CHARACTERISTICS OF ROAD TRAFFIC ACCIDENTS IN KENYA

BY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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This thesis has been submitted for examination wi[th] my approval as University Supervisor.

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In 1967 the author received a telegram informing him of a road traffic accident in which his dear sister, Eunice Nyamokami, that he follows had been involved in a nasty accident. Thank God her life was spared! Today she lives minus her right leg. This was the spark or impetus that set the launching pad for the author's life-long quest and involvement in road safety. To her and similar cases is this study and others to come dedicated. To Professor Gichaga, my supervisor, go sincere thanks for his guidance, supervision and patience during the entire study period. Many sincere thanks go to the University of Nairobi Deans Committee for granting some Kshs.13,872 for the first phase of this study during which background data was acquired, the Kenya Police and the Central Bureau of Statistics for macro data. Many thanks are extended to the author's daughter Boyani who at the age of six helped in patiently reading data for entry, to little Morna and Bogiita who provided comfort and cheer always and a reminder of life's realities, to their mother Elizabeth Agoki who assisted in sorting out data, critizing, providing encouragement and food and for her understanding and patience particularly during the critical moments of this study.

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SUMMARY

The objectives of this study were: to study Road Traffic Accidents (RTAs) in Kenya and to determine where possible their fundamental characteristics and causal factors related to their occurrence, to develop predictive models for Kenya at the national (macro) level to be used for the monitoring of RTAs and the performance of road safety improvement programmes and lastly to develop predictive models through some selected Kenyan roads at the road level (micro) to assist in the proper understanding of the behaviour of RTAs in relation to road design elements. In order to develop these predictive models, various mathematical models were used. These were: growth curve models, namely the logistic curve model and the logarithmic model; polynomial functions and finite differences techniques; harmonic analysis, generalised linear modelling and statistical methods for testing the fitness of the models developed. Macro level data for Kenya were collected from the Kenya Police records and from the Statistical Abstracts of the Central Bureau of Statistics of Kenya. Micro level data were collected through traffic volume counts, study of road geometry and pavement defects and by specially coded forms used for extracting data from the Traffic Police RTA records. The data were collected from the two carriageways of the Nairobi-Thika dual carriageway and the Kiganjo-Nanyuki single carriageway road. The police forms were obtained from the police stations responsible for the roads studied. The data were analysed to provide characteristic patterns and evidence of the mathematical techniques to be used in model development. Computer facilities were used whenever necessary. The major findings at the macro level were: the logistic model is well suited in predicting the growth of RTAs and related phenomena with time, the logarithmic trend curve is well suited in predicting the growth in the distribution of RTA responsibility and involvement whilst the polynomial function is suited in predicting the trend of RTAs in relation to motorization. The major findings at the micro level were: the polynomial functions are suited in predicting the effects of road factors on RTA rates, the logistic curve is well suited in predicting the growth of RTAs in relation to vehicle flow, harmonic functions are suitable for predicting variations in RTAs and vehicle flow with time of day and the generalised linear model is beneficial when trying to study the effects of traffic and geometrical design elements on RTAs on an interactive basis. It is recommended that there be continuous data collection in the form of an accident data base. Such data will then be used on a continuous basis for model calibration and monitoring of road safety improvement measures.

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CHAPTER 1 - INTRODUCTION

Right from the outset of Kenya's independence in 1963, major emphasis and efforts were directed towards the upgrading and expanding of the national road network in order to meet the transport demands of the aspired economic development targets, social and administrative requirements. Road development programmes took the form of reconstruction in order to improve the vertical and horizontal alignment standards and with all weather bitumenized or gravel surfacing simultaneously constructing new sections and extending these to reach areas of the country yet unaccessed.

Concomitant with the rapid transformation of the roads was a rapid increase in vehicle population and human population. With increased travel demand, more vehicles and better faster roads inevitably came the increased road traffic accident deaths, injuries and property damage.

The problem of road traffic accidents (RTAs) remains one of the major yet unsolved problems in Kenya in particular and in other countries of the world in general. It is a significant public health and engineering issue in general and traffic engineering specifically. This problem represents a serious national loss as well as a loss to individual Kenyans in terms of loss of life, injuries, loss of man-hours and the consequent effects on overall efficiency. RTAs are among the leading causes of death in Kenya and in many parts of the world today. In Kenya, while mortality and morbidity rates from transmissable diseases are known to be declining due to better medical and public health programmes, this is certainly not so for RTAs mortality and morbidity rates. During the period 1970-80 [58] statistics reported show that the number of reported deaths from the major notifiable infectious diseases decreased remarkably while the death toll from RTAs rose. For example, deaths from diarrhoeal disease, typhoid, smallpox and malaria decreased from 4631, 2602, 948 and 731 to 182, 4, 0, 20 respectively while RTA deaths increased from 944 to 1413. The carnage on Kenyan roads appears to be continuing into the future unless and until some drastic measure is taken. Whilst motor vehicles are an economic asset to every nation and a necessity for mobility in today's life pursuits they are simultaneously weapons of wanton destruction of human lives.

The problem of RTAs is not very well understood in many circles. The characteristics, the causes, the interplay and counterplay of factors in RTAs causation are least understood. Research in road safety in Kenya will be one of the most significant contributions towards the solution of the RTAs problem in Kenya and elsewhere.

Research in road safety has been pursued by the use of empirical/basic research as well as trial-and-error methods. The trial-and-error method uses experimentation and observation to find out if a "promise-looking" device or idea does in fact increase road safety. The emperical/basic research method, more characteristic of scientific research, uses fundamental investigations which endeavour to build up an understanding of the phenomenon of RTAs. If an individual RTA is considered, the main questions asked are what was the cause and who or what was to blame. If these questions are asked concerning a large number of RTAs the answers could reveal factors which are significant in the causation of RTAs. But experience has shown that this is not entirely satisfactory for the purposes of building a picture of the most important causative factors. The objections include the fact that if one or two factors are named, this may be a matter of opinion in their choice, and many factors are inevitably left out because their relevance is questionable and improperly understood or assumed to be the normal state of affairs warranting no special consideration. For scientific purposes it is thought better to regard the phenomenon of RTAs as a chance process. At any time the road, the traffic, the user and the vehicle in a set of circumstances have a certain probability or chance of leading to a RTA. The statistician thinks more of the probability and whatever affects this probability rather than an individual RTA and its causes. On the other hand, due to the fact that every RTA depends on a serious disturbance in the relationship between the road, the vehicles and the road users, the disturbance is not a matter of chance but traceable to an immediate causal factor. Thus, by studying a large number of RTAs a better understanding of the characteristics and the nature of occurrence of the disturbances giving rise to the RTAs may be obtained. This may provide a better practical approach from the point of view of the improvement of the road safety situation. Methods of defining RTA causes, so that relevant countermeasures are found, are not very well established anywhere in the world. No unified RTA theory exists. The basic source of information so far has been various kinds of in-depth investigations of RTAs. These investigations are extremely time - and money-consuming. Thus in-depth RTA investigation studies are not justified from a resource viewpoint.

For any given country there is necessity to study the individual country's RTA characteristics in order to understand the RTA problem better and provide a means for developing and monitoring road safety countermeasures. Such a research study may also help in the contribution to the knowledge and theory of RTAs and their causation.

The RTA problem may be summarized as the ever increasing tendency of RTAs and their resultant effects, lack of sufficient knowledge of RTAs characteristics both at the national level (macro) and the road environment level (micro) as well as the lack of sufficient knowledge of the characteristic effects of road users, vehicles and the road. Due to the complex nature of the RTA problem as well as their characteristics it is necessary that the data collection be as comprehensive as possible so as to provide sufficient background for the understanding of RTAs within the entire road traffic system. Consequently, the objectives for this study become:

- to study RTAs in Kenya in order to systematically determine their characteristic patterns,
- to develop predictive models for RTAs in Kenya at the national as well as the road level.

In this way a framework for understanding the RTAs problem in Kenya will be provided which will lead to the development of realistic solutions aimed at increasing road safety.

CHAPTER 2 - LITERATURE REVIEW

2.1 Macro Level

Prior to 1972 very little research had been carried out in the developing countries on the problem of RTAs. A reason why RTA studies have been neglected in these countries is given by Jacobs [1]as being that RTA rates have been considered to be low in comparison with countries in Europe and North America.

Using data for road fatalities, vehicles and population for the year 1938 from 20 countries, the majority of which were European, Smeed [1]derived a relationship which is given by the formula

$$F/V = 0.0003 \quad (V/P)^{\frac{2}{3}} \qquad (2.1)$$

where, F = road fatalities

V = number of vehicles

P = population.

The equation was a good fit for data also collected by Smeed for 16 countries, mostly European, ranging over the period 1957-66 and also a good fit for data from 68 countries over the period 1960-67. Smeed [2], in 1949, had developed the formula

$$D = 0.0003 \ (NP^2)^{\frac{1}{3}} \qquad (2.2)$$

where, D = number of deaths in road accidents in any year

N = number of licensed vehicles

P = population.

The statistics N, P and D had been reported by a number of Western European and North American countries. Another form of the Smeed [3] formula that has been used is

$$D/P = 0.0003\ (V/P)^{\frac{1}{3}} \qquad (2.3)$$

with the notations as above.

Using methods similar to those of Smeed, Jacobs and Hutchinson [1] carried out an analysis for 32 developing countries for which 1968 figures were available. The number of vehicles per 10,000 persons and the number of fatalities per 10,000 vehicles were calculated and compared. In order to derive a linear relationship the logarithmic values of the fatality rates were regressed against the logarithmic values of the vehicle-ownership rates and the following equations developed:

$$(F/P) = 0.00077\ (V/P)^{\frac{3}{5}} \qquad (2.4)$$

$$(F/V) = 0.00077\ (V/P)^{-\frac{2}{5}} \qquad (2.5)$$

with notations as above.

A number of countries over the 10-year period 1958-68 or as near to this period as possible had been chosen. For comparison a number of developed countries were included. These relationships were found to be statistically significant at the 1.0 per cent level. The number of fatalities per head of population increased with increase in motorization in all except Cyprus where there was a slight decrease. The injuries per head of population also rose with the rise in motorization in all countries.

The change in fatality and injury rates per licensed vehicle is thought to be a more meaningful indication of the accident situation in any country over a period of time. It has been observed that there is a general tendency for both rates to decrease with time. Out of the 29 countries studied, 15 showed a decrease in fatalities per vehicle and 14 a decrease in injuries per vehicle. This analysis agreed with that carried out by Smeed [1] which showed decreases in 15 out of 16 countries studied. Jacobs and Hutchinson [1] state that in those countries not showing this tendency unusual factors are operating. Kenya, Zambia and Jamaica had considerable increases in the number of fatalities per licensed vehicle. The reasons for this were advanced as non-introduction of training enforcement/regulations, improvement of vehicle standards and road design whilst vehicle ownership was increasing rapidly.

Various reasons for the fatality rate decreases observed have been advanced the most important being:

- a decrease in the proportion of two wheeled traffic on the roads, a category of vehicle with much the highest accident rate,
- a general fall in pedestrian casualty rates which may in turn be due to improved pedestrian facilities,
- an overall tendency towards higher levels of road-user education and training, better maintenance of vehicles and the road system.

Jacobs and Hutchinson [1] conclude that since the Smeed equation predict a greater decrease in fatality rate for an equivalent increase in vehicle ownership than does the equation derived for developing countries, it is possible that improvements in the safety of the road system, the vehicle and the road-user are not taking place as rapidly in the developing countries as in the more developed. If this continues, the accident situation is likely to become very serious indeed in the developing world particularly in situations of rapid motorization.

2.2 Micro Level

Data obtained on rural roads in Kenya and Jamaica were analysed separately by Jacobs [4]. From the analysis equations were derived which related RTAs per kilometre per annum to vehicle flow and RTAs per million vehicle-kilometres to the geometric parameters.

Regression analysis was used to establish and quantify the relationships between a dependent variable and one or more independent variables. The quantity under study was termed the dependent variable. The choice of the independent variables was such that they were 'sensibly' related to the dependent variable, simple to define and reasonably easy to measure for an engineer working in the field. As a first step investigation of which variables were most closely correlated with accident rate, simple regressions of accident rate on each of the road features individually, were performed. The equations derived were of the form

$$y = a + b_1 x_1 \qquad (2.6)$$

where y and x_1 are the dependent and independent variables respectively and a and b_1 the regression constant and coefficient respectively. Since many of the road design features are inter-related simple regression was thought to give a misleading impression of the relationships that they have with accident rate. Multiple regression, in which the accident rate is expressed as a function of several 'independent' variables simultaneously, was thought to be a better guide. The equations developed were then of the form

$$y = a + b_1x_1 + b_2x_2 + b_3x_3 + \ldots + b_nx_n \quad (2.7)$$

where, y, x_1, x_2, x_3, ... x_n, b_1b_2 ..., b_n were as above.

For these estimates to be acceptable it was necessary to test the hypothesis that the value computed for each regression coefficient was unlikely to have arisen by chance. To check that this was true, the standard error of each regression coefficient was computed and tested for significance, variables with non-significant coefficients being eliminated from the analysis. The computer programme used employed the technique called 'stepwise'regression analysis whereby non-significant variables are eliminated and tested with other combinations replacing them where necessary. The relationships significance levels used were 5 or 10 per cent where 5 per cent probability is the level usually accepted in statistical analysis. Due to the many factors affecting accident rates, a relationship found significant at 10 per cent level was also considered satisfactory. The correlation coefficient r was given as well as the coefficient of determination r^2, where r^2 provides a measure of the proportion of variability in y that is accounted for by variability in the appropriate x value.

The number of injury RTAs per kilometre of road per annum occurring on rural roads in Kenya was regressed against the vehicle flow per hour occurring, on each test road section, averaged over a 12-hour period (7 am - 7 pm). The accident rate was found to be related to the vehicle flow at a significance level of 5 per cent. The equation derived for Kenya was

$$y = 0.116 + 0.009x \quad (2.8)$$

where y = personal injury RTAs per km per annum
x = average vehicle flow/hour.

The regression equation of factors related to the accident rate, significant at the 5 per cent level, in Kenya was found to be

$$y = 1.45 + 1.02x_5 + 0.017x_3 \quad (2.9)$$

where, y = accident rate per million vehicle-kilometres
x_3 = horizontal curvature (deg/km)
x_5 = junctions per kilometre

At the 10 per cent level of significance the equation for Kenya was

$$y = 1.09 + 0.031x_3 + 0.62x_5 + 0.0003x_4 + 0.062x_2 \quad (2.10)$$

where y, x_3, x_5 were as above and

x_4 = surface irregularity (mm/km)

x_2 = vertical curvature (m/km)

Thus in Kenya junctions per kilometre was found to be the most significant independent variable with $r^2 = 0.49$. The road studied was the Nairobi-Mombasa, a two-lane single carriageway trunk road. There were never more than two junctions per kilometre. An addition of one junction per kilometre was associated with an increase in the accident rate of over one accident per million vehicle-kilometres.

In Kenya the horizontal curvature was found to be significantly related to the accident rate with a decrease of 35 degrees per kilometre reducing the accident rate by one accident per million vehicle-kilometres.

The effects of surface irregularity and vertical curvature were considerably less than those of junctions per kilometre and horizontal curvature. It was found that the rougher the road the higher the number of accidents per million vehicle-kilometres. An improvement in roughness of 200 mm per kilometre was associated with a reduction in the accident rate of 0.8 accidents per million vehicle-kilometres per annum.

On the Nairobi-Mombasa road, there was very little variation in the road width and the small amount of variation did not provide a significant relationship with accident rate.

In 1973 Silyanov [4] published the results of a comparison of accident rates on roads of different countries using data from Russia, Sweden, USA, Australia, England, Hungary, West Germany, Czechoslovakia, France, Japan and Norway. The data used was for personal injury RTAs.

It was found that the number of RTAs per kilometre of road per year increases with an increase in the hourly traffic flow with the relationship given by the equation

$$n_N = 0.256 + 0.000408N + 1.36 \times 10^{-7} N^2 \qquad (2.11)$$

for $40 < N < 1600$

where, n_N = number of RTAs per km of road per year on two-lane roads.

N = traffic flow (vehicles/hour).

The rise in the number of RTAs per vehicle-kilometer becomes markedly sharp when the width is less than 7 metres. The relationship was described by the formula

$$n_B = 1/(0.173B - 0.21) \qquad (2.12)$$

where, n_B = number of RTAs per million vehicle-kilometres

B = carriageway width (metres) assumed between 4 and 9 metres.

On the effect of the radius of horizontal curves the most dangerous curves were found to be those with radii less than 500 metres. The relationship was described as

$$n_R = 0.647 + 723/R - 649.5/R^2 \qquad (2.13)$$

where, n_R = number of RTAs per million vehicle-kilometres

R = the radius of horizontal curves in metres.

The longitudinal grade was found to greatly affect the RTA rate. The most dangerous effect of the grade was found to be apparent for vehicle movement down the grade. Silyanov [4] for the Russian data found that 65 per cent of all the vehicles involved on hills were moving downwards. The number of RTAs was found to increase continuously with an increase in grade, the increase being particularly sharp on grades of more than 3 per cent. The formula developed was

$$n_i = 0.265 + 0.105i + 0.0229i^2 \qquad (2.14)$$

for $0.5 < n_i < 7$

where, n_i = number of RTAs per million vehicle-kilometres

i = longitudinal grade expressed as percentage.

On sight distance many of the RTAs were found to occur on road sections where sight distance is less than 300 metres. The formula derived for the relationship was

$$n_d = 1/(0.200 + 0.00111d + 0.0000009d^2) \qquad (2.15)$$

for $25 < d < 800$

where, n_d = number of RTAs per million vehicle-kilometres

d = sight distance in metres.

Silyanov concludes that the practical application of the above relationships is for the detection of RTA black spots. Jacobs applied these relationships to study RTA rates in Kenya and Jamaica. His main finding was that RTA rates in developing countries, for similar levels of vehicle flow and geometric design, are considerably greater than in developed countries. It is noted however that some of the factors were not significantly related to RTA. Results from different countries also tend to contradict each other. No functional relationships between RTAs and road design elements have been developed for Kenyan roads to show how RTA rates vary characteristically with various design elements, pavement conditions and varying traffic conditions.

2.3 Road Traffic Accidents Characteristics

2.3.1 Road Traffic Accident Trends

Two deaths were recorded, in 1896 in Great Britain, as due to motor vehicles and one was recorded in the United States in 1899. From these small beginnings a terrible stream of road deaths and injuries has followed. Countries which have become highly industrialized and therefore motorized have suffered similarly to the extent that road accidents are the commonest cause of death in adolescents and young people, particularly males[20].

In most Western countries RTAs constitute the commonest single cause of violent death. For example, in Great Britain in 1963, after road deaths, death by suicide was the next highest cause. Similar trends were observed in Australia. In Canada road death rates showed an equally formidable increase over the period 1944-66 [17].

Smeed [17] has made the following observations in the general trends in RTAs:

- a general tendency for road deaths per registered motor vehicle to decrease as motorization increases. Yerrel [41] cautions that it should not be assumed that as the number of vehicles per person increases in any given country, that such a country will simply and automatically follow a declining path of deaths per vehicle as if obeying some absolute law of nature.
- a general tendency for road deaths per head of population to increase as motorization increases.
- despite the very large differences in traffic conditions in different countries, the number of road deaths in a given country can to a large extent, be predicted from a knowledge of the population and number of vehicles [1, 2, 3].

- the number of pedestrian fatalities in a given country is largely determined by its population and is not very dependent on its degree of motorization.
- as motorization increases, there is a tendency for injuries to occupants of motor vehicles to increase in number relative to injuries to pedestrians.
- a general tendency for road-user behaviour to improve as motorization increases.

An analysis of personal injury RTAs in Great Britain [3] showed the following RTAs trends:

- a steady increase of the total number of casualties for the period 1939-1960s.
- motorcyclists experiencing the greatest number of casualties, of the different classes of road users including children and adults.
- old people having the highest death rate.
- a very large number of casualties to pedal cyclists, motorcyclists and drivers on week-days during the hour 5-6 p.m.
- casualties to child pedestrians being more numerous in summer than in winter while adult pedestrian casualties were found to be relatively more frequent in winter.

- accident rates by night generally exceeding those by day.
- the total number of casualties tending to be greater in wet weather than in dry weather in winter.
- lowest RTA rates occurring on motorways and rural roads in open country and the highest in the centres of large towns. Death rates were found to be low in towns but high on unrestricted roads leading into large towns.
- of the different classes of vehicles, the motorcycle, per kilometre ridden, was found to be the most dangerous from the viewpoint of risk to the driver. The pedal cycle was found to be the next most dangerous. Also from the viewpoint of injury to the pedestrian, the motorcycle, per kilometre ridden, was found to be the most dangerous.
- risk of death, relative to the risk of injury was found to be the greatest for pedestrians.

In the Federal Republic of Germany, Froboese [30] gives the following RTAs trends in the period 1970-82:

- the number of casualties decreased slightly, that of deaths decreased considerably while the number of RTAs did not go down.

- despite the great increases in traffic volumes, the risk of becoming involved in a RTA decreased.
- motorways were found to be the safest roads for motorized traffic.
- the risk, for the occupants of passenger cars, of being injured decreased considerably.
- the number of RTAs involving pedestrians diminished.
- the number of RTAs involving cyclists increased noticeably.
- the RTA risk of the drivers of two-wheeled power-driven vehicles reached an alarming level.
- the number of children involved in RTAs, in particular the number of those killed greatly decreased. As pedestrians they were found to be less endangered, but as cyclists their risk increased.
- Beginner drivers were found to be especially exposed to danger and of particular danger to other road users.
- RTAs outside built-up areas were found to have particularly consequential effects, but the rate of RTAs within built-up areas was found to be higher.

- RTAs involving only one vehicle and collisions with unprotected road users were found to be with the most serious consequences.
- excessive speed and driving under the influence of alcohol were found to be the main causes of serious RTAs.

Sloth and Bach [28] have observed that the number of RTAs and the number of fatalities have followed a similar pattern in most industrialized countries, until they reached unacceptable levels during the late 1960s. For the developing countries, Yerrell [41] has observed that death rates are very often 20 times greater than those of Western Europe or North America. For the period 1978-1980, for 35 developing countries Yerrell found a negative correlation between fatalities per vehicle and the number of vehicles per head of population, showing that the smaller the number of vehicles relative to the population the worse the death rate relative to those vehicles.

2.3.2 Road User Characteristics

2.3.2.1 Driver

The driver's part in RTAs is a question of the adequacy of his response to the road environment [3]. Driver characteristics result from the influence of psychological and physiological characteristics on the performance of the driving task and the interaction of the driver with other road users and the road environment. Drivers, like other road users, are both recipients and causers of RTAs [20]. Various studies concerning driver characteristics are summarised below.

In Great Britain in 1959 [20], drivers of cars, commercial and passenger vehicles comprised 11.2 per cent out of a total of all persons killed on the roads. Using data from Belgium, Denmark, Great Britain, Italy and Sweden [20] it was found that the number of deaths of motor vehicle drivers is not closely related to traffic density or to the number of registered vehicles.

The age distribution of drivers killed showed a peak in Great Britain below the age of 30 [20]. Serious injuries to car and taxi drivers in Great Britain was found to be about 13 times, and slight injuries about 44 times, the number of RTA deaths amongst drivers. In the United States in 1959 [20] drivers under the age of 25 were found to have a considerably worse RTA ratio than that of all drivers. The lowest fatal - RTA ratios were found to be for those aged 50 to 60 (less than half those for drivers under the age of 25). In a London transport study of professional bus drivers for the period 1957-59 it was found that [20] there was a relatively high RTA rate in young and inexperienced drivers. Those under 30 with less than four years of service had nearly four times as many RTAs as the best group, those that were aged 60-64 with about 14 years of service. In the United States it was found that driver rates in fatal RTAs begin to rise at about the age of 65. In Finland in 1958 [20] no correlation was found between age and RTAs. Based on the number of RTAs per vehicle-kilometres of travel age was found to affect RTAs only in the over 65 age group in the United States [21]. Drivers under 25, representing 21 per cent of the driving population in the United States, were found to be involved in 34 per cent of the fatal RTAs.

In the United States [21] persons identified as suffering from epilepsy, heart disease, diabetes and mental illness were found to have a RTA rate roughly twice that of the general public whereas only 0.6 per cent of drivers fell into this category. Drivers with physical defects in sight, hearing and similar impairments were found to be involved in only 1.3 per cent of deaths and 0.6 per cent of all RTAs. It was concluded that physical defects are not a major contributor to RTAs.

Epidemiological studies [18, 20, 21, 26] show that driving occur during periods when drivers are under the active influence of drugs and alcohol. It has been found that tranquilisers, barbiturates and cannabis lead to impairment of driving skills [18]. Drinking drivers are one of the most serious causes of all RTAs problems [21]. Physically and mentally the drinking driver is RTA-susceptible. In the United States the following alcohol related characteristics were found [17]:

- drinking drivers responsible for fatal RTAs had higher Blood Alcohol Concentration (BAC) than those involved in non-fatal RTAs.
- as far as single vehicle RTAs were concerned, 70 per cent of the drivers who died had been drinking beforehand. Further, in fatal single-vehicle RTAs, 49 per cent of the drivers were found to have BAC greater than 0.15 per cent whilst 20 per cent more had BAC between 0.05 and 0.15 per cent.
- alcohol was a factor in about half of all RTA fatalities.
- alcohol was related to RTAs in 30 to 70 per cent of instances.
- persons driving under the influence of alcohol, who were regarded as alcoholics, crashed their vehicles at higher speeds than did social drinkers.
- simple driving skills became impaired when BAC exceed 0.1 per cent.

- alcoholics were liable to incur six times as many RTAs and traffic violations as healthy drivers or drivers affected by medical illnesses uncomplicated by alcohol. In the United States 3 per cent of the drivers are alcoholics, and 4 per cent are "escape" drinkers [21]. Further, of the licensed drivers in the United States, all but 32 per cent drink [21].
- the presence of cirrhosis of the liver was found to be over 60 per cent in those persons who had substantial amounts of alcohol in their bodies at the time of death in RTAs.
- the ages of drinking drivers were found to be predominantly above 25 years.

Studies in Australia revealed the following characteristics concerning the effect of alcohol [17]:

- 40 per cent of drivers taken to hospital as a result of RTAs had BAC levels greater than 0.05 per cent.
- of the road fatalities 39.4 per cent were found to have BAC levels greater than 0.1 per cent.
- 60 per cent of the drivers killed in single vehicle RTAs had BAC levels greater than 0.1 per cent.

- drinking drivers tended to be older, mostly male and came from the lower occupation groups.

Similar studies in Great Britain [17] showed the following characteristics about drinking and driving:

- of the drivers involved in RTAs 41 per cent had been drinking with 34 per cent having BAC levels greater than 0.05 per cent.
- drivers who had been drinking were most frequently involved in single vehicle RTAs.
- of the dead drivers 19 per cent had BAC greater than 0.1 per cent.
- the 30-39 age group had the highest BAC found to be greater than 0.15 per cent.
- 50 per cent of the drivers involved in RTAs between the hours of 10 p.m. and 4 a.m. had been drinking.
- the highest RTA rates were found to occur at week-ends after 10 p.m. when licensed alcohol selling premises closed.

In Canada the studies [17] showed that 28 per cent of all drivers convicted of drunken driving were alcoholics who had repeated RTAs and were less concerned with careful driving after moderate or heavy intake than were those alcoholics who managed to stay out of trouble. The RTA repeater alcoholic believed that liquor had no effect on his competence to drive. In Romania [17] it was found that 28 per cent of the drivers suspected of driving under the influence of alcohol had been involved in RTAs. In Cechoslovakia [17] persons with BAC greater than 0.15 per cent were found to have a 124-fold greater risk of being involved in RTAs when compared with those with lower alcohol levels in their blood. In Finland [17] some 14.6 per cent of road deaths were found to be due to alcohol whereas in Poland the proportion was found to be 15-19 per cent. On the whole most studies [17] show that in the vast majority of cases involving alcohol the subject is male and more commonly in the 30-60 age group. The peak age period for road deaths among drivers lies between 15 and 25. Alcoholism, particularly when complicated by mental and physical illnesses, is an affliction of the middle-aged, a clinical factor of universal occurrence.

2.3.2.2. Pedestrian

The pedestrian as a factor carries much of the responsibility for RTAs mainly for his own safety. The main findings with respect to pedestrian characteristics are as follows:

- in Great Britain RTAs to pedestrians account for about 40 per cent of the fatal RTAs and about 20 per cent in the United States and mostly occurring in urban areas [20].

- the age distribution of fatally injured pedestrians is uneven. From the walking age to age 10 and from age 65 upward pedestrians are at special risk [20]. In Great Britain [3] comparing the number of pedestrian casualties with the population in each age group the maximum risk occurred for the 5-9 year old with risk increasing with age for those over 40. Children under 10 were found to be likely victims of the light commercial vehicles while persons over 70 years of age were more frequently involved with motorcycles and pedal cycles as compared with other age groups.

- the total number of pedestrians injured is about 25 times the number killed. Pedestrian deaths increase at periods of peak travelling, in cities particularly, during working days [20].

- in the United States pedestrians fatally injured consisted of the elderly who had been drinking alcohol a little or not at all and a group of the middle-aged who had been drinking heavily [20]. Further studies in the United States showed that alcohol was causally involved in

- more than 30 per cent of all fatal pedestrian RTAs [18].

Further findings in Great Britain [3] indicate that:

- the number of pedestrian casualties increases at a lower rate than the traffic flow.
- about 67 per cent of pedestrian RTAs the pedestrian is likely to be crossing the road.
- the relative frequencies with which different types of vehicle collide with pedestrians varies with the crossing place.
- the proportion of pedestrian casualties whose injuries were due to being hit by motorcyclists was higher on uncontrolled crossings than elsewhere.

2.3.2.3 Pedal Cyclist

The pedal cyclist like the pedestrian is unprotected unless cycling on cycle tracks. Findings from Great Britain [20] show that pedal cyclists killed annually form about 11 per cent of the total RTA deaths. Those aged 7-15 and the elderly form the higher proportion of pedal cyclist deaths. For each cyclist death there are 75 injuries. The proportion of those killed to the injured pedal cyclists was observed to rise with increasing age.

2.3.2.4 Motorcyclist

The motorcyclist like the pedal cyclist is also unprotected. Moreover, the motorcycle is capable of very high speeds implying greater risk and severe injury. In the United States [20] out of RTA deaths 17.3 per cent have been observed to be motorcyclists. Motorcycle fatalities affect the younger age groups heavily. In Great Britain [20] about 70 per cent of motorcycle deaths affected the age-group 18-40, the majority being male. Thus length of experience and power of motorcycles were found to be the two most important factors in RTAs to young motorcyclists.

In the United States studies [20] have shown that about 1 per cent of registered vehicles are motorcycles which are responsible for 1.3 per cent of the fatal RTAs, showing that the degree of risk to motorcycle riders increases. Studies in Great Britain [21] indicate that the death rate per kilometre for motorcycles was over 20 times that for motor vehicles while the personal injury rate is 3 times as great. In the United States the corresponding figure was found to be 4:1.

2.3.3 Vehicle Characteristics

The proportion of RTAs in which defects in vehicles are thought to be the primary contributor has been shown to be relatively small [20,21,50].

In Great Britain one study [20] showed that only 2.5 per cent of casualties in RTAs were attributable to brake, tyre and steering defects. In the United States [21] in fatal RTAs 2-11 per cent were traced to vehicle defects. In one study in the United States [20] one out of five passenger cars and one out of four trucks inspected were found to require maintenance. Some striking differences in the statistics of vehicle defects in RTAs have been observed. The common belief has been that vehicle inspection is carried out in order to decrease the risk of RTAs through badly maintained vehicles. However, studies have not been conclusive in directly linking poorly maintained vehicles to RTAs [21].

2.3.4 Road Characteristics

Various studies in different countries have shown a strong correlation between RTAs and road design, construction and surfacing. Studies carried out in the United States [55] showed that simply resurfacing and/or widening of substandard roads increases speeds and hence increases the number and severity of RTAs. It was found out that improvements in highway geometry and alignment should be undertaken as well. Road features such as right curves, left curves, upgrades and downgrades were found to have equal traffic exposure. Left curves had a greater

RTA rate than right curves. The explanation was that there is a tendency for vehicles to depart to the right side of the road due to the fact that if a vehicle leaves the travel lane to the left, the adjacent lane allows room for recovery. There was also found a higher RTA rate on curves than on tangent sections. Most of the single vehicle RTAs involved departure on the outside of the curve rather than the inside. The explanation was that a moving object continues along a straight path unless redirected and hence the vehicles tend not to turn enough rather than turn too much. In these studies it was further found out that amany factors, often independent, influence RTAs. It was difficult to find sites where all the important factors are similar for generalization to be made. It was therefore proposed that in future studies, other types of analyses involving operational measurements and theoretical simulations be used to determine the relationship between highway design elements and road safety.

Additional research in the United States [12] on highway features and in particular on downgrades showed that downgrades were overrepresented as RTA sites. The RTA rate for downgrades was found to be 63 per cent higher than for upgrades while left curves were found to be most RTA prone. Injury rates were higher on curves than on tangent sections, higher on downgrades than upgrades and lowest for level straight sections. There were also results which appeared to be contrary to the view that improved conditions are safer. The possible explanation for this was that the better the road, the more careless the driver. However, experience with substandard roads has shown that high design standards have led to improved transportation and road safety.

Studies in the United States [11] to develop and test RTA prediction techniques showed that highways in mountain terrain cause problems especially for large commercial vehicles. The data collected included horizontal curvature, vertical alignment, percentage grade and length of grade. The problems were explained to be poor manouvrability, poor performance on upgrades and braking on descending grades due to loss of vehicle control, loss of brakes and improper downshifting of gears. The results of the analysis showed that:

- there was an increase in the RTA rate as the slope increases.
- a series of curves of decreasing radius place greater demands on vehicle brakes than of increasing radius.

- the average slope of a downgrade is not as significant as horizontal curvature at specific subsections of the grade.
- most RTA prone locations occurred just downgrade from sections of increasing horizontal curvature.
- irregular curves with frequent discontinuities were more RTA prone than smooth curves with few discontinuities.

However, the study was found to be limited in that there was poor agreement in some results due to the small sample size used.

Tests on road safety in Great Britain [10] on a motorway dual carriageway showed a marked relationship between RTA rate and alignment. The results showed that:

- there was a difference in RTA rate for the two carriageways. There was no direct evidence to suggest the reason for this but the possible reasons suggested were driver fatigue, effect of sunglare, differences in skidding resistance due to different surfaces and road gradients.
- relating RTA rate to the curvature and gradient of the carriageway, evidence was found of higher RTA rates on gradients on curved sections than on straight sections.

- the effect of travelling downgrade was found to cause a lot of RTAs. This effect was found to increase stopping distances in three ways: the vehicle achieves greater speed, a small component of the vehicle opposes braking and the friction between the tyre and the road is less

Studies in Denmark [29] on RTAs on different types of roads and intersections as a function of the traffic flow showed that:

- the lowest number of RTAs is still to be found on motorways.
- for a given increase in the traffic volume, the increase in the RTA load will be less. Therefore, it pays off to gather the traffic on a few safe roads instead of spreading it on a large road network.
- the RTA frequency is lower on road sections lined with marginal strips, cyclepaths and the like compared to road sections without marginal stripping and paths. Furthermore, it was concluded that a broad delimitation will yield a lower RTA rate on road sections up to 7 metres compared to narrow types of delimitation.

- two-lane urban roads of 6-9 metres have about twice the number of RTAs of rural road sections per kilometre.
- the number of RTAs per kilometre decreases on two-lane rural roads when the road width is increased up to 7-8 metres as a maximum. Therefore, a further reduction in the number of RTAs cannot be expected by widening two-lane roads with a width of carriageway of 7-8 metres.
- at two-lane roads with ribbon development the number of RTAs per kilometre increases with increasing width of carriageway up to 9 metres.
- signalized four-armed intersections have the highest number of RTAs. In general, the three-armed intersections have lower RTA numbers than the four-armed intersections.
- the black-spot calculations pointed out 11 per cent of the total section length and 5 per cent of the intersections as black-spots.

2.3.5 Road Traffic Accidents Characteristics in Kenya From Previous Studies

An analysis of RTAs in Kenya for the year 1972 [53] showed that:

- the greatest number of RTAs occurred in Nairobi (40 per cent of the total). The number of casualties was also greatest in Nairobi, being 30 per cent of the total.

- the lowest RTA and casualty rates occurred in Nairobi, however. These lower rates were attributed to the fact that almost all the vehicle-kilometres travelled took place in built-up areas where vehicle speeds on average are much lower than elsewhere in Kenya.
- in Nairobi almost 50 per cent of all RTAs involved pedestrians.
- Central, Eastern and Western Provinces had a large majority of casualties occurring in rural areas on roads without 30 or 45 kilometres per hour speed limits.
- in urban areas 14 per cent of all RTA casualties were fatal and 28 per cent were serious. The equivalent figures for Great Britain in 1971, were 2.2 and 25.4 per cent. These differences were found to be statistically significant at the 5 per cent level.
- in rural areas over 16 per cent of all casualties were fatal. This level of severity was found to be consistent with observations in other countries including Great Britain. It was attributed to the fact that RTAs occur at higher speeds in rural areas and that medical treatment is less readily available there.

- 38 per cent of all road casualties occurred to car occupants, which is low compared with most European countries.
- 26 per cent of all road casualties involved pedestrians, which is similar to the situation in Great Britain, Yugoslavia and Spain but rather high compared with Germany, France and Italy. However, the rate of pedestrian casualties per head of population was found to be low in Kenya compared with Great Britain. Pedestrian casualties per head of population was slightly higher in Nairobi than the average value for urban dwellers in Great Britain.
- 16 per cent of the total casualties were occupants of commercial vehicles. This was found to be high compared to most European countries where the percentage is of the order of 5.
- the proportion of two-wheeled motor vehicle casualties was under 5 per cent of the total, being very low compared to European figures.
- 45 per cent of all fatalities were pedestrians.
- of the total casualties 11 per cent are juvenile casualties. The equivalent figure for Great Britain is 18 per cent and for Ghana 23 per cent. Over 19 per cent of all juvenile casualties were fatal whilst the equivalent adult value was 14

per cent, the difference being statistically different at the 5 per cent level. In Great Britain the reverse is the case with 2-3 per cent of the adult casualties being fatal and 1.4 per cent of the juvenile casualties (under 15 years of age being fatal.

- over 12 per cent of all casualties occurring during daylight were fatal, whilst during darkness the equivalent figure was 17 per cent.
- 75 per cent of all casualties were injured during the day and 22 per cent during darkness. In Great Britain a greater percentage of all casualties occurred in darkness (36 per cent), a difference attributed to proportionately more driving being done during darkness than in Kenya.
- the incidence of RTA casualties in Kenya rose sharply between 6 a.m. and 7 a.m., continuing throughout the day to reach a peak at 5 p.m. The casualty rate then decreases sharply until the following morning. In Great Britain for casualties a peak is reached at 5 p.m. but another peak occurred at midnight, attributed to a greater proportion of travel at night and a greater incidence of drinking and driving in Great Britain than in Kenya.
- the highest number of casualties occurred on Saturdays and Sundays whereas in Great Britain

the highest numbers occured on Fridays and Saturdays. The difference was found to be statistically significant at the 5 per cent level and differences in social patterns were thought to be the main reason for the difference.

- the greatest number of casualties occurred in March, April and September. In Great Britain, Sweden, Germany and Yugoslavia the number of casualties were highest in November and December. In Great Britain periods of a high number of casualties do not coincide with high traffic flows. The casualties are affected by short hours of daylight and extreme weather conditions. No evidence of a regular pattern of seasonal traffic flow variation had been observed in Kenya. Therefore, there was no evidence to support the notion that traffic flows are greatest in the month containing the highest number of casualties. In Kenya the climate follows a strong seasonal pattern with long rains in March, April and May and short rains in November. The first period coincides with months when casualties are highest.

- vehicle-pedestrian RTAs were the most frequent being over 39 per cent of the total. In Great Britain the equivalent figure is 29 per cent, the most common RTA being the vehicle-vehicle

RTA which accounts for 45 per cent of the total whilst in Kenya it is 18.2 per cent. Single vehicle RTAs in Kenya were 27.4 per cent of the total for the equivalent figure of 19.5 per cent in Great Britain. Nearly 75 per cent of all single vehicle RTAs were found to occur in rural areas in Kenya whereas the equivalent figure in Great Britain was 42 per cent. The differences were statistically significant at the 5 per cent level.

- on surfaced roads, vehicle-pedestrian RTAs were commonest whereas on murram and unsurfaced roads single vehicle RTAs were the most common. Over 77 per cent of all RTAs occurred on surfaced roads and 18 per cent on murram roads. With 5 per cent of the total vehicle kilometres travelled in Kenya taking place on murram roads, the RTA rate per vehicle-kilometre is much higher on murram roads than on surfaced roads.
- cars and land rovers were involved in 60 per cent of all injury RTAs reported. Motorcycles had the lowest rate, a pattern commonly found in most European countries. In Great Britain however, public service vehicles have a higher RTA rate than private cars since public service vehicle journeys are made in heavy traffic with high occupancy rates.

An epidemilogical review of RTAs in Kenya for the period 1968-73 [23] found that the main factors were behavioural in nature and related to the drivers who accounted for 48 per cent of all RTAs, the pedestrians who accounted for 24.3 per cent, vehicle defects which accounted for 5.3 per cent and road defects which accounted for 2 per cent of the total.

In a review of RTAs in Nairobi for the period 1968-72 [24] it was found that:

- the severity index was 8.9 per cent.
- the fatality rate per 10,000 persons was 3.44.
- seasonal variation of RTAs appeared to be related to the climatic seasons by month of the year, day of the week and time of day.
- children, students and civil servants were greatly involved in RTAs and their casualties resulted in 29 per cent of all RTA deaths.
- the fatality figure for the males was 5 times the figure recorded for the females.
- vehicle drivers were responsible for 48 per cent of all RTAs and the pedestrians were responsible for 36.2 per cent of all RTAs.
- 93.9 per cent of all RTAs were caused by road users.

In a further study on RTAs involving children under 12 years in Nairobi [19] during the year 1975 it was found that:

- RTAs ranked 14th among the top killers in all age groups of children and 2nd in the older more exposed school age group of 5-12 years.
- among the adults RTA deaths accounted for 10.3 epr cent of all deaths and for all ages RTA deaths accounted for 5.9 per cent.
- among RTA deaths there appears to be a male preponderance consistent with findings in the rest of the world.
- 60 per cent of the children involved in RTAs were unaccompanied at the time of the RTA, of whom 60 per cent were school children.
- for every RTA death there were 5 serious injuries and 8-19 slight injuries.
- RTA cases accounted for 7 per cent of all surgical admissions.

A study undertaken to establish the level of traffic laws violation in selected roads in Nairobi [25] indicated how unsafe it is to travel in Nairobi with 3-5.8 per cent of the drivers failing to conform to the traffic lights requirements, 2.8 per cent of the drivers failing to stop at a mandatory stop sign and 24 per cent of the drivers failing to keep to the proper lanes on a roundabout.

The pattern of RTAs in Kenya has been summarized [51] as follows:

- the RTA rate is stable, while the fatality rate is increasing,
- fatal RTAs constitute 15 per cent of the total,
- 60 per cent of all RTAs occur in rural areas,
- 47 per cent of all RTAs occur on rural tarmac roads,
- 45 per cent of all RTA deaths are pedestrians,
- 25 per cent of RTAs occur after dark,
- 12 per cent of RTA deaths involve vehicle occupants,
- 43 per cent of vehicle - pedestrian RTAs occur on tarmac roads, being 36 times the rate elsewhere,
- 40 per cent of RTAs on rural roads involve single vehicles.

An inventory of the factors and activities related to road safety in Kenya in the late 1970s [26] revealed:

- lack of adequate traffic enforcement, which is leading to unconcern about traffic rules and regulations,
- careless and incorrect driving, in which traffic rules are ignored, leading to too high speeds, careless overtaking and lack of care for safety in light traffic.

- passenger transportation on open platforms of commercial vehicles and extremely overloaded matatus,
- the absence of pedestrian and bicycle lanes or separated tracks next to main roads in densely populated areas,
- shortcomings in the pedestrian and bicycle facilities in urban areas, such as the insufficient and too narrow footpaths, too few pedestrian crossings and non-existent two level street crossings,
- the bad condition of some main highways, particularly of the pavement.
- use of improperly maintained and imperfectly equiped vehicles,
- driving under the influence of drink,
- lack of traffic education and information, leading to the ignorance of traffic rules and regulations.

2.4 Appraisal of Previous Research

The Ministry of Transport and Communications has besides the above studies carried out work on the development of an accident data system , a study of dangerous (black spot) locations and investigations on some selected RTAs. The accident data system is based on police RTA records and is aimed at providing statistical information for analysis and dissemination. The study of dangerous locations on roads under the ministry was aimed at the development of countermeasures for highway improvement and consequently road safety improvement. The accident investigation was short-lived and failed to generate further research. Other research on study areas being pursued by the ministry include the review of the traffic legislation in Kenya, monitoring of alcohol amongst drivers, speed checks and the development of road safety devices. Findings from these activities are yet to be studied more comprehensively in order to yield concrete findings and conclusions which will facilitate further research and improvement in safety.

The Smeed relationships [1,3] for the developed countries and the Jacobs and Hutchinson's [1] relationships for the developing countries have been used for international comparisons of accident statistics. These so-called Smeed relationships are merely statistical relationships which do not imply in any way causal relationships. Firstly, international comparisons are made difficult due to the absence of common definitions of death. Secondly, whilst the countries of Western Europe are uniform in many ways developing countries, particularly those of Africa, have wide diversity of conditions and limitations. In particular there is diversity in areal extent, populations, gross national products, road provision per head of population as well as motorization. Therefore the Smeed, Jacobs and Hutchinson's relationships cannot adequately predict fatalities for all countries with the kind of accuracy required for monitoring road safety programmes. Moreover fatalities are not the only parameter that needs to be predicted in RTAs characteristics.

The Silyanov relationships are useful for the detection of RTA black spots for similar traffic conditions. Thus they cannot predict RTA rates for roads of such countries as Kenya which have vastly different traffic and accident characteristics from those studied by Silyanov. Results obtained by the application of these relationships tend to be contradictory.

As an improvement to the foregoing work it is necessary to study the accident situation comprehensively using data available from as far back as records exist to facilitate the development of RTA characteristics and trends over long periods. These trends can then form the basis for prediction of the accident situation in those countries and the possible future directions. Moreover, the study of an individual country's statistics will aid in a better understanding of the accident situation before remedial measures can be developed. Further, the relevant predictive models of the accident trends can be a powerful monitoring tool for road safety improvements. Also, a systematic study of RTAs on a given road or roads over a considerable period of time with varying traffic conditions and geometric design can help in the developement of functional relationships between the various design elements and the accident rates related to the changes in those elements.

2.5 Study objectives

The objectives of this study therefore are:

- to develop predictive models for RTAs in Kenya at the national (macro) level to be used for monitoring the performance of road safety improvement programmes,
- to develop predictive models for RTAs on Kenyan roads at the micro level to aid in the proper understanding of the behaviour of RTAs and the various design elements,
- to study RTAs in Kenya with a view to determining the fundamental and long term characteristics and where possible the causes or reasons for these observed characteristics.

CHAPTER 3 - THEORETICAL ANALYSIS

3.1 Functions in Road Traffic Accident Theory

Road traffic accidents theory is an analytical study that should be concerned with relations that exist, or can be assumed to exist, between quantities which are numerically measurable. Variable quantities in RTAs are, among others, RTA numbers, population of vehicles and humans, growth rates associated with those, road width, road curvature, road gradients and other factors related to the vehicles and roads. Some of these quantities are measurable in physical or 'natural' units. It is sufficient that they are measurable in some units. Mathematical methods are possible in RTA analysis and relations are expressible by means of mathematical functions.

The relations of RTAs, and their related functions which seek to express their form, are usually of unspecified or unknown form. For example, a RTA function cannot automatically be said to be linear or quadratic in form, although it is sometimes convenient to assume that it can be approximately represented in one of such ways. RTA conditions and the very nature of their occurrence impose certain limitations on the form of the functions. Fortunately by considering the problems of RTAs it is possible to say that the function concerned has the mathematical property of being single-valued and decreasing, or may be represented by a certain mathematically shaped curve. This representation is sufficient for the profitable use of mathematics and the understanding of the variations in the measurable quantities in RTAs.

Analytical methods are therefore applicable to RTA problems and their analysis. However, mathematics is a tool for analysis and not a master! In this chapter the theoretical basis, which forms the background for analysis in chapter 4, is set out. The necessary formulae and the curve equations used for curve fitting are presented. These formulae form the basis for the development of the predictive models. The statistical techniques and formulae for testing the fitness of the model equations are stated. Finally, the method of the final analysis is stated. The method of the final analysis used compares predicted data with observed data with the aim of establishing how well the developed models predict observed RTA data as well as the related observed road traffic data.

3.1.1 General Theory of Functionals [8]

The theory of functionals deals with functions of a finite number of variables. The variations of quantities depend on one or more other quantities as well as functions which take a quantity as dependent not only as a finite set of other quantities but upon one or more variable functions.

A variable quantity u is defined as taking its value from the form assumed by a function

$$x = \phi(t) \tag{3.1}$$

To each function $\phi(t)$ corresponds a definite value of u. As the form of the function is changed so is the value of u changed. The dependence of u upon $\phi(t)$ is called a functional and written as

$$u = F\{\phi\} \tag{3.2}$$

A function of a function is expressed as

$$u = F\{\phi(t)\} \tag{3.3}$$

This assumes that $\phi(t)$ is a given function of t and that u is also a definite function of t. The functional takes ϕ as a variable function associating one value of u with each whole function ϕ. The variable t does not itself appear in the determination of u in the functional relation. Generally, when u is a functional of several variable functions $x = \phi(t)$, $y = \psi(t)$, $z = x(t)$; ... the function takes the form

$$u = F\{\phi, \psi, x, \ldots\} \qquad (3.4)$$

The functions ϕ, ψ, x, ... may be functions of several variables instead of one variable t only. In Fig.3.1, the variable function $x = \phi(t)$ is shown by a variable curve C in the plane 0xt. As the form of the function changes (ϕ_1, ϕ_2, ϕ_3, ...), the curve C shifts and takes up different positions and shapes (C_1, C_2, C_3, ...). If u is a functional of ϕ, then its value depends on the particular position taken by the curve C, and to the series of positions (C_1, C_2, C_3, ...) there corresponds a series of definite values of u (u_1, u_2, u_3, ...).

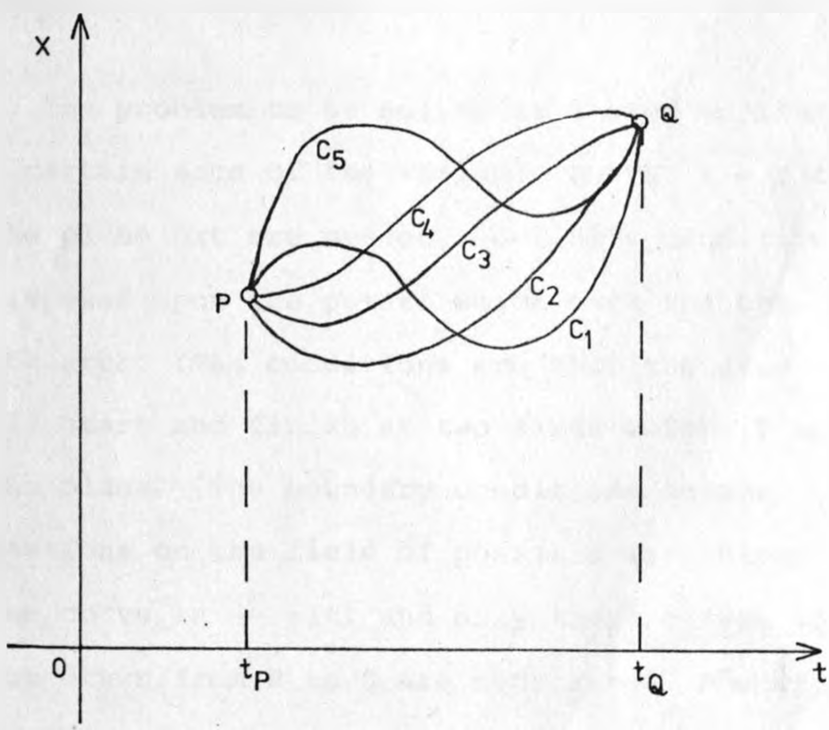


FIG. 3.1 VARIATION OF FUNCTION AND CURVE SHAPE

3.1.2 Calculus of Variations [8]

Frequently the functional $u = F\{\phi\}$ takes the form of an integral. If f(t) is a function varying in form as (t) varies then

$$u = \int_{t_P}^{t_Q} f(t)\,dt \qquad (3.5)$$

where t_P and t_Q are certain limits of integration. The value of u depends on what particular form is taken for $\phi(t)$ and hence for $f(t)$. The problem usually encountered is the determination of that function ϕ which makes u a maximum or a minimum.

The problem to be solved is stated so that only certain arcs of the variable curve $x = \phi(t)$ in the plane Oxt are needed. Definite conditions are imposed upon the points which mark the ends of the arcs. The conditions are that the arcs should start and finish at two fixed points P and Q in the plane. The boundary conditions impose limitations on the field of possible variation of the curve $x = \phi(t)$ and only those curves which can be drawn from P to Q are considered. Analytically, the function $x = \phi(t)$ can only be selected provided that $\phi(t_p) = x_p$ and $\phi(t_Q) = x_Q$ where $P(t_p, x_p)$ and $Q(t_Q, x_Q)$ are the two fixed end-points.

Although the boundary conditions are considered, the field of variation of the function $x = \phi(t)$ is so large that the analysis of the problem is practically impossible unless the field of variation is limited by a further device. For, example, it is possible to take only those functions satisfying the boundary conditions, which are continuous and possess continuous derivatives up to any desired order. Further still, the field could be severely limited by taking functions of a particular type of curves of a particular class. For example, only those functions of the quadratic form represented by parabolas with vertical axis may be taken. The function type or curve class can be represented by a relation involving certain parameters $\alpha, \beta, \gamma, \ldots$ The larger the number of parameters the more general is the function type or class of curve. Consequently, the limitation on the field of the variable functions is to replace the function $x = \phi(t)$ of variable form by

$$x = \phi(t; \alpha, \beta, \gamma, \ldots) \qquad (3.6)$$

where ϕ is now of fixed form and the variation of the function is replaced by the variation of the parameters involved. Thus the function is limited to a more restricted variation described by parameters in a function of fixed form. If the parameters are few the restriction is very severe. For example, if only three parameters are used the function takes the form

$$\phi(t) = \alpha t^2 + \beta t + \gamma \qquad (3.7)$$

so that the variable curve is limited to the class of parabolas with their axes vertical and parallel to 0x. But by taking more parameters the field of variation of the function type is more generalized. If a sufficiently large but finite number of parameters is selected, the restricted field of variation is made different in a few vital respects from the complete field. This is achieved by excluding from the latter the more unusual kinds of functions. The problem of the calculus of variations is thus reduced to a problem of extreme values of an ordinary function of several variables ϕ, β, γ,... Functionals are changed back into functions. The step from functionals to functions is reversed. A functional can be regarded as a function of an infinity of variables. Approximations are made by taking a function of a large number of variables, the parameters α, β, γ,... The extent to which the simplified form approximates the original depends on the number of parameters taken. The vital point about the analysis is that it is quite independent of how many parameters there are, provided their number is finite. The solution obtained is not perfectly general but provides an approximation sufficiently descriptive for practical purposes.

The function $f(t)$, which gives the variable u on integration, depends upon the variable function $x = \phi(t)$ and the derivatives of ϕ. For example, using only the first derivative $\phi'(t)$ and the function $\phi(t)$

$$f(t,x,\frac{dx}{dt}) = f\{t,\phi(t),\ \phi'(t)\}. \tag{3.8}$$

This is a function of t given in the function of functions form. The function ϕ is of variable form, as well as the function f to be integrated. It is further assumed that the boundary conditions are such that the variable curve $x = \phi(t)$ pass through two fixed points P and Q. In particular setting P and Q as 0 and 1 respectively the problem reduces to one of finding extreme values of the integral

$$u = \int_{t_o}^{t_1} f(t,x,\frac{dx}{dt})\,dt \tag{3.9}$$

for all possible variations in the function $x = \phi(t)$, such that $\phi(t_o)x_o$, $\phi(t_1) = x_1$ where (t_o, x_o) and (t_1, x_1) are the fixed points.

