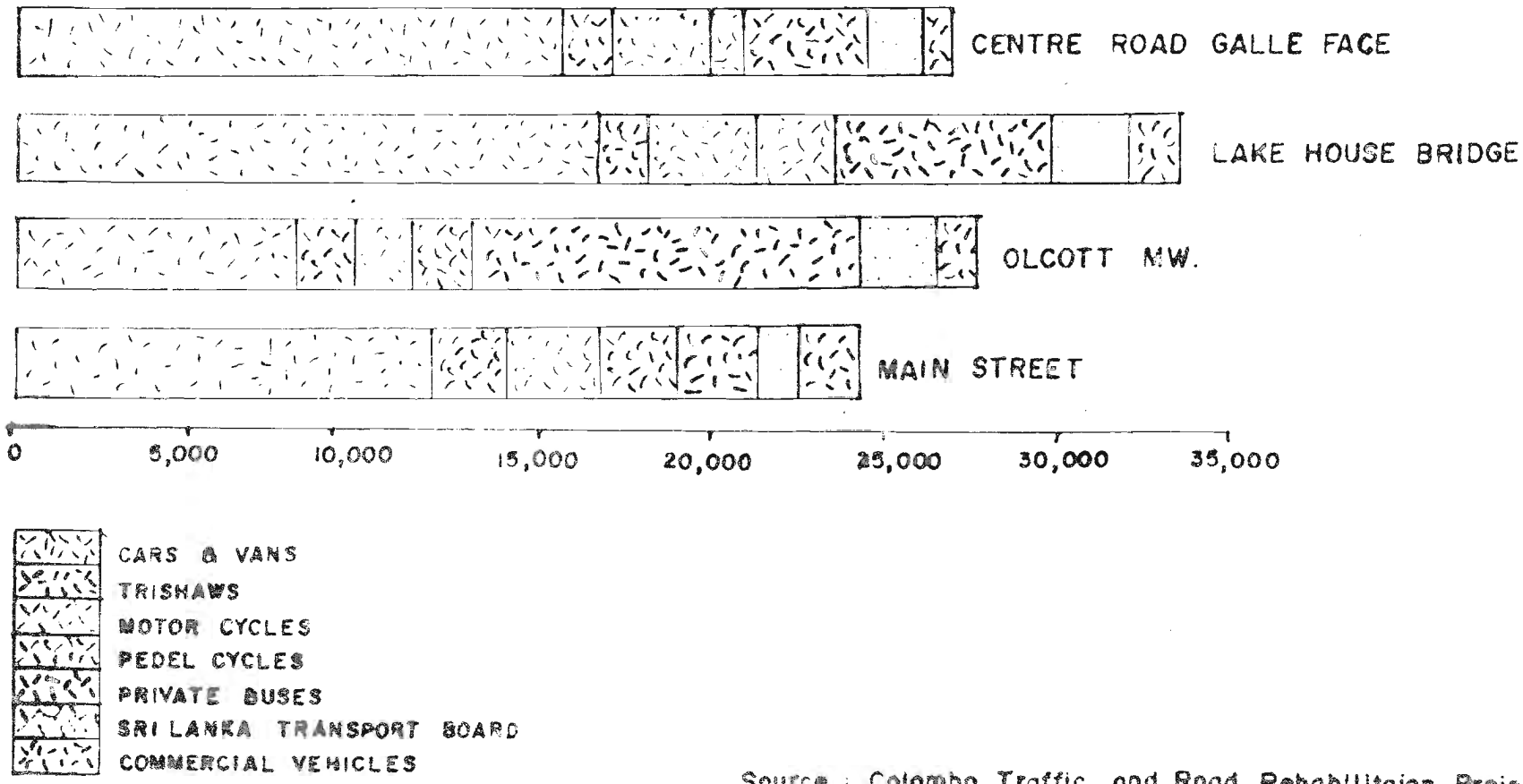
TRAFFIC FLOWS AT SELECTED LINKS IN COLOMBO

(TWO-WAY, 12 HOUR WEEKDAY 1985)



TRAFFIC FLOW – FORT CORDON

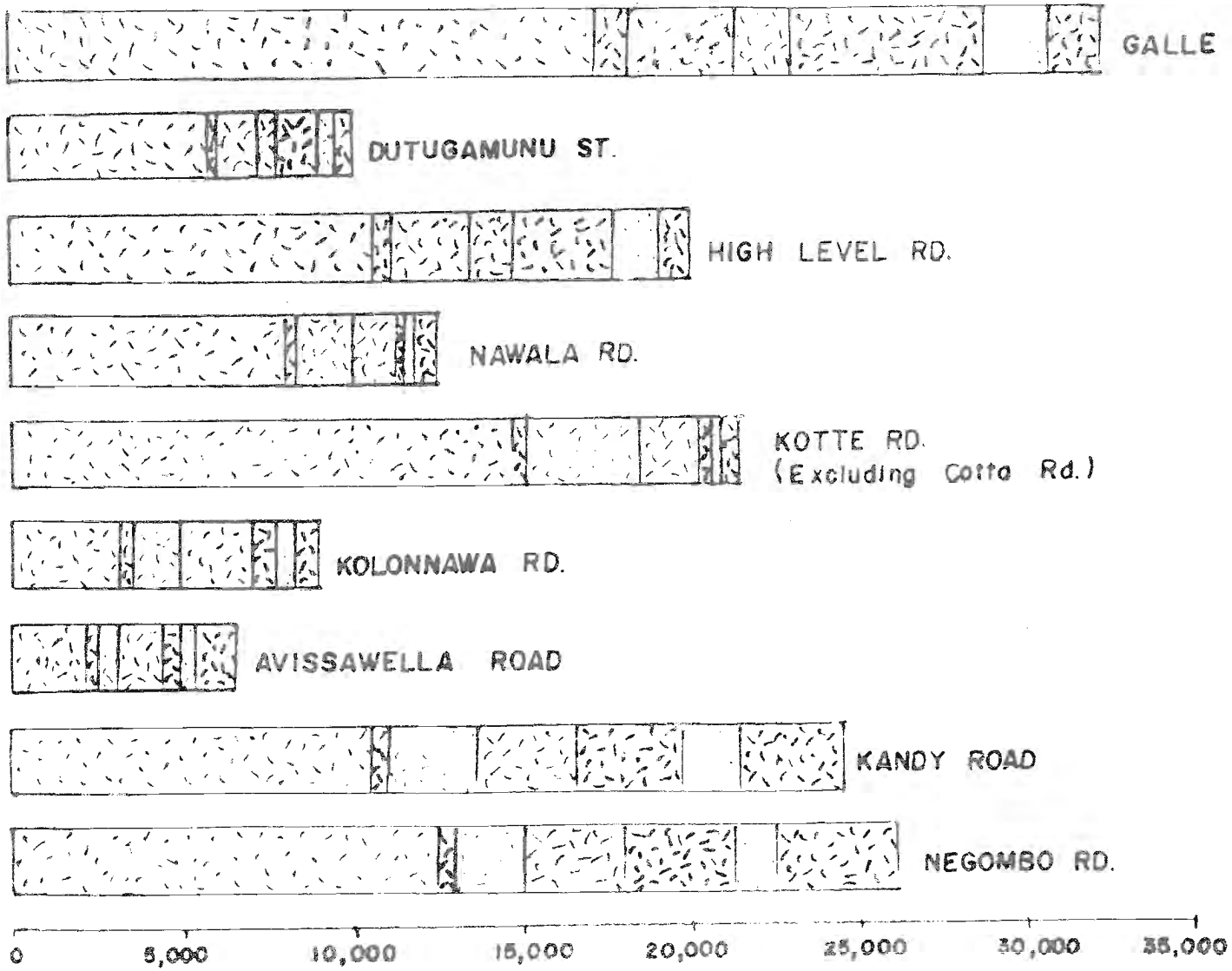
(TWO-WAY, 12 HOUR WEEKDAY 1985)



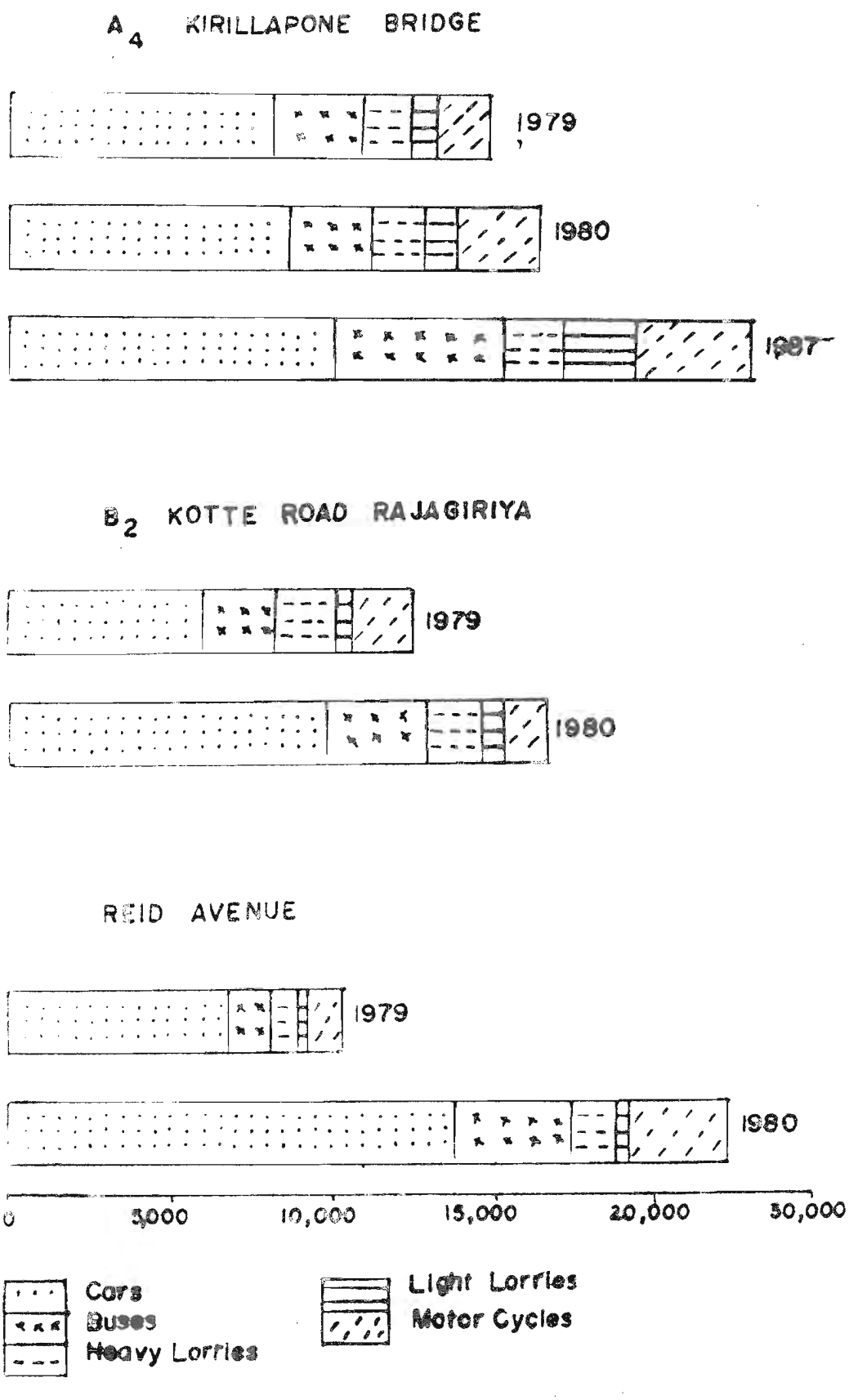
Source : Colombo Traffic and Road Rehabilitaion Project

TRAFFIC FLOW – CMC CORDON

TWO – WAY, 12 HOUR WEEKDAY 1985)



