DETERMINATION OF THE FACTORS INFLUENCING THE EFFICIENCY PERFORMANCE OF ROUNDABOUTS

(A CASE STUDY OF ADETI ROUNDABOUT, ILESA)

BY

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CERTIFICATION

(a) BY STUDENT: This work to the best of my knowledge has not been presented elsewhere for the award of a degree or other purpose.

Candidate's Name: Eladiya Johnson Oluwasanmi.

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(b) BY SUPERVISOR: This is to certify that this research work was carried out by Eladiya Johnson Oluwasanmi in the Department of Civil Engineering of the Federal University of Technology, Akure, Ondo State Nigeria.

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DEDICATION

This research work is dedicated to my wife, Mrs. ELADIYA, Grace Olutoyin for her prayers and encouragements and to all my children.

ACKNOWLEDGEMENT

My greatest debt of gratitude goes go the Almighty God who saw me through the project.

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Special thanks to my wife for her moral and financial support, may God bless you all.

ABSTRACT

Roundabouts constitute special forms of space sharing roadway intersections that are known to enhance safety, reduce delay as well as being aesthetically pleasing. However, the factors influencing their capacities are many and their effects vary. In order to use them optimally in road network, these factors and their influences should be investigated. This is the focus of this work and a specific case study has been adopted.

The roundabout studied is the Adeti roundabout in Ilesa, Osun State. The roundabout, at peak periods of travel is characterized by long vehicle queues and long delays.

Field observations of vehicles flow patterns at roundabout spanning 6am to 7pm daily for a period of five consecutive days (Monday – Friday) were undertaken. Various theories and design models used in different parts of the world were adopted as analytical tools.

The results of the investigation showed that the vehicular flow in the roundabout corresponds well with the gap acceptance concept of the Highway Capacity (lower bound). It was found that when locally obtained values of drivers critical gap and follow up time were substituted into the Highway Capacity model, the corresponding ratio was 0.93. Thus, it is most likely that a totally customized Highway Capacity model would be most suitable for analyzing roundabouts in Nigeria.

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Qe	-	Entry flow
Qc	-	Circulating flow
Qs	-	Exiting flow
Qg	-	Impending flow
tc	-	Critical gap
tf	-	Follow-up time
pcu	-	Passenger Car Unit
φ	-	Entry angle
r	-	Entry radius
v	-	Approach road half width
e	-	Entry width
L'	-	Average effective length
D	-	Inscribed circle diameters
u	-	Circulating Width
d	-	Size factor
A	-	Route A
B	-	Route B
C	-	Route C
a	-	Circulating flow at route A junction
b	-	Circulating flow at route B junction
c	-	Circulating flow at route C junction
HCM	-	Highway capacity manual

PLATES

CHAPTER ONE

INTRODUCTION

1.1 PREAMBLE

Intersections in urban roads network are of the greatest importance in highway design because of their effects on the movement and safety of vehicular traffic flow. Most highway network links are located in the same horizontal plane and they frequently intersect, thereby leading to conflicts between opposing flows of traffic. Various mechanisms are, hence, used to control the traffic at the conflict areas.

At an intersection, a vehicle transfers from the route on, which it is traveling to another route crossing other traffic streams, which flow between it and its destination. Intersections can be divided into four categories:

Uncontrolled Intersections:

These are where the intersecting roads are usually of relatively equal importance and when traffic volumes are so light that no form of control or redesign appears necessary. When conflicts do occur, right of way is assigned to one flow or another by general rule e.g. "vehicle on the right has the right of way".

Priority Intersections:

These occur where one of the intersecting roads is given definite priority over others. The minor road will usually be controlled by some form of sign, marking or humps thus ensuring that priority vehicle traveling on the main highway will incur virtually no delay.

Space Sharing Intersections:

These are intended to permit full and equal priority and to permit continuous movement for all intersecting vehicle flows.

Time Sharing Intersections:

These are those at which alternate flows are given the right of way at different points 'in tine. These intersections are controlled by traffic signals or by traffic officers.

Road network intersections have a considerable influence on safety efficiency of traffic movement. Beside the intersections where the intersecting legs are at the same level, we have these other types of intersections:

Grade Separated Intersections

These are where the intersecting legs are at different levels and their traffic streams do not conflict directly. Carefully designed ramps are used to connect the various intersecting legs for which traffic interchanges are essential. These types of intersections generally have very large initial cost but cause least delay and hazards to the grossing traffic. The grade separation which is simply a bridge that enables the traffic on the intersecting highways to cross-over each other without any traffic interchanges taking place is known as grade separation without ramps.

One of the most popular space sharing intersections is the roundabout. Roundabouts have a number of advantages over other at-grade intersections, whether controlled or uncontrolled. Roundabouts are similar to traffic circle but there are some major differences, which include:

Yield at Entry:

At roundabouts, the entering traffic yields the right of way to the circulating traffic. This yield-at-entry rule prevents traffic from locking-up and allows free flow movement.

Deflection:

The entry and center island of a roundabout deflects entering traffic to help in slowing the approaching vehicles down and reinforce the yielding process.

Flare:

The entry to a roundabout often is flared out from one or two lanes to two or three lanes at the yield line to provide increased entry capacity.

Advantages of roundabout as control mechanism, include:

(a) **Safety**:

Roundabouts have been shown to reduce fatal and injury accidents. Countries like France (Guichet 1997) ; Germany (Brilon . 1997) and Poland (Tracz 1997) that have recently introduced roundabouts have reported that roundabouts return injury accident rates half that for traffic signals.

(b) **Pedestrian safety:**

The safety advantage of roundabouts have been attributed to the slower traffic speed and the pedestrian crossing into two stages, from one side of the road to the slitter island, and then from the splitter island to the other side of the road. In each stage of crossing, the pedestrian has to look in only one direction to cross a one –way traffic stream.

(c) **Low Maintenance:**

Roundabouts eliminate maintenance costs associated with traffic signals.

(d) **Reduced Delay:**

Roundabouts give lower delays during off-peak conditions, due to their inherent flexible operation, even though delays may be higher during peak hours.

(e) Increased Vehicular Capacity:

Intersections with high volumes of left turns are better handled by a roundabout than a multi-phased traffic signal.

(f) Aesthetics:

The central island of a roundabout provides a location for landscaping and/or landmark features for the beauty of the area.

(g) Other Features:

Easy U turns, reduced noise pollution and traffic calming. The disadvantages of roundabouts as control mechanism however include:

(a) Land Cost:

Roundabouts required a large amount of land to be properly constructed. Land cost and right of way acquisition can be very expensive, especially at the central business districts of cities.

(b) Future Traffic Volume:

If future traffic volumes increase greatly, the roundabout may have to be redesigned or removed.

(c) Unequal Flow of Traffic:

The major and minor road meetings at the roundabout give rise to unequal flow of traffic.

(d) Increasing Intersecting Arms:

Roundabouts have a special advantage for a developing country like Nigeria in that roundabouts require low level of technology to operate. There are no electronic gadgets or electrical power directly needed to make them function although good illumination for poor visibility situations can enhance their effectiveness.

The history of traffic signals for intersection control in Nigeria is one of frustration and abandonment. As early as 1955, traffic signals were in operation in Lagos, but they were abandoned after independence when they could no longer be sustained. Subsequently Ibadan, Ilorin, Benin and others used traffic signals for a while but eventually had to be abandoned. On the other hand, roundabouts are easier to maintain and sustain.

It is therefore, important to seek ways of making roundabouts more effective and optimize their usage in-the country. This study is focused in this general direction.

The main thrust of the study is to examine the performance of the Adeti roundabout, Ilesa, with a view to identifying its capacity constraints. The existing capacity is compared with the capacity levels given in the design models used in different parts of the world. A parameter variation of geometrical features of the roundabout is also undertaken with a view to assessing their impart on the capacity of the roundabout.

1.2 AIMS AND OBJECTIVES OF STUDY:

The aim of the study is to provide better understanding to the factors affecting the efficiency of roundabouts and thereby make them more efficient.

The specific objectives of this study are:

(a) To assess the capacity of the roundabout based on the existing conditions through empirical observations.

(b) To estimate the capacity of the roundabout based on empirical models, gap acceptance theory and analytical models as used in different countries of the worlds such as U.S.A., Britain, Australia and Switzerland.

© To determine the models that appears to replicate the situation at Adeti roundabout and possibly identify the most suitable for the roundabout.

(d) To evaluate the effects the geometry of the roundabout has on the capacity as determined from computer simulations.

(e) To make recommendation on how to make the roundabout more efficient.

1.3 JUSTIFICATION FOR STUDY:

Adeti roundabout, Ilesa, seems to be the focus of commercial activities in Ilesa. It is the route terminus of intra city public transport in the town. The concentrated activities in the area, however, interfere with vehicle flows at the junction. This brings congestion and delay in the area.

The finding from the study would help in generating solutions of improving the traffic flow in the area, reducing the delay and thereby boosting 'the economic activities in the area. It is hoped also that the study will be useful in identifying other area of worthy research endeavors that would lead to the emergency of indigenous design standards.

1.4 STUDY LIMITATIONS:

(a) There had been no previous study in the area and no record of such in Ilesa West Local Government. The roundabout is within the purviews of the local government but all effort to source any traffic information from the local government proved abortive.

(b) The period of field traffic observation was confined to the hours of 6a.m. and 7p.m. daily. Although the period outside this observation period normally has a very low volume, it would have been desirable to have twenty- four hours continuous count.

(c) Few vehicles escape to the nearby filing station or bank directly from the circulating flow. This was possible because of the nearness of these commercial centers to the roundabout.

(d) Available funds are not enough to employ more human observers for the work.

1.5 BACKGROUND INFORMATION ON ILESA:

The study site is Ilesa, in Osun State, Nigeria. The founder of the Ijesa Imperial System was Owa Obokun Ajibogun, an adventurous and warlike son of Oduduwa, who began the conquest of the pre-Oduduwa communities of Ijesaland, particularly in the region of present- day Obokun Local Government. With the establishment of the Owa Obokun's Government at Ibokun, Ilesa city became the new royal capital. Ilesa is located in the eastern part of Osun State of Nigeria as shown in Fig. 1.1

Fig 1.1 MAP OF OSUN STATE IN NIGERIA.
Source: Osun State Local Government Service Commission, Annual report for year 2004.

The town is located at the intersection of latitude $7^{0}45^{0}$N and longitude $4^{0}45^{0}$ E. Due to its central location in Ijesa division, it is the focal point of all Ijesa people and because it is accessible from all nooks and corners of Ijesaland, it can be described as a nodal point.

Using a growth rate of 2.9% per annum (N.P.C. 1998), the population of Mesa is about 550,950 in 2004. It has a population density of approximately 10,797 per km2 majority of whom are traders and farmers. As of 2004, the town had 62 primary schools, 34 secondary schools, a Federal Technical College, a School of Health Technology, a Nursing Training Institution in the Wesley Guild Hospital, a College of Education and a School of Agriculture.

Also by 2004, six commercial banks had been established in the area with five concentrated mainly at the center of the town around where the studied roundabout is located. The town contains several traditional markets, the most important of which is the Atakunmosa market located close to the Oba's palace all in the studied roundabout in the town. These are indicated in Fig. 1.2

Several small-scale industries abound in the town. Notable among them are printing, publishing, milling, poultry keeping and bakeries. Medium to large scale industrial establishments generate employment and operate in the areas of Aluminum extrusion, steel works, wire and nail production, plastic molding, beer brewing, gaari production and saw milling

The Adeti roundabout, which is the focus of this study, is a major intersection in-Mesa as it is a nodal point on roads passing through the major activity centers in the town It is also a nodal point on roads linking Ilesa with some other towns like Ijebu-Jesa, Akure, Osogbo, Ibadan etc. However, because it lies at the heart of the Central Business District (C.B.D.), many roadside activities are carried out at the

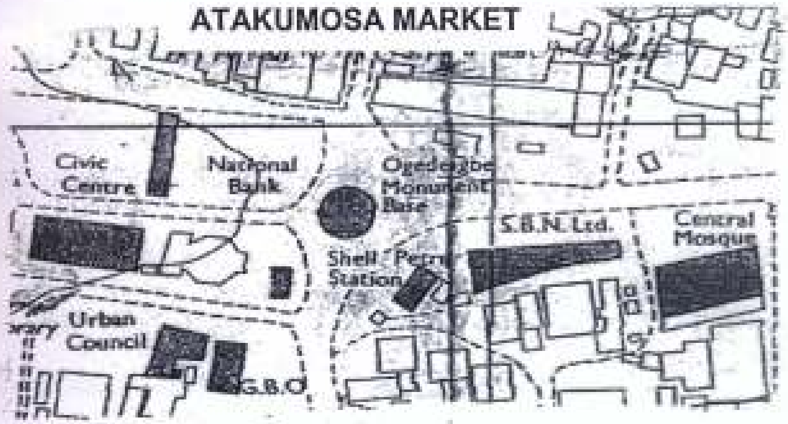

FIG. 1.2 MAP OF THE ADETI ROUNDABOUT

location. The activities in the location of the roundabout have made it a point of focus to many vehicles. Several intra-city public taxi routes terminate at the roundabout. Thus, commuter taxis load at the side of the junctions and this leads to traffic queues at most times. The vehicle queues always interfere with vehicular flows at the junction legs. This brings about congestion and vehicular delays with the attendant economic wastes in terms of time wasting and fuel consumption. The commuters that patronize the taxis similarly get frustrated for they are unable to get vehicles serving their preferred routes easily.

It is obvious that neither the vehicles passing through the intersections nor the passengers seated in the commuter taxis loading at the side of the intersection enjoy good quality of service. It is in the attempt to generate possible solutions to these undesirable situations that this study is designed.

The focus of the work is to ascertain if the roundabout has a capacity problem and the appropriate solutions if such problems exist.

CHAPTER TWO

LITERATURE REVIEW

2.1. BACKGROUND

A roundabout is a circular intersection having specific design features that distinguish it from other circular intersections such as a traffic circle or rotary. Generally, roundabouts are circular intersections with specific design and traffic control features.

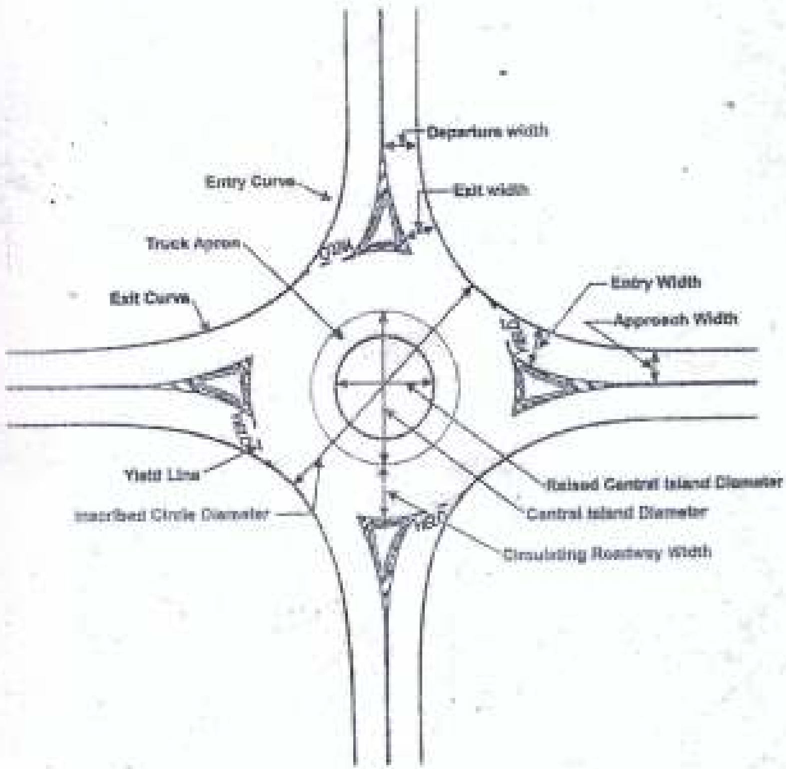

FIG. 2.1 A TYPICAL ROUNDABOUT

These features include yield control of all entering traffic, channelized approaches and appropriate geometric curvature to ensure that travel speeds on the circulatory roadway are typically less than 50km/hr. Thus roundabouts are a subset of a wide range of circular intersection forms. A typical roundabout is illustrated in Fig. 2.1 and the different components are explained in Table 2.1

TABLE 2.1 COMPONENTS OF A ROUNDABOUT

DIMENSION	DESCRIPTION
Inscribed Circle Diameter	It is the basic parameter used to define the size of a roundabout. It is measured between the outer edges of the circulatory roadway.
Circulatory Roadway Width	It defines the roadway width for vehicle circulation around the central island. It is measured as the width between the outer edge of this roadway and the central island.
Approach Width	It is the width of the roadway used by approaching traffic upstream of any changes in width associated with the roundabout. The approach with is typically no more that half of the total width of the roadway.
Departure Width	The departure width is the width of the roadway used by departing traffic downstream of any changes in width associated with the roundabout. The departure width is typically less than or equal to half of the total width of the roadway.
Entry Width	The entry width defines the width of the entry where it meets the inscribed circle. It is measured perpendicularly from the right edge of the entry to the intersection point of the left edge line and the inscribed circle.

Entry Radius	The entry radius is the minimum radius of curvature of the outside curb at the entry.
Exit radius	The exit radius is the minimum radius of curvature of the outside curb at the exit.
Central Island	It is the raised area in the center of a roundabout around which traffic circulates.
Splitter Island	It is a raised or painted area on an approach used to separate entering from exiting traffic, deflect and slow entering traffic and provide storage space for pedestrian crossing the road in two stages.
Circulatory Roadway	It is the curved path used by vehicles to travel in a counterclockwise fashion round the central island.
Apron	It is the mountable portion of the central island adjacent to the circulatory roadway. If required on smaller roundabouts to accommodate the wheel tracking of large vehicles.
Yield Line.	It is a pavement marking used to mark the point of entry from an approach into the circulatory roadway and is generally marked along the inscribed circle. Entering vehicles must yield to any circulating traffic coming from the left before crossing this line into the

	circulatory roadway
Accessible Pedestrian Crossings	This crossing should be provided at all roundabouts. The crossing location is set back from the yield line and the splitter island is cut to allow pedestrian to pass through.

The roads that connect to a roundabout feed traffic into a 'circulatory roadway' that surrounds a central island. The traffic on the circulatory lane flows in a counter clockwise direction. All turns and lanes changes that drivers make when entering and while leaving a roundabout are right turns, which add both to the ease, efficiency and safety with which drivers pass through roundabouts.

Apart from their safety aspects, roundabouts are not appropriate for all intersections but they may be appropriate in the following situations:

- Intersections with a history of accidents
- Intersections with irregular approach geometry.
- Intersections where vehicle queue need to be minimized.
- Intersection in need of less expensive traffic control operations (as oppose to a traffic signal)
- Intersection with a high proportion of U turns and/or
- Intersection with abundant right of way.

2.2 CAPACITY OF A ROUNDABOUT

There are two main approaches to calculating the capacity of a roundabout. The first method involves an empirical formula based on field measurement at saturated roundabouts and the second method uses an analysis based on gap acceptance method. The 1997 Highway Capacity Manual (HCM) and version 3.1 c of the highway capacity software include a procedure for determining the gap acceptance approach. The HCM has selected RODEL 1 as the standard software for analyzing roundabouts. RODEL 1 was developed in England when vehicles travel in opposite direction of the road from that in Nigeria. Designers must label the roundabout entrance legs consecutively in clockwise direction to ensure proper vehicle movement.

2.2.1 ANALYTICAL METHOD

The analytical method based on the fact that the capacity of a roundabout is a function of among others the characteristics of the traffic stream. One of the characteristics of the traffic stream is the gap acceptance behavior. Roundabouts are considered as series of two interacting streams i.e. the entry stream and the circulating stream. The intersections give no positive indication or control to the driver. The driver is not told when to enter the intersection. The driver alone must decide when it is safe to enter the circulating stream. The driver looks for a safe opportunity or "lags" in the circulating stream to enter. This phenomenon has been described as gap acceptance behavior. Gaps are measured in time and may be equal to either the headways or lags within the traffic stream being crossed or entered.

The gap acceptance process has two basic aspects namely:

- The extent drivers find the gaps or opportunities of a particular size acceptable when attempting to enter the circular stream.
- The manner in which gaps of a particular size are made available to the diver.

Consequently, the proportion of gaps of a particular size that are offered to the entering driver and the pattern of the inter-arrival times are important. A few variation of methods premised on the gap acceptance behaviors of drivers entering the round about are reviewed as follows:

(A) AUSTRALIAN ANALYTICAL METHOD:

The Australian method uses an analytical model derived from the gap acceptance concept to calculate the capacity of the roundabout. The method is premised on the assumption that capacity is a function of the following parameters:

- **Critical gap:** It is the minimum gap that all drivers in the entering stream are assumed to accept at all similar locations. According to the driver bahaviour model it assumed that no driver will enter the intersection unless the gap between vehicles in the higher priority stream (circulating stream) is at least equal to the critical (t_c).
- **Follow up time:** It is the additional time it takes a second and subsequent vehicles in the entry stream to accept the same gap. After the first vehicle in the entry stream, subsequent vehicles enter in the long gaps at headways often referred to as the "follow-up time" (t_f).

Computer software premised on the above concept has been developed. It is the Signalized and unsignalized Intersection Design and Research Aid (SIDRA) which is an intersection based program developed by ARRB (Transport Research, Limited in Australia an aid for capacity, timing and performance analysis of isolated intersections (Akcelik, 1998).

SIDRA is a very powerful analytical program for signalized intersections; roundabouts and yield, two-way stop, or all way stop-controlled intersections, with up to eight approaches. It can also be used to perform lane by lane analysis, lane flow calculations, capacities of short lanes etc. However, the Australian data indicated that, for roundabouts, the following geometric parameters were not significant for capacity determination:

(a) Entry radius.

(b) Entry angle

(c) Approach half-width

(d) Flare length

This is partly due to the lane-by-lane analysis and the use of short lanes, and probably due to the roundabout standards used in Australia. (Akcelik, . 1998). SIDRA programmed offers an option to implement the Highway Capacity Manual (HCM) procedures for many computations. . SIDRA has been widely tested arid proven through extensive use in practice around the world. (Akcelik and associates 2004)

(B) HIGHWAY CAPACITY MANUAL (2000) ANALYTICAL METHOD:

The manual roundabout methodology is based on gap acceptance concept (HCM 2000). The headways of the-circulation stream are assumed to be randomly distributed. The estimate of the capacity of a roundabout approach is given by:

$$Q_e = \frac{Q_c e^{-Q_c t_c/3600}}{1-e^{-Q_c t_f/3600}} \quad \text{..2.1}$$

where: Q_e = Maximum entry capacity (veh/hr)

Q_c = Conflicting circulating traffic (veh/hr)

t_c = Critical gap (sec)

tf = Follow-up time (sec)

The relationship between approach capacity and circulating flow for these upper and lower bound values of critical gap and follow-up time is shown in Table 2 .1

TABLE 2.1 : CRITICAL GAP AND FOLLOW-UP TIMES FOR ROUNDABOUTS

	Critical gap (sec) tc	Follow-up times (sec) t_f
Upper bound	4.1	2.6
Lower bound	4.6	3.1

Source: Highway Capacity Manual 2000 (Transportation, Research, Board, National Research Council, Washington D.C. 2000) page 17-46

The estimate indicated that the geometric parameters listed below were not significant for capacity calculations:

- Entry radius
- Entry angle
- Approach half width
- Flare length

2.2.2 EMPIRICAL MODEL

The empirical regression models were developed in the United Kingdom at the Transport and Road Research Laboratory (TRRL) in the late 1970s from data gathered during test track experiments in which full scale models of a roundabout with varying geometric characteristics operating under saturated condition were monitored to measure the capacity of individual entries under such conditions. (Kimber, 1977). The TRRL study yielded a linear relationship between the entry capacities and circulating flow rate that accounts for 90% of the variation in the measurement of entry capacity. The relationship is given in equation:

$$Qe = -fcQc + F \text{.......................} 2.2$$

Where: Q6 = entry capacity (veh/hr)

QC = Circulating stream flow across the subject entry (veh/hr)

$$fc = 0.29 + 0.116e \qquad 2.3$$

and F is given by the equation:

$$F = 329e + 35u + 2.4d - 125 \qquad 2.4$$

Where e = entry width in meters

u = circulating width in meters

d = size factor (meters)

The values e, u and d were found to be significant if empirical derivations are desired and data is available, the graph of Qe can be plotted against Qc from which the values of fc and F could be deduced. From the results obtained, value of d (size factor) can be calculated.

The U.K. research targeted on developing direct geometric relationship to capacity and used linear regression to establish statistically significant relationship between entry capacity and geometric parameters.(Kimber , 1980)

The outcome of the regression analysis was that there were only six significant geometric parameters that played a role in determining capacity. They were:

- Entry width (e)
- Approach width (v)
- Flare length (l')
- Entry angle(Φ)
- Inscribed circle diameter (D)
- Radius of the kerb at entry (r)

Of the six, three were noted to be of particular importance:

- Entry width (e)
- Approach width (v)
- Flare length (l')

The remaining three has comparatively minor effects.

(B) THE GERMAN 'G2' METHODOLOGY:

The German 'G2' methodology is a linear regression formula that has recently been developed and is approved for use by the Federal Government of Germany. This formula was derived from regression analysis of data obtained from series of observations in Germany.

The formula is:

$$Qe = C + d\,Qc \qquad \text{.......................} \; 2.5$$

Where Qe = entry flow capacity (veh/hr) ; Qc = circulating flow rate (veh/hr)

And C and d are as shown in table 2.3 below::

TABLE 2.3 PARAMETERS FOR LINEAR REGRESSION MODELS OF ROUNDABOUT TRAFFIC CAPACITY.

Number of lanes Entry/Circle	C	d	N (Sample size)*
1/1	1218	- 0.74	1504
½ or 1/3	1380	- 0.53	879
2/2	1380	- 0.50	4574
2/3	1409	- 0.42	295

* Number of observed one –minute interval.

Source: Interim Single-lane Roundabout Analysis Methodologies by Transportation Planning Analysis Unit (TPAU) for Oregon.