To solve equation (3.9) the limitations above are imposed on the variation of $\phi(t)$ taking the functions in the form of equation (3.6) where ϕ is a fixed function with a continuous derivative and α, β, γ,... are parameters. Alloting arbitrary differential increments $\delta\alpha$, $\delta\beta$, $\delta\gamma$,... to the parameters the corresponding variations x and x' are first derived in the function x and its derivative $x' = dx/dt$. Thus

$$\delta x = \frac{\partial x}{\partial \alpha}\delta\alpha + \frac{\partial x}{\partial \beta}\delta\beta + \frac{\partial x}{\partial \gamma}\delta\gamma + \ldots \qquad (3.10)$$

$$\text{and } \delta x' = \delta\left(\frac{dx}{dt}\right) = \frac{\partial}{\partial \alpha}\left(\frac{dx}{dt}\right)\delta\alpha + \frac{\partial}{\partial \beta}\left(\frac{dx}{dt}\right)\delta\beta + \frac{\partial}{\partial \gamma}\left(\frac{dx}{dt}\right)\delta\gamma + \ldots$$

$$= \frac{d}{dt}\left(\frac{\partial x}{\partial \alpha}\right)\delta\alpha + \frac{d}{dt}\left(\frac{\partial x}{\partial \beta}\right)\delta\beta + \frac{d}{dt}\left(\frac{\partial x}{\partial \gamma}\right)\delta\gamma + \ldots$$

$$= \frac{d}{dt}\left(\frac{\partial x}{\partial \alpha}\delta\alpha + \frac{\partial x}{\partial \beta}\delta\beta + \frac{\partial x}{\partial \gamma}\delta\gamma + \ldots\right) = \frac{d}{dt}(\delta x) \qquad (3.11)$$

All the variations here are ordinary differentials and subject to the ordinary rules of differentiation.

where, "d" refers to variation in the variable t and

"δ" refers to variation in the parameters $\alpha, \beta, \gamma, \ldots$

The function $f(t,x,x')$ and the integral u can be considered as dependent on the parameters α, β, γ,... and the variations in their values are obtained as

$$\delta f = \frac{\partial f}{\partial x}\,\delta x + \frac{\partial f}{\partial x'}\,\delta x' = \frac{\partial f}{\partial x}\,\delta x + \frac{\partial f}{\partial x'}\,\frac{d}{dt}(\delta x) \qquad (3.12)$$

and

$$\delta u = \delta\left\{\int_{t_o}^{t_1} f(t,x,x')\,dt\right\} = \int_{t_o}^{t_1}(\delta f)\,dt = \int_{t_o}^{t_1}\left\{\left(\frac{\partial f}{\partial x}\,\delta x\right)\right\}dt$$

$$+\int_{t_o}^{t_1}\left\{\frac{\partial f}{\partial x'}\,\frac{d}{dt}(\delta x)\right\}dt$$

Now

$$\frac{d}{dt}\left[\frac{\partial f}{\partial x'}\,\delta x - \int\left\{\frac{d}{dt}\left(\frac{\partial f}{\partial x'}\right)\delta x\right\}dt\right] = \frac{d}{dt}\left(\frac{\partial f}{\partial x'}\,\delta x\right) - \frac{d}{dt}\left(\frac{\partial f}{\partial x'}\right)\delta x$$

$$= \frac{d}{dt}\left(\frac{\partial f}{\partial x'}\right)\delta x + \frac{\partial f}{\partial x'}\,\frac{d}{dt}(\delta x) - \frac{d}{dt}\left(\frac{\partial f}{\partial x'}\right)\delta x = \frac{\partial f}{\partial x'}\,\frac{d}{dt}(\delta x).$$

Hence, except for the addition of an arbitrary constant.

$$\int\left\{\frac{\partial f}{\partial x'}\,\frac{d}{dt}(\delta x)\right\}dt = \frac{\partial f}{\partial x'}\,\delta x - \int\left\{\frac{d}{dt}\left(\frac{\partial f}{\partial x'}\right)\delta x\right\}dt.$$

so $\int_{t_o}^{t_1} \{ \frac{\partial f}{\partial x'} \frac{d}{dt}(\delta x) \} dt = \left[\frac{\partial f}{\partial x'} \delta x \right]_{t_o}^{t_1} - \int_{t_o}^{t_1} \{ \frac{d}{dt} (\frac{\partial f}{\partial x'}) \delta x \} \, dt.$

The expression for the variation in u then becomes

$$\delta u = \left[\frac{\partial f}{\partial x'} \delta x \right]_{t_o}^{t_1} + \int_{t_o}^{t_1} \{ \frac{\partial f}{\partial x} - \frac{d}{dt} (\frac{\partial f}{\partial x'}) \} \delta x \, dt. \quad (3.13)$$

The problem in the calculus of variations is therefore reduced to the simple problem of integrating a differential equation.

3.2. Model Curves

3.2.1 Logistic Curve Model [5]

The variable x increases as t increases at a rate given by

$$\frac{dx}{dt} = bx \left(1 - \frac{x}{L}\right) \quad (3.14)$$

where L and b are given constants.
The curve represents x as a function of t.
To find x as a function of t

$$dx = bx \, dt - \frac{bx^2}{L} dt$$

$$Ldx = Lbx \, dt - bx^2 dt$$
$$= x(L-x) b \, dt$$

$$\frac{L dx}{x(L-x)} = b\,dt$$

$$\int \frac{L\,dx}{x(L-x)} = bt + k.$$

But $$\int \frac{L\,dx}{x(L-x)} = \int \left(\frac{1}{x} + \frac{1}{L-x}\right) dx = \log x - \log(L-x)$$

$$= -\log \frac{L-x}{x}$$

So $$\log \frac{L-x}{x} = -bt - k$$

$$\frac{L - x}{x} = e^{-bt} e^{-k} = a\,e^{-bx}$$

where,

$a = e^{-k}$ is an arbitrary constant.

Rearranging,

$$x = \frac{L}{1 + a\,e^{-bt}} . \qquad (3.15)$$

This is an S - shaped growth curve where x has the initial value of zero at equal to minus infinity. The curve is symmetrical about its inflection point $x = L/2$. The constants should determine where the curve will be in time and the steepness of the sharply rising portion. When $\ln(^{L}/x - 1)$ is plotted against time a straight line is obtained which can be extrapolated into the future. From historical data setting

$$Y_i = \ell n(^L/x - 1) \quad (3.16)$$

values of Y_i corresponding to time t_i are obtained and the expression

$$\sum_i^N (Y_i - \ell n\ a + b\ t_i)^2 \quad (3.17)$$

is minimized to obtain a regression fit of Y on t. The initial growth is slow and the upper portion flattens as it approaches the limit although in some cases this may not be physically achievable. The logistic model above is to be used in developing predictive models where road traffic data and RTAs have shown growing (increasing) tendencies with the passage of time particularly where S-shaped curves are observed.

3.2.2 Linear Model [5]

In the linear model x varies linearly with t such that

$$\frac{dx}{dt} = \beta \quad (3.18)$$

$$dx = \beta dt$$

$$\int dx = \int_o^t \beta dt$$

$$x = \beta t + \alpha \quad (3.19)$$

where α and β are regression constants calculated as

$$\beta = \frac{n\Sigma xt - x\,\Sigma t}{n\Sigma t^2 - (\Sigma t)^2} \qquad (3.20)$$

$$\alpha = \frac{\Sigma x - \beta.\Sigma t}{n}$$

where n is the number of pairs of variables. This model is to be used for the final analysis of each predictive model developed where predicted data using the predictive models is compared with observed road traffic data as well as RTAs data.

3.2.3 Parabolic Model [5]

In this model the variation in x is equated to the acceleration of a new body in equilibrium to a new equilibrium state. The accumulation of the variable is analogous to the distance travelled by the new mass. The rate of x's generation is equivalent to speed and the second derivative of x over time is equivalent to acceleration. Mathematically stated this yields

$$\frac{d^2x}{dt^2} = \text{a constant, } g \qquad (3.22)$$

$$\frac{dx}{dt} = gt$$

$$x = \int_0^t gt\, dt = \frac{g}{2} t^2$$

which may be written more completely as

$$x = \alpha + \beta t + \gamma t^2. \qquad (3.23)$$

The parameters α, β, γ can be solved by the solution of the normal equations

$$\begin{aligned} \Sigma x &= \alpha n + \beta \Sigma t + \gamma \Sigma t^2 \\ \Sigma xt &= \alpha \Sigma t + \beta \Sigma t^2 + \gamma \Sigma t^3 \\ \Sigma xt^2 &= \alpha \Sigma t^2 + \beta \Sigma t^3 + \gamma \Sigma t^4 \end{aligned} \qquad (3.24)$$

The parabolic model is a curve with one bend. This model is to be used where observed data show a curve with a single bend.

3.2.4 Cubic and Higher Polynomial Models

Following similar methods as those used for the linear model and the parabolic model the cubic model is of the form [5]

$$x = \alpha + \beta t + \gamma t^2 + \lambda t^3. \qquad (3.25)$$

The cubic model is a curve with two bends. The parameters α, β, γ and λ can be solved by the solution of the normal equations

$$\begin{aligned}
\Sigma x &= \alpha n + \beta\Sigma t + \gamma\Sigma t^2 + \lambda\Sigma t^3 \\
\Sigma xt &= \alpha\Sigma t + \beta\Sigma t^2 + \gamma\Sigma t^3 + \lambda\Sigma t^4 \qquad (3.26) \\
\Sigma xt^2 &= \alpha\Sigma t^2 + \beta\Sigma t^3 + \gamma\Sigma t^4 + \lambda\Sigma t^5 \\
\Sigma xt^3 &= \alpha\Sigma t^3 + \beta\Sigma t^4 + \gamma\Sigma t^5 + \lambda\Sigma t^6.
\end{aligned}$$

Polynomials of higher degrees may be solved by increasing the number of parameters and the number of normal equations correspondingly. Cubic and higher polynomial curves are to be used where road traffic as well as RTAs data show curves with more than one bend.

Finite difference methods [8]as numerical methods can also be used to get approximate solutions. The principle by which they operate is that very simple equations are adequate to describe the function of a variable over very short distances and times.

Finite-difference methods are applicable to functions for which values are available at equidistant points. Given a series of points

$$x_n = x_o + n.h \qquad (n = 0,1,...,N)$$

with corresponding function values

$$f_n (n = 0,1,...,N).$$

One of the many problems related to the analysis of experimental data is the representation of data by analytical formulae such as those above. Finite-differences are useful in such analysis. The simplest analysis on a table of values is to find the difference between each pair by subtracting each value from its successor in the table, second differences by repeating a similar process on the first differences and so on for higher orders. These differences together comprise the finite differences of the table. Considering a set of pairs of values (x_i, y_i), where $i = a, 1, \ldots, n-1$, which can be represented by points in the xy plane, the differences between successive pairs of ordinates y_{i+1} and y_i is denoted by Δy_i, where Δ is the difference operator.

Thus,

$$\Delta y_i = y_{i+1} - y_i \quad i = 0,1,2,\ldots,n-1. \quad (3.27)$$

The second forward differences are defined by

$\Delta^2 y_i = \Delta y_{i+1} - \Delta y_i$ and in general, the kth forward differences are

$$\Delta^k y_i = \Delta^{k-1} y_{i+1} - \Delta^{k-1} y_i. \quad (3.28)$$

If the rth differences $\Delta^r y_i$ are constant then all the differences of order higher than r are zero. From equations 3.27 and 3.28 it follows that

$$y_i = y_o + \Delta y_o$$

$$y_2 = y_1 + \Delta y_1 = (y_o - \Delta y_o) + (\Delta y_o + \Delta^2 y_o) = y_o + 2\ y_o + \Delta^2 y_o$$

$$y_3 = y_2 + \Delta y_2 = (y_o + 2\Delta y_o + \Delta^2 y_o) + (\Delta y_1 + \Delta^2 y_1)$$

$$= (y_o + 2\Delta y_o + \Delta^2 y_o) + (\Delta y_o + \Delta^2 y_o + \Delta^2 y_o + \Delta^3 y_o)$$

$$= y_o + 3\Delta y_o + 3\Delta^2 y_o + \Delta^3 y_o.$$

Thus

$$y_1 = (1+\Delta) y_o$$

$$y_2 = (1+\Delta)^2 y_o$$

$$y_3 = (1+\Delta)^3 y_o$$

in which $(1+\Delta)^k$ is an operator on y_o with the exponent on the Δ indicating the order of the difference. By induction

$$y_k = (1+\Delta)^k y_o \qquad k = 1,2,... \qquad (3.29)$$

and expanding

$$y_k = y_o + k\Delta y_o + \frac{k(k-1)}{2!}\Delta^2 y_o + \frac{k(k-1)(k-2)}{3!}\Delta^3 y_o + ... \qquad (3.30)$$

With the assumption that the values x_i in a given set of data (x_i, y_i), where $i = 0,1,2,\ldots,n$ are equally spaced with the spacing interval h

$$x_1 = x_o+h, \quad x_2 = x_o+2h, \ldots, \quad x_n = x_o+nh.$$

Letting the data be represented by some formula $y = f(x)$ which for $x = x_o+kh$ yields $y_k = f(x_o+kh)$, noting that $f_k = y_k$ formula (3.30) yields for $r \leqslant k$,

$$y_k = y_o + \binom{k}{1}\Delta y_o + \binom{k}{2}\Delta^2 y_o + \ldots + \binom{k}{r}\Delta^r y_o \quad (3.31)$$

where the binomial coefficients $\binom{k}{r}$ are defined by

$$\binom{k}{r} = \frac{k(k-1)(k-2)\ldots(k-r+1)}{r!}. \quad (3.32)$$

Since the x_i are spaced h units apart,

$$x_k = x_o + kh \qquad k = 1,2,\ldots,n$$

so that

$$k = \frac{x_k-x_o}{h}. \quad (3.33)$$

The expression (3.31) is a polynomial of degree r in k. On substituting in 3.30 for k from 3.32 , a polynomial of degree r in x_k is obtained. Collecting like powers of x_k equation 3.30 takes the form

$$y_k = a_o + a_1x_k + a_2x_k^2 + \ldots + a_rx_k^r. \quad (3.34)$$

Accordingly, the polynomial in x

$$y(x) = a_o + a_1^x + a_2x^2 + \ldots + a_rx^r \qquad (3.35)$$

assumes the values y_k when $x = x_k$. Thus when the rth differences of the y_k are constant and the x_k are equally spaced, the polynomial (3.35) represents these data exactly. When rth differences in a given set of data are not constant but differences are negligible, the polynomial (3.35) represents the data approximately. The finite difference technique is to be used to test tabulated data observed in order to ascertain the suitability of fitting polynomial curves on to such data.

In order to determine the maximum values the first order condition will generally give the value or values of the independent variable for which $\frac{dx}{dt} = 0$. The value of the independent value for which this is the case is called the critical value for the function in question. In order to ascertain whether the critical value so obtained constitutes a relative maximum, the second order condition for a relative maximum is applied which is

$$\frac{d^2x}{dt} < 0.$$

Thus for example for a cubic function $\frac{dx}{dt}$ which is a parabola is solved by using the general quadratic equation

$$\alpha + \beta t + \gamma t^2 = 0 \qquad \gamma \neq 0$$

and $$t = \frac{-\beta \pm \sqrt{(\beta^2 - 4\alpha\gamma)}}{2\gamma} \qquad (3.36$$

3.2.5 <u>Exponential Model [5]</u>

This model is based on the simple explanation that the variation in the variable x is proportional to the level of the variable at any given time

$$\frac{dx}{dt} \propto x \qquad (3.37)$$

$$\frac{1}{2}dx = \beta dt$$

$$\int \frac{1}{x}dx = \int_0^t \beta dt$$

$$\ln x = \beta t + \alpha$$

$$x = \alpha e^{\beta t}. \qquad (3.38)$$

To solve for the parameters α and β equation (3.38) is transformed into

$$\ln x = \ln \alpha + \beta t$$ and α and β

calculated by the expressions

$$\beta = \frac{n\Sigma(t\ln x) - t\Sigma \ln x}{n\Sigma t^2 - (\Sigma t)^2} \qquad (3.39)$$

$$\alpha = e^{\left(\frac{\Sigma \ell n x - \beta \Sigma t}{n}\right)} \tag{3.40}$$

where n is the number of pairs of the variables. This model as a growth curve is to be used in the preliminary analysis of fitting observed data particularly RTAs data at national level that has been observed as increasing with time.

3.2.6 Logarithmic Model [5]

This model is based on the simple explanation that the variation in the variable x is proportional to the inverse of the time

$$\frac{dx}{dt} \propto \frac{1}{t} \tag{3.41}$$

$$dx = \frac{\beta}{t} dt$$

$$\int dx = \int_o^t \frac{\beta}{t} dt$$

$$x = \beta \ell n t + \alpha. \tag{3.42}$$

To solve for the parameters α and β the expressions

$$\beta = \frac{n\Sigma(x \ell n t) - \Sigma \ell n t \, \Sigma x}{n\Sigma(\ell n t)^2 - (\Sigma \ell n t)^2} \tag{3.43}$$

$$\alpha \quad \frac{\Sigma x - \beta \Sigma \ell n t}{n} \tag{3.44}$$

are solved where, n is the number of pairs of the variables. This growth model is to be used in fitting data and developing predictive models for observed data particularly RTAs data at national level which has been observed as showing an increasing trend over time.

3.2.7 Power Model [5]

This model is based on the simple explanation that the variation in the variable x is proportional to the level of the variable and the inverse of time

$$\frac{dx}{dt} \propto \frac{x}{t} \tag{3.45}$$

$$\frac{1}{x}dx = \frac{\beta}{t}dt$$

$$\int \frac{1}{x}dx = \int_0^t \frac{\beta}{t}dt$$

$$\ell nx = \beta \ell nt + \ell n\alpha$$

$$x = \alpha t^{\beta} \tag{3.46}$$

To solve for the parameters α and β the expression

$$\beta = \frac{n\Sigma(\ell nt\ \ell nx) - \Sigma \ell nt\ \Sigma \ell nx}{n\Sigma(\ell nt)^2 - (\Sigma \ell nt)^2} \tag{3.47}$$

$$\alpha = \frac{\Sigma nx - \beta \Sigma \ell nt}{n} \tag{3.48}$$

are solved where n is the number of pairs of the variables. This growth model is to be used for fitting data at the preliminary analysis stage where observed data shows increasing tendencies with time.

3.3. Time Series [5,6]

A time series is a set of observational data taken at specified times more often than not at equally spaced intervals. Mathematically a time series is defined by the values $Y_1, Y_2, \ldots, Y_n$ of a variable at times $t_1, t_2, \ldots, t_n$. Thus Y is a function of t, (with Y the dependent variable and t the independent variable)

$$Y = F(t). \tag{3.49}$$

Using the equation

$$y = \left(\frac{\Sigma xy}{\Sigma x^2}\right) x \tag{3.50}$$

where

$$x = X - \bar{X} \tag{3.51}$$

$$y = Y - \bar{Y}. \tag{3.52}$$

The trend line has the equation

$$Y = A + BX \tag{3.53}$$

where the values of Y computed for various values of X are called trend values. The origin $X = 0$ is the base year and the units of X are 1 year.

If values of X are assigned to the years for which data is available beginning from the base year to the last so that $\Sigma X = 0$, the equation of the least square line can be derived as

$$Y = \bar{Y} + \left(\frac{\Sigma XY}{\Sigma X^2}\right) X \qquad (3.54)$$

where X replaces x which was given by equation 3.51 i.e. $\Sigma(X-\bar{X}) = 0$ and $Y = y$ the initial values.

$$\bar{Y} = \left(\frac{\Sigma Y}{N}\right) \qquad (3.55)$$

where N is the number of years. If the number of years (N) is even the equation must be modified. For N even, the column of x is doubled to yield $\Sigma X=0$ and the origin becomes January 1 (between July 1 of the two middle years. The resulting equation (3.54) has X with units of half years. To measure X in whole years instead of half years, X is replaced by 2X but the origin remains in January 1 as before. For N odd the middle year is the origin (X=0) and the values of Y refer to mid-year values i.e. as of July 1.

The components of a time series are the characteristic movements T, C, S and I and are related by the equation

$$Y = T \times C \times S \times I \qquad (3.56)$$

where, T is the long-term secular movements, secular variation or secular trend indicated by the trend curve,

C is the cyclical movements,

S is the seasonal movements,

I is the irregular, random movements or residual influences.

The analysis of the factors T, C, S and I is called the decomposition of a time series.

The amount of variation present in the time series data can be reduced by the use of techniques such as moving averages. The elimination of these unwanted fluctuations is called the smoothing of a time series.

Given a set of variables $Y_1, Y_2, Y_3, \ldots, Y_n$ a moving average of order N is defined by the sequence of arithmetic means

$$\frac{Y_1+Y_2+\ldots+Y_N}{N}, \quad \frac{Y_2+Y_3+\ldots+Y_{N+1}}{N}, \quad \frac{Y_3+Y_4+\ldots Y_{N+2}}{N} \qquad \ldots (3.57)$$

The sums in the numerators are called moving totals of order N. If the data is given annually, a moving average of order N is called an N year moving average. Any other unit of time can be used. If weighted arithmetic means are used, the weight being prespecified, the sequence is called a weighted moving average of order N.

The estimation of the trend curve is achieved through the following steps in the time series analysis:

- data collection,
- graphing, noting qualitatively the presence of long-term trend, cyclical varations and seasonal variations,
- construction of the long-term trend curve or line by use of least squares method or moving averages method
- prediction and error evaluation.

Time series techniques are to be used where data observed particularly RTAs data at national level shows growing tendencies over time. The techniques are to be used in fitting trend line (curve) equations and data smoothing.

3.4 Harmonic Analysis [8]

This is the problem of representing a suitable periodic function in a trigonometric series. The problem reduces to one of fitting a finite trigonometric function to a set of observed values (x_i, y_i). Letting the set of observed values (x_o, y_o), $(x_1, y_1), \ldots, (x_{2n-1}, y_{2n-1}), (x_{2n}, y_{2n}), \ldots$ be such that the values of y start repeating with y_{2n} (i.e., $y_{2n}=y_o$, $y_{2n+1} = y_1$ etc.). The assumption is that the x_i are equally spaced, $x_o=0$, and that $y_{2n}=2\pi$. On the basis of these assumptions

$$x_i = \frac{i2\pi}{2n} = \frac{i\pi}{n}.$$

The trigonometric polynomial

$$y = A_o + \sum_{k=1}^{n} A_k \cos kx + \sum_{k=1}^{n-1} B_k \sin kx \qquad (3.58)$$

contains the 2n unknown constants $A_o, A_1, A_2, \ldots, A_n, B_1, B_2, \ldots, B_{n-1}$, which can be determined so that equation (3.58) will pass through the 2n given points x_i, y_i by solving the 2n simultaneous equations

$$y_i = A_o + \sum_{k=1}^{n} A_k \cos kx_i + \sum_{k=1}^{n-1} B_k \sin kx_i \quad i=0,1,2,\ldots,2n-1.$$

Since $x_i = \frac{i\pi}{n}$, these equations become

$$y_i = A_o + \sum_{k=1}^{n} A_k \cos \frac{ik\pi}{n} + \sum_{k=1}^{n-1} B_k \sin \frac{ik\pi}{n}$$

$$i=0,1,2,\ldots,2n-1. \qquad (3.59)$$

The solution of equations 3.59 is done by means of a scheme similar to that used for the determination of the Fourier coefficients. The coefficient of A_o is unity. Therefore, multiplying both sides of each equation by the coefficient of A_o and adding the results yields

$$\sum_{i=o}^{2n-1} y_i = 2n\, A_o + \sum_{k=1}^{n} \left(\sum_{k=1}^{2n-1} \cos \frac{ik\pi}{n}\right) A_k + \sum_{k=1}^{n-1} \left(\sum_{i=o}^{2n-1} \sin \frac{ik\pi}{n}\right) B_k .$$

Now,

$$\sum_{i=o}^{2n-1} \cos \frac{ik\pi}{n} = 0 \qquad k = 1,2,\ldots,n$$

and

$$\sum_{i=o}^{2n-1} \sin \frac{ik\pi}{n} = 0 \qquad k = 1,2,\ldots,n-1 .$$

Therefore

$$2nA_o = \sum_{i=o}^{2n-1} y_i . \qquad (3.60)$$

Multiplying both sides of each equation in 3.59 by the coefficient of A_j in it, and adding the results, yields

$$\sum_{i=o}^{2n-1} y_i \cos \frac{ij\pi}{n} = \sum_{k=1}^{n} \left(\sum_{i=o}^{2n-1} \cos \frac{ik\pi}{n} \cos \frac{ij\pi}{n}\right)$$

$$A_k + \sum_{k=1}^{n-1} \left(\sum_{i=o}^{2n-1} \sin \frac{ik\pi}{n} \cos \frac{ij\pi}{n}\right) B_k$$

for $j = 1,2,\ldots,n-1$,

But

$$\sum_{i=o}^{2n-1} \cos \frac{ik\pi}{n} \cos \frac{ij\pi}{n} = 0 \qquad \text{if } k \neq j$$
$$= n \qquad \text{if } k = j$$

and

$$\sum_{i=o}^{2-1} \sin \frac{ik\pi}{n} \cos \frac{ij\pi}{n} = o \quad \text{for all values of } k.$$

therefore,

$$n A_j = \sum_{i=o}^{2n-1} y_i \cos \frac{ij\pi}{n} \qquad j = 1,2,\ldots,n-1. \quad (3.61)$$

To determine the coefficient of A_n the same procedure is followed, but

$$\sum_{i=o}^{2n-1} \cos \frac{ik\pi}{n} \cos i\pi = 0 \qquad \text{if } k \neq n$$
$$= 2n \qquad \text{if } k = n.$$

Hence,

$$2n\, An = \sum_{i=o}^{2n-1} y_i \cos i\pi . \qquad (3.62)$$

On multiplying both sides of each equation of (3.59) by the coefficient of B_k in it and adding, it is found that

$$nB_j = \sum_{i=o}^{2n-1} y_i \sin \frac{ij\pi}{n} \qquad (3.63)$$

$$j = 1, 2, \ldots, n-1.$$

Equations 3.60 to 3.63 give the constants in equation 3.58 . A compact schematic arrangement is used to simplify the labour of evaluating these constants. The method is based on the equations that determine the constants together with trigonometric relations such as

$$\sin{}^{\pi}/n = \sin\left(\frac{n-1}{n}\right)\pi = -\sin\left(\frac{n+1}{n}\right)\pi = -\sin\frac{(2n-1)\pi}{n}$$

$$\cos{}^{\pi}/n = -\cos\frac{(n-1)\pi}{n} = -\cos\frac{(n+1)\pi}{n} = \cos\frac{(2n-1)\pi}{n}.$$

For a six-ordinate scheme 2n=6; the given data being (x_i, y_i), where $x_i = \frac{i\pi}{3}$ (i=0,1,2,3,4,5); and equation 3.58 yields

$$y = A_o + A_1\cos x + A_2\cos 2x + A_3\cos 3x + B_1\sin x + B_2\sin 2x.$$

With the notation given below

	y_o	y_1	y_2	v_o	v_1	w_o	w_1
	y_3	y_4	y_5		v_2		w_2
sum	v_o	v_1	v_2	p_o	p_1	r_o	r_1
difference	w_o	w_1	w_2		q_1		s_1

equations 3.60 to 3.63 , with n=3, yield

$$6A_o = \sum_{i=o}^{5} y_1 = y_o+y_1+y_2+y_3+y_4+y_5 = p_o+p_1$$

$$3A_j = \sum_{i=o}^{5} y_1 \cos \frac{ij\pi}{3} \qquad j=1,2$$

$$3A_1 = \sum_{i=o}^{5} y_i \cos \frac{i\pi}{3} = y_o+y_1\cos\frac{\pi}{3} +y_2\cos\frac{2\pi}{3} + y_3\cos\pi$$

$$+ y_4\cos\frac{4\pi}{3} + y_5\cos\frac{5\pi}{3}$$

$$= y_o+\frac{1}{2}y_1 - \frac{1}{2}y_2 - y_3-\frac{1}{2}y_4 + \frac{1}{2}y_5$$

$$3A_2 = \sum_{i=o}^{5} y_i\cos \frac{i2\pi}{3} = y_o+y_1\cos \frac{2\pi}{3}+ y_2\cos\frac{4\pi}{3}+ y_3\cos2\pi$$

$$+ y_4\cos\frac{8\pi}{3} + y_5\cos\frac{10\pi}{3}$$

$$= y_o-\frac{1}{2}y_1 - \frac{1}{2}y_2 + y_3 - \frac{1}{2}y_4 - \frac{1}{2}y_5$$

$$6A_3 = \sum_{i=o}^{5} y_i\cos i\pi = y_o+y_1\cos\pi+y_2\cos2\pi+y_3\cos3\pi$$

$$= y_o-y_1+y_2-y_3+y_4-y_5$$

$$3B_j = \sum_{i=o}^{5} y_1 \sin \frac{ij\pi}{n} \qquad j = 1,2$$

$$3B_1 = \sum_{i=o}^{5} y_i \sin \frac{i\pi}{3} = y_1 \sin \frac{\pi}{3} + y_2 \sin \frac{2\pi}{3} + y_4 \sin \frac{4\pi}{3} \sin \frac{5\pi}{3}$$

$$= \frac{\sqrt{3}}{2} y_1 + \frac{\sqrt{3}}{2} y_2 - \frac{\sqrt{3}}{2} y_4 - \frac{\sqrt{3}}{2} y_5$$

$$3B_2 = \sum_{i=o}^{5} y_i \sin \frac{2i\pi}{3} = y_1 \sin \frac{2\pi}{3} + y_2 \sin \frac{4\pi}{3} + y_4 \sin \frac{8\pi}{3}$$

$$+ \quad y_5 \sin \frac{10\pi}{3} = \frac{\sqrt{3}}{2} y_1 - \frac{\sqrt{3}}{2} y_2 + \frac{\sqrt{3}}{2} y_4 - \frac{\sqrt{3}}{2} y_5$$

giving

$$6A_o = p_o + p_1, \quad 3A_1 = r_o + \frac{1}{2} s_1, \quad 3A_2 = p_o - \frac{1}{2} p_1$$

$$6A_3 = r_o - s_1, \quad 3B_1 = \frac{\sqrt{3}}{2} r_1, \quad 3B_2 = \frac{\sqrt{3}}{2} q_1 .$$

with the checks on the calculations given by

$$A_o + A_1 + A_2 + A_3 = y_o \quad \text{and} \quad B_1 + B_2 = \frac{\sqrt{3}}{3} (y_1 - y_5).$$

For a 24-ordinate scheme 2n=24, n=12, given data (x_i, y_i) where $x_i = \frac{i\pi}{12}$ (i= 0,1,2,...,22,23) equation 3.58 becomes

$$y = A_o + \sum_{k=1}^{12} A_k \cos kx + \sum_{k=1}^{11} B_k \sin kx.$$

To calculate all the coefficients and set out a scheme for their solution equations 3.60 to 3.63 are used as

$$24\, A_o = \sum_{i=o}^{23} y_i, \quad 12A_1 = \sum_{i=o}^{23} y_i \cos \frac{i\pi}{12}, \ \ldots$$

Harmonic analysis techniques are to be used in representing suitable periodic functions in a trigonometric series for observed road traffic as well as RTAs data where such data show periodic variation for example, the variation of road traffic flow and the variation of RTAs over a period of 24 hours. The periodic functions will then be fitted to predict the variation of traffic or RTAs.

3.5 Errors in Prediction Models

3.5.1 Errors and Confidence Levels of Predictions [5,6,7]

It is desirable to assess the confidence levels in predictions and to have some measure of the probability of error. This is necessary because predictive models, particularly when they are approximating functions, contain inherent errors. The assessment of the errors is done by regression analysis and correlation analysis which are measures of fitting curves to the variation of errors and a measurement of the degree of fit respectively. This is achieved by determining the standard error of estimate and the calculation of the correlation coefficient.

Just as the standard deviation measures the variation of the values of a variable about their arithmetic mean, the standard error of the estimate is a prediction of the scatter of the variables about a line. The standard error of the estimate, symbolized by $S_{y.x}$ represents the standard deviation of the y's on the x's.

$$S_{y.x} = \left(\frac{\Sigma (y-\bar{y}_p)^2}{n-2} \right)^{\frac{1}{2}} \qquad (3.64)$$

where,

$(y-\bar{y}_p)$ are vertical deviations from the regression line, $\bar{y}_p$ is the predicted value and

n-2 are the degrees of freedom.

If a large number of data are observed, calculating each $\bar{y}_p$ point on the regression line and then squaring the differences is very involving. For ease of computation the formula used is

$$S_{y.x} = \left| \frac{\Sigma y^2 - a(\Sigma y) - b\ (\Sigma xy)}{(n-2)} \right|^{\frac{1}{2}} . \qquad (3.65)$$

Theoretically the standard error of the estimate is a valid measure in setting the confidence limits about a predicted value $\bar{y}_p$ if the size of the sample is large and the points on the scatter diagram are normally distributed.

In the confidence limits

$\bar{y}_p \pm S_{y.x}$ encompasses the middle 68% of the data points,

$\bar{y}_p \pm 1.96\ S_{y.x}$ encompasses the middle 95% of of the data points and

$\bar{y}_p \pm 3.S_{y.x}$ encompasses the middle 99.7% of the data points.

The equation of the confidence level is

$$\bar{y}_p \pm t(S_{y.x}) = \left(\frac{1}{n} + \frac{(x-\bar{x})^2}{\Sigma(x-\bar{x})^2} \right)^{\frac{1}{2}} \qquad (3.66)$$

where n = number of observation

t = value from Students t - distribution obtainable from statistical tables.

Generally, the standard error of estimate is rather difficult to interpret. A standard error of zero means that all of the variation is explained by x. The proportion of the variation explained is called the coefficient of determination r^2 and the unexplained variation is called the coefficient of non-determination denoted by (k^2). The value of the coefficient of determination varies from 0 to 1. A coefficient of determination zero indicates that none of the variation in y is explained by the variable x. A coefficient of determination 1 indicates that 100 per cent of the variation in y is explained by x. The variation in y which is not associated with x is measured by the standard error of the estimate $S_{y.x}$. To convert the variation to a coefficient $S_{y.x}$ is divided by the total variation thus,

$$r^2 = 1 - \frac{\text{unexplained variance}}{\text{total variance}} = 1 - \frac{S^2_{y.x}}{S^2_y} \quad (3.67)$$

The square root of the coefficient of determination is called the correlation coefficient. A more convenient formula for calculating the correlation coefficient is

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\{[n(\Sigma x^2) - (\Sigma x)^2][n(\Sigma y^2) - (\Sigma y)^2]\}^{\frac{1}{2}}}$$

The value of r lies between + 1 (for perfect positive relationships) and -1 (for perfect negative relationships). A correlation coefficient of 0.9 and greater is considered quite significant.
To calculate the level of significance the value of t in equation 3.66 may be calculated from the equation

$$t = \frac{r(n-2)^{\frac{1}{2}}}{(1-r^2)^{\frac{1}{2}}} \qquad (3.69)$$

where, r is the correlation coefficient,

r^2 is the coefficient of determination and

n are the number of observations.

The statistical techniques above are to be used in evaluating the quality of fitness of the predictive models developed and the confidence levels of such predictions.

3.5.2 Method of Final Analysis on Predicted Data

In order to predict the relative accuracies of the models developed, each model is used as applicable to predict the dependent variable whose variation is being sought to be fitted to a curve. Simple linear regression is used to compare the observed data with the predicted data by each model. A similar test is applied to models, developed by other researchers, predicting the same variable. Perfect prediction by any formula would result in a regression line whose slope = 1, intercept = 0, a correlation coefficient r of 1.0 and the critical coefficient or the coefficient of determination $r^2 = 1$. The less accurate a prediction is, the more the regression line varies from this ideal and the lower the correlation coefficient. A further measure of the data scatter for each regression is obtained by calculating the standard error about the observed = predicted line. The slope and correlation coefficient for various predictive models can be compared since these are dimensionless.

3.6 Generalised Linear Models [59]

A generalised linear model is generally regarded as consisting of two elements. These are the systematic component and the random component. The systematic component describes the way the predicted values of the dependent variable relate to a set of independent variables. In the ordinary least squares regression the fitted equation has the form

$$\mu = a_o + a_1x_1 + a_2x_2 + a_3x_3 + \ldots \qquad (3.70)$$

where μ is the value of the dependent variable predicted by the regression line for a particular set of the independent variables. The a's are the regression coefficients. The generalised linear model preserves the linear form of the right-hand side of equation 3.70, but generalises the relationship between the value of the linear predictor denoted by η and the fitted value μ yielding the equations

$$\eta = a_o + a_1x_1 + a_2x_2 + a_3x_3 + \ldots \qquad (3.71)$$

$$\eta = f(\mu). \qquad (3.72)$$

Equation 3.72 is a relationship giving the link function. For accident data, the dependent variable is the number of accidents occurring at a particular site within a given period. The number of accidents is normally regarded as having a Poisson error structure. The independent variables are those associated with traffic flow and road geometry. By using a logarithm link such that

$$\eta = \ln (\mu) \qquad (3.73)$$

where $\ln$ is the logarithm to the base e a multiplicative model becomes

$$A = e^k K^b e^{(\Sigma a_i x_i)} \qquad (3.74)$$

where A is the number of accidents, K is the vehicle-kilometres of travel during the period under study, a_i are the coefficients, x_i are the independent variables and k is the constant.
The linear equation becomes

$$\ln A = k + b \ln K + a_1 x_1 + a_2 x_2 + a_3 x_3 + \ldots \qquad (3.75)$$

The other component of the generalised model is the random element. In least squares regressions the observations are regarded as drawn from a population with a mean equal to the value given by the regression line. The variance is constant throughout the range of the data. If the data is drawn from a normal population standard significance tests are applied and the least squares estimates of the regression parameters are maximum likelihood estimates. If the observations are drawn from a non-normal population, as in this case where in RTAs the error distribution is regarded as Poisson, the constant variance assumption is violated since the variance of the Poisson distribution equals its mean. The generalised linear model formula allows either a known or assumed error distribution of the dependent variable to be specified explicitly for the exponential family of distributions.

Once the link function and the error structure have been specified, the maximum likelihood estimates of the coefficients are calculated. The 'normal' equations are solved to give the coefficient estimates. These equations are similar to those for ordinary weighted least squares regression but the dependent variable is replaced by a modified variate given as

$$\eta + \delta(y-\mu)$$

where η is the linear predictor, y is the observed dependent variable, μ is the predicted value and δ is $\frac{d\eta}{d\mu}$ which is the derivative of the link function. The procedure is iterative. Each cycle of the fit uses estimates of the various parameters from the previous cycle until convergence is obtained. Convergence is obtained usually in 3 or 4 cycles.

For significance testing the Scaled Deviance is used. Deviance is a likelihood ratio equal to $-2\ \ell n\lambda$, where

$$\lambda = \frac{\max L}{\max L_f} . \qquad (3.76)$$

Therefore,

$$\text{Scaled Deviance} = -2[\ell n(\max L) - \ell n(\max L_f)]$$

where $\ell n(\max L)$ is the maximised log-likelihood for the model under review and $\ell n\ (\max L_f)$ is the corresponding value for the full model which exactly fits all the data points ($\mu = y$).

A generalised linear model is good if Scaled Deviance (S.D)/degrees of freedom (d.f) is near 1.

The generalised linear modelling technique will be used through the computer program GLIM to obtain unified RTA models for the single carriageway road (Kiganjo-Nanyuki) and the dual carriageway road (Nairobi-Thika).

CHAPTER 4 - ROAD TRAFFIC AND ACCIDENT DATA COLLECTION AND ANALYSIS

In this chapter road traffic and road traffic accident data collection and analysis are presented. Road traffic data and analysis is presented followed by road traffic accident data and analysis. Firstly, road traffic data collection and analysis is presented in three sections covering national traffic, dual carriageway (Nairobi-Thika Road) traffic and the single carriageway (Kiganjo-Nanyuki Road) traffic. Secondly, road traffic accident data collection and analysis is also presented in three sections covering national road traffic accidents, dual carriageway RTAs and the single carriageway RTAs. The data analysis is based on the threoretical analysis presented in Chapter 3.

4.1 Road Traffic Data Collection and Analysis

4.1.1 National Road Traffic

4.1.1.1. Data Collection

At the national level the data collected relating to the Kenya transportation system (Fig.4.1) included human population, cumulative number of vehicles, vehicle composition and the total length of classified roads. These data were collected from the Central Bureau of Statistics of Kenya (CBSK) for the years 1949-1983 (Appendix A.13).

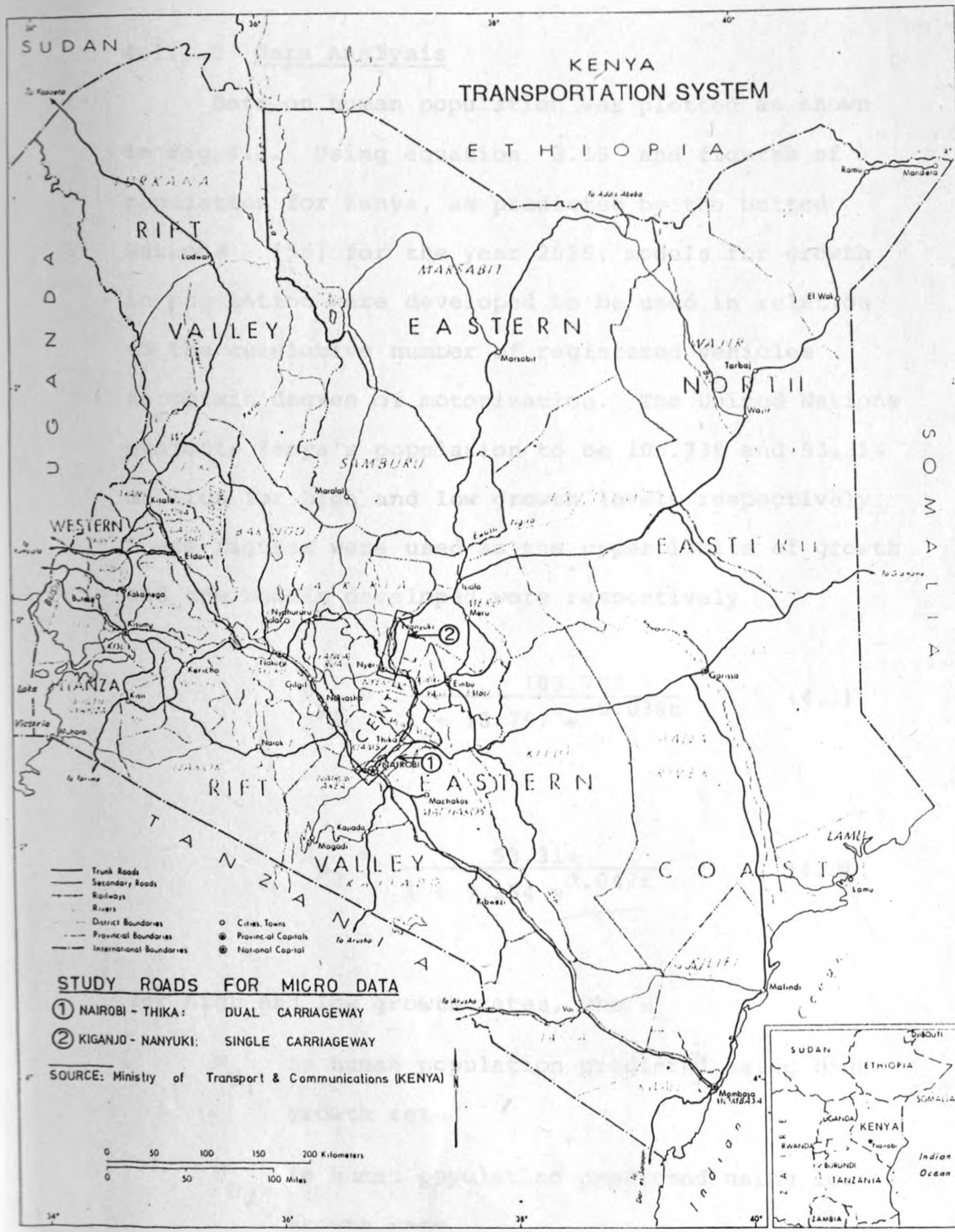


FIG 4.1 KEY PLAN

4.1.1.2 Data Analysis

Data on human population was plotted as shown in Fig.4.2. Using equation 3.15 and figures of population for Kenya, as predicted by the United Nations [56] for the year 2025, models for growth in population were developed to be used in relation to the cumulative number of registered vehicles to obtain degree of motorization. The United Nations projects Kenya's population to be 103.738 and 53.314 million for high and low growth levels respectively. These figures were used as the upper limits of growth and the models developed were respectively

$$H_{p_1} = \frac{103.738}{1 + 18.797\ e^{-0.038t}} \qquad (4.1)$$

$$H_{p_2} = \frac{53.314}{1 + 9.254\ e^{0.042t}} \qquad (4.2)$$

for high and low growth rates, where

H_{p_1} is human population predicted using high growth rate

H_{p_2} is human population predicted using low growth rate

t is time in years

e is base of natural logarithms.

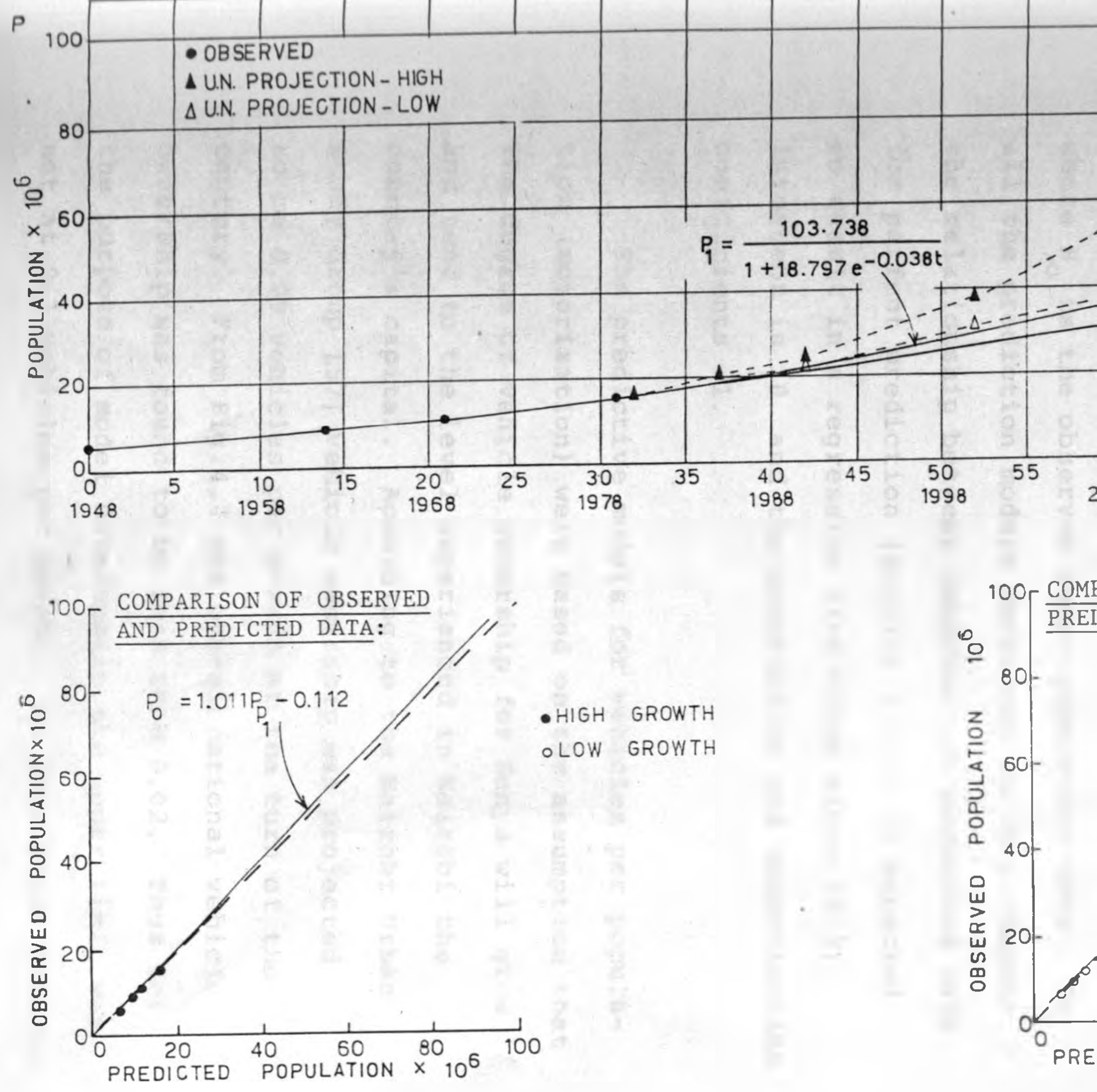


FIG.4.2 KENYA HUMAN POPULATION GROWTH.

On the basis of the method of analysis outlined in 3.5.2 and using equation 3.19 the regression equations were

$$H_o = 1.004\ H_{p_1} - 0.036$$

with $r = 0.99$, $r^2 = 0.99$ and standard error of 4.256,

$$H_o = 1.011\ H_{p_2} - 0.112$$

With $r = 0.99$, $r^2 = 0.99$ and standard error of 4.271 where H_o is the observed human population data. In all the prediction models developed in this chapter the relationship between observed and predicted data for perfect prediction (section 3.5.2) is expected ro result in a regression line whose slope is 1, intercept is 0 and the correlation and determination coefficients 1.

The predictive models for vehicles per population (motorization) were based on the assumption that the degree of vehicle ownership for Kenya will grow and tend to the level experienced in Nairobi the country's capital. According to the Nairobi Urban Study Group [57] vehicle ownership was projected to be 0.09 vehicles per person at the turn of the century. From Fig.4.4 the overall national vehicle ownership was found to be less than 0.02. Thus for the purpose of model development the upper limit was set at 0.1 vehicles per person. On this basis the two

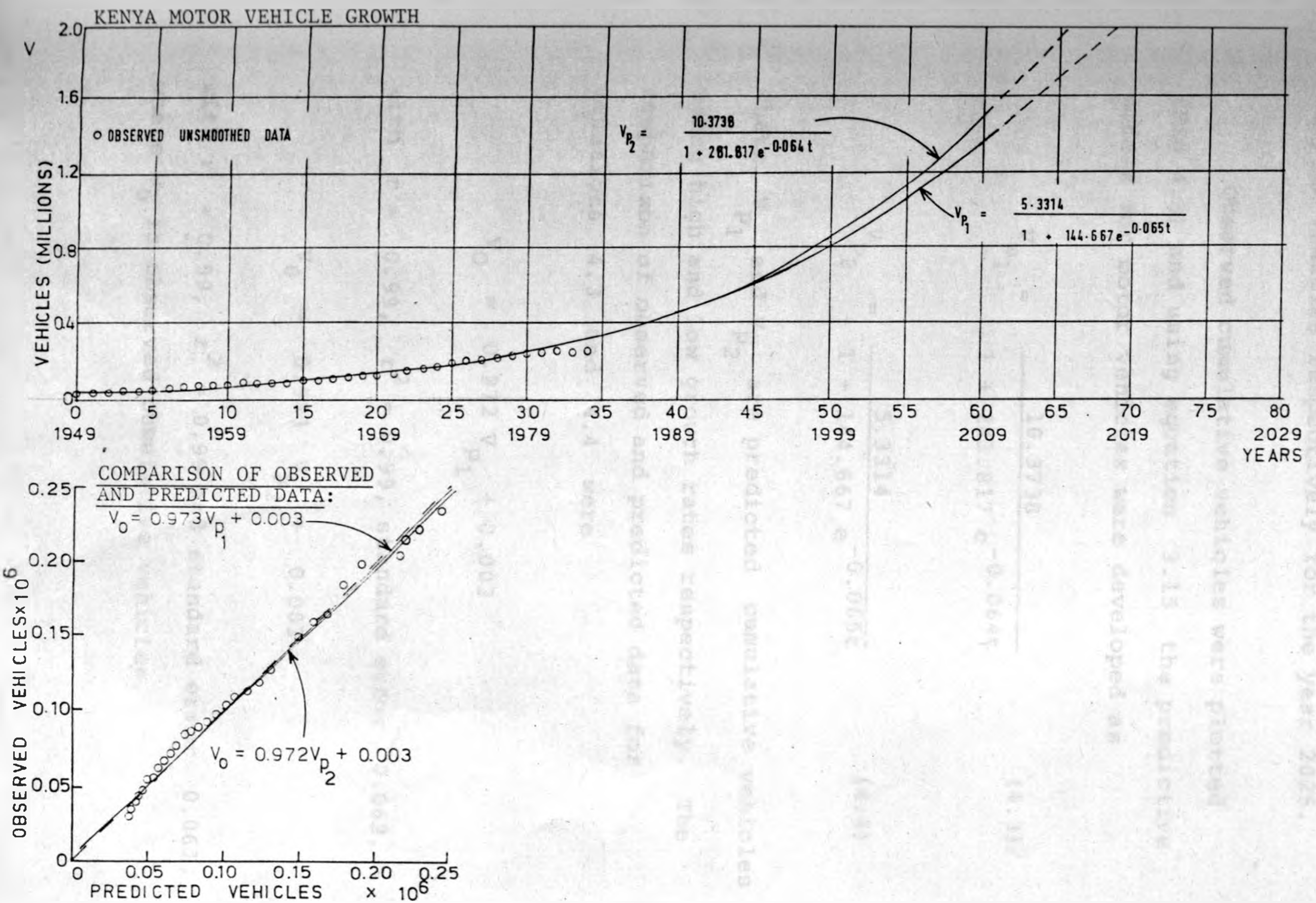


FIG.4.3 KENYA MOTOR VEHICLE GROWTH.

upper limits for vehicles, corresponding to the human population were derived as 5.3314 and 10.3738 million vehicles respectively for the year 2025.

Observed cumulative vehicles were plotted (Fig.4.3) and using equation 3.15 the predictive models for motor vehicles were developed as

$$V_{p_1} = \frac{10.3738}{1 + 281.817\ e^{-0.064t}} \qquad (4.3)$$

$$V_{p_2} = \frac{5.3314}{1 + 144.667\ e^{-0.065t}} \qquad (4.4)$$

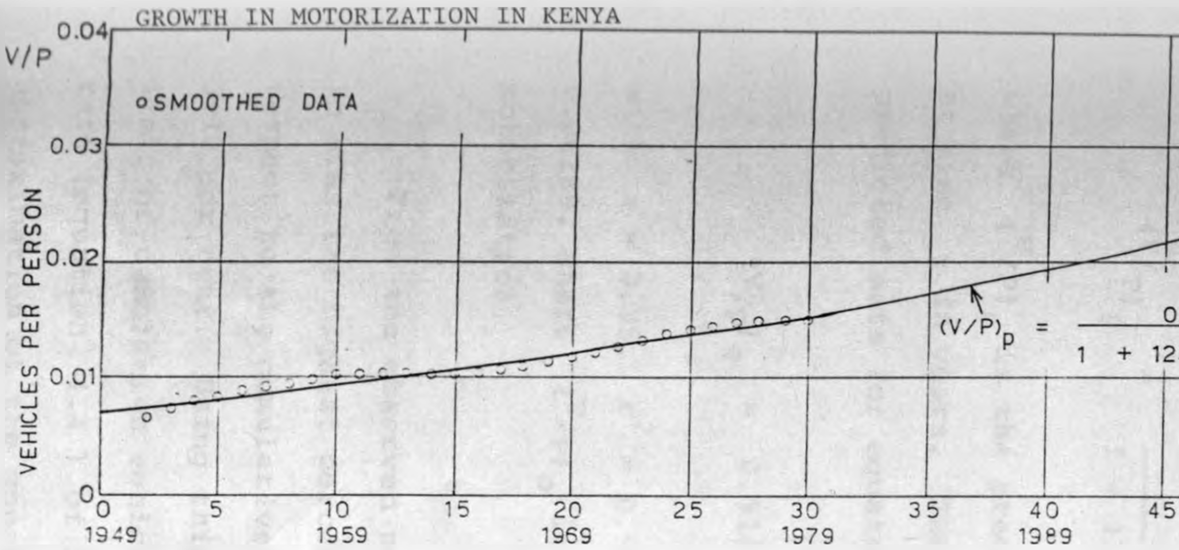
where, V_{p_1} and V_{p_2} are predicted cumulative vehicles using high and low growth rates respectively. The comparison of observed and predicted data for equations 4.3 and 4.4 were

$$V_O = 0.972\ V_{p_1} + 0.003$$

with $r = 0.99$, $r^2 = 0.99$, standard error 0.062,

$$V_0 = 0.973\ V_{p_2} + 0.003$$

with $r = 0.99$, $r^2 = 0.99$ and standard error 0.061, where V_0 is observed cumulative vehicles.



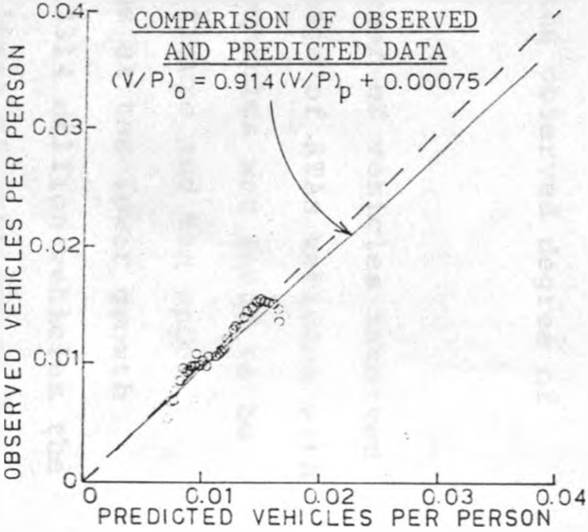


FIG.4.4 GROWTH IN VEHICLES PER PERSON (MOTORIZATION) IN KENYA

Using the figure of 0.1 vehicles per person for the first upper limit for the degree of motorization in Kenya, the observed vehicles per person were plotted against time and the data smoothed by the moving averages technique N = 5 years, using equation 3.57 to get rid of fluctuations (Fig.4.4). Using equation 3.15 the predictive model for the growth in motorization was developed as

$$({}^{V}/_{P})_p = \frac{0.1}{1 + 12.790\, e^{-0.028t}} \qquad (4.5)$$

where, $({}^{V}/P)_p$ is the predicted level of motorization at time t in years. The comparison of observed and predicted data for equation 4.5 was

$$({}^{V}/_{p})_o = 0.914\ ({}^{V}/p)_p + 0.00075$$

with r = 0.95, r^2 = 0.90 and standard error of 0.00289, where $({}^{V}/p)_o$ is the observed degree of motorization.