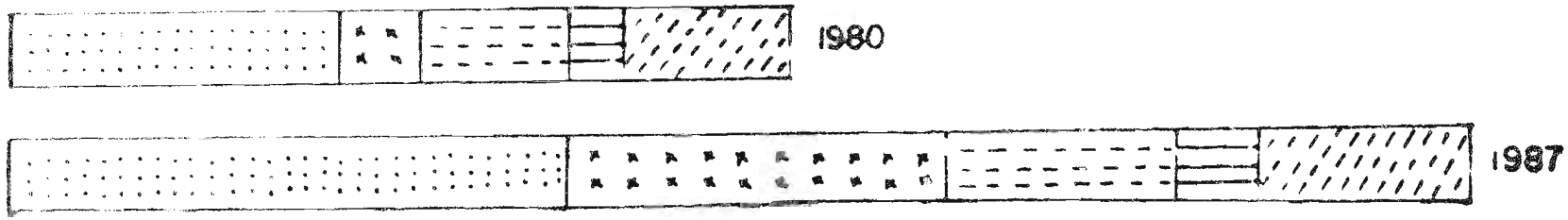
COMPOSITION OF AVERAGE DAILY TRAFFIC



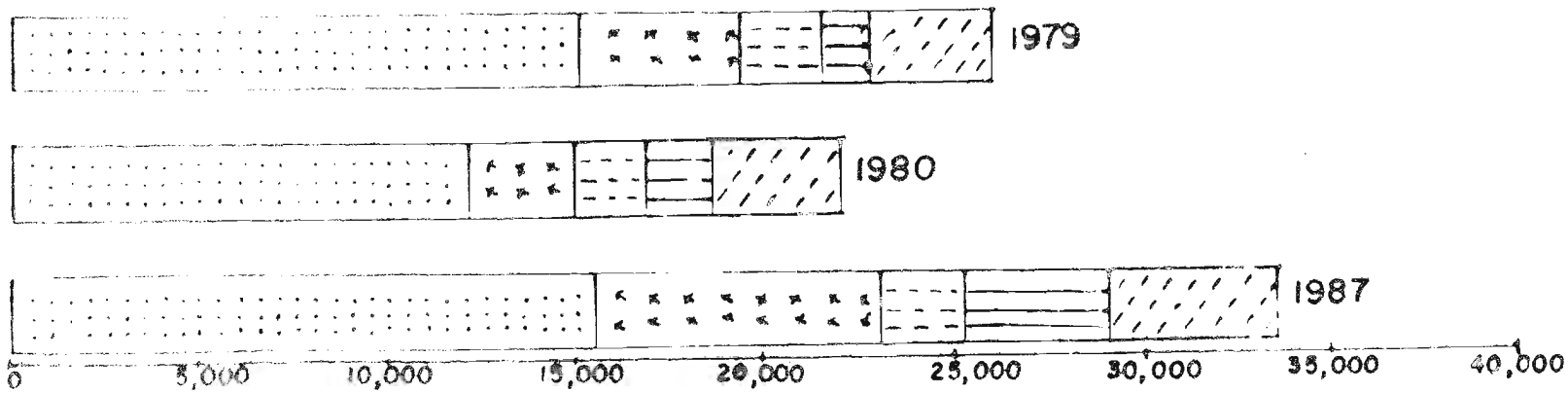
SOURCE : RDA

COMPOSITION OF AVERAGE DAILY TRAFFIC

A_1 COLOMBO - KANDY RD - NEW KELANI BRIDGE

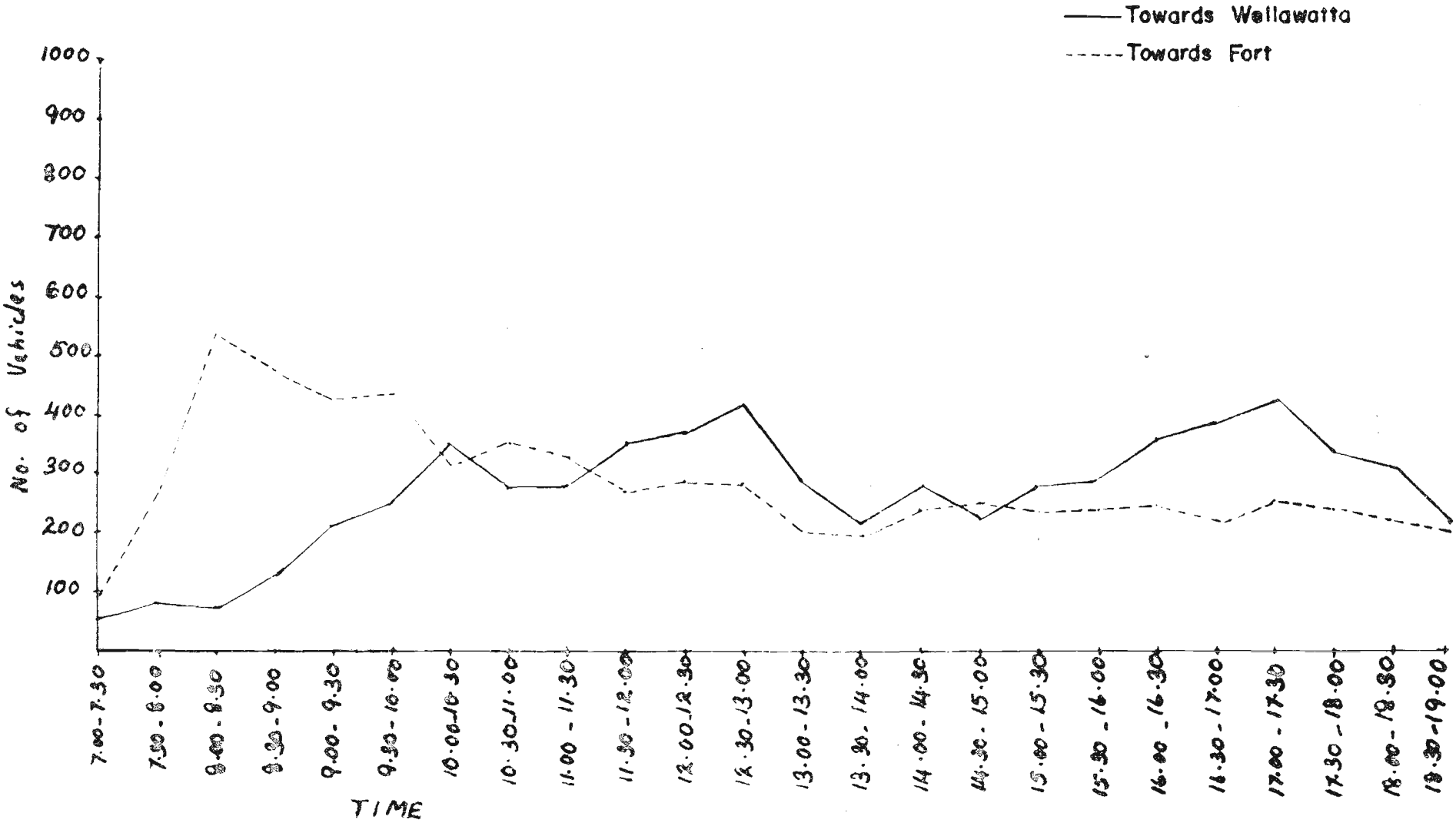


A_2 GALLE ROAD DEHIWALA BRIDGE



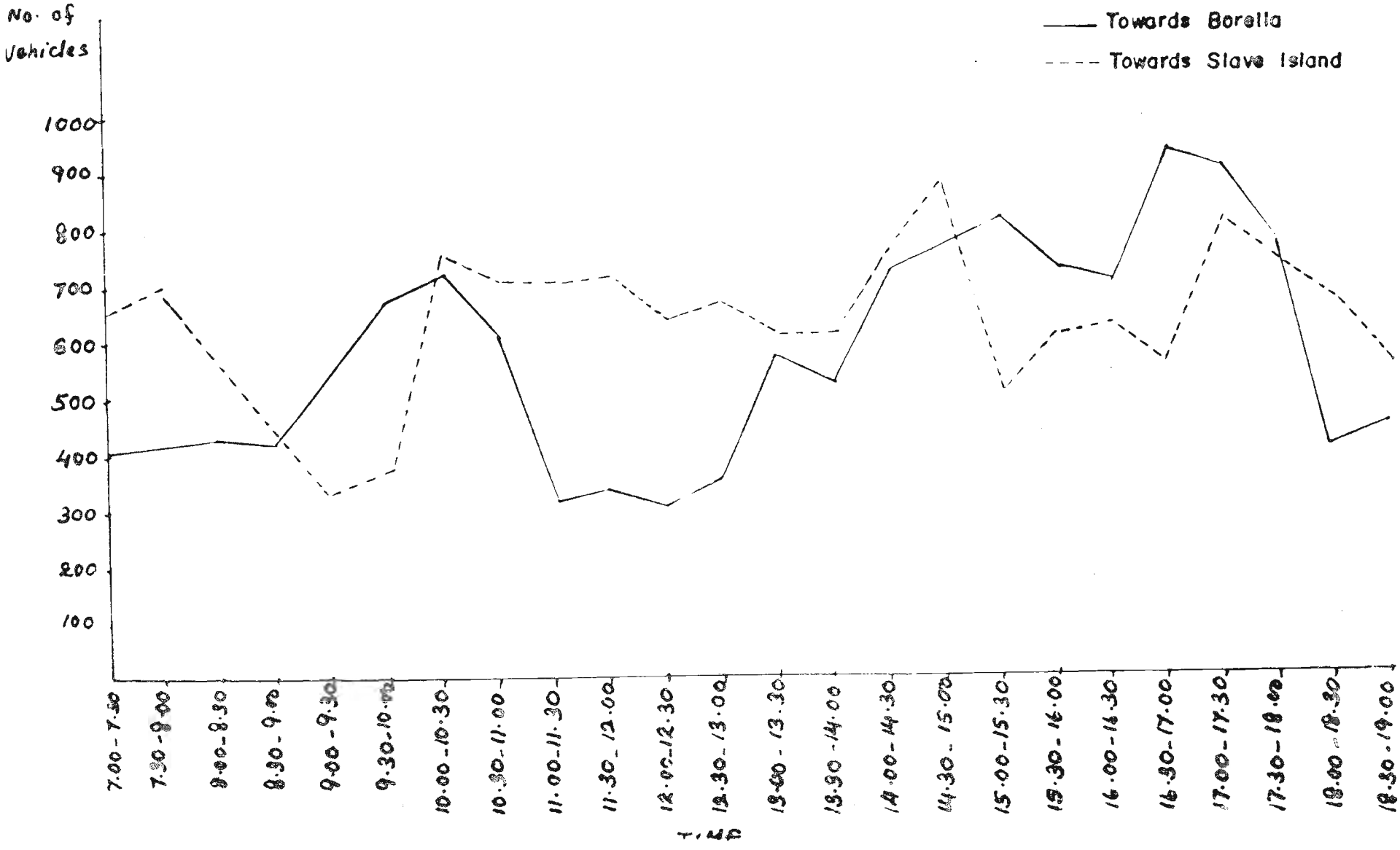
TRAFFIC COUNTS — CITY OF COLOMBO

DUPLICATION RD. MONDAY 19·8·85



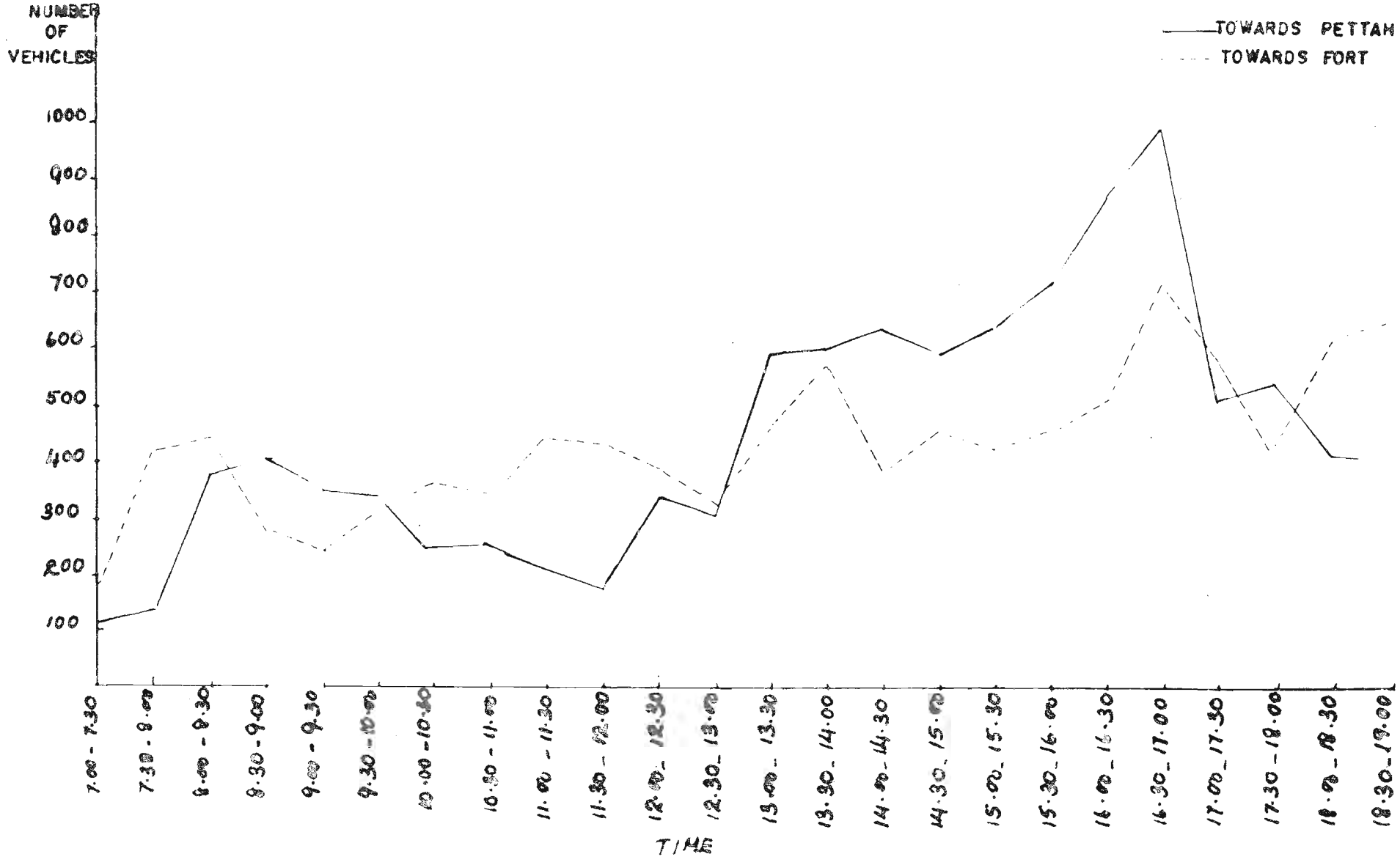
TRAFFIC COUNTS - CITY OF COLOMBO

UNION PLACE MONDAY 30.9.85



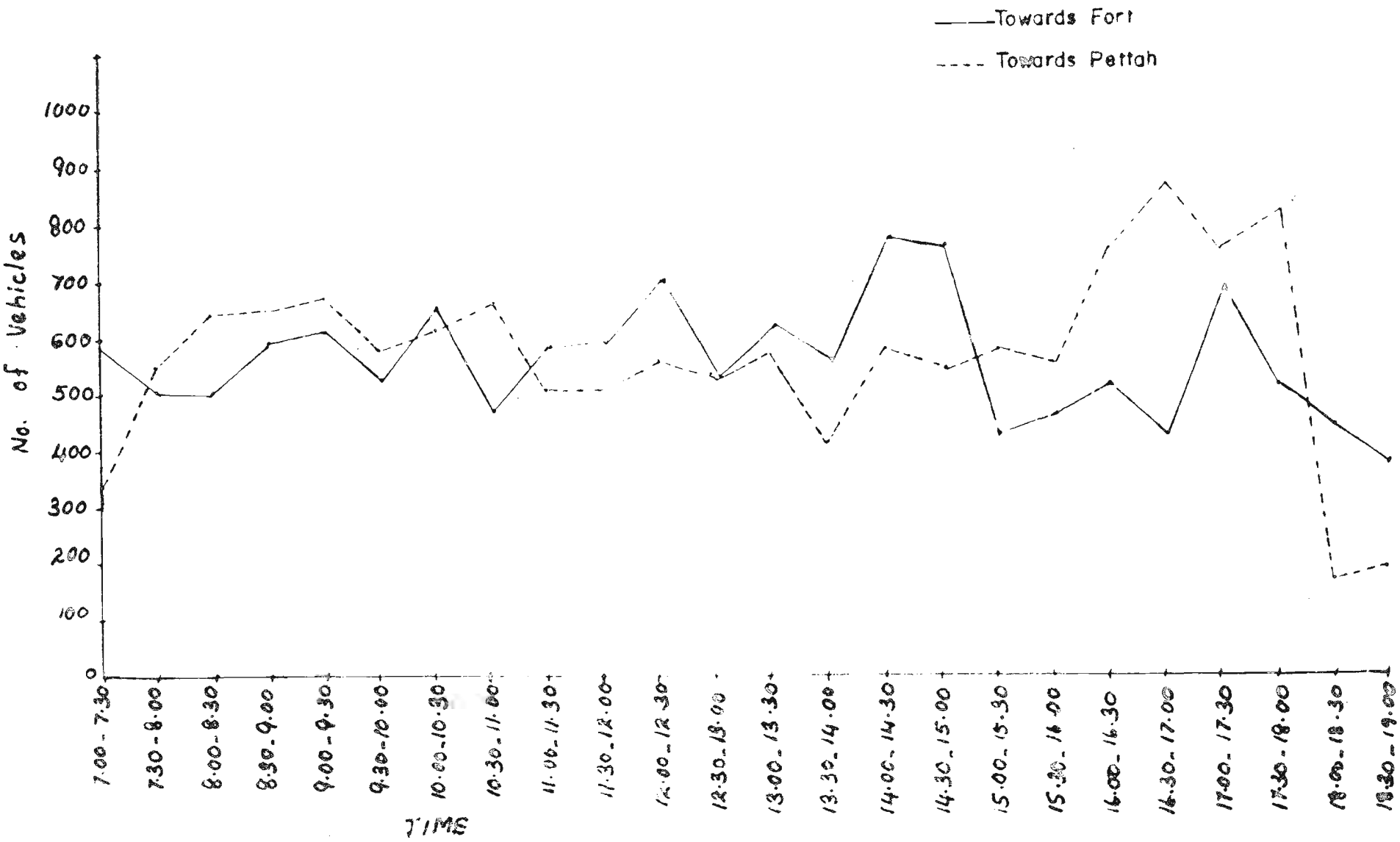
TRAFFIC COUNTS – CITY OF COLOMBO

MAIN STREET THURSDAY 02·05·85



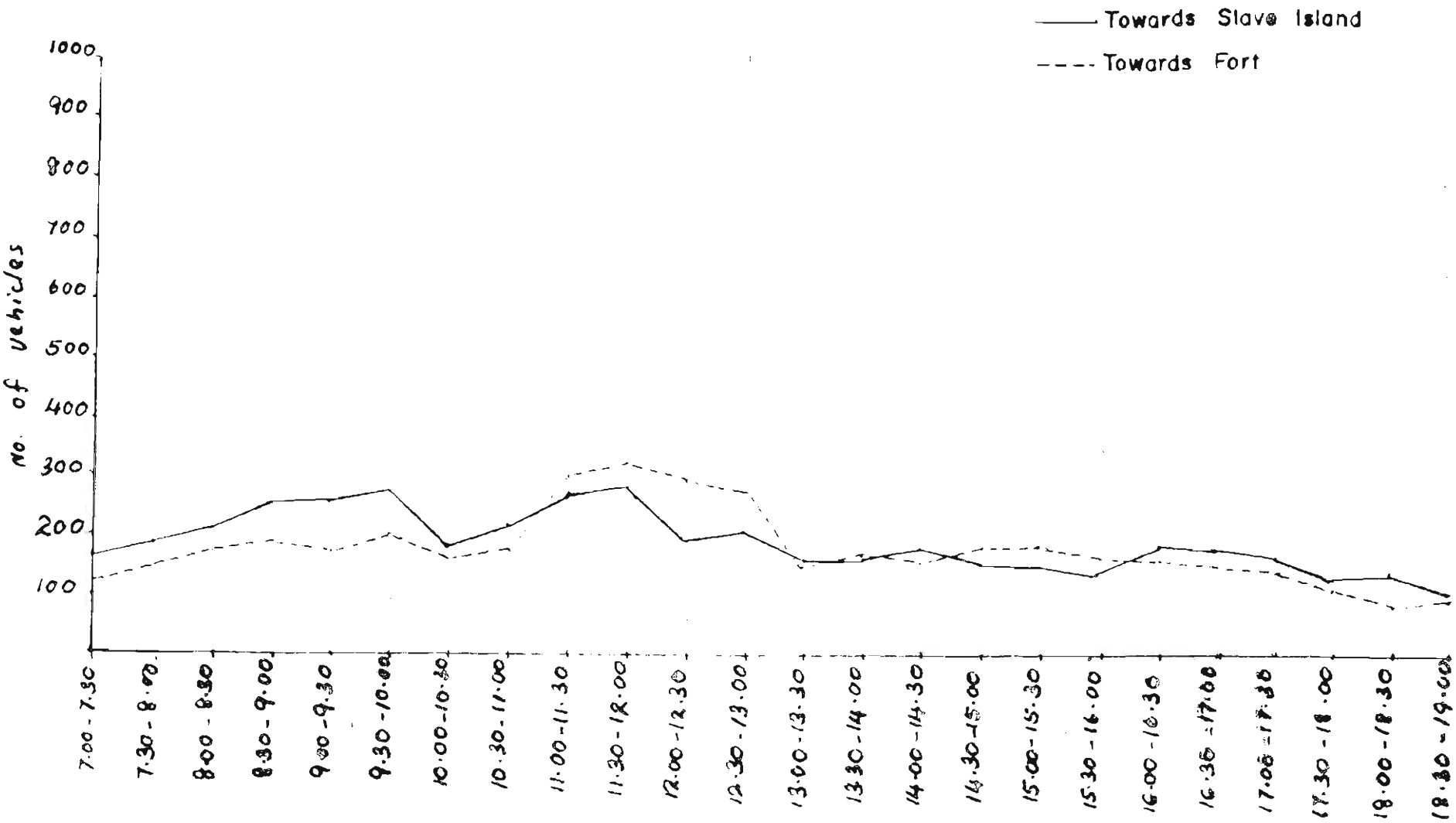
TRAFFIC COUNTS – CITY OF COLOMBO

OLCOTT MW. THURSDAY 28 · 2 · 85



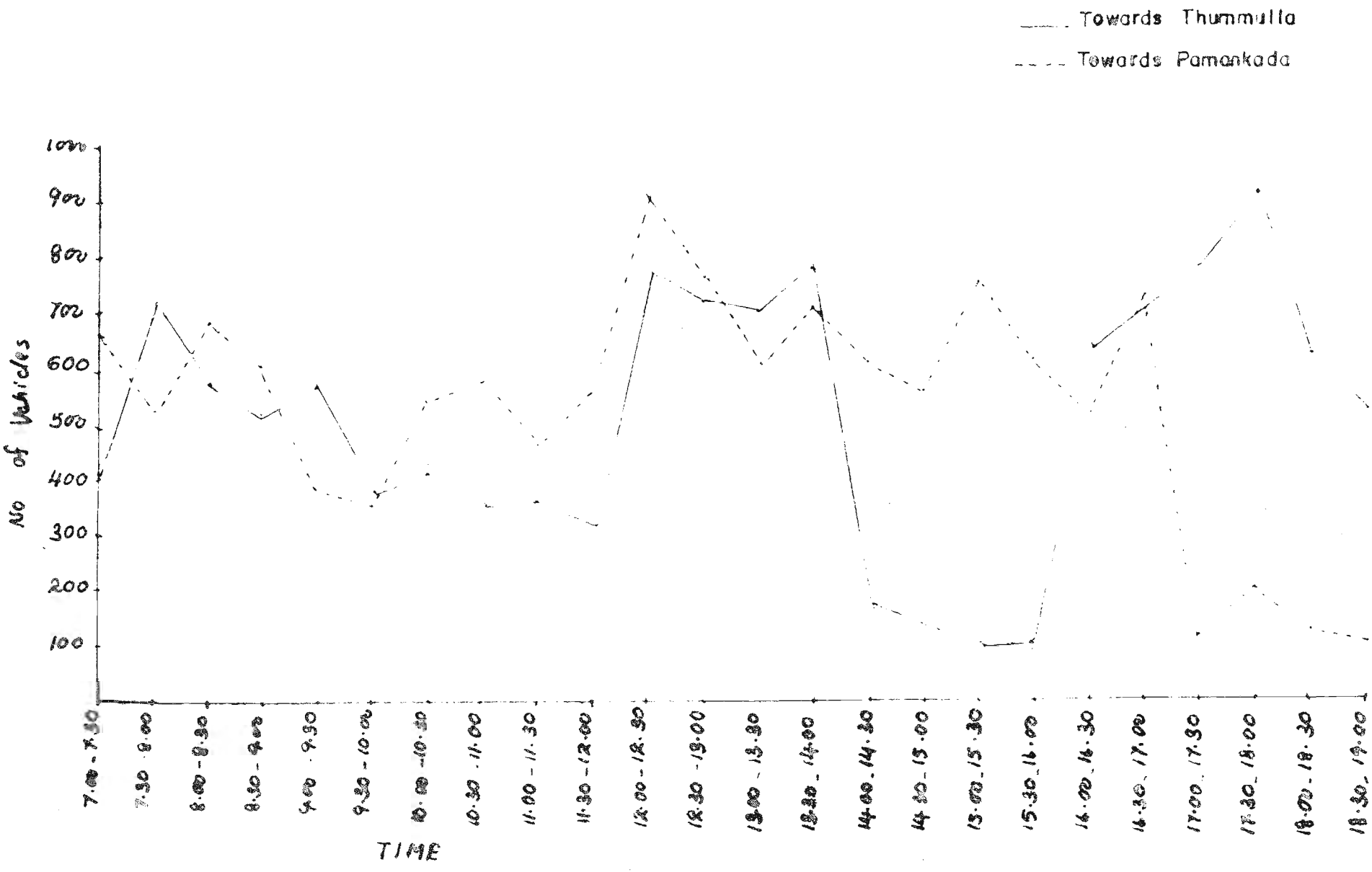
TRAFFIC COUNTS – CITY OF COLOMBO

PARSONS RD. THURSDAY 29·8·85



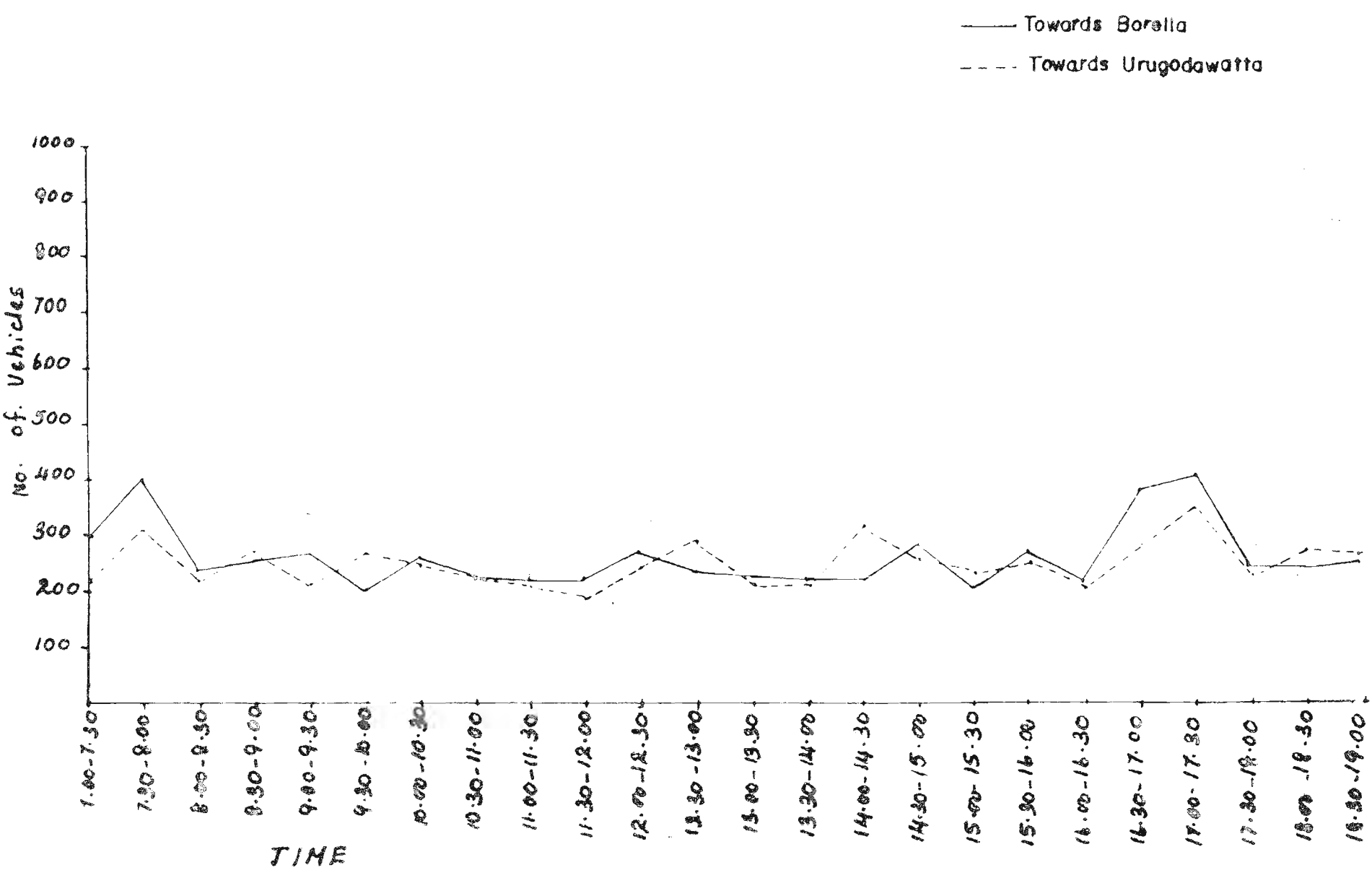
TRAFFIC COUNTS - CITY OF COLOMBO

HAVELOCK RD. THURSDAY 28-1-88



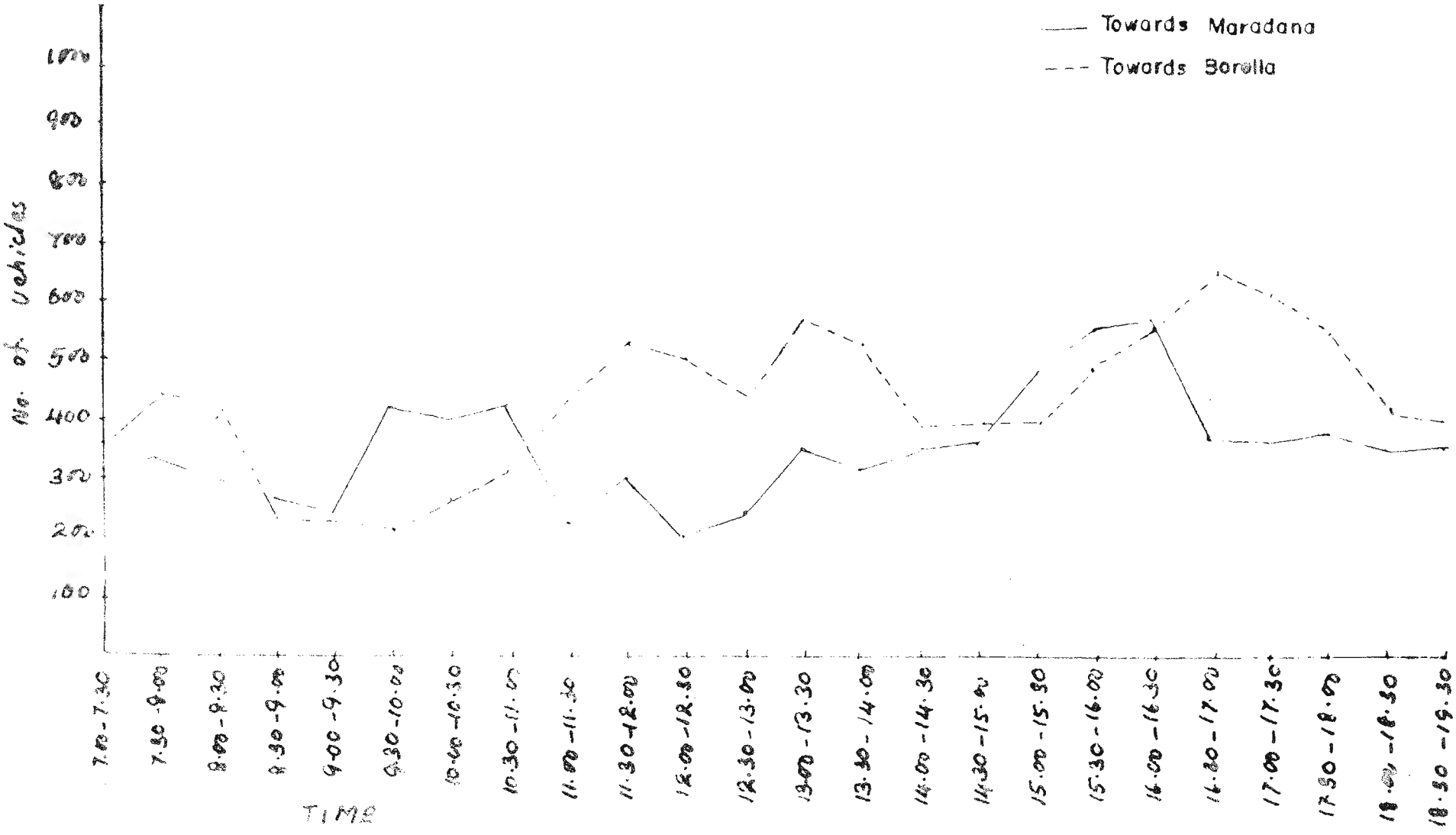