TPAU has worked example problems comparing each of the methodologies listed below:

- SIDARA 5.1 (updated Australian Method)
- Highway Code Manual (H.C.M.)

- Australian (AUSTROADS) 1993
- German (G1) (exponential regression)
- German (G2) (new linear regression)
- United Kingdom

TPAU reported that when there are heavy traffic flows circulating in the roundabout, the SIDRA 5.1 computer program and the German 'G2' methodology are more conservative in this situation compared to other methods.

(C) THE SCOTLAND METHODOLOGY:

The capacity (Qe) of each arm of the roundabout in pcu/hr is given by equation 2.6 (NESA manual 1998). .

$$Qe = K(F - fcQc) \quad\ldots\ldots 2.6$$

Where the terms are defined as:

$$K = 1 - 0.00347\,(\Phi - 30) - 0.978\,[r^{-1} - 0.05] \quad\ldots\ldots 2.7$$

$$F = 303\,x_2 \quad\ldots\ldots 2.8$$

Q_c = the circulating flows across the entry in pcu/hr

$$fc = 0.210\,t_D(1 + 0.2\,x_2) \quad\ldots\ldots 2.9$$

$$t_D = 1 + \frac{0.5}{1 + \exp\frac{(D - 60)}{10}} \quad\ldots\ldots 2.10$$

$$x_2 = v + \frac{e - v}{1 + 2s} \quad\ldots\ldots 2.11$$

$$s = \frac{1.6\,(e - v)}{r'} \quad\ldots\ldots 2.12$$

where: Φ = entry angle(degree).

r = entry radius (m)

D = inscribed circle diameter (m)

v = approach road half width(m)

e = entry width (m)

l' = average effective length over which the flare is developed (m)

(D) SWISS TRANSPORT METHODOLOGY:

The Swiss guide on roundabout design for roundabout full capacity use the equation 2.13 (Swiss Transport 2001)

$$Qe = k[1500 - 8/9 \times Qg] \quad \text{.......2.13}$$

Where: Qe = maximum inflow of an entry (veh/hr)

Qg = impending flow (veh/hr)

k = a factor depending on the entry lanes such that for:

1 lane in entry, k = 1

2 lanes in entry, k = 1.4 – 1.6

3 lanes in entry, k = 2 .

$$Qg = \beta \times Qc + \alpha \times Qs \quad \text{.......2.14}$$

Where: β = a factor depending on the circulating lane, such that for:

1 lane; β = 0.9 – 1.0

2 lanes; β = 0.6 – 0.8

3 lanes; β = 0.5 – 0.6

Qc = circulating flow crossing the entry.

Qs = flow leave the roundabout by the previous exit.

α = a value between 0.1 and 0.6 depending on Lba (the distance between diverging point at exit and converging point at entry.) see fig 2.2

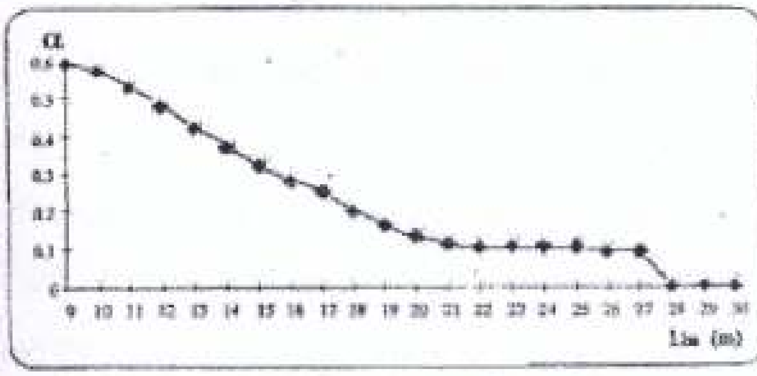

FIG. 2.2. THE RELATION OF α AND Lba
Source: Swiss Transport Research Conference on March 13, 2001 page 3

(E) FRANCE METHODOLOGY:

The original French formula for roundabout capacities was developed in 1988 by CETUR (now known as CERTU) (CETUR 1988)

The CETUR formula expresses the entry capacity as a function of the impending flow (as opposed to the circulating flow in the British and Australian methods) similar to the U.S.A. method for signalized intersections, the impending flow is a summation of circulating flow plus a proportion of the exiting flow at the same branch, or

$$Qg = Qc + \alpha\, Qs \quad \text{..........} 2.15$$

Where: Qg = Impending flow (veh/hr)

Qc= Circulating flow (veh/hr)

α = variable that is a function of the width of the splitter island (0.2 on the average).

Qs = exiting flow (veh/hr)

The entry capacity Qe is defined as:

$$Qe = 1500 - 8/9\ Qg\ ; \quad \text{for } Qg < 1800 \quad \text{..........} 2.16$$

If Qg $\geq$ 1800, Qe = 0

CHAPTER THREE

MATERIALS AMD METHODS

3.1 Preamble:

Adeti roundabout Ilesa, the focus of this study has always been a major constraint to smooth traffic flow during certain period of the day because of the congestion and the delay in the area. The peak flow in the area has always been a serious problem to the commuters. Plate 1 shows the pictorial view of the saturated roundabout.

PLATE 1 : THE PICTORIAL VIEW OF THE SATURATED TRAFFIC CONDITION OF ADETI ROUNDABOUT.

This study is designed to find out the probable cause(s) of the congestion at the roundabout and prefer feasible solution to the problem. A number of design models from different countries in the world had been considered in the literature review. The capacity calculated based on these models will be compared to the field obtained capacity at Adeti roundabout. Suggestions will then be made on how to improve either the existing operational practices or the geometry and infrastructure in the roundabout to reduce the congestion observed during the peak period.

3.2. DATA GATHERING:

Several methods can be used to estimate the entry flows in the roundabout. These are the manual counts, machine assisted counts, which involve the use of automatic vehicle counters and the use of a radio cassette.

In the measurement of the entry flows in this research work, the manual method was used. Thus, human observers observed and recorded the traffic volume counts at fifteen minutes intervals during the periods of 6.00a.m. to 700 p.m. daily during the week. About three months observation (1st April to 25th June, 2004) showed that the busiest period during which traffic congestion was observed in Adeti roundabout was usually between the periods under consideration.

The manual method was found the most feasible and, perhaps, the cheapest method to obtain traffic flows generally in the current Nigerian situation.

The observers were first trained and educated on the importance of the exercise before they embarked on the exercise. The training was designed to enable the human observers identify the different vehicle classifications adopted in the vehicle counting and how to record their observations for each time intervals. A pretest was organized for the observers on Saturday 26th June 2004. And the exercise was successful.

On Monday, 28th June 2004, the field work started from 6.00a.m. Two human observers were assigned to man each entry to the roundabout with one observing and recording the type and the number of vehicles passing towards the roundabout. The second observer was expected to be on stand-by and swap places with the first observer. Another human observer was to stand at the yield line of each entry respectively, pasting a red tag, yellow tag or blue tag at different entrances to the roundabout. The colour coding was red for vehicles entering through route A, yellow for vehicles entering through route B and blue for vehicles entering through route C.

Another observer was to stand at the exit of each of the legs of the roundabout respectively, observing and recording the numbers of vehicles with particular colours of the tag as they flow out of the roundabout. In recording the numbers of vehicles, four categories i.e. cars, motorcycles, buses and two or three axle trucks were adopted. The number of vehicles in each category passing was recorded for each fifteen minutes interval as shown in Table 1A to Table 15A in the appendix. An example is shown in figure 3.1.

Table 3.1 RAW COUNT OF VEHICLE MOVEMENT TOWARDS THE ROUNDABOUT, 200M AWAY

Vehicle Type / Time	Cars	Motorcycles	Buses	2/3 Axle Trucks
6 – 6.15am	𝍸 𝍸	𝍸	II	IIII
6.15 – 6.30am	𝍸	𝍸	II	I

The observation spanned Monday, 28th June 2004 to Friday, 2nd July 2004. The weather condition was fine in all the days with no rains recorded. The law enforcement agent helped in reducing the number of intra city public transport in the routes terminus during the period. The raw traffic volume counts were then converted to equivalent passenger car unit (pcu) using the equivalent factors in Table 4.1. Different vehicle sizes have different capacity impacts and passenger cars are used as the basis for comparison. From the pcu's got for each time interval, the cumulative pcu's were calculated. The graph of the cumulative pcu variation with time was then plotted with time intervals expressed in hours. From the cumulative counts, estimates of average flows were .obtained by plotting tangent to the cumulative counts plots at different points within the overall time intervals spanned.

A typical set of results is shown in Fig. 4.1 to Fig. 4.15 in the appendix. Different slopes in the graph imply different flows. The period of highest slope (flow) as well as other flows were estimated for each of the traffic streams.

Each of the human observers was provided with a stop watch or wristwatch with a second hand and a clipboard and paper to record the data.

The detailed survey of the roundabout was undertaken with the following instruments: Theodolite, steel tape and the ranging poles. The detail points were picked by Tachometry survey method because of the heavy traffic around the area.

The points were plotted to scale of 1:200 to give the actual direction and dimensions of the roundabouts geometric features. The diagram showing the roundabout is as shown in figure 2.3.

The graph showed that the peak hour flow exists between 7am and 9am daily. The peak hour flow was adjusted by dividing the peak hour factor. The exit flows, the circulating flow were all calculated.

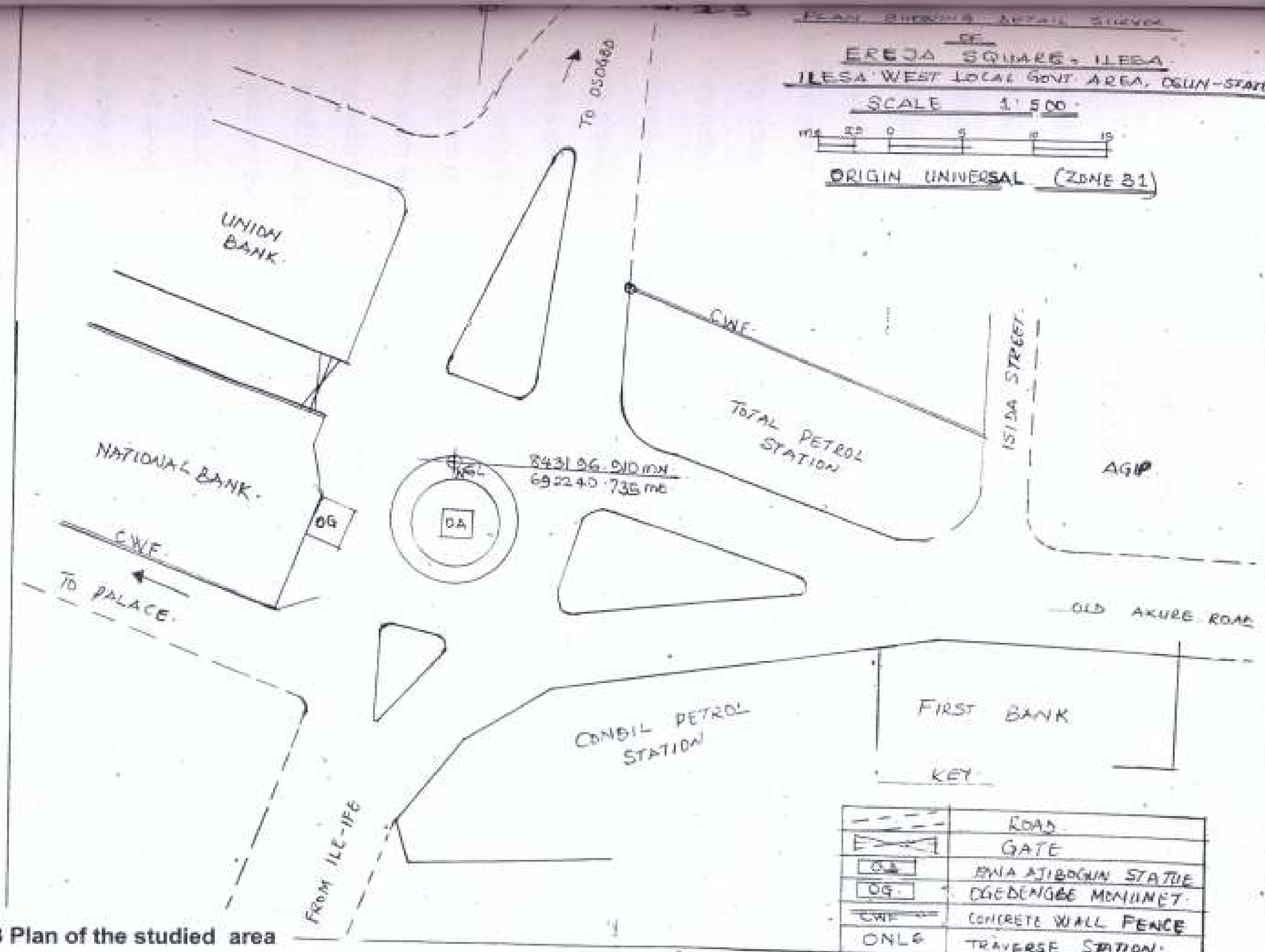

Fig. 2.3 Plan of the studied area

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 GEOMETRIC PARAMETERS:

From fig. 3.1, the following are the geometric parameters of the roundabout:

1. Inscribed diameter (D) = 33.4m
2. Approach half width (v) = 4m
3. Circulating width (u) = 7m
4. Effective flare length (l') = 12.3m
5. Entry radius (r) [Route A to B] = 9.1m
6. Entry radius (r) [Route B to C] = ∞
7. Entry radius (r) [Route C to A] = 13.3m
8. Entry angle (Ø) [Route A to B] = 48°
9. Entry angle (<Ø)[Route C to A] = 30°
10. Entry angle (Ø) [Route B to C] = 142°
11. Entry width (e) [Route A] = 8m
12. Entry width (e) [Route C] = 10m
13. Entry width (e) [Route B] = 10.5m

4.2 GENERAL OBSERVATION

It was observed that:

- A junction about 60m along the entry in route A, about 20m in the entry of route B and about 30m in exit of route C influence the capacity of traffic in the roundabout.
- At each of the junction legs of the roundabout, the taxi drivers queue for passengers. The parking area also tended to disturb the smooth traffic flow.

- The monitoring of the origin and destination of the motorcyclist in the roundabout was not visible. The assumption made in the project was to use the proportion of the vehicles in various routes to be the same with the motorcyclists.
- Permission from the Traffic Warden Services not to influence the traffic flow in the junctions was granted for the period.

4.3 RESULTS OF TRAFFIC VOLUME STUDIES

The raw vehicular volume counts (inflow) and the converted values in pcu on route A, route B and route C are given in Appendix 1. The volumes are typically expressed in passenger car units for each period of 15 minutes. The passenger car units (pcu) shown in Table 4. 1 have been adopted to convert the different vehicle types to equivalent passenger car units.

TABLE 4. 1 CONVERSION FACTORS FOR PASSENGER CAR UNIT (PCU) FOR ROUNDABOUTS

VEHICLE TYPE	PASSENGER CAR UNITS (PCU)
Truck with trailer	2.0
Bus	1.5
Car	1.0
Bicycle /Motorcycle	0.5

Source: Roundabouts: An information guide by U.S Department of Transportation Federal Highway Administration page 84

The graph of the cumulative pcu's against the time is shown in Appendix 1 The average traffic flows were then deduced for different periods and are shown in Tables 4.2 (A to C)

The cumulative (pcu's) were calculated for each route as shown in Appendix 1

TABLE 4.2 (A) **ROUTE A**

Day	Q1	Q2	Q3	Q4	Q5	Q6
Monday	250.0	500.0	528.6	500.0	447.1	-
Tuesday	300.0	625.0	480.0	480.0	500.0	500.0
Wednesday	300.0	500.0	640.0	488.9	445.0	500.0
Thursday	334.0	500.0	533.0	447.0	413.0	-
Friday	350.0	600.0	520.0	400.0	500.0	-

TABLE 4.2 (B) **ROUTE B**

Day	Q1	Q2	Q3	Q4	Q5	Q6
Monday	333.4	550.0	472.7	436.4	450.0	-
Tuesday	350.0	533.4	346.7	376.5	320.0	461.5
Wednesday	333.4	492.3	457.1	400.0	457.2	-
Thursday	313.0	571.0	457.0	413.0	-	-
Friday	416.0	533.0	438.0	350.0	445.0	-

TABLE 4.2 (C) **ROUTE C**

Day	Q1	Q2	Q3	Q4	Q5	Q6
Monday	250.0	700.0	571.4	700.0	600.0	-
Tuesday	333.4	640.0	540.0	600.0	533.3	-
Wednesday	440.0	600.0	566.7	566.7	600.0	-
Thursday	357.0	636.0	600.0	530.0	-	-
Friday	300.0	500.0	700.0	609.0	591.0	-

The flow at different hours of the day are labeled to facilitate day-to-day comparisons and also to enable the flow situations at the roundabout to be separately analyzed for each demand period of the day.

The average maximum hourly flows generally occur between the hours of 7am and 9am every day of the week. The average maximum hourly flows are calculated and are shown in Table 4.3.

TABLE 4.3 THE AVERAGE MAXIMUM HOURLY FLOW.

DAY/TIME	ROUTE A(vph)	ROUTE B(vph)	ROUTE C(vph)
Monday 7-9 a.m.	500	550	700
Tuesday 7 - 9 am	625	533	640
Wednesday 7 - 9am	640	492	600
Thursday 7 -.9 am	533	533	636
Friday 7 - 9 am	600	533	700

The Peak Hour Factor is the ratio of the peak hourly volume to the peak rate of flow within the hour. It is a common practice to use a peak 15 minute rate of flow for its-computations as specified in the highway capacity manual of 1985. The Peak Hour Factor (PHF) is a measure of the steadiness of traffic. It is also as adjustment factor to traffic flow for design purpose (Oglesby 1975).

$$PHF = \frac{v}{4 \quad x \quad V_{15}} \qquad \ldots\ldots\ldots\ldots 4.1$$

Where V = Peak Hour Volume (vph)

V_{15} = Volume during the peak 15 minutes of flow (veh/min)

The peak hour factors of the different routes in the roundabout are calculated by using equation 4.1; Thus:

For route A, V = 640 vph; V_{15} = 177 vph

$$PHF = \frac{v}{4 \quad x \quad V_{15}} = \frac{640}{4 \quad x \quad 177} = 0.904$$

Similarly for routes B and C. The result is as shown in Table 4.4

TABLE 4.4 THE PHF OF THE ROUTES

ROUTES	PEAK HOUR VOLUME	V_{15}	PHF
A	640	177	0.904
B	550	161.5	0.851
C	700	193	0.907

The actual peak hour volume is then factored with the peak hour factor to obtain the adjusted peak hour volume as shown in equation 4.2

$$Qadj = \frac{Q}{PHF} \quad \text{.......................................} 4.2$$

And where:

Qadj = adjusted peak hour volume

Q = actual peak hour volume

PHF = calculated peak hour factor

The values of the adjusted peak hour volumes for route A are calculated using equation 4.2, thus, for Monday:

Q = 500vph PHF = 0.904

$$Qadj = \frac{500}{0.904} = 553.1 \text{ vph}$$

The adjusted peak hour volume of the routes for different days follows the same procedure and it is tabulated in Table 4.5

TABLE 4.5 ADJUSTED PEAK HOUR ENTRY VOLUME (vph)

DAY	ROUTE A (Q_A)	ROUTE B (Q_B)	ROUTE C (Q_C)
Monday	553.1	646.3	771.8
Tuesday	691.4	626.3	705.6
Wednesday	707.9	578.5	661.5
Thursday	589.6	646.3	701.2
Friday	663.7	626.3	771.8

The numbers of vehicles going to different routes is as shown in table 4.6 and the proportion is determined.

TABLE 4.6 PROPORTION OF VEHICLE FLOWS IN ONE HOUR

Day/Route	Route A	Proportion	Route B	Proportion	Route C	Proportion
Monday:						
U Turn	20	6.2%	31	14.5%	25	6.8%
Left Turn	284	87.9%	30	14.1%	118	32.0%
Right Turn	19	5.8%	152	71.4%	225	61.1%
Tuesday:						
U Turn	26	6.1%	31	14.7%	25	7.1%
Left Turn	374	88%	29	13.8%	112	32.0%
Right Turn	25	5.9%	150	71.4%	213	60.8%
Wednesday:						
U Turn	19	5.0%	27	15.0%	29	7.1%
Left Turn	334	87%	25	13.8%	131	31.9%
Right Turn	27	7.1%	128	71.1%	250	60.9%
Thursday:						
U Turn	17	4.8%	37	14.8%	29	6.9%
Left Turn	304	86.8%	35	14.0%	134	31.9%
Right Turn	29	8.2%	178	71.2%	257	61.2%
Friday:						
U Turn	21	5.5%	32	14.5%	26	7.0%
Left Turn	339	88%	30	13.6%	118	31.9%
Right Turn	25	6.5%	158	71.8%	226	61.1%

The average proportion for U turn in route A is :

$$\frac{6.2 + 6.1 + 5.0 + 4.8 + 5.5}{5} = 5.52\%$$

Similarly, the average turning in each of the routes are equal to:

Routes	U turns	Left turns	Right turns
A	5.52%	87.72%	6.76%
B	14.7%	13.86%	71.44%
C	6.98%	31.94%	61.08%

4.4 EXIT, CIRCULATING AND ENTRY VOLUME COMPUTATIONS:

4.4.1 EXIT VOLUME COMPUTATIONS:

The raw counts of the different color tags of the vehicles (R – red; Y – yellow; B – blue) that made their way out of routes A,B and C during the maximum flows in each of the routes are as shown in tables 4.7A to 4.7C for Monday. The total hourly flow (pcu) is then calculated based on the conversion factors in Table 4.1.

TABLE 4.7 A Raw counts of vehicular volume in exit of Route 'A' on Monday between 7 am and 8 am

Vehicle	Cars			Buses			2/3 Axle Trucks			Motorcycle
Time	R	Y	B	R	Y	B	R	Y	B	
7.00 -7.15	4	8	45	-	2	5	-	-	1	141
7.15 -7.30	4	9	54	-	3	9	-	-	1	150
7.30 - 7.45	5	10	31	-	3	5	-	-	-	140
7.45 - 8.00	5	7	64	-	3	3	-	-	1	145
Total	18	34	194	-	11	21	-	-	3	576

TABLE 4.7 B Raw counts of vehicular volume in exit of Route 'B' on Monday between 7 am and 8 am

Vehicle	Cars			Buses			2/3 Axle Trucks			Motorcycle
Time	R	Y	B	R	Y	B	R	Y	B	
7.00 - 7.15	4	8	27	-	1	3	-	-	1	92
7.15 -7.30	4	10	27	-	2	6	-	-	1	90
7.30 - 7.45	5	8	23	-	2	4	-	-	-	91
7.45 - 8.00	5	8	39	-	1	2	-	-	1	86
Total	18	34	113	-	6	15	-	-	3	359

TABLE 4.7 C Raw counts of vehicular volume in exit of Route 'C' on Monday between 7 am and 8 am

Vehicle	Cars			Buses			2/3		Axl	Motorcycle
Time	R	Y	B	R	Y	B	R	Y	B	
7.00 - 7.15	40	25	5	9	6	3	-	-	1	200
7.15 -7.30	50	25	6	6	10	3	1	3	1	210
7.30 - 7.45	60	61	7	8	12	1	2	-	-	190
7.45 - 8.00	71	31	9	5	6	2	1	-	1	196
Total	221	162	27	28	33	9	4	3	3	796

The total hourly exit flows on Monday between 7 am and 8 am is the sum of the vehicles with red tag (R), the vehicles with yellow tag (Y), the vehicles with blue tags (B) and the proportion of motorcycles i.e. from Table 4.7A.

Total number of cars = 18 + 34 + 194 = 246

Total number of buses = - + 11 + 21 = 32

Total number of 2/3 Axle Trucks = - + - + 3 = 3

Total number of motorcycles = 141 + 150 + 140 + 145 = 576

Total Hourly (pcu) . = 246 x 1 + 32 x 1.5 + 3 x 2 + 576 x 0.5 = 588

The calculation for the other routes for the week follows the same procedure. The result is as shown in Table 4.8 The calculated total hourly exit flows between 8 am and 9am is similarly calculated and shown in Table 4.9. The average of the total hourly flow(pcu) is as shown in Table 4.10

TABLE 4.8 TOTAL HOURLY EXIT FLOWS FOR THE WEEK BETWEEN 7 AM AND 8 AM.

DAY	ROUTE	CARS	BUSES	2/3 AXLE TRUCKS	MOTOR CYCLES	TOTAL HOURLY (PCU)
Monday	A	246	32	3	576	588
	B	165	21	3	359	382
	C	410	70	10	796	933
Tuesday	A	253	13	4	575	568
	B	159	10	4	372	368
	C	488	68	14	1168	1202
Wednesday	A	233	16	-	534	524
	B	154	12	1	340	344
	C	434	58	2	1104	1077
Thursday	A	273	14	4	500	552
	B	174	9	-	369	372
	C	439	51	7	1019	1039
Friday	A	274	18	2	614	612
	B	180	14	2	346	378
	C	442	60	12	1068	1090

TABLE 4.9 TOTAL HOURLY EXIT FLOWS FOR THE WEEK BETWEEN 8 AM AND 9 AM.