From the observed number of vehicles involved in RTAs the highest percentage of RTAs vehicles with respect to the cumulative vehicles was found to be 3.12 per cent. Using this figure and the upper limit of cumulative vehicles at the lower growth rate (equation 4.4) of 5.3314 million vehicles the approximation of the upper limit of vehicles to be involved in RTAs was estimated as 166 073 vehicles. Using this limit and equation 3.15 the predictive model for the growth of RTAs vehicles was developed as (Fig.4.5)

$$(V_A)_p = \frac{166\ 073}{1 + 77.867\ e^{-0.052t}} \qquad (4.6)$$

where $(V_A)_p$ is the predicted number of vehicles involved in RTAs. The comparison of observed and predicted data for equation 4.6 was

$$(V_A)_o = 0.882\ (V_A)_p + 451$$

with $r = 0.94$, $r^2 = 0.88$ and standard error of 1437.

Observed data on vehicle composition was plotted and smoothed by moving averages. The data was converted into percentage vehicle composition for the individual class or group of vehicle type in order to determine their proportion in relation to the cumulative vehicles. After testing the data by various models the curve of best fit was found to be equation 3.42 , the logarithmic model. The model for the percentage composition of cars and utilities was developed as (Fig.4.35)

$$((\%)_{CU})_p = 76.427 - 2.160\ \ell nt \qquad (4.7)$$

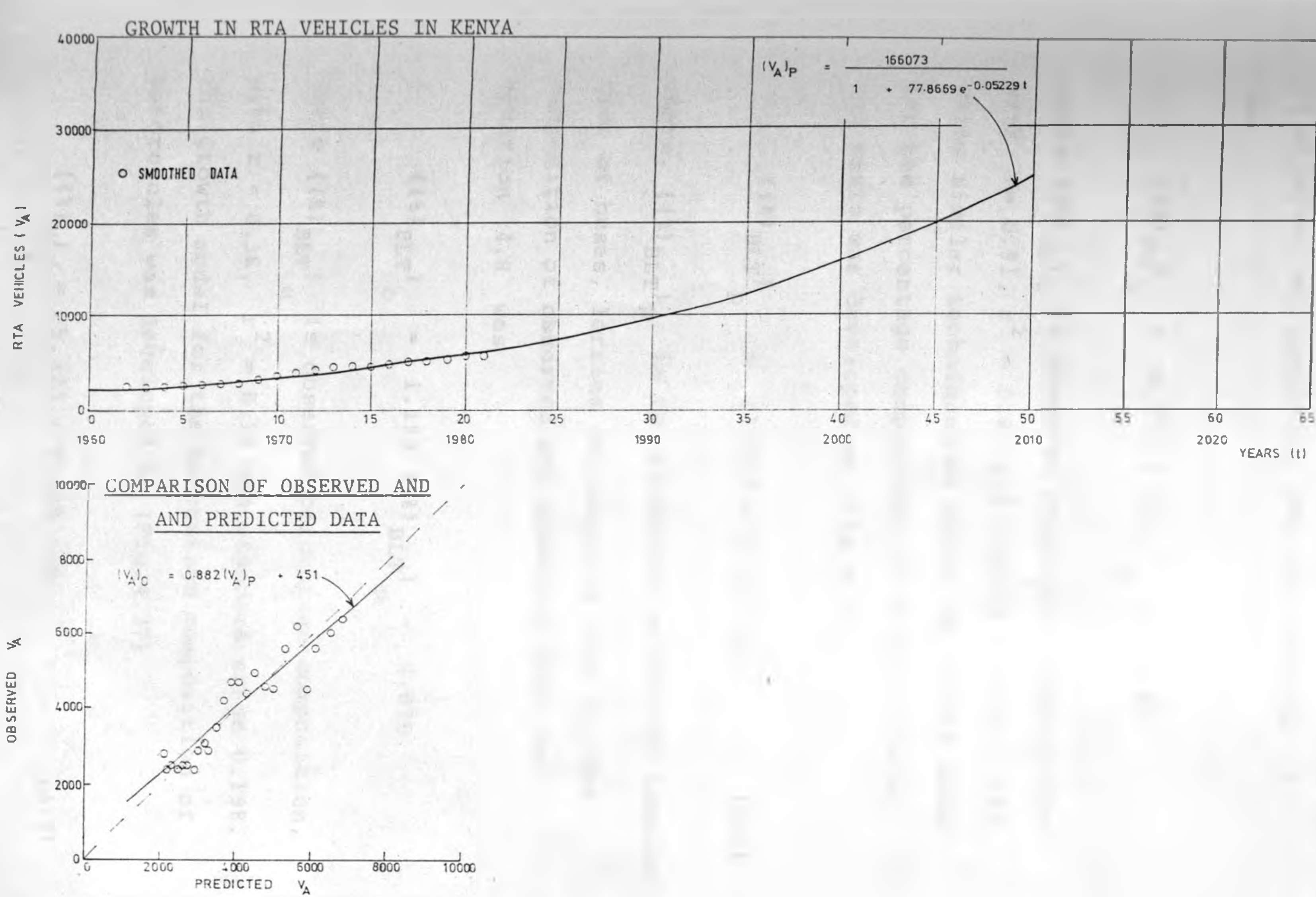


FIG. 4.5 GROWTH IN RTA VEHICLES IN KENYA

where, $((\%)_{CU})_p$ is the predicted eprcentage composition of cars and utilities at time t. The composition of observed and predicted data for equation 4.7 was

$$((\%)_{CU})_o = 0.994\ ((\%)_{CU})_p + 0.489$$

where $((\%)_{CU})_o$ is observed percentage composition, with $r = 0.91$, $r^2 = 0.82$ and standard error 1.785. Using similar techniques as above the growth model for the percentage composition of buses, lorries and taxis was developed as (Fig.4.36)

$$((\%)_{BLT})_p = 11.873 + 0.239\ \ell nt \qquad (4.8)$$

where, $((\%)_{BLT})_p$ is the predicted percentage composition of buses, lorries and taxis at time t. The composition of observed and predicted data for equation 4.8 was

$$((\%)_{BLT})_o = 1.158\ ((\%)_{BLT})_p - 2.070$$

where $((\%)_{BLT})_o$ is observed percentage composition, with $r = 0.38$, $r^2 = 0.14$ and standard error 0.198. The growth model for the percentage composition of motorcycles was developed as (Fig.4.37)

$$((\%)_M)_p = 5.323 + 0.309\ \ell nt \qquad (4.9)$$

where $((\%)_M)_p$ is the predicted percentage composition of motorcycles at year (time) t. The comparison of observed and predicted data yielded the equation

$$((\%)_M)_o = 1.123\ ((\%)_M)_p - 0.705$$

where $((\%)_M)_p$ is observed percentage composition, with $r = 0.63$, $r^2 = 0.40$ and standard error of 0.256.

The relationships developed as equations 4.1 to 4.9 were found to be significant at a level of 5 per cent.

4.1.2 Dual Carriageway (Nairobi-Thika Road) Traffic

The Nairobi-Thika Road was chosen for this study because of a number of reasons. The most important of these reasons are: as a dual carriageway it has a higher capacity for traffic than any other trunk road in Kenya thus providing a wide range of variation in traffic volumes, speeds, vehicles compositions and geometric design, it passes through land uses which vary from urban through semi-urban to semi-rural which greatly influence traffic movement. These reasons together with the fact that as a tarmac road with a high level of service consequently making it one of the roads in Kenya with a high potential for RTAs made the choice of this road for study a natural or

The Nairobi-Thika Road is a Class A international trunk road according to the road classification of the Ministry of Transport and Communications (MOTC) of Kenya. This road is part of the trunk road designated A2 and is one of the two major trunk routes emanating from Nairobi on which the road system in Kenya's Central Province is focussed (Fig.4.1). The trunk route A2, commences in Nairobi skirts the eastern flanks of the Nyandarua via Thika and Muranga, serving as the through route for all traffic travelling in a north-south direction in the densely populated districts of Kiambu, Muranga, Nyeri and Kirinyaga. Due to the prohibitive deeply gullied topography of the area the main Nairobi-Thika Road is the sole connection between the numerous roads leading into the densely populated districts of Kiambu and Muranga. Nearly all the major urban centres of Central Province are located on or near this route and owe their development to the stimulus to trade provided by this bituminized road. The distance from Nairobi to Thika is some 38 kilometres making the total distance of the dual carriageway studied 76 kilometres. Each carriageway was built as a two lane 6.5 metre wide road. The design speed is 80 kilometres per hour.

4.1.2.1 Data Collection

The data collection points are shown in Fig.4.6.

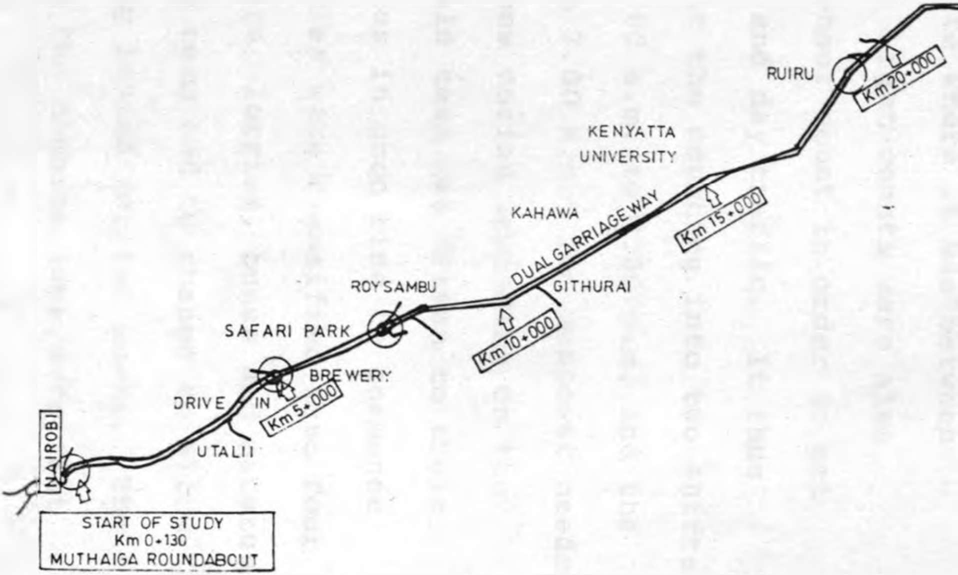
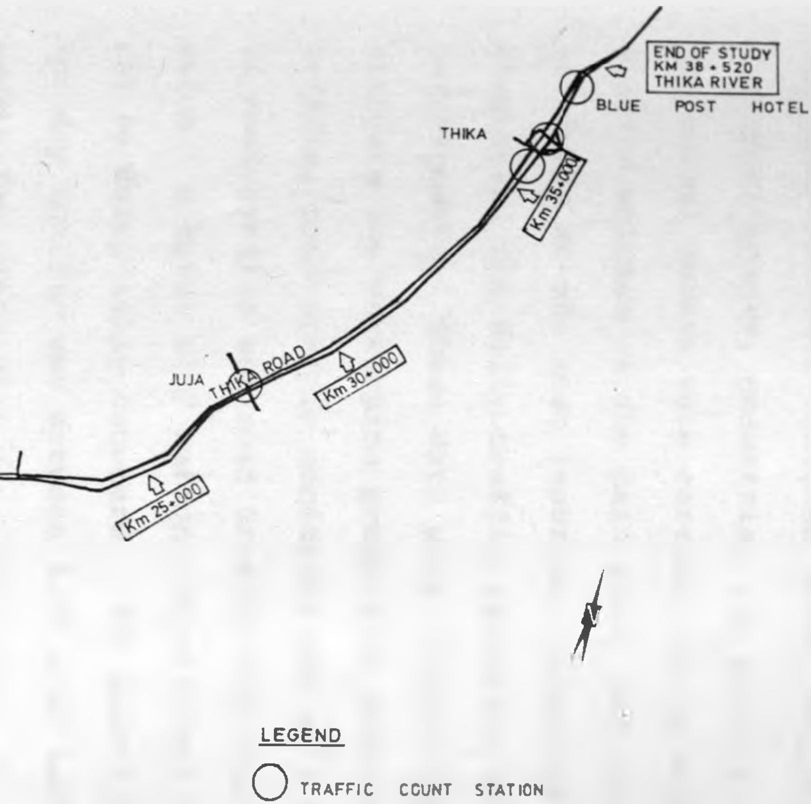


FIG 4.6 NAIROBI - THIKA ROAD DATA COLLECTION


END OF STUDY
KM 38 + 520
THIKA RIVER
BLUE POST HOTEL
THIKA
Km 35+000
JUJA
THIKA ROAD
Km 30+000
Km 25+000
LEGEND
TRAFFIC COUNT STATION

The data collected included manual counts, public transport counts, pedestrian and pedal cyclist counts. The manual counts were carried out in order to obtain traffic volumes on the main road, the turning vehicle movements at the most important junctions and round-abouts and the daily traffic variation on the main carriageways. These data were further used in the analysis for developing predictive models for road traffic, road traffic accidents and as a background to road traffic and road traffic accident characteristics. A total of 7 persons carried out the enumaration using tally counters. The counting period for day traffic was between 6.30 a.m. and 6.30 p.m. except for Outer Ring site where it was between 7.00 a.m. and 7.00 p.m. Night counts were also made to complete the 24-hour count in order to get the proportion of night and day traffic. It thus became necessary to split the counting into two shifts. One shift lasted from 7.00 a.m. to 7.00 p.m. and the second from 7.00 p.m. to 7.00 a.m. The manpower needed at the different locations varied depending on the traffic volume. The field team was driven to their appropriate counting sites in good time to commence the counting. The vehicles were classified into four categories: passenger cars, lorries, buses and matatus. Each half hour the field team had to change to allow for breaks. The counting lasted for two weeks. The major constraints during the observations were fast vehicle speeds, high volumes and poor lighting at night. Fortunately, these limitations did not affect the quality of the results since the enumerators were trained well before hand to cope with such difficulties

The public transport counts were carried out in order to provide the necessary background data for RTAs analysis, to reveal the importance of this transportion mode and to give specific background information on the usage of matatus (mini-buses) as opposed to buses. Two sections of the Nairobi-Thika Road were chosen as representative. One located near the Safari Park Hotel and another east of Ruiru. The enumeration period was one week for each direction. Day as well as night counts were made. Besides the amount of buses and matatus, the number of passengers were also recorded. A total of 8 enumerators assisted by two policemen carried out the survey. The policemen stopped the buses and matatus on a queue and the enumerators quickly carried out the counting of the passengers. The major constraint was the delays experienced by these vehicles because of stopping. This led to some annoyance to both the operators as well as the passengers particularly at the start of the enumeration period. Poor lighting at night made the enumeration particularly of passengers difficult. These limitations however, did not affect adversely the quality of the results.

Parallel with the vehicular traffic manual counts, pedestrians and pedal cyclists crossing the Nairobi-Thika Road were counted at some locations in order to give an indication of these road users level in order to provide the necessary background for understanding the RTAs related to these road users. The locations chosen were near the Drive-In-Cinema, near the Githurai junction and near the Juja junction. The enumaration near Githurai was done at half hour intervals. The enumaration for the other two sites was carried out as a whole from 6.30 a.m. to 6.30 p.m. to yield the approximate total number. The major limitation during this enumaration was the large number of pedestrians rushing across the carriageway at certain times, particularly at the start and end of the day.

4.1.2.2 Data Analysis

The directional vehicle movement counts showed that through traffic on Thika Road was dominating at intersections. Outer Ring Road and Garissa Road contributed most of the traffic onto Thika Road. Outer Ring had 40 per cent more than the through traffic. Outer Ring is a distributor road for traffic from Mombasa Road towards Thika and Nyeri area as well as serving the industrial corridor along the road. Garissa Road connects Thika Road to Thika Town an industrial and commercial town of rapid development. Ruiru urban area with industrial activities equally contributed substantial traffic especially lorries and buses. Most of the buses from Nairobi went through Ruiru Township towards Thika.

Although the enumeration days were different for each site, the peak hours were occurring almost at the same time. The morning peak hour was between 7.30 a.m. and 8.30 a.m. whilst the afternoon peak hour occurred between 4.30 p.m. and 5.30 p.m. with some sections occurring between 5.00 p.m. and 6.00 p.m. (Fig.4.7). The traffic variation at Ruiru (Appendix A.1) differed from this general pattern. It was observed that the heaviest morning traffic was as late as 10.30 a.m. to 11.30 a.m. This enumeration point occurs more or less midway between Nairobi and Thika. Therefore due to its location the peak hour is likely to be influenced by the travel time from Nairobi to Ruiru and Thika to Ruiru. Further, Ruiru has a number of industrial activities which draw traffic from Nairobi and therefore such traffic which leaves Nairobi and possibly Thika at about 9.00 a.m. is likely to lead to this observed traffic pattern. The traffic from Nairobi reached a peak between 6.30 p.m. and 7.30 p.m.

The vehicle counts revealed that the traffic varied only slightly during the weekdays. Sunday

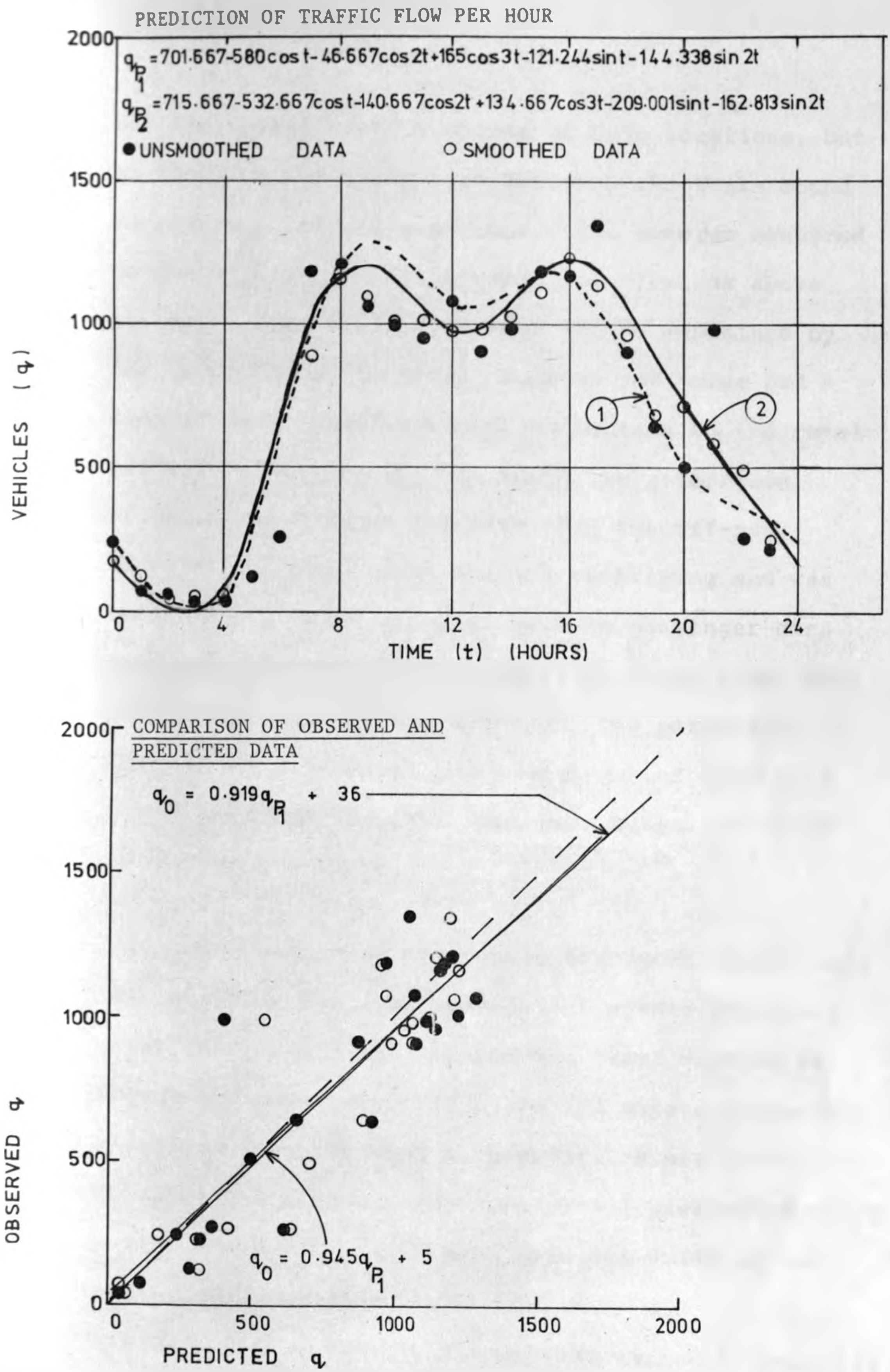


FIG.4.7 PREDICTION OF AVERAGE TRAFFIC FLOW PER HOUR: NAIROBI - THIKA ROAD

had the lowest traffic volume at both locations, but on Saturday the traffic at Ruiru on the Thika bound carriageway reached a maximum. The reverse occurred on Monday when traffic towards the city was above average. This traffic pattern can be explained by the recreational traffic. Lorries and buses had a similar daily traffic variation pattern as the total traffic. However, at peak hours the proportion of buses and lorries was less than the off-peak hours of the day. This was not surprising and was confirmed by other surveys, because passenger cars carrying people to and from work at those times were dominating. During the week days, the percentage of heavy traffic (lorries and buses) varied less near Drive-In-Cinema (19-22%) than near Ruiru (19-30.5%) of the total traffic.

The results of the public transport counts were influenced by the four week period within which the enumeration was done. During the first weekend of August the high number of buses and matatu passengers was found to be related to pay day. Buses were found to carry the larger proportion of all passengers using public transport. At Safari Park 66% - 79% of the passengers were found to be bus users and 21%-34% matatu users. At Ruiru the figures varied between 53% and 71% for buses and 29%-47% for matatus. Comparing the number of vehicles passing the enumeration sites, matatus had a higher percentage. The survey revealed that matatus are a vital factor in public transportation on the study road as well as the whole area. The census indicated that many of the vehicles not only matatus but buses as well, were overloaded with passengers. The highest number of passengers recorded in an ordinary matatu (weight 1070 kg) was 24 with others carrying over 20. Ordinary matatus have a passenger capacity varying between 13 and 20. Buses with a capacity of 90 passengers had up to 200 passengers, but most of the buses did not exceed their allowed capacity. From this analysis it was observed that both buses and matatus are necessary in the day to day passenger as well as goods transportation at the same time their overloading being a significant factor linked to RTAs (Appendix A.3).

Parallel with the vehicle counts, pedestrians crossing Thika Road were recorded at some selected locations. Near the Drive-In-Cinema where only the total number was required some 1300 pedestrians crossed the road in connection with the bus-stops sited there. Many pedestrians were also observed to be walking alongside the road on both sides as well as in the median. The highest number of pedestrians crossing the dual carriageway was recorded at the Juja intersection, where some 4000 pedestrians and 250 bicyclists were crossing during the day. This high number of crossings was related to the fact that industrial use lies on one side of the road whilst housing lies on the other coupled with the fact that the shops are located close to the road on both sides. In order to obtain the variation of pedestrian and pedal cyclist crossings during the day the observations at Githurai had been done at hourly intervals with a total of 2121 pedestrians and 83 (Appendix A.4) pedal cyclists crossing the road. The crossings at Githurai were made in connection with bus-stops and the market located close to the road. Not surprisingly, these crossings are a significant factor related to the RTAs on the study road.

In order to develop apredictive model, one day's data, on traffic observed at Muthaiga, was plotted and smoothed by moving averages (Fig.4.7). Using the technique of harmonic analysis from 3.4 equations 3.60 to 3.63 were used and a six-ordinate scheme developed to calculate the coefficients of a suitable periodic function in a trigonometric series to fit the observed data. To test the effect of data smoothing two predictive models were developed, one for unsmoothed data and an improved model for the smoothed data. Both models were analysed for fitness. For the unsmoothed data the predictive model gave the following expression:

$$q_{p_1} = 701.667 - 580 \cos t - 46.667 \cos 2t$$
$$+ 165 \cos 3t - 121.244 \sin t$$
$$- 144.338 \sin 2t \qquad (4.10)$$
$$40 < q \; 1800$$

where, q_{p_1} is the predicted number of vehicles per hour at time t. The comparison of observed and predicted data yielded the equation

$$q_o = 0.919\, q_{p_1} + 36$$

with r = 0.91, r^2 = 0.83 and standard error of 458 where, q_o is the observed number of vehicles at time t.

Similarly, the equation for the smoothed data was developed as

$$q_{p_2} = 715.667 - 532.667 \cos t - 140.667 \cos 2t$$
$$+ 134.667 \cos 3t - 209.001 \sin t$$
$$- 162.813 \sin 2t \qquad (4.11)$$
$$40 < q < 1800$$

where, q_{p_2} is the predicted number of vehicles per hour at time t. The comparison of observed and predicted data yielded the equation

$$q_o = 0.945\, q_{p_2} + 5$$

with $r = 0.93$, $r^2 = 0.86$ and standard error of 452 where, q_o is as above. Both models were tested and found to be statistically significant at the 5 per cent level. The models can be improved by adopting an ordinate scheme greater than six such as 8 or better still using all data in a 24-ordinate scheme. The effect of data smoothing can be seen in the change in the slope and intercept of the linear regressions obtained above by comparing the observed and peridicted data. The slope improves from 0.919 to 0.945 and the intercept drops from 36 to 5 for the two cases respectively. These two parameters indicate, by the method of final analysis outlined in section 3.5.2,that the calibration of the models, particularly that obtained using smoothed data, is quite acceptable and therefore the predictions are close to the observed values since 0.945 is close to 1 and 5 (vehicles) is close to 0.

4.1.3 Single Carriangeway (Kiganjo-Nanyuki Road)Traffic

The Kiganjo-Nanyuki Road was chosen for this study due to a number of reasons. The most important of these reaons are: the continuation of the trunk road A2 of which the Nairobi-Thika Road studied earlier is part, it serves a typically rural area where 60 per cent of all RTAs occur [15] and is one of the rural tarmac roads which contribute 47 per cent of all RTAs in Kenya, it has a good geometric design implying that the effect of geometric design was likely to be of less significance compared to the effect of junctions and pavement defects, it offered a variety of pavement defects which at the time of study were the major factors influencing RTAs together with the many junctions and accesses to the farms in this rural area.

The Kiganjo-Nanyuki single carriageway road is of class A international trunk road classification according to the MOTC. It is part of the trunk road designated A2 and one of the major trunk routes from Nairobi on which the road system in Kenya's Central Province is focussed (Fig.4.1). The Kiganjo-Nanyuki Road is located on the western side of Mount Kenya, partly in the densely populated Nyeri District of Central Province and partly in Laikipia District of the Rift Valley Province. The road starts at the junction of Kiganjo-Nanyuki Road A2 and the Nyeri-Kiganjo secondary road C75, some 142 kilometres from Nairobi and ends at Nanyuki. The total length of the study road is 48 kilometres. It is a two lane road of 6.1 metres width. The design speed is 80 kilometres per hour.

4.1.3.1 Data Collection

The data collection sites were located as shown in Fig.4.8. The data collection comprised mainly of classified traffic counts. These vehicle counts were done manually using six persons. The manual counts were carried out in order to obtain traffic volumes on the main road, the turning vehicle movements at the most important junctions and the daily traffic variation and composition on the main road. The data were further used in the analysis for developing predictive models for road traffic, RTAs and as a background to road traffic and road traffic accident characteristics. Tally counters were used during the enumeration. The enumeration phase lasted for two weeks Friday 21-1.83 to Thursday 27.1.83 and Tuesday 1.2.83 to Monday 7.2.83. The first week was used for recording the classified manual counts between Naro Moru and Nanyuki whilst the second week was used for the Kiganjo-Naro Moru section. After a day's training the enumerators performed satisfactorily. The enumerators worked in groups of twos for eight-hour shifts with overlaps of up to one hour for changing the teams. The counts included day and night traffic. The major constraint in the enumeration was the poor lighting conditions at night characteristic of rural roads in Kenya. The enumerators were however, equipped with torches and this limitation did not adversely affect the results. The results were plotted for each enumeration site (Appendix A.2).

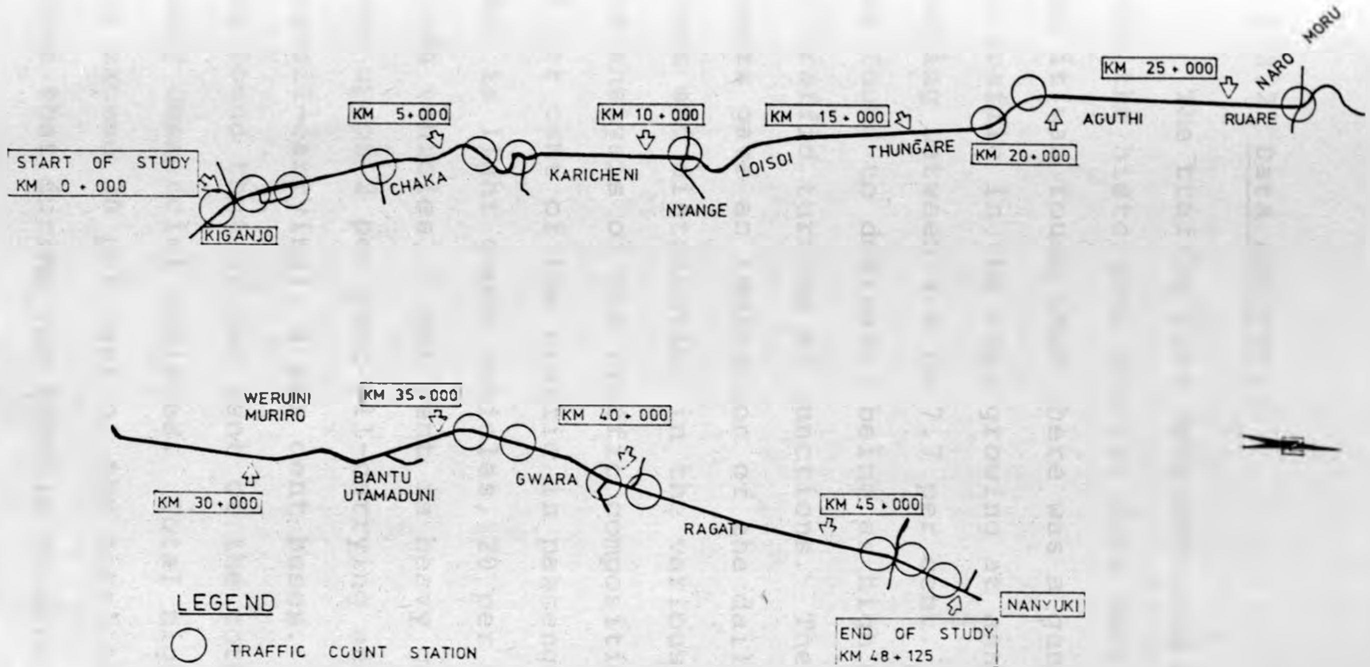


FIG. 4.8 KIGANJO - NANYUKI ROAD DATA COLLECTION

Parallel with manual counts information on origin and destination was obtained from heavy vehicles to provide a background for RTAs contribution by heavy vehicles.

4.1.3.2 Data Analysis

The traffic flow data obtained was compared with the historical traffic data kept by the MOTC and it was found that there was a general increase in traffic in the area growing at annual rates varying between 4.4 to 7.7 per cent. Through traffic was found to dominate, being as high as 12 times that of traffic turning at junctions. The classified manual counts gave an indication of the daily traffic variations and distribution in the various vehicle types. The analysis of the traffic composition revealed that 42 per cent of the traffic is passenger cars, 30 per cent is light goods vehicles, 20 per cent is medium goods vehicles, 5 per cent is heavy goods vehicles (made up of 2 per cent oil-carrying and 3 per cent non-oil-carrying), 4 per cent buses. Regrouping, it was found that 29 per cent of the total traffic was heavy commercial vehicles. Total night traffic did not exceed 30 per cent of the total traffic. It was noted that during the traffic enumeration the ban on night driving of heavy vehicles was in force. Matatus were found to be four times the number of buses. Matatus were found to be making more frequent trips than buses plying the same routes.

Peak hour traffic varied at different sites generally recurring between noon and 4.00 p.m. along the whole study road. Due to the night ban on heavy traffic they were almost non-existent except those carrying essential services. Traffic varied only slightly during the weekdays. Sunday had the lowest traffic volume, particularly at Naro Moru. From information on origin and destination it was observed that of all the heavy traffic at Nanyuki, 75 per cent is through traffic. At Kiganjo it was found to be as high as 95 per cent. At Nanyuki 40 per cent of the through traffic had their origin/destination as Meru, with significant amounts going as far north as Isiolo and Marsabit. At Kiganjo, 30 per cent of the through traffic had its origin and destination as Meru, Isiolo and Marsabit. South bound heavy traffic (i.e. Nanyuki to Kiganjo) was found to be 78 per cent and 55 per cent of all through heavy traffic at Kiganjo and Nanyuki respectively.

Using equations 3.60 to 3.63 and a six-ordinate scheme of the harmonic analysis predictive models for traffic flow on the single carriageway were developed for both smoothed and unsmoothed data. The predictive model for the observed unsmoothed traffic flow data was developed as (Fig.4.9)

$$q_{p_1} = 64.167-64.667 \cos t-0.667 \cos 2t+8.167 \cos 3t$$
$$-24-249 \sin t + 6.928 \sin 2t \qquad (4.12)$$

$$40 < q < 100$$

where, q_{p_1} is the predicted number of vehicles at time t. The comparison of observed and predicted data gave the equation

$$q_o = 1.019\, q_{p_1} + 0.354$$

with $r = 0.94$, $r^2 = 0.88$ and standard error of 51 where, q_o is the observed number of vehicles at time t. Similarly, the equation for the smoothed data was developed as

$$q_{p_2} = 65.333-63.5 \cos t-2.833 \cos 2t+11 \cos 3t$$
$$-28.001 \sin t + 8.372 \sin 2t \qquad (4.13)$$

$$40 < q < 100$$

where, q_{p_2} is the predicted traffic flow at time t. The comparison of observed and predicted data yielded the equation

$$q_o = 1.011\, q_{p_2} - 0.217$$

with $r = 0.94$, $r^2 = 0.89$ and standard error of 51

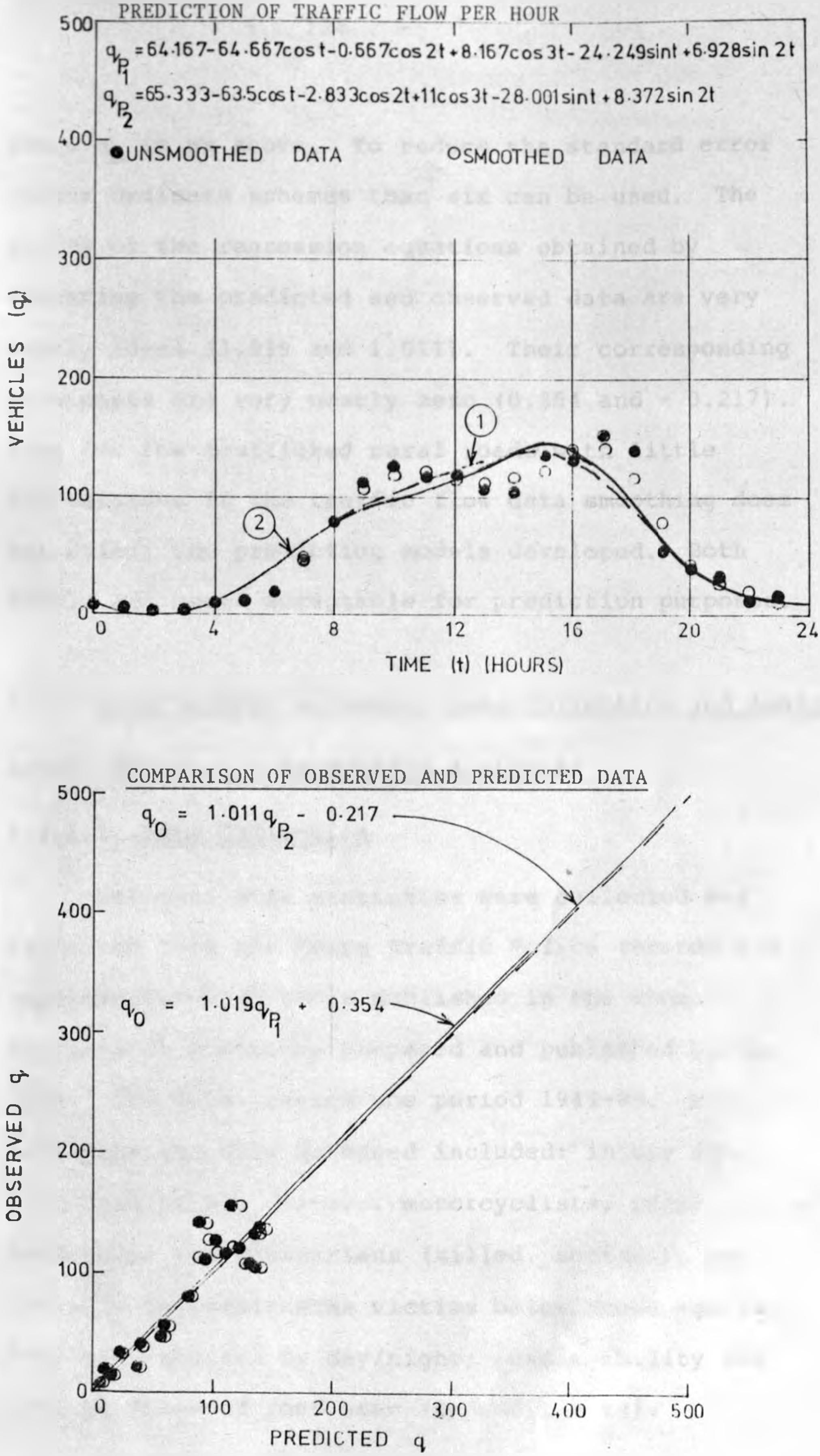


FIG. 4·9 PREDICTION OF AVERAGE TRAFFIC FLOW PER HOUR: KIGANJO - NANYUKI ROAD where q_o is as above. To reduce the standard error larger ordinate schemes than six can be used. The slopes of the regression equations obtained by comparing the predicted and observed data are very nearly ideal (1.019 and 1.011). Their corresponding intercepts are very nearly zero (0.354 and - 0.217). Thus for low trafficked rural roads with little flactuations in the traffic flow data smoothing does not affect the prediction models developed. Both models are quite acceptable for prediction purposes.

4.2 Road Traffic Accidents Data Collection and Analysis

4.2.1 National Road Traffic Accidents

4.2.1.1 Data Collection

National RTAs statistics were collected and extracted from the Kenya Traffic Police records and supplemented with those published in the annual Statistical Abstracts prepared and published by the CBSK. The data covered the period 1949-83. For each year the data gathered included: injury RTAs; road fatalities; drivers, motorcyclists, pedal cyclists passengers and pedestrians (killed, seriously and slightly injured); RTAs victims below/above age 16; RTAs distribution by day/night; responsibility for RTAs by class of road user (Appendix A.13).

4.2.1.2 Data Analysis

In order to develop mathematical models each plot of data was smoothed using the technique of moving averages. The curve shape revealed by the smoothed data was then determined. Using the smoothed data as the model data and choosing an appropriate function from Chapter 3 the predictive model, was developed and tested by the method of analysis of comparing observed and predicted data as outlined in 3.5.2. Finally the level of significance for each relationship was determined.

Injury Road Traffic Accidents

For injury RTAs growth models for RTAs and RTAs per 10^6 vehicle-kilometres were developed. Models predicting RTAs and RTAs per vehicle as functions of motorization were also derived. For injury RTAs the growth model was developed as a logistic curve which the shape of the smoothed data suggested (Fig.4.10). It was necessary to choose a limit for this model and the figure of 8049 which was the maximum observed was used for limit approximation. The model developed then was (using equation 3.15)

$$A_{P_1} = \frac{8049}{1 + 1.984\, e^{-0.137t}} \qquad (4.14)$$

where, A_{p_1} is predicted injury RTAs at year t. The comparison of observed and predicted data yielded the equation

$$A_o = 0.946\, A_{p_1} + 399$$

where A_o is observed injury RTAs, with $r = 0.91$, $r^2 = 0.83$ and standard error of 1394. Smoothed data of the number of RTAs were plotted against motorization. Using the finite differences technique for equally spaced data the data suggested a polynomial curve of third degree (Fig.4.11). Using formulae in 8.26 the predictive model was developed as

$$A_{p_2} = 6.6981\text{x}10^{-8}(V/p)^3 - 0.82263376(V/p)^2 + 270.438684(V/p + 15342.4929 \qquad (4.15)$$

where, A_{p_2} is the number of injury RTAs and V/p is vehicles per 10^4 persons. The comparison between observed injury RTAs (A_o) and the predicted number of injury RTAs yielded the equation

$$A_o = 1.135\, A_{p_2} - 605$$

with $r = 0.92$, $r^2 = 0.85$ and stnadard error of 1259. The predictions by the two models (4.14, 4.15) are quite consistent ($r^2 = 0.83$, 0.85 respectively) but model 4.14 predicts injury RTAs closer to the

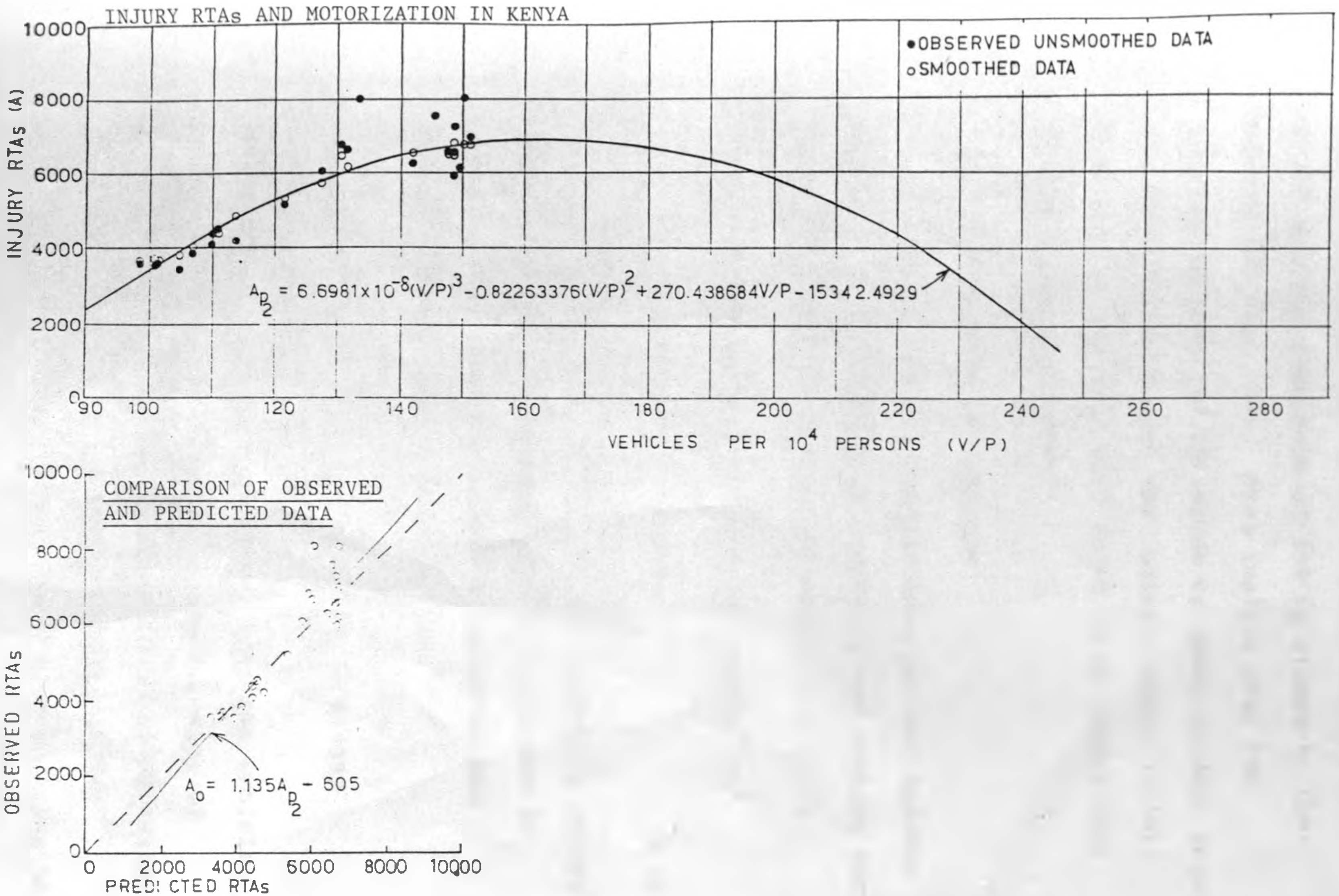


FIG 4.11 RELATION BETWEEN RTAs AND MOTORIZATION

observed values since the slope of the regression equation (0.946) is closer to the ideal (1) than 1.135 and the intercept of 399 is closer to the origin (0) than -605. This implies that the polynomial model (4.15) tends to under-predict injury RTA when compared with the logistic model (4.14). Models 4.14 and 4.15 were found to be significant at the 5 per cent level.

Injury RTAs per Vehicle

Injury RTAs per vehicle were plotted against motorization. After data smoothing and testing for polynomial fit the predictive model (Fig.4.12)

$$(A/V)_p = 0.656\text{x}10^{-12}(V/P)^3 - 0.000\ 00484(V/P)^2 + 0.001059\ V/P - 0.0183 \qquad (4.16)$$

was developed where, $(A/V)_p$ is the number of injury RTAs per vehicle predicted and V/P is degree of motorization. The comparison of observed and predicted data yielded the equation

$$(A/V)_o = 1.246(A/V)_p - 0.0092$$

where, $(A/V)_o$ is observed injury RTAs per vehicle, with $r = 0.80$, $r^2 = 0.64$ and standard error of 0.0034. The regression equation of observed values compared with predicted values indicates good correlation (r=0.80) but the model 4.16 explains only

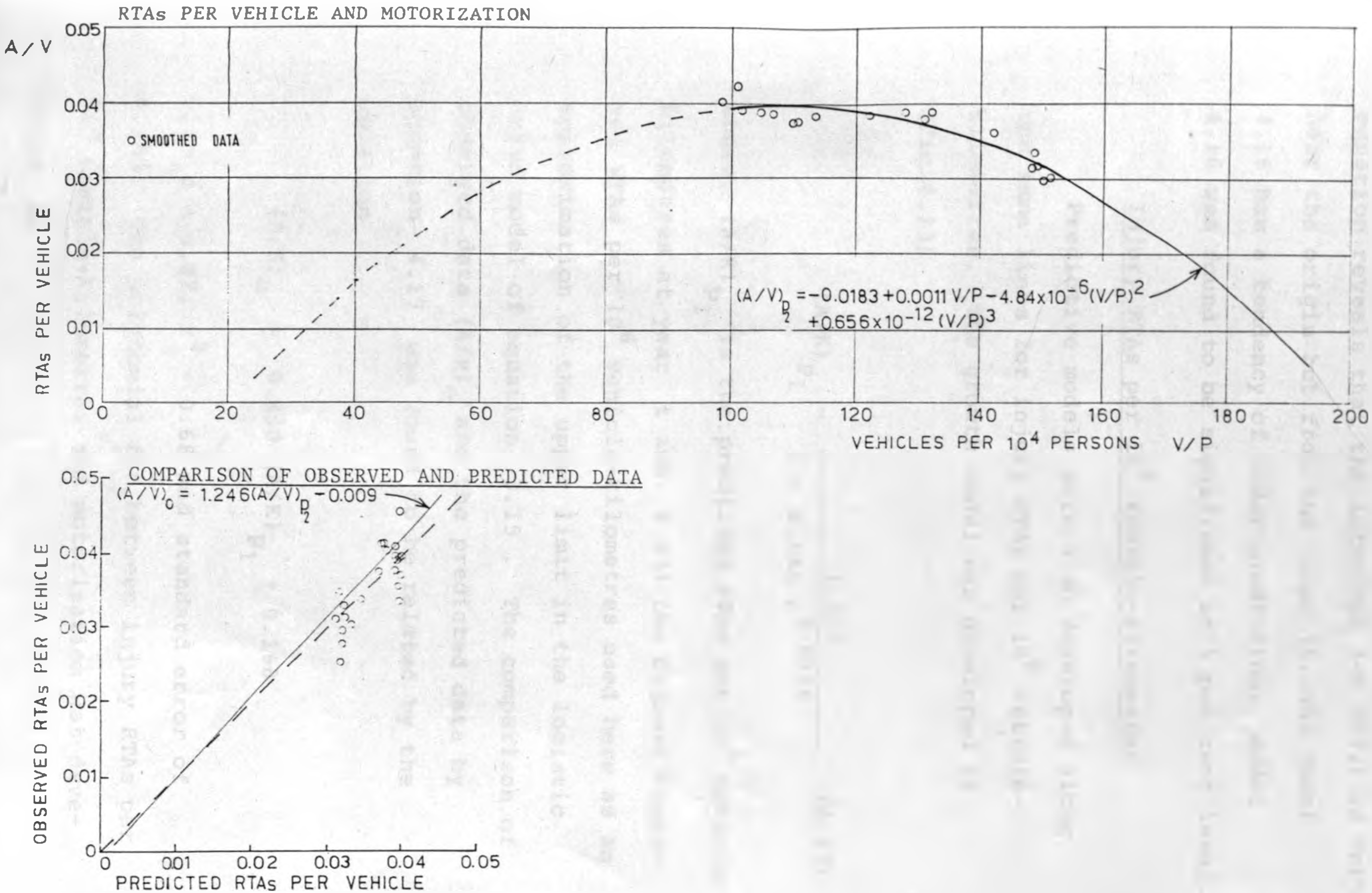


FIG.4.12 RELATION BETWEEN RTAs PER VEHICLE AND MOTORIZATION

64 per cent of the variation in data. The regression equation reveals that the intercept (-0.0092) is very near the origin but from the slope (1.246) model 4.16 has a tendency of under-predicting. Model 4.16 was found to be significant at 5 per cent level.

<u>Injury RTAs per 10^6 Vehicle-Kilometres</u>

Predictive models were also developed along the same lines for injury RTAs per 10^6 vehicle-kilometres. The growth model was developed as (Fig.4.13)

$$(A/K)_{p_1} = \frac{1.833}{1 + 0.085\, e^{0.093t}} \qquad (4.17)$$

where, $(A/K)_{p_1}$ is the predicted RTAs per 10^6 vehicle-kilometres at year t and 1.833 the highest observed RTAs per 10^6 vehicle-kilometres used here as an approximation of the upper limit in the logistic curve model of equation 3.15 . The comparison of observed data $(A/K)_o$ and the predicted data by equation 4.17 was found to be related by the equation

$$(A/K)_o = 0.890\,(A/K)_{p_1} + 0.168$$

with $r = 0.82$, $r^2 = 0.68$ and standard error of 0.195. The polynomial fit between injury RTAs per 10^6 vehicle-kilometres and motorization was developed as

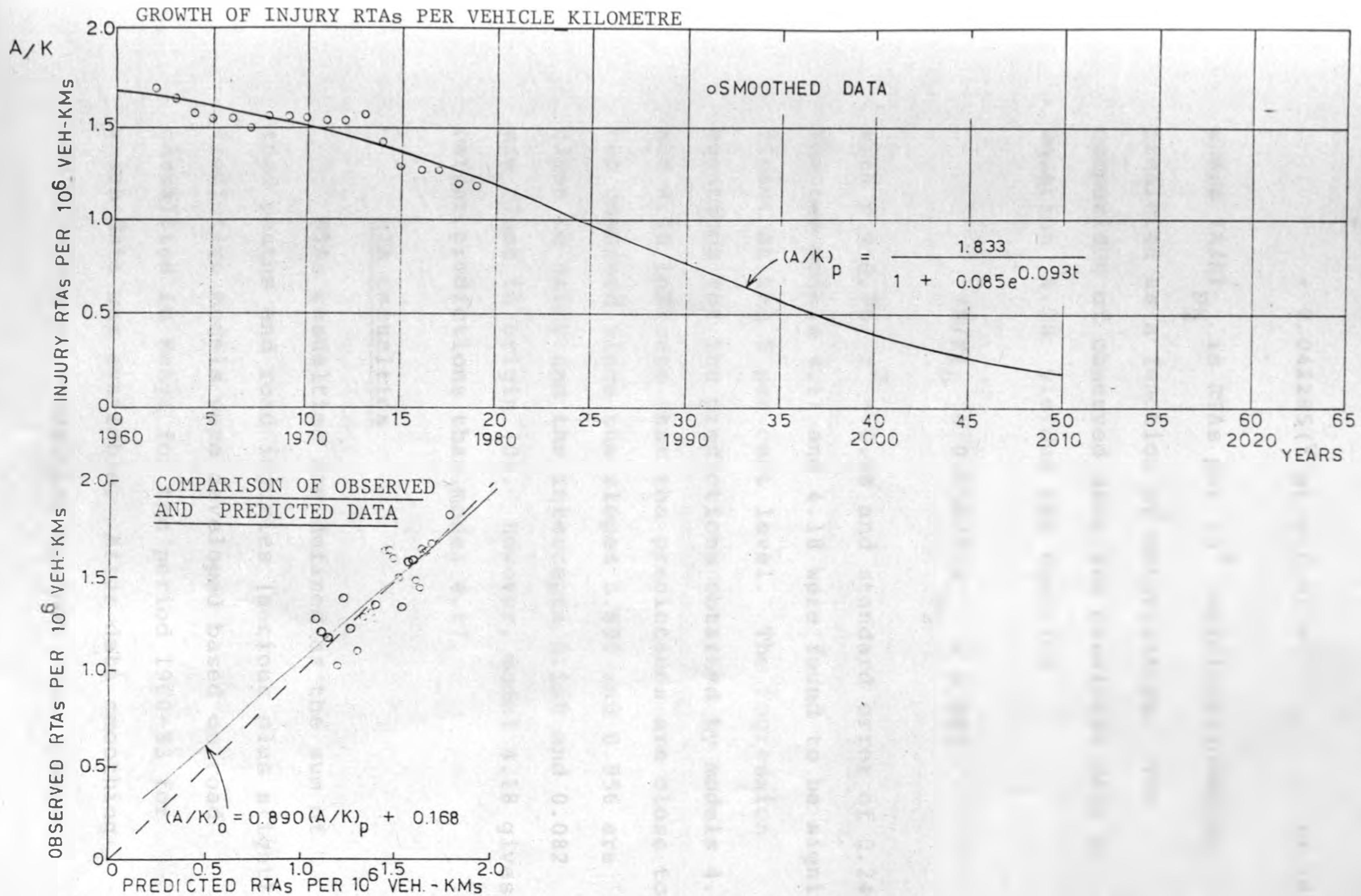


FIG. 4.13 GROWTH OF INJURY RTAs PER 10^6 VEHICLE-KILOMETRES IN KENYA

$$(A/K)_{P_2} = 0.2728\times10^{-10}(V/P)^3 - 0.00019613(V/P)^2$$

$$+ 0.042285(V/P) - 0.6774 \qquad (4.18)$$

where $(A/K)_{P_2}$ is RTAs per 10^6 vehicle-kilometres predicted as a function of motorization. The comparison of observed data and predicted data by equation 4.18 yielded the equation

$$(A/K)_O = 0.956(A/K)_{P_2} + 0.082$$

with r = 0.76, r^2 = 0.58 and standard error of 0.246. The two models 4.17 and 4.18 were found to be significant at the 5 per cent level. The regression equations for the predictions obtained by models 4.17 and 4.18 indicate that the predictions are close to the observed since the slopes 0.890 and 0.956 are close to unity and the intercepts 0.168 and 0.082 are close to origin (0). However, model 4.18 gives better predictions than model 4.17.