TRAFFIC COUNTS - CITY OF COLOMBO

BASELINE RD. WEDNESDAY 17 10 84



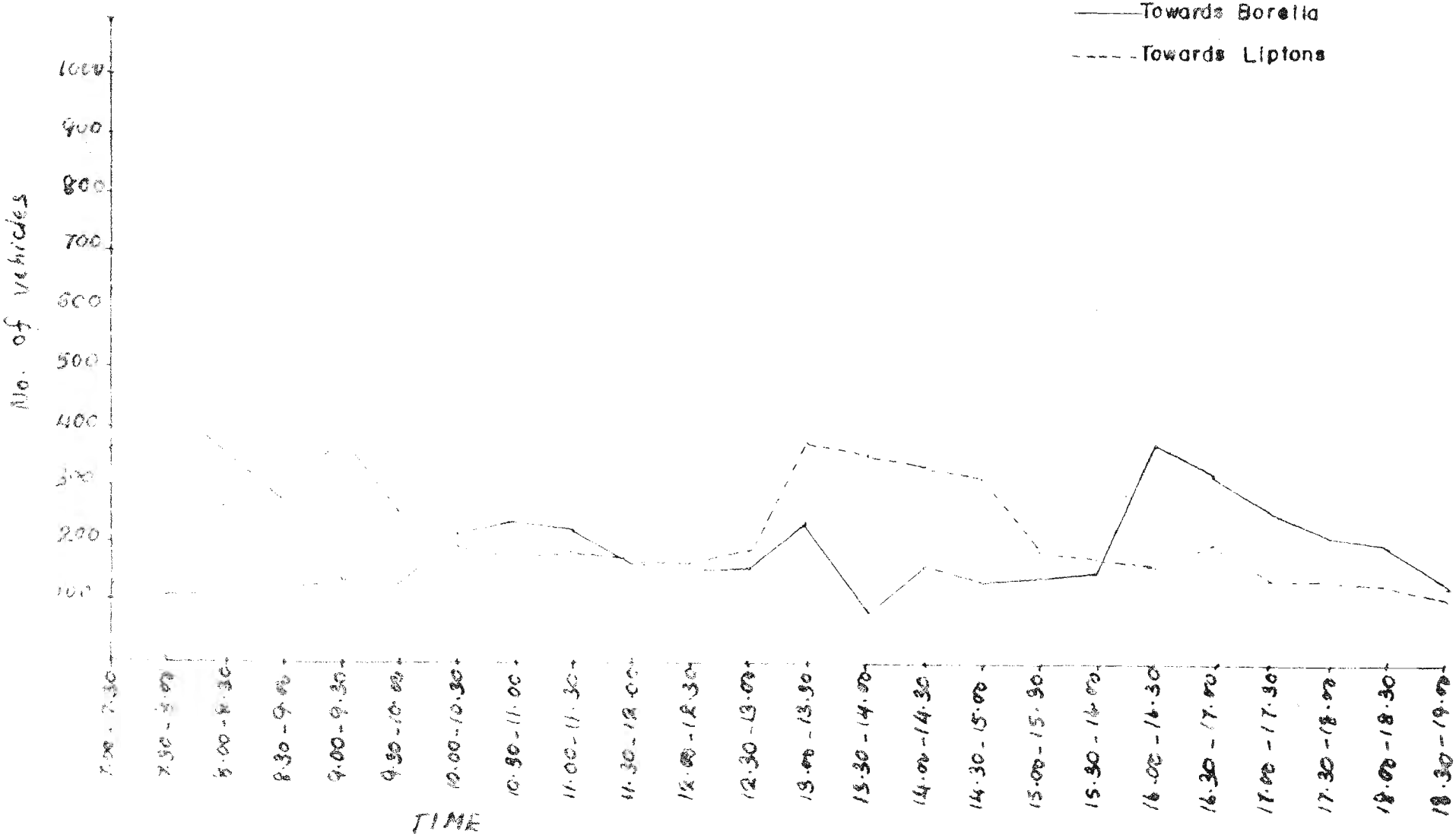
TRAFFIC COUNTS – CITY OF COLOMBO

MARADANA RD. TUESDAY 30·7·85



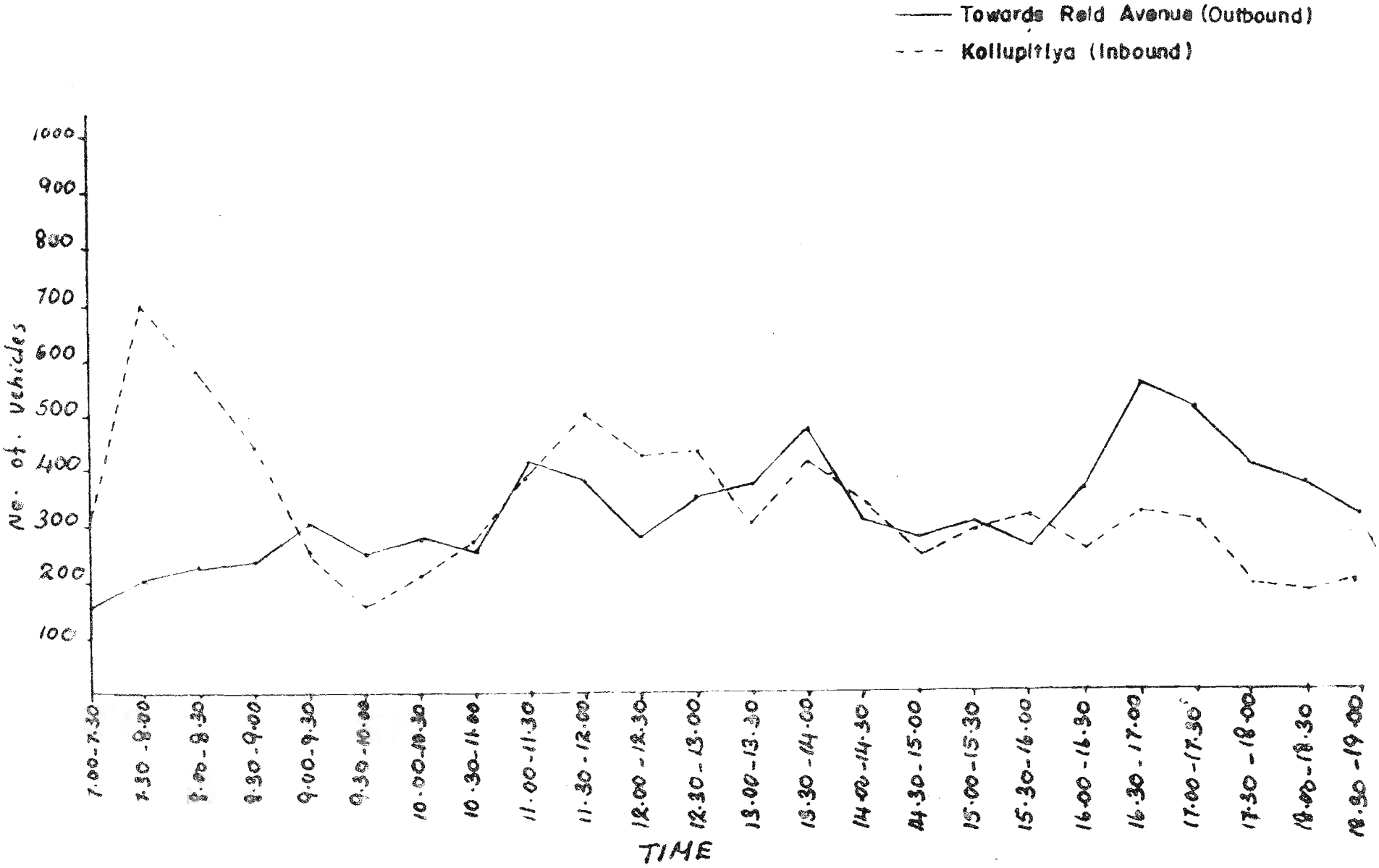
TRAFFIC COUNTS - CITY OF COLOMBO

WARD PLACE SATURDAY 27 · 4 · 85



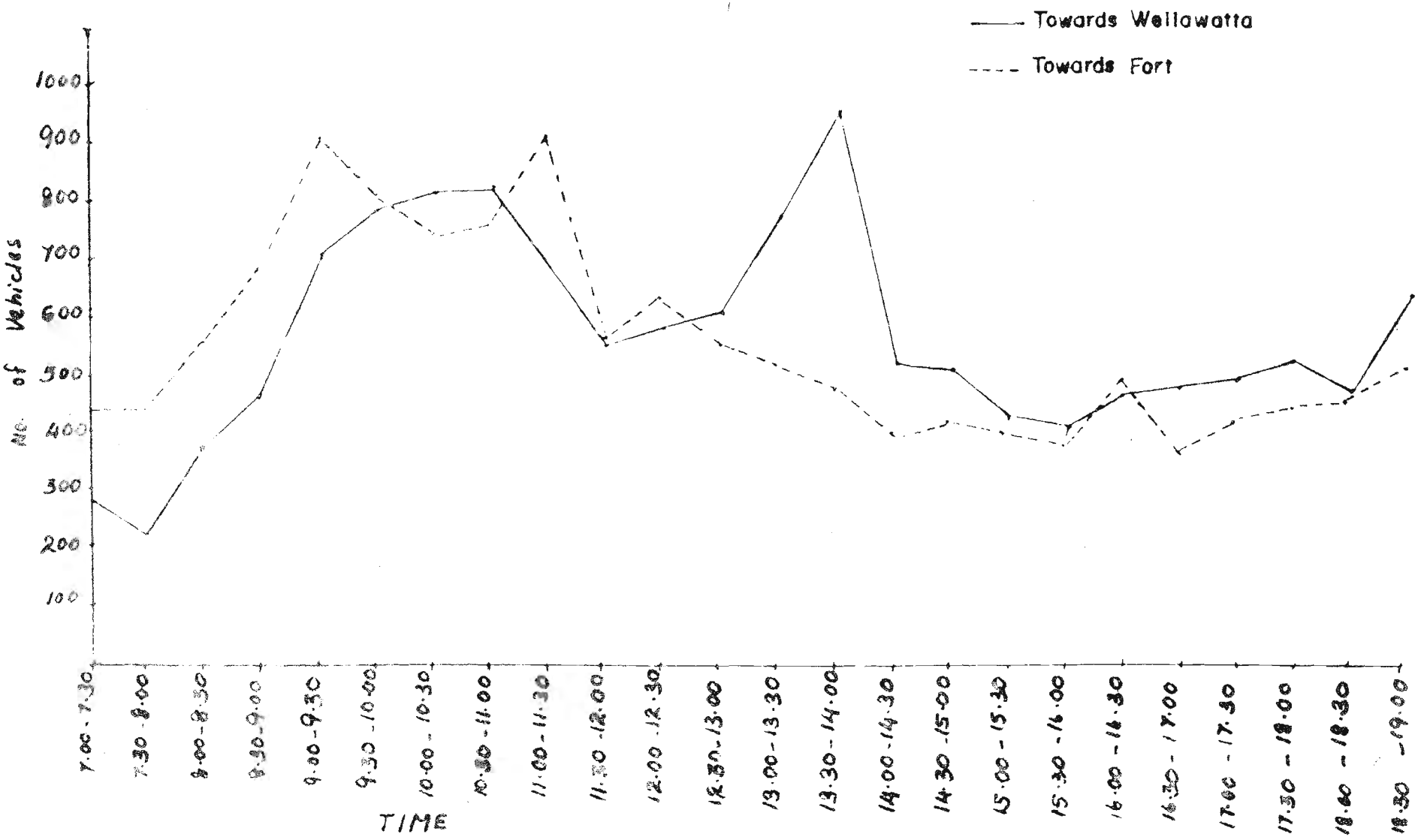
TRAFFIC COUNTS - CITY OF COLOMBO

FLOWER RD SATURDAY 25·7·84



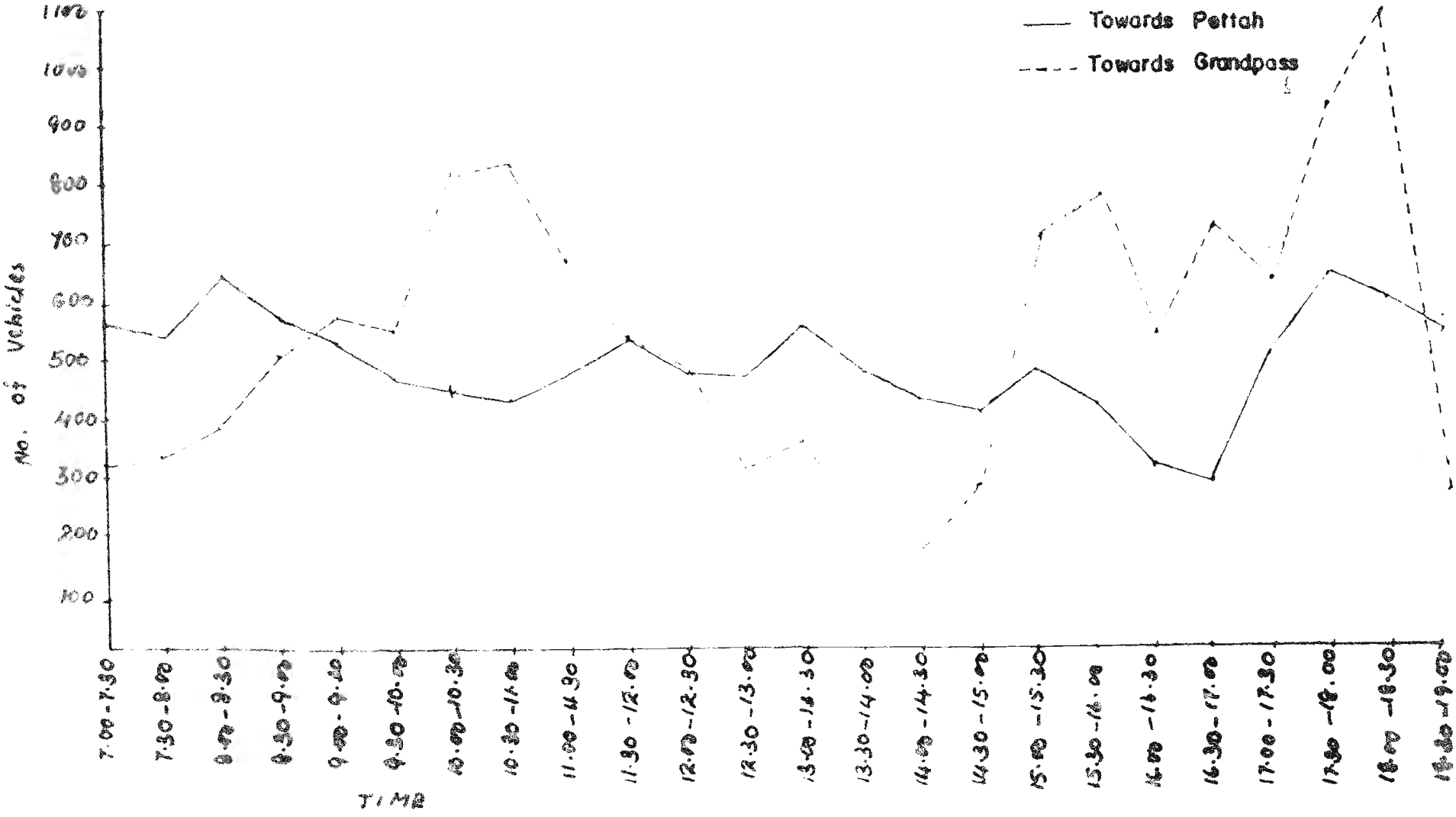
TRAFFIC COUNTS - CITY OF COLOMBO

GALLE RD. **SATURDAY** 15·9·84



TRAFFIC COUNTS - CITY OF COLOMBO

SIRIMAVO BANDARANAYAKA MW. SATURDAY 15·10·84



BOTTLENECKS IN THE COLOMBO TRANSPORT SYSTEM AND SOLUTIONS THROUGH BETTER INFRASTRUCTURE AND PRICING POLICIES

K.G.D.D. Dheerasinghe
Central Bank of Sri Lanka

The objective of this paper is to discuss the various constraints in the urban transport system in Colombo. The paper also examines how these constraints can be reduced and efficiency achieved through better infrastructure facilities and effective pricing policies.