DAY	ROUTE	CARS	BUSES	2/3 AXLE TRUCKS	MOTOR CYCLES	TOTAL HOURLY (PCU)
Monday	A B C	278 159 450	20 15 59	0 3 6	584 381 905	600 378 1003
Tuesday	A B C	245 152 402	15 12 35	0 0 2	565 380 1079	550 360 998
Wednesday	A B C	230 162 431	18 12 52	1 4 2	542 348 1120	530 362 1073
Thursday	A B C	267 170 410	16 19 55	2 1 5	530 389 1045	560 395 1025
Friday	A B C	270 170 424	20 14 52	5 2 4	580 374 1100	600 382 1060

TABLE 4.10 AVERAGE OF THE HOURLY EXIT FLOWS

Day	Route	Total hourly 7am - 8 am	Total hourly 8am - 9 am	Average total Hourly flow(pcu)
Monday	A B C	588 382 933	600 378 1003	594 380 983
Tuesday	A B C	568 368 1202	550 360 998	559 384 1100
Wednesday	A B C	524 344 1077	530 362 1073	527 353 1075
Thursday	A B C	552 372 1039	560 395 1025	556 383.5 1032
Friday	A B C	612 378 1090	600 382 1060	606 380 1075

4.4.2 CIRCULATING FLOWS COMPUTATIONS:

Generally, the entry flow for each legs of the roundabout is the sum of the entering turning moments. This is illustrated with the sketch of traffic movement on Monday in figure 4.1

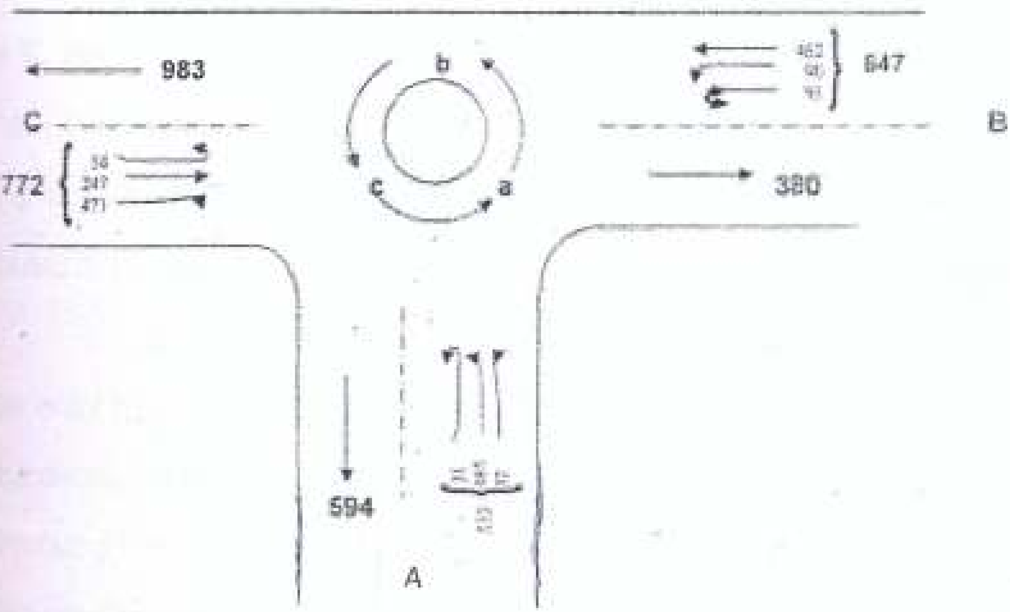

FIG. 4.1 ILLUSTRATION OF ENTERING FLOW COMPUTATIONS ON MONDAY

Thus, I we consider approach route "A" in fig 4.1, the adjusted peak hour flow is 553 vph (Table 4.5). The entry flow is divided according to the average proportion in Table 4.7. For U turn, the flow is:

$$\frac{5.52}{100} \times 553 = 30.52 = 31$$

For the right turn, the flow is:

$$\frac{6.76}{100} \times 553 = 37.38 = 37$$

For the left turn, the flow is:

$$\frac{87.72}{100} \times 553 = 485$$

Similar calculation was done for the other routes:

For Route B: U turn = 95.1 = 95

Left turn = 89.67 = 90

Right turn = 462.21 = 462

For Route C : U turn = 53.8 = 54

Left turn= 246,6 = 247

Right turn = 471.53 = 472

Thus, the total entry volume in Route A is the sum of the vehicles moving towards route 'B', the vehicles moving towards route C and the vehicles making a U turn. For example, the peak entering flows in route A is the sum of the vehicles with red tags moving to different locations and the motorcycles. The motorcycles have been distributed in the ratio of the proportion of the vehicles moving into different locations.

Q_A = 31 + 485 + 37 = 553vph as indicated in figure 4.1

The entry flow computations in the other approaches follow the same procedure. The circulating volume computation is the sum of all the traffic flows contributing to the circulating flow at a particular junction in the roundabout.

If we consider the flow in figure 4.1, the flows contributing to the circulating flow in point 'a' are:

(i) U – turn from route B.

(ii) Flow from route C to route B

(iii) U turn from route C.

i.e 'a' = 95 + 247 + 54 = 396 vph

Similarly, 'b' = 31 + 485 + 54 = 570 vph

'c' = 95 + 90 + 31 = 216 vph

Points a, b, c, represent the circulating flow in the junction. The circulating flows in the junction for the other days of the week are similarly calculated and are shown in Table 4.11.

TABLE 4.11 CIRCULATING FLOWS IN THE JUNCTIONS.

DAYS	'a' (vph)	'b'(vph)	'c' (vph)
Monday	396	570	216
Tuesday	327	628	187
Wednesday	306	638	175
Thursday	331	541	192
Friday	351	608	185

4.4.3 ENTRY FLOW COMPUTATIONS FROM OTHER FORMULA IN OTHER COUNTRIES OF THE WORLD:

(A) UNITED STATES CHART 4.1

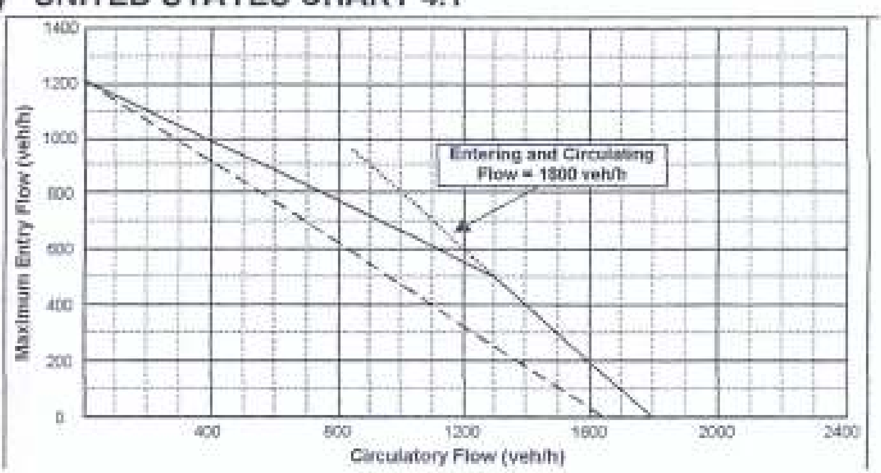

Chart 4.1 Approach capacity of a single lane roundabout.
Source: Roundabouts: An information guide. Chapter 4 Exhibit 4.3 by the U.S. Department of transportation, Federal Highway Administration. (June 2000)

At Route 'A' in figure 4.1, Circulating flow = 396 vph

Entering flow = 553 vph

From Chart 4.1, The maximum entry flow = 1000 vph

$$\text{Volume to capacity ratio} = \frac{553}{1000} = 0.553$$

At Route 'B' in figure 4.1, Circulating flow = 570 vph

Entering flow = 647 vph

From Chart 4.1, The maximum entry flow = 900 vph

$$\text{Volume to capacity ratio} = \frac{647}{900} = 0.72$$

At Route 'C' in figure 4.1, Circulating flow = 216 vph

Entering flow = 772 vph

From Chart 4.1, The maximum entry flow = 1100 vph

$$\text{Volume to capacity ratio} = \frac{772}{1100} = 0.70$$

Similarly, the ratio of the entry flow and the maximum entry flow are calculated for the other days of the week and it is presented in Table 4.12

TABLE 4.12 TABULATION OF THE RATIO OF THE ENTRY FLOW AND THE MAXIMUM ENTRY FLOW FOR THE WEEK BASED ON CHART 4.1.

DAY	ROUTE	Circulating Flow (vph)	Entry Flow (vph)	Maximum Entry Flow(vph)	Ratio
Monday	A	396	553	1000	0.55
	B	570	647	900	0.72
	C	216	772	1100	0.70
Tuesday	A	327	691	1050	0.66
	B	628	626	880	0.71
	C	187	706	1100	0.64
Wednesday	A	306	708	1050	0.67
	B	638	579	850	0.68
	C	175	662	1100	0.60
Thursday	A	331	590	1050	0.56
	B	541	671	920	0.73
	C	192	701	1100	0.64
Friday	A	351	664	1020	0.65
	B	608	626	900	0.69
	C	185	772	1100	0.70
				AVERAGE =	0.66

(B) SCOTLAND (ENGLAND) CAPACITY FORMULA.
(NETWORK EVALUATION FROM SURVEYS AND ASSIGNMENT(NESA) MANUAL 1998)

The entry capacity (Qe) of each of the arms of the roundabout in pcu/hr is given from equations 2.6 to 2.12

$$Qe = K (F - fc\ Qc)$$

Where the terms are defined as:

$K = 1 - 0.00347 (\Phi - 30) - 0.978 [r^{-1} - 0.05]$

$F = 303 x_2$

Qc = the circulating flows across the entry in pcu/hr

$fc = 0.210 t_D (1 + 0.2 x_2)$

$$t_D = 1 + \frac{0.5}{1 + \exp\left(\frac{D - 60}{10}\right)}$$

$$x_2 = v + \frac{e - v}{1 + 2s}$$

$$s = \frac{1.6 (e - v)}{l'}$$

where: Φ = entry angle(degree)

r = entry radius (m)

D = Inscribed circle diameter (m)

v = approach road half width(m)

e = entry width (m)

l' = average effective length over which the flare is developed (m)

From the field measurements in Sheet 1, the dimension of route A is:

Diameter (D) = 33.4m

Effective length (l') = 12.3m

Approach half width (v) = 4m

Entry width (e) = 8m

Entry radius (r) = 9.1m

Entry angle (Φ) = 48^0

$K = 1 - 0.00347(48 - 30) - 0.978 [13.3^{-1} - 0.05]$.

$= 0.9129$

$$s = \frac{1.6 \times (8-4)}{12.3} = 0.52$$

$$X_2 = 4 + \frac{8 - 4}{1 + 2 \times 0.52} = 5.96$$

$$F = 303 \times 5.96 = 1805.88$$

$$t_D = 1 + \frac{0.5}{1 + \exp\left(\frac{33.4 - 60}{10}\right)}$$

$$= 1.499$$

$$fc = 0.210 \times 1.499 \times (1 + 0.2 \times 5.96) = 0.6862$$

$$Qe = 0.9129\,(1805.88 - 0.6862\,Qc) \qquad \text{4.3}$$

The equation of the maximum entry flow in route A follows equation 4.3. Similarly the equations of the maximum entry flow are derived from individual route measurements.

For route B measurement:

Diameter (D)	= 33.4 m
Effective length (l')	= 12.3m
Approach half width (v)	= 4m
Entry width (e)	= 10.5m
Entry radius (r)	= ∞
Entry angle (Φ)	= 142^0

The equation of maximum entry flow becomes:

$$Qe = 0.66\,(1946.9 - 0.719 \times Qc) \qquad \text{4.4}$$

For route C measurement:

Diameter (D)	= 33.4 m
Effective length (l')	= 12.3m
Approach half width (v)	= 4m

Entry width (e) = 10m

Entry radius (r) = 13.3 m

Entry angle (Φ) = 30^0

The equation of the maximum entry flow becomes:

$$Qe = 0.97536\ (1922.14 - 0.714\ Qc) \qquad 4.5$$

Substituting the values of the circulating flows to equations 4.3 to 4.5, the maximum entry flows are calculated for the week. The ratio of the entry flow to the maximum flow is shown in Table 4.13

TABLE 4.13 TABULATION OF THE ENTRY FLOW WITH THE MAXIMUM ENTRY FLOW BASED ON SCOTLAND FORMULA

DAY	ROUTE	Circulating Flow (vph)	Entry Flow (vph)	Maximum Entry Flow(vph)	Ratio
Monday	A	396	553	1399.14706	0.3952408
	B	570	647	1014.4662	0.63777384
	C	216	772	1724.35455	0.44770375
Tuesday	A	327	691	1442.61023	0.47899286
	B	628	626	986.94288	0.63428189
	C	187	706	1744.55035	0.40468881
Wednesday	A	306	708	1455.83815	0.4863178
	B	638	579	982.19748	0.58949449
	C	175	662	1752.90724	0.37765832
Thursday	A	331	590	1440.09062	0.40969644
	B	541	671	1028.22786	0.65257909
	C	192	701	1741.06832	0.40262636
Friday	A	351	664	1427.4926	0.46515127
	B	608	626	996.43368	0.62824051
	C	185	772	1745.94317	0.44216789

AVERAGE = 0.496

(C) GERMAN 'G2' METHODOLOGY:

The formula is as shown in equation 2.5 is below:

$$Qe = C + d\ Qc$$

Where Qe = entry flow capacity (veh/hr); Qc = circulating flow rate (veh/hr)

And C and d are as shown in table 2.3.

In the case of the roundabout under consideration, C = 1218 and d = - 0.74

The resulting relationship then becomes:

$$Qe = 1218 - 0.74\,Qc \qquad \text{.......... 4.6}$$

The calculated maximum entry flow based on the methodology is as shown in Table 4.14.

TABLE 4.14: TABULATION OF THE ENTRY FLOW WITH THE MAXIMUM ENTRY FLOW BASED ON GERMAN 'G2' METHODOLOGY.

DAY	ROUTE	Circulating Flow (vph)	Entry Flow (vph)	Maximum Entry Flow(vph)	Ratio
Monday	A	396	553	924.96	0.59786369
	B	570	647	796.2	0.8126099
	C	216.	772	1058.16	0.72956831
Tuesday	A	327	691	976.02	0.7079773
	B	628	626	753.28	0.83103229
	C	187	706	1079.62	0.65393379
Wednesday	A	306	708	991.56	0.71402638
	B	638	579	745.88	0.77626428
	C	175	662	1088.5	0.60817639
Thursday	A	331	590	973.06	0.60633466
	B	541	671	817.66	0.82063449
	C	192	701	1075.92	0.65153543
Friday	A	351	664	958.26	0.69292259
	B	608	626	768.08	0.81501927
	C	185	772	1081.1	0.7140875

AVERAGE = 0.715

(D) SWISS TRANSPORT METHODOLOGY:

The Swiss consider:

$$Qe = k[1500 - 8/9\ Qg] \qquad \text{.......... 4.7}$$

to be the full capacity formula of roundabouts. (Section 2.2.2 E)

Where Qe = maximum inflow of an entry

$$Qg = [\beta \times Qc + \alpha \times Qs] \qquad \text{.......... 4.8}$$

For the roundabout in consideration:

Consider Route A: On Monday, $k = 1$

$L_{ba} = 14m$ (figure2.2) and $\alpha = 0.35$, $Q_c = 396$ vph and $Q_s = 594$vph

$Q_g = Q_c + Q_s \times \alpha$

$= 396 + 594 \times 0.35 = 603.9$vph

$Q_e = 1500 - 8/9 \times 603.9 = 963.21$ vph

Consider Route B on Monday;

$L_{ba} = 18m$ (figure 2.2) and $\alpha = 0.25$; $Q_c = 570$ vph and $Q_s = 380$ vph

$Q_g = 570 + 380 \times 0.25 = 665$ vph

$Q_e = 1500 - 8/9 \times 665 = 908.9$ vph

For route C on Monday:

$L_{ba} = 16m$ (figure 2.2) and $\alpha = 0.3$; $Q_c = 216$ vph, $Q_s = 983$ vph

$Q_g = 216 + 983 \times 0.3 = 510.9$ vph

$Q_e = 1500 - 8/9 \times 510.9 = 1045.9$ vph

The calculation of all the maximum flow in each of the routes for various exit flows follows the same procedure. The tabulation is as shown in Table 4.15

TABLE 4.15: TABULATION OF THE ENTRY FLOW WITH THE MAXIMUM ENTRY FLOW BASED ON SWISS TRANSPORT METHODOLOGY:

DAY	ROUTE	Circulating Flow (vph) (Qc)	Exit flow (Qs)	α	Entry Flow (vph)	Maximum Entry Flow(vph)	Ratio
Monday	A	396	594	0.35	553	963.2	0.57
	B	570	380	0.25	647	908.8889	0.71
	C	216	983	0.30	772	1045.867	0.74
Tuesday	A	327	559	0.35	691	1035.422	0.67
	B	628	384	0.25	626	856.4444	0.73
	C	187	1100	0.30	706	1040.444	0.68
Wed.	A	306	527	0.35	708	1064.044	0.67
	B	638	353	0.25	579	854.4444	0.68
	C	175	1075	0.30	662	1057.778	0.63
Thursday	A	331	556	0.35	590	1032.8	0.57
	B	541	383.5	0.25	671	933.8889	0.72

	C	192	1032	0.30	701	1054.133	0.67
Friday	A	351	606	0.35	664	999.4667	0.66
	B	608	380	0.25	626	875.1111	0.72
	C	185	1075	0.30	772	1048.889	0.73

AVERAGE 0.68

(E) FRANCE METHODOLOGY:

The formula is as shown below (equation 2.15 to 2.16) :

$$Qg = Qc + \alpha Qs$$

Where : Qg = Impending flow (veh/hr)

Qc = Circulating flow (veh/hr)

α = variable that is a function of the width of the splitter island (0.2 on the average)

Qs = exiting flow (veh/hr)

The entry capacity Qe is defined as:

$$Qe = 1500 - 5/6\, Qg \; ; \quad \text{for } Qg < 1800$$

If $Qg \geq 1800$, $Qe = 0$

Consider Route A on Monday;

$Qg = 396 + 0.2 \times 594 = 514.8$ vph

$Qe = 1500 - 5/6 \times 514.8 = 1071$ vph.

The calculation of all the maximum flows are similar and are shown in Table 4.16

TABLE 4.16. TABULATION OF THE ENTRY FLOW WITH THE MAXIMUM ENTRY BASED ON FRANCE METHODOLOGY.

DAY	ROUTE	Circulating Flow (vph) (Qc)	Exit flow (Qs)	α	Entry Flow (vph)Qe	Maximum Entry Flow(vph) Qe	Ratio
Monday	A	396	594	0.2	553	1071	0.52
	B	570	380	0.2	647	961.6667	0.67
	C	216	983	0.2	772	1156.167	0.67
Tuesday	A	327	559	0.2	691	1134.333	0.61
	B	628	384	0.2	626	912.6667	0.69
	C	187	1100	0.2	706	1160.833	0.61
Wed.	A	306	527	0.2	708	1157.167	0.61
	B	638	353	0.2	579	909.5	0.64
	C	175	1075	0.2	662	1175	0.56
Thursday	A	331	556	0.2	590	1131.5	0.52
	B	541	383.5	0.2	671	985.25	0.68
	C	192	1032	0.2	701	1168	0.60
Friday	A	351	606	0.2	664	1106.5	0.60
	B	608	380	0.2	626	930	0.67
	C	185	1075	0.2	772	1166.667	0.66

AVERAGE 0.62

(F) HIGHWAY CAPACITY MANUAL 2000:

The estimate of the capacity of a roundabout approach is given by:

$$Q_e = \frac{Q_c\, e^{-Q_c t_c/3600}}{1 - e^{-Q_c t_f/3600}}$$

where:

Q_e = Maximum entry capacity (veh/hr)

Q_c = Conflicting circulating traffic (veh/hr)

t_c = Critical gap (sec)

t_f = Follow-up time (sec)

For instance, on Monday in route A when the circulating flow (Qc) = 396 vph, the maximum entry flow based on the equation is:

$$Q_e = \frac{396\, e^{-396 \times 4.1/3600}}{1 - e^{-396 \times 2.6/3600}} = 1017.14 \text{ vph}$$

First case: (Upper bound : tc = 4.1 seconds and tf = 2.6 seconds)

This is shown in Table 4.17.

TABLE 4.17: THE CALCULATED MAXIMUM ENTRY CAPACITY BASED ON THE UPPER BOUND OF THE HCM 2000.

DAY	ROUTE	Circulating Flow (vph)Qc	Entry Flow (vph)Qe	Maximum Entry Flow(vph) Qe	Ratio
Monday	A	396	553	1014.115	0.545303
	B	570	647	882.5302	0.733119
	C	216	772	1169.304	0.660222
Tuesday	A	327	691	1071.186	0.645079
	B	628	626	842.3339	0.743173
	C	187	706	1196.282	0.590162
Wednesday	A	306	708	1089.14	0.650054
	B	638	579	835.5787	0.692933
	C	175	662	1207.613	0.548189
Thursday	A	331	590	1067.797	0.552539
	B	541	671	903.293	0.742838
	C	192	701	1191.589	0.58829
Friday	A	351	664	1051.004	0.631777
	B	608	626	855.9976	0.73131
	C	185	772	1198.163	0.64432

AVERAGE 0.65

Second case: (Lower bound t_c = 4.6 second and t_f = 3.1 second)

This is shown in Table 4.18.

TABLE 4.18: THE CALCULATED MAXIMUM ENTRY CAPACITY BASED ON THE LOWER BOUND OF THE HCM 2000.

DAY	ROUTE	Circulating Flow (vph)Qc	Entry Flow (vph)Qe	Maximum Entry Flow(vph) Qe	Ratio
Monday	A	396	553	826.3	0.669248
	B	570	647	709.6	0.911781
	C	216	772	970.1	0.795794
Tuesday	A	327	691	878.2	0.786837
	B	628	626	673	0.930163
	C	187	706	994.4	0.709976
Wednesday	A	306	708	891.6	0.794078
	B	638	579	668.2	0.866507
	C	175	662	998.8	0.662795
Thursday	A	331	590	874	0.675057
	B	541	671	727	0.922971
	C	192	701	989	0.708797
Friday	A	351	664	859.3	0.772722
	B	608	626	685.5	0.913202
	C	185	772	986.25	0.782763

AVERAGE 0.80

4.4.4. SUMMARY OF THE FINDINGS.

The computed entry saturation flows from different models are compared with the field flow and is shown in Table 4.19

TABLE 4.19 COMPUTED ENTRY SATURATION FLOWS FROM DIFFERENT MODELS COMPARED WITH THE FIELD FLOW.

COUNTRIES	US CHART 4.1	SCOTLAND	GERMAN G2	SWISS	FRANCE	HCM2000 UPPER	HCM2000 LOWER
AVERAGE	0.66	0.496	0.715	0.68	0.62	0.65	0.80

CHAPTER FIVE

DISCUSSION OF RESULTS

The summary of the average of the ratio of the computed entry saturation flows from different models compared to the field flow is as shown in Table 5.1.

TABLE 5.1 COMPUTED AVERAGE SATURATION FLOWS FROM DIFFERENT MODELS COMPARED TO THE FIELD FLOW:

S/N	Models from different parts of the world	Average
1.	U.S. Chart 4.1	0.66
2.	Scotland Formula	0.50
3.	German 'G2' methodology	0.715
4.	Swiss Transport methodology	0.68
5.	France methodology	0.62
6.	Highway Capacity Formula (Upper bound)	0.65
7.	Highway Capacity Formula (Lower bound)	0.80

The result shows that the best analytical model that replicates the situation at Adeti roundabout is the Highway Capacity Formula (Lower bound). Also the best empirical method that replicates the situation at Adeti roundabout is the German 'G2" methodology.

5.1. HIGHWAY CAPACITY FORMULAR (LOWER BOUND)

The model is based on the driver's gap acceptance characteristics. The replication of the model to the situation at Adeti roundabout is an indication that the drivers' behavioral attitude in Ilesa can well be compared with other countries of the world. The study carried out in Nigeria showed the estimated driver's critical gap (t_c) was 4.95 sec. (Adebisi 1982). The follow-up time (t_f) can then be calculated using the maximum entry flow collected in the field.

Since $$Q_e = \frac{Q_c\, e^{-Q_c t_c/3600}}{1 - e^{-Q_c t_f/3600}}$$ from equation 2.1

where:

Q_e = Maximum entry capacity (veh/hr)

Q_c = Conflicting circulating traffic (veh/hr)

t_c = Critical gap (sec)

t_f = Follow -up time (sec)

then,

Since $$\frac{Q_e}{Q_c} = \frac{e^{-Q_c t_c/3600}}{1 - e^{-Q_c t_f/3600}}$$

from where tf can be calculated . The computer programme was used to calculate the values of tf for different values of Qc and Qe as shown in table 5.2

Table 5.2 The Calculated follow up time (tf)

Days	Route	Qc	Qe	tc(sec)	Tf(sec)
Monday	A	396	553	4.95	4.880698808
	B	570	647	4.95	3.250937662
	C	216	772	4.95	3.884425292
Tuesday	A	327	691	4.95	3.955928024
	B	628	626	4.95	3.152673949
	C	187	706	4.95	4.41211271
Wed.	A	306	708	4.95	3.926434079
	B	638	579	4.95	3.459258046
	C	175	662	4.95	4.792339906
Thursday	A	331	590	4.95	4.78428258
	B	541	671	4.95	3.21533844
	C	192	701	4.95	4.427952488
Friday	A	351	664	4.95	4.05006996
	B	608	626	4.95	3.235347439
	C	185	772	4.95	4.000235659
			AVERAGE		3.961869003

The average follow up time (tf) was found to be 3.9sec. Now, substituting the values of the follow-up time of 3.96 and the critical gap value of 4.95sec in the HCM formula, the values of the maximum entry flows is as shown in Table 5.3. Therefore, the new computed entry saturation flows compared with the field flow is shown in Table 5.3 below:

Table 5.3 *The new computed entry saturation flows* compared with the field flow:

DAYS	ROUTES	Circulating Flows(Qc)	Entry Flows(Qe)	Maxim.Entry flows (Qe)	Ratio
Monday	A	396	553	547.153061	0.9894268
	B	570	647	479.1252105	0.7405335
	C	216	772	624.6108843	0.8090814
Tuesday	A	327	691	575.9839237	0.8335512
	B	628	626	457.9107648	0.7314868
	C	187	706	637.7751837	0.9033642
Wed.	A	306	708	584.9703287	0.8262292
	B	638	579	454.3257235	0.7846730
	C	175	662	643.2784602	0.9717197
Thursday	A	331	590	574.2834646	0.9733618
	B	541	671	490.003822	0.7302590
	C	192	701	635.4918288	0.9065503
Friday	A	351	664	565.8350077	0.8521611
	B	608	626	465.1447403	0.7430427
	C	185	772	638.6901191	0.8273188
				AVERAGE:	0.8415

5.2 GERMAN G2 METHODOLOGY:

The methodology is an empirical formula developed and approved for use by the Federal Government of Germany. The formula is:

$$Qe = C + d\,Qc$$ from equation 2.