RTA Casualties

RTAs casualties are defined as the sum of road deaths and road injuries (serious plus slight). Predictive models were developed based on road casualties in Kenya for the period 1960-83 for which data was available. After data smoothing and plotting of casualties against time (years) and using equation (3.15) the predictive model for casualties was developed as (Fig.4.14)

$$C_{p_1} = \frac{14749}{1 + 3.772\ e^{-0.137t}} \qquad (4.19)$$

where, C_{p_1} is the predicted number of casualties at time t and 14749 was the highest level of casualties observed used here as an approximation of the limit. The comparison between observed data (C_o) and predicted data by model 4.19 gave the equation

$$C_o = 1.014\ C_{p_1} + 204$$

with $r = 0.94$, $r^2 = 0.88$ and standard error of 3137. Using formulae 3.26 and plynomial fitting techniques as before the polynomial function predicting casualties as a function of motorization was determined as

$$C_{p_2} = 0.1162\text{x}10^{-6}(V/P)^3 - 1.10706866(V/P)^2$$
$$+ 414.989047\ V/P - 26131.0196 \qquad (4.20)$$

where C_{p_2} is the predicted value of casualties at a given level of motorization (V/P). Observed and predicted values by equation 4.20 were compared and yielded the equation

$$C_o = 1.090\ C_{p_2} - 733$$

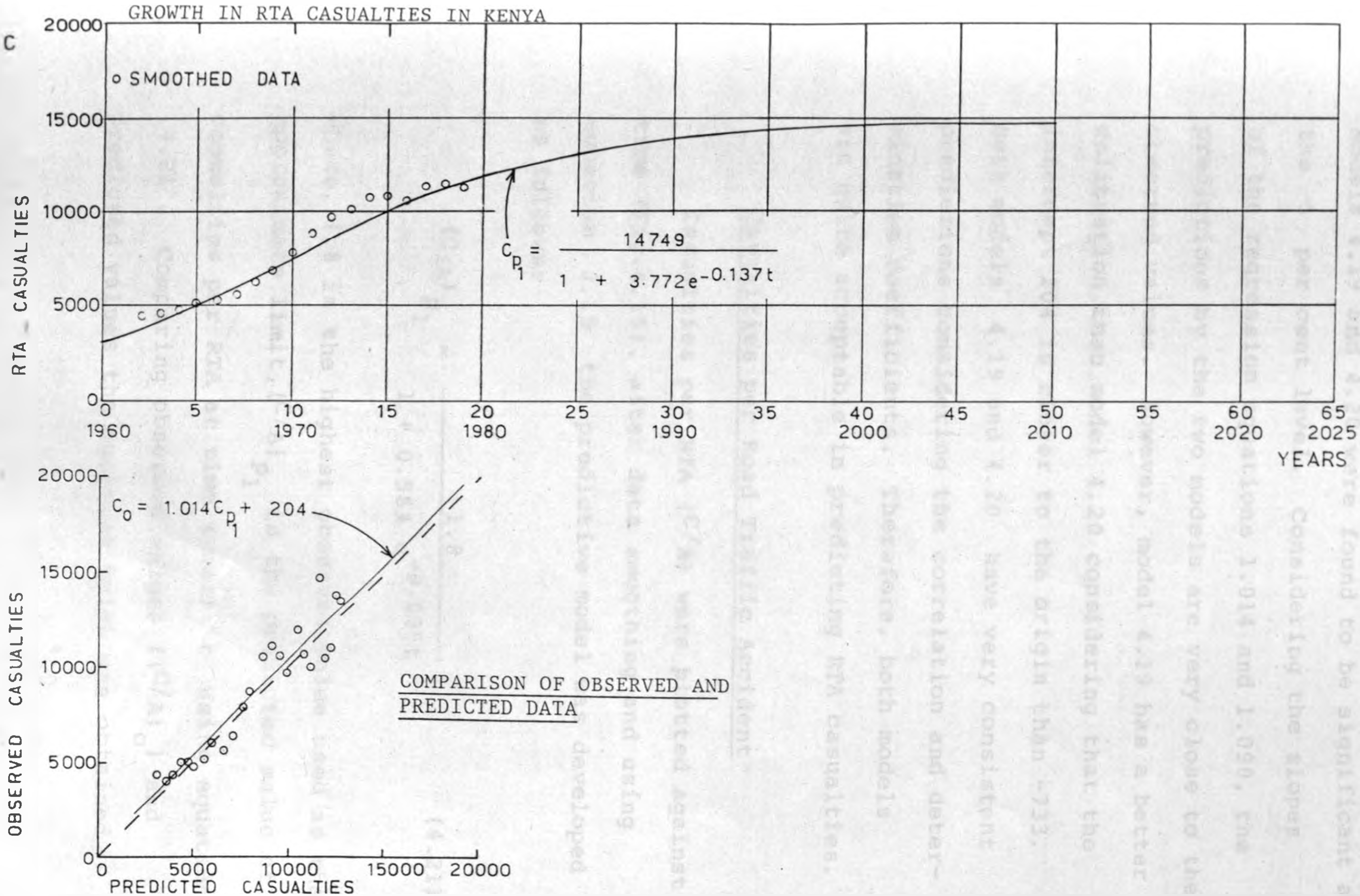


FIG 4.14 GROWTH IN RTA CASUALTIES IN KENYA

with r = 0.93, r^2 = 0.86 and standard error of 2690. Models 4.19 and 4.20 were found to be significant at the 5 per cent level. Considering the slopes of the regression equations 1.014 and 1.090, the predictions by the two models are very close to the observed values. However, model 4.19 has a better calibration than model 4.20 considering that the intercept 204 is closer to the origin than -733. Both models 4.19 and 4.20 have very consistent predictions considering the correlation and determination coefficients. Therefore, both models are quite acceptable in predicting RTA casualties.

Casualties per Road Traffic Accident

Casualties per RTA ($^C/A$) were plotted against time (Fig.4.15), after data smoothing and using equation 3.15 the predictive model was developed as follows:

$$(C/A)_{p_1} = \frac{1.8}{1 + 0.584\, e^{-0.095t}} \qquad (4.21)$$

where, 1.8 is the highest observed value used as the approximate limit, $(^C/A)_{p_1}$ is the predicted value of casualties per RTA at time (year) t using equation 4.21 . Comparing observed values ($(^C/A)_o$) and predicted values the equation below was obtained

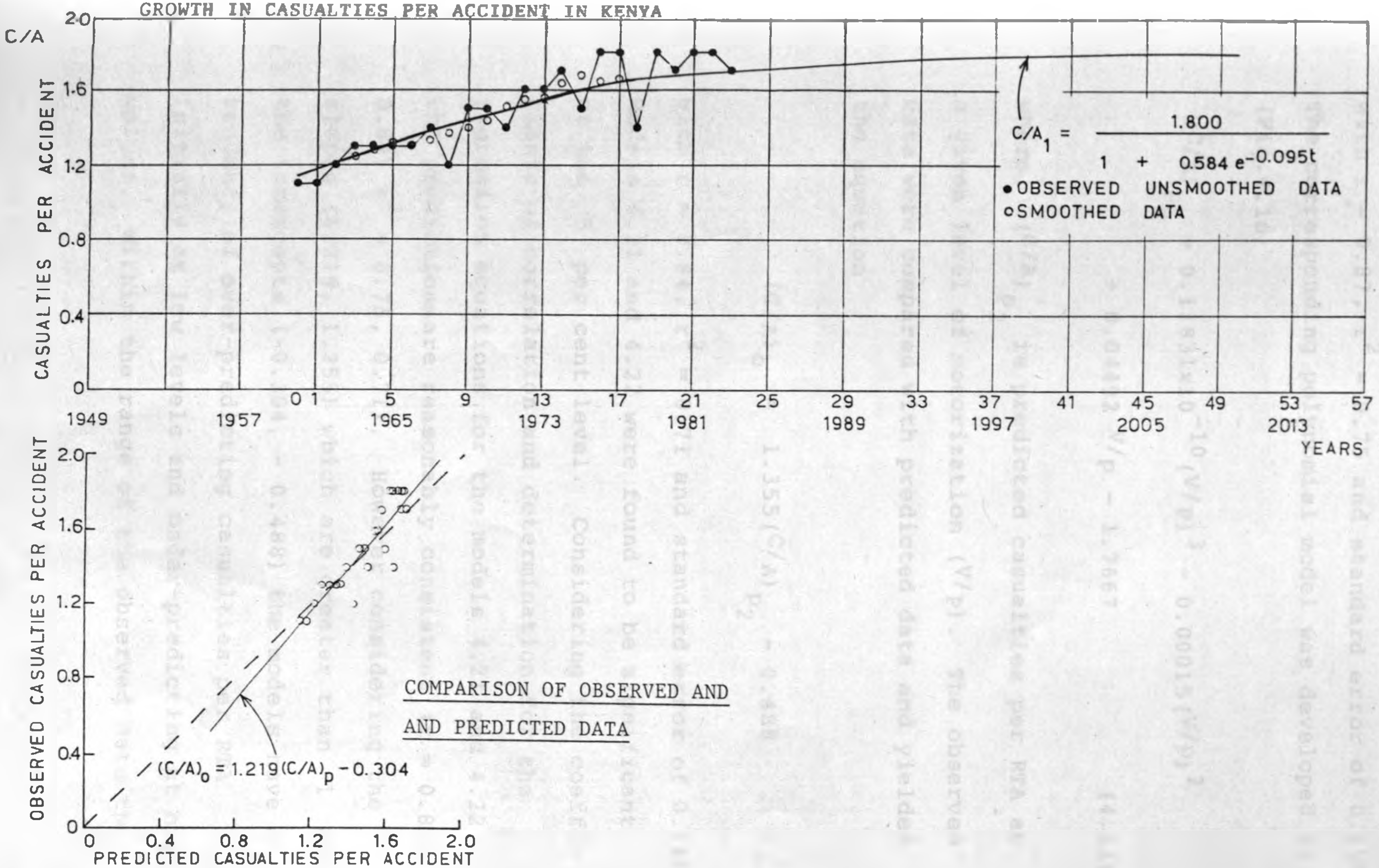


FIG.4.15 GROWTH IN CASUALTIES PER ACCIDENT IN KENYA

$$(C/A)_o = 1.219\,(C/A)_{p_1} - 0.304$$

with r = 0.87, r^2 = 0.75 and standard error of 0.159 The corresponding polynomial model was developed as (Fig.4.16)

$$(C/A)_{p_2} = 0.11831\times10^{-10}(V/P)^3 - 0.00015(V/P)^2 + 0.04492\,V/p - 1.7667 \qquad (4.22)$$

where, $(C/A)_{p_2}$ is predicted casualties per RTA at a given level of motorization (V/p). The observed data were compared with predicted data and yielded the equation

$$(C/A)_o = 1.355(C/A)_{p_2} - 0.488$$

with r = 0.84, r^2 = 0.71 and standard error of 0.146. Models 4.21 and 4.22 were found to be significant at the 5 per cent level. Considering the coefficients of correlation and determination for the regression equations for the models 4.21 and 4.22 the predictionsare reasonably consistent (r = 0.87, 0.84; r^2 = 0.75, 0.71). However considering the slopes (1.219, 1.355) which are greater than 1 and the intercepts (-0.304, - 0.488) the models have a tendency of over-predicting casualties per RTA initially at low levels and under-predicting at high values. Within the range of the observed data the

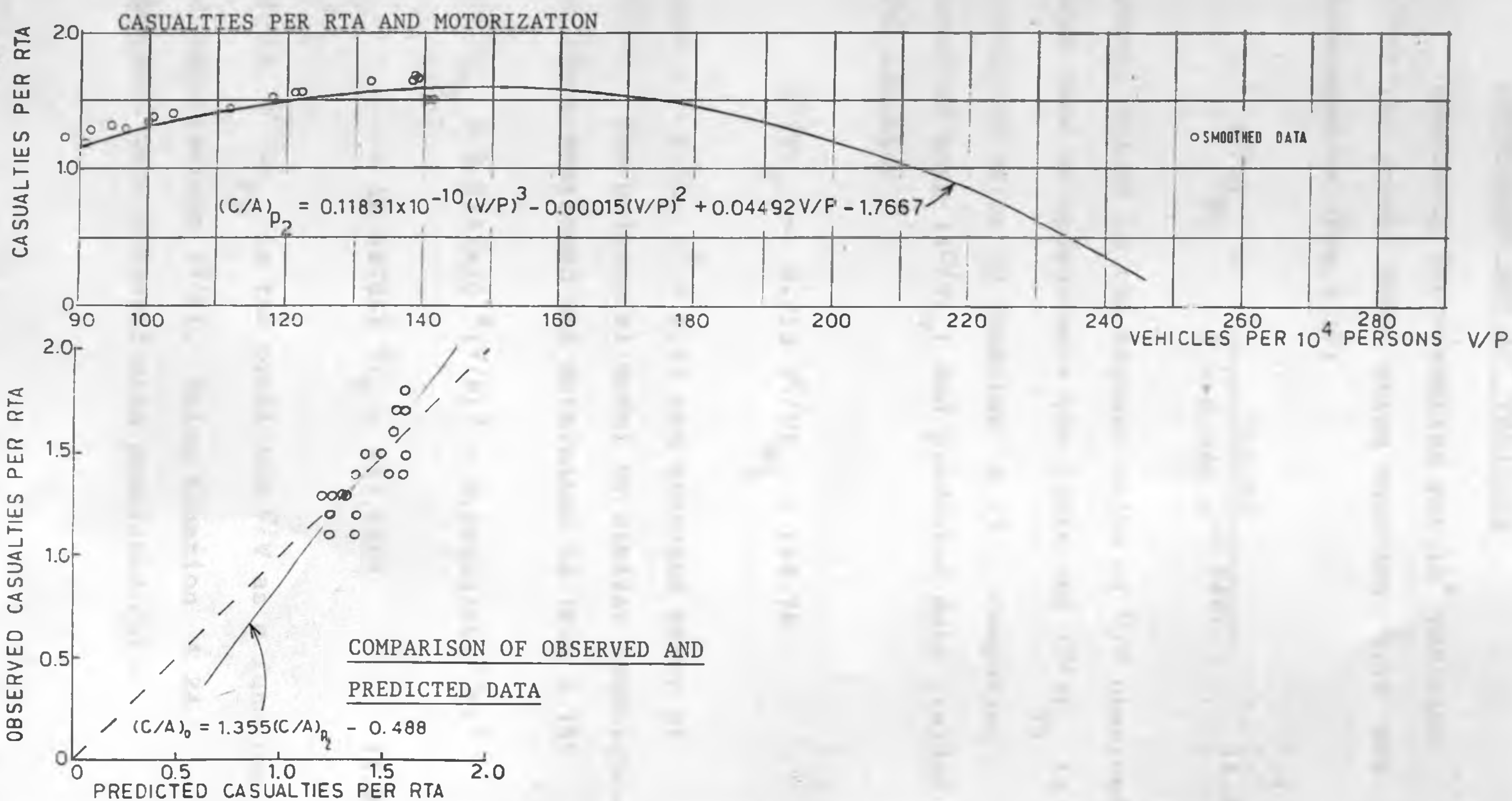


FIG.4.16 RELATION BETWEEN CASUALTIES PER RTA AND MOTORIZATION

predictions are quite close to the observed values.

Casualties per 10^4 Vehicles

Similarly for casualties per 10^4 vehicles ($^C/_V$) the growth model using equation 3.15 was developed as (Fig.4.17)

$$(^C/_V)_{p_1} = \frac{713.67}{1 + 0.964\, e^{-0.048t}} \qquad (4.23)$$

where, 713.67 is the highest value of $^C/_V$ observed used here to approximate the limit and $(^C/_V)_{p_1}$ is the predicted value by equation 4.23 . Comparing observed data ($(^C/_V)_o$) and predicted data yielded the equation

$$(^C/_V)_o = 0.713\, (^C/_V)_{p_1} + 144.78$$

with r = 0.52, r^2 = 0.27 and standard error of 72.47. The polynomial model by similar techniques as afore-mentioned was determined as (Fig.4.18)

$$(^C/_V)_{p_2} = 8.8191\text{x}10^{-8}(^V/_P)^3 - 0.04464166(^V/_P)^2$$

$$+ 12.597057\ ^V/_P - 337.6169 \qquad (4.24)$$

where, $(^C/_V)_{p_2}$ is the predicted $^C/_V$ as a function of motorization ($^V/_P$). Using equation 4.24 observed data compared with predicted data

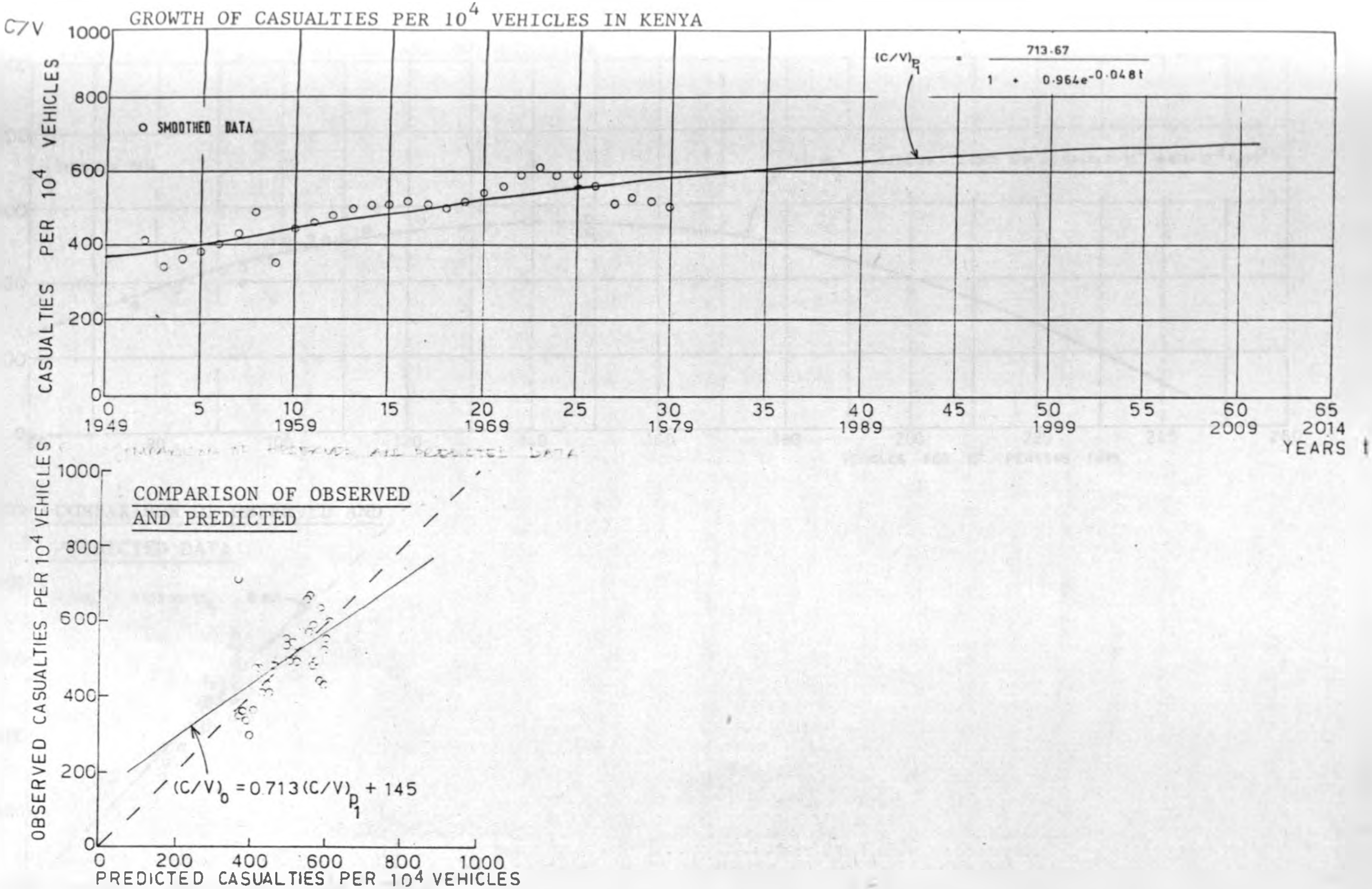
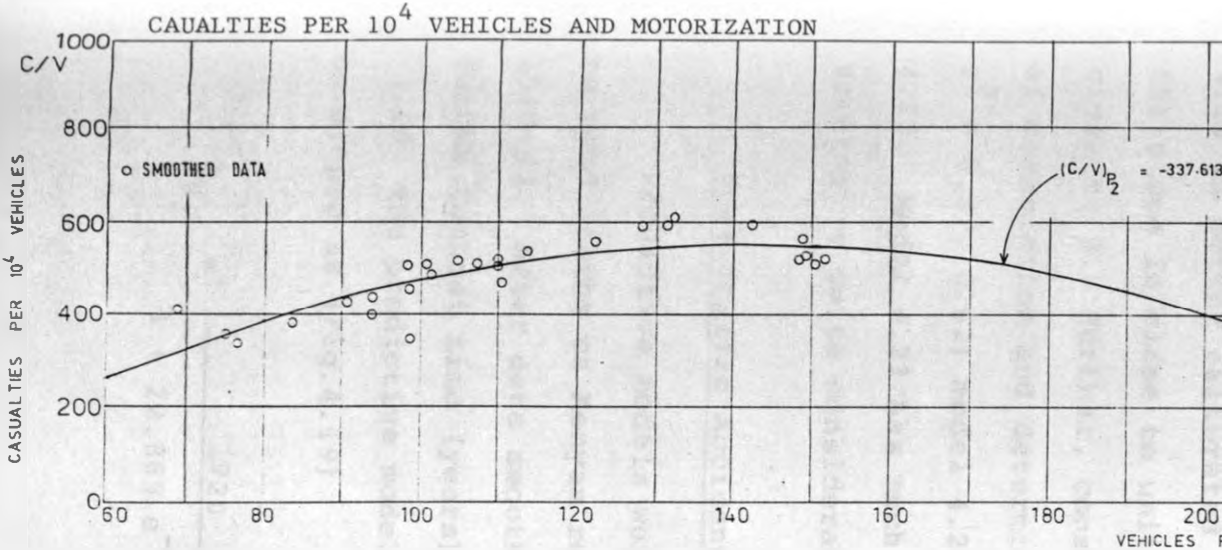


FIG 4.17 GROWTH OF CASUALTIES PER 10^4 VEHICLES IN KENYA



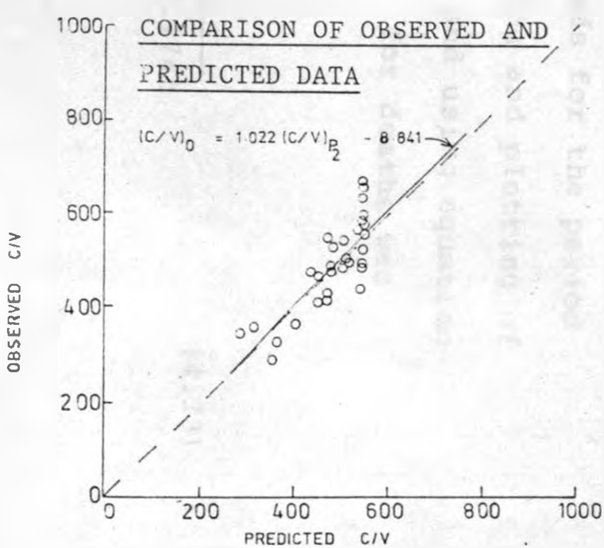


FIG 4.18 RELATION BETWEEN CASUALTIES PER 10^4 VEHICLES AND MOTORIZATION

resulted in the equation

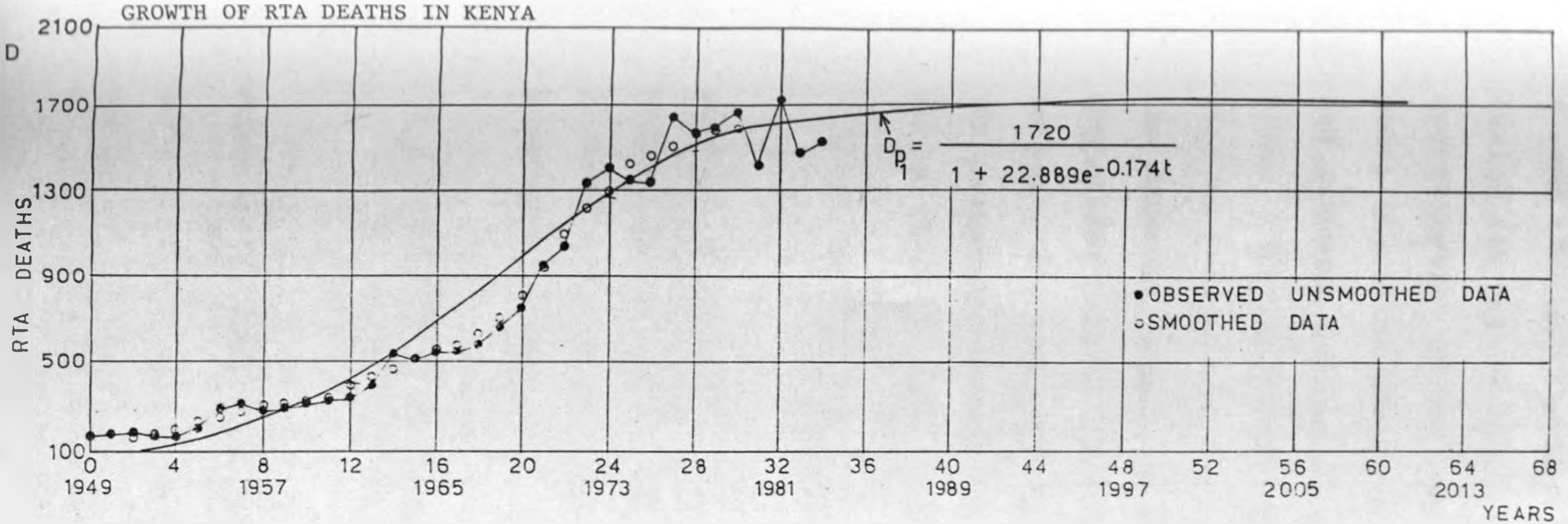
$$(C/V)_o = 1.022\ (C/V)_{P_2} - 8.841$$

with r = 0.79, r^2 = 0.62 and standard error of 71.414. Models 4.23 and 4.24 were found to be significant at the 5 per cent level. Considering the slopes of the regression equations (0.713, 1.022) and their intercepts (144.78, -8.841), model 4.24 is better calibrated than model 4.23 since the slope is close to unity and the intercept is close to 0. Further, considering the coefficients of correlation and determination (r = 0.52, 0.79; r^2 = 0.27, 0.62) model 4.24 fairs better than model 4.23. Model 4.23 has much lower consistency, as the scatter is quite considerable, than model 4.24.

Road Traffic Accident Deaths

Predictive models were also developed based on road deaths on Kenyan roads for the period 1949-83. After data smoothing and plotting of deaths against time (years) and using equation 3.15 the predictive model for deaths was developed as (Fig.4.19)

$$D_{P_1} = \frac{1720}{1 + 22.889\ e^{-0.174t}} \qquad (4.25)$$



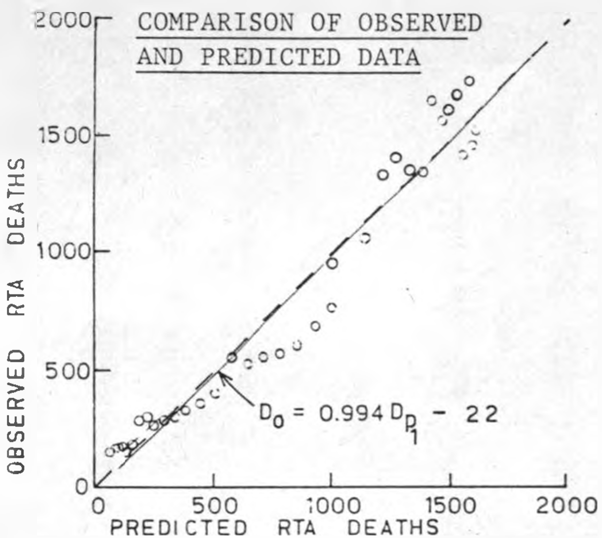


FIG 4.19 GROWTH OF RTA DEATHS IN KENYA

where, D_{p_1} is the number of predicted deaths at time t and 1720 was the highest level of deaths observed during the period under study, used here as an approximation of the limit. A higher value (like 2000) than 1720 would alter the limit of saturation and increase the rate of growth of RTA deaths with time. This was tried and the model obtained was used to predict RTA deaths which were compared with the observed value. It was found that the resulting regression equation did not significantly differ from the one obtained using 1720 as the upper limit. The comparison between observed data (D_o) and predicted data by model 4.25 gave the equation

$$D_o = 0.994\, D_{p_1} - 22$$

with r = 0.97, $r^2 = 0.95$ and standard error of 553. Using formulae 3.26 and polynomial fitting techniques as before the polynomial function predicting deaths as a function of motorization was developed as (Fig.4.20)

$$D_{p_2} = 229.7235 - 11.960418\, V/P + 0.14040617 (V/P)^2 + 0.18958\text{x}10^{-6} (V/P)^3 \qquad (4.26)$$

where D_{p_2} is the number of predicted deaths at a given degree of motorization V/P. Comparing observed data against predicted data yielded the equation

$$D_o = 1.009\, D_{p_2} - 10$$

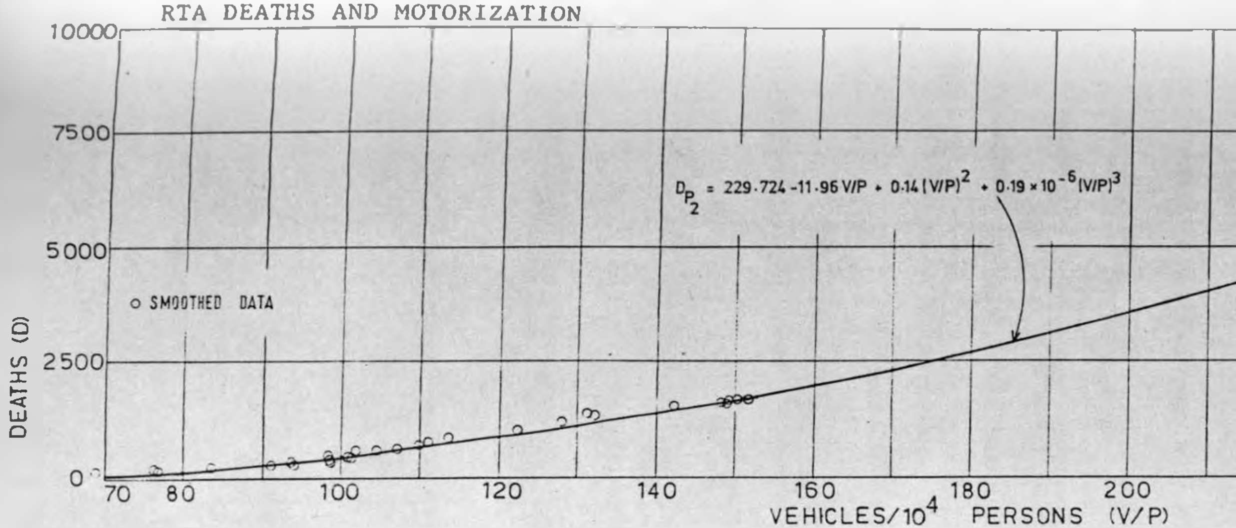
with r = 0.97, r^2 = 0.94 and standard error of 545. Models 4.25 and 4.26 were found to be significant at the 5 per cent level. Considering the coefficients of correlation and determination of the regression equations (r = 0.97; r^2 = 0.95, 0.94) the predictions obtained by the two models are very consistent. Considering the slopes (0.994, 1.009) and the intercepts (-22, - 10) the calibration of the two models are very near perfect since these parameters are very close to 1 and 0 respectively. Both models are therefore acceptable as the predicted values are almost identical to the observed values.

RTA Deaths per 10^4 Persons

Road deaths per 10^4 persons ($^D/_P$) were smoothed and plotted against motorization (Fig.4.21). Using polynomial function fitting techniques as above the predictive model was developed as

$$(D/P)_{P_1} = 1.9788\text{x}10^{-10}(V/P)^3 + 0.00001494(V/P)^2 + 0.007762(V/P) - 0.4127 \qquad (4.27)$$

where $(^D/_P)_{P_1}$ is the predicted number of road deaths per 10^4 persons at a given level of motorization ($^V/_P$). Observed data $(^D/_P)_O$ was compared with the predicted data by equation (4.27) yielding



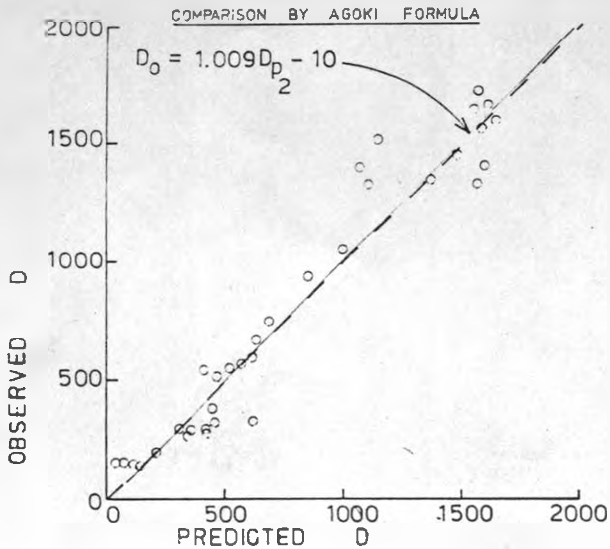


FIG.4.20 RELATION BETWEEN RTA DEATHS AND MOTORIZATION

equation

$$(D/P)_o = 0.923(D/P)_{p_1} + 0.054$$

with r = 0.93, r^2 = 0.87 and standard error of 0.31. Model 4.27 was found to be significant at the 5 per cent level. The regression of predicted values against observed values showed a consistent prediction and strong correlation (r = 0.93, r^2 = 0.87). The slope (0.923) and intercept (0.054) indicate slight under-prediction for low ranges and slight over-prediction for high ranges. The predictions, nonetheless, are close to the observed values and quite acceptable as the slope is close to 1 and the intercept nearly 0.

RTA Deaths per 10^4 Vehicles

Further, road deaths per 10^4 vehicles (D/V) were smoothed and plotted against motorization (Fig.4.22). Again, using the polynomial function fitting techniques as before the predictive model was developed as

$$(D/V)_{p_1} = 1.4218\times10^{-8}(V/P)^3 - 0.00022871(V/P)^2 + 0.577548\ V/P - 5.4171 \qquad (4.28)$$

where $(D/V)_{p_1}$ is the predicted number of deaths per 10^4 vehicles for a given level of motorization.

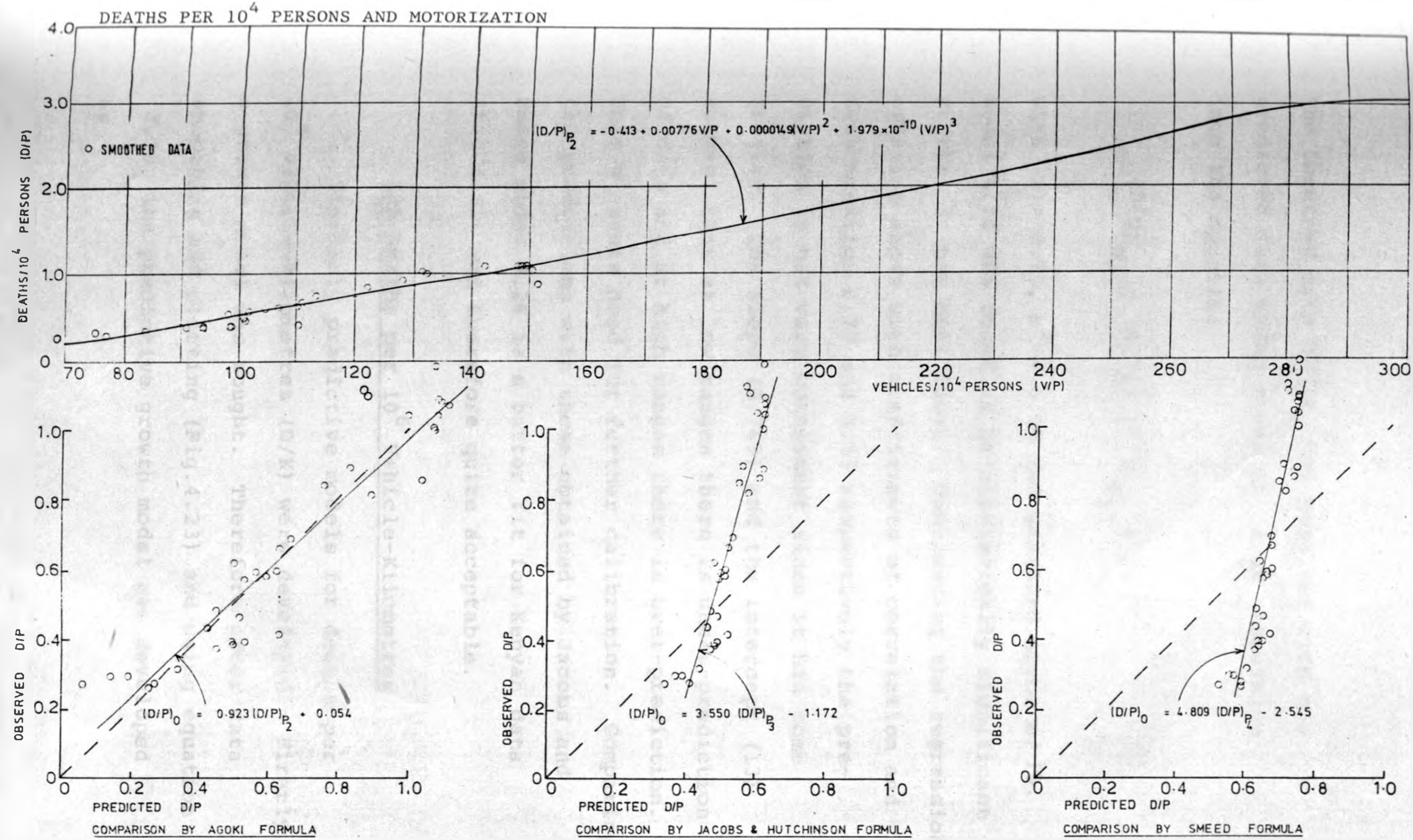


FIG.4.21 RELATION BETWEEN DEATHS/10^4 PERSONS AND MOTORIZATION

The observed data $(^{D}/_{V})_o$ was compared with the predicted data using equation 4.28 resulting into the equation

$$(^{D}/_{V})_o = 0.769\ (^{D}/_{V})_{p_1} + 13$$

with $r = 0.77$, $r^2 = 0.59$ and standard error of 15. Model 4.28 was found to be statistically significant at the 5 per cent level. Considering the regression equation above with coefficients of correlation and determination 0.77 and 0.59 respectively the prediction is not very consistent since it has some scatter. The slope (0.769) and the intercept (13) suggest that at low ranges there is under-prediction of data and at high ranges there is over-prediction. This suggests need for further calibration. Comparing the predictions with those obtained by Jacobs and Smeed model 4.28 is a better fit for Kenyan data (Fig.4.22) and therefore quite acceptable.

RTA Deaths per 10^6 Vehicle-Kilometres

Similarly predictive models for deaths per 10^6 vehicle-kilometres (D/K) were developed. Firstly, a growth model was sought. Therefore after data smoothing and plotting (Fig.4.23) and using equation 3.15 the predictive growth model was developed as

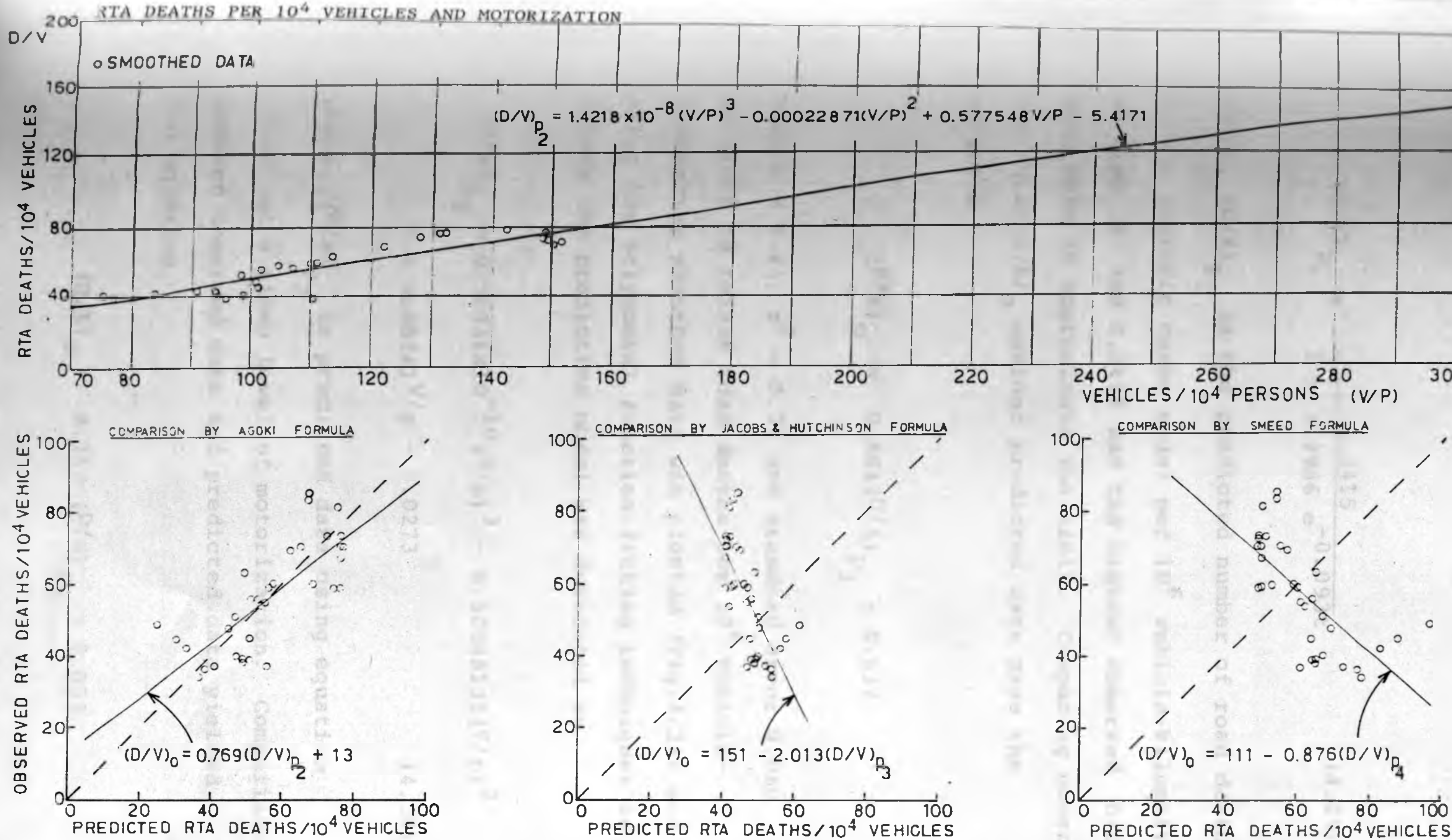


FIG. 4.22 RELATION BETWEEN RTA DEATHS PER 10^4 VEHICLES AND MOTORIZATION

$$(D/K)_{p_1} = \frac{0.3415}{1 + 1.9986\ e^{-0.093t}} \qquad (4.29)$$

where, $(D/K)_{p_1}$ is the predicted number of road deaths by the logistic curve model per 10^6 vehicle-kilometres at time t and 0.3415 was the highest observed D/K used here to approximate the limit. Comparing observed data $(D/K)_o$ against predicted data gave the equation

$$(D/K)_o = 0.864(D/K)_{p_1} + 0.032$$

with $r = 0.84$, $r^2 = 0.71$ and standard error 0.060. In order to relate road deaths per 10^6 vehicle-kilometres smoothed data was plotted (Fig.4.24) and using the polynomial function fitting techniques as before the predictive model was developed as

$$(D/K)_{p_2} = 0.58935\text{x}10^{-10}(V/p)^3 - 0.00000131(V/p)^2 + 0.00241V/p - 0.0273 \qquad (4.30)$$

where, $(D/K)_{p_2}$ is predicted data using equation 4.30 at a given level of motorization. Comparison between observed data and predicted data yielded the equation

$$(D/K)_o = 0.763\ (D/K)_{p_2} + 0.053$$

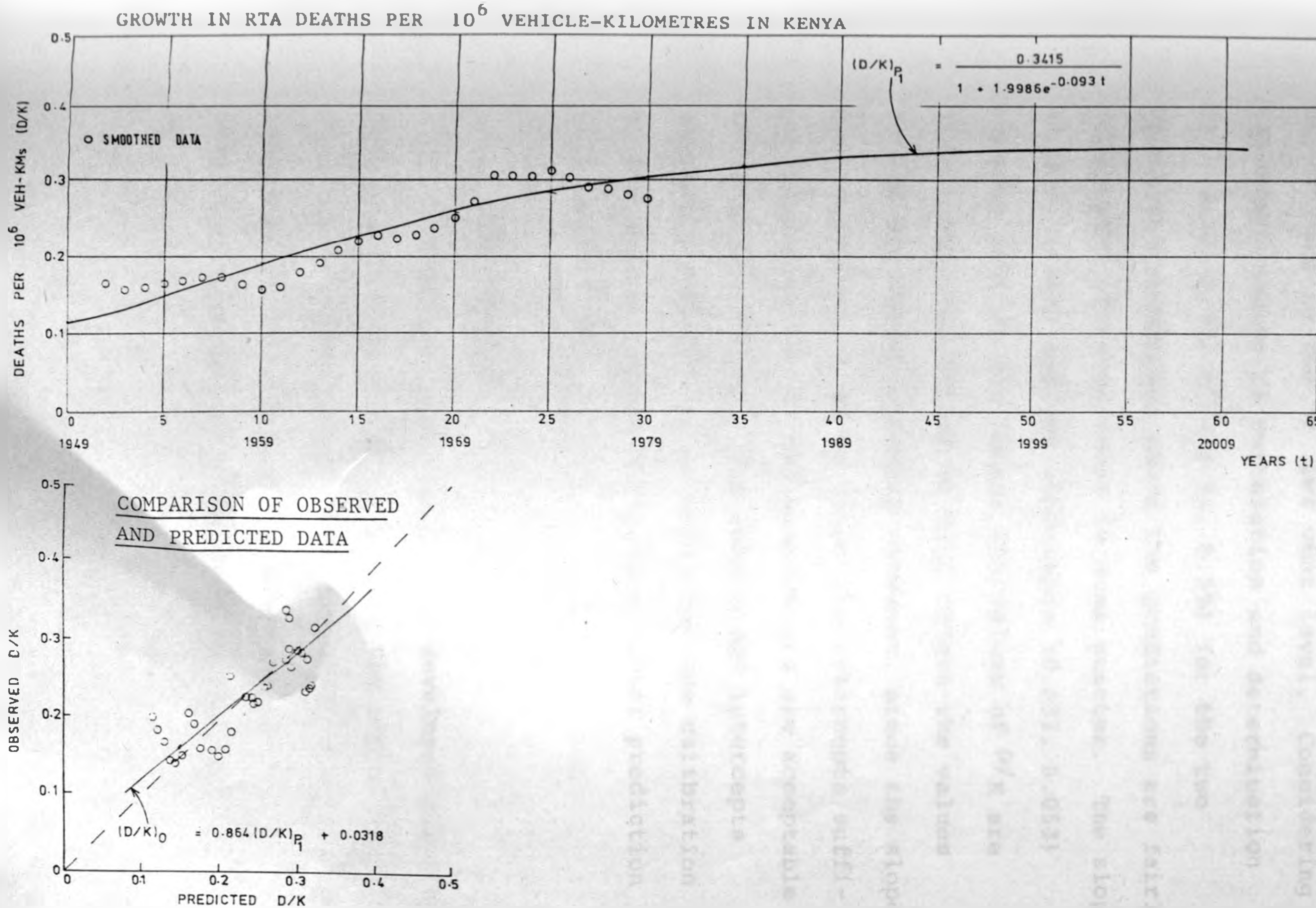


FIG. 4.23 GROWTH IN DEATHS PER 10^6 VEH-KMs IN KENYA

with $r = 0.77$, $r^2 = 0.59$ and standard error of 0.059. The predictive models 4.29 and 4.30 were found to be significant at the 5 per cent level. Considering the coefficients of correlation and determination ($r = 0.84, 0.77$; $r^2 = 0.71, 0.59$) for the two regression equations above the predictions are fairly consistent although there is some scatter. The slopes (0.864, 0.763) and the intercepts (0.032, 0.053) suggest that at low ranges the values of D/K are under-predicted whilst at high ranges the values of D/K are over-predicted. However, since the slopes are reasonably close to 1 and the intercepts sufficiently close to 0 the predictions are acceptable for the data fitted. The slopes and intercepts suggest a possibility of improving the calibration of the models. Model 4.29 makes better prediction than model 4.30.

RTA Injuries

Predictive models were also developed based on RTAs injuries on Kenyan roads for the period 1949-83. After data smoothing and plotting of injuries against time (years) and using model equation 3.15 the predictive growth model for injuries was developed as (Fig.4.25)

$$I_{p_1} = \frac{13526}{1 + 12.095\, e^{-0.122t}} \qquad (4.31)$$

RTA DEATHS PER 10^6 VEHICLE KILOMETRES AND MOTORIZATION

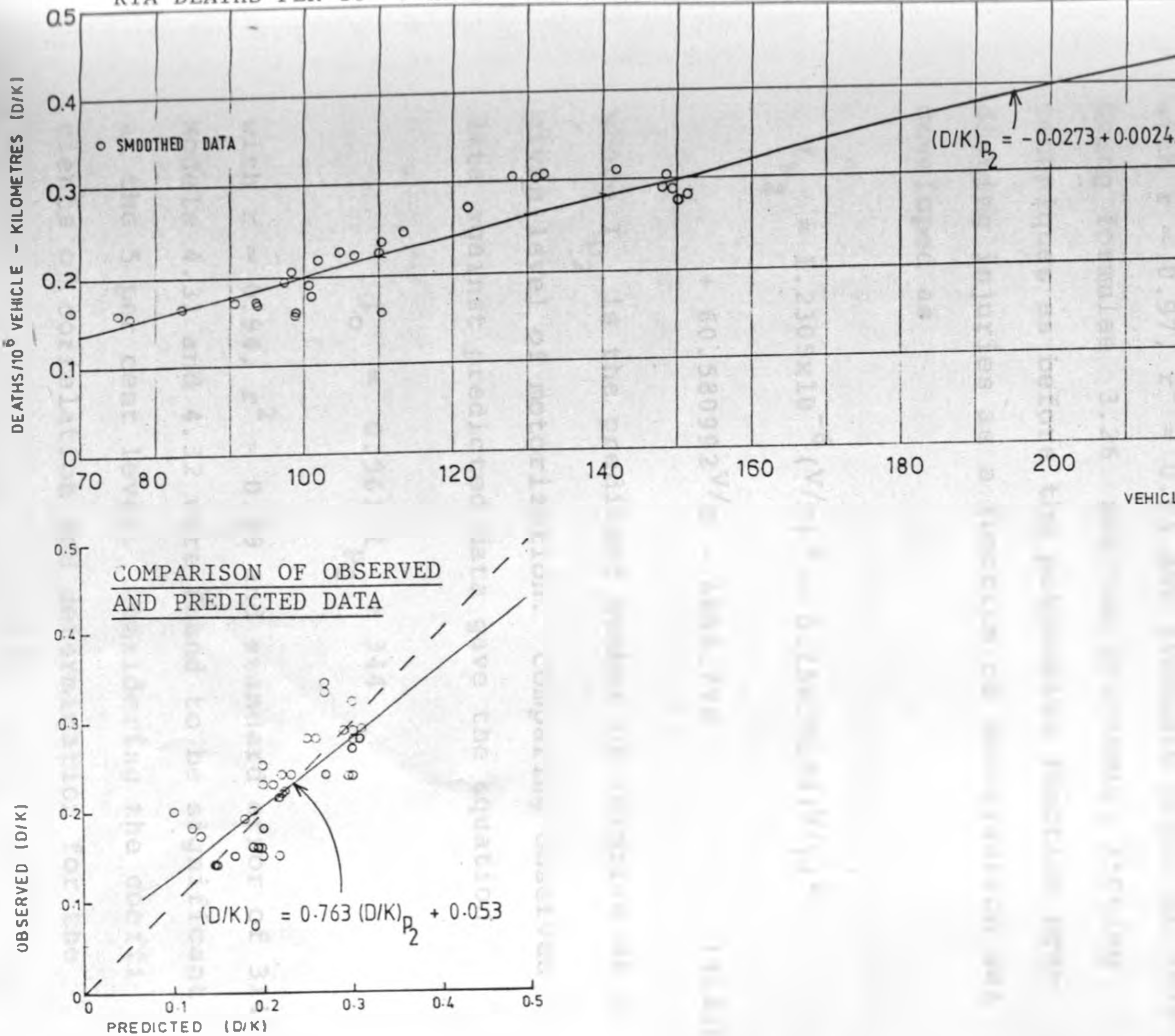


FIG 4.24 RELATION BETWEEN DEATHS PER 10^6 VEH-KMs AND MOTORIZATION

where, I_{p_1} is the predicted number of injuries at time t and 13526 was the highest level of injuries observed, used here as an approximation of the limit. The comparison between observed data I_o and predicted data as obtained by using model 4.31 yielded

$$I_o = 1.045\, I_{p_1} - 171$$

with r = 0.97, r^2 = 0.93 and standard error of 3430. Using formulae 3.26 and the polynomial fitting techniques as before the polynomial function predicting injuries as a function of motorization was developed as

$$I_{p_2} = 1.2305\text{x}10^{-6}(V/P)^3 + 0.25629308(V/P)^2 + 60.580992\,V/P - 4849.778 \quad (4.32)$$

where I_{p_2} is the predicted number of injuries at a given level of motorization. Comparing observed data against predicted data gave the equation

$$I_o = 0.961\, I_{p_2} + 344$$

with r = 0.94, r^2 = 0.89 and standard error of 3144. Models 4.31 and 4.32 were found to be significant at the 5 per cent level. Considering the coefficients of correlation and determination for the regression equations above ($r=0.97$, 0.94; $r^2 = 0.93$, 0.89) the consistency in the predictions is very good. Further, the slopes (1.045, 0.961) and the intercepts (-171, 344) suggest that the calibration of the two models is good since the two parameters are sufficiently close to 1 and 0 respectively. The models are therefore quite acceptable for the data fitted.

RTA Injuries per 10^4 Persons

Then injuries per 10^4 persons (I/P) were smoothed and plotted (Fig.4.26) against time (years) and using model equation 3.15 the predictive growth model for injuries per 10^4 persons was developed as

$$(I/P)_{P_1} = \frac{8.483}{1 + 2.788\, e^{-0.086t}} \qquad (4.33)$$

where, $(I/P)_{P_1}$ is the predicted number of injuries at time t and 8.483 was the highest level of injuries per 10^4 persons observed, used here as an approximation of the limit. The comparison between observed data $(I/p)_o$ and predicted data as obtained by using model (4.33) yielded

$$(I/p)_o = 1.047(I/P)_{P_1} - 0.149$$

with $r = 0.91$, $r^2 = 0.83$ and standard error of 1.509. Using formulae (3.26) and the polynomial function

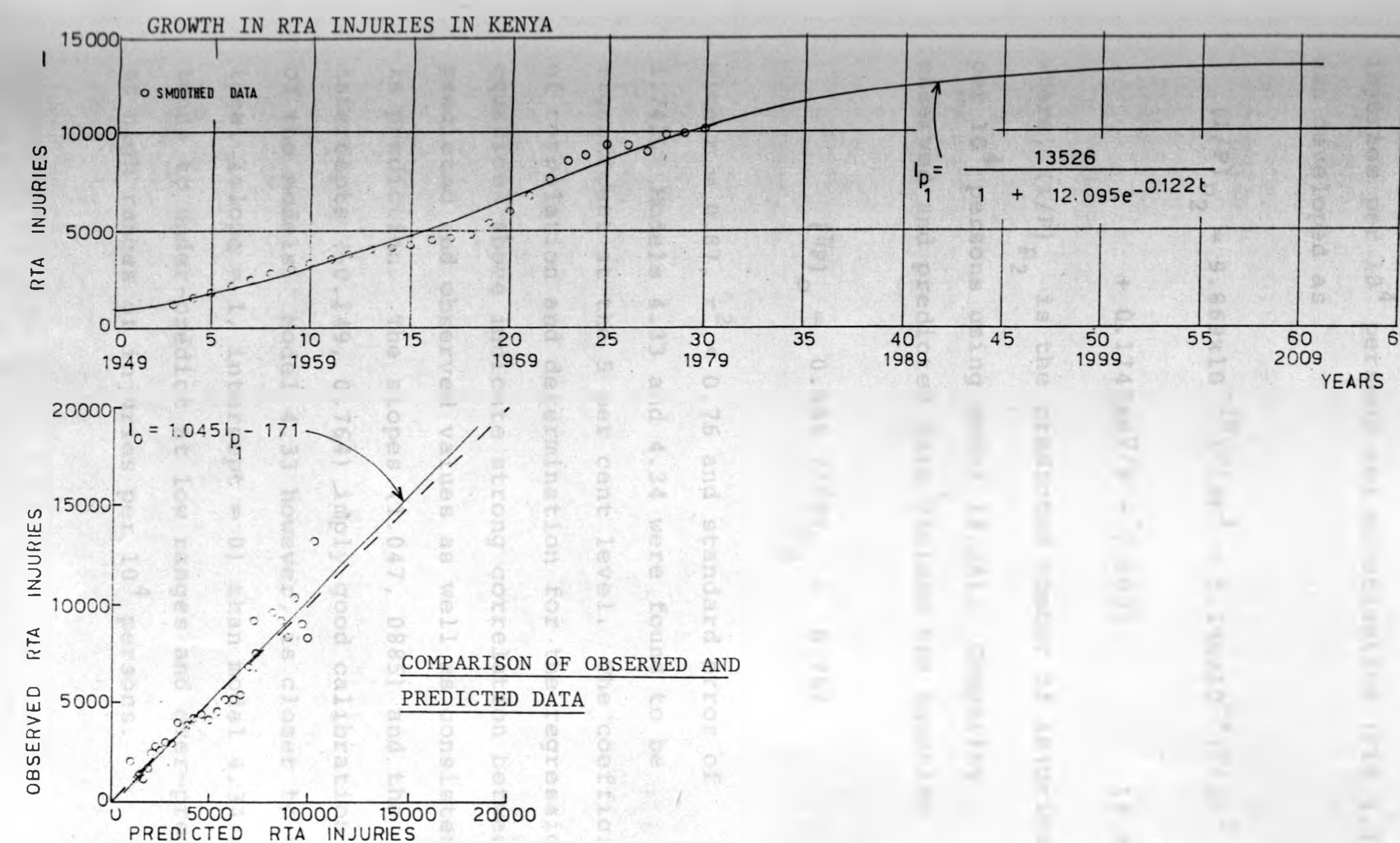


FIG 4.25 GROWTH IN RTA INJURIES IN KENYA

fitting techniques the predictive model relating injuries per 10^4 persons and motorization (Fig.4.27) was developed as

$$(I/P)_{P_2} = 9.869x10^{-10}(V/P)^3 - 5.156x10^{-4}(V/P)^2$$

$$+ 0.174566 V/P - 7.9035 \qquad (4.34)$$

where, $(I/P)_{P_2}$ is the predicted number of injuries per 10^4 persons using model (4.34). Comparing observed and predicted data yielded the equation

$$(I/P)_o = 0.885 (I/P)_{P_2} + 0.764$$

with $r = 0.87$, $r^2 = 0.76$ and standard error of 1.742. Models 4.33 and 4.34 were found to be significant at the 5 per cent level. The coefficients of correlation and determination for the regression equations above indicate strong correlation between predicted and observed values as well as consistency in prediction. The slopes (1.047, 0885) and the intercepts (-0.149, 0.764) imply good calibration of the models. Model 4.33 however, is closer to the ideal (slope = 1, intercept = 0) than model 4.34 which tends to under-predict at low ranges and over-predict at high ranges of injuries per 10^4 persons.