It is difficult to give geographical limits to the Colombo Transport System (CTS). However, for the purpose of this paper, the CTS is defined as the urban transport system in the Greater Colombo area. It has been observed in previous studies that most of the urban transport problems are location specific and depend on network characteristics, availability of infrastructure and a number of other socio-economic factors. Clear reference is therefore, made wherever the problems which are exclusive to a particular area are discussed.

Increased costs to vehicle operators in particular and to society in general are general features of a poor transport system. The existence of bottlenecks in a transport system resulting in external costs may be viewed as originating from three main sources: firstly, inadequate infrastructure characterised by insufficient running space, signalling, policing and parking facilities; secondly, inadequate locomotion and carriage; and thirdly, insufficient terminal facilities for loading and unloading. Characterised by these factors, a common outcome in a poor urban transport system is what we describe as traffic congestion.

(1) Urban Congestion

The demand for transport is derived from the demand for other goods and services which require transport inputs for production or distribution. It is because these activities vary over time that the demand for transport is unevenly distributed by (a) time of day, (b) day of the week, and (c) season.

Although the peak problem is a built-in characteristic in any transport system, flow profiles showing hourly traffic variations on an average week day at the Colombo Municipal Council (CMC) border and on entry roads to Fort demonstrate substantial differences. These differences are illustrated in Figures 1 and 2 respectively.

The in-bound traffic flows in the CMC border are high in the morning peak due to journeys to work and school. A small

mid-day peak, attributable to journeys home for lunch and trips from school, is followed by a less concentrated outbound peak in the afternoon. The traffic flows through Fort show minimal directional imbalances. The peak in fact occurs in the mid-morning and mid-afternoon periods when business, commercial and retail activities are at their greatest levels.

1.1 Congestion Costs

Congestion reduces the speed at which vehicles could move. In so far as slower speed means increased cost, both because operating expenses are greater at lower speeds and because time (whether leisure or working time) is itself valuable, the unit operating cost increases as traffic volume increases. This can be illustrated by the relationship between speed and flow and by the variation of cost with speed.

We may regard the total social cost of providing the transport service involved (T) as being equal to the average operating cost (A) multiplied by the traffic flow (q) plus the wear and tear cost (W). Thus,

$$T = Aq + W \quad \text{----------(1)}$$

If W is assumed to be a constant, the Marginal Social Cost (M) can be defined as the first derivative of (T). Thus,

$$M = \frac{dT}{dq} = A + \frac{qdA}{dq} \quad \text{----------(2)}$$

Practical experience shows that the cost of operation relates to the speed of operation (V). It is usually assumed that operating cost per kilometre is part fixed and part inversely related to speed. Thus,

$$A = a + \frac{b}{V} \quad \text{----------(3)}$$

A strong relationship can be observed between the traffic flow and the speed of the flow and this approximates to a decreasing linear function.

$$V = d - fq \quad \text{----------(4)}$$

From (4) we get

$$q = \frac{d - v}{f} \quad \text{---------(5)}$$

By differentiating (3) with respect to q we get

$$\frac{dA}{dq} = \frac{dA}{dv} \cdot \frac{dv}{dq} = \frac{-b}{v^2} - F$$

$$= \frac{bf}{v^2} \qquad \text{----------(6)}$$

Thus from (5) and (6) we get

$$q = \frac{dA}{dq} = \frac{b(d-v)}{v^2} \qquad \text{----------(7)}$$

From (2), (3) and (7) we find that Marginal Social Cost (M) can be related to speed and to the parameters of the speed/flow and cost/speed relationships. Thus,

$$M = a + \frac{b}{v} + \frac{b(d-v)}{v^2} \qquad \text{----------(8)}$$

Based on the theoretical framework outlined in (1) - (8) above, a clear relationship between flow, speed and cost can be established. Using the data on major radial roads in Colombo the following flow speed relationship was identified.

$$V = 52 - 0.0267\ q$$

where,

V = average speed (km/h)

q = traffic flow (PCUs/standard lane per hour)

1.2 Physical Causes of Congestion

Congestion effects are relatively high in the CMC area and in certain suburban areas. The major physical causes of congestion in the CTS have been identified as follows:

(a) narrow bridges
(b) railway crossings, and
(c) restricted carriage ways.

Some of these constraints are presently undergoing improvements. However, much of the congestion throughout Greater Colombo is associated more with poor use of the track, than with capacity constraints. These shortcomings can be summarised as follows:

(a) inappropriate traffic control methods and traffic signs,
(b) indiscriminate and unregulated parking,
(c) inadequate lane demarcation,
(d) inadequate junction layouts,
(e) undisciplined behaviour at bus-stops, particularly by drivers of private buses,
(f) pedestrian interference with traffic
(g) slow moving vehicles.

The existing capacity of the track and terminal facilities can be more efficiently used by way of appropriate traffic management measures and other policy measures.

(2) **Bottlenecks in the Network**

In addition to physical causes and poor use of existing capacity there are certain characteristics in the network that contribute to congestion. Many locations suffer traffic levels in excess of existing capacity, resulting in delays for road users mainly during peak hours of the day. These are attributable largely to certain network characteristics which can be summarised as follows:

(a) The number of approach roads to the CMC area is limited to five major radial routes. There are four other less important roads. Both in-bound and out-bound traffic flows are concentrated on these roads with limited opportunities for diversion. During peak hours, congestion is inevitable on these roads.

(b) Owing to a large volume of rail traffic concentrating on a small number of stations at Maradana, Dematagoda and Slave Island, a heavy congestion of traffic and delays occur due to railway crossings on certain routes in the city.

(c) Traffic movements into and out of the central business area (Fort) of the city are concentrated on five approach roads. Flows are high on all these routes during peak periods.

(d) Both in- and out-bound traffic flows in the South of the city have to cross the Kirillapone canal. Although this canal is crossed by three roads, since the major attractions are better served by Galle Road and High Level Road, those alternatives suffer a high degree of congestion.

(e) The other routes with substantial concentration of traffic include Prince of Wales Avenue, Central Road and Union Place adjacent to the Lipton roundabout. Links that suffer severe strain of traffic and very slow speeds

include Galle Road adjacent to the CMC boundary, Maradana Road adjacent to the railway line, Olcott Mawatha, Union Place and Cotta Road.

(3) Delays at Junctions

Delays at junctions are common to any transport system. However, there are a number of junctions in the city which suffer additional congestion. A large number of these junctions do not have a proper traffic control system and as a result, priorities are established by drivers pushing out into the opposing stream.

(4) Parking in the Central Area of Colombo City

The availability of parking facilities in Colombo Fort in 1985 was estimated to be around 1250 parking spaces. This included 850 public spaces on streets, 200 public spaces off streets and 200 private spaces off streets. Surveys conducted on parking habits reveal that on-street parking is an obstruction to movement of vehicles. It has also been observed that the demand for parking spaces in Colombo is much in excess of the existing supply. Most of the large organisations in Colombo do not have parking facilities for use by their employees or clients. Parking demand in Fort on an average week day is illustrated in Figure 3.

(5) Impact of Pedestrians, Cyclists, Slow Moving Vehicles and Other Objects

A very high proportion of journeys are made by foot or by bicycle. Slow moving vehicles, which are sometimes non-road-worthy, and other non-motorised vehicles such as bullock carts add to congestion in peak hours. The habits of pedestrians and carelessness of cyclists create traffic control problems. Because of the poor state of foot paths, pedestrians tend not to use them. There are a number of other stationary objects such as vegetable and fruit stalls, and occupation of the road surface in this manner mainly at junctions reduces the capacity, resulting in bottlenecks.

(6) Capacity Expansion, Maintenance and Policies for Better Management

Some important issues have been brought to light in the foregoing discussion. These issues relate particularly to inadequate availability and poor maintenance and management of existing capacities. Therefore, capacity expansion would lead to easing the congestion.

With regard to efficient allocation of existing capacity, pricing policies are of paramount importance. Issues relating

to pricing in this context are two fold because transport entails both adverse and favourable external effects. Such adverse external effects should be subject to taxes and positive external effects may be subsidized. Our subject of discussion is basically on the adverse external effects of transport. The argument is that motorists cause congestion costs which impinge on other motorists and the rest of the society and these costs must be internalized by fiscal means.

6.1 Charging for the Use of Infrastructure

The road users can be charged on the basis of (a) ownership and (b) use. The former is easy to implement but ineffective in achieving the objective, whilst the latter is difficult to implement and administer, but a more effective method of pricing. The main considerations of congestion taxing should be timing of payment, ease of collection, cost of monitoring and relation to actual costs.

Measures for rationalising the use of transport facilities are outlined in Table 1. These include pricing policies and measures of physical control. Of these measures, the focus of pricing policies is to ensure efficient use of capacity. Pricing policies may be either direct or indirect. The indirect measures are related either to vehicle ownership or usage, while direct measures are related either to charges registered on vehicle or charges registered off vehicle.

Measures of physical control are related to both efficient use of capacity and to secure distributional equalities. However, imposition of physical restraints must be done carefully because the objective of any transport system should be to facilitate the movement of traffic and not to restrict.

(7) Conclusions

The following observations can be made on the basis of the above analysis.

7.1 Traffic bottlenecks in the CTS are partly due to inadequate capacity and partly due to inefficient use of existing capacities.

7.2 Improvements in the CTS should necessarily be supported by expansion of the capacity. These improvements include new and better infrastructure.

7.3 Efficient use of infrastructure, locomotion and carriage and terminal facilities necessarily entails appropriate physical controls and effective pricing policies.