The constants C and d are based on long period of observation. The capacity is also a function of only two geometric parameters:

(i) Number of circulating lanes

(ii) Number of entry lanes.

Increase in the number of circulating and entry lanes will cause an increase in the area of the roundabout. This is very costly in a built-up area like Adeti roundabout, Ilesa.

An empirical model that has almost all the geometric parameters to be a function of the entry flow (Qe) is the Scotland empirical methodology.

5.3. The Scotland methodology:

The capacity/geometry relationship in the Scotland method according to RODEL is as shown in Fig 5.1 below:

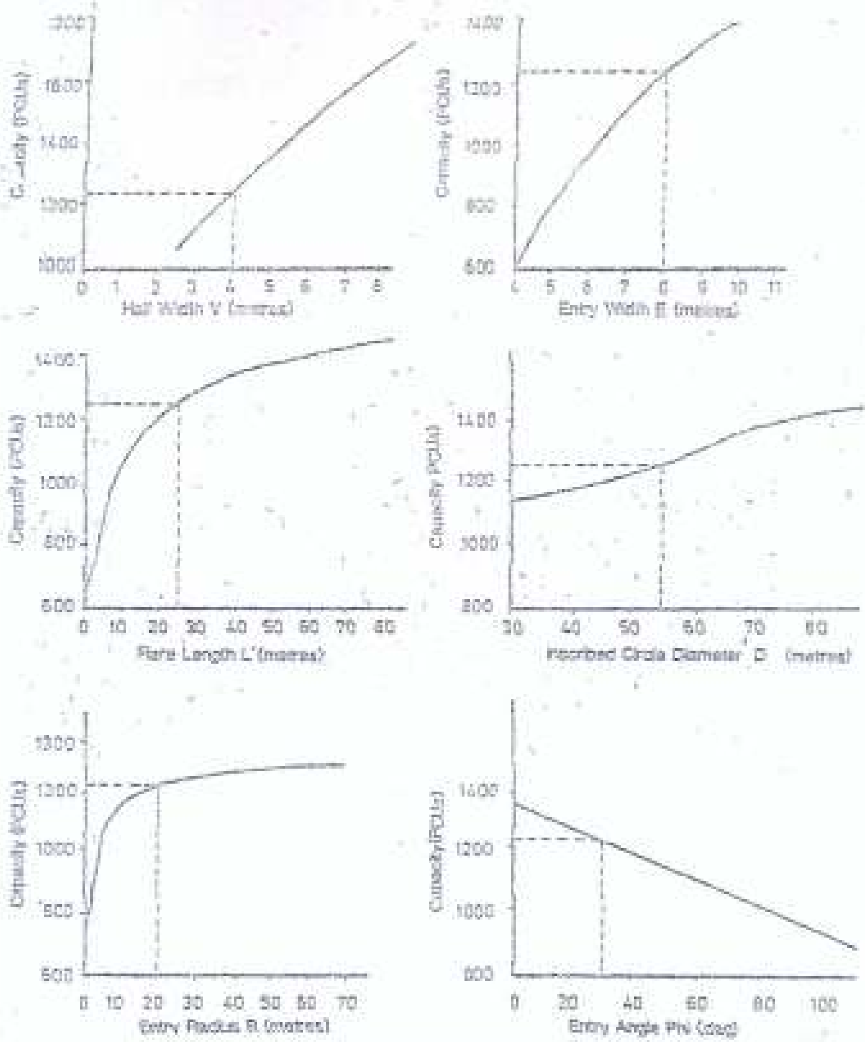

Figure 5.1 Capacity / Geometry relationships

Source: Rodel 1 Interactive Roundabout Design, Rodel software Limited and Stafford shire County council Stafford, Great Britain (not dated)

The relationships show the graph of capacity against half width (v), flare length, the entry radius (r), the entry width (e), the inscribed circle diameter (d,) and the entry angle.

The geometry parameters which are specifically chosen for maximum entry capacity in the Kimber equation (Scotland model) are that:

(i) Inscribed diameter (D) = -40m

(ii) Entry radius (r) = 20m

(iii) Entry angle (φ) = 30°

(iv) Approach half width (v) = 4m

(v) Entry width (e) = 4m

(vi) Effective flare length (l') = 40m

It can be seen from equations 2.7 to 2.12 that when these values are substituted, the resulting equation becomes:

$$Qe = 1212 - 0.5447\ Qc \qquad \text{.......................................} \quad 5.5$$

This equation gives higher values of the entry capacity. As for the Adeti roundabout, the activities and the building around limit how the geometric parameters can be altered. The parameters that can be altered in the present situation are

(i) Entry angle (φ) of routes A and B to 30°

(ii) Flare length (l') of all the routes to be 40m.

TABLE 5.4 COMPUTER STIMULATION ON VARIATION OF DIAMETER AND THE ENTRY ANGLE WITH THE ENTRY FLOW:

Angle(o)	$\boxed{Radius\,(r)}$	K	V	a	l'	S	$\boxed{x_2}$	F	fc	D	(D-60)/10	$\boxed{t_D}$	Qc	Qe
30	9.1	0.941	4	8	12	0.52	5.96	1806	-1	33	-2.66	1.467	570	1700
40	9.1	0.907	4	8	12	0.52	5.96	1806	-1	33	-2.66	1.467	570	1005
50	9.1	0.872	4	8	12	0.52	5.96	1806	-1	33	-2.66	1.467	570	966.2
60	9.1	0.837	4	8	12	0.52	5.96	1806	-1	33	-2.66	1.467	570	927.7
70	9.1	0.803	4	8	12	0.52	5.96	1806	-1	33	-2.66	1.467	570	889.3
80	9.1	0.768	4	8	12	0.52	5.96	1806	-1	33	-2.66	1.467	570	850.8
90	9.1	0.733	4	8	12	0.52	5.96	1806	-1	33	-2.66	1.467	570	812.4
20	9.1	0.976	4	8	12	0.52	5.96	1806	-1	33	-2.66	1.467	570	1082
30	9.1	0.941	4	8	12	0.533	5.935	1798	-1	30	-3	1.476	570	953.7
30	9.1	0.941	4	8	12	0.533	5.935	1798	-1	40	-2	1.44	570	1200
30	9.1	0.941	4	8	12	0.533	5.935	1798	-0	50	-1	1.366	570	1447
30	9.1	0.941	4	8	12	0.533	5.935	1798	0	60	0	1.25	570	1693
30	9.1	0.941	4	8	12	0.533	5.935	1798	0.5	70	1	1.134	570	1940
30	9.1	0.941	4	8	12	0.533	5.935	1798	0.9	80	2	1.06	570	2186
30	9.1	0.941	4	8	12	0.533	5.935	1798	1.4	90	3	1.024	570	2432
30	9.1	0.941	4	8	12	0.533	5.935	1798	1.8	100	4	1.009	570	2679
30	9.1	0.941	4	8	12	0.533	5.935	1798	2.3	110	5	1.003	570	2925
30	9.1	0.941	4	8	12	0.533	5.935	1798	2.8	120	6	1.001	570	3172
30	9.1	0.941	4	8	12	0.533	5.935	1798	3.2	130	7	1	570	3418

5.5 COMPUTER PROGRAMS:

Since roundabout design is fairly new, there are very few programmes developed that are used for analysis of roundabouts. Some of the popular programs are RODEL, ARCADY, SIDRA, KREISEL, GIRABASE and HCM (Highway Capacity Manual). Of these programmes, SIDRA is the most commonly used.

(A) SIDRA:

The SIDRA (Signalized and Unsignalized Intersection Design and Research

Aid) package has been developed by ARRB Transport Research in Australia, as

an aid for design and evaluation of the following intersection types:

- Signalized intersections
- Roundabouts
- Two-way stop control
- All-way stop control
- Yield sign control.

SIDRA is based on gap acceptance processes. (Kerenyi, 1998). It uses field data for the gap acceptance parameters to calibrate the model, such as the number of entry and circulating lanes, central island diameter and circulating roadway width.

(B) ARCADY:

ARCADY is a British roundabout analysis program which has the Kimber's theoretical background. The model assumes a linear relationship between the circulating flow and the maximum entry flow. The input parameters include entry width, inscribed circle diameter, flare length, approach circle diameter, flare length, approach road width, entry radius and entry angle.

(C) **KREISEL**:

KREISEL was developed in Germany. It gives the average capacity from a number of different procedures. It provides a means to compare these procedures.

(D) **RODEL:**

RODEL like ARCADY uses Kimber's empirical equations for capacity estimate. RODEL predicts both approach capacity and lane capacity. It is also a British roundabout analysis.

(E) **GIRABASE**:

GIRABASE is a French method of analysis. Capacity, delay and queuing projections are based on regression. It is sensitive to geometric parameters and gives average values.

(F) **HIGHWAY CAPACITY MANUAL (HCM0 SOFTWARE:**

HCM software is the U.S. method. The capacity estimation is based on entering and circulating volume. Optional gap acceptance parameter values provide both a liberal and conservative estimate of capacity.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 SUMMARY OF FINDINGS FROM THE COMPUTER OUTPUT.

Based on the computer program output shown in Table 5.4, the increase in the inscribed diameter (D) of the roundabout increases the entry capacity. It also showed that the maximum entry capacity of the roundabout occurs when the entry angle is 30^{o}. (see tables 6.1 and 6.2) The graph of the variation of diameter and the entry angle with the entry flow is shown in Figure 6.1 and 6.2 respectively.

TABLE 6.1 VARIATIONS OF THE DIAMETER AND THE ENTRY FLOW.

DIAMETER(M)	30	40	50	60	70	80	90	100	110	120	130
ENTRY FLOW(VEH/HR)	953.7	1200	1440	1693	1940	2186	2432	2679	2925	3172	3418

TABLE 6.2 VARIATIONS OF THE ENTRY ANGLE AND THE ENTRY FLOW

ENTRY ANGLE(DEGREE	20	30	40	50	60	70	80	90
ENTRY FLOW(VEH/HR	1082	1700	1005	988.2	927.7	889.3	850.8	812.4

From the graph, the maximum entry flow occurs when the entry angle is 30^{0} Also the rate of increase in the diameter to the entry flow from the graph is: 4%

6.2 CONCLUSION:

In this research work, it has been shown that the capacity of the roundabout based on the existing condition is lower than the maximum capacity of the roundabout. It is shown that the model that best replicates the situation in the roundabout is the Highway capacity (lower bound). The ratio of the model's computer entry saturation flow and the field flow is 0.80.

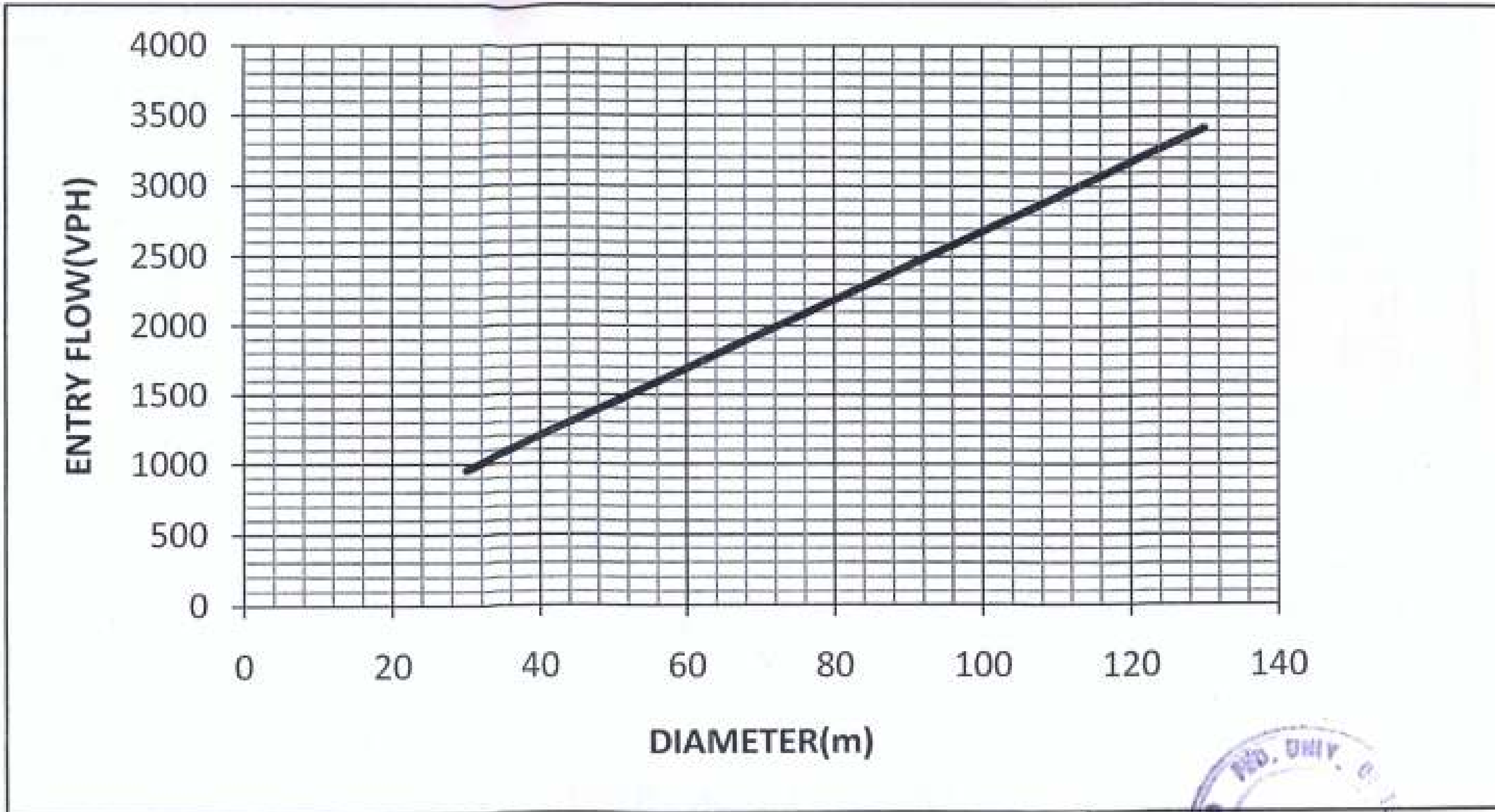

FIG 6.1. The variation of the entry flow (vph) against the diameter (m).

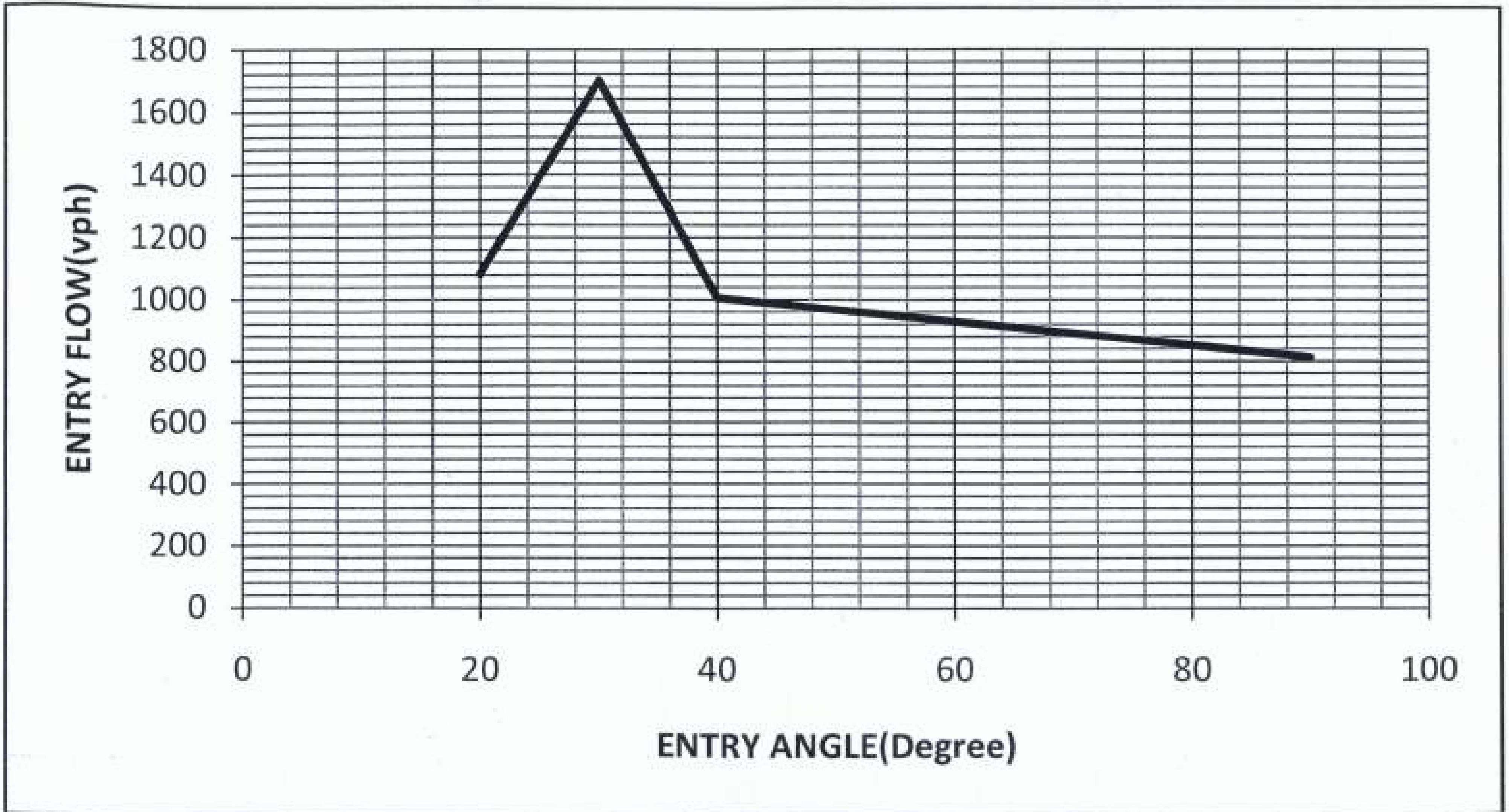

FIG 6.2 The variation of the entry flow (vph) against the entry angle.

owever, a totally customized Highway Capacity (lower bound) would describe the flow where e critical gap (tc) = 4.9 sec and the follow-up time (tf) = 3.96 sec.

The computer simulation showed that the entry angle and the diameter have effect on e roundabout capacity. For the maximum entry flow, the entry angle would be 30^0. The crease in diameter has little increase in the entry flow. The rate of increase would only be 4%.

6.3 RECOMMENDATIONS:

for the satisfactory performance of Adeti roundabout, the following parameters are to be put n place.

(i) The entry angle of routes A and B should be made to be 30^0 for the entry flow to be the maximum. Moreover, there is no justification for the increase in the inscribed diameter of the roundabout. The increase in the inscribed diameter will only produce 4% increase in the entry flow. The present inscribed diameter of 33.4m should be maintained.

(ii) More research could be done to find the model that will best replicate the traffic situation in the area. The estimate driver's critical gap (tc) of 4.95sec.that was used in the research was carried out in Zaria. The value could be estimated for the area.

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APPENDIX 1

TABLE 1A RAW COUNT OF VEHICLE MOVEMENT ON ROUTE 'A' ON MONDAY (JUNE 28, 2004) TOWARDS THE ROUNDABOUT

Veh. Type Time	Cars	Motor-cycles	Buses	2/3 Axle Trucks	Quarterly hour	Cummula-tive
6.00 – 6.15 am	30	50	3	0	59.5	59.5
6.15 – 6.30 am	45	66	1	0	79.5	139
6.30 – 6.45 am	35	75	2	2	79.5	218.5
6.45 – 7.00 am	60	63	3	0	96	314.5
7.00 – 7.15 am	66	70	8	0	113	427.5
7.15 – 7.30 am	70	82	5	1	120.5	548
7.30 – 7.45 am	80	87	7	2	138	686
7.45 – 8.00 am	86	95	4	1	141.5	827.5
8.00 – 8.15 am	95	110	5	0	157.5	985
8.15 – 8.30 am	99	114	10	2	175	1160
8.30 – 8.45 am	85	99	7	2	149	1309
8.45 – 9.00 am	90	89	5	0	142	1451
9.00 – 9.15 am	75	89	7	1	132	1583
9.15 – 9.30 am	82	72	7	1	130.5	1713.5
9.30 – 9.45 am	79	80	6	0	138	1841.5
9.45 – 10.00 am	59	75	6	0	105.5	1941
10.00 – 10.15	70	78	6	0	118	1947
10.15 – 10.30	71	66	4	0	110	2065
10.30 – 10.45	76	93	6	1	133.5	2175
10.45 – 11.00	73	62	2	0	107	2308.5
11.00 – 11.15	61	75	2	0	101.5	2415.5
11.15 – 11.30	65	84	5	0	114.5	2517
11.30 – 11.45	66	63	6	2	110.5	2631.5
11.45 – 12.00	71	65	4	0	199.5	2742
12.00 – 12.15	58	85	5	0	108	2851.5
12.15 – 12.30	54	73	12	0	108.5	2959.5
12.30 – 12.45	79	72	5	1	124.5	3068
12.45 – 1.00pm	52	52	3	3	88.5	3192.5
1.00 – 1.15pm	73	91	3	2	127	3281
1.15 – 1.30pm	56	53	1	0	84	2408
1.30 – 1.45pm	73	70	4	1	106	3492
1.45 – 2.00pm	64	50	5	0	96.5	3608
2.00 – 2.15pm	62	57	5	0	98	3704.5
2.15 – 2.30pm	77	70	3	0	116.5	3802.5
2.30 – 2.45pm	94	51	3	0	124	4043
2.45 – 3.00pm	57	58	0	1	88	4131
3.00 – 3.15pm	59	60	9	0	102.5	4233.5
3.15 – 3.30pm	71	61	4	0	107.5	4341
3.30 – 3.45pm	63	53	3	2	98	4439
3.45 – 4.00pm	74	57	6	1	113.5	4552.5
4.00 – 4.15pm	59	67	9	0	106	4658.5
4.15 – 4.30pm	75	87	7	0	129	4787.5
4.30 – 4.45pm	76	49	8	0	121.5	4909
4.45 – 5.00pm	39	92	0	0	63.5	4972
5.00 – 5.15pm	92	71	11	1	156.5	5129
5.15 – 5.30pm	75	78	8	0	122.5	5251.5
5.30 – 5.45pm	78	54	5	1	126.5	5378
5.45 – 6.00pm	73	72	5	2	111.5	5489.5
6.00 – 6.15pm	75	76	8	0	123	5612.5
6.15 – 6.30pm	74	76	7	0	122.5	5735
6.30 – 6.45pm	78	80	13	1	139.5	5874.5
6.45 – 7.00pm	63	77	5	0	109	5983.5

TABLE 2A RAW COUNT OF VEHICLE MOVEMENT ON ROUTE 'A' ON *TUESDAY (JUNE 29, 2004) TOWARDS THE ROUNDABOUT*

Veh. Type Time	Cars	Motor-cycles	Buses	2/3 Axle Trucks	Quarterly hour	Cummula-tive
6.00 - 6.15 am	28	60	1	0	59.5	59.5
6.15 - 6.30 am	32	75	4	2	79.5	139
6.30 - 6.45 am	32	72	5	2	79.5	218.5
6.45 – 7.00 am	45	92	2	1	96	314.5
7.00 - 7.15 am	83	90	13	2	151.5	466
7.15 – 7.30 am	95	105	4	1	155.5	621.5
7.30 - 7.45 am	100	87	11	2	164	785.5
7.45 - 8.00 am	91	90	7	2	150.5	936
8.00 – 8.15 am	94	107	8	1	161.5	1097.5
8.15 – 8.30 am	109	108	8	0	175	1272.5
8.30 - 8.45 am	98	95	3	0	150	1422.5
8.45 - 9.00 am	95	105	4	1	155.5	1578
9.00 – 9.15 am	76	84	6	0	127	1705
9.15 – 9.30 am	65	74	4	0	108	1813
9.30 – 9.45 am	90	86	5	0	140.5	1953.5
9.45 -10.00 am	76	75	7	0	124	2077.5
10.00 – 10.15	60	75	5	1	107	2184.5
10.15 - 10.30	76	77	5	0	122	2306.5
10.30 – 10.45	79	80	5	0	126.5	2433
10.45 – 11.00	67	82	7	1	120.5	2553.5
11.00 – 11.15	71	86	5	1	123.5	2677
11.15 – 11.30	56	52	3	1	88.5	2765.5
11.30 – 11.45	77	83	8	0	130.5	2896
11.45 – 12.00	62	67	3	1	102	2998
12.00 – 12.15	85	84	7	1	139.5	3137.5
12.15 – 12.30	61	84	4	1	111	3248.5
12.30 – 12.45	99	89	8	0	155.5	3404
12.45 – 1.00pm	78	68	3	1	118.5	3522.5
1.00 – 1.15pm	63	62	6	0	103	3625.5
1.15 – 1.30pm	69	86	7	0	122.5	3748
1.30 - 1.45pm	74	78	4	1	121	3869
1.45 - 2.00pm	74	55	8	1	115.5	3984.5
2.00 - 2.15pm	67	81	6	0	166.5	4101
2.15 – 2.30pm	86	62	4	0	123	4224
2.30 – 2.45pm	100	60	6	1	141	4365
2.45 – 3.00pm	62	65	5	0	102	4467
3.00 – 3.15pm	70	61	5	1	110	4577
3.15 – 3.30pm	77	63	3	0	113	4690
3.30 – 3.45pm	82	81	5	3	136	4826
3.45 – 4.00pm	70	70	7	1	117.5	4943.5
4.00 – 4.15pm	78	68	6	2	125	5068.5
4.15 - 4.30pm	64	58	5	2	104.5	5173
4.30 - 4.45pm	67	58	8	1	110	5283
4.45 - 5.00pm	73	76	2	0	114	5397
5.00 – 5.15pm	76	72	8	0	124	5521
5.15 – 5.30pm	85	76	5	0	130.5	5651.5
5.30 – 5.45pm	59	75	8	1	110.5	5762
5.45 – 6.00pm	60	72	10	1	113	5875
6.00 – 6.15pm	70	56	4	0	104	5979
6.15 – 6.30pm	66	74	6	1	114	6093
6.30 – 6.45pm	65	83	4	0	112.5	6205.5
6.45 – 7.00pm	71	76	6	0	118	6323.5