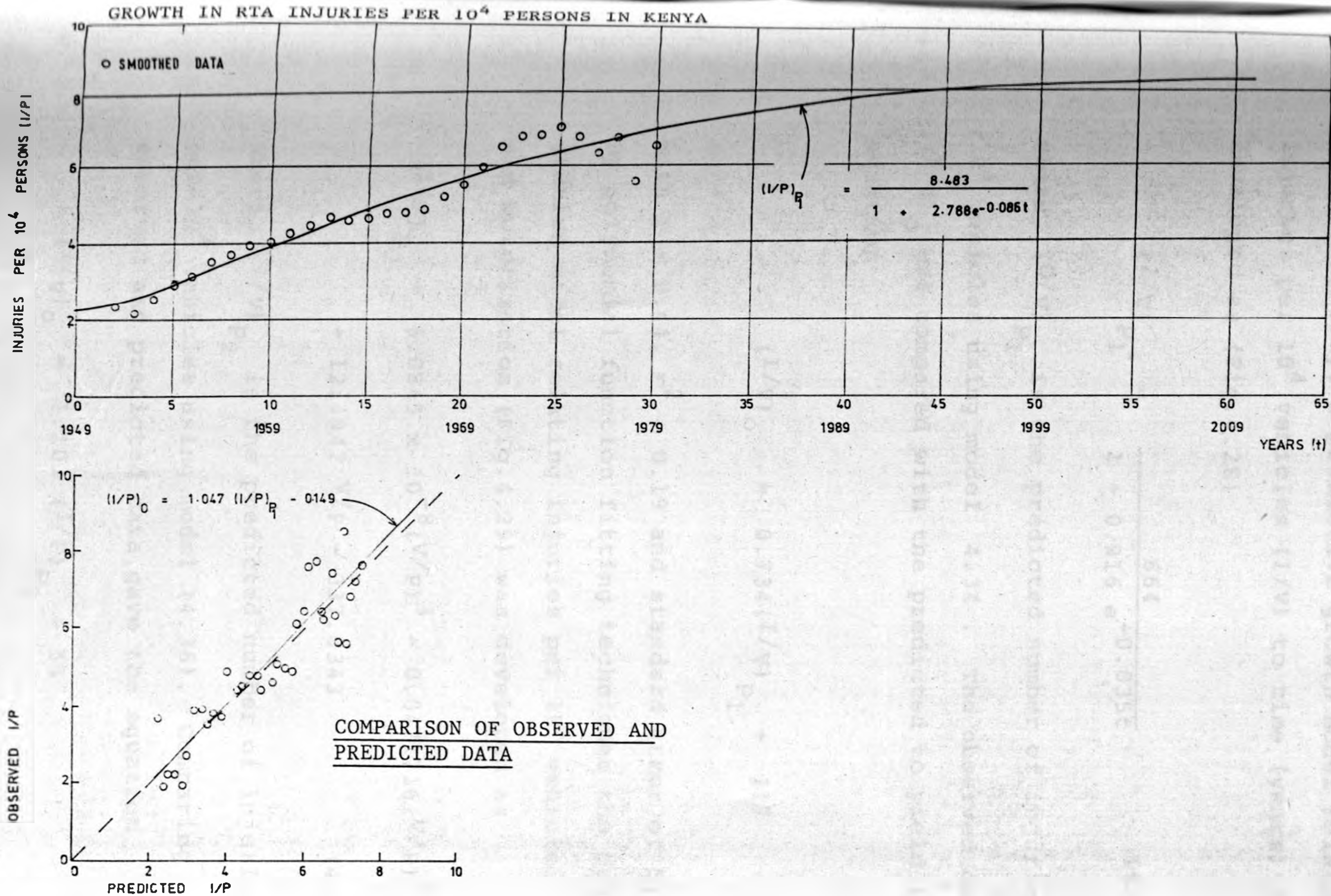


FIG 4 26 GROWTH IN RTA INJURIES PER 10^4 PERSONS IN KENYA

Injuries per 10^4 Vehicles

Similarly, a predictive growth model relating injuries per 10^4 vehicles (I/V) to time (years) was developed as (Fig.4.28)

$$(I/V)_{P_1} = \frac{664}{1 + 0.916\, e^{-0.035t}} \qquad (4.35)$$

where, $(O/V)_{P_1}$ is the predicted number of injuries per 10^4 vehicles using model 4.34 . The observed data $(I/V)_o$ was compared with the predicted to yield the equation

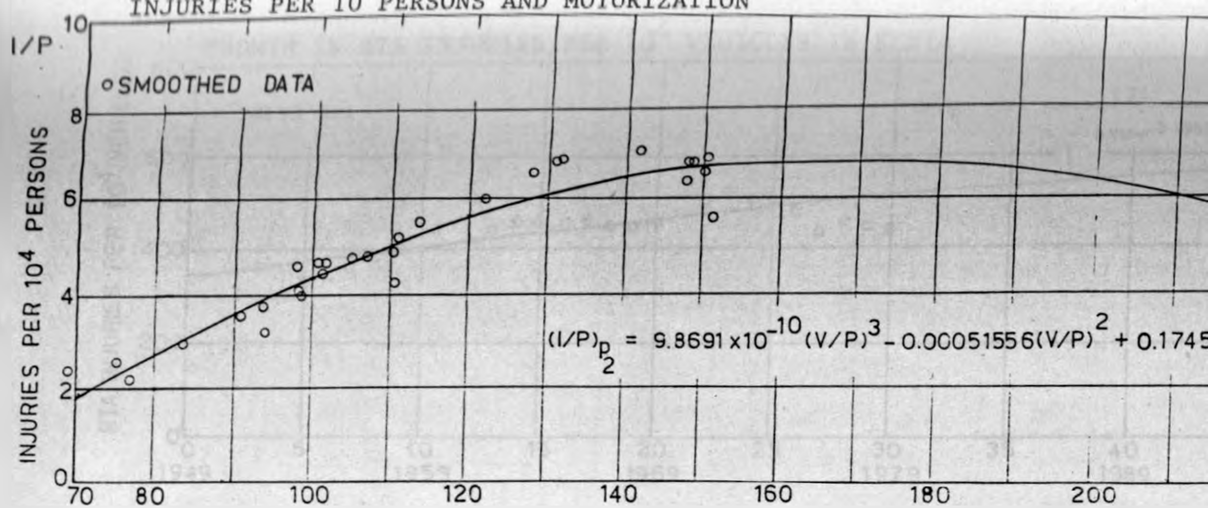
$$(I/V)_o = 0.734(I/V)_{P_1} + 117$$

with r = 0.44, r^2 = 0.19 and standard error of 54. By polynomial function fitting techniques the predictive model relating injuries per 10^4 vehicles and motorization (Fig.4.29) was developed as

$$(I/V)_{P_2} = 6.0845 \times 10^{-8}(V/P)^3 - 0.0471716(V/P)^2 + 12.4842\, V/P - 337.0343 \qquad (4.36)$$

where, $(I/V)_{P_2}$ is the predicted number of injuries per 10^4 vehicles using model (4.36). Comparing observed and predicted data gave the equation

$$(I/V)_o = 1.103\ (I/P)_{P_2} - 55$$



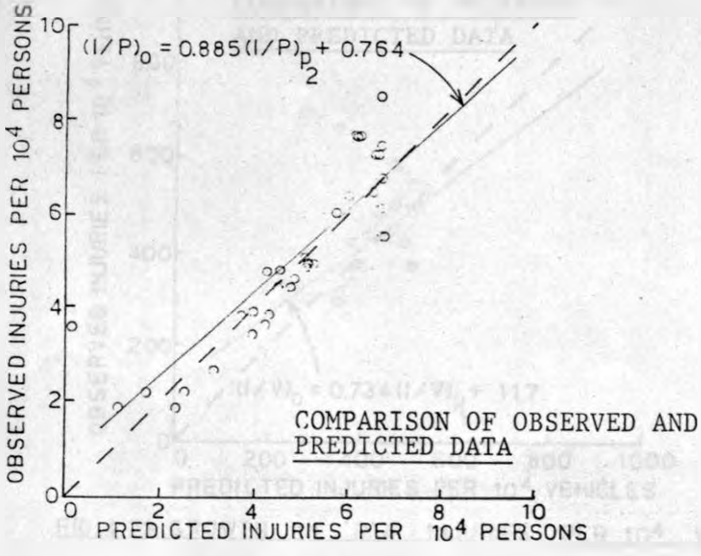


FIG.4.27 RELATION BETWEEN INJURIES PER 10^4 PERSONS AND MOTORIZATION

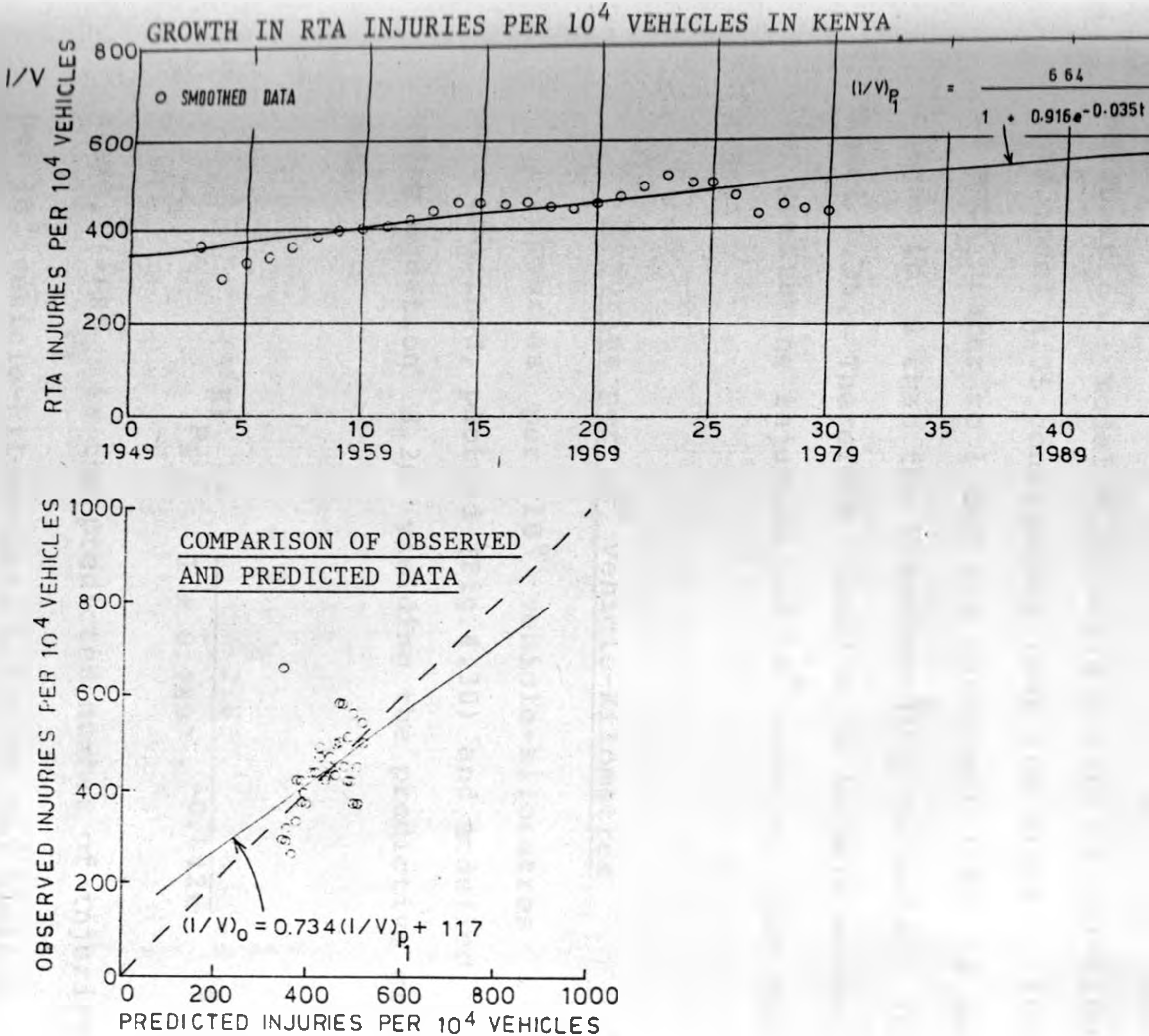


FIG 4.28 GROWTH IN RTA INJURIES PER 10^4 VEHICLES IN KENYA

with $r = 0.78$, $r^2 = 0.60$ and standard error of 56. Models 4.35 and 4.36 were found to be significant at the 5 per cent level. The regression equation obtained by using model 4.35 for prediction shows that the prediction is not very consistent as the scatter is very considerable and correlation, between observed and predicted values, weak ($r = 0.44$, $r^2 = 0.19$). However, the slope (0.734) and the intercept (117 are fair indicating a fair calibration. Model 4.36 has a better calibration than model 4.35 considering that the slope (1.103) is much nearer to 1 and the intercept (-55) is much closer to 0 than the corresponding parameters for model 4.35. Therefore, model 4.36 is more acceptable for predicting injuries per 10^4 vehicles than model 4.35.

<u>Injuries per 10^6 Vehicle-Kilometres</u>

Injuries per 10^6 vehicle-kilometres were smoothed, plotted (Fig.4.30) and modelled using equation 3.26 yielding the predictive growth model

$$({}^{I}/_{K})_{P_1} = \frac{2.657}{1 + 0.9897\, e^{-0.042t}} \qquad (4.37)$$

where, $({}^{I}/_{K})_{P_1}$ is the predicted number of injuries per 10^6 vehicle-kilometres, 2.657 is the limit

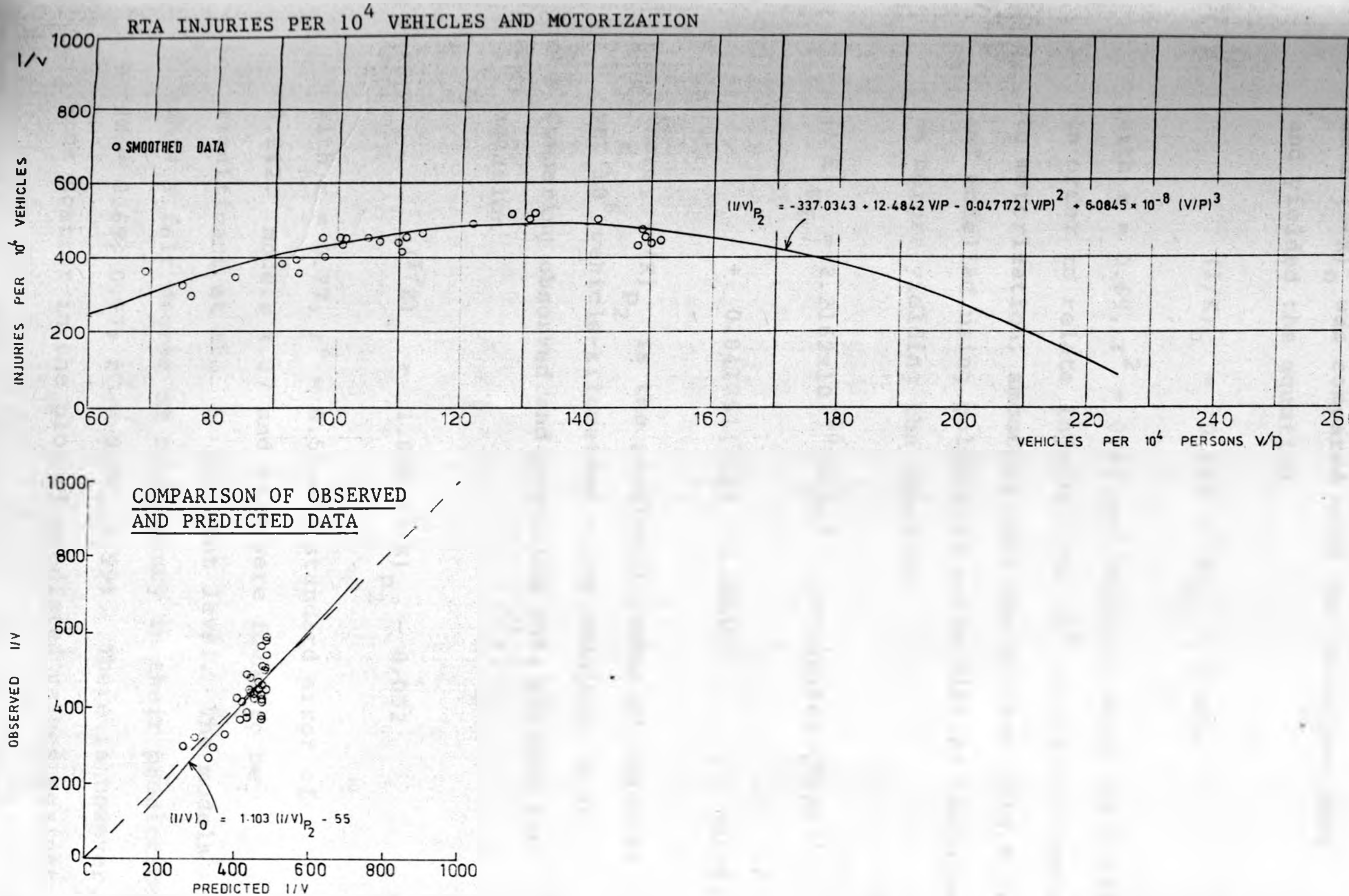


FIG 4.29 RELATION BETWEEN RTA INJURIES PER 10^4 VEHICLES AND MOTORIZATION

approximated from the observed highest number of injuries per 10^6 vehicle-kilometres. The observed data $(^I/K)_o$ was compared with the predicted data and yielded the equation

$$(I/K)_o = 0.924\ (^I/K)_{P_1} + 0.084$$

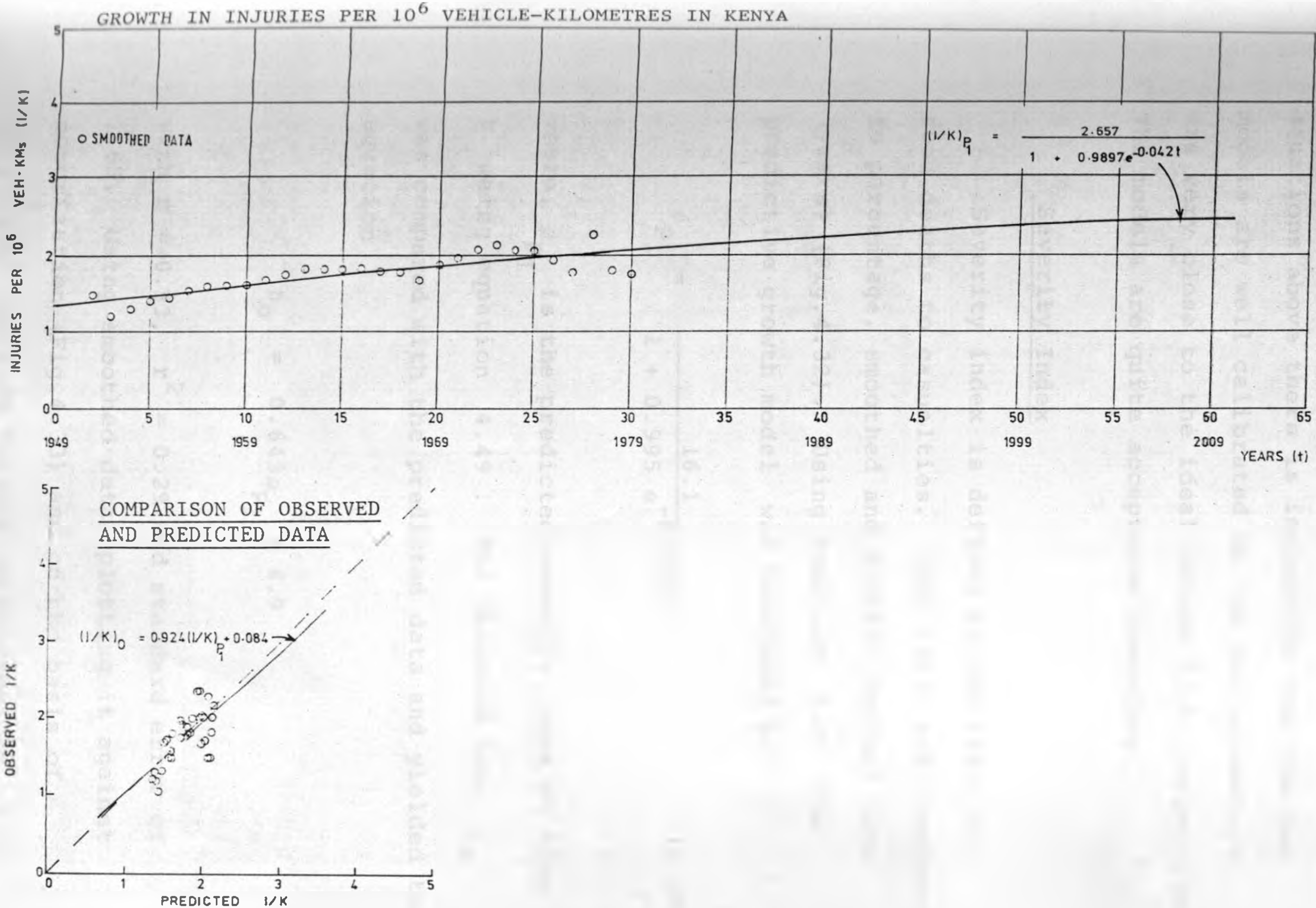
with $r = 0.69$, $r^2 = 0.47$ and standard error of 0.239. In order to relate injuries per 10^6 vehicle-kilometres to motorization, smoothed data was plotted (Fig.4.31) and modelled using polynomial curve fitting techniques as before yielding the equation

$$(^I/K)_{P_2} = 2.2162x10^{-10}(^V/P)^3 - -0.00014687(^V/P)^2 + 0.041751(^V/P) - 1.0039 \qquad (4.38)$$

where, $(^I/K)_{P_2}$ is the predicted number of injuries per 10^6 vehicle-kilometres using equation 4.38 . Comparing observed and predicted data yielded the equation

$$(^I/K)_o = 1.020\ (^I/K)_{P_2} - 0.052$$

with $r = 0.77$, $r^2 = 0.59$ and standard error of 0.242. Models 4.37 and 4.38 were found to be significant at the 5 per cent level. The models show a fair degree of consistency in their prediction ($r = 0.69, 0.77$; $r^2 = 0.47, 0.59$). There is however, some scatter in the plot of predicted values against



G 4.30 GROWTH IN INJURIES PER 10^6 VEH-KMs IN KENYA observed data. Considering the slopes (0.924, 1.020) and the intercepts (0.084, - 0.052) of the regression equations above there is indication that the two models are well calibrated as the two parameters are very close to the ideal values (1,0) respectively. The models are quite acceptable therefore.

Severity Index

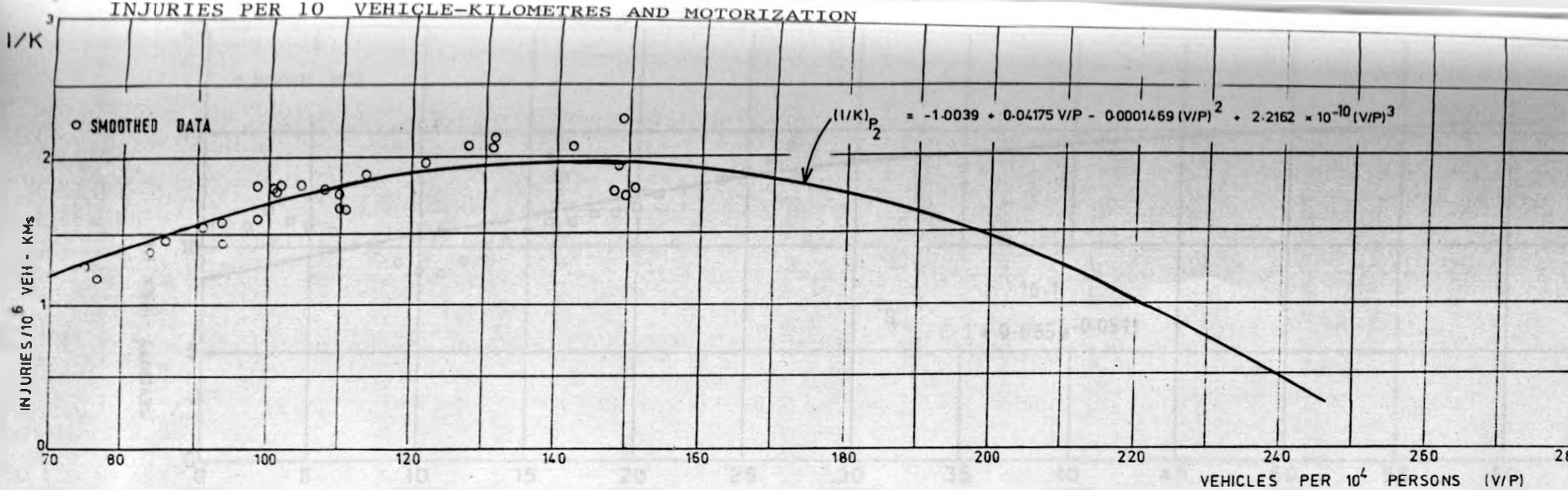
Severity index is defined as the ratio of road deaths to casualties. This ratio was converted to percentage, smoothed and plotted against time (years) (Fig.4.32). Using equation 3.26 the predictive growth model was developed as

$$\rho_{p_1} = \frac{16.1}{1 + 0.995\, e^{-0.051t}} \qquad (4.39)$$

where, ρ_{p_1} is the predicted severity index at time t using equation 4.49 . The observed data ρ_o was compared with the predicted data and yielded the equation

$$\rho_o = 0.643\rho_{p_1} + 8.9$$

with r = 0.53, $r^2 = 0.29$ and standard error of 1.65. Using smoothed data, plotting it against motorization (Fig.4.33) and on the basis of polynomial function fitting techniques the



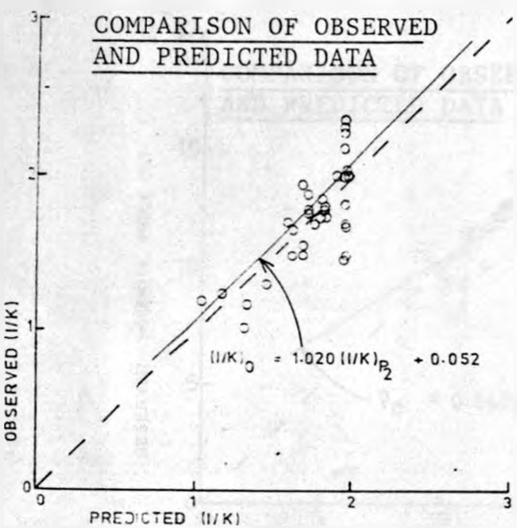


FIG 4.31 RELATION BETWEEN INJURIES PER 10^6 VEH-KMs AND MOTORIZATION

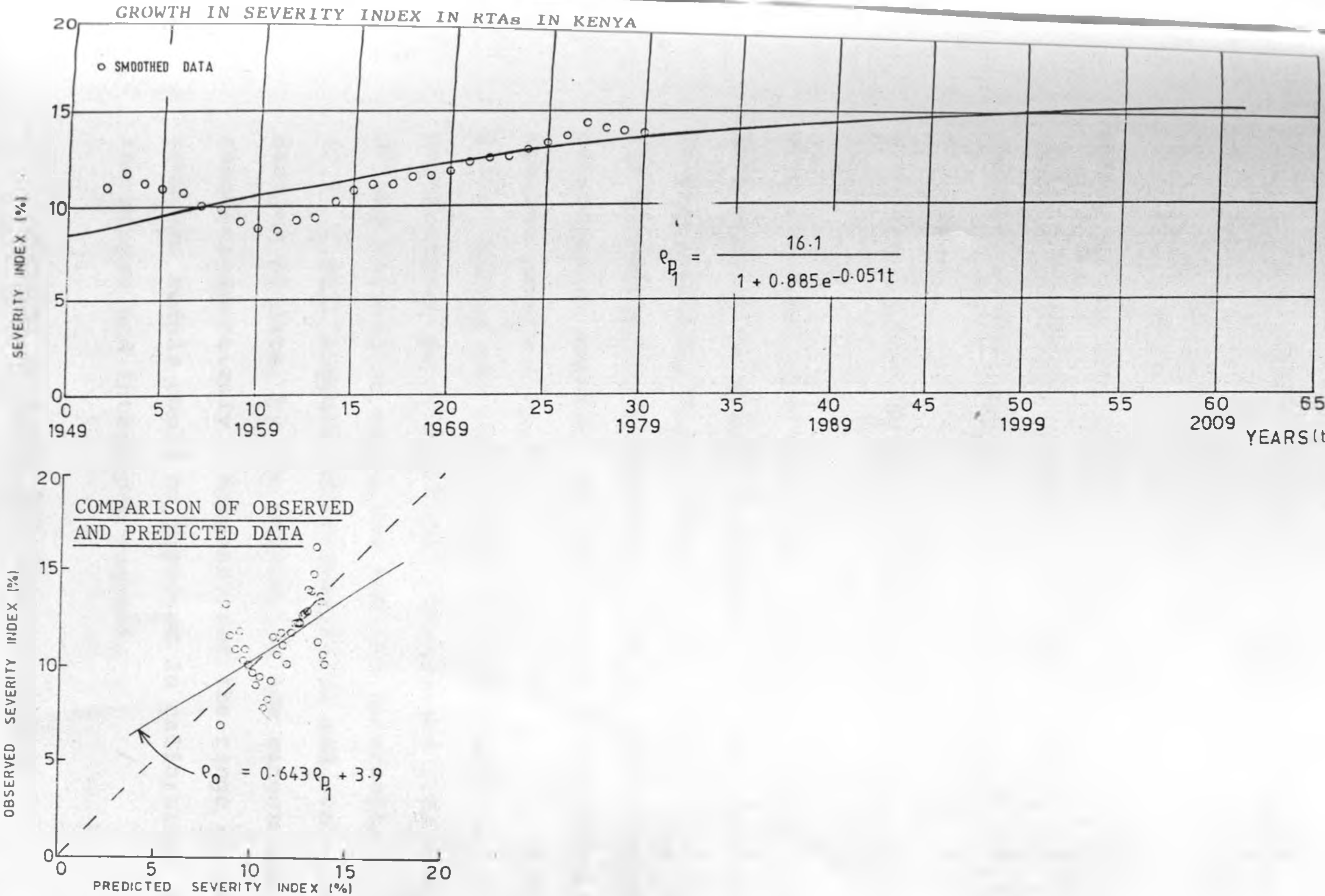


FIG 4.32 GROWTH IN SEVERITY INDEX IN RTAs IN KENYA

predictive model developed was

$$\rho_{p_2} = 0.106 \times 10^{-8} (V/P)^3 + 0.00121676 (V/P)^2$$

$$- 0.2271\ V/P + 20.8768 \qquad (4.40)$$

where, ρ_{p_2} is the predicted severity index using model 4.40 . Comparing observed and predicted data yielded the equation

$$\rho_o = 0.833 \rho_{p_2} + 1.655$$

with $r = 0.63$, $r^2 = 0.40$ and standard error of 1.508. Both predictive models 4.39 and 4.40 were found to be statistically significant at the 5 per cent level. The corresponding regression eqations above reveal considerable scatter, of the plot of predicted values against observed values ($r = 0.53, 0.63$; $r^2 = 0.29, 0.40$), making the correlation a rather weak one particularly for model 4.39. The slopes 0.643, 0.833 of the regression equations and the intercepts (3.9, 1.655) suggest under-prediction and over-prediction of data, by the models, at low ranges and high ranges respectively. However, for the range of data used the models could be improved in calibration as the slopes and intercepts suggest.

Further National RTA Characteristics

Further national RTA characteristics were modelled relating to the percentage distribution of RTAs by day and night, percentage responsibility for RTAs, percentage distribution of those killed above/below age 16, percentage distribution of RTAs victims killed and injured. For each of these a predictive growth model was sought. In order to develop such models the available data, which covered the periods 1960-83 for some of them and 1973-83 for others,were smoothed using the technique of moving averages with N = 5 years (equation 3.57). These data were then plotted and models developed using trend curve fitting techniques by trying each of the following models: linear model (3.19), exponential model (3.38), logarithmic model (3.42) and the power model (3.46). The model that best described the trends was the logarithmic model. Logarithmic time series trend curves were then developed accordingly for each of the above mentioned characteristics.

RTAs Distribution by Day and Night

For the growth of percentage distribution of RTAs by day and night in Kenya, the predictive model developed was (Fig.4.34)

$$((\%)_{A_{d}})_{p} = 81.073 - 5.656 \ln t \qquad (4.41)$$

with $r = -0.76$, $r^2 = 0.58$, where $((\%)_{A_{d}})_{p}$ is the

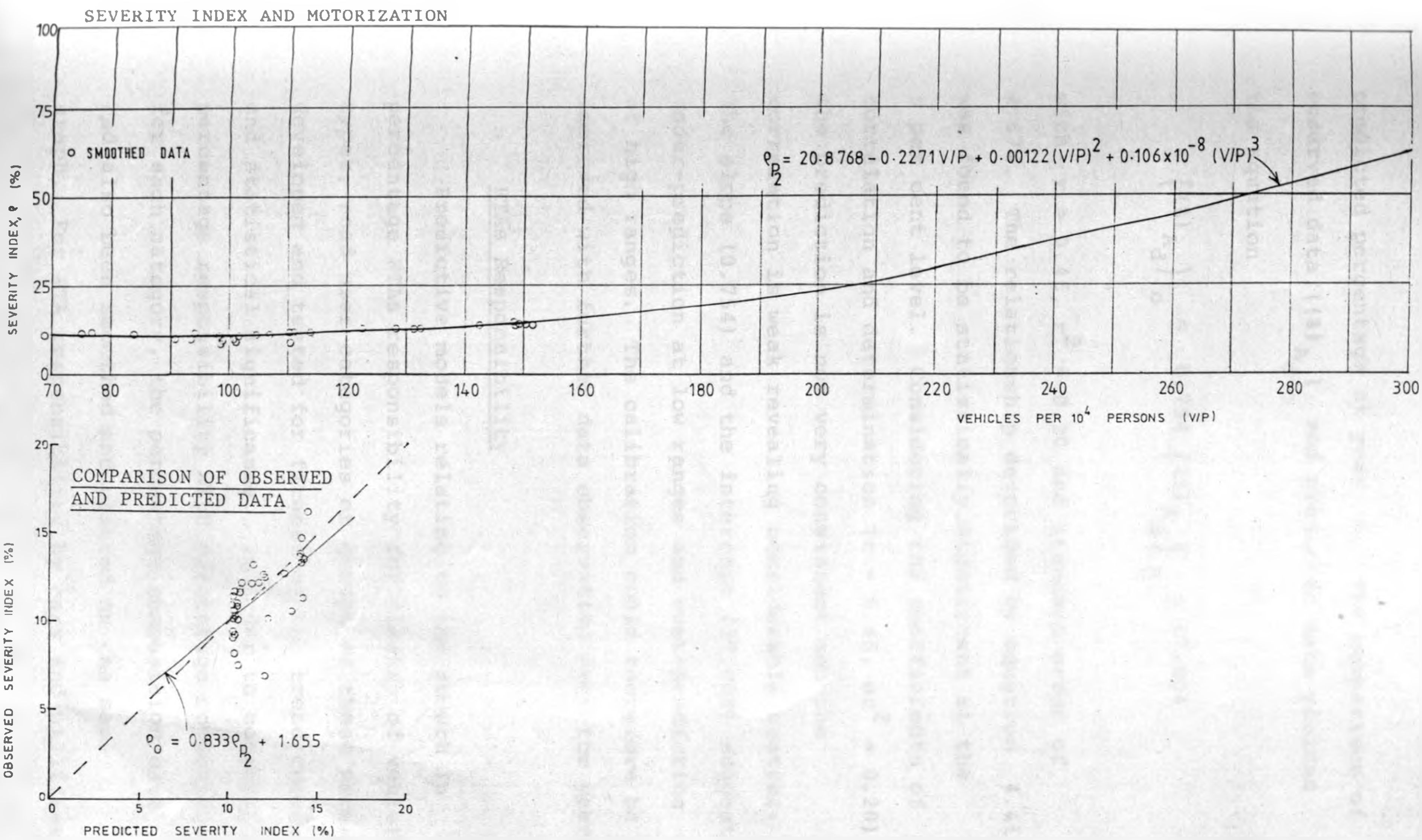


FIG 4.33 RELATION BETWEEN SEVERITY INDEX AND MOTORIZATION

predicted percentage at year t. The comparison of observed data $((\%)_{A_d})_o$ and predicted data yielded the equation

$$\left((\%)_{A_d}\right)_o = 0.754 \left((\%)_{A_d}\right)_p + 17.004$$

with $r = 0.45$, $r^2 = 0.20$ and standard error of 4.674. The relationship described by equation 4.41 was found to be statistically significant at the 5 per cent level. Considering the coefficients of correlation and determination ($r = 0.45$, or $r^2 = 0.20$) the prediction is not very consistent and the correlation is weak revealing considerable scatter. The slope (0.754) and the intercept (17.004) suggest under-prediction at low ranges and over-prediction at high ranges. The calibration could therefore be improved with further data observation over the years.

RTAs Responsibility

Predictive models relating to the growth in percentage RTAs responsibility for classes of vehicle types, road user categories or groups of these were developed and tested for fitness of the trend curve and statistical significance. In order to compare percentage responsibility with percentage composition for each category, the percentage composition data had also been smoothed and plotted on the same graph. For RTA responsibility by cars and utilities the trend curve was developed as the model given by the equation (Fig.4.35)

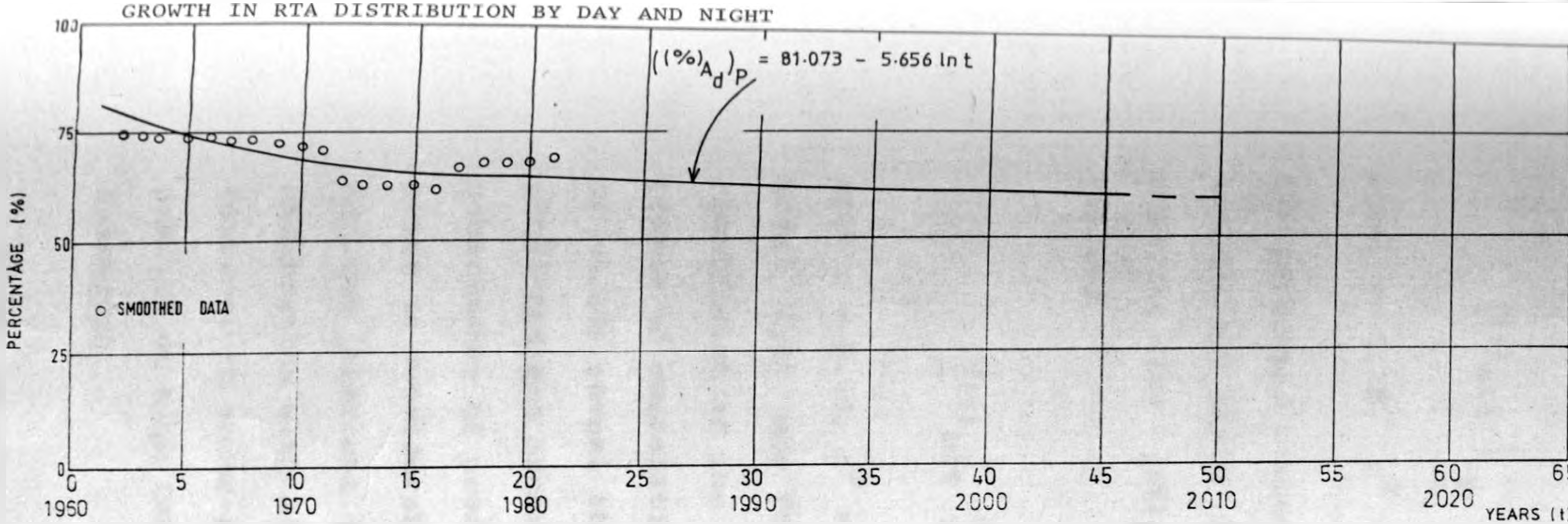
$$\left((\%)_{cu}\right)_p = 74.161 - 1.923 \ln t \qquad (4.42)$$

with $r = -0.70$, $r^2 = 0.49$, where $(\%)_{cu\,p}$ is the predicted percentage responsibility by cars and utilities for year t as predicted by equation 4.42 . Comparing observed data $\left((\%)_{cu}\right)_o$ and predicted data yield the equation

$$\left((\%)_{cu}\right)_o = 0.887 \left((\%)_{cu}\right)_p + 14.661$$

with $r = 0.43$, $r^2 = 0.18$ and standard error of 1.59. Equation 4.42 was found to be statistically significant at 5 per cent level. The coefficients of correlation ($r = 0.43$) and determination ($r^2 = 0.18$) show that the prediction is not very consistent and the correlation is weak due to the considerable scatter. The slope (0.787) and the intercept (14.661) indicate under-prediction at low ranges and over-prediction at high ranges. The calibration could be further improved with additional data observation over the years

For RTA responsibility by buses, lorries and taxis the trend curve developed is represented by



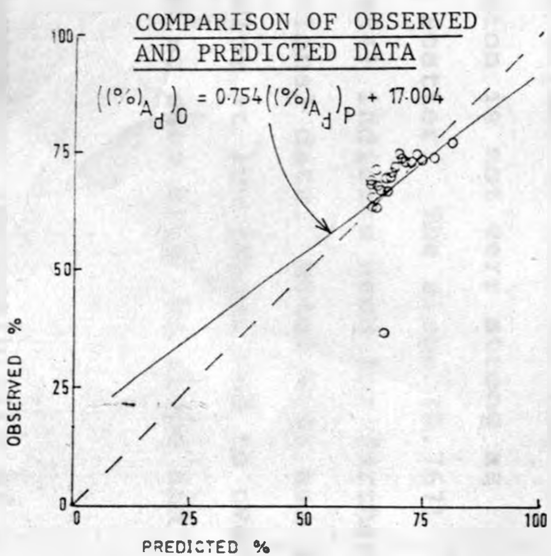


FIG. 4.34 PERCENTAGE DISTRIBUTION OF RTAs BY DAY AND NIGHT IN KENYA

the equation (Fig.4.36)

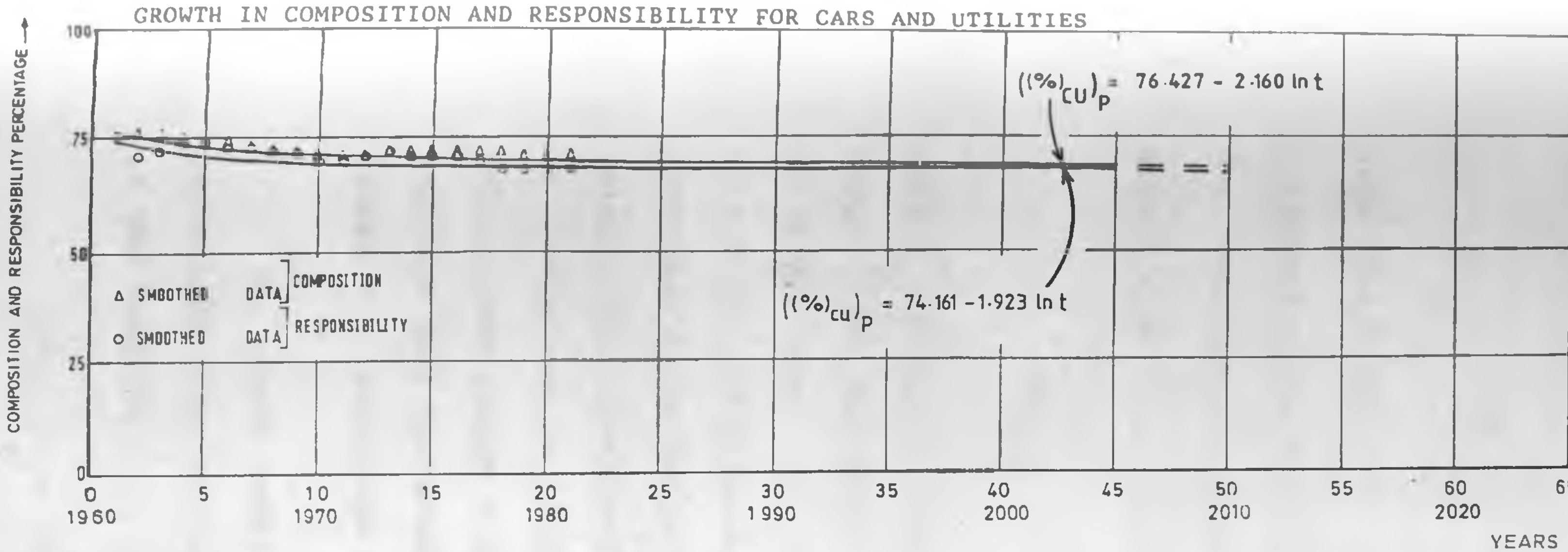
$$\left((\%)_{b\ell T'}\right)_p = 18.268 + 2.652\ \ell nt \qquad (4.43)$$

with r= 0.78, r^2 = 0.60, where $(\%)_{b\ell T'_p}$ is the predicted percentage responsibility by buses, lorries and taxis by equation 4.43 . Comparing observed data $\left((\%)_{b\ell T'}\right)_o$ and predicted data yielded

$$\left((\%)_{b\ell T'}\right)_o = 0.767 \left((\%)_{b\ell T'}\right)_p + 5.894$$

with r = 0.53, r^2 = 0.29 and standard error of 2.19. Model 4.43 was found to be statistically significant at the 5 per cent level. The coefficients of correlation (r = 0.53) and determination (r^2=0.29) reveal that the correlation between predicted and observed values is fair but the consistency of prediction is not very strong as there is considerable scatter. The slope (0.767) and the intercept (5.894) indicate need for further calibration with additional data. Model 4.43 has a tendency to under-predict at low ranges and to over-predict at high ranges as seen from the slope and intercept.

The growth in percentage responsibility of



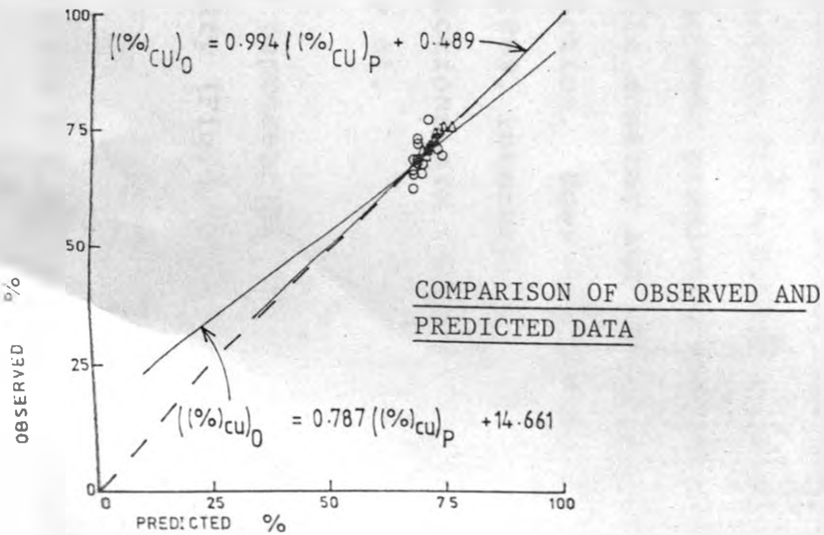


FIG.4.35 PERCENTAGE COMPOSITION AND RESPONSIBILITY FOR RTAs OF CARS AND UTILITIES IN KENYA

motorcycles was developed as the growth model (Fig.4.37)

$$\left((\%)_m\right)_p = 6.956 - 0\text{-}552 \ \ell nt \qquad (4.44)$$

with $r = 0.042$, $r^2 = 0.18$ where $\left((\%)_m\right)_p$ is the predicted percentage responsibility of motorcycles. The comparison of observed $(\%)_{m_o}$ and predicted data yielded the equation

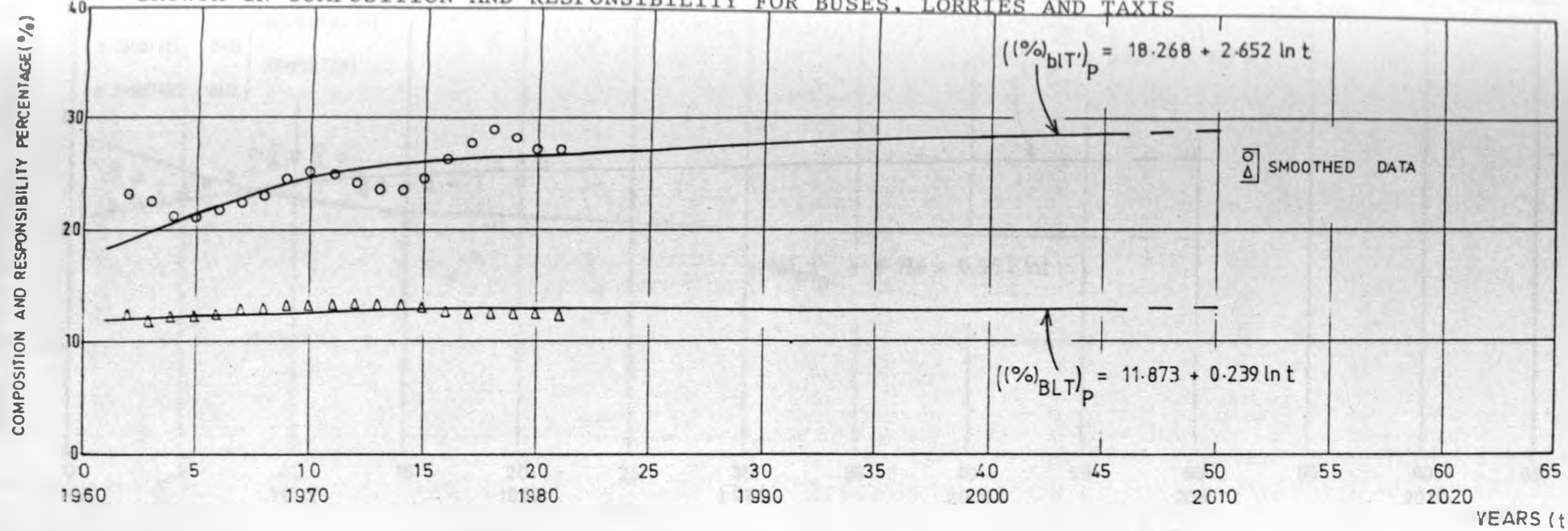
$$\left((\%)_m\right)_o = 0.868 \left((\%)_m\right)_p + 0.727$$

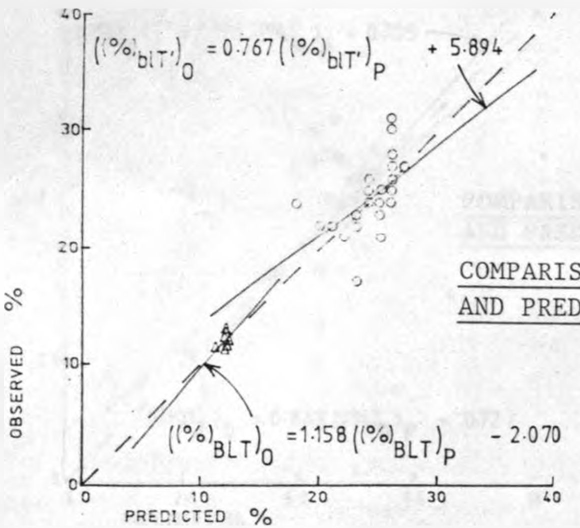
with $r = 0.30$, $r^2 = 0.09$ and standard error of 0.453. Model 4.44 was found to be statistically significant at 10 per cent. The coefficients of correlation ($r = 0.30$) and determination ($r^2 = 0.09$) suggest very weak correlation between predicted and observed values, very considerable scatter and therefore lack of consistency in prediction. However, the model calibration (slope = 0.869, intercept = 0.727) indicate that the predictions are close to ideal (slope = 1, intercept = 0).

The growth model representing pedal cyclists percentage responsibility (Fig.4.38) was developed as the equation

$$\left((\%)_{b'}\right)_p = 11.748 - 2.003 \ \ell n \ t \qquad (4.45)$$

GROWTH IN COMPOSITION AND RESPONSIBILITY FOR BUSES, LORRIES AND TAXIS





COMPARISON OF OBSERVED AND PREDICTED DATA

FIG. 4.36 PERCENTAGE COMPOSITION AND RESPONSIBILITY FOR RTAs OF BUSES LORRIES TAXIS IN KENYA

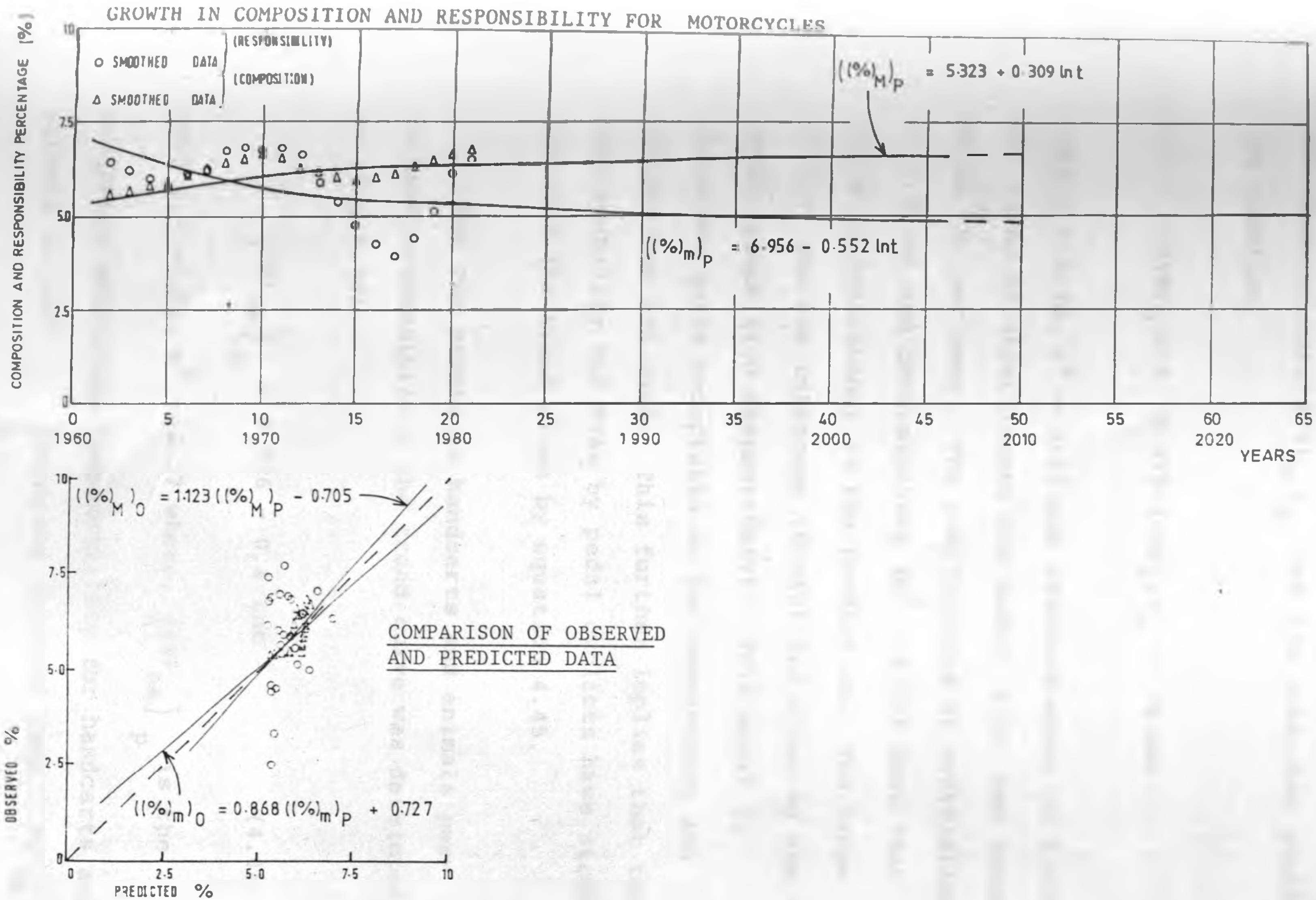


FIG.4.37 PERCENTAGE COMPOSITION AND RESPONSIBILITY FOR RTAs OF MOTORCYCLES IN KENYA

with $r = 0.94$, $r^2 = 0.89$ where, $((\%)_{b'})_p$ is the predicted percentage for pedal cyclists. Comparing the observed data $((\%)_{b'})_o$ and the predicted yielded the equation

$$((\%)_{b'}) = 0.979\,((\%)_{b'})_p + 0.040$$

with $r = 0.76$, $r^2 = 0.57$ and standard error of 1.655. The level of significance for model 4.45 was found to be 5 per cent. The coefficients of correlation ($r = 0.76$) and determination ($r^2 = 0.57$) show that there is consistency in the prediction. The slope (0.979) and the intercept (0.040) are close to the ideal values (1,0 respectively). This model is therefore quite acceptable as the consistency and calibration are good. This further implies that the responsibility for RTAs by pedal cyclists have strongly followed the trend given by equation 4.45.