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FIGURE 1

DAILY TRAFFIC PROFILE

MUNICIPAL CORDON

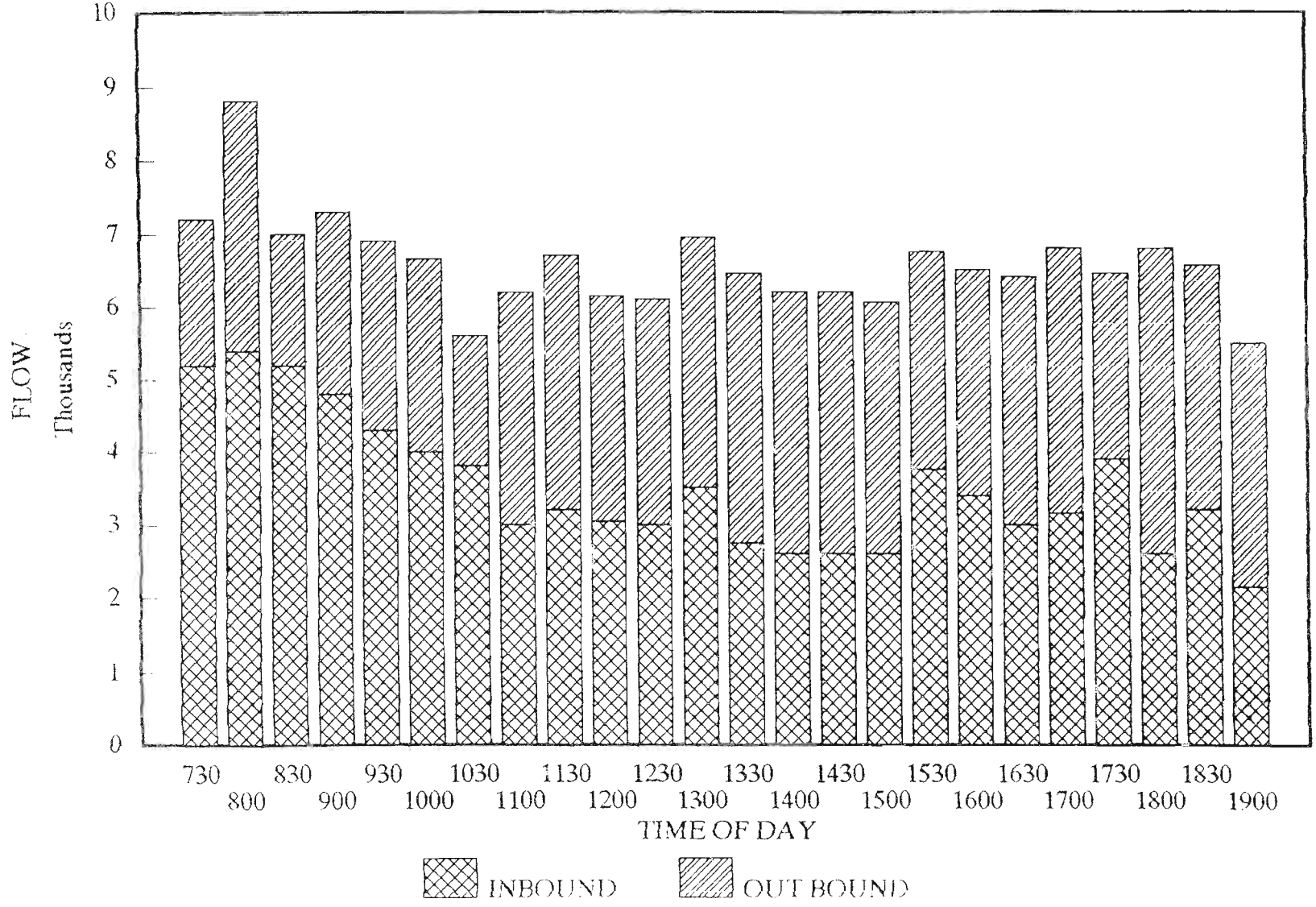


FIGURE 2

DAILY TRAFFIC PROFILE

FORT CORDON

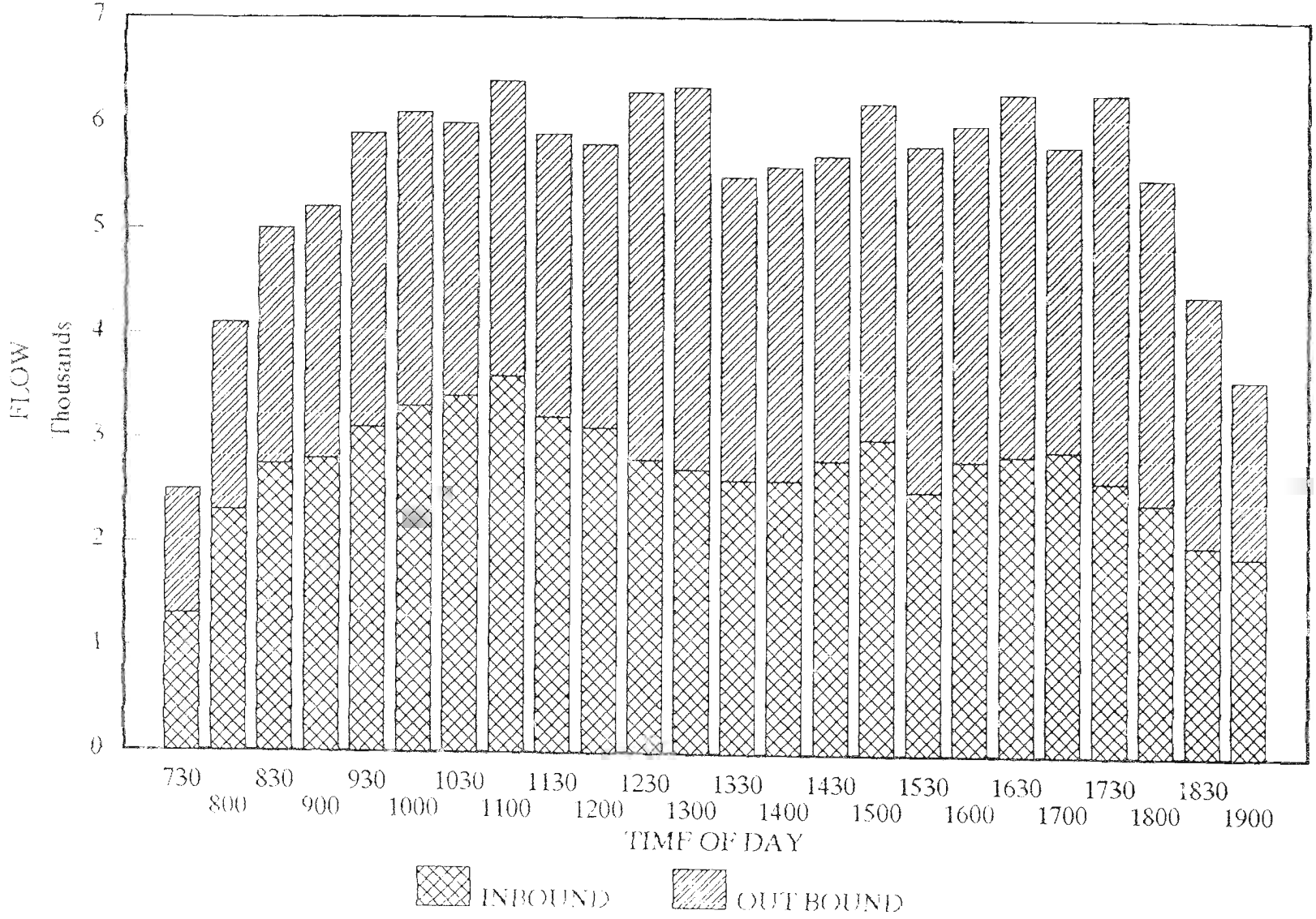


FIGURE 3

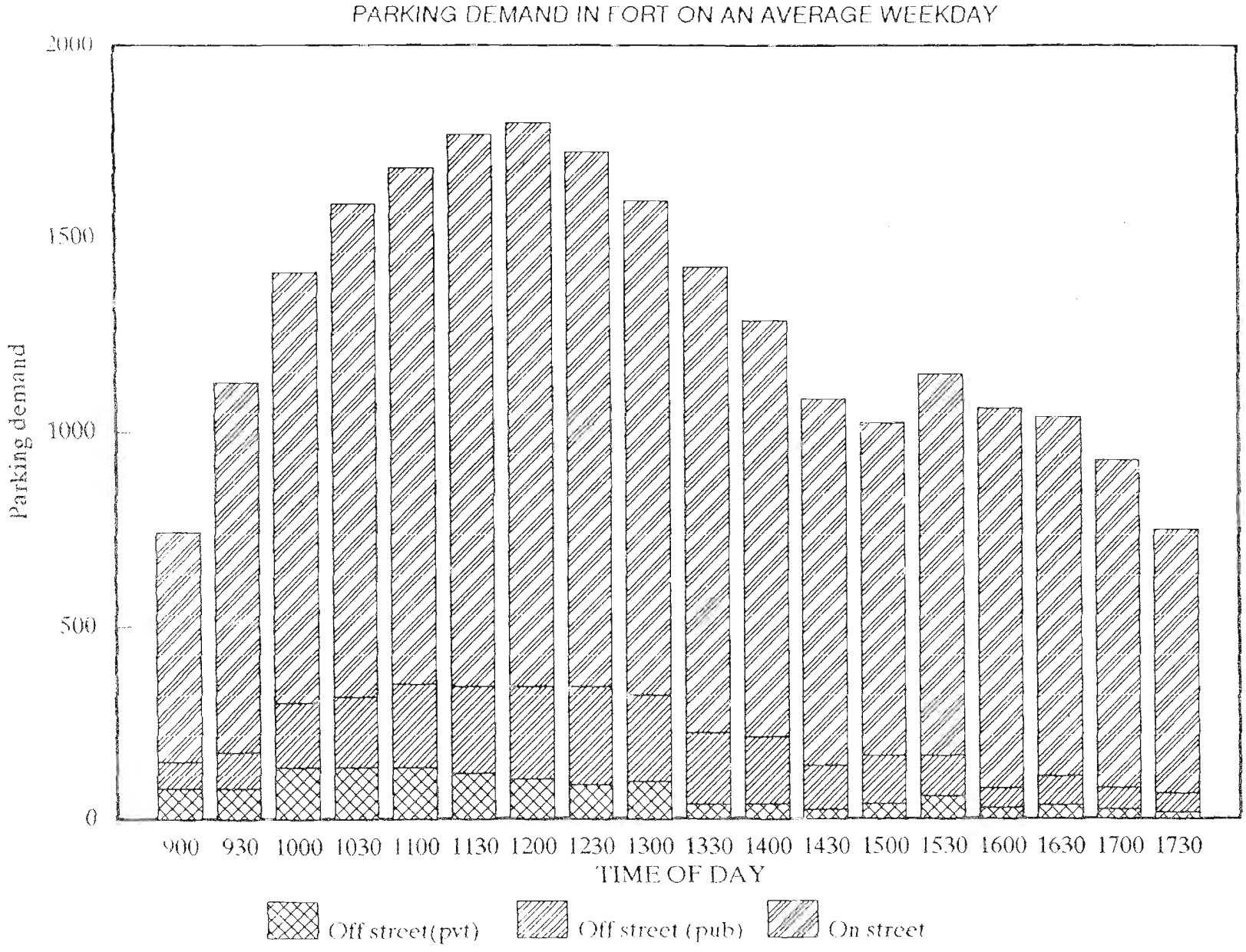
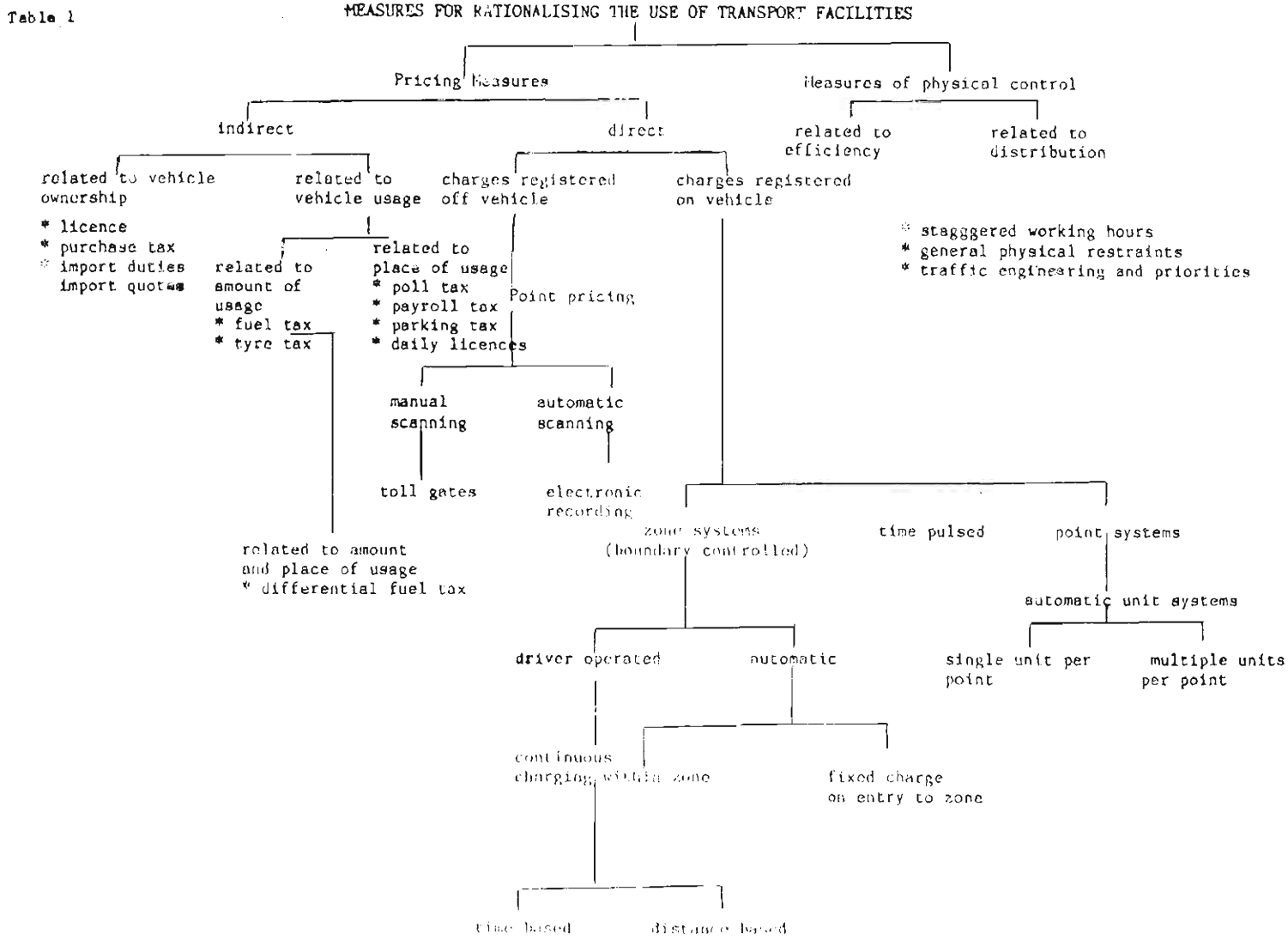

PARKING DEMAND IN FORT ON AN AVERAGE WEEKDAY
2000
1500
1000
500
0
Parking demand
900 930 1000 1030 1100 1130 1200 1230 1300 1330 1400 1430 1500 1530 1600 1630 1700 1730
TIME OF DAY
Off street(pvt)
Off street (pub)
On street

Table 1


MEASURES FOR RATIONALISING THE USE OF TRANSPORT FACILITIES
Pricing Measures
Measures of physical control
indirect
direct
related to efficiency
related to distribution
related to vehicle ownership
related to vehicle usage
charges registered off vehicle
charges registered on vehicle
* licence
* purchase tax
* import duties
import quotas
related to amount of usage
* fuel tax
* tyre tax
related to place of usage
* poll tax
* payroll tax
* parking tax
* daily licences
Point pricing
* stagggered working hours
* general physical restraints
* traffic engineering and priorities
manual scanning
automatic scanning
toll gates
electronic recording
related to amount and place of usage
* differential fuel tax
zone systems (boundary controlled)
time pulsed
point systems
automatic unit systems
driver operated
automatic
single unit per point
multiple units per point
continuous charging within zone
fixed charge on entry to zone
time based
distance based

ROAD MAINTENANCE PRACTICE AND EFFECTIVE TRAFFIC CONTROL MEASURES

Denzil D. Senanayake
Road Development Authority

(1) Road Maintenance Practice

Generally, road maintenance is considered in four inter-related stages or phases.

They being:
- Routine Maintenance
- Recurrent Maintenance
- Periodic Maintenance
- Urgent Maintenance

Essentially routine maintenance is devoted to up keep of the road side and the drainage system by a process of cleaning and clearing.

Recurrent maintenance is generally meant to keep the riding surface free of potholes, cracks and depressions which are caused mainly due to the damaging effects of traffic and rainfall.

Periodic maintenance as the words imply is a maintenance procedure carried out periodically with the view of preventing damage to the road due to the effects of traffic, rainfall etc. This activity is also referred to as preventive maintenance.

Urgent maintenance is an activity devoted to deal with urgent situations of sudden damages to roads or bridges or situations of road blocks caused by floods, landslides, etc., normally requiring solutions which cannot be pre-planned.

Another aspect that is closely related to road maintenance is road rehabilitation which too could be looked at in two phases, namely light rehabilitation and heavy rehabilitation.

The difference between maintenance and rehabilitation is that in the latter the road is brought to a predetermined standard such that normal maintenance would not be required for a defined period of time. In light rehabilitation, however, the work done is very much similar to that of periodic maintenance and normally is not associated with any improvements as would be required in heavy rehabilitation.

These activities have varying effects on flow of traffic and cause obstructions to traffic in varying degrees depending on the extent/magnitude of the activity.

In the following an attempt is made to deal with these activities separately in relation to the effect on traffic flow and traffic control measures adopted.

(2) Effect on Traffic Flow and Traffic Control Measures

(a) Routine Maintenance

In carrying out routine maintenance stacking of debris along the road side and non-removal of same quickly to dumping grounds, is one of the major causes for obstruction to traffic movements.

Very often debris, resulting from clearing of drains etc., is stacked along the road edge and traffic flow is hindered. This is particularly so where passing or overtaking manoeuvres of traffic have to take place along narrow roads. It is very necessary that such debris be removed to dumping grounds without delay. This activity needs to be properly planned out and there is also the need to use appropriate tools and equipment in the performance of this activity.

(b) Recurrent Maintenance

Recurrent maintenance activities, mainly involving "patching up operations" of the carriageway, will require closure of sections of roads if they are to be carried out effectively. This is often not possible, particularly on narrow roads. In such instances resort has to be made to carrying out work quickly and to allow the road to traffic without delay. Patching up using premixed materials may be the most effective under such circumstances. However, the use of porper type of premixed patching material and careful planning of the operation is essential.

Slowing down of traffic or temporarily stopping of traffic is essential. Effective use of flag men is emphasized in this regard.

Traffic cones and barricade boards may be used to narrow down carriageway widths and barricade part of the carriageway for undertaking road repairs.

Night work certainly is helpful in this regard but such work is costly and difficult from an organisational point of view.

(c) Periodic Maintenance

Periodic maintenance is an activity which provides plenty of time for planning of the activity. However lack of

necessary facilities and insufficient widths of roads are causes for obstruction to traffic. Essentially periodic maintenance require the construction of a sealing layer or overlaying with a thin layer of material of the carriageway. For this purpose it is necessary that a defined width of a road for a defined length be closed for traffic for a reasonable duration of time.

In this regard too night work is considered helpful, costs permitting and provided that the organisational difficulties could be overcome.

Use of flagmen and other traffic control devices is a must in this case. Traffic cones and barricade boards could be used effectively to narrow down carriageway widths and close sections of roads as suitable. Warning signs for traffic, may also be used. Where possible it is desirable to divert traffic through other roads.

A typical layout of signs, cones and barricade boards for closing part of the carriageway is shown in Figure 1.

(d) Urgent Maintenance

Urgent maintenance due to an earthslip, damaged structure or section of road getting washed off will involve the closure of the road for traffic, partially or fully. In such cases it is mandatory that barricade boards be put up to barricade the section of road closed for traffic and lighting be provided in the night to prevent accidents. If the road is totally impassable diversion routes must be established and adequate number of traffic diversion signs should be provided, giving directions and destinations in order to cause minimum inconvenience to the road user.

Informing the public without delay, through radio, TV and other means of communication, of the traffic diversions is considered essential.

(e) Rehabilitation of Roads

In rehabilitation of roads the methods of management of traffic will be similar to that of periodic maintenance but will always be of a more complicated nature. It is in this sort of work that real traffic management methods, with the participation of police as well, has a real meaning. Signs, cones and barricade boards as shown in Figure 1 with suitable modifications where necessary could be effectively used along with flagmen to control traffic.

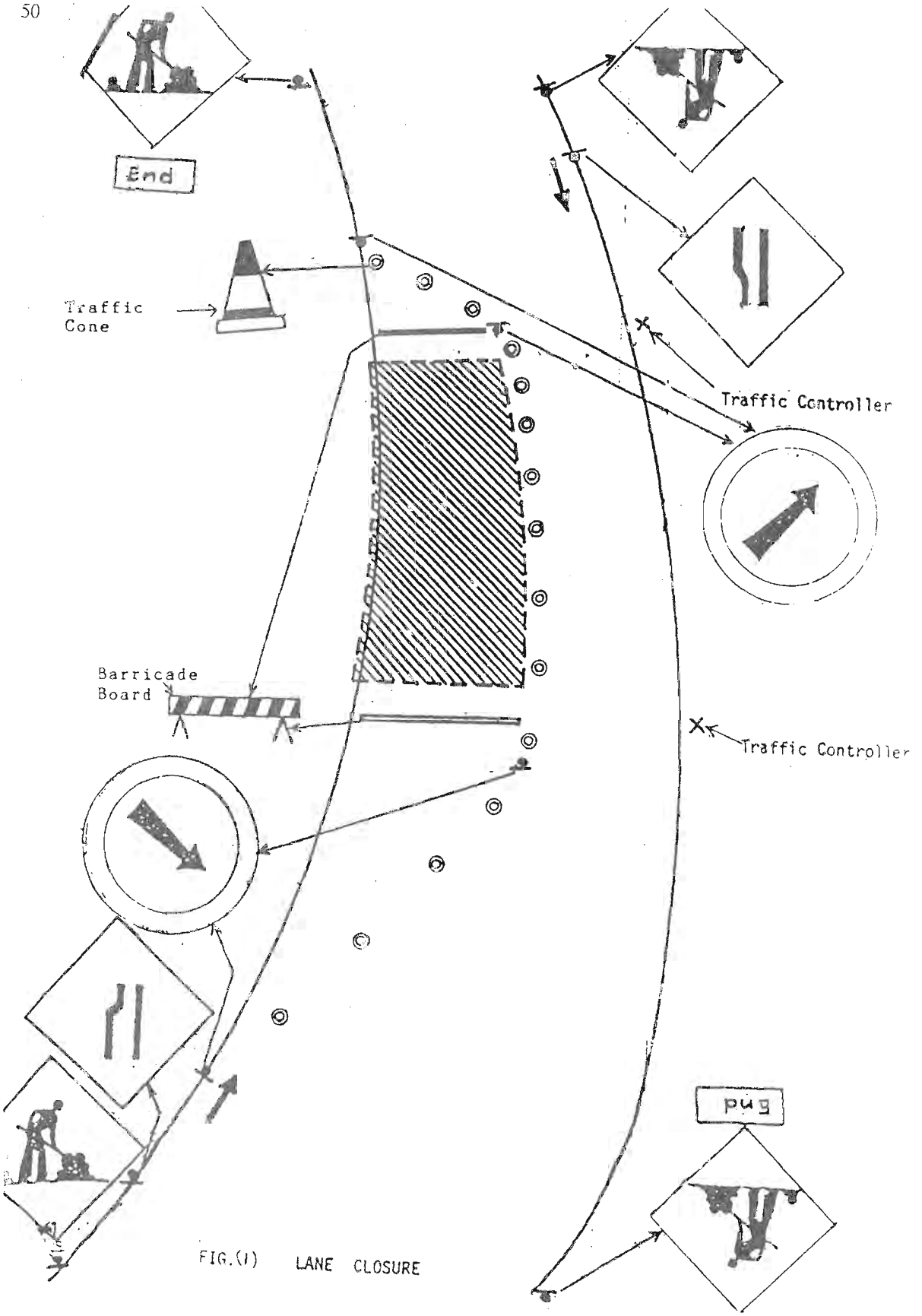


FIG.(1) LANE CLOSURE

ROLE OF MUNICIPALITY IN MAKING URBAN TRAFFIC MORE ENERGY EFFICIENT

T. Kanagasingham
Colombo Municipal Council

(1) Introduction

1.1 Energy for Transport

Energy consumption of all countries irrespective of developing or developed are increasing progressively with the increase of economic activities and improvement of standard of living. The sources of energy are namely fossil fuel, coal, electricity, nuclear power and sun etc. A large chunk of energy is used in the transport sector. Fossil fuel or liquid petroleum plays a very vital role in road transport. Developing countries are finding it very difficult to meet the cost of fuel bills as they are struggling with other basic pressing problems. Therefore it is the paramount duty of developing countries to adopt ways and means to reduce fuel consumption without affecting development and basic amenities.

1.2 Urban Transport and Energy Consumption

A common problem for many cities in developing countries is that of inadequate roads, in terms of both capacity and scale. The consequence of present day traffic demands of many types of road users and mixed street activities in urban areas often leads to considerable congestion which can have very costly affects on urban transport. Poor road surface conditions, lack of maintenance and management measures,poor coordination between highway authority and utility agencies, and poor enforcement of regulations lead to reduction of the vehicular capacity of roads and increase the degree of congestion. As a result, the operating speed is reduced and fuel consumption and vehicular operating costs are increased.

Increase of speed of vehicles upto 50 k.p.h. decreases the consumption of fuel and thereafter fuel usage increases with the speed. There is a rule of thumb, that the reduction of journey time by 10 minutes results in reduction of fuel consumption by 6-7%. Hence, congestion in the cities will have to be tackled to have energy efficient urban traffic (Fig. 1).

1.3 Municipality and its Role

The functions of a Municipal Council are as follows

- maintenance of thoroughfares
- public health and curative health facilities
- sports and recreation
- maintenance of essential services such as water supply, solid waste management, drainage and street lights
- infrastructure for community development
- public assistance

The above functions are carried out by 13 departments in the Colombo Municipal Council.

Provision and maintenance of thoroughfares and essential services is the responsibility of the Municipal Engineer's department. About 75% of the Council staff is employed in the Engineer's department which has several sections to manage its affairs efficiently and easily. How the Municipal Council, and in particular the Engineer's department could contribute to achieve energy efficient transport in the city, will be described in detail in the following sections.

(2) Thoroughfares

2.1 City Road Networks

Within the Colombo Municipal area some 480 km of paved city roads, of which almost 50 km are Ministry of Highways roads, are maintained by the council under delegated authority. On much of the road network traffic flows are light, and capacities are generally adequate although congestion is a regular occurrence in certain areas, or key routes and at various bottlenecks. There is a general lack of traffic management, street signs and road markings, all of which contribute to poor driver discipline. There are also several hundreds of private roads which are not maintained by Council. Recognition of the deteriorating condition of the roads and decline in overall highway standards led the Municipality to commence the Colombo Roads Rehabilitation Programme and to strengthen the maintenance capability of the Council.

2.2 Rehabilitation of Roads

The Colombo Traffic and Road Rehabilitation Project (CTRRP) began in May 1984, with the appointment of WS Atkins International to assist the Municipality on a range of highway improvement measures. The work progressed over several points, including major improvements of road surface, drainage, footways and lighting over selected key routes, rehabilitation of lower order roads and introduction of traffic management measures to increase capacity and improve road safety. Maintenance work required the training of labour gangs in better techniques, the procurement of basic equipment, and certain financial reforms.

Galle Road and Prince of Wales Avenue are being rehabilitated under an ODA grant and many other roads have been rehabilitated with council funds.

2.3 Maintenance

The aims of maintenance are -

- to reduce the rate of deterioration of the road
- to retain a low vehicle operating cost over a road by providing a good running surface and enable regular and punctual operation of transport services
- to provide a continual high degree of safety for road users

Routine, recurrent and periodic maintenance should be carried out to achieve the objectives mentioned above.