TABLE 3A RAW COUNT OF VEHICLE MOVEMENT ON ROUTE 'A' ON WEDNESDAY (JUNE 30, 2004) TOWARDS THE ROUNDABOUT

Veh. Type Time	Cars	Motor-cycles	Buses	2/3 Axle Trucks	Quarterly hour	Cummula-tive
6.00 - 6.15 am	28	49	2	2	59.5	59.5
6.15 - 6.30 am	45	60	3	0	79.5	139
6.30 - 6.45 am	40	63	4	1	79.5	218.5
6.45 – 7.00 am	56	60	1	0	87.5	306
7.00 - 7.15 am	59	60	1	0	90.5	396.5
7.15 – 7.30 am	81	74	8	1	132	528.5
7.30 - 7.45 am	75	65	8	2	123.5	652
7.45 - 8.00 am	105	94	5	2	163.5	815.5
8.00 – 8.15 am	92	96	7	1	152.5	968
8.15 – 8.30 am	113	110	6	0	177	1145
8.30 - 8.45 am	105	97	8	2	169.5	1314.5
8.45 - 9.00 am	79	74	3	2	124.5	1439
9.00 – 9.15 am	82	73	6	0	127.5	1566.5
9.15 – 9.30 am	77	78	3	2	124.5	1691
9.30 – 9.45 am	71	84	3	2	121.5	1812.5
9.45 -10.00 am	80	90	2	2	132	1944.5
10.00 – 10.15	68	85	7	0	121	2065.5
10.15 - 10.30	71	69	4	1	113.5	2179
10.30 – 10.45	78	68	5	1	121.5	2300.5
10.45 – 11.00	88	70	6	1	134	2434.5
11.00 – 11.15	66	52	7	2	106.5	2541
11.15 – 11.30	73	61	4	2	113.5	2654.5
11.30 – 11.45	83	62	3	0	118.5	2773
11.45 – 12.00	71	65	1	1	107	2880
12.00 – 12.15	75	72	2	2	118	2998
12.15 – 12.30	69	81	7	2	124	3122
12.30 – 12.45	64	64	3	0	100.5	3222.5
12.45 – 1.00pm	71	54	3	3	108.5	3331
1.00 – 1.15pm	72	65	2	0	107.5	3438.5
1.15 – 1.30pm	76	70	5	2	122.5	3561
1.30 - 1.45pm	72	66	3	1	111.5	3672.5
1.45 - 2.00pm	82	71	4	1	125.5	3798
2.00 - 2.15pm	81	81	8	1	135.5	3933.5
2.15 – 2.30pm	100	69	1	2	140	4073.5
2.30 – 2.45pm	90	62	1	2	126.5	4200
2.45 – 3.00pm	69	65	5	2	113	4313
3.00 – 3.15pm	72	69	8	1	120.5	4433.5
3.15 – 3.30pm	87	75	6	3	139.5	4573
3.30 – 3.45pm	68	66	7	3	117.5	4690.5
3.45 – 4.00pm	76	74	4	2	123	4813.5
4.00 – 4.15pm	69	67	5	0	110	4923.5
4.15 - 4.30pm	65	66	12	0	116	5039.5
4.30 - 4.45pm	65	80	9	1	120.5	5160
4.45 - 5.00pm	72	62	9	0	116.5	5276.5
5.00 – 5.15pm	92	74	7	0	139.5	5416
5.15 – 5.30pm	84	72	6	2	133	5549
5.30 – 5.45pm	74	70	5	1	118.5	5667.5
5.45 – 6.00pm	64	86	5	2	118.5	5786
6.00 – 6.15pm	78	79	4	1	125.5	5911.5
6.15 – 6.30pm	86	70	7	1	133.5	6045
6.30 – 6.45pm	77	89	6	1	132.5	6177.5
6.45 – 7.00pm	71	81	4	0	117.5	6295

TABLE 4A RAW COUNT OF VEHICLE MOVEMENT ON ROUTE 'A' ON THURSDAY (JULY 1, 2004) TOWARDS THE ROUNDABOUT

Veh. Type Time	Cars	Motor-cycles	Buses	2/3 Axle Trucks	Quarterly hour	Cummula-tive
6.00 - 6.15 am	25	49	4	2	59.5	59.5
6.15 - 6.30 am	40	70	3	0	79.5	135
6.30 - 6.45 am	38	63	4	2	79.5	218.5
6.45 – 7.00 am	56	71	3	0	96	314.5
7.00 - 7.15 am	50	72	16	0	110	424.5
7.15 – 7.30 am	52	120	2	0	115	539.5
7.30 - 7.45 am	52	126	10	0	130	669.5
7.45 - 8.00 am	70	132	4	0	142	811.5
8.00 – 8.15 am	67	135	71	0	160	971.5
8.15 – 8.30 am	62	142	22	0	166	1137.5
8.30 - 8.45 am	62	140	9	0	145.5	1283
8.45 - 9.00 am	55	135	13	1	144	1427
9.00 – 9.15 am	55	141	3	0	130	1557
9.15 – 9.30 am	50	130	18	4	150	1707
9.30 – 9.45 am	48	123	8	2	125.5	1832.5
9.45 -10.00 am	50	100	0	0	100	1932.5
10.00 – 10.15	48	98	9	1	112.5	2045
10.15 - 10.30	51	96	6	1	110	2155
10.30 – 10.45	60	97	11	5	135	2290
10.45 – 11.00	45	108	4	0	105	2395
11.00 – 11.15	42	86	6	3	100	2495
11.15 – 11.30	58	105	4	2	120.5	2615.5
11.30 – 11.45	59	90	4	0	110	2725.5
11.45 – 12.00	50	89	7	0	105	2830.5
12.00 – 12.15	50	110	0	0	105	2935.5
12.15 – 12.30	60	120	0	0	120	3055.5
12.30 – 12.45	45	100	2	1	100	3155.5
12.45 – 1.00pm	40	98	3	0	93.5	3249
1.00 – 1.15pm	60	97	15	2	135	3384
1.15 – 1.30pm	32	96	2	1	85	3469
1.30 - 1.45pm	46	97	9	1	110	3579
1.45 - 2.00pm	40	100	2	1	95	3673
2.00 - 2.15pm	53	94	2	0	103	3898
2.15 – 2.30pm	62	94	4	3	121	4023
2.30 – 2.45pm	60	82	12	3	125	4111
2.45 – 3.00pm	42	46	2	0	88	4211
3.00 – 3.15pm	47	90	4	1	100	4313.5
3.15 – 3.30pm	50	102	1	0	102.5	4412.5
3.30 – 3.45pm	42	114	0	0	99	4523.5
3.45 – 4.00pm	50	105	3	2	111	4623.5
4.00 – 4.15pm	47	106	0	0	100	4754
4.15 - 4.30pm	67	103	4	3	130.5	4877
4.30 - 4.45pm	67	112	0	0	123	4942
4.45 - 5.00pm	30	70	0	0	65	5102
5.00 – 5.15pm	90	82	14	4	160	5232
5.15 – 5.30pm	80	85	5	0	130	5262
5.30 – 5.45pm	82	87	3	0	130	5362
5.45 – 6.00pm	70	80	0	0	110	5472
6.00 – 6.15pm	65	96	0	1	115	5587
6.15 – 6.30pm	63	98	6	1	123	5710
6.30 – 6.45pm	85	98	4	0	140	5850
6.45 – 7.00pm	60	100	0	0	110	5960

TABLE 5A RAW COUNT OF VEHICLE MOVEMENT ON ROUTE 'A' ON FRIDAY (JULY 2, 2004) TOWARDS THE ROUNDABOUT

Veh. Type Time	Cars	Motor-cycles	Buses	2/3 Axle Trucks	Quarterly hour	Cummula-tive
6.00 - 6.15 am	31	44	3	1	59.5	59.5
6.15 - 6.30 am	43	61	4	0	79.5	139
6.30 - 6.45 am	40	56	5	2	79.5	218.5
6.45 – 7.00 am	61	61	3	0	96	314.5
7.00 - 7.15 am	40	72	6	2	89	403.5
7.15 – 7.30 am	62	95	5	4	125	528.5
7.30 - 7.45 am	60	112	3	0	120.5	649
7.45 - 8.00 am	82	100	16	2	160	809
8.00 – 8.15 am	75	110	8	4	150	959
8.15 – 8.30 am	84	130	7	4	167.5	1126.5
8.30 - 8.45 am	80	132	4	4	160	1286.5
8.45 - 9.00 am	63	112	1	0	120.5	1407
9.00 – 9.15 am	65	115	5	0	130	1537
9.15 – 9.30 am	61	110	3	1	122.5	1659.5
9.30 – 9.45 am	60	117	1	0	120	1779.5
9.45 -10.00 am	66	115	6	0	132.5	1912
10.00 – 10.15	60	120	0	0	120	2032
10.15 - 10.30	55	95	4	1	110.5	2142.5
10.30 – 10.45	60	102	6	0	120	2262.5
10.45 – 11.00	68	126	2	0	134	2396.5
11.00 – 11.15	53	100	1	0	104.5	2501
11.15 – 11.30	56	112	0	0	112	2613
11.30 – 11.45	60	100	4	2	120	2733
11.45 – 12.00	53	102	0	1	106	2839
12.00 – 12.15	54	112	2	2	117	2956
12.15 – 12.30	54	117	7	1	125	3081
12.30 – 12.45	61	113	2	0	120.5	3201.5
12.45 – 1.00pm	55	100	2	1	110	3311.5
1.00 – 1.15pm	53	105	0	0	105.5	3417
1.15 – 1.30pm	60	114	2	0	120	3537
1.30 - 1.45pm	55	104	2	0	110	3647
1.45 - 2.00pm	61	120	1	0	122.5	3769.5
2.00 - 2.15pm	67	120	2	1	132	3901.5
2.15 – 2.30pm	62	136	6	3	145	4046.5
2.30 – 2.45pm	60	105	5	0	120	4166.5
2.45 – 3.00pm	60	100	0	0	110	4276.5
3.00 – 3.15pm	66	102	5	3	130.5	4407
3.15 – 3.30pm	70	132	0	2	140	4547
3.30 – 3.45pm	60	101	0	1	112.5	4659.5
3.45 – 4.00pm	60	110	2	1	120	4779.5
4.00 – 4.15pm	55	107	1	0	110	4889.5
4.15 - 4.30pm	56	100	4	0	112	5001.5
4.30 - 4.45pm	60	109	1	2	120	5121.5
4.45 - 5.00pm	55	100	2	1	110	5231.3
5.00 – 5.15pm	70	127	2	2	140.5	5372
5.15 – 5.30pm	65	115	5	0	130	5502
5.30 – 5.45pm	55	105	5	0	115	5617
5.45 – 6.00pm	55	105	4	1	115.5	5732.5
6.00 – 6.15pm	60	110	2	1	120	5852.5
6.15 – 6.30pm	65	111	4	2	130.5	5983
6.30 – 6.45pm	68	120	2	2	135	6118
6.45 – 7.00pm	60	115	2	0	120.5	6238.5

APPENDIX I

TABLE 6A RAW COUNT OF VEHICLE MOVEMENT ON ROUTE B ON MONDAY (JUNE 28, 2004) TOWARDS THE ROUNDABOUT

Veh. Type Time	Cars	Motor-cycles	Buses	2/3 Axle Trucks	Quarterly Hour	Commula-tive
6.00-6.15am	30	55	-	1	59.5	59.5
6.15-6.30am	42	75	-	-	79.5	139.0
6.30-6.45am	38	70	3	1	79.5	218.5
6.45-7.00am	42	86	6	1	96	314.5
7.00-7.15am	52	125	7	-	125	439.5
7.15-7.30am	71	130	13	3	161.5	601.0
7.30-7.45am	60	133	15	-	149	750.0
7.45-8.00am	54	145	7	-	137	887.0
8.00-8.15am	57	113	6	1	124.5	1011.5
8.15-8.30am	50	131	6	-	124.5	1136.0
8.30-8.45am	60	138	11	-	124.5	1281.5
8.45-9.00am	64	143	9	-	149	1430.5
9.00-9.15am	59	118	5	1	124	1554.5
9.15-9.30am	45	111	6	2	117	1671.5
9.30-9.45am	46	112	7	1	114.5	1786.0
9.45-10.00	55	104	4	-	113.0	1899.0
10.00-10.15	51	125	6	-	122.5	2021.5
10.15-10.30	50	112	3	-	110.5	2132.0
10.30-10.45	51	136	1	2	124.5	2256.5
10.45-11.00	60	109	6	2	127.5	2384.0
11.00-11.15	49	105	6	-	110.5	2494.5
11.15-11.30	58	90	5	1	112.5	2607.0
11.30-11.45	61	91	5	-	114.0	2721.0
11.45-12.00	52	86	7	-	105.5	2826.5
12.00-12.15	39	104	5	2	102.5	2929.0
12.15-12.30	40	90	3	1	91.5	3020.5
12.30-12.45	38	85	5	1	90.0	3110.5
12.45-1.00	47	99	5	2	108.0	3218.5
1.00-1.15pm	47	85	4	1	97.5	3318.0
1.15-1.30pm	65	104	7	1	129.5	3445.5
1.30-1.45pm	47	100	5	-	104.5	3550.0
1.45-2.00pm	58	98	10	1	124	3674.0
2.00-2.15pm	47	79	6	-	95.5	3769.5
2.15-2.30pm	43	84	8	-	97.0	3866.5
2.30-2.45pm	59	85	4	1	109.5	3976.0
2.45-3.00pm	34	79	5	1	83	4059.0
3.00-3.15pm	53	103	7	2	119	4178.0
3.15-3.30pm	20	44	6	-	51	4229.0
3.30-3.45pm	45	89	6	-	98.5	4327.5
3.45-4.00pm	38	86	3	-	85.5	4413.0
4.00-4.15pm	54	87	13	-	119.0	4532.0
4.15-4.30pm	66	106	8	-	131.0	4663.0
4.30-4.45pm	44	87	4	1	95.5	4758.5
4.45-5.00pm	63	121	6	1	134.5	4893.0
5.00-5.15pm	43	112	6	-	108.0	5001.0
5.15-5.30pm	65	106	13	-	137.5	5138.5
5.30-5.45pm	42	110	4	3	109.0	5247.5
5.45-6.00pm	35	80	1	1	78.5	5326.0
6.00-6.15pm	53	120	1	-	113.5	5439.5
6.15-6.30pm	37	107	6	-	99.5	5539.0
6.30-6.45pm	42	131	1	1	111.0	5650.0
6.45-7.00pm	42	107	6	-	104.5	5754.5

TABLE 7A RAW COUNT OF VEHICLE MOVEMENT ON ROUTE B ON TUESDAY (JULY 29, 2004) TOWARDS THE ROUNDABOUT

Veh. Type Time	Cars	Motor-cycles	Buses	2/3 Axle Trucks	Quarterly Hour	Commula-tive
6.00-6.15am	30	59	0	0	59.5	59.5
6.15-6.30am	42	72	1	0	79.5	139
6.30-6.45am	40	75	0	1	79.5	218.5
6.45-7.00am	45	82	4	2	96	218.5
7.00-7.15am	68	107	4	1	129.5	314.5
7.15-7.30am	54	129	5	0	126	444
7.30-7.45am	70	150	3	0	149.5	570
7.45-8.00am	57	120	1	0	118.5	719.
8.15-8.15am	48	147	6	0	130.5	838
8.15-8.30am	54	155	3	0	136	968.5
8.30-8.45am	53	138	5	2	133.5	1104.5
8.45-9.00am	53	127	2	0	119.5	1238
9.00-9.15am	52	124	2	1	119	1476.5
9.30-9.30am	45	97	4	0	99.5	1576
9.30-9.45am	47	103	5	1	108	1684
9.45-10.00a	53	132	4	2	129	1813
10.00-10.15	54	100	5	0	111.5	1924.5
10.15-10.30	45	110	6	2	113	2037.5
10.30-10.45	41	103	0	0	92.5	2130
10.45-11.00	35	84	7	0	87.5	2217.5
11.00-11.15	42	88	5	0	93.5	2311
11.15-11.30	41	76	5	1	88.5	2399.5
11.30-11.45	52	91	3	0	102	2501.5
11.45-12.00	35	88	6	0	88	2589.5
12.00-12.15	42	104	2	0	97	2686.5
12.15-12.30	46	75	4	1	91.5	2778
12.30-12.45	33	96	2	0	84	2862
12.45-1.00p	40	90	5	1	94.5	2956.5
1.00-1.15pm	30	79	5	0	77	3033.5
1.15-1.30pm	53	77	4	0	97.5	3131
1.30-1.45pm	48	102	5	0	106.5	3237.5
1.45-2.00pm	47	107	2	0	103.5	3341
2.00-2.15pm	46	81	4	1	94.5	3435.5
2.15-2.30pm	33	94	7	0	90.5	3526.5
2.30-2.45pm	51	98	4	1	108	3634
2.45-3.00pm	53	103	0	0	104.5	3538.5
3.00-3.15pm	42	86	2	0	88	3826.5
3.15-3.30pm	42	103	7	0	104	3930.5
3.30-3.45pm	50	106	7	0	113.5	4044
3.45-4.00pm	40	95	4	2	97.5	4141.5
4.00-4.15pm	23	79	4	0	68.5	4210
4.15-4.30pm	37	95	3	1	91	4301
4.30-4.45pm	42	73	3	1	85	4386
4.45-5.00pm	54	87	4	0	103.5	4489.5
5.00-5.15pm	51	90	9	1	111.5	4601
5.15-5.30pm	42	86	6	0	94	4695
5.30-5.45pm	57	110	2	0	115	4810
5.45-6.00pm	46	115	2	1	108.5	4918.5
6.00-6.15pm	50	111	4	1	113.5	5032
6.15-6.30pm	46	92	8	0	104	5136
6.30-6.45pm	41	127	0	0	104.5	5240.5
6.45-7.00pm	53	130	6	3	133	5373.5

TABLE 8A RAW COUNT OF VEHICLE MOVEMENT ON ROUTE B ON WEDNESDAY (JULY 2, 2004) TOWARDS THE ROUNDABOUT

Veh. Type Time	Cars	Motor-cycles	Buses	2/3 Axle Trucks	Quarterly Hour	Commula-tive
6.00-6.15am	32	52	1	0	59.5	59.5
6.15-6.30am	40	3	2	0	79.5	139
6.30-6.45am	38	73	3	0	79	218
6.45-7.00am	43	86	3	0	90.5	308.5
7.00-7.15am	49	90	1	1	97.5	406
7.15-7.30am	56	116	5	0	121.5	527.5
7.30-7.45am	50	90	4	1	103	630.5
7.45-8.00am	52	120	4	0	118	748.5
8.15-8.15am	62	125	4	2	134.5	883
8.15-8.30am	54	119	1	3	121	1004
8.30-8.45am	53	160	4	1	141	1145
8.45-9.00am	52	147	5	0	133	1278
9.00-9.15am	51	121	2	1	116.5	1394.5
9.30-9.30am	57	130	5	1	131.5	1526
9.30-9.45am	59	134	4	0	132	1658
9.45-10.00a	51	119	4	0	116.5	1774.5
10.00-10.15	45	130	4	1	118	1892.5
10.15-10.30	52	131	1	2	123	2015.5
10.30-10.45	42	135	4	0	115.5	2131
10.45-11.00	45	115	2	0	105.5	226.5
11.00-11.15	62	104	5	0	121.5	2358
11.15-11.30	57	85	0	1	101.5	2459.5
11.30-11.45	44	108	9	0	111.5	2571
11.45-12.00	46	99	5	0	103	2674
12.00-12.15	48	107	8	2	117.5	2791.5
12.15-12.30	40	97	5	1	98	2889.5
12.30-12.45	47	105	0	0	99.5	2989
12.45-1.00p	46	99	3	2	104	3093
1.00-1.15pm	56	98	3	0	109.5	3202.5
1.15-1.30pm	55	90	4	0	106	3308.5
1.30-1.45pm	58	95	7	0	116	3424.5
1.45-2.00pm	42	87	2	1	90.5	3515
2.00-2.15pm	47	88	5	1	100.5	3615.5
2.15-2.30pm	51	93	7	0	108	3723.5
2.30-2.45pm	51	85	5	1	103	3826.5
2.45-3.00pm	50	76	5	0	95.5	3922
3.00-3.15pm	50	135	9	0	131	4053
3.15-3.30pm	53	120	7	0	123.5	4153
3.30-3.45pm	43	114	11	1	118.5	4176.5
3.45-4.00pm	56	100	2	0	109	4295
4.00-4.15pm	45	107	5	1	108	4404
4.15-4.30pm	55	79	5	0	102	4614
4.30-4.45pm	40	115	3	1	104	4718
4.45-5.00pm	43	98	6	1	103	4821
5.00-5.15pm	68	127	7	0	142	4821
5.15-5.30pm	55	109	6	2	122.5	4963
5.30-5.45pm	57	123	4	0	124.5	5085.5
5.45-6.00pm	50	85	4	1	100.5	5210.5
6.00-6.15pm	66	115	0	0	123.5	5434
6.15-6.30pm	63	108	5	2	128.5	5562.5
6.30-6.45pm	52	113	7	1	121	5683.5
6.45-7.00pm	78	115	10	2	154.5	5838

TABLE 9A RAW COUNT OF VEHICLE MOVEMENT ON ROUTE B ON THURSDAY (JULY 2, 2004) TOWARDS THE ROUNDABOUT

Veh. Type Time	Cars	Motor-cycles	Buses	2/3 Axle Trucks	Quarterly Hour	Commula-tive
6.00-6.15am	25	51	6	0	59.5	59.5
6.15-6.30am	42	72	1	0	79.5	139
6.30-6.45am	38	77	2	0	79.5	218.5
6.45-7.00am	42	90	6	0	96	314.5
7.00-7.15am	67	130	0	2	136	450.5
7.15-7.30am	55	100	5	0	112.5	563
7.30-7.45am	50	92	0	0	96	659
7.45-8.00am	92	170	6	1	188	847
8.15-8.15am	52	110	2	2	114	961
8.15-8.30am	70	132	0	2	140	1101
8.30-8.45am	75	144	2	0	150	1251
8.45-9.00am	76	139	3	0	150	1401
9.00-9.15am	77	145	5	0	157	1558
9.30-9.30am	74	146	2	0	150	1708
9.30-9.45am	58	98	0	0	107	1815
9.45-10.00a	59	111	1	0	116	1931
10.00-10.15	55	101	3	0	110	2041
10.15-10.30	56	105	5	0	116	2157
10.30-10.45	62	110	6	1	128	2285
10.45-11.00	48	90	2	0	96	2381
11.00-11.15	57	100	2	2	114	2495
11.15-11.30	62	116	2	0	123	2618
11.30-11.45	54	100	2	0	107	2725
11.45-12.00	56	99	0	0	105.5	2830.5
12.00-12.15	54	97	2	0	105.5	2936
12.15-12.30	60	105	3	2	121	3057
12.30-12.45	50	97	1	0	100	3157
12.45-1.00p	42	80	0	0	82	3239
1.00-1.15pm	67	125	3	0	134	3373
1.15-1.30pm	34	66	2	0	70	3443
1.30-1.45pm	60	100	4	2	120	3563
1.45-2.00pm	40	74	2	0	80	3643
2.00-2.15pm	72	131	3	0	142	3785
2.15-2.30pm	34	45	1	0	58	3843
2.30-2.45pm	75	144	2	0	150	3993
2.45-3.00pm	60	103	1	0	113	4106
3.00-3.15pm	49	92	0	0	95	4201
3.15-3.30pm	50	89	2	0	97.5	4298.5
3.30-3.45pm	48	89	1	1	96	4394.5
3.45-4.00pm	58	100	2	1	113	4507.5
4.00-4.15pm	50	91	2	0	98.5	4606
4.15-4.30pm	66	112	6	1	133	47399
4.30-4.45pm	53	92	4	0	105	4844
4.45-5.00pm	36	65	1	0	70	4914
5.00-5.15pm	70	134	2	0	140	5054
5.15-5.30pm	80	120	8	3	158	5212
5.30-5.45pm	66	115	3	2	132	5344
5.45-6.00pm	62	105	5	1	124	5468
6.00-6.15pm	48	82	2	2	96	5564
6.15-6.30pm	70	114	6	3	142	5706
6.30-6.45pm	50	87	3	1	100	5806
6.45-7.00pm	56	90	6	1	112	5918