For the growth in handcarts and animals percentage responsibility the trend curve was developed as (Fig.4.38)

$$\left((\%)_{ha}\right)_p = 3.526 - 0.4\ \ell nt \qquad (4.46)$$

with $r = -0.52$, $r^2 = 0.27$ where, $\left((\%)_{ha}\right)_p$ is the predicted percentage responsibility for handcarts and animals in year t. Comparing observed data $(\%)_{ha\ o}$

and predicted data yielded

$$\left((\%)_{ha}\right)_o = 0.596 \quad \left((\%)_{ha}\right)_p + 0.983$$

with r = 0.15, r^2= 0.02 and standard error of 0.331. Model 4.46 was found to be statistically significant at 25 per cent level. The coefficients of correlation (r = 0.15) and determination (r^2 = 0.02) show that the predicted and observed values are not well correlated. This implies that the prediction is not consistent and the scatter is very considerable. This further implies that the responsibility for RTAs of animals and handcarts has remained stable. The slope (0.596) and the intercept (0.983) suggest a need for further calibration.

Finally, the growth model for pedestrian together with passenger percentage responsibility was developed as (Fig.4.38)

$$((\%)_{wp})_p = 7.016 + 9.073 \ \ell nt \qquad (4.47)$$

with r = 082, r^2 = 0.67 where, $((\%)_{wp})_p$ is the predicted percentage using equation 4.47 . Comparing observed data $((\%)_{wp})_o$ and predicted data gave the equation

$$((\%)_{wp})_o = 0.736 \quad ((\%)_{wp})_p + 7.496$$

with $r = 0.53$, $r^2 = 0.28$ and standard error of 7.498. The model relationship described by equation 4.47 was found to be statistically significant at 5 per cent level. The coefficients of correlation ($r = 0.53$) and determination ($r^2 = 0.28$) suggest fair correlation. Further, the consistency of prediction is affected adversely by the very considerable scatter. The slope (0.736) and the intercept (7.496) show that the model (4.47) has a tendency of under-predicting at low ranges and over-predicting at high ranges. The responsibility of pedestrians and passengers for RTAs has also followed the trend suggested by model 4.47 fairly closely. Thus the responsibility by pedal cyclists, pedestrians and passengers, have shown definite tendencies in Kenya.

Distribution by Age of RTA Victims killed

The growth model for the percentage distribution of those killed above age 16 (Fig.4.39) was developed using the logarithmic model as described above (equation 3.42). The model is described by the equation

$$\left((\%)_{D_{16+}}\right)_p = 86.051 - 2.884 \ \ell nt \qquad (4.48)$$

with $r = -0.72$, $r^2 = 0.52$ where, $\left((\%)_{D_{16+}}\right)_p$ is the predicted percentage using equation 4.48. Comparing

GROWTH IN RESPONSIBILITY FOR PEDAL CYCLISTS, ANIMALS, HANDCARTS, PEDESTRIANS AND PASSENGERS

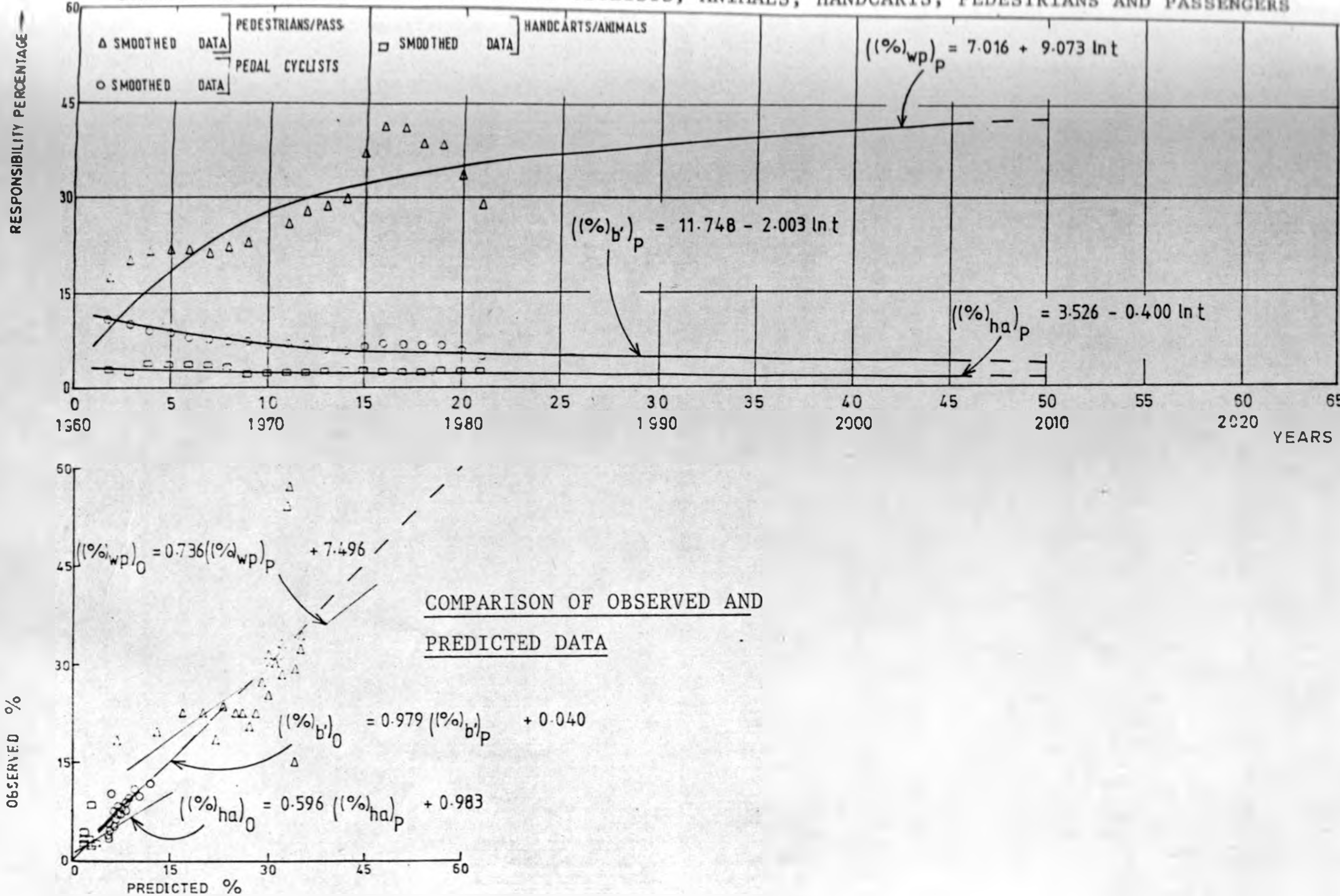


FIG 4.38 PERCENTAGE RESPONSIBILITY FOR RTAs OF PEDAL CYCLISTS ANIMALS AND HANDCARTS, PEDESTRIANS AND PASSENGERS IN KENYA

observed data $\left((\%)_{D_{16}}\right)_o$ and predicted yielded the equation

$$\left((\%)_{D_{16+}}\right)_o = 0.211 \left((\%)_{D_{16+}}\right)_p + 64.905$$

with $r = 0.05$, $r^2 = 0.003$ and standard error 1.547. The relationship in equation (4.48) was found not to be statistically significant. Considering that the predicted values and the observed values are not correlated ($r = 0.05$, $r^2 = 0.003$) model 4.48 requires more data for recalibration. The slope (0.211) and intercept (64.905) are far from ideal.

<u>Distribution by Age of RTA Victims Injured</u>

The growth model for the percentage distribution of those injured above age 16 (Fig.4.39) was found to be statistically significant at the per cent level of 20. The model was developed as

$$\left((\%)_{I_{16+}}\right)_p = 91.01 - 2.468 \, \ell nt \qquad (4.49)$$

with $r = -0.81$, $r^2 = 0.66$ where, $\left((\%)_{I_{16+}}\right)_p$ is the predicted percentage using equation 4.49 . The observed data $\left((\%)_{I_{16+}}\right)_o$ compared with predicted data gave the equation

$$\left((\%)_{I_{16+}}\right)_o = 0.856 \left((\%)_{I_{16+}}\right)_p + 13.117$$

with r = 0.40, r^2 = o.16 and standard error of 1.808. Considering the coefficients of correlation (r = 0.40) and determination (r^2 = 0.16) the scatter of the predicted against observed values is very considerable and the correlation weak. This implies that the prediction by model 4.49 is not very consistent and requires additional data observation. The calibration is otherwise tending to the ideal considering that the slope (0.856) and the intercept (13.117) are approaching 1 and 0 respectively. With additional data the characteristic trend curve could be improved.

Distribution by Class of Road User of RTA Victims Killed

The growth in percentage distribution of RTA drivers killed was developed into the model represented by (Fig.4.40) the equation

$$\left((\%)_{D_{D'}}\right)_p = 14.695 - 0.541 \ln t \qquad (4.50)$$

with r = -0.44, r^2 = 0.19 where, $\left((\%)_{D_{D'}}\right)_p$ is the predicted percentage distribution obtained by using equation 4.50 . Comparing observed $\left((\%)_{D_{D'}}\right)_o$ and predicted data yielded the equation

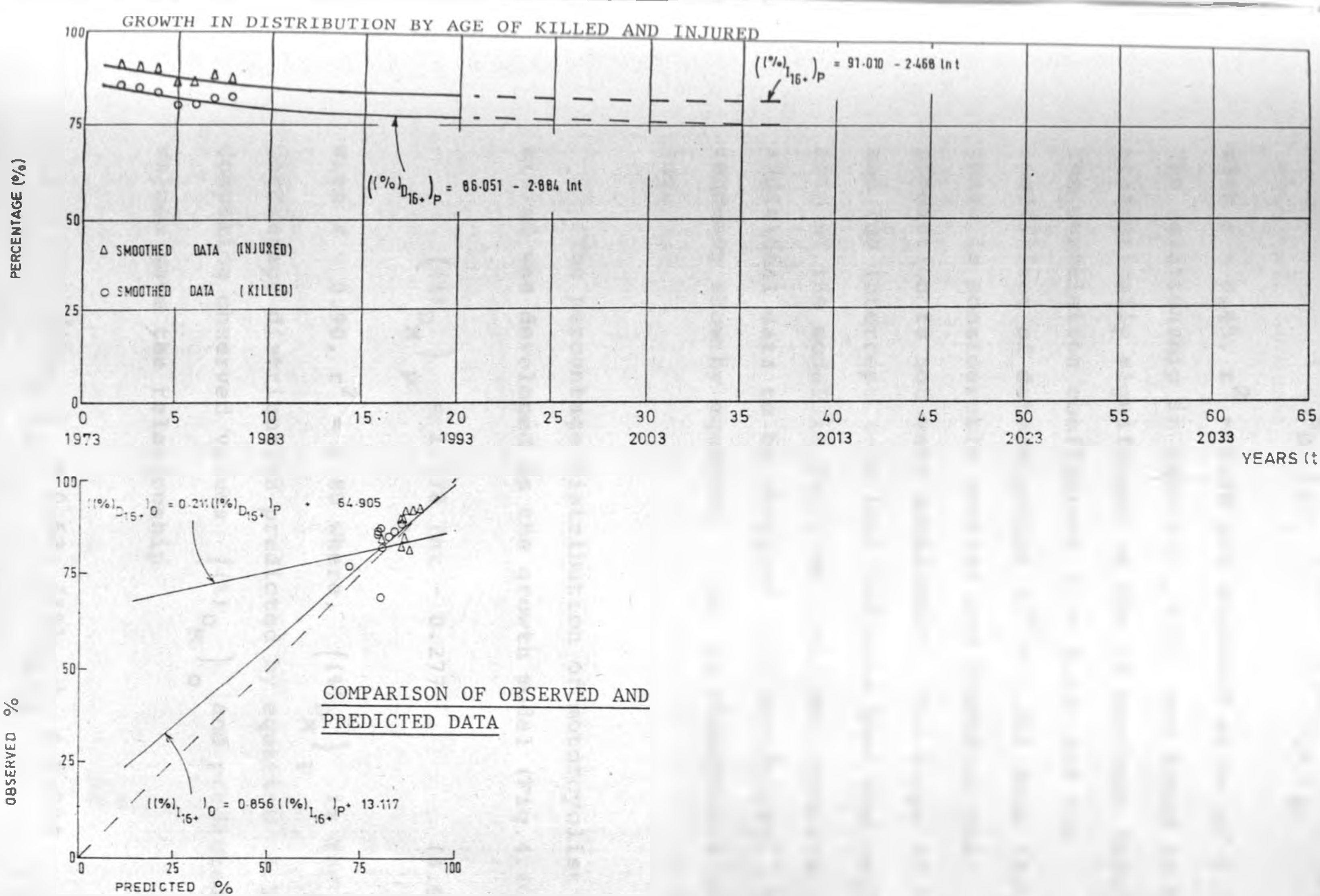


FIG.4.39 RTAs PERCENTAGE DISTRIBUTION BY AGE OF KILLED AND INJURED IN KENYA

$$\left((\%)_{D_{D'}}\right)_o = 3.147 \left((\%)_{D_{D'}}\right)_p - 30.145$$

with $r = 0.45$, $r^2 = 0.20$ and standard error of 0.398. The relationship in equation 4.50 was found to be statistically significant at the 10 per cent level. The correlation coefficient ($r = 0.45$) and the coefficient of determination ($r^2 = 0.20$) show that there is considerable scatter and therefore the prediction is not very consistent. The slope (3.147) and the intercept (-30.145) indicate that the calibration of the model is far from ideal and requires additional data to be obtained over the future. The tendency shownby equation 50 is therefore a weak one.

The percentage distribution of motorcyclist killed was developed as the growth model (Fig.4.40)

$$\left((\%)_{D_M}\right)_p = 1.778 \ \ell nt - 0.277 \qquad (4.51)$$

with $r = 0.90$, $r^2 = 0.80$ where, $\left((\%)_{D_M}\right)_p$ is the percentage distribution predicted by equation 4.51. Comparing observed values $\left((\%)_{D_M}\right)_o$ and predicted values gave the relationship

$$\left((\%)_{D_M}\right)_o = 0.63 \left((\%)_{D_M}\right)_p + 0.884$$

with r = 0.36, r^2 = 0.13 and standard error of 1.303. Equation 4.51 was found to be statistically significant at the 20 per cent level. The trend shown by equation 4.51 is a strong one (r = 0.90, r^2 = 0.80). However the prediction is not very consistent (r = 0.36, r^2 = 0.13) as there is very considerable scatter. The slope (0.63) and the intercept (0.884) are tending to the required slope (1) and intercept (0). With further data observation the calibration could be improved even more.

The growth in percentage distribution of pedal cyclists killed was developed as the model (Fig.4.40)

$$\left((\%)D_{B'}\right)_p = 10.397 - 3.049 \ \ln t \qquad (4.52)$$

with r = 0.38, r^2 = 0.15 where, $\left((\%)D_{B'}\right)_p$ is the predicted value of the percentage distribution of pedal cyclists killed. Comparing observed data $\left((\%)D_{B'}\right)_o$ and predicted data yielded the equation

$$\left((\%)D_{B'}\right)_o = 0.42 \ \left((\%)D_{B'}\right)_p + 3.161$$

with r = 0.38, r^2 = 0.15 and standard error of 2.235, the relationship being significant at the 20 per cent level. The trend shown in equation 4.52 is weak. This has led to weak correlation between predicted and observed values as shown by the coefficients of correlation (0.38) and determination (0.15) for the regression of predicted values against observed values. The considerable scatter has led also to very poor consistency in prediction resulting in poor calibration as seen by the slope (0.42) being far from 1 and the intercept (3.161) being far from 0. This implies need for additional data over the coming years.

The growth in percentage distribution of pedestrians killed in RTAs was developed as the model (Fig.4.40)

$$\left((\%)_{D_W}\right)_p = 39.74 + 2.023 \ \ln t \qquad (4.53)$$

with $r = 0.87$, $r^2 = 0.77$ where, $\left((\%)_{D_W}\right)_p$ is the percentage distribution predicted of pedestrians killed. Comparing observed $(\%)_{D_{W\ o}}$ and predicted data yielded the equation

$$\left((\%)_{D_W}\right)_o = 0.925 \left((\%)_{D_W}\right)_p + 3.197$$

with $r = 0.45$, $r^2 = 0.20$ and standard error of 1.484, the relationship being significant at 10 per cent level. The trend shown in model equation 4.53 was the strongest in terms of the distribution of killed RTA victims. This shows the significant unfortunate role played by pedestrians in RTAs in

Kenya on the one hand and on the other, the need for concentrating on pedestrian safety for the reduction of RTAs in Kenya. The slope (0.925) and the intercept (3.197) show that the calibration is very near the ideal (1, 0 respectively). The consistency can be improved however by further data observation as the scatter is very considerable (r = 0.45), r^2 = 0.20).

The growth in percentage distribution of passengers killed in RTAs was determined as the model equation (Fig.4.40)

$$\left((\%)_{D_P}\right)_p = 34.240 + 0.434 \ \ell n\ t \qquad (4.54)$$

with r = 0.37, r^2 = 0.14 where, $\left((\%)_{D_P}\right)_p$ is the predicted percentage in equation 4.54 . The observed data $\left((\%)_{D_P}\right)_o$ and the predicted data were compared and yielded the equation

$$\left((\%)_{D_O}\right)_o = 1.339 \ \left((\%)_{D_P}\right)_p - 11.235$$

with r = 0.21, r^2 = 0.04 and standard error of 0.319. The relationship described by equation 5.54 was found to be significant at 30 per cent level. The regression equation of the predicted and observed values indicates by slope (1.339) and intercept (-11.235) that the

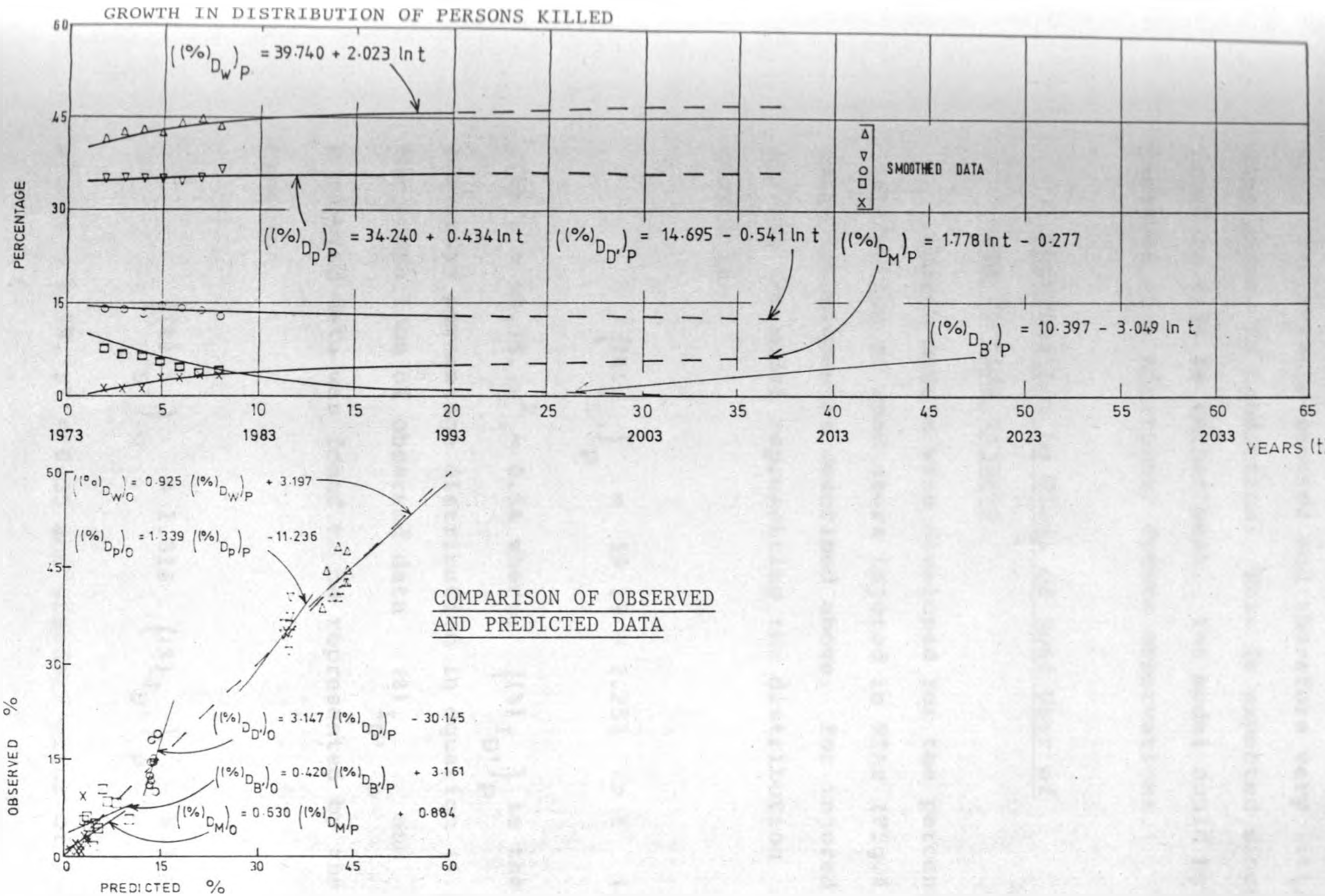


FIG 4.40 PERCENTAGE DISTRIBUTION OF PERSONS KILLED IN RTAs IN KENYA

calibration is fair. However, the coefficient of correlation (0.21) and determination (0.04) indicate very considerable scatter and therefore very little consistency in prediction. This is expected since the trend in 4.54 is rather weak. The model could be improved with additional future observations.

Distribution by Class of Road User of RTA Victims Injured

Growth models were developed for the percentage distribution of road users injured in RTAs (Fig.4.41) using techniques as described above. For injured drivers the model representing the distribution growth is

$$\left((\%)_{I_{D'}}\right)_p = 19.19 - 2.251 \ \ell n \ t \qquad (4.55)$$

with $r = -0.75$, $r^2 = 0.56$ where, $\left((\%)_{I_{D'}}\right)_p$ is the predicted percentage distribution in equation (4.55). The comparison of observed data $(\%)_{I_{D'}\,o}$ and predicted data was found to be represented by the equation

$$\left((\%)_{I_{D'}}\right)_o = 1.516 \ \left((\%)_{I_{D'}}\right)_p - 8.112$$

with $r = 0.59$, $r^2 = 0.35$ and standard error of 1.65,

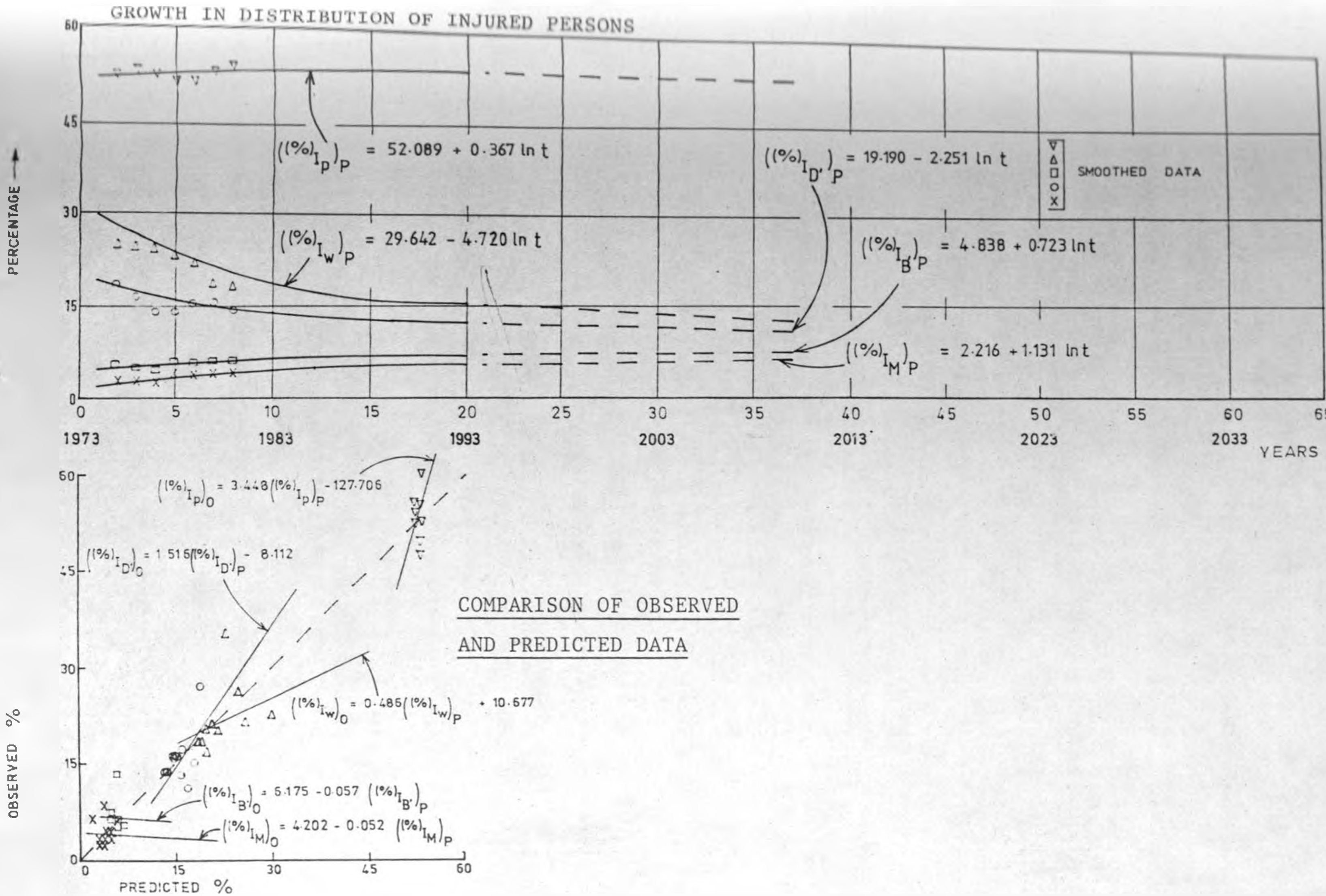


FIG.4.41 PERCENTAGE DISTRIBUTION OF PERSONS INJURED IN RTAs IN KENYA

the relationship being significant at the 5 per cent level. The trend shown by model 4.55 is fair as well as the correlation (0.59) of the predicted values against observed, but the consistency of prediction is low as the scatter is very considerable ($r^2 = 0.35$). The slope (1.516) and intercept (-8.112) indicate over-prediction at low ranges and under-prediction at high ranges. The model could improve in calibration with additional future data.

For motorcyclists the model developed is

$$\left((\%)\, I_M\right)_p = 2.216 + 1.131\ \ell nt \qquad (4.56)$$

with r = 0.83, $r^2 = 0.69$ where $\left((\%)\, I_M\right)_p$ is the predicted percentage distribution by equation 4.56 . Comparing observed data $\left((\%)\, I_M\right)_o$ and predicted data gave the equation

$$\left((\%)\, I_M\right)_o = 4.202 - 0.052 \left((\%)\, I_M\right)_p$$

with r = -0.02, $r^2 = 0$, standard error of 0.673 and the relationship in equation (4.56) being found not significant statistically. Although the trend shown by model equation 4.56 is good (r=0.82, $r^2 = 0.69$), there is no correlation between predicted values and observed values (r = -0.02, $r^2 = 0$) as the scatter is very considerable. This suggests further calibration with additional data.

The model for the growth in percentage distribution of pedal cyclists injured in RTAs was developed as

$$\left((\%)I_{B'}\right)_p = 4.838 + 0.723 \ \ell n \ t \qquad (4.57)$$

with $r = 0.67$, $r^2 = 0.44$ where, $\left((\%)I_{B'}\right)_p$ is the predicted value by equation 4.57 . Comparing observed data $\left((\%)I_{B'}\right)_o$ and predicted data gave the equation

$$\left((\%)I_{B'}\right)_o = 6.175 - 0.057 \ \left((\%)I_{B'}\right)_p$$

with $r = -0.01$, $r^2 = 0$ and standard error of 0.529. The relationship in equation 4.57 was found not to be statistically significant. The model equation shows a fair trend. Due to the scatter of the data the slope (-0.057) and the intercept (6.175) are far from ideal. This suggests further data observation and recalibration.

The growth in percentage distribution of pedestrians injured in RTAs was modelled as

$$\left((\%)I_W\right)_p = 29.642 - 4.72 \ \ell n \ t \qquad (4.58)$$

with $r = -0.86$, $r^2 = 0.75$ where, $\left((\%)_{I_W}\right)_p$ is the predicted value of the percentage distribution by equation 4.58 . Comparing observed $\left((\%)_{I_W}\right)_o$ data and predicted data yielded the equation

$$\left((\%)_{I_W}\right)_o = 0.486 \left((\%)_{I_W}\right)_p + 10.677$$

with $r = 0.30$, $r^2 = 0.09$ standard error of 3.46, the relationship in equation 4.58 being statistically significant at 20 per cent level. The trend shown by model equation 4.58 is good but due to the considerable scatter in the predicted values against observed values the consistency of prediction is poor. The slope (0.486) and intercept (10.677) indicate much under-prediction at low ranges and over-prediction at high values. This implies need for further calibration with additional data.

Finally, the growth in percentage distribution of passengers injured in RTAs was modelled as

$$\left((\%)_{I_P}\right)_p = 52.089 + 0.367 \ \ell n\ t \qquad (4.5$$

with $r = 0.18$, $r^2 = 0.03$ where, $\left((\%)_{I_P}\right)_p$ is the predicted percentage distribution of passengers injured as predicted by the model in equation 4.59 .

The observed data $\left((\%)_{I_P}\right)_o$ was compared with the predicted data to yield the equation

$$\left((\%)_{I_P}\right)_o = 3.448 \left((\%)_{I_P}\right)_p - 127.706$$

with $r = 0.22$, $r^2 = 0.05$ and standard error of 0.268. The relationship described by the model equation 4.59 was found to be statistically significant at 30 per cent level. The trend shown by equation 4.59 is very weak and consequently because of much scatter the slope (3.448) and the intercept (-127.706) of the regression equation vary considerably from ideal. This suggests need for additional data.

4.2.2 Dual Carriageway Road Traffic Accidents

4.2.2.1 Data Collection

Data collection was based on police records of past RTAs based on the Police Form 41 (Appendix A.5). Forms 1 and 2 (Appendix A.6) were used for data acquisition. The study road falls under four Police Stations of Muthaiga, Ruiru, Juja and Thika. The information coded included road condition, traffic regulations and the environment, sociological and psychological conditions of the persons directly involved in RTAs.

The study area was zoned. The road network was classified into road classes A, B, C, D and E. The local road network consisting of feeder roads and accesses and other locations consisting of parking lots, yards, petrol stations and the like were also classified. The nodes were located on junctions between the trunk road and the secondary roads. Each node was numbered in relation to its zone. The number consisted of 4 digits where the first three referred to the zone number and the last, to the node in that zone (Appendix A.6/3). One zone could only have nine nodes. If a junction was complex or was a roundabout, a special area was introduced. The special areas got their identification number starting for example, with 1000. A special area designated 1011 meant that it was the first special area and the first node in that area being partitioned into 9 subnodes only.

To define the location of a RTA the node numbers were used. If the RTA ocurred at a junction (node) only one number, the node number, was coded. The section of road between two nodes was partitioned into a grid of 8 squares horizontally and 9 vertically in order to locate the RTA spot more precisely. The spot was then coded using the horizontal and vertical digits. The RTA spot at a junction was located precisely using an equally partitioned grid of 9 squares horizontally and vertically. The coordinates of the RTA spot were then coded.

The description of a RTA started with choosing the primary elements, where an element was defined as any vehicle or road user involved in the RTA in question of which the primary elements were the principal or main participants. In a single vehicle RTA there would be only one primary element whereas in a vehicle-vehicle or vehicle-pedestrian RTA for example there would be a maximum of two primary elements. Thus, there was a possibility of a maximum of two primary elements. These primary elements were further supposed to be the ones involved in the initial and last moments of the RTA. Such primary elements would then as a result of the RTA have incurred some degree of damage as a result of the collision. Secondary elements were defined as any other vehicles or road users involved in the RTA in question other than the primary elements defined above. Such secondary elements were deemed to have been involved because they were indirectly made to participate in the RTA in question due to their presence in the traffic situation. Such involvement, in the RTA in question, by the secondary elements was defined as the disturbance phase of the RTA under study.

4.2.2.2 Data Analysis

During the period January 1977 to July 1980, 725 RTAs were recorded on the study road. Of these, 702 were used for systematic analysis. Out of the total, 450 (64%) of the RTAs involved injuries and 130 (20%) were fatal. Although 167 persons were killed and 868 were injured. Therefore an average of 2.3 persons are killed or injured in every injury RTA on this road. The average annual increase in RTAs for the period 1977-79 was 16.5%. More than half of the fatal RTAs involved pedestrians. The RTA category which occurred most frequently apart from those involving pedestrians, were RTAs between vehicles travelling in the same direction (38%). Single vehicle RTAs had a share of 34% of the total.

The monthly distribution of RTAs (Fig.4.42) does not seem to indicate that certain seasons are significantly more RTA-prone than others. The two peak periods are May and December. These two coincide with the long rains in May when schools are closed and the Labour day public holiday (May 1), together with December when schools are closed and the Jamhuri celebrations (December 12) and of course Christmas and New Year celebrations.

The daily RTA trend (Fig.4.43) shows that weekends have considerably more RTAs than the rest of the

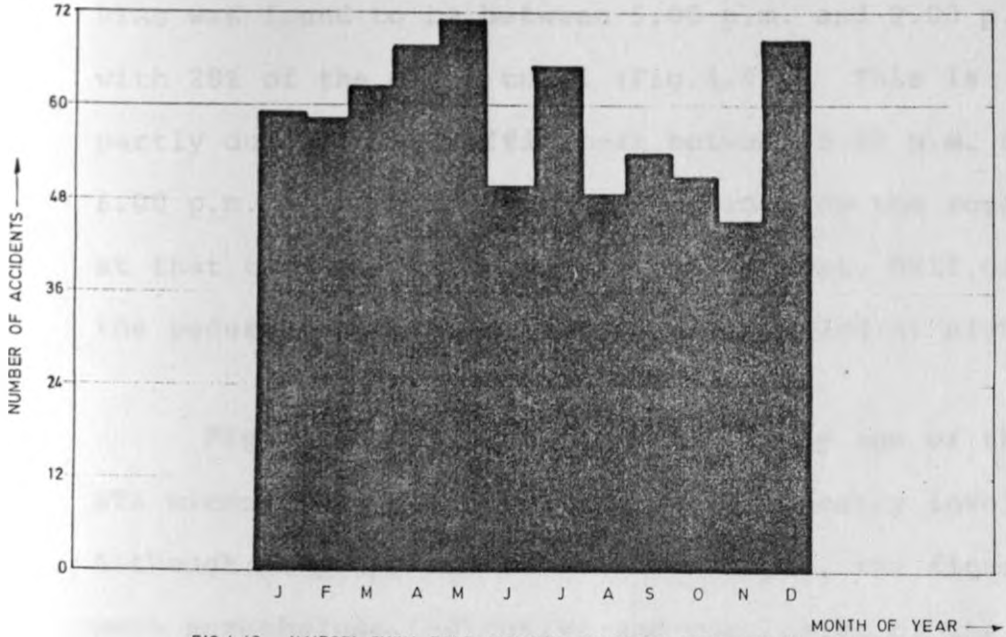


FIG.4.42 NAIROBI-THIKA ROAD: MONTHLY ACCIDENT DISTRIBUTION

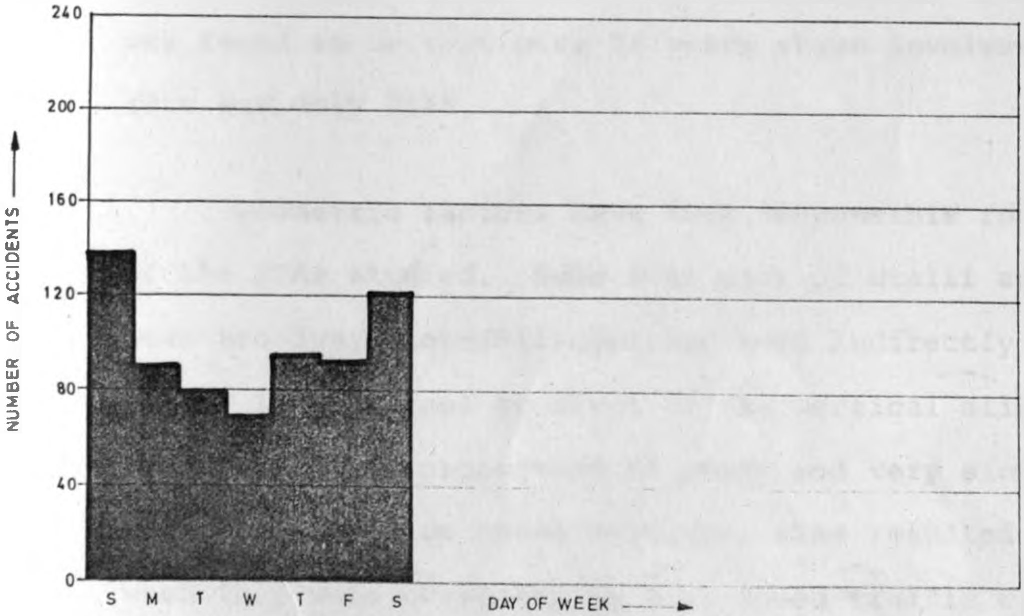


FIG.4.43 NAIROBI-THIKA ROAD: ACCIDENT DISTRIBUTION BY DAY OF WEEK

week. Of all RTAs 36% happened on Saturdays and Sundays, but only 24% of the weekly traffic falls on those two days. The time of the day with the most RTAs was found to be between 5.00 p.m. and 8.00 p.m, with 28% of the daily total (Fig.4.44). This is partly due to the traffic peak between 5.00 p.m. and 6.00 p.m., the bad lighting conditions on the road at that time and drunken driving. Almost, half of the pedestrians killed in RTAs were killed at night.

Fig.4.45 shows the distribution by age of the RTA elements (drivers, pedestrians) directly involved. Although many did not reveal their ages, the figures were nonetheless indicative and conclusive of the fact that the most RTA involved age-group is ages 26-40. This group alone had an involvement per cent of 36. The ages least involved according to this study was found to be that over 56 years whose involvement rate was only 2.4%.

Geometric factors have been responsible for many of the RTAs studied. Some RTAs west of Utalii and near Broadway Store/Allsopps had been indirectly caused by the longitudinal gradient of the vertical alignment. Due to the high proportion of heavy and very slow speed vehicles on these sections, RTAs resulted when they were overtaken by high speed traffic using the inner lanes. Increased RTA rates were recorded

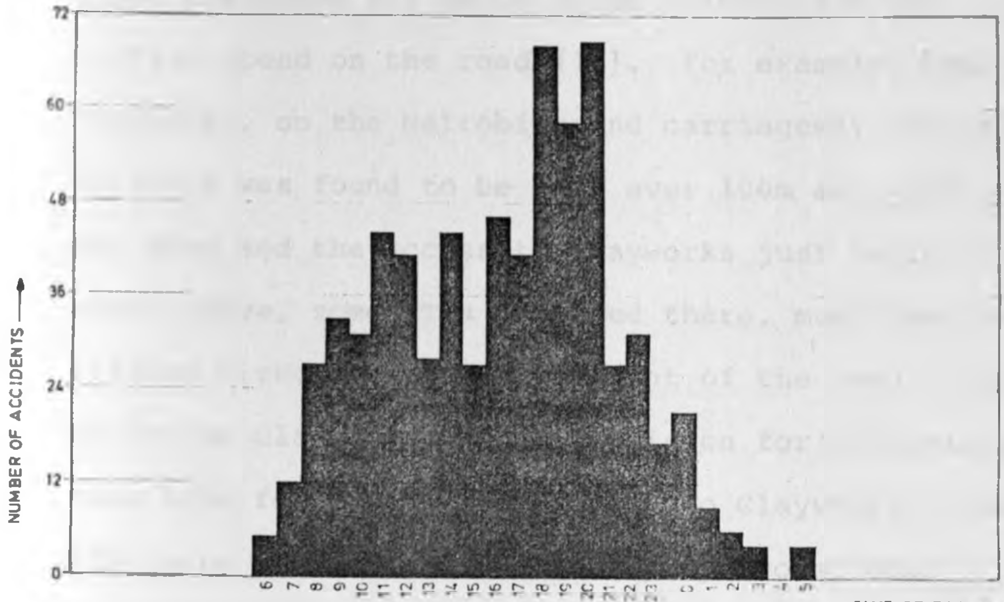


FIG 4.44 NAIROBI - THIKA ROAD ACCIDENT DISTRIBUTION BY HOUR OF DAY

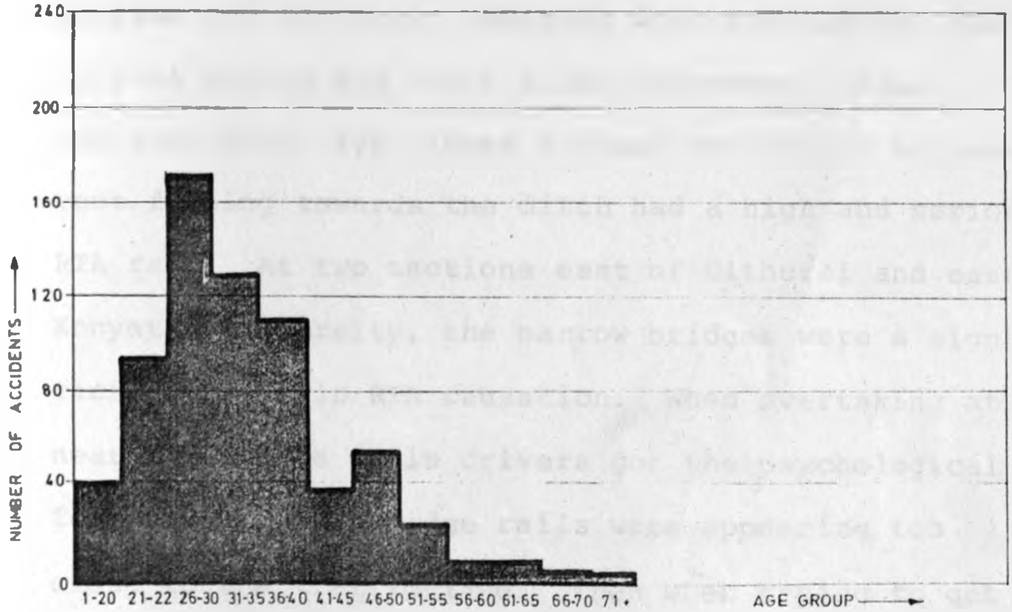


FIG.4.45 NAIROBI - THIKA ROAD ACCIDENT INVOLVEMENT BY AGE GROUP

in both crest and sag curves as compared to the tangent portions of the vertical alignment. The vertical alignment and especially crest curves had sight distances far below those allowed for the traffic speed on the road [14]. For example, near Clayworks, on the Nairobi bound carriageway, the sight distance was found to be just over 100m and with a bus stop and the access to Clayworks just behind the crest curve, some RTAs recorded there, must have been related directly to the alignment of the road. The access to Clayworks had no provision for a deceleration lane for vehicles turning into Clayworks. Many RTAs were also caused indirectly by broken down vehicles. Without provision for parking off the traffic lanes, broken vehicles were often forced to stand in either the inner or outer lanes. As a result on-coming vehicles had no chance of stopping in time and hit other vehicles when overtaking, due to high speeds and short sight distances. Some sections with high slopes without guardrails to prevent falling towards the ditch had a high and serious RTA rate. At two sections east of Githurai and east of Kenyatta University, the narrow bridges were a significant factor in RTA causation. When overtaking at or near the bridge rails drivers got the psychological feeling that the bridge rails were appearing too close to the traffic lane. Then when trying to get back to the outer lane, the vehicle hit others often resulting in overturning. In some RTAs the bridge rails were hit causing serious damage to the vehicles and injury to persons. Besides the geometric layout, road surfacing in general caused many RTAs. This was especially observed in the outer lane, which was, at the time of the study, cracked both on the surface and edges. The bad surfacing together with high speeds resulted in many RTAs. Drivers got aware of the cracks or potholes only too late and in trying to avoid them with a quick turning movement, lost control over the vehicle either overturning on the carriageway or into the ditch. At some locations the openings in the central reserve had many RTAs. Both the paved and track opening had bad sight distances in relation to the traffic on the main road. These very short sight distances coupled with the difficulty to judge high speeds from a distance were causally related to RTA occurrence there. At one of the most RTA rated spots, the entering carriageway from Nairobi towards Roysambu roundabout proved particularly dangerous. There appeared to be no obstacles to sight and at first glance the geometry looked satisfactory but the manouvre at the roundabout led to RTAs. The approaching carriageway was observed to have a crest curve just before the roundabout. The geometry together with underestimating speed is likely to have been the cause of RTAs. Almost every RTA studied here involved overturning of vehicles towards the centre of the roundabout.

Vehicular factors were equally significant in RTA causation. The mechanical condition of the vehicles was found to be causing more RTAs than 8%. In both the single vehicle RTAs and the vehicle-vehicle RTAs between vehicles in the same direction, the causes were related to the careless behaviour of drivers combined with the bad mechanical conditions of the vehicles. Burst tyres, faults in the breaking and steering systems often resulted into loss of control, overturning of vehicles and collisions between vehicles. RTAs resulting into vehicles running off the carriage-way were significant in frequency and severity. The single vehicle RTAs were found to be more than twice as likely to be fatal as other vehicle RTAs. Most of these single vehicle (RTAs involved either over-turning on the carriageway or on the roadside. Speed-ing, improper driving, overloading, vehicle shape and the unsatisfactory road conditions were significant causation factors. For example, matatus were involved in some fatal and serious RTAs with an indication of overloading. Overloading left the front wheels with light pressure on the road. Consequently, when hitting a bump or pothole or making a sudden movement to avoid an obstacle the vehicle easily overturned.

Road user characteristics were observed to be an important causal factor in RTAs. Most of the fatalities were caused by pedestrians crossing the

Pedestrians had a high night to day RTA ratio. Only closest to Muthaiga was there any lighting. At other locations it was extremely difficult to discover pedestrians on the carriageway in darkness.

Traffic signing was found to be generally very poor. Many of the RTAs could be traced to lack of warning signs to the dangerous locations. Reduce speed signs were non-existent at the time of the study (Appendix A.11).

In order to model RTAs independent variables were chosen from the above analysis of the causative factors influencing RTAs. The independent variables chosen were longitudinal gradient, sight distance, carriageway width, junctions, horizontal curve radius, super-elevation, vehicle flow and time of day. All coded RTAs were plotted along the study road. Using traffic data obtained from the traffic counts vehicle-kilometres were calculated for the period of study. The dependent variable was then developed as RTAs per 10^6 vehicle-kilometres. For each of the above independent variables the observed RTAs per 10^6 vehicle-kilometres were recorded. RTAs per 10^6 vehicle-kilometres were then plotted against each of the independent variables. In order to obtain model data it was necessary to smooth the data both for the dependent and the independent variables. Data smoothing was achieved by meaning, repeated meaning by interpolation and use of moving averages. The aim of data smoothing was to obtain values of the dependent variable from group data representing the worst possible RTA situation and the best possible RTA situation. From these two extreme cases the most probable unsafe condition representing the dependent variable was chosen as the model data. This smoothed data was then replotted against the independent variable with ranges indicated where necessary. The plots indicated certain curve functions. These were then tried for best fit using models in section 3.2 and tested by the methods of analysis outlined in section 3.5 (Appendix A.14).

Longitudinal Gradient

For longitudinal gradient a histogram of RTAs and downgrade as well as upgrade gradient was constructed (Fig.4.46). This revealed that flatter gradients are more RTA prone. RTAs decrease with increase in gradient. The data from both carriageways was combined. A plot of the smoothed data for the upgrade gradients was made (Fig.4.47). The curve shape was observed as a quadratic polynomial function fitting techniques using finite differences were used for points at equal intervals to confirm the curve shape. Using formulae 3.24 the model was developed as

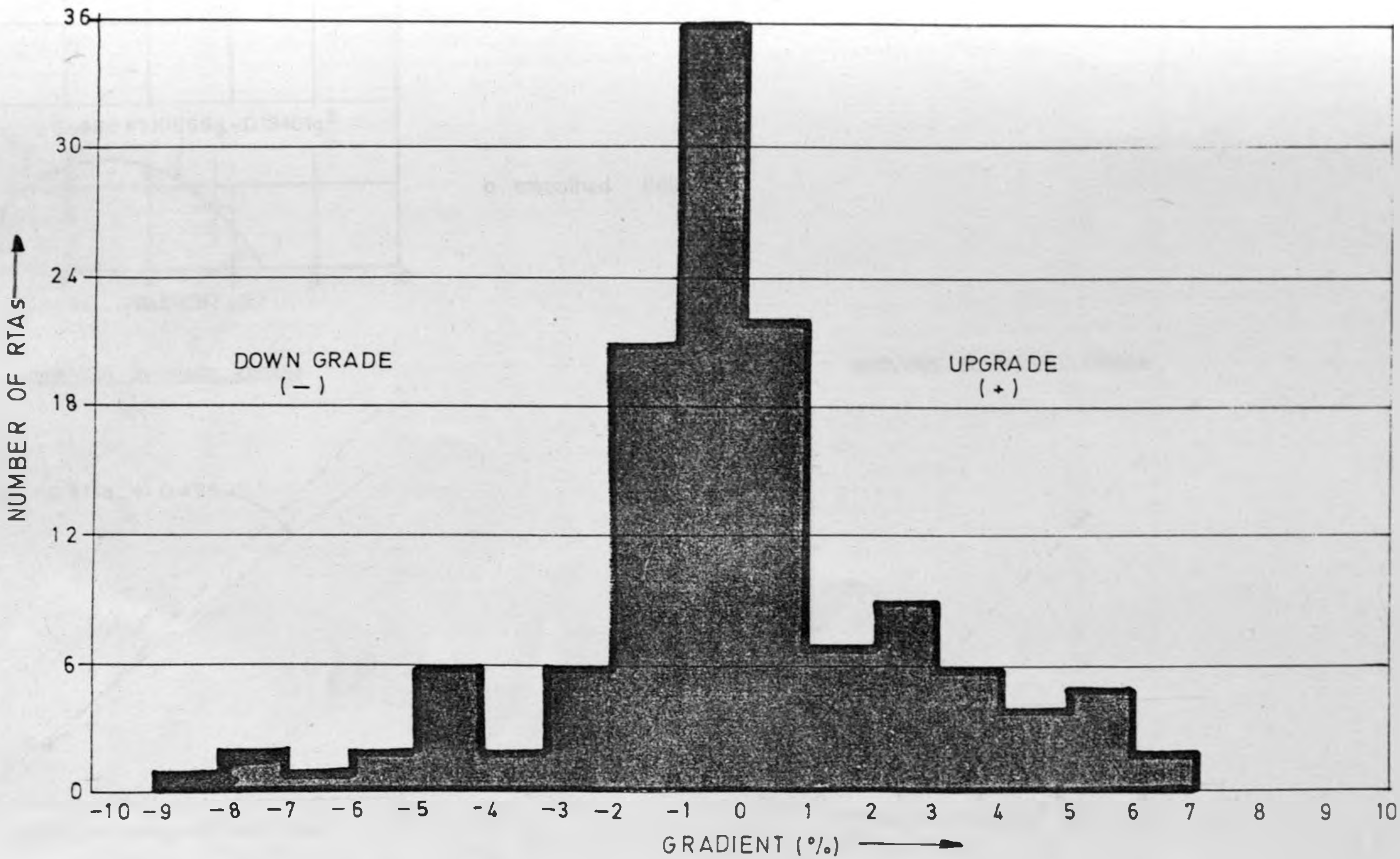


FIG.4.46 NAIROBI - THIKA ROAD: NUMBER OF ACCIDENTS AGAINST GRADIENT

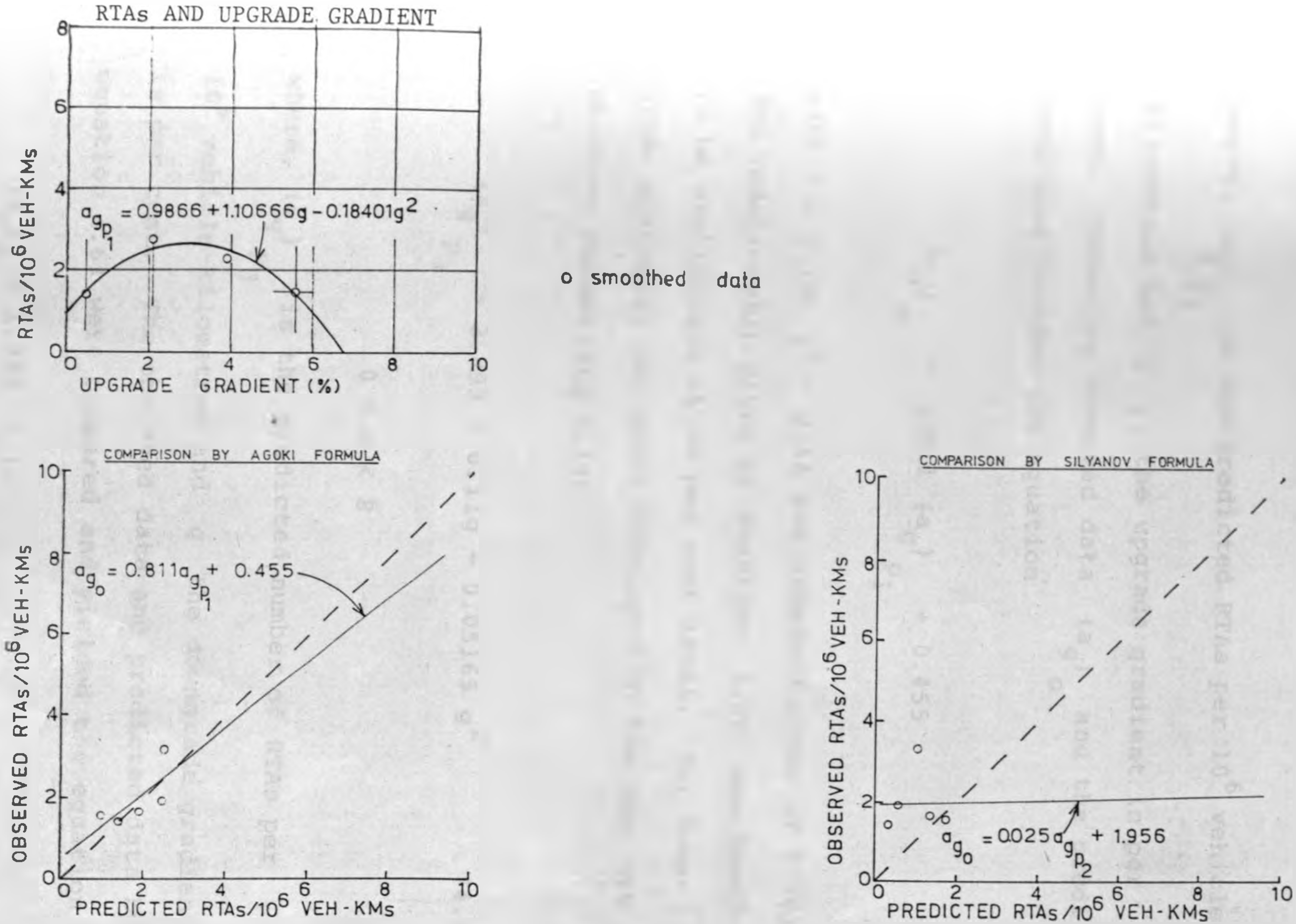


FIG.4.47 RELATION BETWEEN RTAs/10^6 VEHICLES-KILOMETRES AND UPGRADE GRADIENT

$$(a_g)_{p_1} = 0.9866 + 1.10666g - 0.18401\, g^2 \qquad (4.60)$$

$$0 < g < 6$$

where, $(a_g)_{p_1}$ is the predicted RTAs per 10^6 vehicle-kilometres and g is the upgrade gradient in per cent. Comparing observed data $(a_g)_o$ and the predicted data yielded the equation

$$(a_g)_o = 0.811\, (a_g)_{p_1} + 0.455$$

with r = 0.68, r^2 = 0.46 and standard error of 0.781. The relationship given by equation 4.60 was found to be significant at 20 per cent level. For downgrade gradients the model developed in the same way as above became (Fig.4.48)

$$(a_g)_{p_3} = 2.993 + 0.11g - 0.05165\, g^2 \qquad (4.61)$$

$$0 < g < 8$$

where, $(a_g)_{p_3}$ is the predicted number of RTAs per 10^6 vehicle-kilometres and g the downgrade gradient in per cent. The observed data and predicted data by equation 4.61 were compared and yielded the equation

$$(a_g)_o = 1.018\, (a_g)_{p_3} - 0.095$$

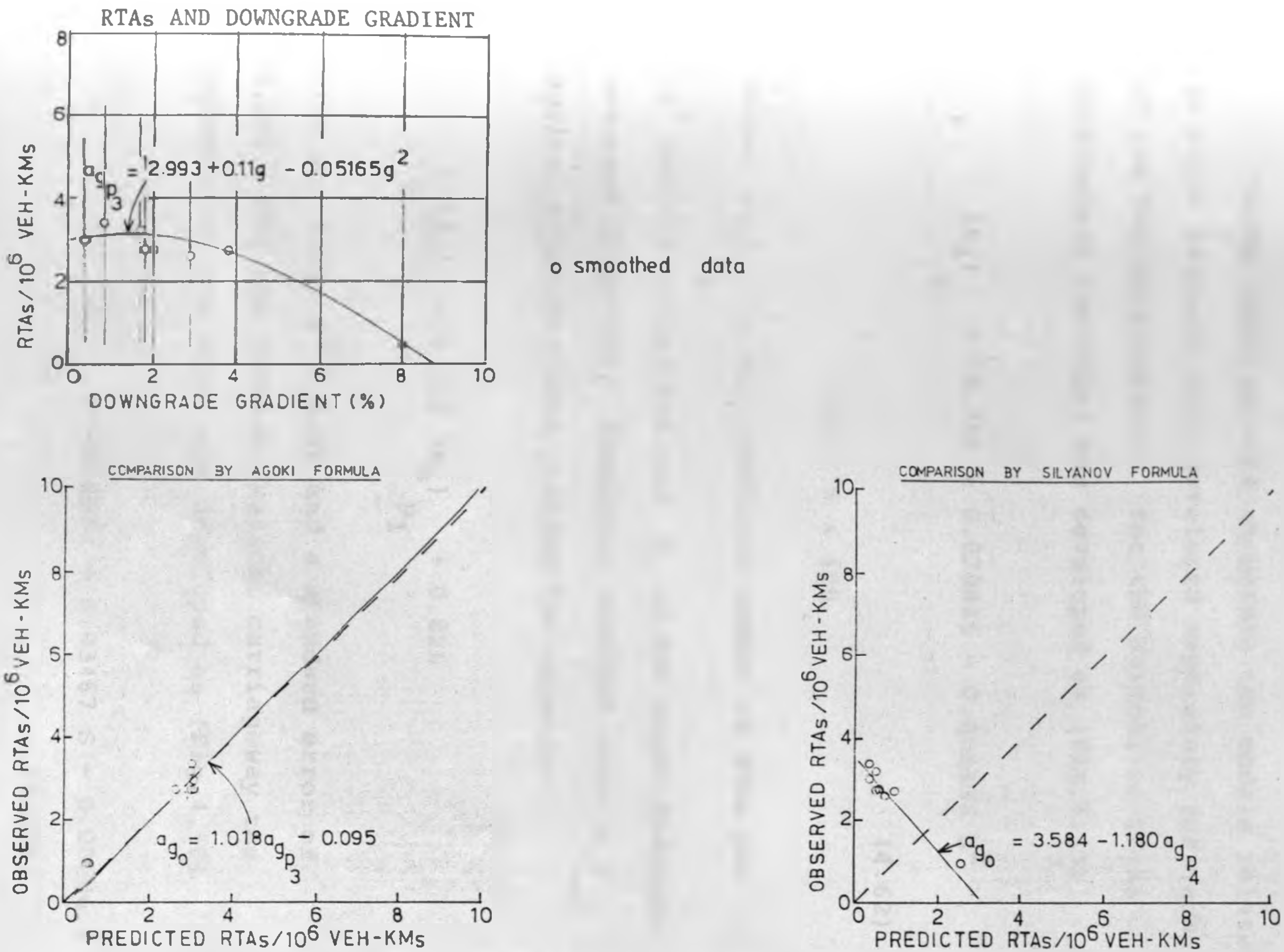


FIG.4.48 RELATION BETWEEN RTAs/VEHICLE-KILOMETRES AND DOWNGRADE GRADIENT

with $r = 0.97$, $r^2 = 0.94$. The relationship (4.61) was found to be significant at the 5 per cent level.