Maintenance works in urban sections take considerable time due to heavy traffic and utility services. Therefore maintenance has to be planned and carried out without any obstruction to traffic and utility services. Normally peak hours are avoided for maintenance purposes. Some of the roads with very high traffic volume are repaired at night or on public holidays. Adequate safety and traffic management measures have to be implemented for road work to prevent accidents and obstructions to traffic flow. The Council has arranged training programmes for road engineers, supervisors and even to contractors on these measures.

A pavement management strategy is being worked out on a computer database to manage the pavement in a planned and scientific manner. The inventory and condition surveys of the road network have been fed into the computer. The maintenance priorities for the roads are worked out by

computer on laid down standards of maintenance. This system will ensure a standard of maintenance and good mobility of traffic, and thereby lead to reduction of fuel consumption,and a good environment.

2.4 Traffic Management Measures

Considering the ever increasing development and vehicular demands in Colombo it was inevitable that traffic management measures and traffic engineering techniques were required in order to alleviate congestion. New traffic signals were introduced at a small number of junctions to demonstrate the benefit of programmed installation and these continue to function sucessfully today. Their specification has been used for many other sites and the programme of installation continues. The installed traffic signals have the facilities for interlinking. It is the ultimate aim of the Council to have an (UTC) Urban Traffic Control system so that delay could be further reduced and also achieve priority for public transport or any other vehicles.

The conventional way of increasing the capacity of roads ie. by way of widening, is very prohibitive in urban situations. Therefore low cost traffic management techniques could be implemented to increase the capacity and road safety. However, enforcement and education is very esential to reap the desired benefits.

The Municipal Engineer's department has developed a good and cordial relationship with the City Traffic Police; and discussions are carried out at design and implementation stage for successful implementation of traffic management schemes.

2.5 Parking

Parking facilities are an integral part of transport system. Travel is not usually generated for the usage of movement, but rather for partaking in activities at the end of the trip. In order to partake in these activities namely private or public businesses, recreation, etc, the vehicle must be parked. The lack of appropriate parking facilities can result in congestion and frustration. The Fort and Pettah areas show a high degree of congestion due to insufficient parking facilities. Our study reveals that existing parking facilities both on and off-streets are about 600. But the demand is about 1800. The Municipal Council is trying desperately to provide off-street parking facilities to cater to the demand.

Parking, in particular is such a sensitive issue that parking policies in many communities often appear to be both conflicting and indecisive. However, the public has

reluctantly accepted the need to exercise firm controls on parking in town centres. Good parking management and control can lead to some or all of the following:

Higher car occupancies, decreasing person-trips, faster travel times and less travel delays, greater public transport usage, decreasing congestion, and reduced air and noise pollution. The effect of on-street parking on useful carriage width is shown in Annexe 1. The Council has implemented no-parking on congested routes in peak hours, and alternative parking is allowed depending on the direction of flow. New parking bays are provided wherever possible without hindrance to traffic flow.

(3) Essential Services

3.1 Solid Waste Management

Solid waste management is a very important and essential responsibility of the Council : Some important information is given in Annexe 2. There are three components in solid waste management, namely

- Collection
- Transportation
- Disposal

For the above activities, the city road network is extensively used. Therefore, the activities have to be carefully planned so as not to cause any obstruction to traffic flow.

The daily collection of garbage is about 450 m tons. Hence, the council has the herculean task of collection and disposal. About 2300 labourers are employed to achieve this task with several compactors, trucks, lorries and other equipments.

Streets are swept by the labourers and sweepings are transported by about 400 handcarts. This operation is planned to avoid peak hours and night work is carried out in very congested areas. Several hundreds of temporary dumps are selected to store the solid waste till removal, after giving enough consideration for the smooth flow of traffic.

3.2 Water Supply

Colombo Municipal Council is an agent for the National Water Supply and Drainage Board, for the maintenance of the water distribution system in the city. There are

about 450 miles of network of water main ranging from 3" to 30". Since the water distribution network is very old, there are frequent break downs and 'no water' complaints. Several hundreds of valves and fire hydrants have to be maintained. All these maintenance works are planned to be carried out on public holidays and off peak hours, to prevent obstruction to traffic. Main bursts are promptly repaired to prevent damage to road surface and holding up of traffic streams. Laying of mains and giving of service connections are carried out after proper road safety measures are taken. Some important statistics about waterworks are given in Annexe 3. Preventive measures such as regular flushing of mains, replacement of perished mains and descaling of silted mains are carried out to avoid sudden repairs to water mains.

3.3 Drainage

Colombo city has two independent sewerage systems for the collection and disposal of stormwater and foul water. Since the systems are very old, they need extensive repairs and rehabilitation. The Foul Sewer System was rehabilitated a couple of years back.

Important information regarding the city sewer system is given an Annexe 4.

Water is an enemy to a road. Therefore the drainage system should be efficient to get rid of water as early as possible. There are several hundreds of manholes and gully pits which have to be maintained, and drainage lines have to be desilted in time to prevent flooding, so that the road network will be in good condition.

Another burning problem is the stealing of cast iron manhole and gully covers by organised gangs. This leads to accidents and obstructions to traffic flow and also serious damage is caused to entire drainage systems due to entry of unsuitable and unwanted materials such as stones, branches and earth etc. The Council has already produced concrete manhole and gully covers and successfully tested them.

Action is being taken to replace the lost covers with concrete ones.

(4) Coordination of Utility Agencies

Lack of co-ordination and unplanned trenching of roads by utility institutions have been highlighted almost everyday in newspapers.

Since the CMC is the highway authority within the City Limits, it is the responsibility of the Council to effectively coordinate with the utility agencies such as the Ceylon Electricity Board, Telecommunications Department, Gas Company and National Water Supply and Drainage Board, to avoid traffic hold ups, accidents and economic loss to the country. It has been heartening to note that the agencies concerned are showing positive response to proper coordination. However, there are problems in dealing with breakdowns and repair work. Now, it is the policy of the Council to issue the trenching permits with specific instructions regarding time, date and period of execution of work and safety measures. City Traffic Police has been requested to check at site for permits etc.

(5) **Conclusions**

Traffic in the urban area consumes more energy due to congestion. The average speed of the vehicles have to be increased to make them energy efficient. This could be achievedby the Municipality through the following measures:-

- Proper maintenance of road network
- Application of Traffic Management Scheme
- Management of Parking
- Effective maintenance of essential services and coordination

In addition to these measures, road users have to be educated to use the highway facility properly and to obey the traffic regulations. Enforcement by the Traffic Police should be effective so that the Municipal Council could implement the proposals according to design standards and specifications and thus reap the desired benefits.

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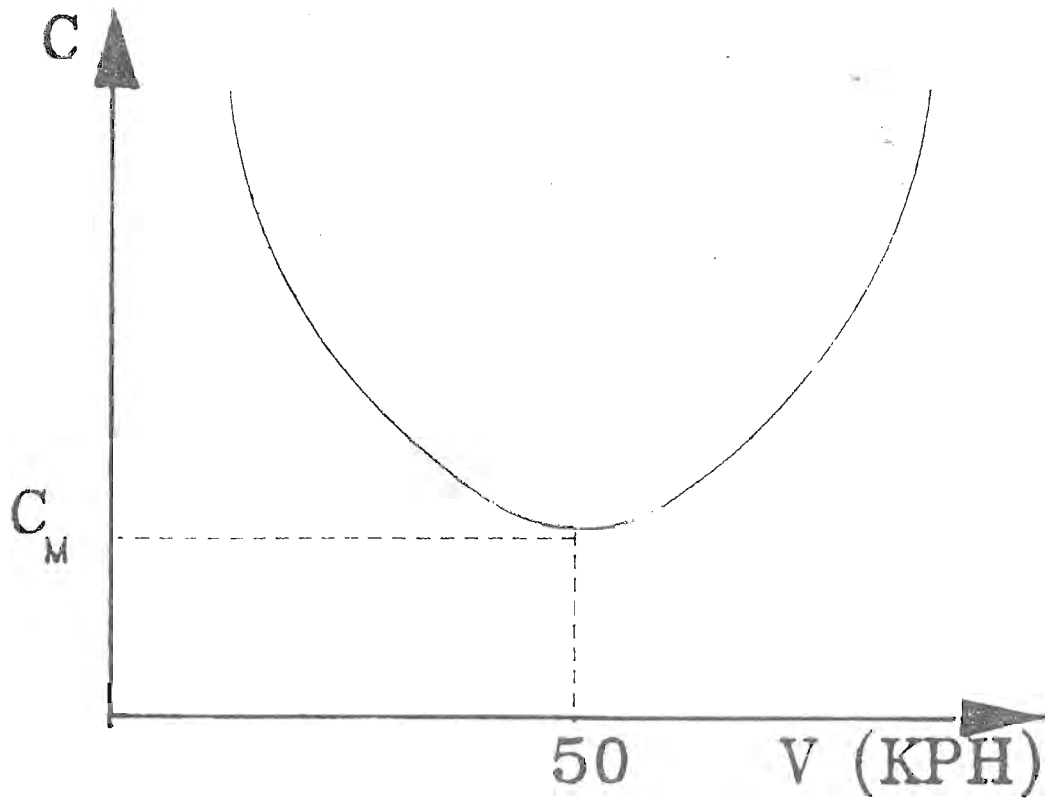
FIGURE 1

RELATIONSHIP BETWEEN FUEL COST AND SPEED



C – FUEL COST /Km

C_M – MINIMUM FUEL COST /Km

V – AVERAGE JOURNEY SPEED IN KPH

V < 50 KPH – Stop and Start Situation
– Congestion
– Urban Situation

$$C = a + b / v + v^2$$

ANNEXE 1

EFFECT OF PARKED VEHICLES UPON USEFUL CARRIAGEWAY WIDTH

No of Parked Vehicles / Km (Both Sides)	Effective Loss of Carriageway Width in M
3	0.9
6	1.2
30	2.1
60	2.6
125	3.0
310	3.7

Source : Urban Traf fic Engineering Techniques HMSO 1965

ANNEXE., 2

SOLID WASTE MANAGEMENT
COLOMBO CITY

* Daily Collection	500 T/Day
* Hand Carts	400 Nos.
* Big Skips	15 Nos.
* Bins (1 Cubic Meter)	200 Nos
* Temporary Dumps	1200

ANNEXE 3

WATER – COLOMBO CITY

Length of Water Mains (3" – 30")	800 Km
No of Valves	3600
No of Fire Hydrants	3000

DETAILS OF WORK DONE FOR THE YEAR 1990

* Number of applications received for 1990	2,110
* Number of Service Connections given in 1990	386
* Descaling of Water Mains (M)	7,620
* Number of Service Connection repaired, renewed and cleaned	6,599
* Number of Stand – Posts repaired	563
* Number of Main leaks, Hydrant leaks, Valve leaks & Joint leaks attended & Emergency repairs	2,680
* Water Mains laid (for improvements)(2" – 6")	3,963 M
* Number of complaints received regarding water leaks, Low Pressure & No Water	7,000

ANNEXE 4

DRAINAGE – COLOMBO CITY

	LENGTH
Foul Sewers	224 Km
Rainwater Sewers	350 Km
Open Drain	500 Km
No of Manholes on Rain Water System	4200 Km
No of Rain Water Gullies	5500 Km

No of Sewer Blockages Received /Month 800 (average)

No of House Connections Given / Year 300 – 350

ENERGY WASTAGE DUE TO LACK OF ADEQUATE PARKING FACILITIES

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Transportation Consultant

The subject of the paper concerns essentially an urban phenomenon. The analysis of the subject requires both a field study as well as data on a number of other aspects. This includes the availability of parking in the area under consideration, the distribution of parking spaces, the rate of occupancy and vehicle operating costs. A field study is needed to find the waiting times of a vehicle, occupants waiting to find a vacant parking space at a parking lot, travel times from one parking lot to another and the wage rates of occupants of vehicles awaiting parking to evaluate the energy loss.

It would therefore, appear that a fairly comprehensive study is necessary to evaluate the energy wastage due to lack of adequate parking facilities. This is particularly difficult as no bench mark studies have been done in this area. In the absence of such information it is a very difficult task to satisfactorily deal with the problem.

Nevertheless, an attempt is made to focus the attention on the factors which contribute to the situation so that suitable measures could be taken to minimize such losses of energy.

An important trend in recent times has been the expansion of urban areas particularly in Colombo and the suburbs. The liberalized import policy, the investment incentives afforded to developers and the impetus given by the Urban Development Authority have encouraged large building projects in the Colombo Urban Area. These constitute hotels, offices, industrial buildings, warehouses, public housing and other amenities. In fact, the floor space in the Central Area of Colombo - Fort and Pettah, has nearly doubled. The problem in the outstations is not acute except perhaps in Kandy.

Consequently, there has been a very large growth of urban traffic but no corresponding increase in infrastructure development. Space occupied by road infrastructure in Colombo is about 7% while in developed countries it is about 20 - 25%. This has brought about severe problems in the management of traffic in the urban areas.

Motor Vehicle Growth

An analysis of motor vehicle registrations for the whole island for a few significant years is very revealing.

Type of Vehicle	YEARS 1980	% increase per year	1984	% increase per year	1989	ANNUAL GROWTH 80-89 per year
Motor Cars	120,873	17.3	141,730	15.6	163,779	3.9
Buses & Pass. Vehicles	20,752	67.1	34,681	11.3	38,603	9.6
Lorries	55,838	53.5	85,701	13.4	97,159	8.2
Motor Cycles	79,803	73.7	138,632	121.7	307,392	31.7
All Vehicles	337,382	41.7	478,099	49.4	714,058	12.4

The above figures show the growth for the years between 1980 - 1984 and between 1984 - 1989. The most significant is the growth of the motor cycles population between 1984 - 1989 of 121.7%. The annual growth has been 31.7% for motor cycles, buses and passenger vehicles 9.6%, lorries 8.2% and other cars 3.9%.

This is an alarming situation, as the greater part of these vehicles operate in the Colombo district and have destinations to the Colombo City.

It is further exemplified by the rate of growth of vehicle populations in the Colombo district as revealed by the next table.

Growth of Motor Vehicles Registration in the Colombo District

Year	Colombo District	Western Province	All Island
1975	52.7	56.2	100
1978	55.8	59.0	100
1979	61.2	63.9	100

It may be noted that while the registration of vehicles for the whole of the Western Province has 63.9% of the all island value the figure for the Colombo district is 61.2% for the year 1979. Undoubtedly this growth rate for the Colombo district would have considerably increased during the last 4 years. It brings to focus the serious trends in vehicle growth but the infrastructure growth during this period is minimal.

Traffic Flows

Another important area for attention is in the disposition of traffic growth. It would be sufficient for this purpose to concentrate attention to Colombo and in particular to the Central Area - Fort and Pettah, where the situation is acute.

The Colombo Galle road to the South of the City, Sir Chittampalam Gardiner Mawatha to the South-East, D.R. Wijewardena Mawatha and Olcott Mawatha to the East and Reclamation Road to the North bring in traffic to the Central Area. Some of the traffic flows on these roads are listed below.

Daily Traffic Flows in the Main Street
Vehicle Flows

Route	1977	1979	1989
Colombo-Galle	23,400	30,980	30,233
Sir Chittampalam	22,800	24,986	N.A.
D.R. Wijewardene	10,000	13,360	37,977
Olcott Mawatha	23,200	27,094	30,789
Reclamation	24,900	27,981	N.A.

In 1979 approximately 100,000 vehicles entered and left the Fort/Pettah area between 6 A.M. - 6 P.M. on a typical day. This has increased, substantially but not phenomenally by 1989.

The percentage distribution of this traffic is shown in the next table.

Analysis of Vehicles Entering/Leaving the
Central Area 6 A.M. - 6 P.M.

	%
Cars	76.5
Buses	8.6
Lorries	3.2
Motor Cycles	7.5
Bicycles	4.2
	100.0

It will be seen that the largest use of road space in the Central Area is by cars and motor cycles. The problem therefore, essentially centres around finding parking space for these two categories of vehicles.

Parking in the Central Area

A parking survey conducted by the Colombo Municipality at the end of 1985 shows that about 1200 car parking spaces were available in the Central Area distributed as follows.

	Car spaces available
Off-street public car parks	200
Off-street private car parks	200
On-street car parking	950
	1200

The off-street public car parks are located off York-street. The off-street private car parks are in the Ports Authority premises, Ceylinco, Central Bank and in some business premises mostly on Janadhipathi Mawatha. These have however, regular customers. The on-street parking is the one that really concerns us, as it is usually the casual traveller who finds it difficult to find a parking space. The on-street parking lots approved by the C.M.C. and parking distributed in them in a typical day between 10/30 a.m. and 11/30 a.m. when parking rate has peaked is as follows.

1985 - Street Parking 10/30 - 11/30 A.M.

Name of Street	Vehicles Parked
Marine Drive	48
Road and Port terminal	68
Upper Chatham Street	34
Janadhipathi Mawatha	15
Sir Baron Janatileke Mawatha	58
York Street (Bank of Ceylon)	97
Leydon Bastian Road	137
Main Street	57
York Street (Chatham & Main Street)	84
Duke Street	20
Bristol Street	50
Lower Chatham Street	04
Bank of Ceylon New Building	100
Lotus Road (Galadari H)	15
York Street	73
Lotus Road (Telecom. Dept.)	85
	945

It has been found from the survey that 70% of the cars are parked on-street for one hour or less, 10% for more than three hours and 10% stay the whole day.

Energy Usage

The energy demand for transportation is primarily from petroleum products and distributed in the following manner -

Sector	%
Transport	50
Domestic & Commercial	30
Industry	20
TOTAL	100

Here we are concerned with car parking and the use of mainly petrol, which is approximately 20% of the total usage. The petrol prices have almost doubled between 1979 to 1989 and at present nearly 3.5 times more. The vehicle operating cost for a car in terms of fuel and oil is about 15% (economic) and 20% (financial) of the total costs. Also the total cost is about Rs 4 (economic) and Rs 8 (financial) per km.

The most probable areas where a vacancy for a parking space could occur are Leydon Bastian, York and Lotus Road. If a car were to do this circuit once, it will be over one km. From this may be gauged the approximate loss due to absence of car parking facility.

FUELS AND FUEL EFFICIENCY IN TRANSPORT

Victor Mendis
State Development & Construction Corporation

Ever since the price of crude oil started skyrocketing from US$ 3 a barrel in 1973 to a phenomenal US$ 38 a barrel in 1985, and subsequently, going upto US$ 40 a barrel, the interest in alternative fuels, power sources for automobiles and fuel economy in automobiles has been steadily growing. Renewed interest in storage batteries, fuel cells, solar cells, steam engines and stirling engines as power sources for automobiles are now being investigated in a large way.

In Sri Lanka, a search for alternative fuels for conventional internal combustion engines is being carried out at the Universities of Moratuwa and Peradeniya, and, in a much more concentrated form at the National Engineering Research and Development Centre at Ekala, where Vidya Jothi Dr A.N.S. Kulasinghe has set up a separate department for research in alternative fuels not only for automobiles but also for other industrial applications.

The possibilities of using coconut oil, rubber seed oil and castor oil as fuels for compression ignition engines has been established. The use of mixtures of coconut oil and kerosene oil for spark ignition engines are being investigated with success. The use of producer gas obtained from wood and charcoal, and also that of biogas have been known for ages. With the research carried out at the NERD Centre, most of the factors which prevented the use of wood gas becoming popular as an automobile fuel has now been eliminated.

The major sources of energy that we utilize at present are deposits of crude oil, coal and natural gas. The fact that these sources will be over some day need not instil fear in us. As long as the sun lasts, renewable forms of energy will manifest themselves in a variety of ways, and as we could see from the present level of technological development that we have attained, the solar photovoltaic cell and Hydrogen will be the ultimate sources of energy which will last as long as the sun lasts.