TABLE 10A RAW COUNT OF VEHICLE MOVEMENT ON ROUTE B ON FRIDAY (JULY 2, 2004) TOWARDS THE ROUNDABOUT

Veh. Type Time	Cars	Motor-cycles	Buses	2/3 Axle Trucks	Quarterly Hour	Commula-tive
6.00-6.15am	22	57	6	0	59.5	59.5
6.15-6.30am	38	80	1	0	79.5	139
6.30-6.45am	45	69	0	0	79.5	218.5
6.45-7.00am	46	90	2	1	96	314.5
7.00-7.15am	53	70	3	0	92.5	407
7.15-7.30am	57	105	5	0	117	524
7.30-7.45am	57	116	4	0	121	645
7.45-8.00am	70	135	5	3	151	796
8.15-8.15am	57	135	6	2	137.5	933.5
8.15-8.30am	62	155	1	0	141	1074.5
8.30-8.45am	63	135	1	0	132	1206.5
8.45-9.00am	62	130	3	2	135.5	1342
9.00-9.15am	55	140	5	1	134.5	1476.5
9.30-9.30am	55	127	4	1	126.5	1603
9.30-9.45am	47	94	3	0	98.5	1701.5
9.45-10.00a	50	96	5	1	107.5	1809
10.00-10.15	44	107	5	2	109	1918
10.15-10.30	51	130	3	2	124.5	2042.5
10.30-10.45	65	101	6	1	126.5	2169
10.45-11.00	50	88	2	0	97	2266
11.00-11.15	42	110	0	1	99	2365
11.15-11.30	47	101	4	1	105.5	2470.5
11.30-11.45	57	101	2	0	110.5	2581
11.45-12.00	42	85	1	2	90	2671
12.00-12.15	57	97	2	1	110.5	2781.5
12.15-12.30	55	116	5	1	122.5	2904
12.30-12.45	45	93	4	0	97.5	3001.5
12.45-1.00p	27	45	2	0	52.5	3054
1.00-1.15pm	50	84	2	2	99	3153
1.15-1.30pm	26	76	1	1	67.5	3220.5
1.30-1.45pm	58	80	8	0	110	3330.5
1.45-2.00pm	50	104	3	0	106.5	3437
2.00-2.15pm	35	95	3	0	87	3524
2.15-2.30pm	63	107	2	1	121.5	3645.5
2.30-2.45pm	50	110	8	0	117	3762.5
2.45-3.00pm	54	94	2	0	104	3866.5
3.00-3.15pm	41	125	4	0	109.5	3976
3.15-3.30pm	50	92	4	0	102	4078
3.30-3.45pm	46	95	4	0	99.5	4177.5
3.45-4.00pm	59	110	7	0	124.5	4302
4.00-4.15pm	54	85	5	0	104	4406
4.15-4.30pm	55	105	2	1	112.5	4518.5
4.30-4.45pm	64	95	2	0	114.5	4633
4.45-5.00pm	53	70	7	0	98.5	4731.5
5.00-5.15pm	66	115	3	2	132	4863.5
5.15-5.30pm	52	97	2	0	103.5	4967
5.30-5.45pm	79	105	6	0	140.5	5107.5
5.45-6.00pm	50	120	7	1	122.5	5230
6.00-6.15pm	70	135	10	2	156.5	5386.5
6.15-6.30pm	37	98	6	3	101	5487.5
6.30-6.45pm	73	115	8	2	146.5	5634
6.45-7.00pm	87	115	14	3	171.5	5805.5

TABLE 11A RAW COUNT OF VEHICLE MOVEMENT ON ROUTE 'C' ON MONDAY (JULY 28, 2004) TOWARDS THE ROUNDABOUT

Veh. Type Time	Cars	Motor-cycles	Buses	2/3 Axle Trucks	Quarterly hour	Cummula-tive
6.00 - 6.15 am	19	36	0	0	37	37
6.15 - 6.30 am	40	80	0	1	82	119
6.30 - 6.45 am	43	89	1	1	91	210
6.45 – 7.00 am	53	101	0	0	103.5	313.5
7.00 - 7.15 am	80	105	9	3	152	465.5
7.15 – 7.30 am	90	122	16	3	181	646.5
7.30 - 7.45 am	64	159	8	0	155.5	802
7.45 - 8.00 am	113	140	6	3	198	1000
8.00 – 8.15 am	102	160	18	4	217	1217
8.15 – 8.30 am	108	155	0	0	185.5	1402.5
8.30 - 8.45 am	83	135	9	1	166	1568.5
8.45 - 9.00 am	86	127	10	2	168.5	1737
9.00 – 9.15 am	108	127	5	3	185	1922
9.15 – 9.30 am	104	127	5	0	175	2097
9.30 – 9.45 am	105	145	9	1	193	2290
9.45 -10.00 am	85	117	10	1	160.5	2450.5
10.00 – 10.15	95	124	8	5	179	2629.5
10.15 - 10.30	102	136	3	5	184.5	2814
10.30 – 10.45	102	102	7	3	169.5	2983.5
10.45 – 11.00	100	124	10	3	183	3166.5
11.00 – 11.15	95	118	3	4	166.5	3333
11.15 – 11.30	96	111	4	2	161.5	3494.5
11.30 – 11.45	95	121	6	1	166.5.	3661
11.45 – 12.00	82	102	2	3	142	3803
12.00 – 12.15	85	125	8	2	163.5	3966.5
12.15 – 12.30	90	102	6	7	164	4130.5
12.30 – 12.45	91	109	5	4	161	4291.5
12.45 – 1.00pm	76	109	3	2	139	4430.5
1.00 – 1.15pm	88	106	12	1	161	4591.5
1.15 – 1.30pm	79	95	3	5	141	4732.5
1.30 - 1.45pm	83	126	10	1	163	4895.5
1.45 - 2.00pm	86	95	8	2	149.5	5045
2.00 - 2.15pm	71	100	7	6	143.5	5188.5
2.15 – 2.30pm	95	102	13	2	165	5353.5
2.30 – 2.45pm	82	88	8	3	144	5497.5
2.45 – 3.00pm	79	79	6	6	139.5	5637
3.00 – 3.15pm	103	107	6	5	175.5	5812.5
3.15 – 3.30pm	87	88	7	4	149.5	5962
3.30 – 3.45pm	88	100	5	1	147.5	6109.5
3.45 – 4.00pm	95	104	10	2	166	6275.5
4.00 – 4.15pm	85	95	13	3	158	6433.5
4.15 - 4.30pm	80	110	6	3	150	6583.5
4.30 - 4.45pm	74	95	10	1	138.5	6722
4.45 - 5.00pm	60	90	4	1	113	6835
5.00 – 5.15pm	69	76	10	0	122	6957
5.15 – 5.30pm	61	105	4	2	123.5	7080.5
5.30 – 5.45pm	76	90	12	6	151	7231.5
5.45 – 6.00pm	63	112	7	1	131.5	7363
6.00 – 6.15pm	58	82	10	4	1.22	7485
6.15 – 6.30pm	80	92	11	3	148.5	7633.5
6.30 – 6.45pm	73	131	16	5	172.5	7806
6.45 – 7.00pm	62	103	12	2	135.5	7941.5

TABLE 12A RAW COUNT OF VEHICLE MOVEMENT ON ROUTE 'C' ON TUESDAY (JULY 2, 2004) TOWARDS THE ROUNDABOUT

Veh. Type Time	Cars	Motor-cycles	Buses	2/3 Axle Trucks	Quarterly hour	Cummula-tive
6.00 - 6.15 am	16	35	1	1	37	37
6.15 - 6.30 am	40	80	0	1	82	119
6.30 - 6.45 am	45	89	1	0	91	210
6.45 – 7.00 am	52	112	1	2	113.5	323.5
7.00 - 7.15 am	79	86	4	1	130	453.5
7.15 – 7.30 am	75	143	5	1	156	609.5
7.30 - 7.45 am	66	139	3	2	144	753.5
7.45 - 8.00 am	95	150	4	3	182	935.5
8.00 – 8.15 am	89	136	4	2	167	1102.5
8.15 – 8.30 am	80	144	5	5	169.5	1272
8.30 - 8.45 am	8 1	126	14	2	169	1441
8.45 - 9.00 am	76	118	2	1	140	1581
9.00 – 9.15 am	87	113	2	5	156.5	1737.5
9.15 – 9.30 am	82	100	3	3	142.5	1880
9.30 – 9.45 am	82	134	7	3	165.5	2045.5
9.45 -10.00 am	97	97	6	3	160.5	2206
10.00 – 10.15	78	96	5	2	137.5	2343.5
10.15 - 10.30	79	94	5	0	133.5	2477
10.30 – 10.45	68	77	4	5	122.5	2599.5
10.45 – 11.00	74	77	4	6	130.5	2730
11.00 – 11.15	70	117	4	7	148.5	2878.5
11.15 – 11.30	64	107	6	2	130.5	3009
11.30 – 11.45	67	107	7	4	139	3148
11.45 – 12.00	57	98	6	1	117	3265
12.00 – 12.15	92	90	9	8	166.5	3431.5
12.15 – 12.30	63	100	2	1	118	3549.5
12.30 – 12.45	68	108	12	0	140	3689.5
12.45 – 1.00pm	65	87	7	1	121	3810.5
1.00 – 1.15pm	78	87	8	2	137.5	3948
1.15 – 1.30pm	78	102	1	4	138.5	4086.5
1.30 - 1.45pm	64	104	4	1	124	4210.5
1.45 - 2.00pm	59	99	4	3	120.5	4331
2.00 - 2.15pm	86	104	11	6	166.5	4497.5
2.15 – 2.30pm	91	85	7	2	148	4645.5
2.30 – 2.45pm	79	96	1	2	132.5	4778
2.45 – 3.00pm	82	80	2	1	127	4905
3.00 – 3.15pm	76	98	5	1	134.5	5039.5
3.15 – 3.30pm	101	103	4	2	162.5	5202
3.30 – 3.45pm	79	99	8	2	144.5	5346.5
3.45 – 4.00pm	66	79	3	2	114	5460.5
4.00 – 4.15pm	71	82	6	0	121	5581.5
4.15 - 4.30pm	84	83	4	1	133.5	5715
4.30 - 4.45pm	66	72	20	2	136	5851
4.45 - 5.00pm	81	87	8	0	136.5	5987.5
5.00 – 5.15pm	75	74	9	1	127.5	6115
5.15 – 5.30pm	65	95	14	2	137.5	6252.5
5.30 – 5.45pm	63	92	9	1	124.5	6377
5.45 – 6.00pm	63	84	12	1	125	6502
6.00 – 6.15pm	78	89	10	0	137.5	6639.5
6.15 – 6.30pm	57	85	12	4	125.5	6765
6.30 – 6.45pm	57	90	11	0	118.5	6883.5
6.45 – 7.00pm	76	86	6	1	130	7013.5

TABLE 13A RAW COUNT OF VEHICLE MOVEMENT ON ROUTE 'C' ON WEDNESDAY (JULY 30, 2004) TOWARDS THE ROUNDABOUT

Veh. Type Time	Cars	Motor-cycles	Buses	2/3 Axle Trucks	Quarterly hour	Cummula-tive
6.00 - 6.15 am	18	35	1	0	37	37
6.15 - 6.30 am	38	80	0	2	82	119
6.30 - 6.45 am	42	89	3	0	91	210
6.45 – 7.00 am	56	97	6	0	133.5	323.5
7.00 - 7.15 am	48	60	7	0	88.5	412
7.15 – 7.30 am	61	84	3	1	103.5	521.5
7.30 - 7.45 am	83	111	6	2	151.5	673
7.45 - 8.00 am	88	108	10	1	159	832
8.00 – 8.15 am	91	129	3	2	164	996
8.15 – 8.30 am	77	142	5	4	162.5	1158.5
8.30 - 8.45 am	75	133	1	4	151	1309.5
8.45 - 9.00 am	92	138	3	4	173.5	1483
9.00 – 9.15 am	86	105	7	4	157	1640
9.15 – 9.30 am	73	123	6	4	151.5	1791.5
9.30 – 9.45 am	70	120	2	4	141	1932.5
9.45 -10.00 am	87	112	5	5	160.5	2093
10.00 – 10.15	85	101	3	2	144	2237
10.15 - 10.30	80	96	12	3	152	2389
10.30 – 10.45	62	80	8	4	122	2511
10.45 – 11.00	71	97	9	1	135	2646
1.00 – 11.15	68	103	11	4	144	2790
11.15 – 11.30	68	100	4	3	130	2920
11.30 – 11.45	78	104	7	3	146.5	3066.5
11.45 – 12.00	77	92	8	4	143	3209.5
12.00 – 12.15	59	108	4	4	127	3336.5
12.15 – 12.30	60	103	3	2	120	3456.5
12.30 – 12.45	75	106	7	4	146.5	3603
12.45 – 1.00pm	68	63	1	1	103	3706
1.00 – 1.15pm	76	95	6	2	136.5	3842.5
1.15 – 1.30pm	79	77	10	1	134.5	3977
1.30 - 1.45pm	80	100	3	6	164.5	4123.5
1.45 - 2.00pm	65	95	8	4	132.5	4256
2.00 - 2.15pm	93	92	9	3	158.5	4414.5
2.15 – 2.30pm	76	87	4	2	129.5	4544
2.30 – 2.45pm	86	86	10	1	146	4690
2.45 – 3.00pm	80	110	9	4	156.5	4846.5
3.00 – 3.15pm	71	109	18	7	166.5	5013
3.15 – 3.30pm	72	81	1	0	114	5127
3.30 – 3.45pm	65	72	8	2	117	5244
3.45 – 4.00pm	83	71	7	4	137	5381
4.00 – 4.15pm	70	85	9	1	128	5509
4.15 - 4.30pm	68	102	9	3	138.5	5647.5
4.30 - 4.45pm	72	100	10	1	139	5786.5
4.45 - 5.00pm	70	96	7	3	134.5	5921
5.00 – 5.15pm	65	90	8	3	128	6049
5.15 – 5.30pm	59	94	8	1	120	6169
5.30 – 5.45pm	65	94	10	0	127	6296
5.45 – 6.00pm	62	107	3	1	122	6418
6.00 – 6.15pm	58	64	7	0	100.5	6518.5
6.15 – 6.30pm	55	92	9	2	118.5	6637
6.30 – 6.45pm	55	80	10	1	112	6749
6.45 – 7.00pm	80	95	14	4	156.5	6905.5

TABLE 14A RAW COUNT OF VEHICLE MOVEMENT ON ROUTE 'C' ON THURSDAY (JULY 1, 2004) TOWARDS THE ROUNDABOUT

Veh. Type Time	Cars	Motor-cycles	Buses	2/3 Axle Trucks	Quarterly hour	Cummula-tive
6.00 - 6.15 am	20	25	3	0	37	37
6.15 - 6.30 am	40	48	12	0	82	119
6.30 - 6.45 am	40	47	17	1	91	210
6.45 – 7.00 am	60	73	10	1	113.5	323.5
7.00 - 7.15 am	72	105	6	2	137.5	461
7.15 – 7.30 am	70	97	10	2	137.5	598.5
7.30 - 7.45 am	78	118	4	1	145	743.5
7.45 - 8.00 am	83	140	4	2	163	906.5
8.00 – 8.15 am	97	145	4	3	181.5	1088
8.15 – 8.30 am	92	139	6	4	178.5	1266.5
8.30 - 8.45 am	90	115	5	6	167	1433.5
8.45 - 9.00 am	74	112	6	5	149	1582.5
9.00 – 9.15 am	76	86	2	1	124	1706.5
9.15 – 9.30 am	85	205	4	1	195.5	1902
9.30 – 9.45 am	109	110	5	0	171.5	2073.5
9.45 -10.00 am	80	100	4	0	136	2209.5
10.00 – 10.15	80	81	8	0	132.5	2342
10.15 - 10.30	73	96	3	1	127.5	2469.5
10.30 – 10.45	67	90	1	0	113.5	2583
10.45 – 11.00	65	100	6	5	134	2717
1.00 – 11.15	67	106	9	1	135.5	2852.5
11.15 – 11.30	65	98	5	1	123.5	2976
11.30 – 11.45	70	83	6	0	120.5	3096.5
11.45 – 12.00	100	95	8	1	161.5	3258
12.00 – 12.15	63	100	7	0	123.5	3381.5
12.15 – 12.30	69	100	13	1	140.5	3522
12.30 – 12.45	73	106	7	2	140.5	3662.5
12.45 – 1.00pm	66	85	11	1	127	3789.5
1.00 – 1.15pm	71	89	4	1	123.5	3913
1.15 – 1.30pm	80	85	9	2	140	4053
1.30 - 1.45pm	59	78	7	2	112.5	4165.5
1.45 - 2.00pm	64	107	5	1	127	4292.5
2.00 - 2.15pm	80	95	8	1	141.5	4434
2.15 – 2.30pm	68	79	6	2	120.5	4554.5
2.30 – 2.45pm	69	66	5	0	109.5	4664
2.45 – 3.00pm	78	90	5	0	130.5	4794.5
3.00 – 3.15pm	80	63	3	0	116	4910.5
3.15 – 3.30pm	92	88	8	2	152	5062.5
3.30 – 3.45pm	75	78	7	0	124.5	5187
3.45 – 4.00pm	75	85	9	2	135	5322
4.00 – 4.15pm	77	71	7	0	123	5445
4.15 - 4.30pm	80	69	15	0	137	5582
4.30 - 4.45pm	55	79	5	0	102	5684
4.45 - 5.00pm	90	95	15	1	162	5846
5.00 – 5.15pm	83	108	11	1	155.5	6001.5
5.15 – 5.30pm	70	120	8	1	144	6145.5
5.30 – 5.45pm	70	95	8	0	129.5	6275
5.45 – 6.00pm	75	102	8	1	140	6415
6.00 – 6.15pm	60	100	9	0	123.5	6538.5
6.15 – 6.30pm	75	114	9	2	149.5	6688
6.30 – 6.45pm	79	105	8	0	143.5	6831.5
6.45 – 7.00pm	51	86	11	0	110.5	6942

TABLE 15A RAW COUNT OF VEHICLE MOVEMENT ON ROUTE 'C' ON FRIDAY (JULY 2, 2004) TOWARDS THE ROUNDABOUT

Veh. Type Time	Cars	Motor-cycles	Buses	2/3 Axle Trucks	Quarterly Hour	Cummula-tive
6.00 - 6.15 am	15	32	4	0	37	37
6.15 - 6.30 am	40	78	2	0	82	119
6.30 - 6.45 am	45	86	2	0	91	210
6.45 – 7.00 am	54	109	2	1	113.5	323.5
7.00 - 7.15 am	55	77	3	1	100	423.5
7.15 – 7.30 am	68	97	1	1	120	543.5
7.30 - 7.45 am	68	172	4	0	160	703.5
7.45 - 8.00 am	70	180	2	1	165	868.5
8.00 – 8.15 am	75	177	3	1	170	1038.5
8.15 – 8.30 am	85	154	6	1	173	1211.5
8.30 - 8.45 am	82	157	2	1	165.5	1377
8.45 - 9.00 am	120	101	5	1	180	1557
9.00 – 9.15 am	92	133	3	2	167	1724
9.15 – 9.30 am	90	95	15	1	162	1886
9.30 – 9.45 am	72	120	4	2	142	2028
9.45 -10.00 am	85	141	3	1	162	2190
10.00 – 10.15	92	102	2	2	150	2340
10.15 - 10.30	95	109	1	1	153	2493
10.30 – 10.45	73	105	7	2	140	2633
10.45 – 11.00	98	97	7	4	165	2798
1.00 – 11.15	90	95	15	1	162	2960
11.15 – 11.30	94	102	2	1	150	3110
11.30 – 11.45	90	102	2	4	152	3262
11.45 – 12.00	110	155	6	1	198.5	3460.5
12.00 – 12.15	70	97	5	2	130	3590.5
12.15 – 12.30	72	82	4	3	125	3715.5
12.30 – 12.45	95	84	5	3	150.5	3866
12.45 – 1.00pm	109	110	4	0	170	4036
1.00 – 1.15pm	84	62	4	2	125	4161
1.15 – 1.30pm	75	102	8	1	140	4301
1.30 - 1.45pm	85	87	3	1	135	4436
1.45 - 2.00pm	95	90	4	2	150	4586
2.00 - 2.15pm	86	160	4	0	172	4758
2.15 – 2.30pm	105	91	5	2	162	4920
2.30 – 2.45pm	110	52	3	1	142.5	5062.5
2.45 – 3.00pm	70	103	3	2	130	5192.5
3.00 – 3.15pm	85	106	4	4	152	5344.5
3.15 – 3.30pm	100	101	5	1	160	5504.5
3.30 – 3.45pm	97	108	5	2	162.5	5667
3.45 – 4.00pm	109	84	6	3	166	5833
4.00 – 4.15pm	51	85	11	0	110	5943
4.15 - 4.30pm	75	62	4	7	126	6069
4.30 - 4.45pm	70	120	8	1	144	6213
4.45 - 5.00pm	90	91	5	1	145	6358
5.00 – 5.15pm	110	90	2	0	158	6516
5.15 – 5.30pm	72	79	3	2	120	6636
5.30 – 5.45pm	65	101	3	1	122	6758
5.45 – 6.00pm	80	65	5	2	124	6882
6.00 – 6.15pm	72	85	3	3	125	7007
6.15 – 6.30pm	58	70	2	2	100	7107
6.30 – 6.45pm	70	82	2	2	118	7225
6.45 – 7.00pm	75	64	2	1	112	7337