Sight Distance

Using formulae 3.24 as before the models related to sight distance were developed separately for each of the two carriageways. For the Nairobi-to-Thika carriageway the model was developed as (Fig.4.49)

$$(a_s)_{P_1} = -8.745 + 0.079815 - 0.000136\ s^2 \quad (4.62)$$

$$150 < 5 < 400$$

where, $(a_s)_{P_1}$ is the predicted number of RTAs per 10^6 vehicle-kilometres and S is the sight distance measured in metres. Comparing observed data $(a_s)_o$ against predicted data yielded the equation

$$(A_s)_o = 0.723\ (a_s)_{P_1} + 0.826$$

with $r = 0.83$, $r^2 = 0.69$ and a standard error of 0.996. For the Thika-to-Nairobi carriageway the equation of the model was developed as (Fig.4.50)

$$(a_s)_{P_2} = -1.8551 + 0.03467\ S - 0.00006\ S^2 \quad \ldots (4.63)$$

$$150 < 5 < 500$$

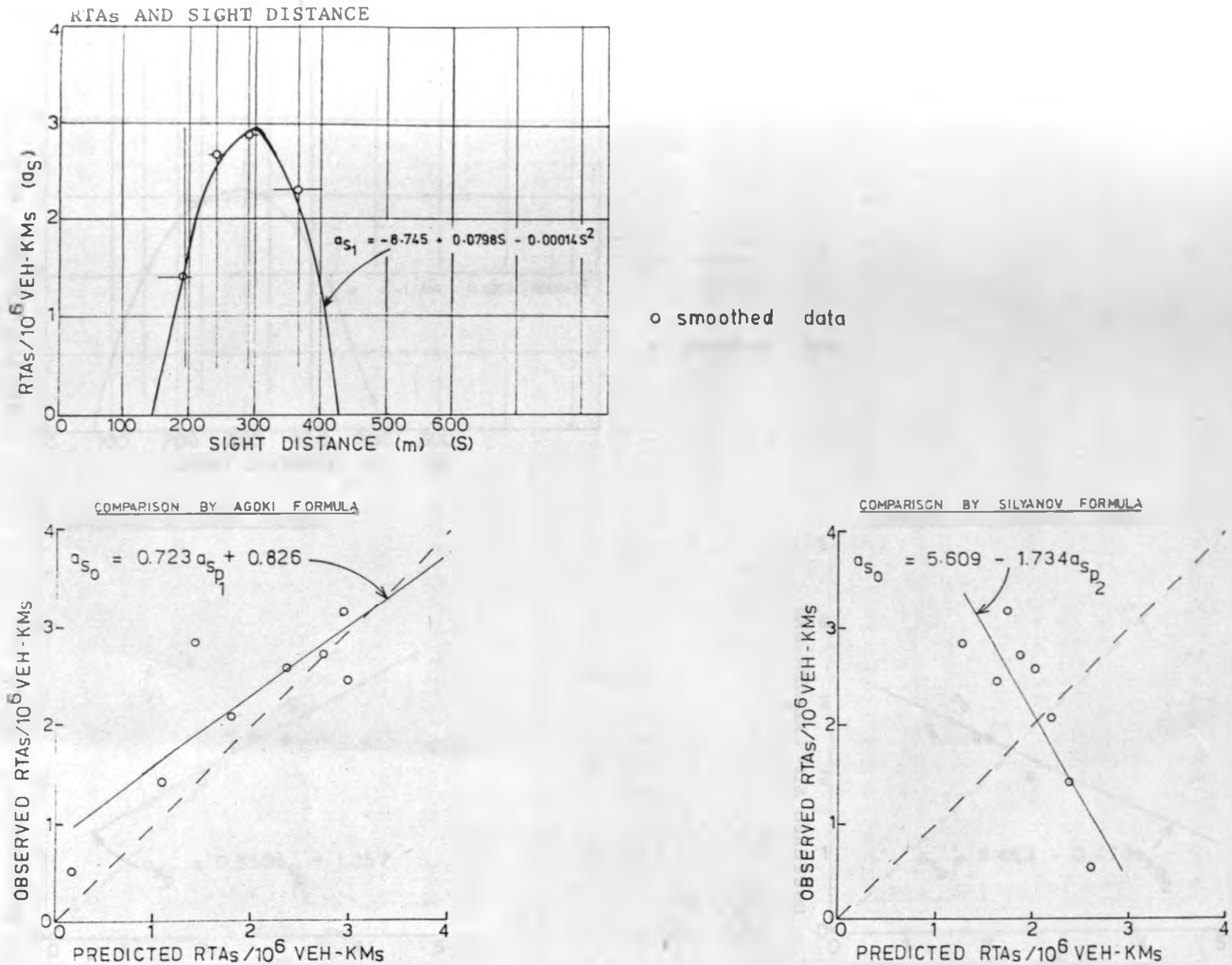


FIG 4.49 RELATION BETWEEN RTAs/10^6 VEH-KMs AND SIGHT DISTANCE: NAIROBI-TO-THIKA CARRIAGEWAY

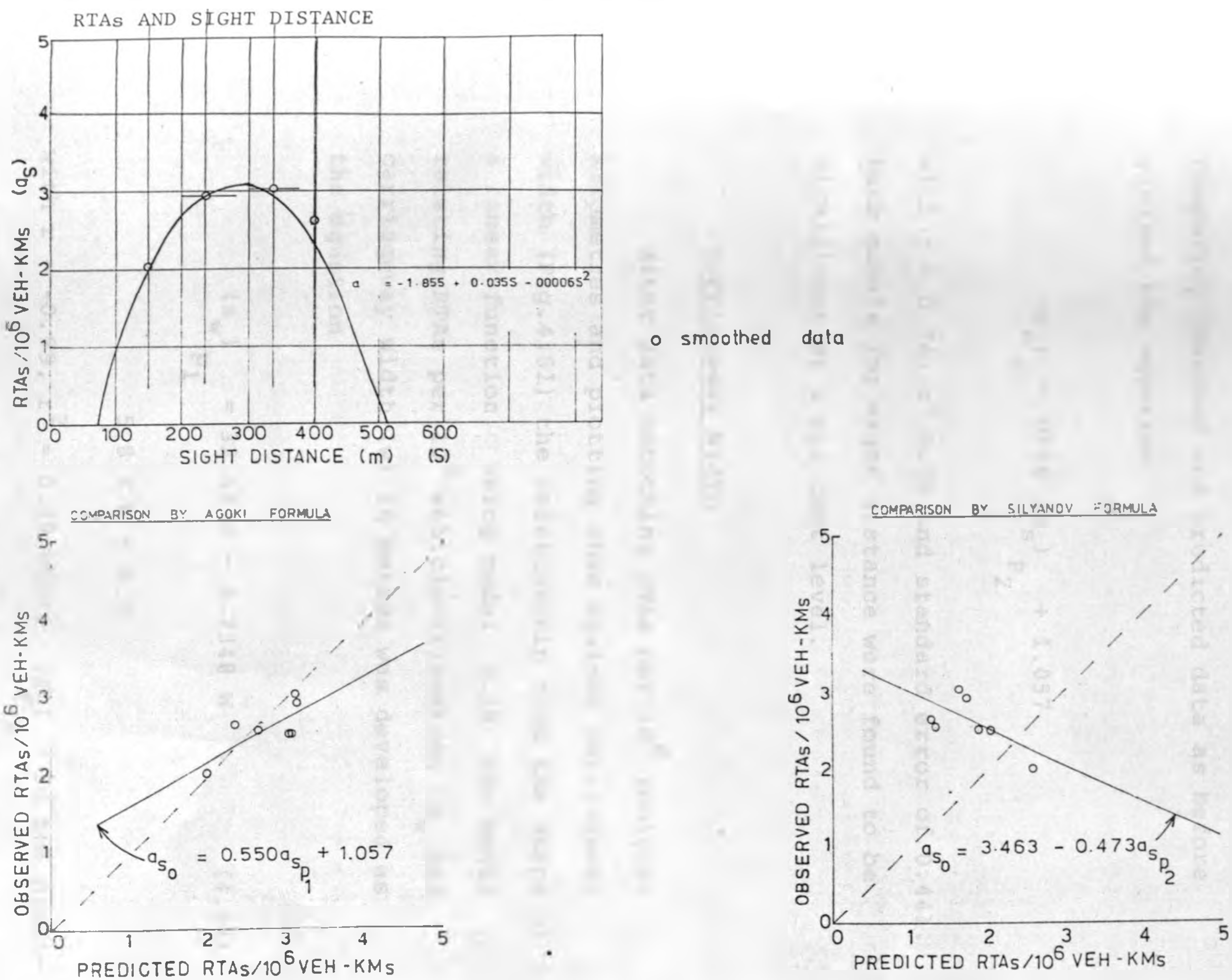


FIG 4.50 RELATION BETWEEN RTAs/10^6 VEH-KMs AND SIGHT DISTANCE: THIKA-TO-NAIROBI CARRIAGEWAY

where, $(a_s)_{P_2}$ is the predicted number of RTAs per 10^6 vehicle-kilometres predicted by equation 4.63 . Comparing observed and predicted data as before yielded the equation

$$(a_s)_o = 0550\ (a_s)_{P_2} + 1.057$$

with r = 0.74, r^2 0.55 and standard error of 0.441. Both models for sight distance were found to be significant at 5 per cent level.

Carriageway Width

After data smoothing RTAs per 10^6 vehicle-kilometres and plotting them against carriageway width (Fig.4.51) the relationship took the shape of a linear function. Using model 3.19 the model relating RTAs per 10^6 vehicle-kilometres a_w and carriageway width (w) in metres was developed as the equation

$$(a_w)_{P_1} = 32.6439 - 4.2348\ W \qquad (4.64)$$

$$5.8 < W < 6.5$$

with r = -0.99, r^2 = 0.99 where, $(a_w)_{P_1}$ is the predicted data using equation 4.64 . The observed data

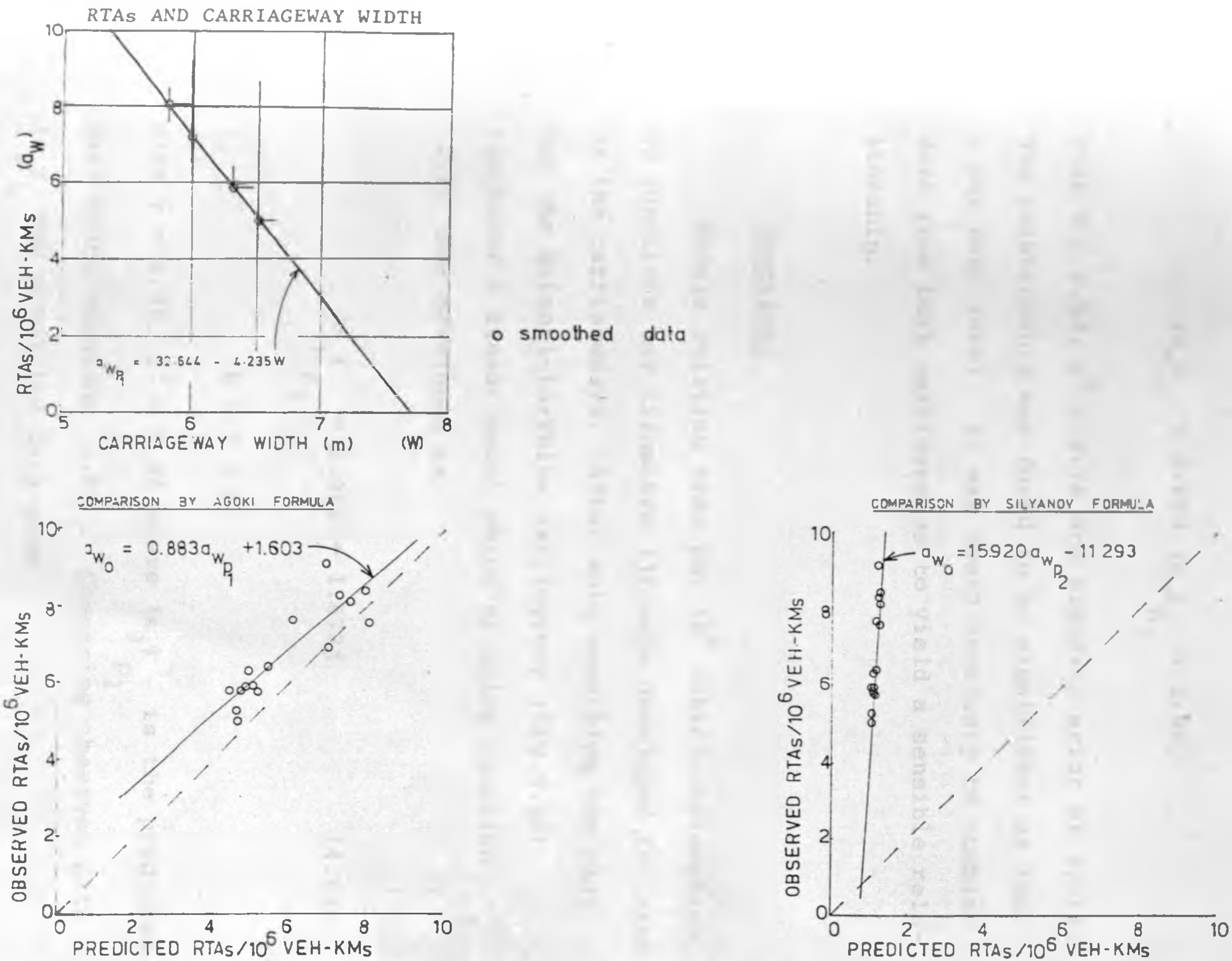


FIG 4.51 RELATION BETWEEN RTAs/10^6 VEH-KMs AND CARRIAGEWAY WIDTH: NAIROBI THIKA ROAD

$(a_w)_o$ and the predicted data were compared yielding the equation

$$(a_w)_o = 0.883\ (a_w)_{p_1} + 1.603$$

with $r = 0.88$, $r^2 = 0.78$ and standard error of 1.316. The relationship was found to be significant at the 5 per cent level. It was found necessary to combine data from both carriageways to yield a sensible relationship.

Junctions

Models relating RTAs per 10^6 vehicle-kilometres to junctions per kilometre (j) were developed for each of the carriageways. After data smoothing the plot for the Nairobi-to-Thika carriageway (Fig.4.52) suggested a linear model which by using equation 3.19 was developed as

$$(a_j)_{p_1} = 5.068 + 1.672j \qquad (4.65)$$

$$0 < j < 4$$

with $r = 0.92$, $r^2 = 0.84$ where $(a_j)_{p_1}$ is the predicted data using equation 4.65 . Comparing observed data $(a_j)_o$ and predicted data gave

$$(a_j)_o = 1.001\ (a_j)_{p_1} - 0.004$$

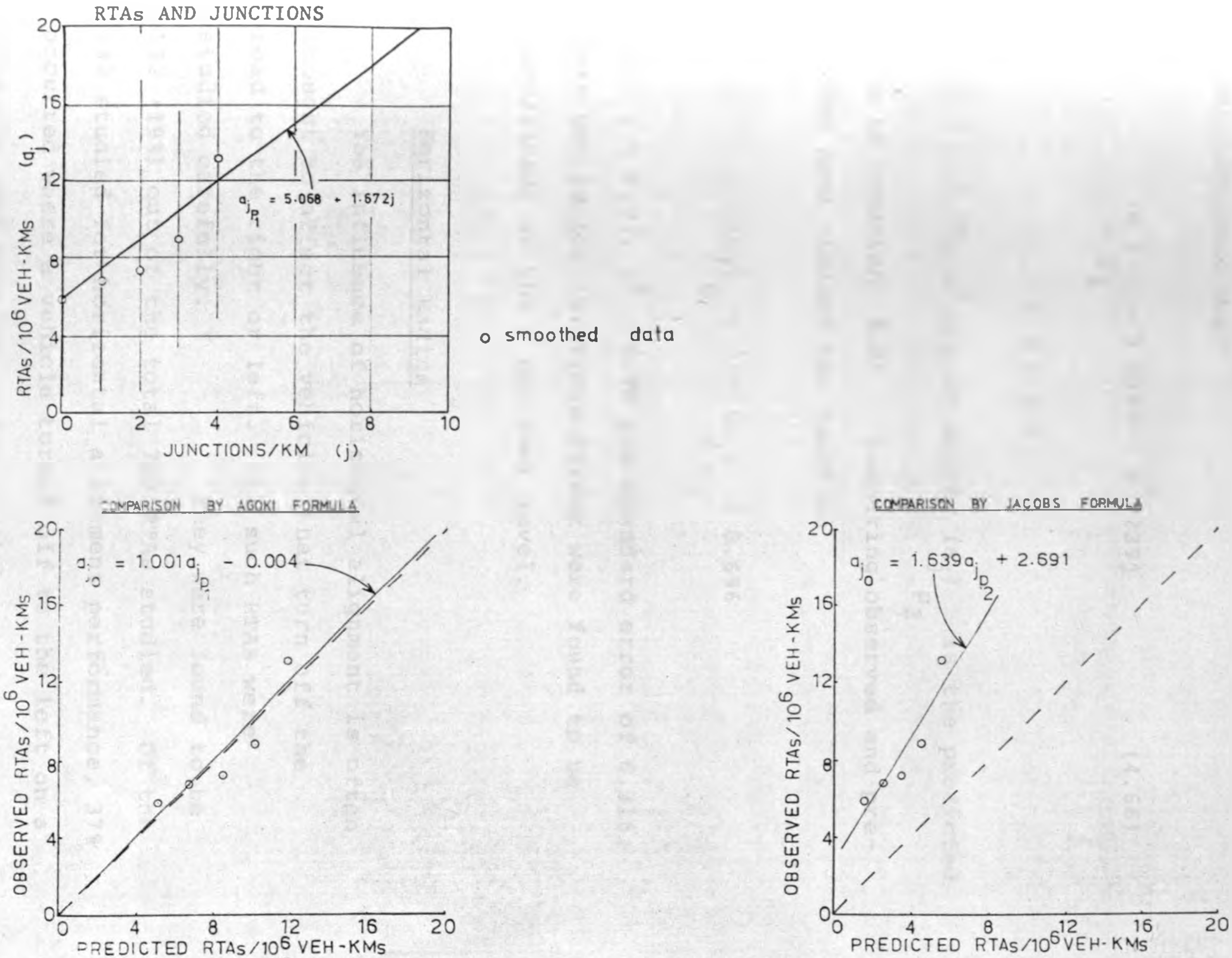


FIG.4.52 RELATION BETWEEN RTAs/10^6 VEH-KMs AND JUNCTIONS/KM: NAIROBI -TO- THIKA CARRIAGEWAY

with r = 0.92, r^2 = 0.84 and standard error of 2.644. For the Thika-to-Nairobi carriageway (Fig.4.53) the model developed was

$$(a_j)_{P_2} = 3.0099 + 2.9239j \qquad (4.66)$$

$$0 < j < 6$$

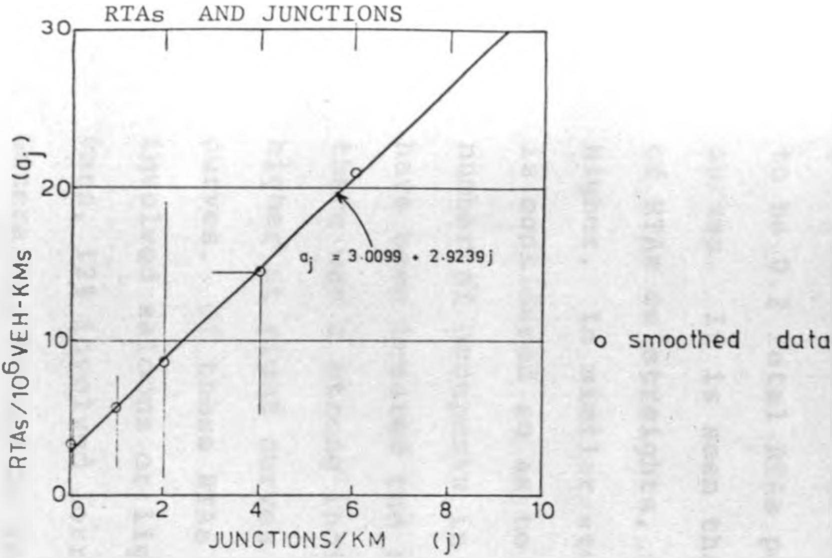
with r = 0.99, r^2 = 0.99 where, $(a_j)_{P_2}$ is the predicted data by equation 4.66 . Comparing observed and predicted data yielded the equation

$$(a_j)_o = 0.97(a_j)_{P_2} - 0.696$$

with r = 0.93, r^2 = 0.86 and standard error of 6.316. Both models for junctions effect were found to be significant at the 5 per cnet level.

Horizontal Radius

The influence of horizontal alignment is often thought to affect the vehicles that turn off the road to the right or left. All such RTAs were studied carefully. They were found to be 132 (19%) out of the total 702 RTAs studied. Of the 132 studied for horizontal alignment performance, 37% occurred where a vehicle turned off to the left on a straight road section (radius = ∞), as opposed to 24% which turned off to the right on a straight section.



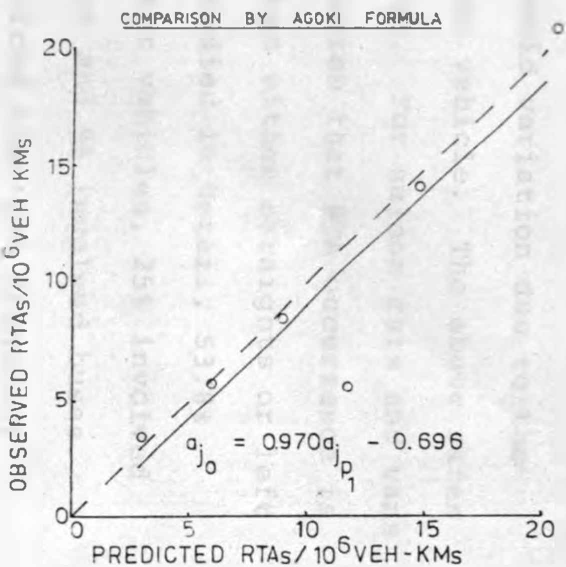
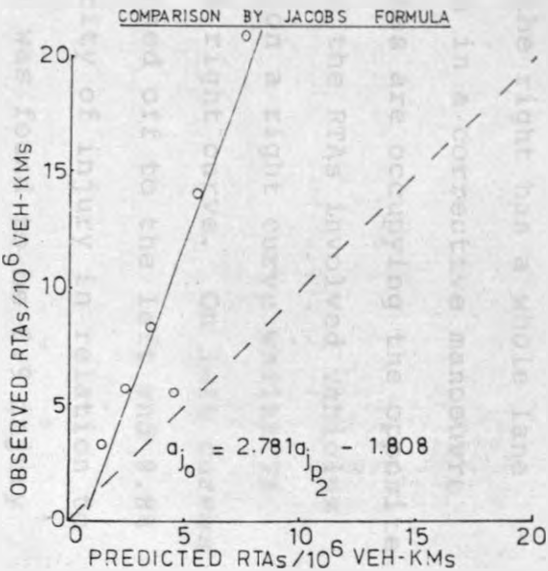


FIG 4.53 RELATION BETWEEN RTAs/10^6 VEH-KMs AND JUNCTIONS/KM THIKA-TO



– NAIROBI CARRIAGEWAY

Since on Kenyan roads vehicles are driven on the left side it may be argued that this is the main reason for a greater percentage turning off to the left. A vehicle turning off to the right has a whole lane width in which to regain in a corrective manoeuvre assuming no other vehicles are occupying the opposite lane. On curves, 11% of the RTAs involved vehicles turning off to the left on a right curve whilst 7% turned to the right on a right curve. On left curves 8.3% of the vehicles turned off to the left and 9.8% to the right. The severity of injury in relation to the horizontal alignment was found to be 0.9 injury RTAs per kilometre on straights and 1.9 injury RTAs per kilometre on curves. The fatality rate was found to be 0.2 fatal RTAs per kilometre on straights and curves. It is seen that in spite of a greater number of RTAs on straights, the injury rate on curves is higher. In similar studies [12] only driver injury is considered so as to avoid variation due to the number of occupants in the vehicle. The above rates have been treated the same. For saloon cars and vans there was a strong indication that RTA occurrence is higher at right curves than either straights or left curves. Of these RTAs studied in detail, 53.8% involved saloons or lighter vehicles, 25% involved vans, 12% involved lorries and 9% involved buses. Generally, it can be inferred that the frequency of occurrence decreases with increase in vehicle masses.

For lighter vehicles the pattern observed here is to be expected given that a moving object tends to continue in motion in a straight line until redirected and vehicles are ordinarily travelling on the left. Evidently, lighter vehicles are travelling at higher speeds than heavy ones. Hence speed is a significant factor in contributing to RTA causation. For the same phenomenon there were, only one RTA involving a bus, one involving a lorry on a right curve and two involving lorries and three buses on left curves.

The horizontal alignment effect was analysed using two independent variables. These were the horizontal curve radius and the superelevation of the horizontal alignment. Further, in order to distinguish the effect of upgrade and downgrade vertical curves, the horizontal curves were divided into those occurring on crests and those occurring at sags. Firstly, the RTA density per kilometre for each horizontal curve was calculated and a histogram constructed (Fig.4.54). This showed that small radii curves were more RTA prone than larger radii curves. However, RTAs per kilometre rose again with increased radius. To confirm this observation the histogram for RTAs and superelevation was constructed (Fig.4.57). This revealed that as superelevation tended to zero (i.e. horizontal radius tended to infinity) RTAs increased and as superelevation increased (i.e. horizontal radius

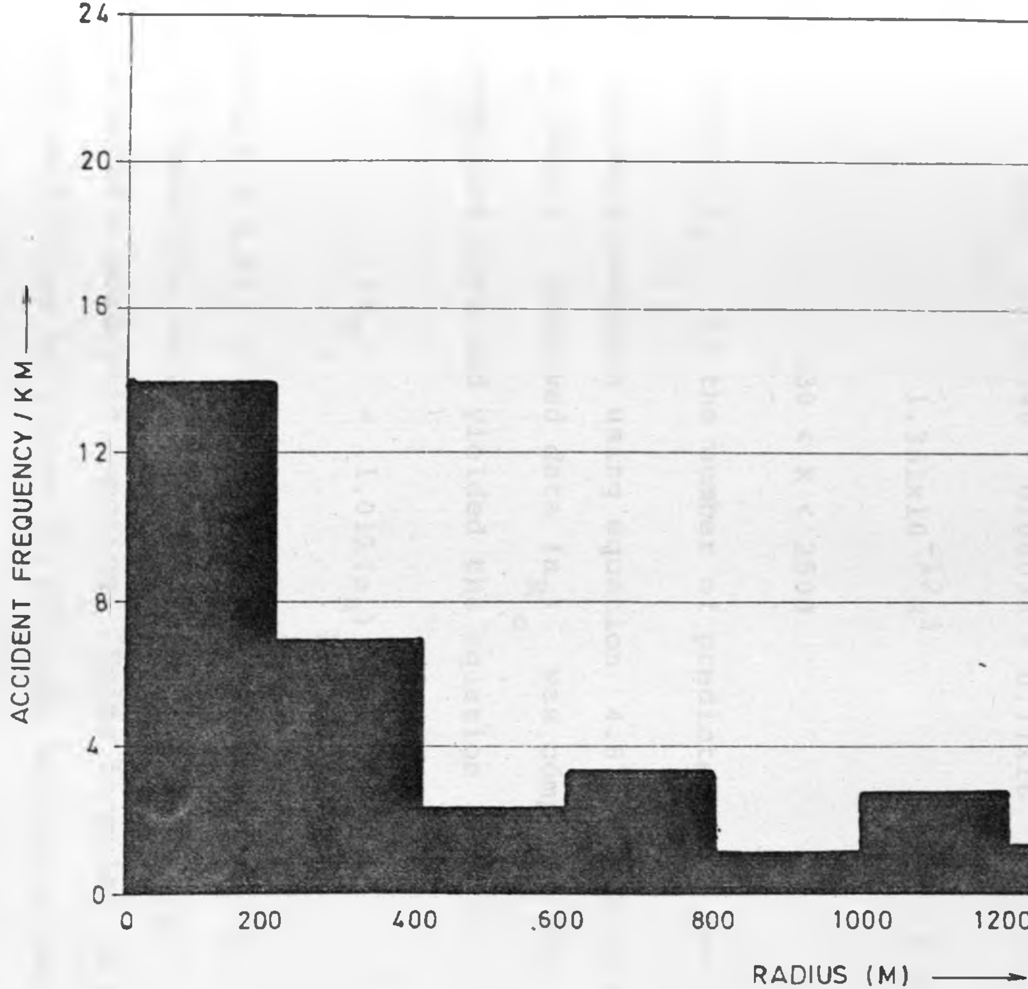


FIG.4.54 NAIROBI-THIKA ROAD: GRAPH OF NUMBER OF ACC

decreased) RTAs decreased. These observations were used in plotting RTAs per 10^6 vehicle-kilometres against horizontal curve radius. For upgrade curves the smoothed plot (Fig.4.55) revealed two bends in the curve. By polynomial fitting techniques and confirming the shape by the finite differences technique formulae 3.26 were used and the model developed as

$$(a_R)_{p_1} = 3.346 - 0.0009R + 0.77\times10^{-7}R^2 - 1.361\times10^{-12}R^3 \qquad (4.67)$$

$$130 < R < 2500$$

where, $(a_R)_{p_1}$ is the number of predicted RTAs per 10^6 vehicle-kilometres using equation 4.67 and R is radius in metres. Observed data $(a_R)_o$ was compared with predicted data and yielded the equation

$$(a_R)_o = 1.011(a_R)_{p_1} - 0.055$$

with $r = 0.67$, $r^2 = 0.44$ and standard error of 0.774. For downgrade curves the smoothed plot (Fig.4.56) revealed a quadratic function. Using formulae 3.24 and confirming by finite differences technique the relationship was modelled as

$$(a_R)_{p_2} = 6.8699 - 0.0031R + 0.000\,000397R^2 \quad \ldots.(4.68)$$

$$130 < R < 6000$$

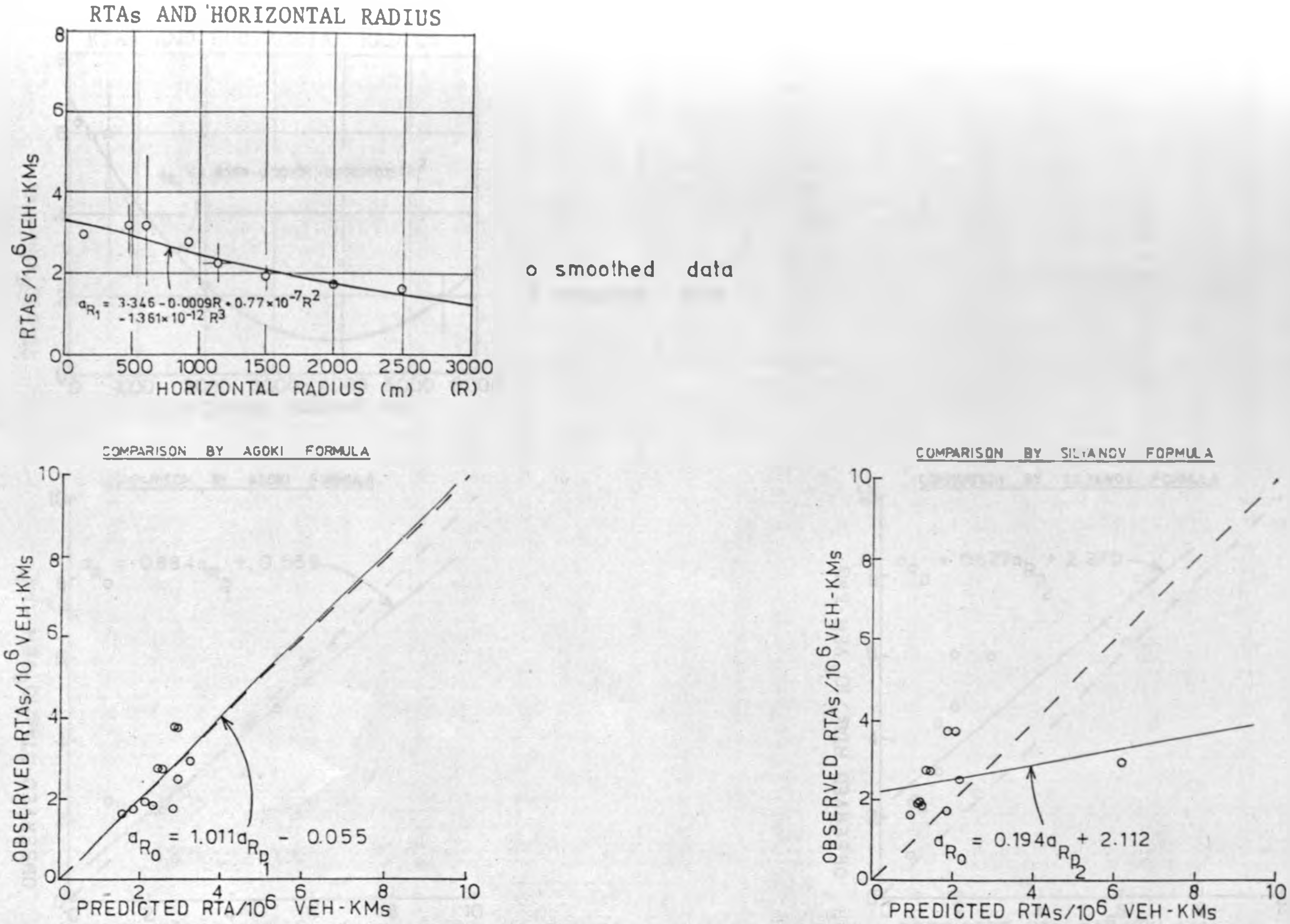


FIG 4.55 RELATION BETWEEN RTAs/10^6 VEH-KMs AND HORIZONTAL RADIUS (UPGRADE CURVES): NAIROBI - THIKA ROAD

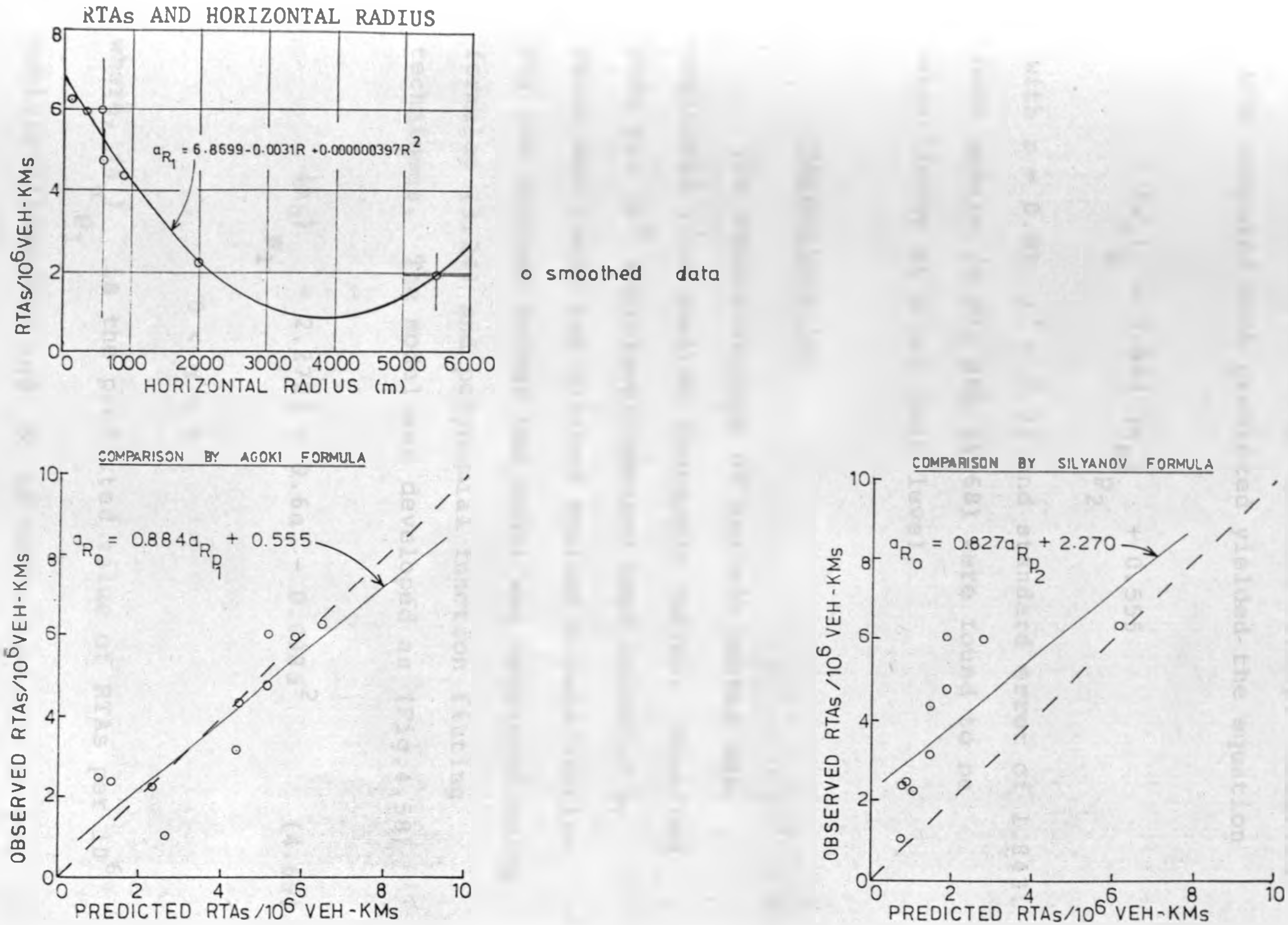


FIG.4.56 RELATION BETWEEN RTAs/10⁶VEH-KMs AND HORIZONTAL RADIUS (DOWNGRADE CURVES): NAIROBI-THIKA ROAD

where, $(a_R)_{p_2}$ is the predicted value of RTAs per 10^6 vehicle-kilometres using equation (4.68). Observed data compared with predicted yielded the equation

$$(a_R)_o = 0.844\ (a_R)_{p_2} + 0.555$$

with $r = 0.88$, $r^2 = 0.77$ and standard error of 1.843. Both models (4.67) and (4.68) were found to be significant at 5 per cent level.

Superelevation

The superelevation of upgrade curves was separated from that of downgrade curves. Observed RTAs per 10^6 vehicle-kilometres were smoothed as afore-mentioned and plotted against superelevation. For the upgrade curves the model was developed using formulae (3.24) and polynomial function fitting techniques. The model was developed as (Fig.4.58)

$$(a_\alpha)_{p_1} = 2.2729 + 0.6\alpha - 0.098\alpha^2 \qquad (4.69)$$

$$0 < \alpha < 5$$

where, $(a_\alpha)_{p_1}$ is the predicted value of RTAs per 10^6 vehicle-kilometres and α is superelevation in per cent. Comparing observed data $(a_\alpha)_o$ and predicted data yielded the equation

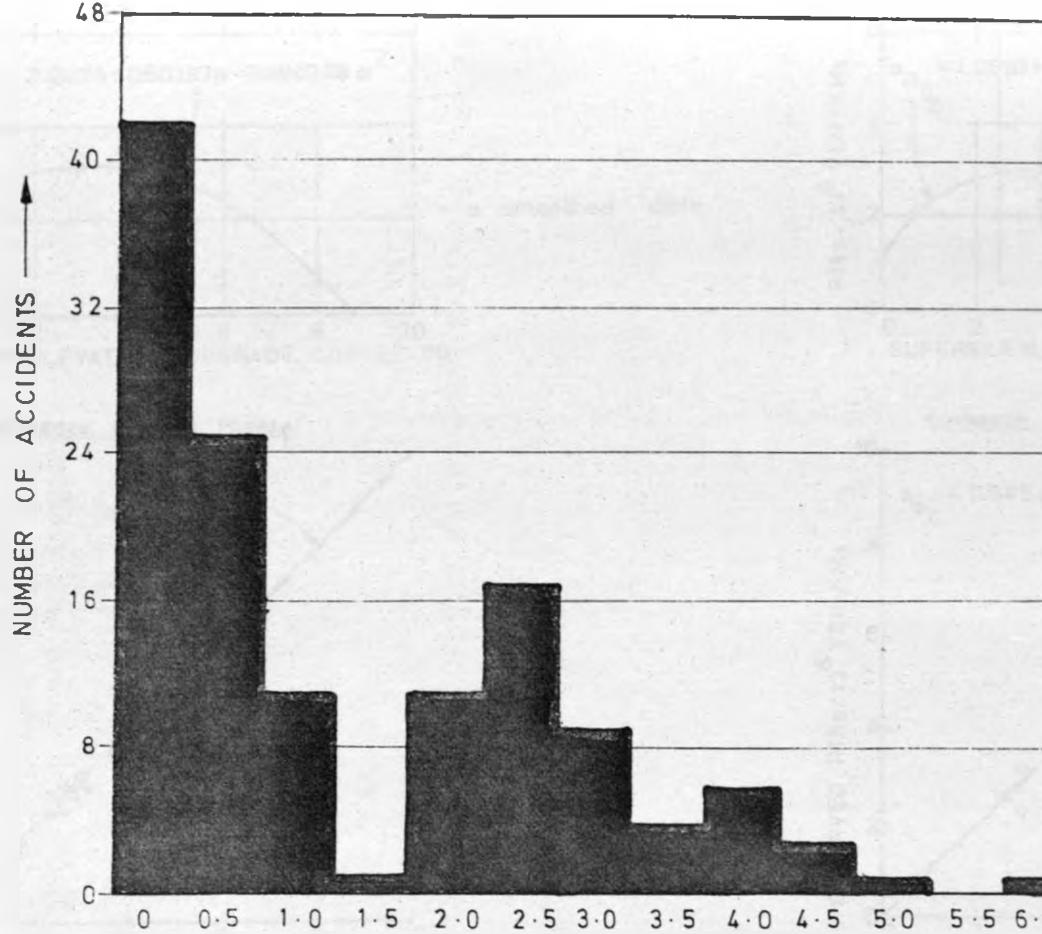


FIG.4.57 NAIROBI - THIKA ROAD: ACCIDENT FREQUENCY AGA

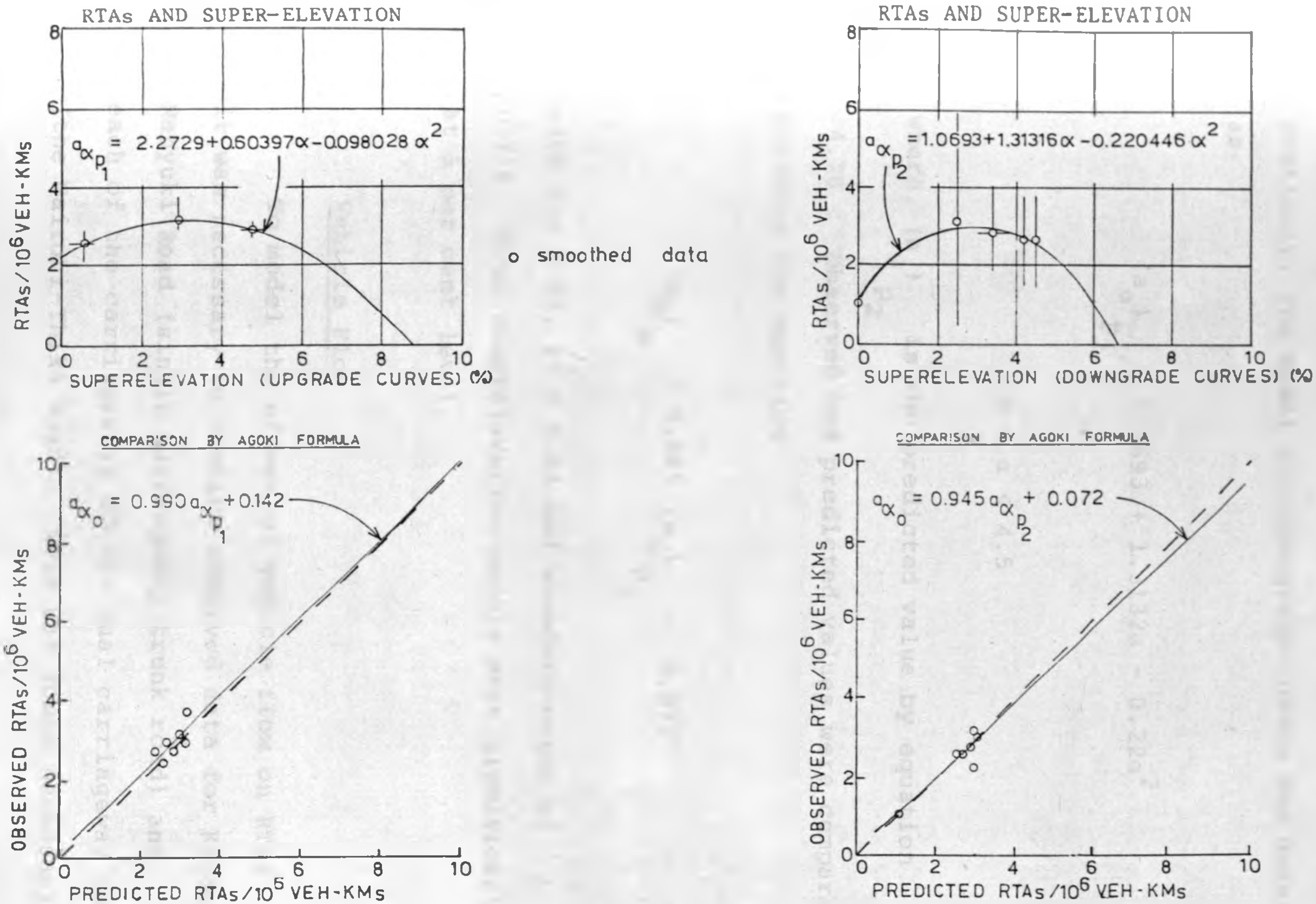


FIG.4.58 RELATION BETWEEN RTAs/10^6 VEHICLE - KILOMETRES AND SUPERELEVATION: NAIROBI - THIKA ROAD

$$(a_\alpha)_o = 0.99\ (a\ )_{p_1} + 0.142$$

with $r = 0.7$, $r^2 = 0.5$ and standard error of 0.43. Similarly, the model for downgrade curves was developed as

$$(a_\alpha)_{p_2} = 1.0693 + 1.3132\alpha - 0.22\alpha^2 \qquad (4.70)$$

$$o < \alpha < 4.5$$

where, $(a_\alpha)_{p_2}$ is the predicted value by equation 4.70 . Observed and predicted values were compared yielding the equation

$$(a_\alpha)_o = 0.945\ (a_\alpha)_{p_2} + 0.072$$

with $r = 0.91$, $r^2 = 0.83$ and standard error of 0.718. Both sueprelevation models were significant at 5 per cent level.

Vehicle Flow

To model the effect of vehicle flow on RTAs it was necessary to combine observed data for Kiganjo-Nanyuki Road (single carriageway trunk road) and each of the carriageways of the dual carriageway road (the Nairobi-Thika Road). This was found necessary because applying data smoothing techniques adopted for this study, the range of vehicle flow on the single carriageway yielded only a single model data point. It was observed that RTAs rise slowly at first with increase in vehicle flow to reach a saturation level where RTAs are many but a majority of which are non injury. Since the RTAs studied here were mainly injury RTAs, they represent the earlier portion of a logistic curve model. Therefore, the equation 3.15 was the basis for modelling. The result of the analysis of the combined Kiganjo-Nanyuki road and the Nairobi-to-Thika carriageway (Fig.4.59) was the model

$$(a_q)_{p_1} = \frac{18.89}{1 + 24.128\, e^{-0.002q}} \qquad (4.71)$$

$$30 < q < 1430$$

where 18.89 is the highest observed level of RTAs/km/annum used as approximate limit, $(a_q)_{p_1}$ is the predicted RTAs per kilometre per annum and q is average vehicle flow per hour. Observed data $(a_q)_o$ compared to predicted data yielded the relationship

$$(a_q)_o = 0.966\,(a_q)_{p_1} + 0.065$$

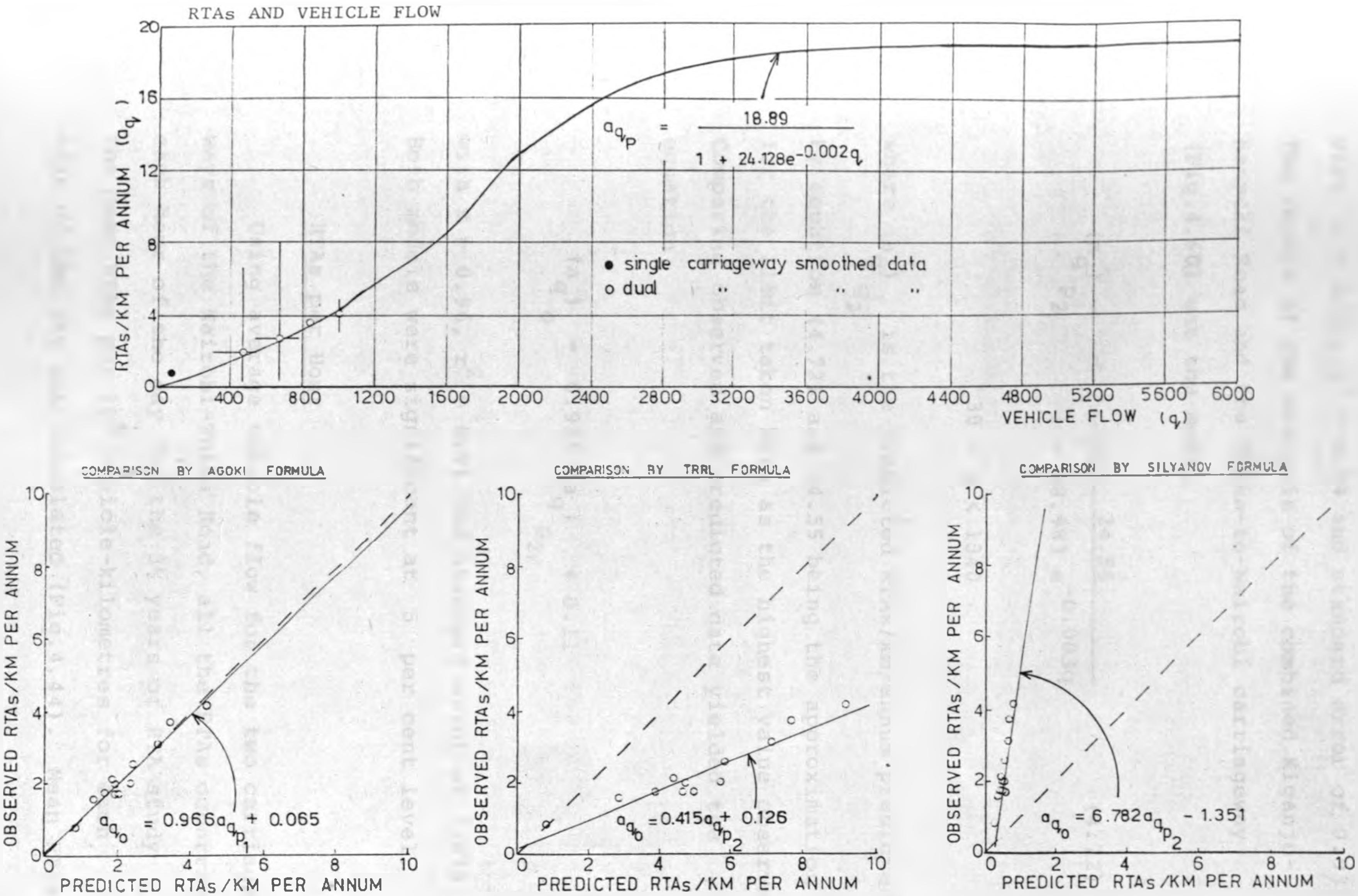


FIG.4.59 RELATION BETWEEN RTAs/KM PER ANNUM AND VEHICLE FLOW: COMBINED KIGANJO-NANYUKI ROAD AND NAIROBI-TO-THIKA CARRIAGEWAY

with $r = 0.97$, $r^2 = 0.94$ and standard error of 0.937. The result of the analysis of the combined Kiganjo-Nanyuki Road and the Thika-to-Nairobi carriageway (Fig.4.60) was the model

$$(a_q)_{p_2} = \frac{24.55}{1 + 38.983\, e^{-0.003q}} \qquad (4.72)$$

$$30 < q < 1340 \, .$$

where $(a_q)_{q_2}$ is the predicted RTAs/km/annum predicted by equation (4.72) and 24.55 being the approximation for the limit taken here as the highest value observed. Comparing observed and predicted data yielded the equation

$$(a_q)_o = 0.921\, (a_q)_{p_2} + 0.11$$

with $r = 0.96$, $r^2 = 0.91$ and standard error of 1.679. Both models were significant at 5 per cent level.