The fuel crisis which commenced in 1973, made the automobile users conscious of fuel economy. With the world demand for automobiles declining, and automobile giants like General Motors and Chrysler Corporation being faced with the prospects of having to close down a few of their factories, the automobile industry is now facing severe competition and is struggling to exist, competing to meet the consumers' demand for power and fuel economy. Advertisements carrying a mass of information, both speculative and factual have been generated

by competing manufacturers about fuel consumption, multivalve engines, twin overhead cam engines, turbocharged engines etc. Fuel consumption plays a very important part from the manufacturer's point of view, not only because of its concern by their customers, but also because of the American Federal regulations which specify the maximum average fuel consumption of automobiles manufactured by any American manufacturer or imported into America by a dealer. Figure I shows the Corporate Average Fuel Economy standards for passenger cars from 1978 to 1985. The CAFE standards might be anywhere from 40 to 85 miles per gallon by the year 2000.

There are a number of facors which influence the fuel economy of an automobile. Some of them are optimized during the stages of design and manufacture and have subsequently to be maintained by an automobile repair shop or competent motor mechanic. The design factors are :-

1. Compression Ratio
2. Ignition Timing/Fuel injection timing
3. Valve Timing
4. Preparation of correct air/fuel mixture, and
5. Steering Geometry

The factors which influence fuel consumption and have to be looked after by the automobile user are :-

1. Tyre Pressures
2. Type of tyre used (Cross ply or radial type)
3. Driving Speed
4. Driving Habits
5. Cleanliness of Air Cleaner, and
6. Viscosity of Lubricating oil

The Compression Ratio

The efficiency of an engine increases as the compression ratio increases. But as the compression ratio increases a better fuel, having a higher octane number, has to be used. When the cylinder and piston rings wear out the effective compression ratio reduces and fuel consumption increases, due not only to the decrease in the effective compression ratio, but also due to the leak between the pistons and cylinder walls.

Ignition Timing

The ignition timing or the time at which the spark occurs and initiates combustion, has an important bearing on the power output and consequently on the fuel consumption, as shown in Figures II & III. The best time for the spark to

occur depends upon a large number of factors, of which the load, speed and air/fuel ratio are the three main ones.

The classical ignition systems had only a mechanical governor and vacuum control device to cater for variations in speed and load only, and that too, they did in the manner indicated in the space graph shown in Figure IV. The ideal ignition timing with respect to load and speed, taking other variables also into account, is shown in the space graph given in Figure V. This was achieved by some manufacturers using microprocessors having up to eleven inputs. But now with the vast amount of experience they have gained in the recent past, automobile manufacturers have been able to simplify the engine electronics by using only two sensing devices. A knock sensor which feeds in a signal and optimizes the ignition timing and a lambda sensor which feeds in a signal and optimizes fuel consumption.

Fuel Injection Timing

The Fuel injection timing of a compression ignition engine is as critical as ignition timing in a spark ignition engine, as far as the power and fuel is concerned. But the optimum fuel injection timing is not so sensitive to variations in speed or load as a spark ignition engine. These variations, even if catered for, would be around one to five degrees for commercial vehicles. But for large engines as used in locomotives, power stations and ships, the injection timing is varied both according to speed and load, as the very small percentage of fuel thus saved, would work out to be a large amount of fuel in these cases, and would be worth the additional and more complex equipment installed.

Valve Timing

The times at which the inlet and exhaust valves open and close will influence both the power and fuel efficiency of the engine. Although the optimum valve timing varies with the speed, there are still no production models, having this facility. Therefore design considerations produce engine characteristics of torque, volumetric efficiency and specific fuel consumption which reach optimum values around 2000 to 3000 r.p.m. while the maximum engine speeds are around 5000 to 7000 r.p.m. Therefore, if fuel consumption is the main consideration, driving too slow or too fast will be uneconomical. If the car has a revolution counter the engine speed could be monitored not to fall below or rise above the 2000 - 3000 r.p.m. range for best fuel economy.

Preparation of the Correct Air/Fuel Mixture

This will apply only to spark ignition engines. The flame speed and consequently, the time taken for combustion, varies with the air/fuel ratio and the degree of mixing or turbulence in the mixture. The stoichiometric mixture always gives the highest speed and increases as the degree of turbulence increases. Since the flame speed is closely linked with the

ignition timing, the full benefits of any alterations of the air/fuel ratio or degree of turbulence can be reaped only with corresponding changes in the ignition timing. It is possible to economise on fuel by weakening the mixture and increasing the turbulence to regain the original speed of combustion. Turbulence can be increased by introducing an impeller or a system of vanes in the path of the mixture in a carburettor system; or by restricting the inlet valve opening and supercharging in the case of a petrol injection system, producing a partial type of valve throttling.

Steering Geometry

Setting the correct toe-in or toe-out and adjusting the caster and camber angles to the manufacturers' values, will produce perfect rolling of the front wheels of a vehicle when travelling along a straight path and give the minimum of scrubbing while negotiating curves, keeping the rolling resistance at a minimum. The power required to propel a vehicle is made up of -

1. Power to overcome rolling resistance
2. Power to overcome aerodynamic drag
3. Power to overcome gravitational force when going up an incline, and
4. Power to accelerate the vehicle

The tyre pressure plays an important part in the rolling resistance which increases as the pressure decreases, and vice versa as shown in Figure VI. The type of tyre used, Radial-ply or Cross-ply, and to a small extent even the tread pattern affects the resistance to motion and consequently the fuel consumption as shown in Figure VII.

If the driving speeds are below 60 m.p.h. the difference in resistance to motion offered by a radial-ply tyre and cross-ply tyre is small, but at higher speeds the difference becomes appreciable.

The fuel consumption of a vehicle will vary with the driving speed, and driving techniques as shown in Figure VIII.

Fast driving and fuel economy are not compatible. At a steady speed of 80 m.p.h. in top gear, the fuel consumption may be twice as high as at 30 m.p.h. A car gives best performance, combined with fuel economy, at the speed at which the engine develops the maximum torque; usually between 2000 and 3000 r.p.m., at a road speed of around 50 m.p.h.

If the car has a revolution counter, the precise time at which the gears have to be changed is known. If it does not have one, the best time to change gears is at half the maximum speed recommended by the manufacturer for each gear. Always

avoid peak revs in each gear as over-revving the engine can cause damage.

It is always economical to press the accelerator pedal gently even if it takes a little longer time to reach the speed that you want, unless you need the extra speed quickly for safety when overtaking.

Upto about 40 m.p.h. the aerodynamic drag on a vehicle is very small but beyond 40 m.p.h. is starts increasing rapidly as shown in Figure IX. Therefore for vehicles cruising at higher speeds it pays to have an aerodynamic design and avoid protrusions like wing mirrors, number plates, hood-racks etc., which increase the drag coefficient. At these speeds even the cleanliness of the surface of the car body counts. Keeping it clean and polished brings down the drag coefficient and consequently the resistance to motion.

The air cleaner prevents the dust in the intake air reaching the engine and producing wear. It also damps the intake noise to comply with legal regulations pertaining to the overall vehicle noise levels enforced in certain countries. Blockage of the air cleaner, particularly those having paper elements, amounts to choking of the inlet manifold, resulting not only in increased fuel consumption, but also increased cylinder wear and sump dilution.

An average sized engine would draw in 1 to 50 gm of dust over 1000 km. depending upon the road conditions and vehicle use, and it is difficult to give a time interval at which the paper element should be replaced or wire mesh cleaned. The best indication that the air cleaner needs attention can be obtained from a vaccum gauge connected to the inlet manifold. The normal reading of such a gauge on a non supercharged engine is 17 to 21 in Hg. A consistently higher reading than this indicates a choked air cleaner.

The viscosity of the lubricating oil is a very important parameter that has to be monitored by the automobile user, as it influences engine performance, engine life and fuel consumption. The ideal would be to have a high viscosity oil while starting to produce better boundary layer lubrication and a low viscosity oil while running at high speed to reduce viscous drag while hydrodynamic lubrication takes place. No automobile manufacturer has provided for this, but they all recommend a viscosity value which reasonably caters for both these conditions. Here it has to be stressed that under tropical conditions straight oils satisfy these conditions better than multigrade oils.

The degree of oiliness of a lubricating oil deterioratesdue to sustained high temperature and frequent rapid acceleration. Hence, periodic oil changes becomes necessary. The time interval for oil changes will depend on the quality of the oil

used and the type of driving the vehicle is subjected to. The colour of the oil is not a rigid indication of its quality, as modern oils contain additives which keep the carbon particles in colloidal suspension. Normal oil filters cannot trap these particles and hence the oil begins to darken within a few hours of use.

There are various simple tests that could be done to determine whether the oil is still useable, but it is convenient to stick to a time interval recommended by the manufacturer. Most fleet owners change oil at 10,000 mile intervals.

Dealing with fuel economy, it is appropriate to mention here that various emission control and fuel economy devices are being tried out in research laboratories all over the world and improvements in specific fuel consumption by up to 24% has been obtained by intake valve throttling. An invention of Vidya Jothi Dr A.N.S. Kulasinghe, which is a fuel saving retrofit device consisting of two small cylindrical chambers with connections to the fuel line and the air cleaner, will revolutionize the fuel consumption of the spark ignition engine by giving the vehicle a 73% increase in the miles per gallon.

I had the privilege of testing a Peugeot 505 fitted with this retrofit device at the NERD Centre. With this device disconnected the car gave a normal consumption of 6 km per bottle. When the car was tested under the same driving conditions with the device connected, it gave a consumption of 10.4 km per bottle. I know that this retrofit device has given an incredible increase in performance but I do not know how it does it.

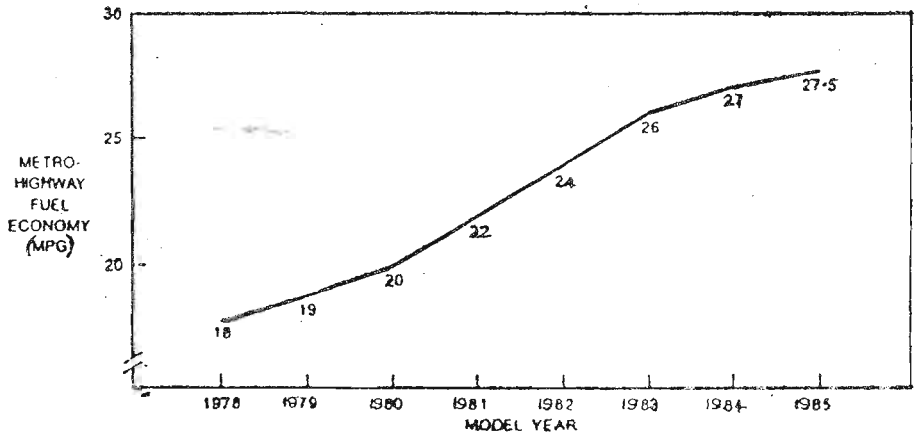


Figure 1 — Passenger Car CAFE Standards, 1978-85

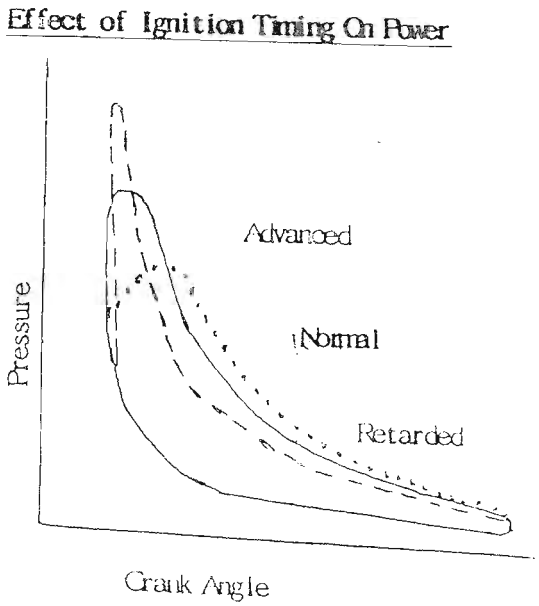


FIGURE II

Effect of Ignition Timing On Fuel Consumption

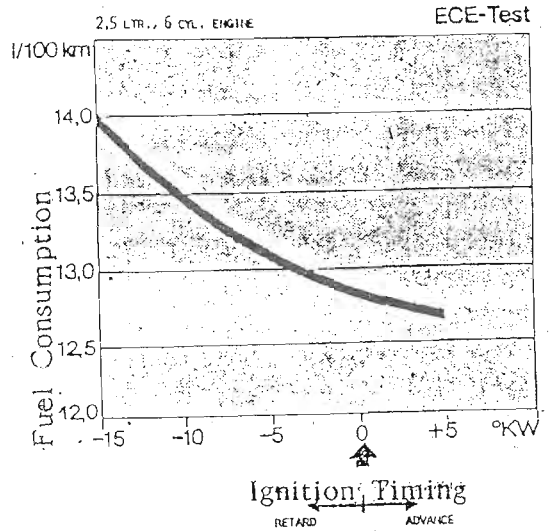


FIGURE III

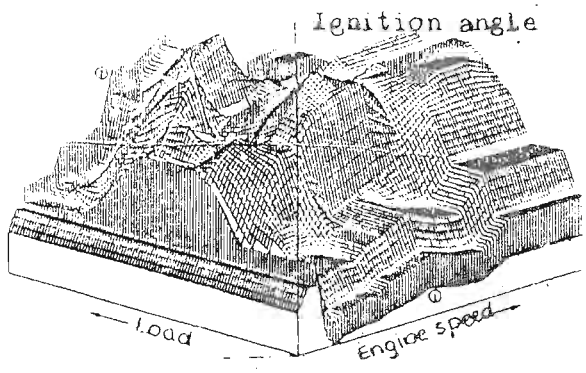


Figure V

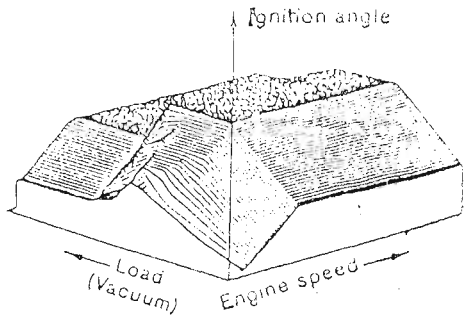


Figure IV

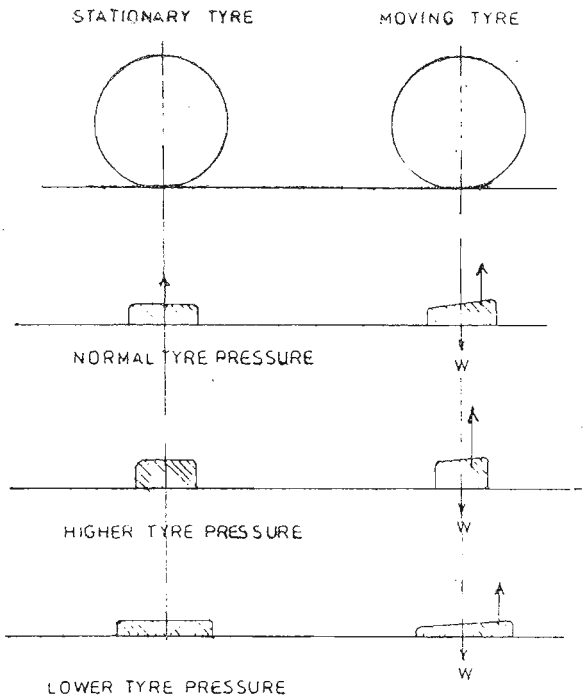


Figure VI.

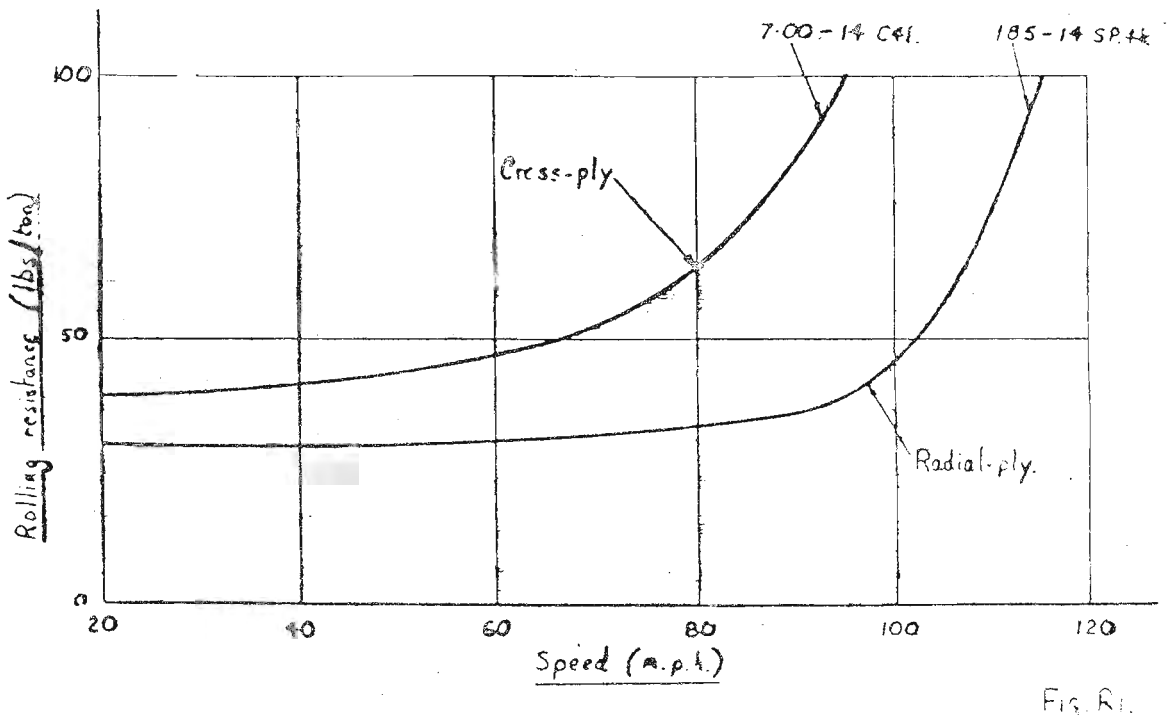
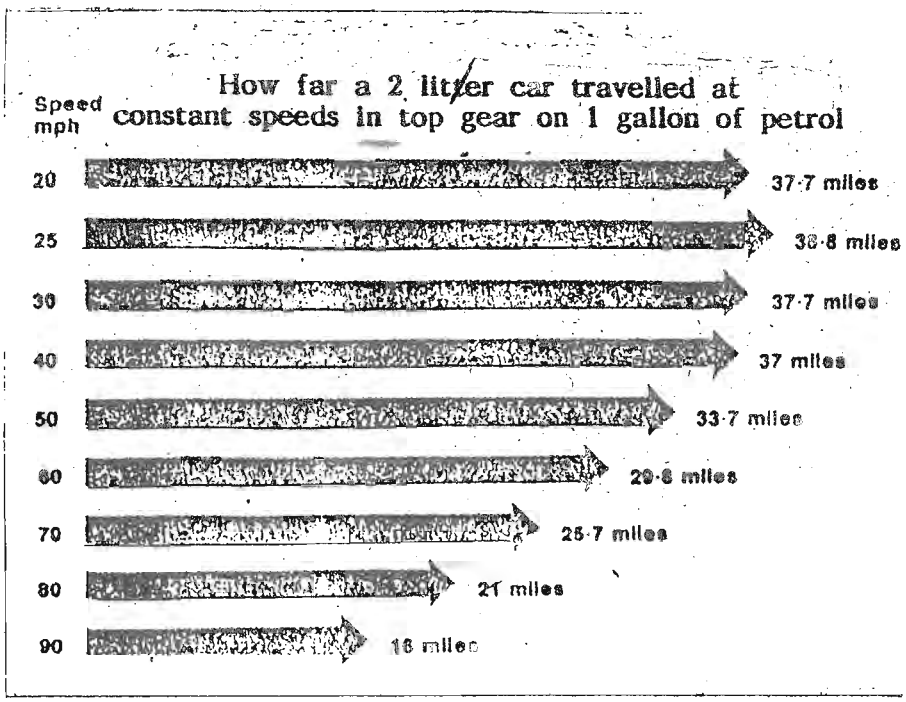


Figure VII.