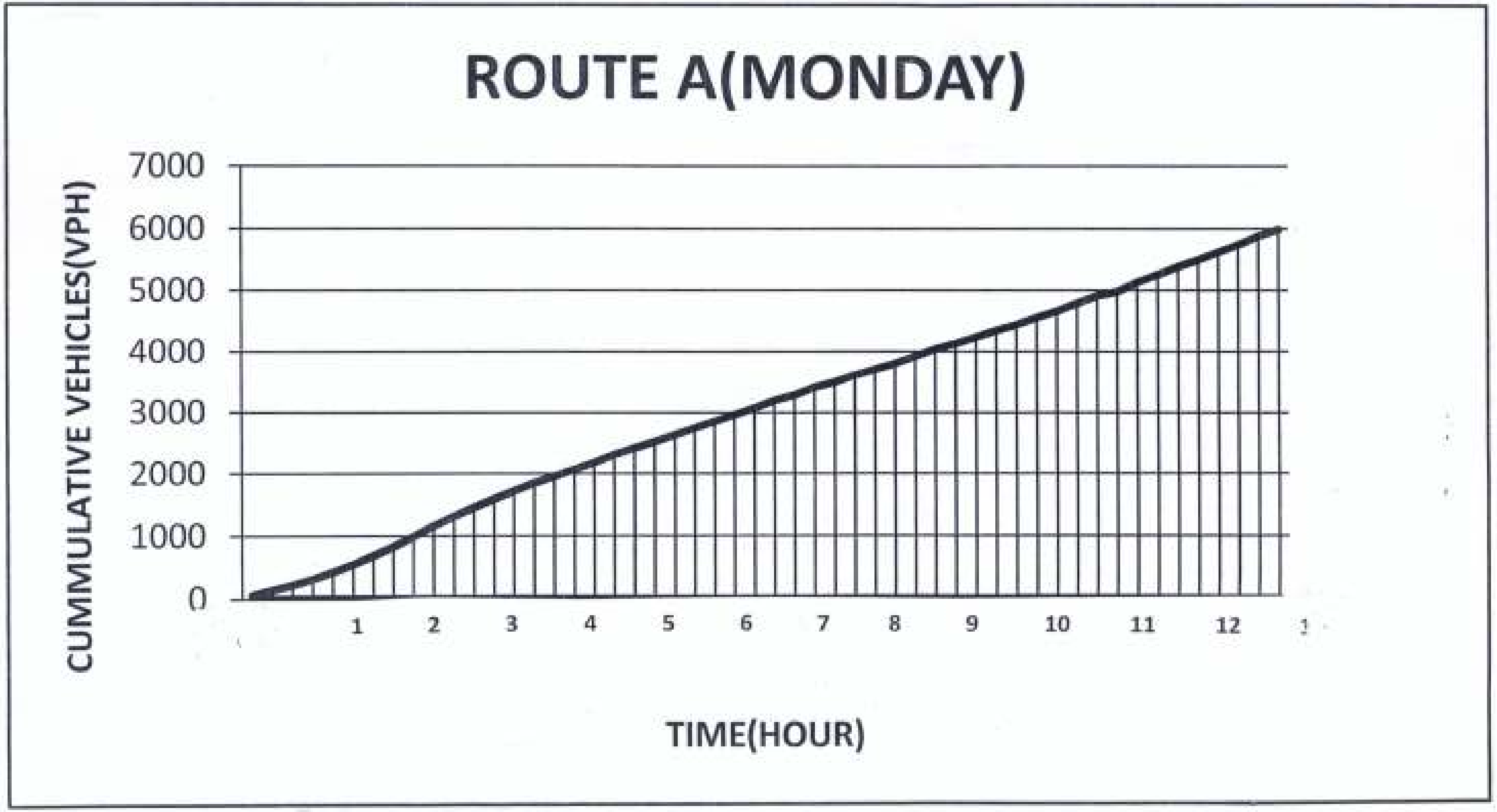

FIG.4.1 GRAPH OF THE CUMMULATIVE VEHICLES AGAINST TIME

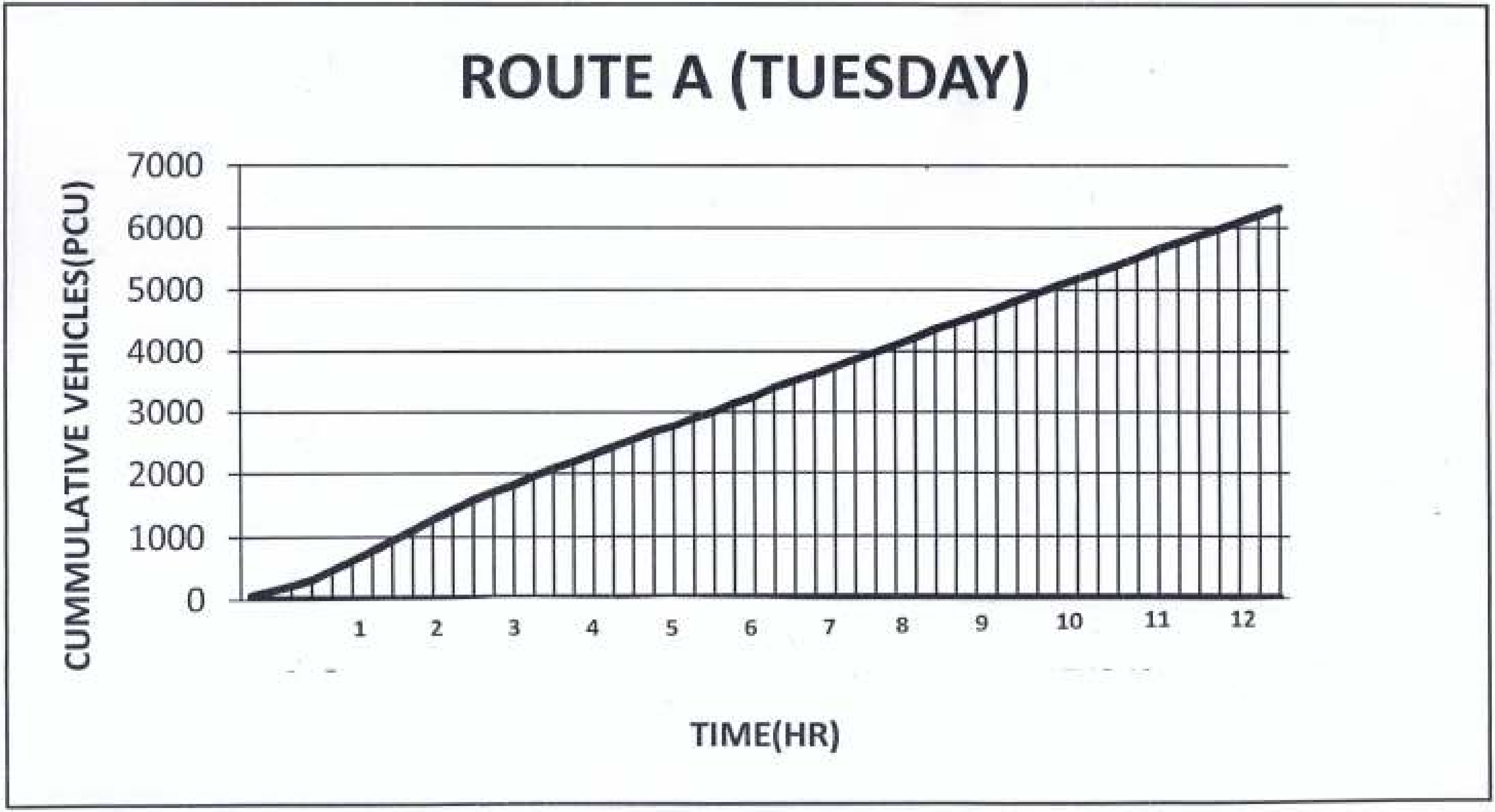

FIG.4.2 GRAPH OF THE CUMMULATIVE VEHICLES AGAINST TIME

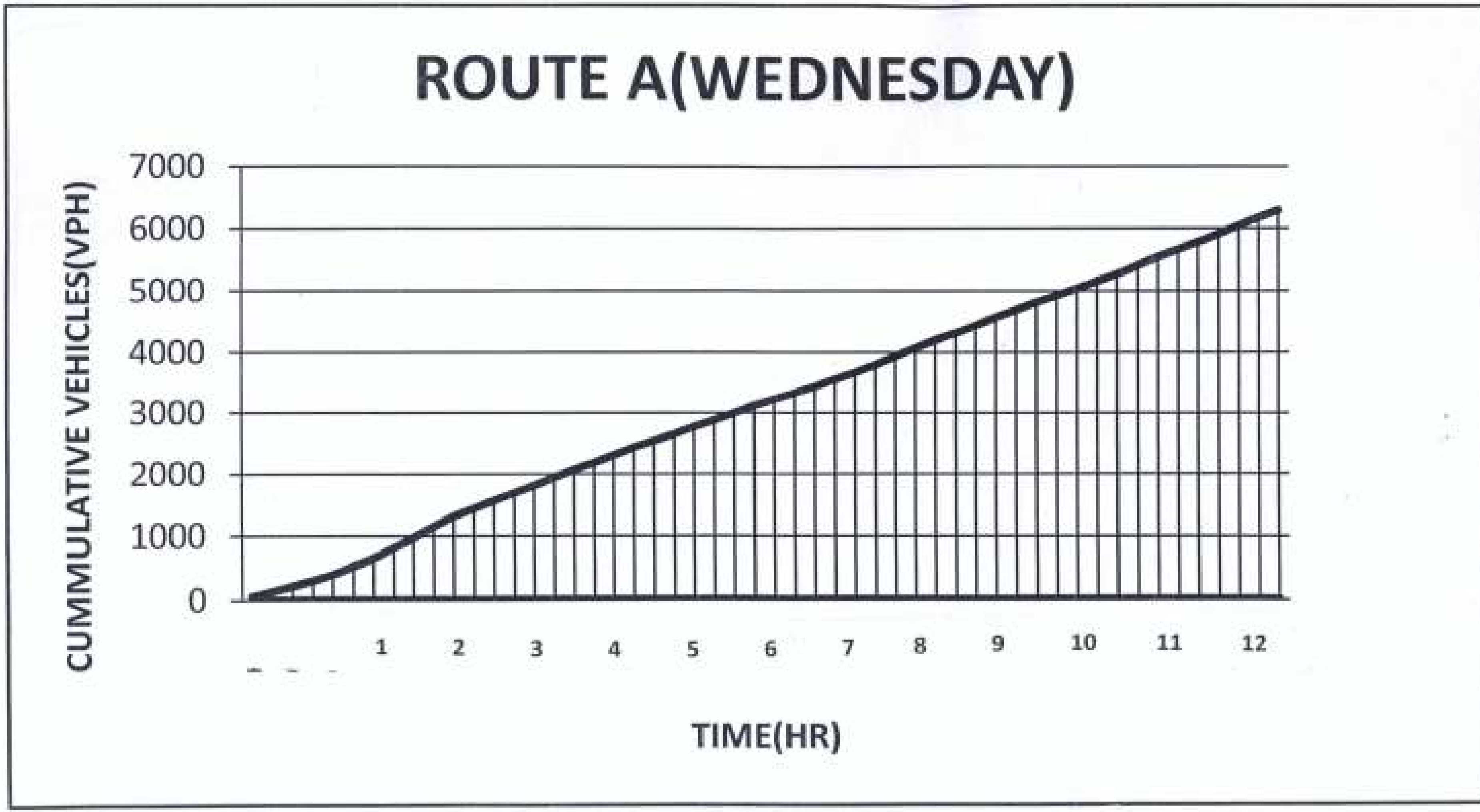

FIG.4.3 GRAPH OF THE CUMMULATIVE VEHICLES AGAINST TIME

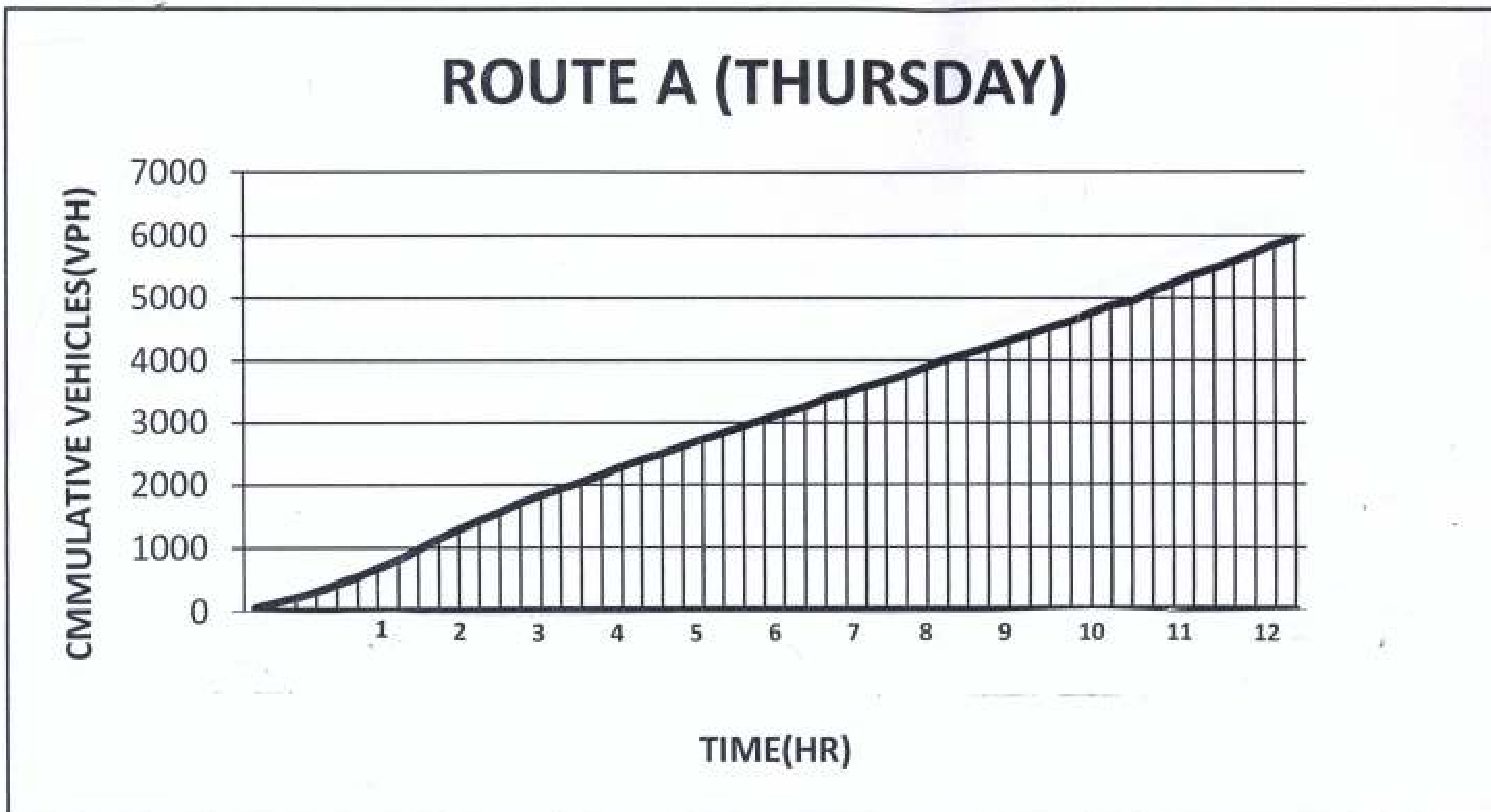

FIG.4.4 GRAPH OF THE CUMMULATIVE VEHICLES AGAINST TIME

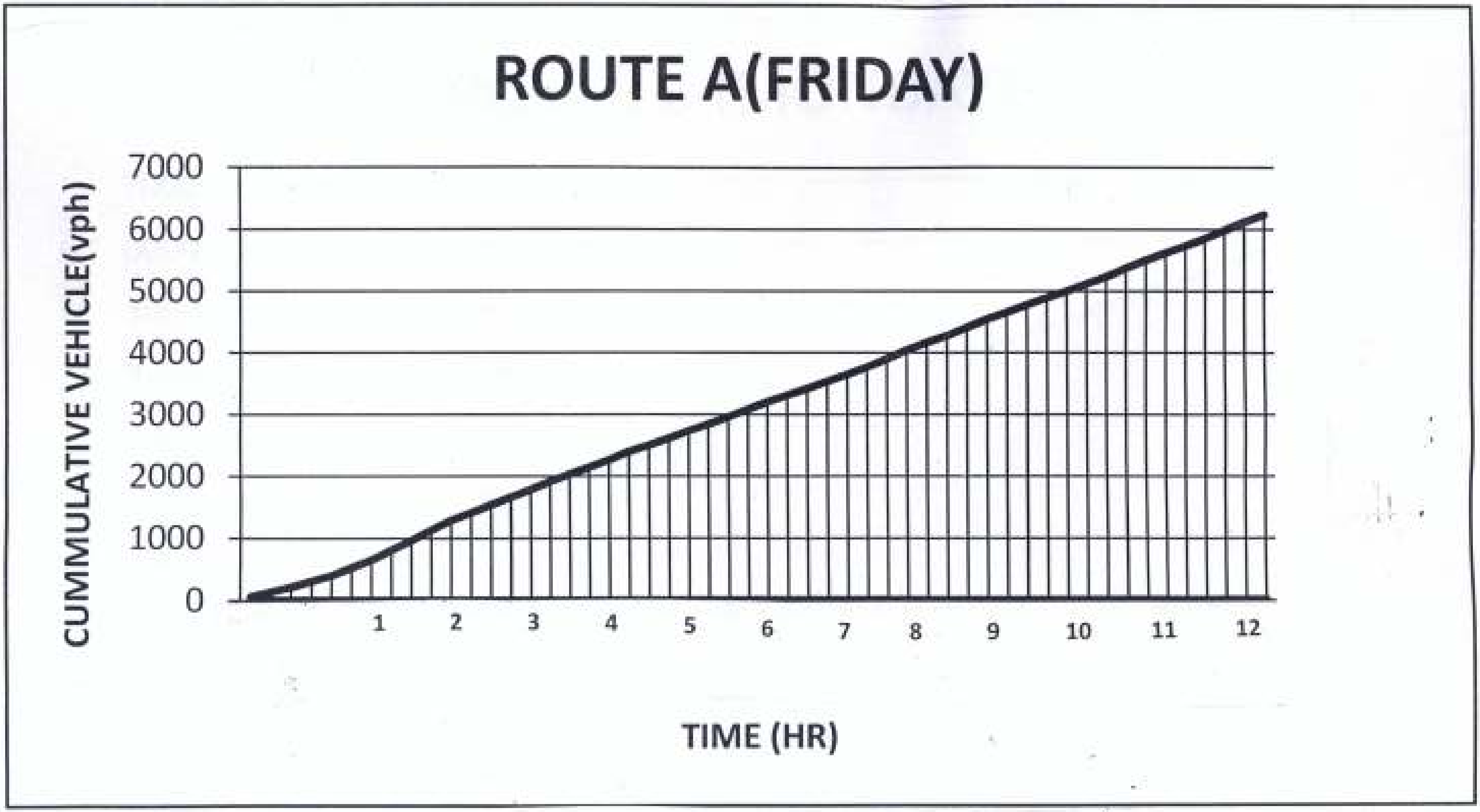

FIG.4.5 GRAPH OF THE CUMMULATIVE VEHICLES AGAINST TIME

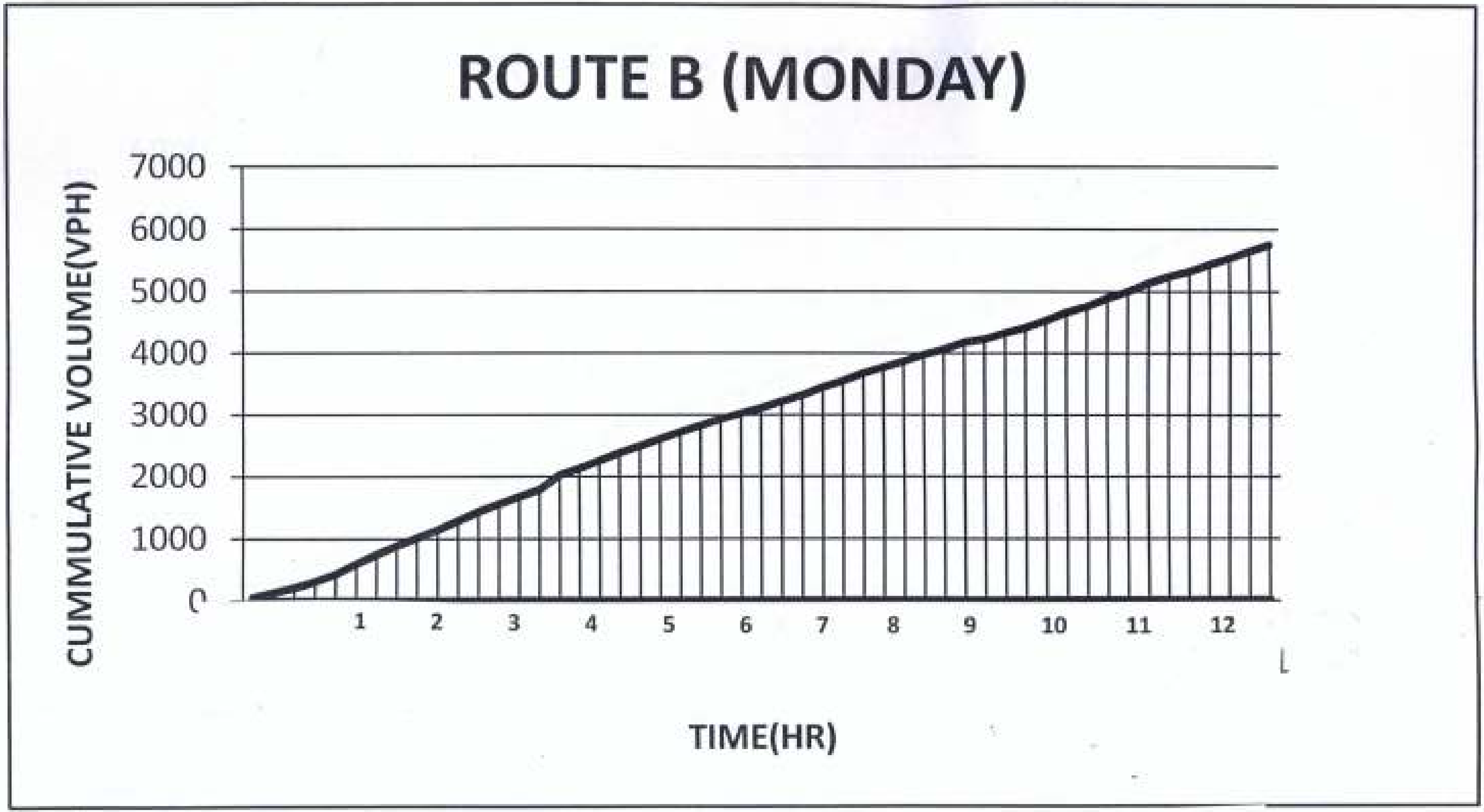

FIG.4.6 GRAPH OF THE CUMMULATIVE VEHICLES AGAINST TIME

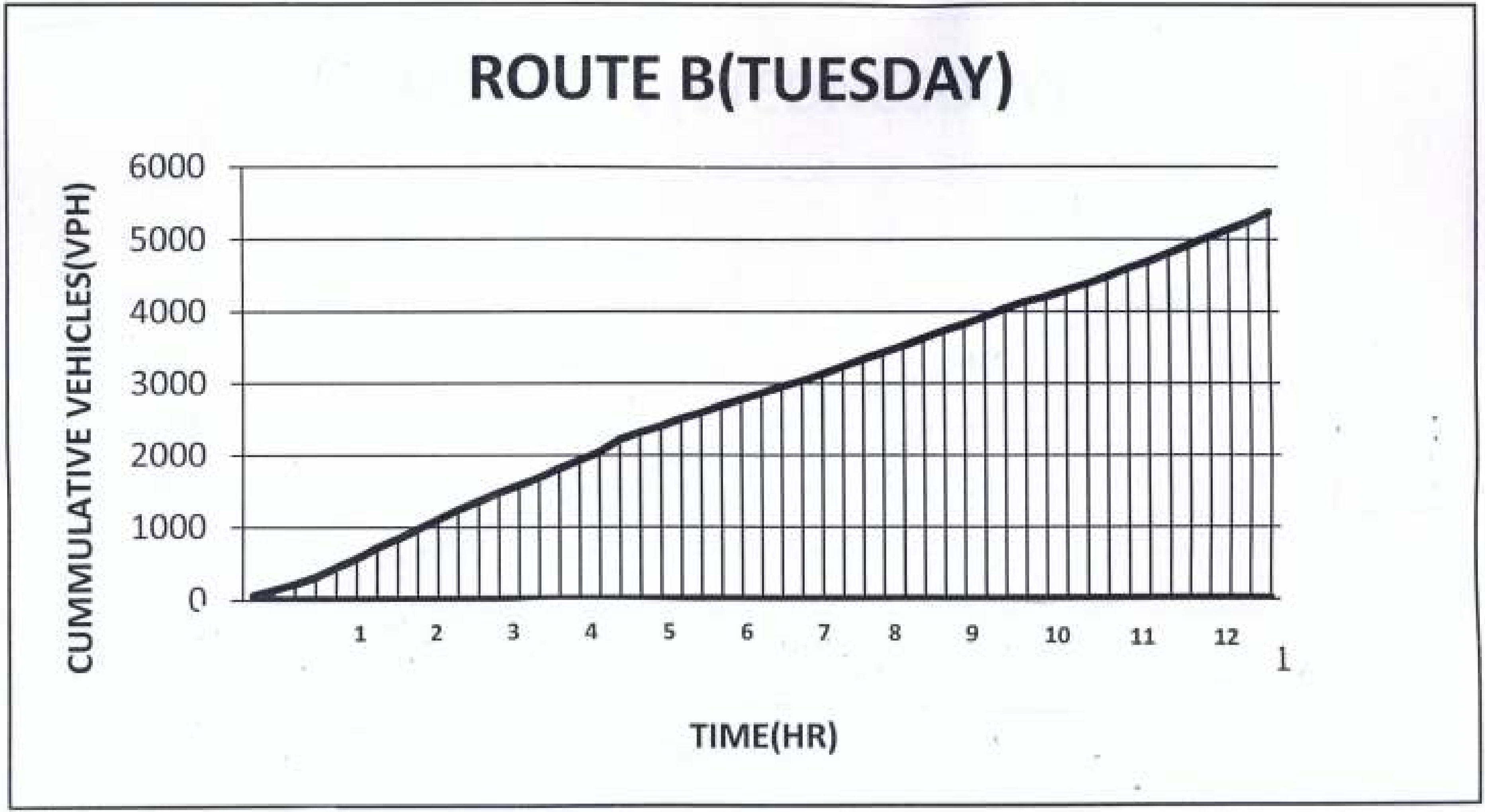

FIG.4.7 GRAPH OF THE CUMMULATIVE VEHICLES AGAINST TIME

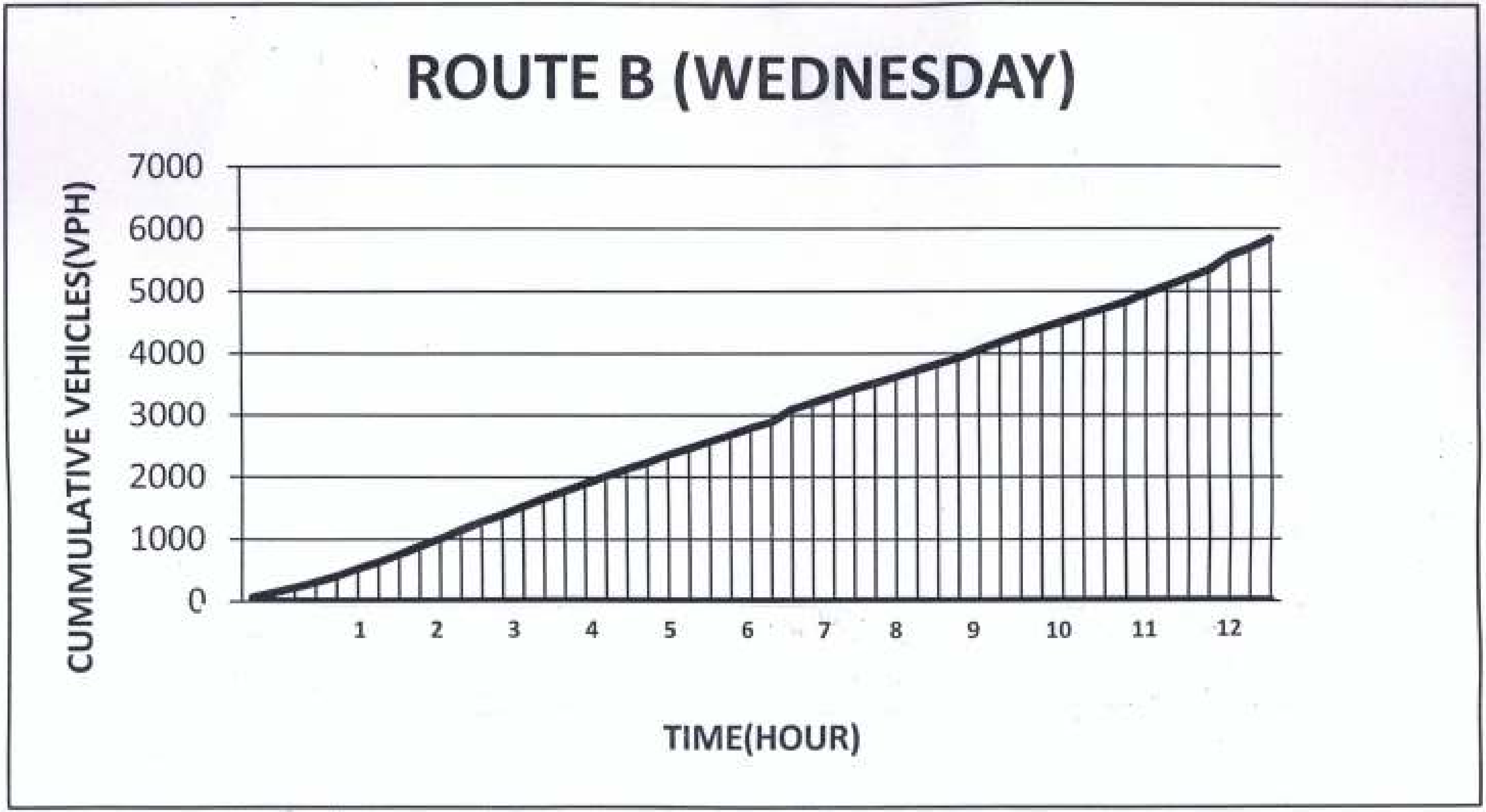

FIG.4.8 GRAPH OF THE CUMMULATIVE VEHICLES AGAINST TIME

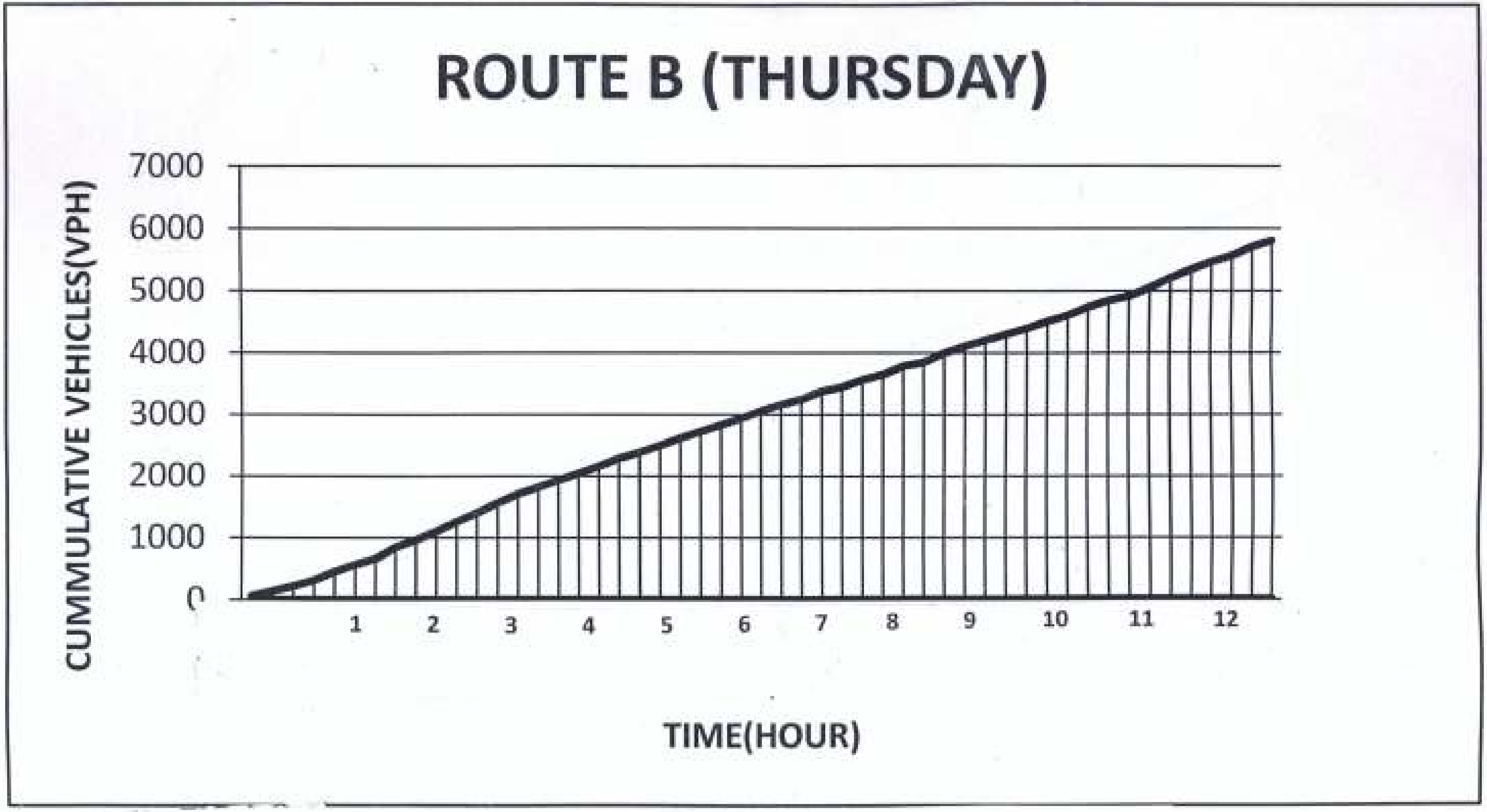

FIG.4.9 GRAPH OF THE CUMMULATIVE VEHICLES AGAINST TIME

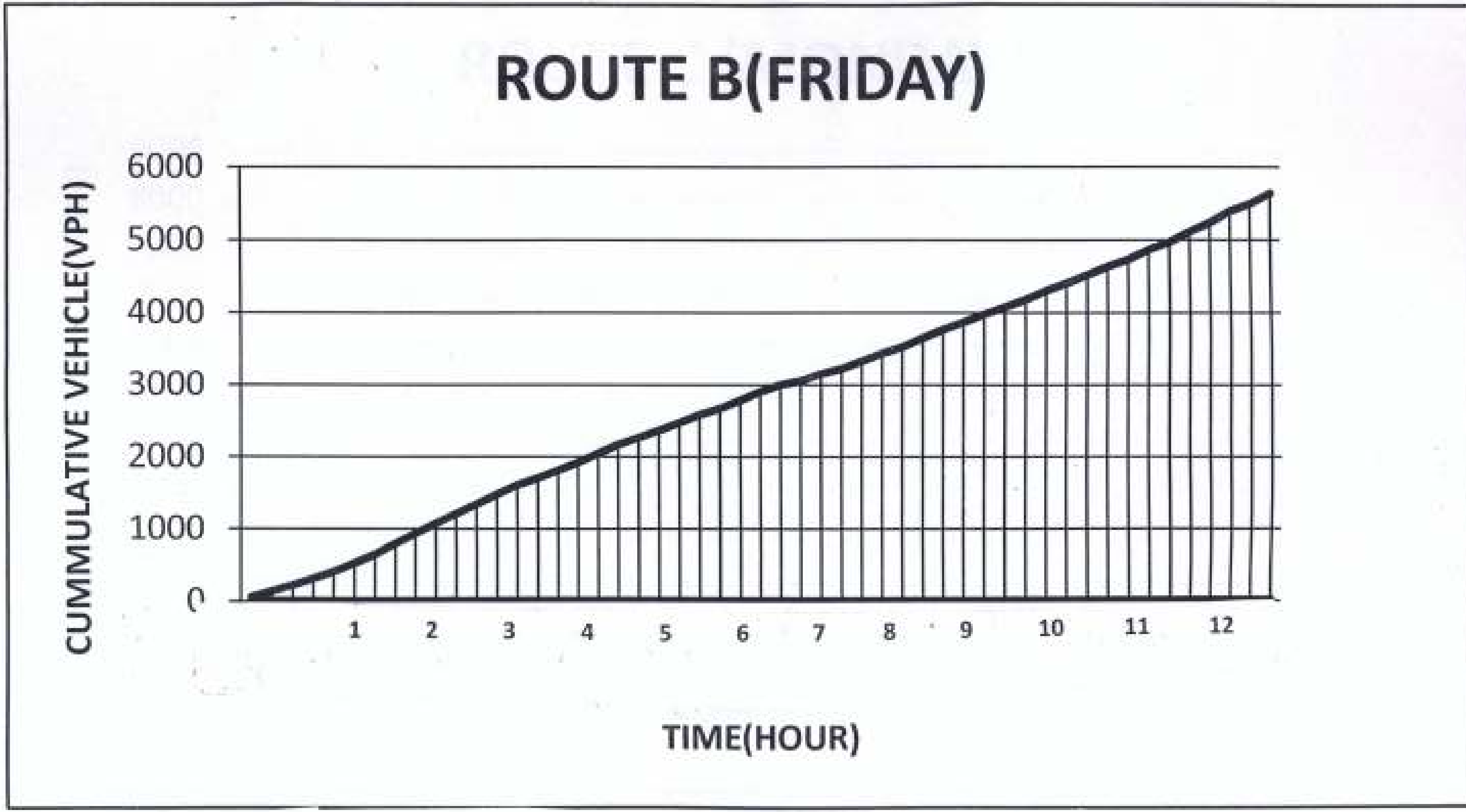

FIG.4.10 GRAPH OF THE CUMMULATIVE VEHICLES AGAINST TIME

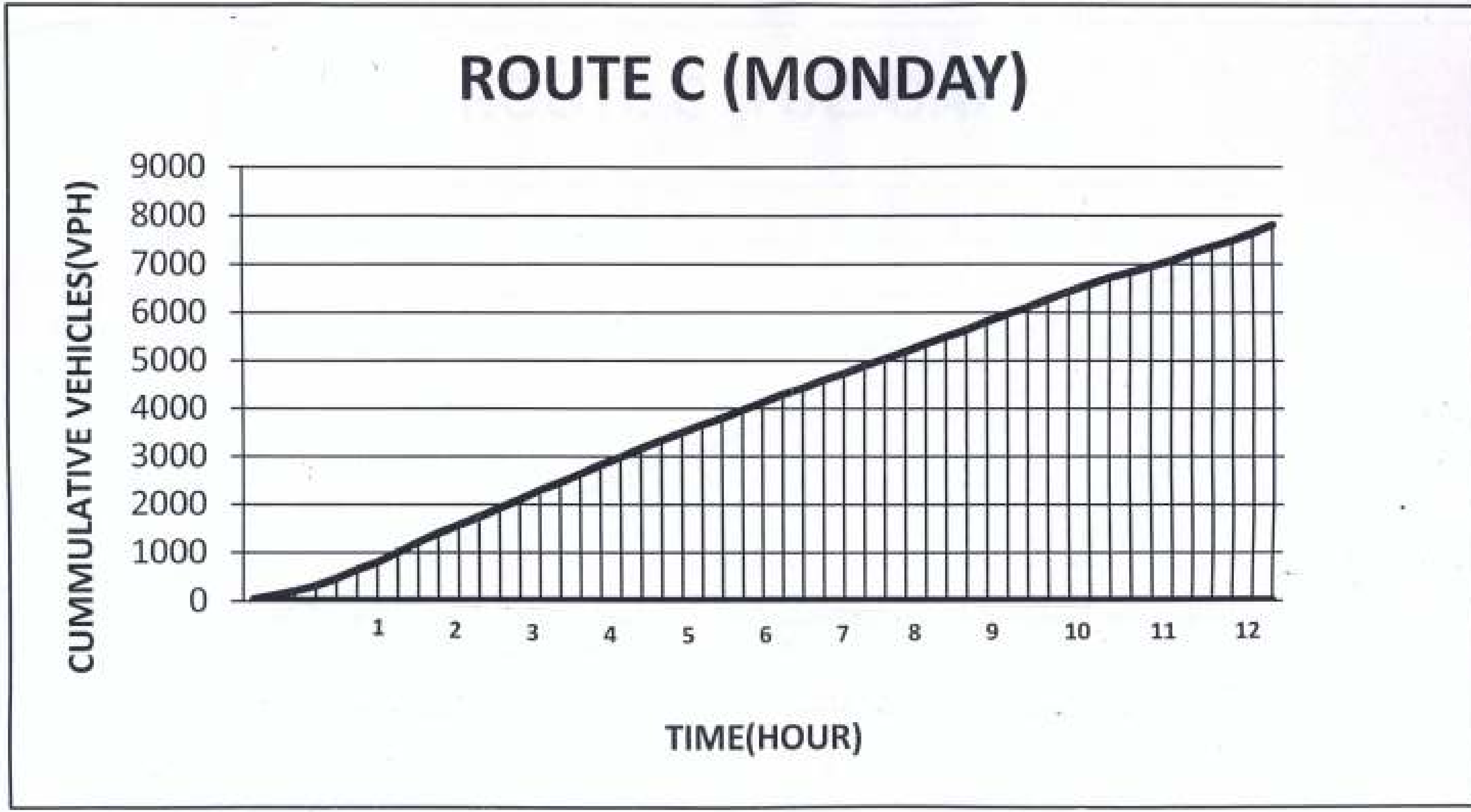

FIG.4.11 GRAPH OF THE CUMMULATIVE VEHICLES AGAINST TIME

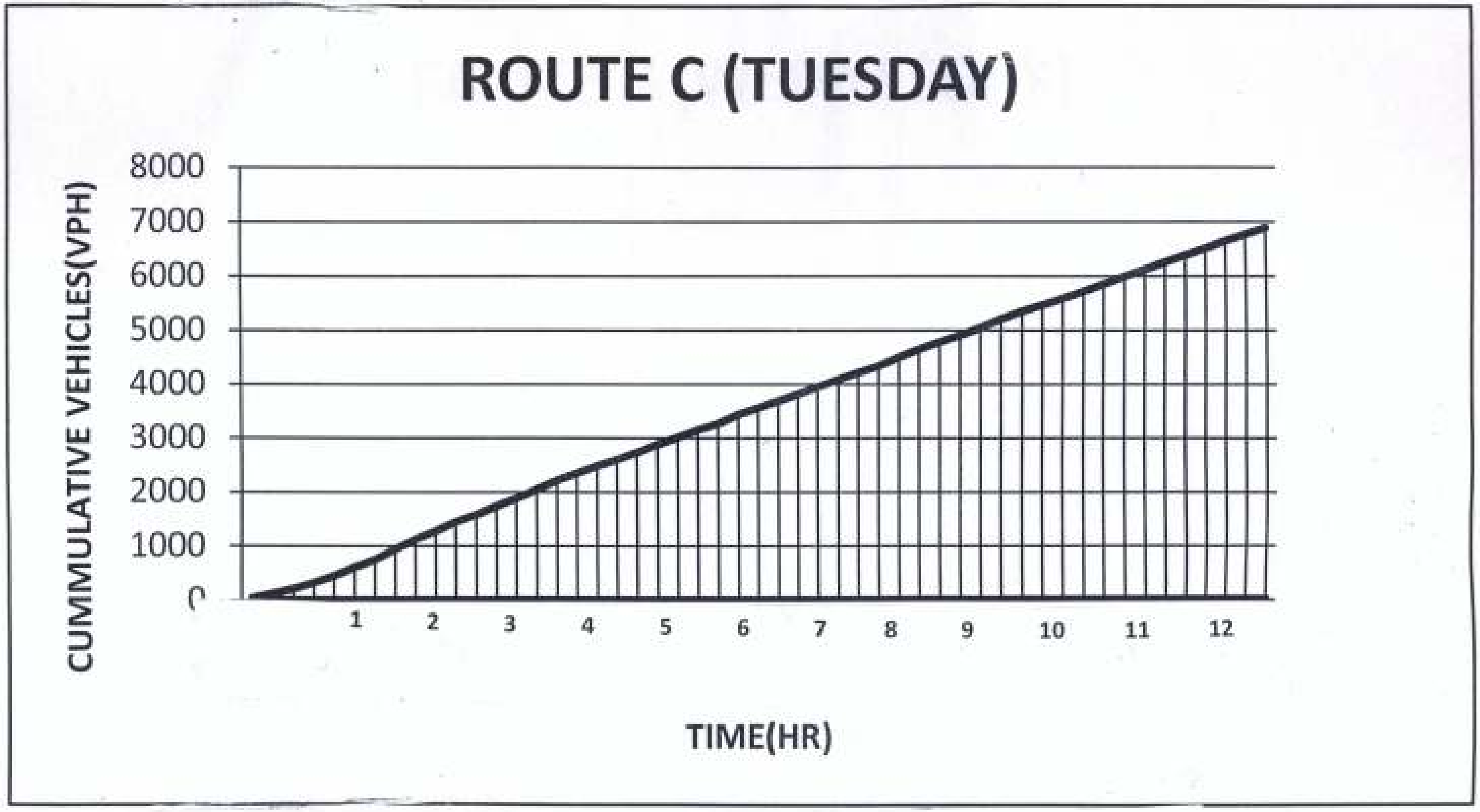

FIG.4.12 GRAPH OF THE CUMMULATIVE VEHICLES AGAINST TIME

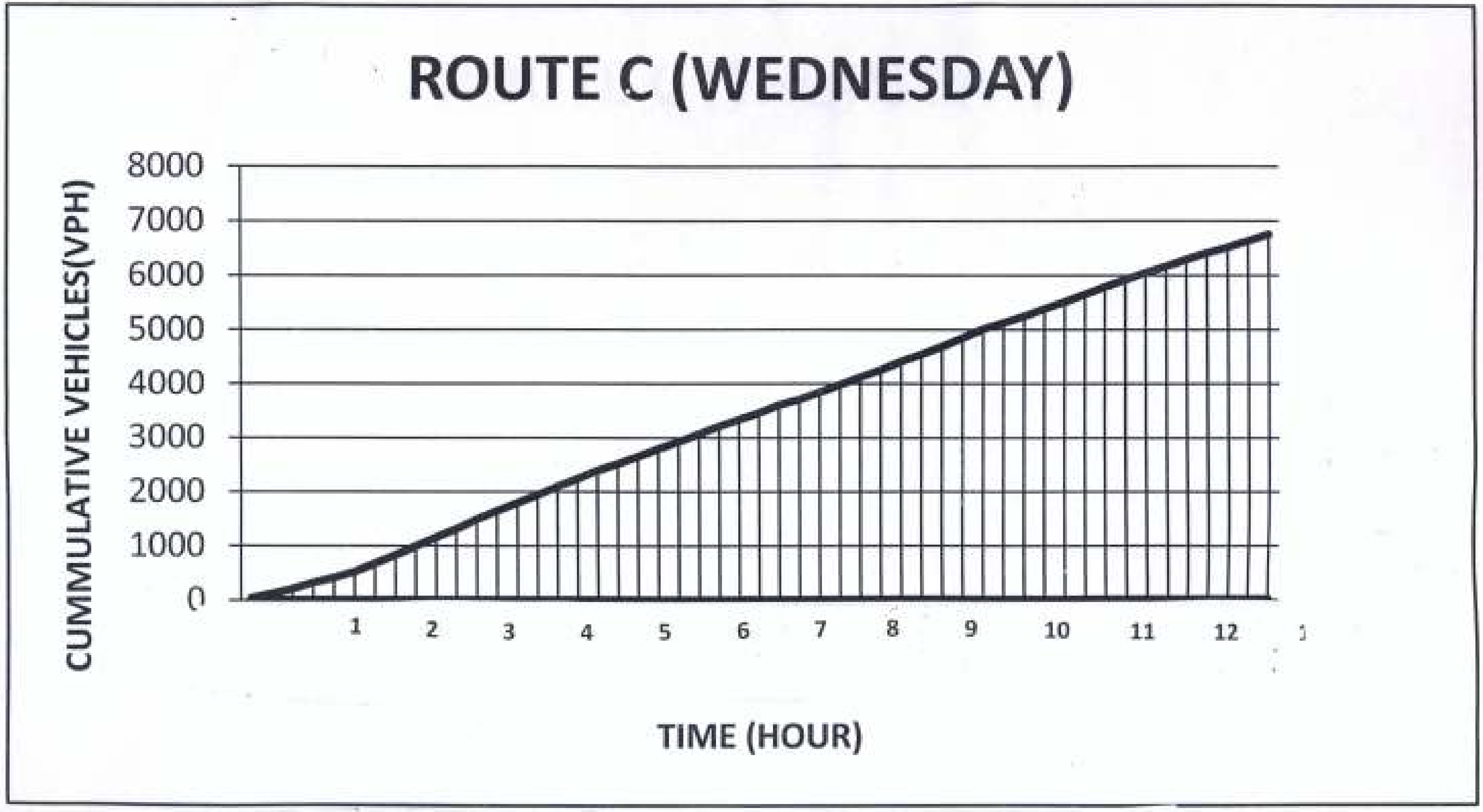

FIG.4.13 GRAPH OF THE CUMMULATIVE VEHICLES AGAINST TIME

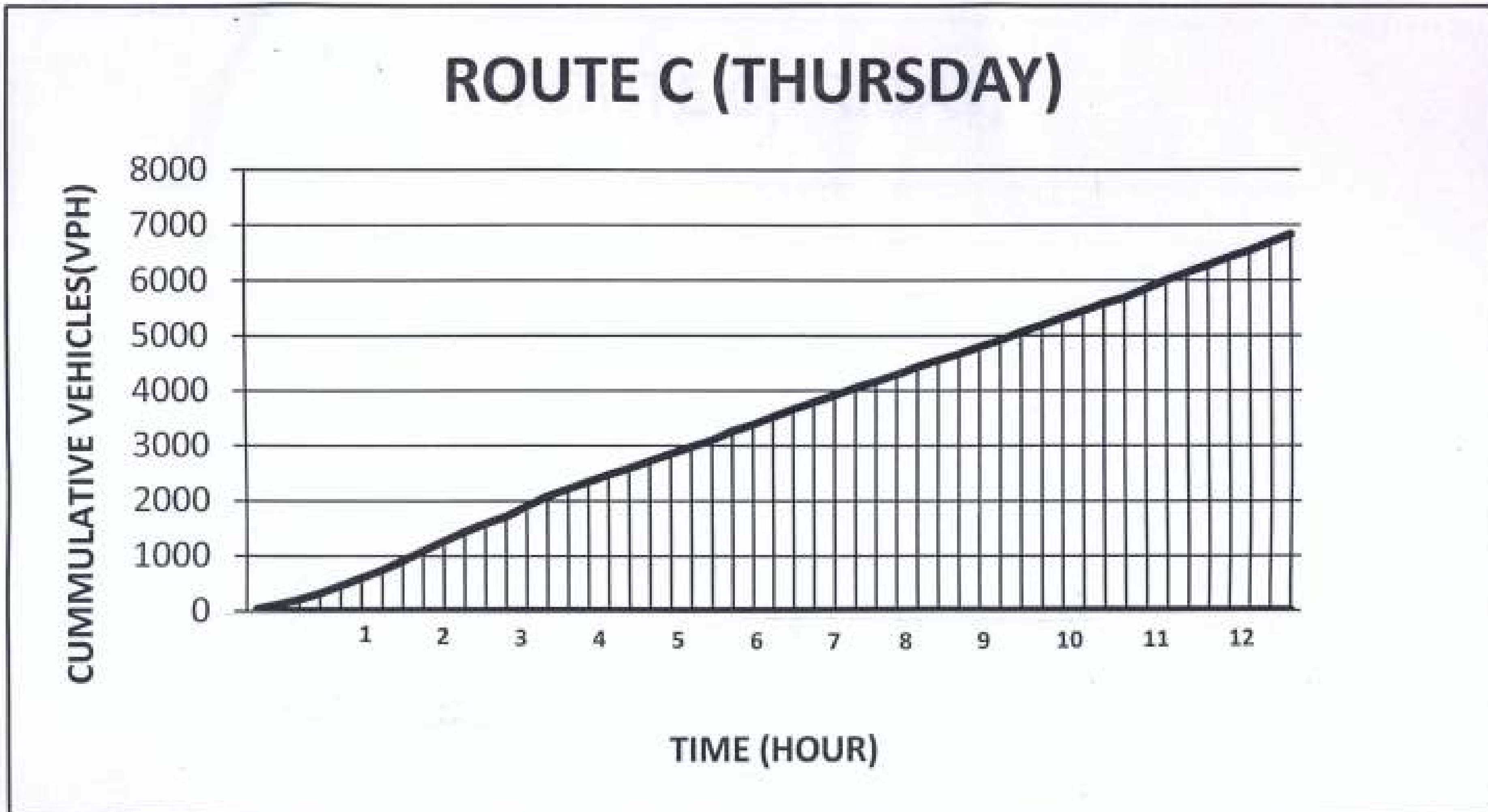

FIG.4.14 GRAPH OF THE CUMMULATIVE VEHICLES AGAINST TIME

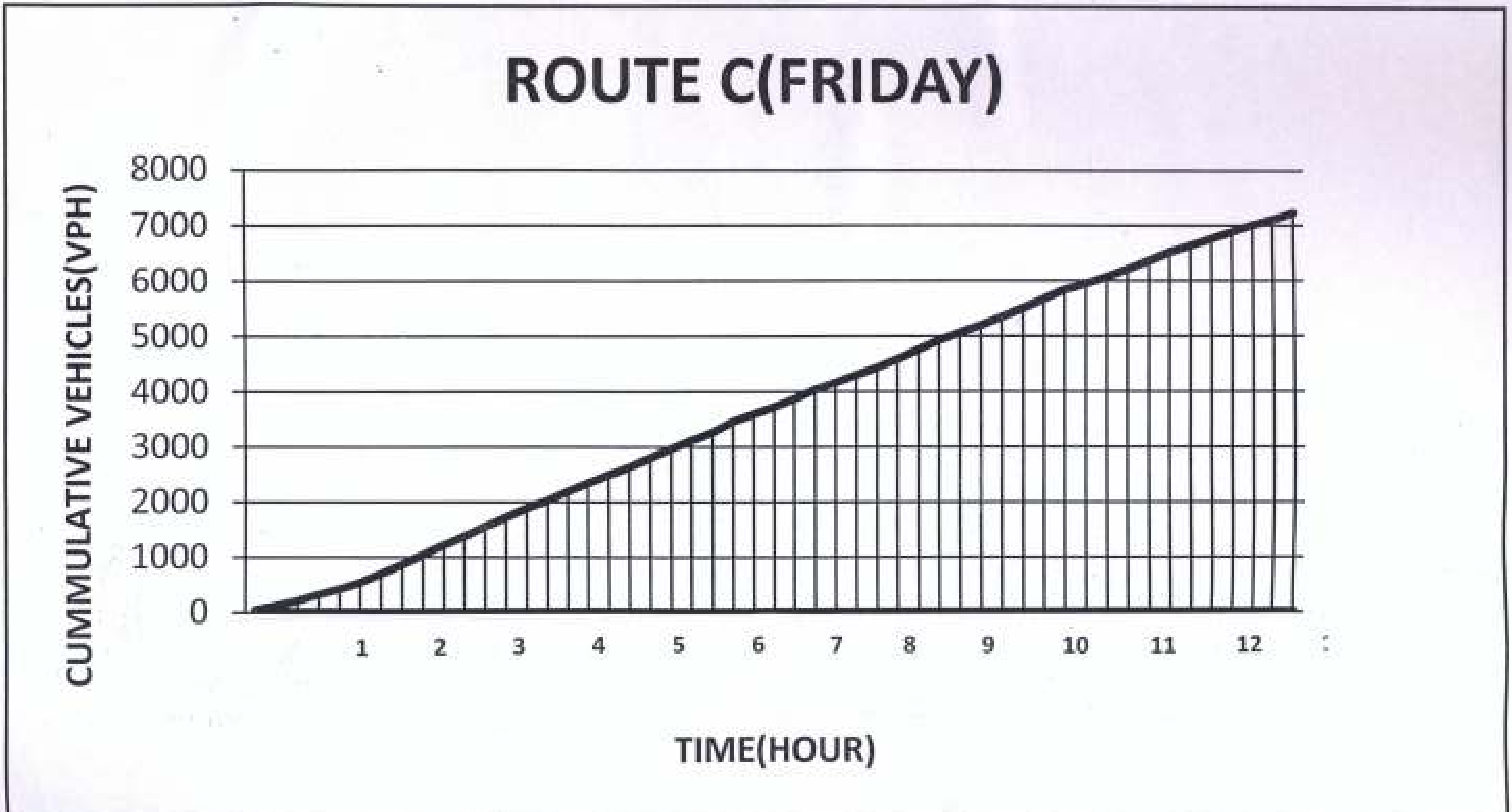

FIG.4.15 GRAPH OF THE CUMMULATIVE VEHICLES AGAINST TIME