How far a 2 litter car travelled at constant speeds in top gear on 1 gallon of petrol
Speed mph
20
37·7 miles
25
38·8 miles
30
37·7 miles
40
37 miles
50
33·7 miles
60
29·6 miles
70
25·7 miles
80
21 miles
90
18 miles

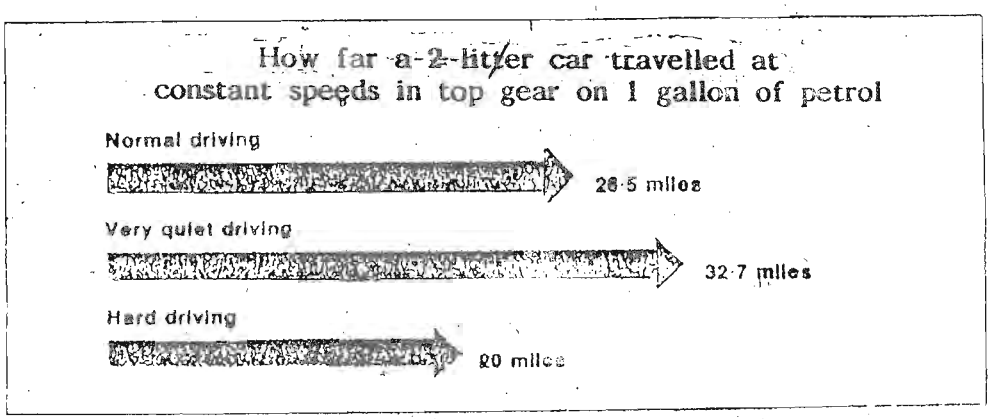

How far a 2-litter car travelled at constant speeds in top gear on 1 gallon of petrol
Normal driving
26·5 miles
Very quiet driving
32·7 miles
Hard driving
20 miles

Figure VIII.

ENERGY EFFICIENCY IN TRANSPORT IN FRAMING TRAFFIC RULES

T. Perinpanayagam
Police Department

The transport sector accounted for 12 percent of Sri Lanka's energy consumption in 1989 and 60 percent of all petroleum consumption amounting to 475,000 metric tons of diesel and 160,000 tons of super petrol. There are over half a million registered vehicles in Sri Lanka. In 1990 alone, more than 100,000 vehicles were registered. According to available information, the vehicle population increased fourteen-fold between the year 1970 and 1990.

The Government spends substantial amount of its foreign exchange on the import of crude oil which is subsequently refined and supplied for the use of the transport sector. Incidentally, petroleum products use up most of our foreign exchange reserves.

The need for energy conservation in the transport sector has always been widely felt. However, steps taken to-date have not been fruitful in conserving petroleum products. The on-going Gulf crisis will seriously affect the overall economic situation of the country and in time to come may adversely affect the growth potential, as the bulk of the world's petroleum reserves are found in the conflict region. Sri Lanka will have to look towards other countries for purchase of petroleum products. Therefore, more than ever before, there is an urgent need for energy conservation in the transport sector. Government intervention alone will not succeed if there is no public co-operation in reducing fuel consumption.

Historically, traffic rules were framed from the point of view of ensuring orderly vehicle flow and disciplined driving. This concept has gradually changed in many parts of the world. Therefore, we in Sri Lanka will have to re- examine the priorities while framing new regulations or amending existing regulations. Energy conservation related traffic regulations can take many forms including restricted vehicular flow during peak hours, discouraging use of private cars in busy commercial areas, ensuring maximum passenger load in vehicles - especially private cars - and fines for poorly maintained and managed vehicles.

Another important factor from use of fuel without conservation or limits is the problem of air pollution. We read daily in newspapers of people complaining about excessive vehicle emissions on Colombo roads. Incidentally, Colombo district alone accounts for nearly 60 percent of the registered vehicles in Sri Lanka. Though no existing measurements are

available, estimates based on WHO and United States Environment Protection Agency Emission Factors and the Sri Lanka Petroleum Consumption figures show that nearly 98 percent of the carbon monoxide is emitted by the transport sector. Two thirds of the buses and trucks plying on Sri Lankan roads contribute 79 percent of all petroleum oxides of nitrogen emission from vehicles.

In formulating any new regulations, a realistic and holistic approach should be sought. A system of flexbile implementation through legal mechanisams should be considered.

Incentives could be granted to motorists who practice fuel conservation and population reduction.

(1) All Traffic Energy Management measures have complementary attributes, which are namely travel time, emission and accidents. The change effected in one will have an impact on others. Therefore traffic rules should be drafted considering all four aspects. Energy should not be treated exclusively.

(2) The following are some examples of how traffic rules will affect energy consumption.

(a) Speed Limit

Fuel consumption for vehicles increase at very slow and very high speeds. For most light duty engines the most efficient speed would be 40 - 70 km/hr.

(b) Uniform Flow

Energy is consumed least during uniform speed. Uniform speed is possible when there is a uniformity in the flow. This can be improved by introducing rules on adhering to designated lanes. (Cycle lanes, Bus lanes etc).

(c) Intersection Control

There are several types of Intersection control. Each of these will operate efficiently only when proper right of way rules are followed.

(d) Turning Movements Restrictions

Reduce congestion.

(e) Parking

The proper location and use of parking areas have to be strictly enforced in order to reduce use of lane space for parking. The location and use of Bus Bays is equally important.

(f) Emission Regulation

Allowing faulty vehicles on the road causes health and safety hazards. These engines also perform at much lower levels of efficiency, thereby increasing energy consumption.

(g) Over Loading

Specially on Public Transport, an overloading vehicle performs poorly and will deteriorate much faster than a vehicle which operates under design conditions.

A system of surveillance monitoring and testing should be established country-wide for examining vehicle emissions, fuel consumption, etc. This activity could be handled by the private sector and in many cases, could turn out to be self- employment opportunities.

DISCUSSION

1. **Mr H.P. Dharmasena** (Sri Lanka Railways)

A transport policy for the country should include a proper assignment of shares of traffic between road and rail transport. There is open competition in the area of transport in the last few years, and this situation cannot be altered. Even Government departments and corporations are not cooperating with the Railway. One of the disadvantages of the railway is the time factor. However, the railway can transport bulk goods better than road transport, and, if the Government decides, as a matter of policy, that a greater share of such haulage be assigned to the railway, then the railway can increase its present share by up to 25% within its present resources.

2. **Mr G.L. Perera** (GCEC)

Mr Jayasekera stated that the electrification of the railway for mass transport would have distinct cost advantages over road transport. The subject of railway electrification has cropped up off and on during the last few years. Is electrification only a concept or is it accepted as a matter of policy, and are there any plans and programmes for implementation.

3. **Mr D.M. Jayasekera** (National Planning Dept.)

The electrification of the railway has been accepted politically by the present Government. The question now is to do a feasibility study and attract foreign capital. Electrification of the railway and track is a very costly business, so a feasibility study must be done. For this purpose, Government has already invited donor participation from France and Japan. A feasibility study carried out by Soferail of France, - in fact the first study was carried out in 1975 or 1976 - is being studied by the Ministry. At the same time, the Japanese too have submitted a report without any form of input. Other countries too have expressed their interest, showing international interest in this project.

4. **Prof. K.K.Y.W. Perera**

a) Regarding railway electrification the question of electrifying the suburban railway, where traffic density is high, is being studied, and the results look promising. The number of passengers, or passenger miles can virtually be increased by 50% to 60% due to the rapid acceleration and deceleration of the electric train.

On the question of assignment of traffic to the railway, policy wise, people are not forced to use the railway. It was up to the Railway to improve its services, establish itself on a proper commercial footing, and go out and canvass customers, similar to a private sector organisation.

b) When roads have to be closed for long periods during periodic maintenance, working at night would ensure a minimum of harassment to road users. It would be interesting to know whether nighht work has been attempted, and with what results.

5. **Prof. Hema Ranasinghe** (Dept. of Geography, Univ. of Colombo)

Climatic factors probably affect road maintenance programmes. Perhaps these factors are taken into account in executing maintenance work.

6. **Mr Naga Jayawawrdene** (Transportation Consultant)

In the recent road rehabilitation programme, very little attention is given to the sides of the road. The sides of the roads should be widened and rehabilitated.;

7. **Mr D.D. Senanayake** (RDA)

a) Working at night has been carried out, but with poor results. One problem was drunkenness on the part of the staff employed. Another was poor lighting. The consequences were poor quality of work. Night work thoughh preferable from the point of view of harassment to the road user, is normally not carried out now.

b) In practice, it is difficult to take climatic factors into consideration in road maintenance. However, emulsions were being used in a big way, and they are very effective in rainy weather.

c) Rehabilitation of roadsides is related, firstly, to finances. The carriageway is done first, and therafter additional funds have to be found to do thhe shoulders etc. Secondly, when widening is contemplated, there are serious problems in land acquisition.

There is also the problem of heavy cost overruns, particularly when foreign contractors and consultants are employed on rehabilitation programmes which are foreign funded. In many instances, cost overruns have been about 3 times the original estimates.

However, the problem of the roadsides is not being neglected. Currently the carriageway is being rehabilitated with foreign funds. Rehabilitation of the shoulders and drains is being carried out with local funds as a second stage, as can be seen, particularly on Galle Road. This, however, is a slow process.

8. **Mr G.L. Perera** (GCEC)

Regarding financial constraints in the rehabilitation of roads, the demolition of the bridge opposite the old Parliament building is taking a long time. In fact, demolition is taking a longer time than reconstruction. Was the reconstruction of the bridge necessary, and if so, was that project assigned the correct priority.

9. **Mr D.D. Senanayake** (RDA)

With regard to the bridge by the old Parliament building, there was probably a reason, in the long term, for demolishing and reconstructing it. Perhaps it would not have lasted for 50 years, or even 20 years. However, the demolition and reconstruction of the bridge is reported to be a difficult task.

10. **Mr M.J. Koniotes** (W.S. Atkins International Ltd.)

a) The original inspection of the parliament bridge was carried out by him. It was found to be in poor condition and would not last 15 to 20 years; certainly not a 110 or 111 years. A well constructed bridge will olast about 120 years. The reason for the delay in rehabilitating it was the fificulty in breaking the road surface which was extremely hard. However the work is expected to be completed by September 1991.

b) Experience revealed that work done at night was invariably of poor quality resulting in such work having to be redone. This, in turn contributed to further congestion of traffic.

c) Regarding patching up of potholes, here too, if it is properly done the repair should last for as much as 20 years.

11. **Prof. K.K.Y.W. Perera**

The Ceylon Petroleum Corporation prices its products taking into account process costs etc, but ultimately it has to cater to market demands. Generally, differential pricing of the products is adjusted in such a way that all outputs are consumed. The pricing of petroleum products is also subject to exigencies arising in the country. For

instance, about 4 to 5 years ago, when world petroleum prices were coming down, duty was around 5%. At a time when prices had halved, Government had to find Rs 4 to 5 billion virtually overnight due to escalation of the war in the north, so a sudden decision was taken to raise the duty to 45%. Consequently, the prices of petroleum products to the consumer remained unchanged. In the long term however, as some studies where Central Bank officials had participated had shown, doubling oil prices effects a reduction in the GDP by something like 2%. On the other hand, reducing prices to half could increase the GDP by more than 2%. Thus, pricing in the long term should take into account the macro-economic implications on the G.D.P.

12. **Mr Victor Mendis** (S.D. & C.C.)

The present speed limits both within and outside city limits are too low.

13. **Mr T. Perinpanayagam** (Police Dept.)

Present day cars are designed for high maximum speeds. The roads in Sri Lanka, though improved, are not suitable for high speeds. Accidents are caused by speeding combined with negligent and reckless driving. The current speed limits are :-

Cars - 56 km/h within the city
72 km/h outside city limits

Heavy vehicles - 32 km/h

Perhaps if the necessary approvals, are granted, the speed limits can be rationalised as follows :-

Cars - 60 km/h within the city
70 km/h outside city limits

Heavy vehicles - 40 km/h

14. **Mr Hemantha Jayasundera** (UDA)

a) Parking has become a big issue. Mr Naga Jayawardene who was a consultant to the UDA, has recommended setting up parking facilities close to the Colombo city centre and to provide a traffic management system that will minimise congestion. The UDA, acting on this recommendation, has identified a block of land close to the Lake House as being suitable for constructing a high rise multistoreyed parking lot. The traffic management system envisages that people will park their vehicles at that spot and walk to their destinations along walkways that are now being planned. This proposal has already been intimated to

the Ministry of Highways. It is also intended to set up similar parking facilities close to the city centre. All these plans will be part of a coordinated effort to reduce traffic congestion.

b) Land uses in Colombo city bear great relationship with traffic problems. Consequent to a survey, carried out in 1981, of the location of industries and warehouse facilities in Colombo involving the movement of heavy vehicles, a decision was implemented not to allow major industries, warehouses and container yards in Colombo, and to discourage all such uses in the city. As an alternative, industrial projects, one in Peliyagoda and one in the Homagama area, were approved, and plans are under way to set up more industrial projects in the Homagama area so as to avoid movement of heavy vehicles in the city. High rise buildings, too, have presented serious problems. The UDA, in its Colombo Development Plan which is being implemented by the Colombo Municipal Council, has introduced a Floor Area Ratio (FAR). That is the floor area that can be constructed based on several criteria such as availability of infrastructure, road coverage, road frontage, parking area etc. The FAR is different for different zones in the city. The Floor Area Ratio has been severely criticised particularly by developers, who argue that with land prices being high, perhaps Rs 500,000/- to Rs 1,000,000/- a perch they are not allowed to optimise land use by constructing high rise buildings.

Another trend is the conversion of residential buildings for commercial use due to the heavy demand for commercial floor space. A factor contributing to this trend is the very high value of commercial floor space in Fort and Pettah. The UDA has set up a separate unit to look into this aspect and to take corrective measures.

15. Mr Nihal Wickramaratne (CMC)

a) A properly designed exhaust system plays an important role in reducing fuel consumption of a vehicle. Locally manufactured exhaust silencers do not contain the internal chambers found in imported units, and are, perhaps, unsuitable for use.

b) When turbocharged vehicles are imported, the Customs Department imposes an additional levy on the basis that a turbocharger is a luxury item. A turbocharger increases the efficiency of an engine, and consequently fuel consumption is lowered. The argument might be put forward that a turbocharger only provides fast acceleration and is thus not relevant to

this country. On the other hand, a turbocharger is very appropriate for a diesel engine. It is necessary for experts to recommend to Government that additional taxes should not be imposed on turbochargers, but to encourage people to import them.

16. Mr Victor Mendis (S.D. & C.C.)

a) An exhaust silencer is fitted just to reduce exhaust noise. If more power is required, the silencer can be removed at the expense of low noise levels. However, in this instance fuel increases purely as a result of the increase in power output. What is important regarding fuel consumption is the back pressure created by the silencer. If a locally produced silencer reduces noise to an acceptable level, it could be considered adequate, but it may or may not create the same back pressure as a genuine replacement part.

b) Multiple valves and turbo chargers are used as means of obtaining more power from any given capacity of engine. This may have come about by the system of taxing on cylinder capacity adopted in many countries.

In the past, in Britain, higher taxes were levied on high powered cars categorised on the basis of the formula, Horse Power = $D^2N/2.5$, which had been proposed by the Royal Automobile Club of Gt. Britain. D is the piston diameter in inches and N the number of cylinders. This formula was a simple derivation of the equation HP = PLA/13000 where P is the mean effective pressure, L the stroke and A the area of the piston. An average value was given to the mean effective pressure that was realisable at that time, and the piston speed was limited to 200 ft/sec. (based on the lubricants in use and the type of finish that could be obtained on the cylinder walls and piston surface).

In order to obtain more power within given taxable horsepower ratings, British manufacturers produced long stroke engines, keeping piston diameters small. All the well known British cars of yesteryear that people are fond of, the cars of the X and Z registration series, had long stroke engines. They were very good engines. In competition however, British cars did not fare well against the continental cars which were fitted with short stroke engines that were essentially high speed engines. Consequently, Britain abandoned the RAC h.p. rating, and based their taxes on cylinder capacity eg. 1000 cc, 1100 cc etc, irrespective of the number of cylinders, bore or stroke.

Multiple valves per cylinder essentially increases the volumetric efficiency. Turbochargers increase inlet fuel/air mixture from atmospheric pressure or less to a design pressure above atmospheric pressure. Both measures, by themselves or in combination increase the specific output of an engine, and fuel consumption has a more direct relationship with the power output.

17. Dr A.N.S. Kulasinghe (NERD Centre) - invited to speak by the Chairman

The NERD Centre has been working on gasifiers using wood fuel, from 1982. The gasifier has various applications. For instance, in the tea industry, it has brought down the fuel consumption from about 1/2 to 1/3 of normal consumption. Similar savings can be obtained in the coconut industry. Another application is in transport. The use of gasifiers in transport is not new. They were used in vehicles during world war II when fuel was in very short supply. A personal Toyota Hiace van converted to gasifier use, runs a kilometer with about 30 cents worth of firewood. There were initial problems with lack of power for acceleration and hill climbing, but they have been solved. Several vehicles of the NERD Centre have been converted and are in regular use. The gasifiers are now beyond the experimental stage. The units are rather bulky, and are more suited for fitting on to heavy vehicles than on to cars.

Regarding energy conservation, the NERD Centre has introduced into several industries, the use of agricultural waste like paddy husk, and industrial waste such as sawdust, which have replaced very economically and efficiently, the use of firewood. For example, the baking oven, which has been given a little publicity, uses paddy husk or sawdust, and brings down the cost of baking a loaf of bread from 30 to 40 cents to about 4 cents.

The invention of the fuel saving retrofit device mentioned by Mr Victor Mendis, has a wide range of applications, from petrol engined vehicles to ships. There is tremendous potential. The details cannot be disclosed until the invention is protected outside this country. Filing a patent is an expensive business. It costs about 12,000 in America. However, the intention is to patent it in the European countries where the cost is expected to be around 4,000. When this is done, the invention will be sufficiently protected, after which the details will be divulged.

CONCLUSIONS

1. The transport sector accounts for over 50% of the net domestic consumption of petroleum products.

2. Petroleum products imported into Sri Lanka currently amounts to 10% of all imports, and accounts for nearly 20% of the country's total export earnings giving rise to severe balance of payments implications.

3. The transport sector is growing at the rate of about 5% a year.

4. There is a need to contain consumption of fuel whilst expanding and improving transportation which is vital for an expanding economy. In other words, improving energy efficiency.

5. Road transport is the dominant mode of transport. The distribution of traffic between road and rail is in the ratio of approximately 85 to 15.

6. Traffic congestion is the major cause of energy inefficiency in the transport sector in the urban areas, especially in the Colombo city.

7. Traffic density on the City road network is very high. Traffic movement pattern within the Greater Colombo Area is essentially radial centred on the city. In bound traffic flow increases strikingly towards the CMC border causing congestion on the roads immediatly approaching the city, particularly during peak hours.

   The radial structure of strategic highways and lack of supportive concentric links provide little opportunity for traffic diversion.

   Road capacity is reduced by indiscriminate parking on road sides due to unavailability of parking spaces.

   Traffic is constrained to run at low average speeds due to restrictions in availability of carraigeway caused by bus stops, turning traffic, pedestrians, cyclists, non motorised vehicles, lack of proper traffic control systems at junctions, lack of road discipline, accidents and road repair.

8. Speed limits presently imposed do not allow vehicles to operate at fuel efficient levels.

9. In the current context, energy efficiency in the transport sector can be increased in the following manner :-

(a) Operating the railway on commercial principles and sound management, with the objective of diversifying passenger and goods transport without resorting to deliberate traffic assignment, will provide an energy efficient means of transport. Electrification of the suburban railway will provide a very efficient mass transit system to Greater Colombo Area.

(b) Ensuring that all high rise buildings, particularly commercial buildings, have adequate parking facilities.

(c) Providing adequate parking facilities through the construction of multi-storeyed parking lots in strategic locations.

(d) Introduction of traffic energy management systems taking into consideration speed limits, uniform flow of traffic, intersection control, turning movement control, parking, and emission control regulations.

(e) Maintenance of vehicles in peak mechanical condition through regular attention by the owners to correct tyre pressures, engine tuning, replacement of air cleaner and oil filter elements, as well as lubricating oils at manufacturer's recommended intervals.

(f) Strict enforcement of road disciplines.