<u>RTAs per Hour</u>

Using average vehicle flow for the two carriageways of the Nairobi-Thika Road, all the RTAs occurring each hour of the day for the 3½ years of RTA study the mean RTAs per 10^6 vehicle-kilometres for each hour of the day was calculated (Fig.4.44). Mean RTAs

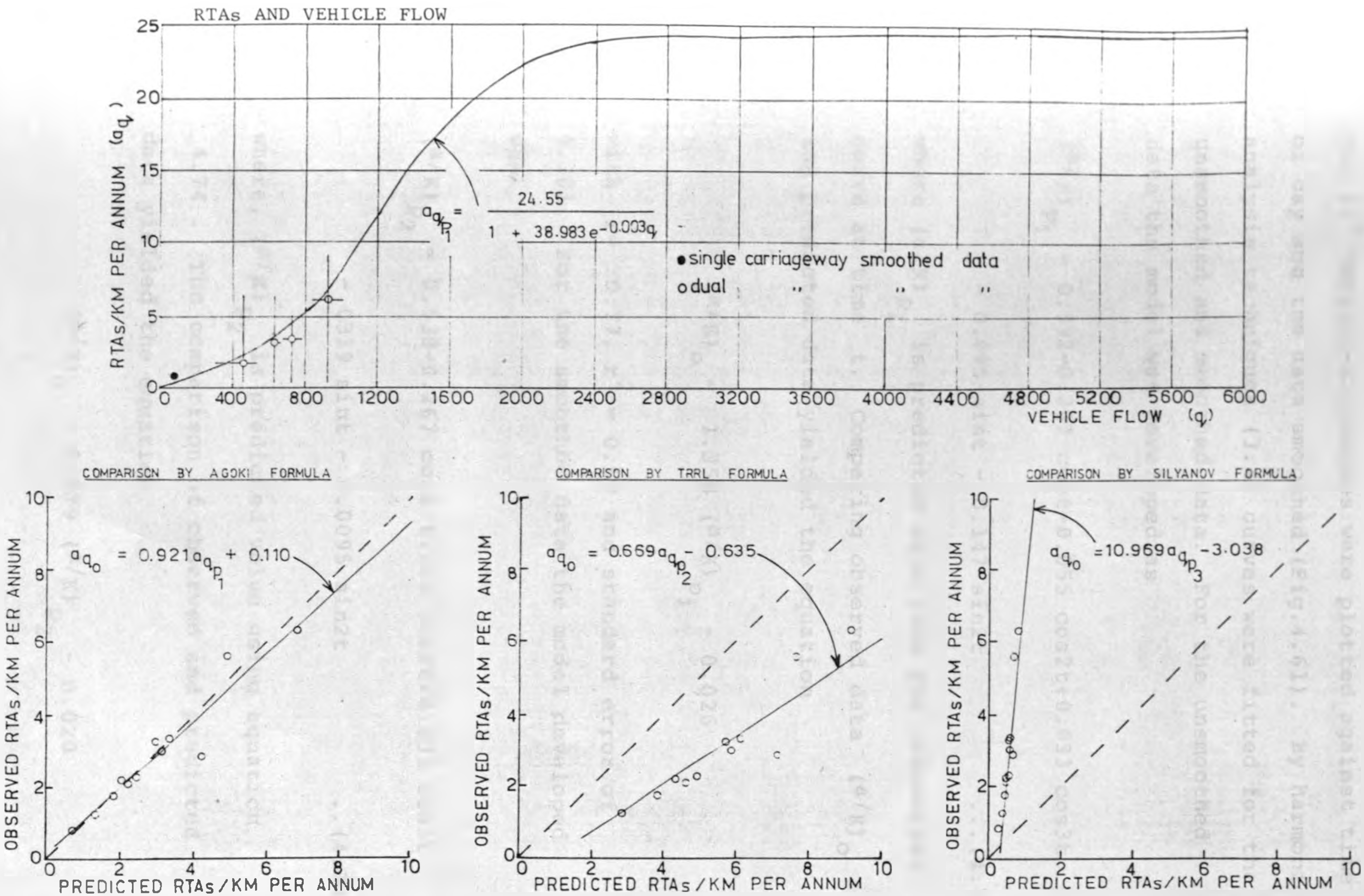


FIG.4.60 RELATION BETWEEN RTAs / KM PER ANNUM AND VEHICLE FLOW: COMBINED KIGANJO-NANYUKI ROAD AND THIKA-TO-NAIROBI CARRIAGEWAY

per 10^6 vehicle-kilometres were plotted against time of day and the data smoothed (Fig.4.61). By harmonic analysis techniques (3.4) curves were fitted for the unsmoothed and smoothed data. For the unsmoothed data the model was developed as

$$(a/K)_{p_1} = 0.392-0.207 \cos t-0.055 \cos 2t+0.033 \cos 3t$$

$$- 0.095 \sin t - 0.147 \sin 2t \qquad ...(4.73)$$

where $(a/K)_{p_1}$ is predicted data from the unsmoothed curve at time t. Comparing observed data $(a/K)_o$ and predicted data yielded the equation

$$(a/K)_o = 1.358 (a/K)_{p_1} - 0.026$$

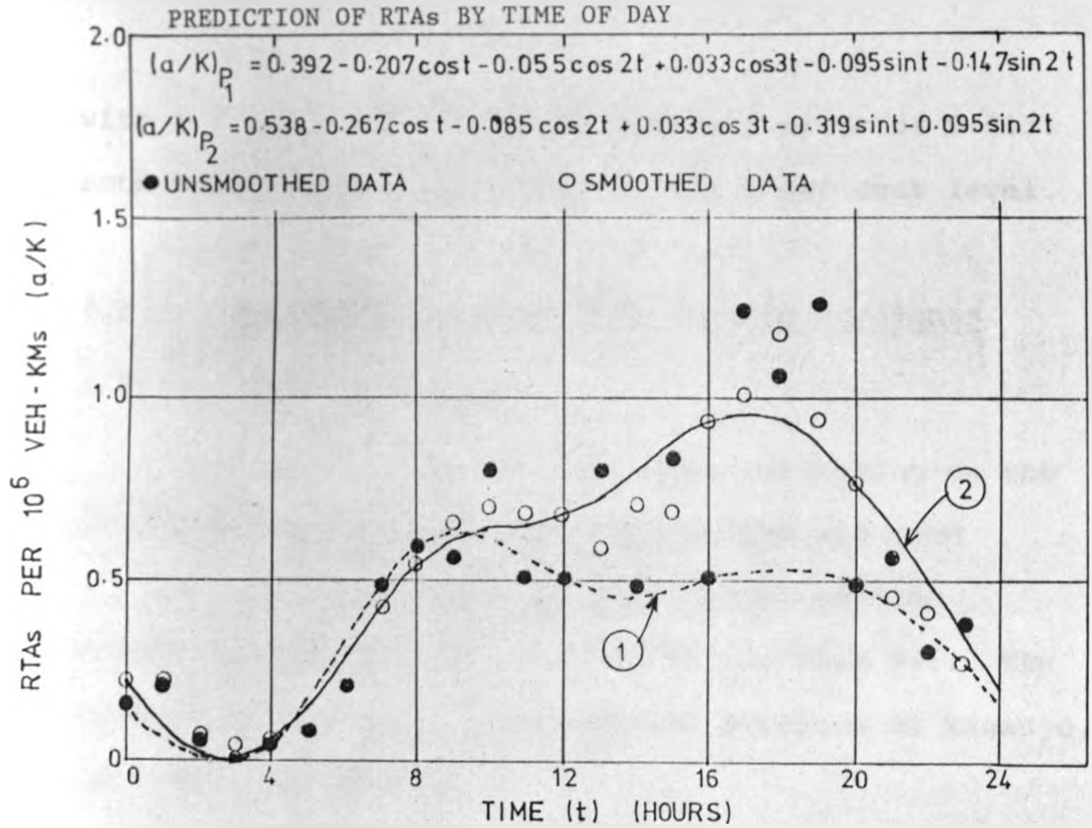
with r= 0.77, r^2 = 0.59 and standard error of 0.201. For the smoothed data the model developed was

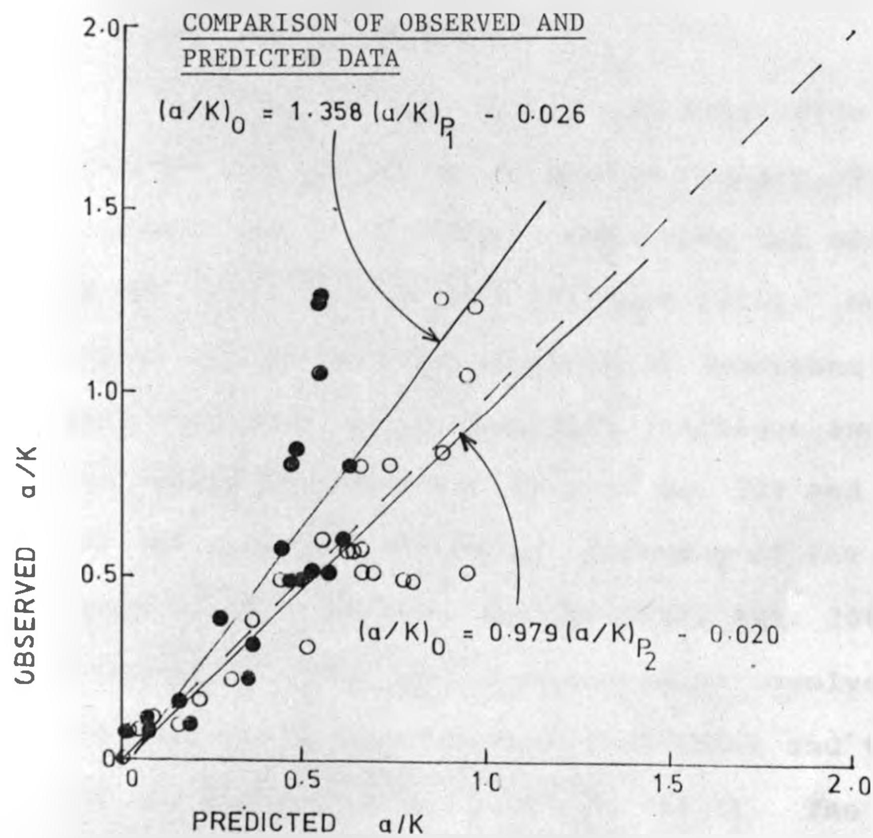
$$(a/K)_{p_2} = 0.538-0.267 \cos t-0.085 \cos 2t+0.033 \cos 3t$$

$$- 0319 \sin t - 0.0095 \sin 2t \qquad ..(4.74)$$

where, $(a/K)_{p_2}$ is predicted value using equation 4.74 . The comparison of observed and predicted data yielded the equation

$$(a/K)_o = 0.979 (a/K)_{p_2} - 0.020$$





G.4.61 PREDICTION OF MEAN RTAs PER 10^6 VEH-KMs: NAIROBI-THIKA ROAD with r = 0.87, r^2 = 0.75 and standard error of 0.315. Both models were significant at the 5 per cent level.

4.2.3 Single Carriageway Road Traffic Accidents

4.2.3.1 Data Collection

The methodology for RTAs data collection on the single carriageway was identical to the one used for the dual carriageway as outlined in section 4.2.2.1 and on the basis of the Police Form P41. The study road fell under three Police Stations at Kiganjo, Naro Moru and Nanyuki.

4.2.3.2 Data Analysis

A total of 94 injury and fatal RTAs was recorded during the study period January 1979 to December 1982. Non-injury RTAs were not studied. Of the total injury RTAs 28% were fatal. Nearly 10% of the fatal RTAs occurred at junctions but many more were associated with junctions and accesses. The annual increase for 1979-80 was 32% and that for 1981-82 was 38%. An annual decrease of 16% was recorded for 1980-81. Of the fatal RTAs 20% involved pedestrians. The most frequent RTAs involved over-turning (21%), head-on collision (21%) and turning off the road onto the roadside (21%). The second category most frequently observed involved vehicles driving in the same direction (14%) and pedestrians crossing the carriageway (13%).

The monthly distribution of RTAs (Fig.4.62) indicated that March, May, September and December were the most RTA rated months for the four quarters of the year respectively. As observed earlier May is the month for the long rains and Labour day public holiday. December is the Christmas and New Year festivities as well as school holidays.

The daily RTA trend showed that (Fig.4.63) weekends had considerably more RTAs than the rest of the week. Of the total RTAs 59% occurred on Friday, Saturday and Sunday. For the remaining days Tuesday had a higher proportion than the others (17%). This trend was observed to coincide with high traffic volumes on Friday and Saturday. The worst times of the day (Fig.4.64) were observed to be 12.00 noon and 5.00 p.m., coinciding with the traffic peaks. These hours alone had 14% and 15% of the fatal RTAs respectively.

The road factors on this road found to be causally related to RTAs were road work or cleaning, damaged carriageway, loads on carriageway. The road environment contributed to 19% of the RTAs directly.

Vehicular factors on this road contributed to

FIG.4.62 KIGANJO - NANYUKI ROAD MONTHLY ACCIDENT DISTRIBUTION

FIG.4.63 KIGANJO - NANYUKI ROAD ACCIDENT DISTRIBUTION BY DAY OF WEEK

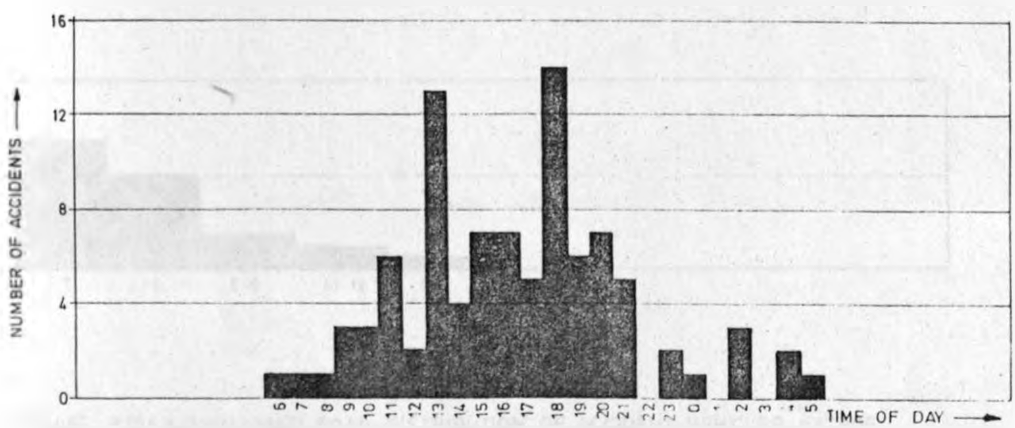


FIG.4.64 KIGANJO-NANYUKI ROAD ACCIDENT DISTRIBUTION BY HOUR OF DAY

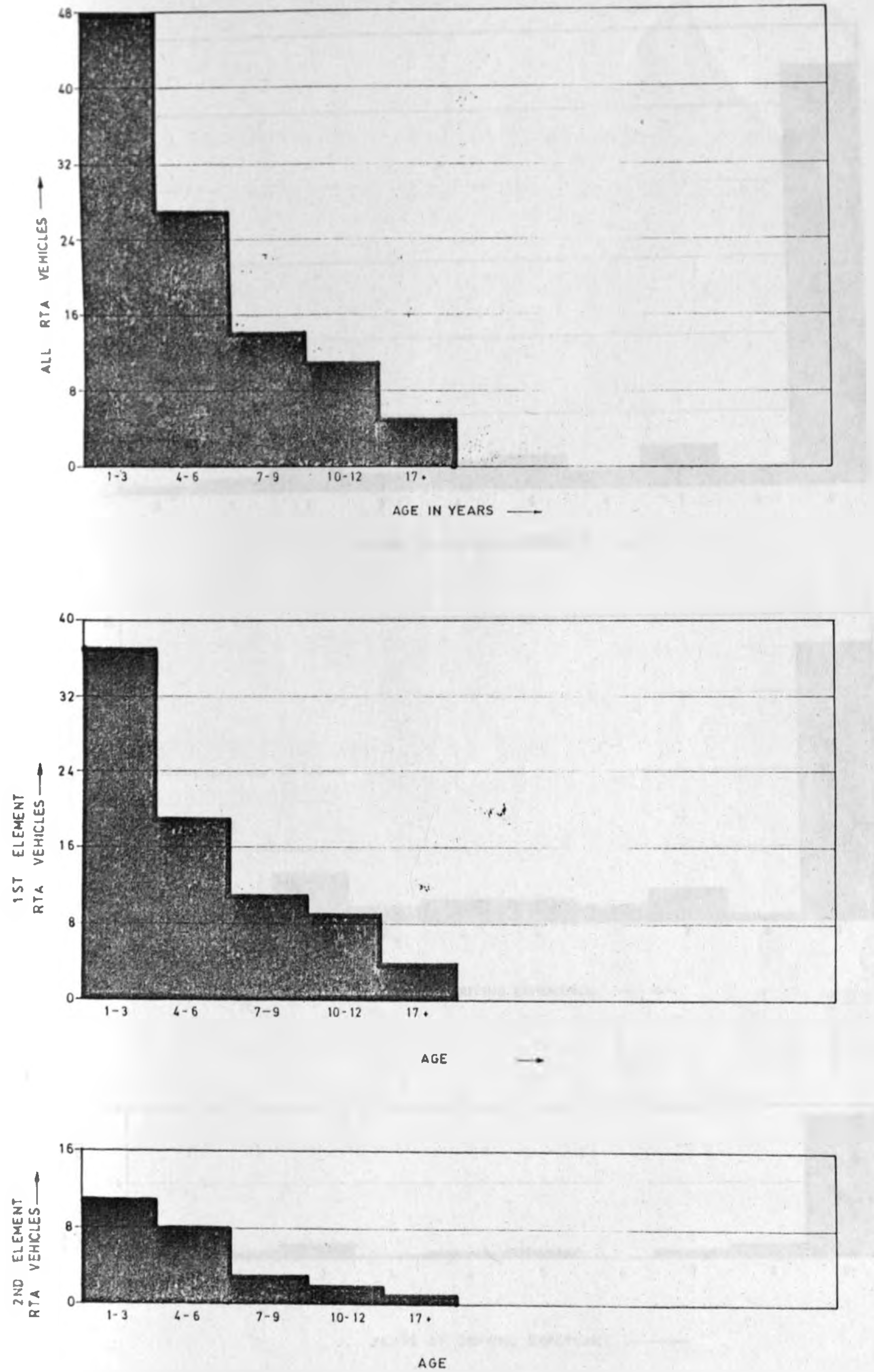


FIG.4.65 KIGANJO-NANYUKI ROAD DISTRIBUTION OF ACCIDENT VEHICLES BY AGE

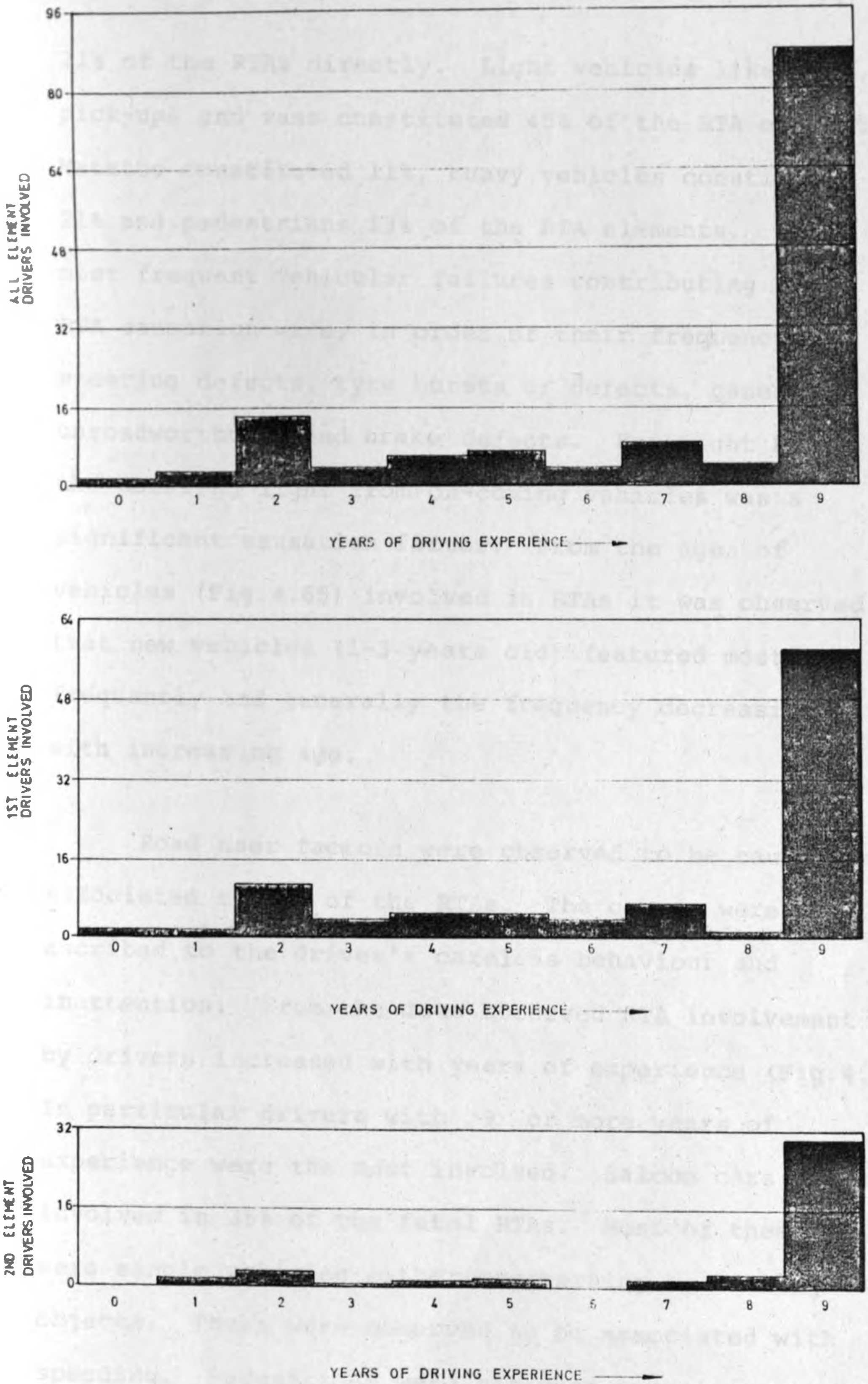


FIG.4.66 KIGANJO - NANYUKI ROAD ACCIDENT INVOLVEMENT BY DRIVING EXPERIENCE

21% of the RTAs directly. Light vehicles like cars, pick-ups and vans constituted 45% of the RTA elements. Matatus constituted 11%, heavy vehicles constituted 21% and pedestrians 13% of the RTA elements. The most frequent vehicular failures contributing to RTA causation were, in order of their frequency: steering defects, tyre bursts or defects, general unroadworthiness and brake defects. For night RTAs the dazzling light from on-coming vehicles was a significant causation factor. From the ages of vehicles (Fig.4.65) involved in RTAs it was observed that new vehicles (1-3 years old) featured most frequently and generally the frequency decreasing with increasing age.

Road user factors were observed to be causatively associated to 60% of the RTAs. The causes were ascribed to the driver's careless behaviour and inattention. From the data observed RTA involvement by drivers increased with years of experience (Fig.4.66). In particular drivers with 9 or more years of experience were the most involved. Saloon cars were involved in 36% of the fatal RTAs. Most of them were single vehicles either overturning or hitting objects. These were observed to be associated with speeding. Pedestrians were hit when crossing the carriageway behind parked vehicles (masked) or rushing suddenly onto the carriageway in the path of

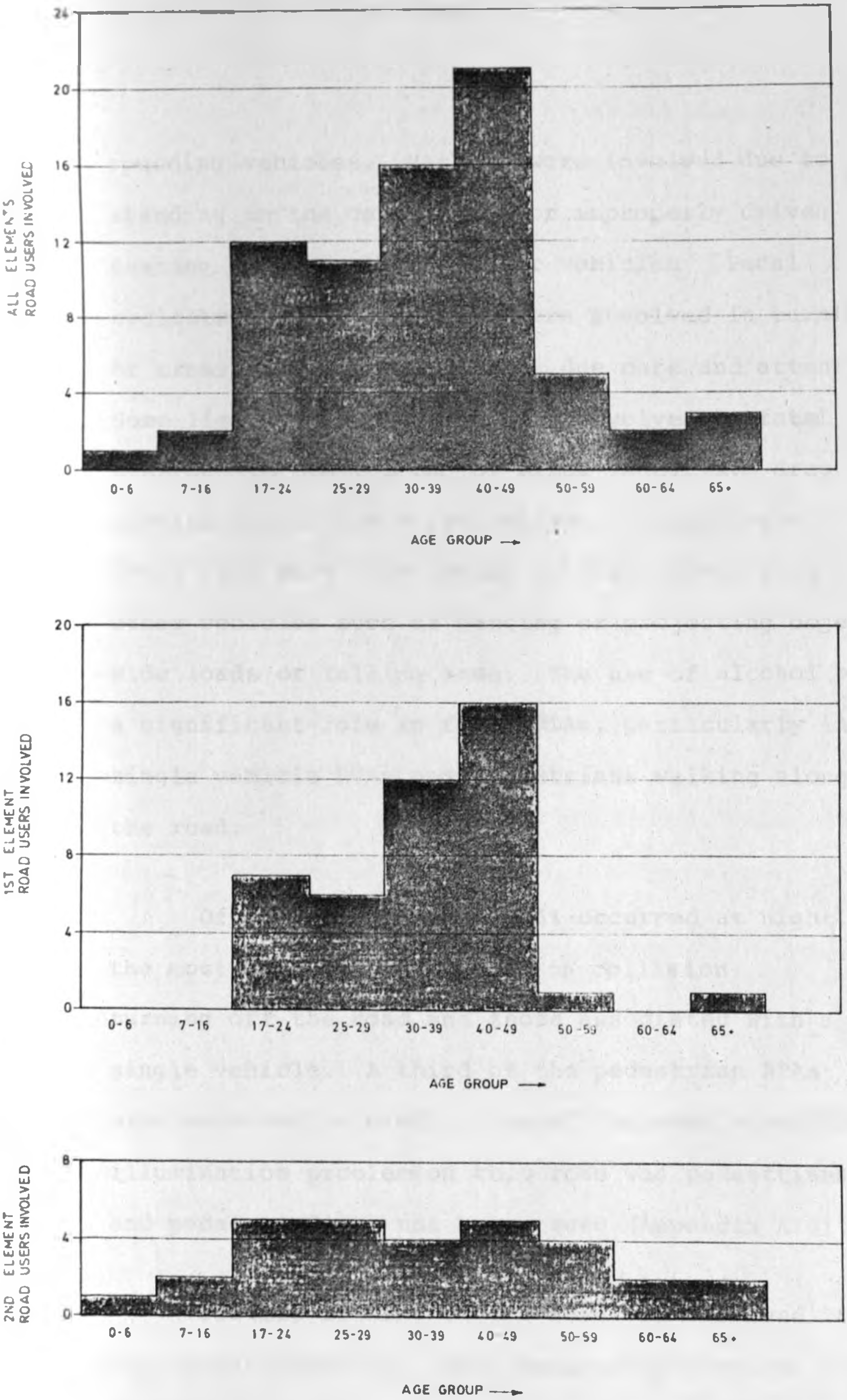


FIG4.67 KIGANJO-NANYUKI ROAD ACCIDENT INVOLVENT BY AGE GROUP

speeding vehicles. Matatus were involved due to standing in the carriageway or improperly driven causing collisions with other vehicles. Pedal cyclists and motorcyclists were involved in turning or crossing movements without due care and attention. Some light goods vehicles were involved in fatal RTAs due to overloading of miraa (addictive drug chewing plant) and miraa dealers. Significant fatal RTAs were also caused by disturbance from other vehicles such as hanging or projecting objects, wide loads or falling ones. The use of alcohol played a significant role in fatal RTAs, particularly in single vehicle RTAs and pedestrians walking along the road.

Of all RTAs studied, 26% occurred at night, the most frequent being head-on collision turning off the road and those associated with a single vehicle. A third of the pedestrian RTAs also occurred at night. One of the most significant illumination problems on this road was pedestrians and pedal cyclists not being seen (Appendix A.9).

Traffic signing on the road was observed to be very unsatisfactory. Many dangerous locations had no warning signs. The few signs observed on the road were rusty and a majority of them non-standard.

Other factors associated with RTA causation were animals and trees on the roadside. RTAs involving cattle and sheep occurred when they crossed the road from nearby bushes. RTAs involving wild animals occurred mainly at night and involved crossing. Along the Nanyuki end of the road some fatal and serious RTAs occurred in connection with vehicles hitting trees along the road.

Age and sex were used as social indicators of those responsible for RTAs. Of all the drivers, pedestrians, pedal and motorcyclists involved 87.1% were found to be male (Appendix A.10). The females were 4.3%, undetermined road users were 6.7% and animals had a 1.8% share. The age distribution data (Fig.4.67) revealed that the most affected ages lie in the group 17-49. This was true particularly of all road users and those primary elements in RTAs causation.

The geometric elements on the single carriageway did not feature directly as causative factors. They modified RTAs whose main causation lay in other factors. It was observed however, that the road had many junctions and accesses which influenced RTA occurrence directly. Pavement conditions were also observed to have caused RTAs directly for example potholes, damaged sections and repair works. The overall assessment of the RTA situation left as independent variables to be studied

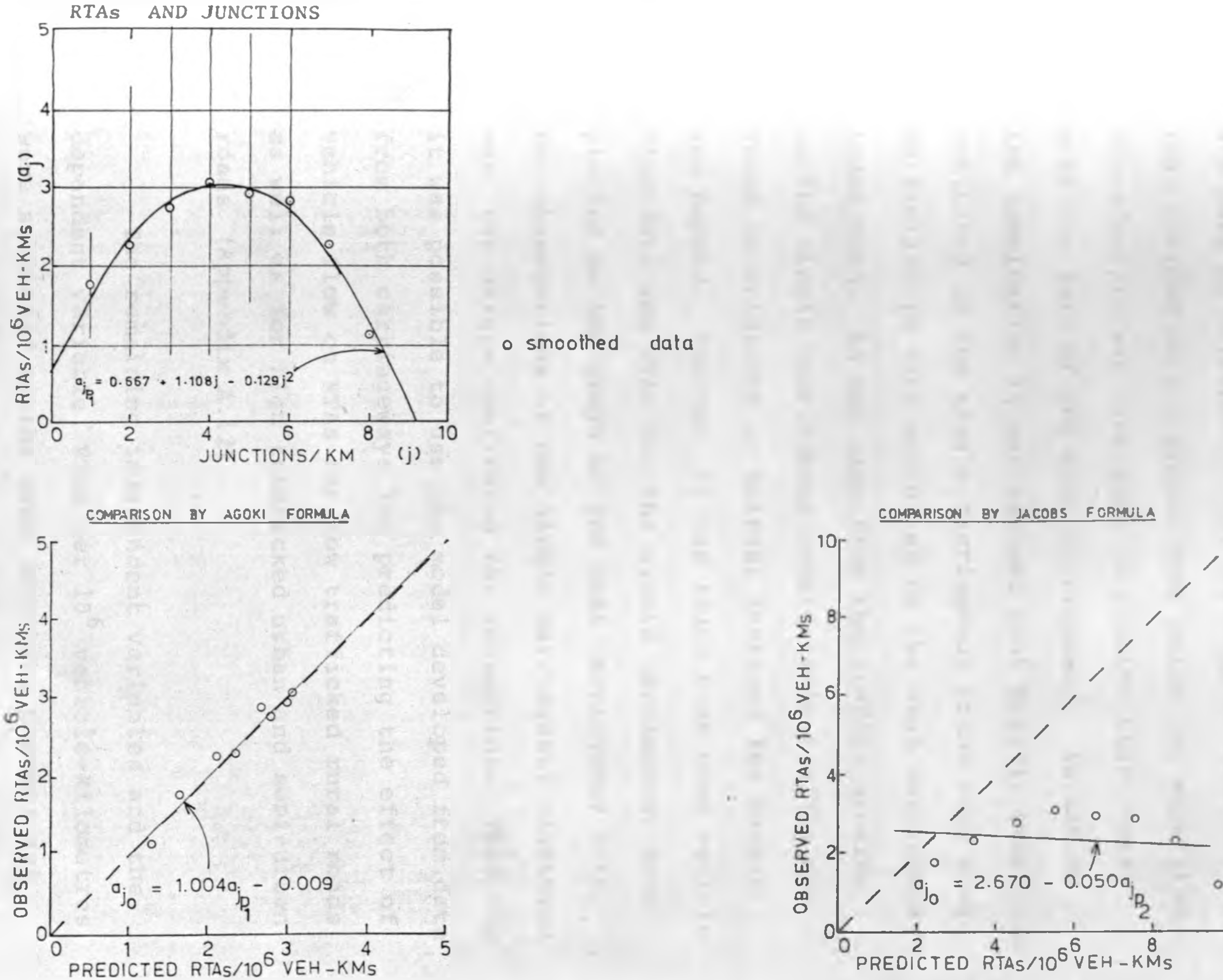


FIG.4.68 RELATION BETWEEN RTAs/10^{6}VEH-KMs AND JUNCTIONS/KM: KIGANJO-NANYUKI ROAD

as junctions, pavement condition, vehicle flow and time of day. As earlier noted, the smoothing of RTA data in relation to the low vehicle flow on this road yielded only a single data point for modelling. Therefore it was necessary to combine these data with the data of the dual carriageway. In making the combination it was assumed that traffic behaviour exhibited on the single carriageway trunk road would be similar to that exhibited on the dual carriageway trunk road. In any case from the traffic studies on the single carriageway considerable traffic was found to originate in Nairobi destined for Nanyuki and beyond. Further, it was found that when vehicle flow data and RTAs for the single carriageway were plotted on the graph of the dual carriageway data, the observations of the single carriageway clustered near the origin confirming the assumption. This way it was possible to use the model developed from data from both carriageways for predicting the effect of vehicle flow on RTAs for low trafficked rural roads as well as for high trafficked urban and semi-urban roads (Appendix A.12).

The remaining independent variables and the dependent variable RTAs per 10^6 vehicle-kilometres were subjected to the same smoothing process as outlined earlier and plots made. The suggested curve shapes were then fitted by the modelling techniques outlined in Chapter 3.

Junctions

For junctions per kilometre and their effect on RTAs (Fig.4.68) the model developed was a polynomial of second degree given by the equation

$$(a_j)_p = 0.6668 + 1.1082j - 0.1288j^2 \qquad (4.75)$$

$$1 < j < 8$$

where, $(a_j)_p$ is the predicted number of RTAs per 10^6 vehicle-kilometres for j junctions per kilometre. Observed data $(a_j)_o$ compared with predicted data yielded the equation

$$(a_j)_o = 1.004(a_j)_p - 0.009$$

with $r = 0.98$, $r^2 = 0.96$ and standard error of 0.642. The relationship was found to be significant at 5 per cent level.

Pavement Defects

The pavement defects were observed under the following: rutting; crazing and cracking; potholes, patches, depressions and upheavals; edge spalling. After data smoothing each separate plot the data

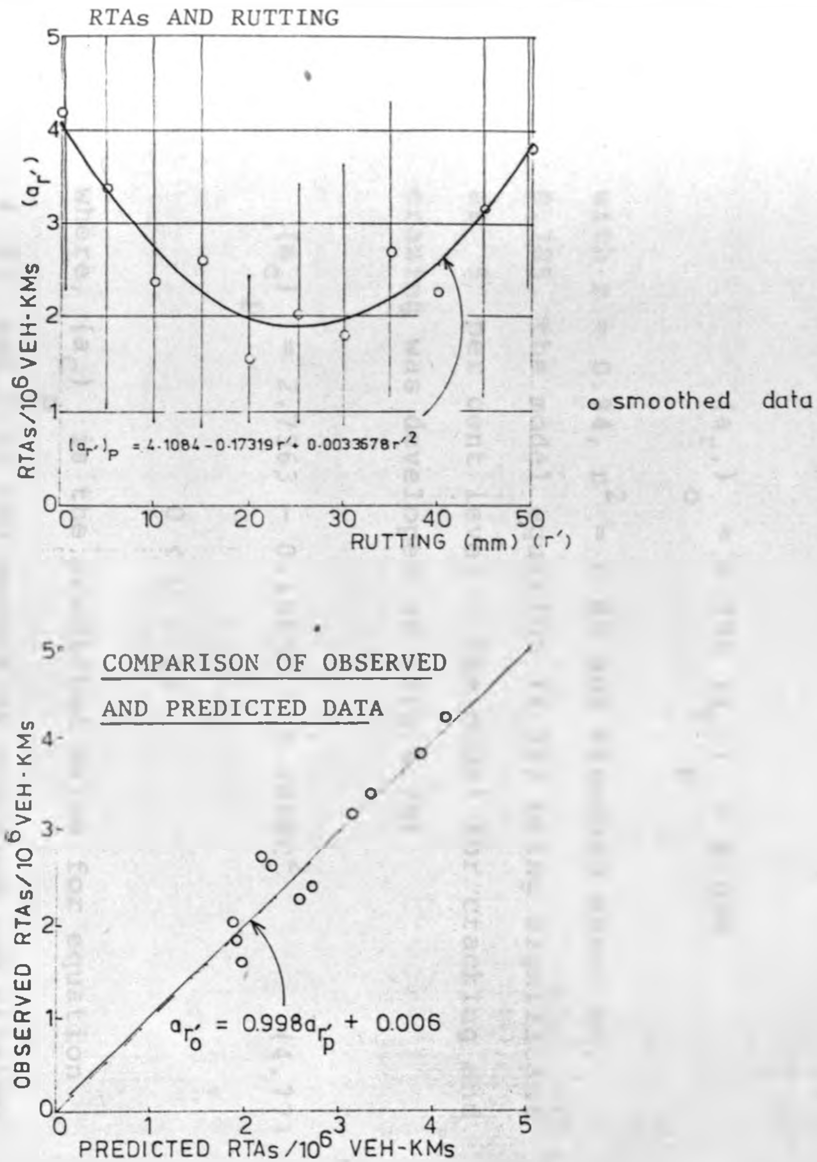


FIG. 4.69 RELATION BETWEEN RTAs/10^6 VEH-KMs AND RUTTING

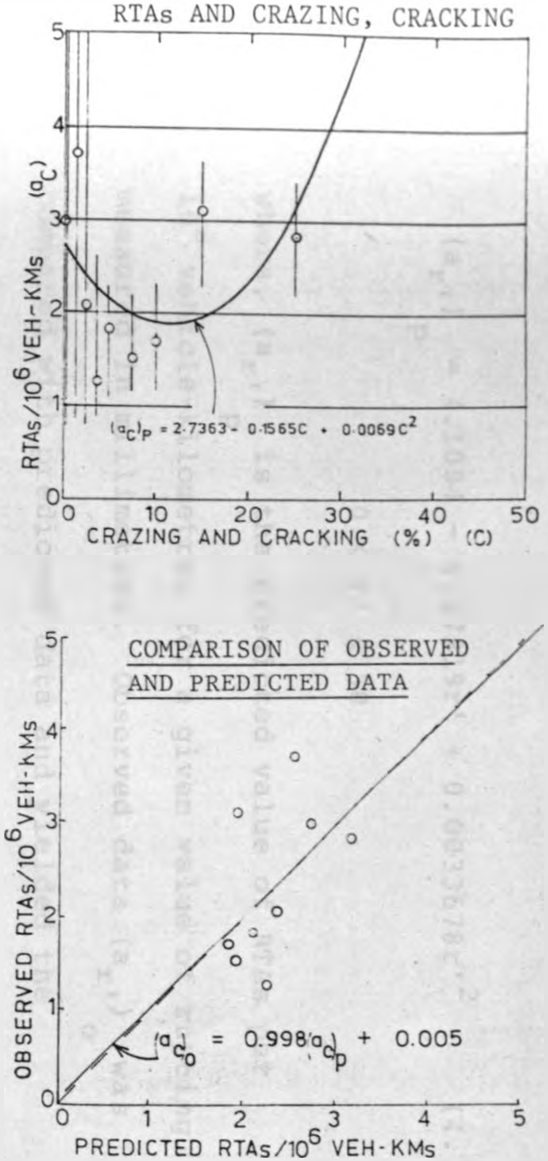


FIG. 4.70 RELATION BETWEEN RTAs/10^6 VEH-KMs AND CRAZING, CRACKING: KIGANJO - NANYUKI ROAD

fitted a quadratic function as before. For rutting the model developed was represented by the equation (Fig.4.69)

$$(a_{r'})_p = 4.1084 - 0.17319r' + 0.0033678r'^2 \qquad (4.76)$$

$$0 < r' < 50$$

where, $(a_{r'})_p$ is the predicted value of RTAs per 10^6 vehicle-kilometres for a given value of rutting measured in millimetres. Observed data $(a_{r'})_o$ was compared with predicted data and yielded the equation

$$(a_{r'})_o = 0.998\ (a_{r'})_p + 0.006$$

with $r = 0.94$, $r^2 = 0.88$ and standard error of 0.785, the model equation (4.76) being significant at 5 per cent level. The model for cracking and crazing was developed as (Fig.4.70)

$$(a_c)_p = 2.7363 - 0.1565C + 0.0069C^2 \qquad (4.77)$$

$$0 < C < 25$$

where, $(a_C)_p$ is the predicted value for equation 4.77 and C is the amount of cracking and crazing (%) in the section of road. Comparing observed data $(a_c)_o$ and predicted data gave

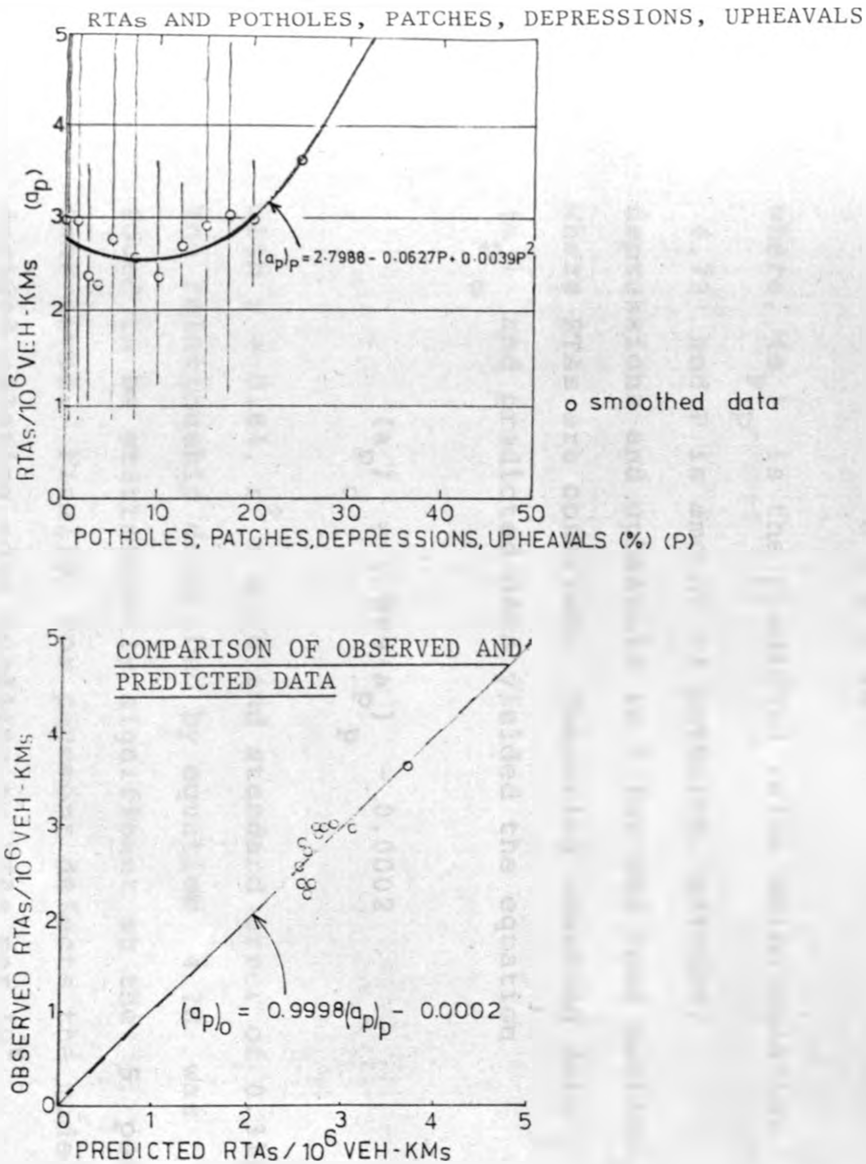


FIG 4.71 RELATION BETWEEN RTAs/10^6 VEH-KMs AND POTHOLES, PATCHES, DEPRESSIONS, UPHEAVALS KIGANJO - NANYUKI ROAD

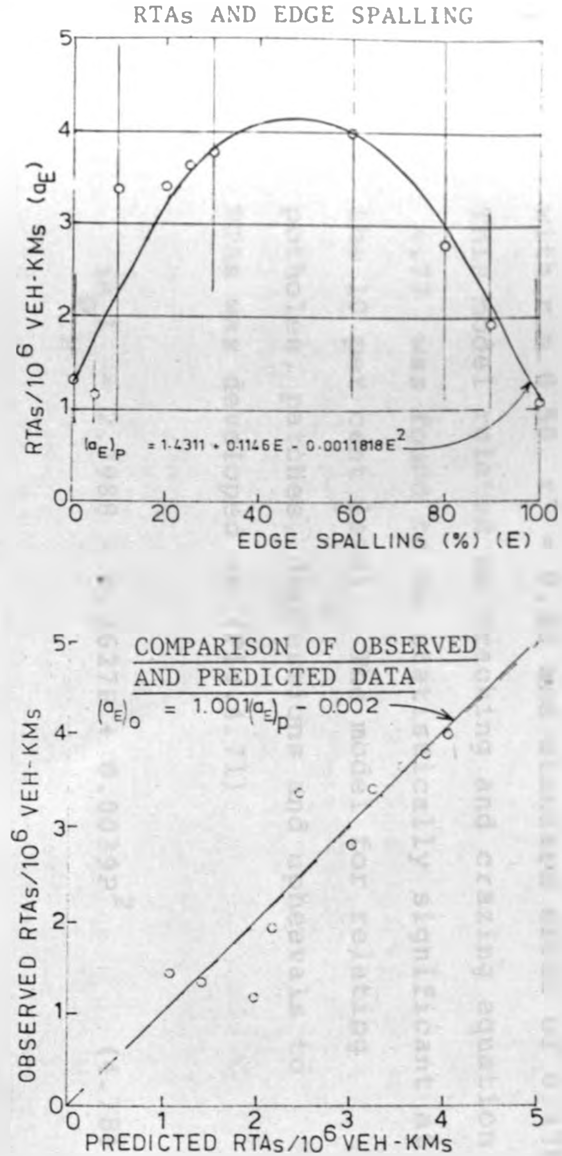


FIG. 4.72 RELATION BETWEEN RTAs/10^6 VEH-KMs AND EDGE SPALLING, KIGANJO - NANYUKI ROAD

$$(a_c)_o = 0.998\ (a_c)_p + 0.005$$

with r = 0.50, r^2 = 0.25 and standard error of 0.428. This model related to cracking and crazing equation 4.77 was found to be statistically significant at the 10 per cent level. The model for relating potholes, patches, depressions and upheavals to RTAs was developed as (Fig.4.71)

$$(a_p)_p = 2.7988 - 0.0627P + 0.0039P^2 \qquad (4.78)$$

$$0 < P < 25$$

where, $(a_p)_p$ is the predicted value using equation 4.78 and P is amount of potholes, patches, depressions and upheavals in % for the road section where RTAs are observed. Comparing observed data $(a_p)_o$ and predicted data yielded the equation

$$(a_p)_o = 0.999(a_p)_p - 0.0002$$

with r = 0.84, r^2 = 0.70 and standard error of 0.318. The relationship described by equation 4.78 was found to be statistically significant at the 5 per cent level. Finally, for pavement defects the model derived relating edge spalling to RTAs per 10^6 vehicle-kilometres is given by the equation (Fig.4.72)

$$(a_E)_p = 1.4311 + 0.1146E - 0.0011818E^2 \qquad (4.79)$$

$$0 < E < 100$$

where $(A_E)_p$ is the predicted number of RTAs per 10^6 vehicle-kilometres at a given per cent of edge spalling (E) in a road section. Observed and predicted data yielded the equation

$$(a_E)_o = 1.001(a_E)_p - 0.002$$

with $r = 0.92$, $r^2 = 0.84$, standard error of 1.018 where, $(a_E)_o$ is observed data. The relationship described by equation 4.79 was found to be significant at the 5 per cent level.

RTAs per Hour

For the prediction of mean RTAs per 10^6 vehicle-kilometres at a given time of the day, the data for the single carriageway were treated in the same manner as for the dual carriageway. Using harmonic analysis as before models were developed for unsmoothed as well as smoothed data. For the unsmoothed data (Fig.4.73) the model was developed as

$$({}^{a}/K)_{p_3} = 0.803 - 0.832 \cos t + 0.357 \cos 2t - 0.327 \cos 3t - 0.309 \sin t - 0.103 \sin 2t \qquad \ldots (4.80)$$

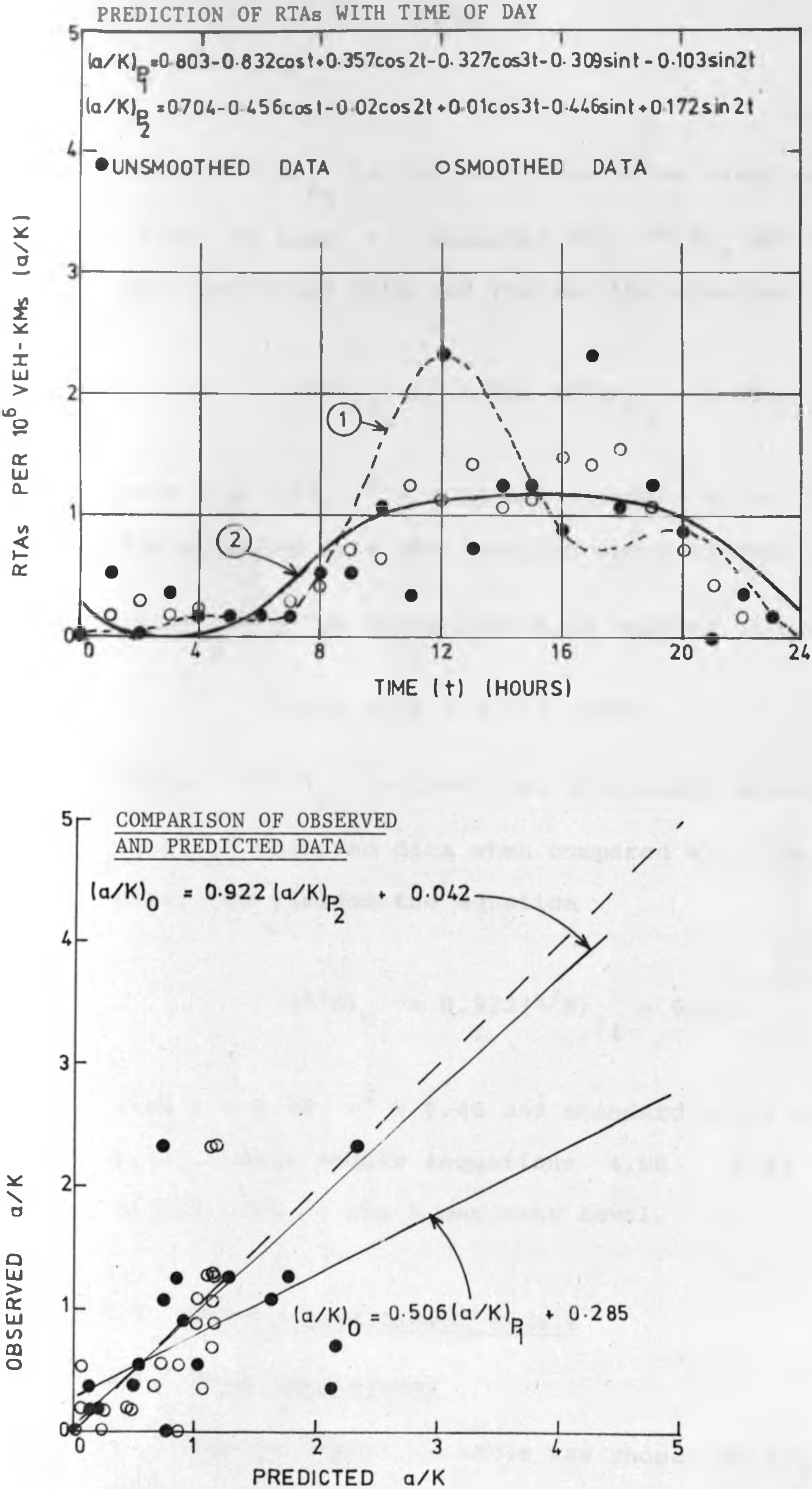


FIG.4.73 PREDICTION OF MEAN RTAs/10^6 VEH-KMs KIGANJO-NANYUKI ROAD

where, $(^{a}/K)_{p_3}$ is the predicted value using equation 4.80 at time t. Observed data $(^{a}/K)_{o}$ was compared with predicted data and yielded the equation

$$(^{a}/K)_{o} = 0.506\ (^{a}/K)_{p_3} + 0.285$$

with $r = 0.57$, $r^2 = 0.33$ and standard error of 0.734. For smoothed data the equation was developed as

$$(^{a}/K)_{p_4} = 0.704\ 0.456\ \cos t - 0.02\ \cos 2t + 0.01\ \cos 3t$$
$$-0.446\ \sin t + 0.172\ \sin 2t \qquad .. (4.81)$$

where, $(^{a}/K)_{p_4}$ is predicted data using equation 4.81. Observed data when compared with the predicted yielded the equation

$$(^{a}/K)_{o} = 0.922 (^{a}/K)_{p_4} + 0.042$$

with $r = 0.68$, $r^2 = 0.46$ and standard error of 0.477. Both models (equations 4.80, 4.81 were significant at the 5 per cent level.

4.3. Generalised Linear Models

4.3.1 Dual Carriageway

The dependent variable was chosen as the number of RTAs that had occurred on a given section

of the carriageway during the study period. The independent variables chosen included the average daily traffic, vehicles per hour, the percentage of lorries and buses, junctions per kilometre, horizontal curve radius, superelevation, longitudinal gradient and sight distance. These data were observed and recorded for each section length (in metres) of road studied (Appendix A.15). The horizontal curve radius was classified into 3 classes as follows:
0-800m, 800-3200m and >3200m.

Two models were developed. The first model related to those sections under curves and the second model related to straight sections. Using the generalised linear modelling techniques outlined in 3.6 and the computer program GLIM it was found that the variables which were reasonably related to RTAs were vehicle-kilometres (exposure), junctions, lorries and buses, horizontal curve radius and superelevation. The estimated values for fitting the model equation 3.74 for the first model are tabulated in Table 4.1. The estimated values were obtained at cycle 4.

The parameters are interpreted for equation 3.74

$$A = e^k K^b e^{(\Sigma a_1 x_1)}$$

TABLE 4.1 MODEL 1 for DUAL CARRIAGEWAY

Estimate	s.e.	Parameter
-0.09198	0.4942	k
0.7248	0.07462	b
0.0849	0.02295	JPK
0.01904	0.006628	LAB
-0.7595	0.5382	FCR(2)
-0.2860	0.4984	FCR(3)
-0.1692	0.1371	FCR(1).SUE
-0.01629	0.08199	FCR(2).SUE
-0.2639	0.09962	FCR(3).SUE

as follows:

k is the constant,

b is the power of K,

JPK is the coefficient of the junction effect,

LAB is the coefficient of the effect of lorries and buses,

FCR(2) is the coefficient of the effect of horizontal radius (800-3200m),

FCR(3) is the coefficient of the effect of horizontal radius (>3200m),

FCR(1).SUE is the coefficient of the effect of the interaction of horizontal radius (0-800m) and superelevation, FCR(2).SUE is the coefficient of the effect of horizontal radius (800-3200m) and superelevation and

FCR(3).SUE is the coefficient of the effect of horizontal radius(>3200m) and superelevation.

For FCR(1), the bottom level of the horizontal radius (0-800m), the effect is included in the constant term (e^k). Therefore, the model may be stated as

$$A_1 = e^{-0.09198} K^{0.7248} e^{(\Sigma a_i x_i)} \qquad (4.82)$$

where the coefficients a_i and the independent variables x_i are chosen from table 4.1, noting that A_1 is the predicted number of RTAs for the period under study and K is the travel in vehicle-kilometres during the corresponding period. For this model S.D./d.f. was found to be 1.81.

The parameters of the second model for the dual carriageway are tabulated in Table 4.2.

TABLE 4.2 MODEL 2 FOR DUAL CARRIAGEWAY

Estimate	s.e.	Parameter
-0.6274	0.2716	k
0.7532	0.07081	b
0.07437	0.02435	JPK
0.02132	0.006333	LAB
67.36	31.50	AR
-0.1213	0.04734	SUE

The parameters are interpreted as before and AR is the reciprocal of the horizontal radius which is equal to zero for a straight road section. Therefore, the second model may be stated as

$$A_2 = e^{-0.6274} K^{0.7532} e^{(\Sigma a_i x_i)} \qquad (4.83)$$

where A_2 is the predicted number of RTAs for straight sections for the period under study. The remaining terms are as before and the coefficients a_i and independent variables x_i are chosen from Table 4.2. For this second model S.D./d.f was found to be 1.79.

4.3.2 Single Carriageway

The dependent variable was chosen as the number of RTAs that had occurred on a given section of the carriageway during the study period. The independent variables chosen were average daily traffic, vehicles per hour, the percentage of lorries and buses, junctions per kilometre, horizontal curve radius, edge spalling, crazing and cracking, potholes and rutting. These data were observed and recorded for each 500m section (Appendix A.16). The horizontal curve radius was classified as <799m, 800-3099m, >3100m. Edge spalling was classified as <29%, 30%-60%, >60%. Crazing and cracking was classified as <5%, 5%-10%, >10%. Lorries and buses were classified as <28%, >28%. Junctions were classified as <3 junctions, 3-7 junctions, >7 junctions. Using the techniques outlined in 3.6 the most suitable model was developed whose parameters are tabulated in Table 4.3.

TABLE 4.3 MODEL FOR SINGLE CARRIAGEWAY

Estimate	s.e	Parameter
-0.1617	0.4770	k
1.138	0.6950	b
0.8154	0.2300	FJ(2)
0.3817	0.4030	FJ(3)
-0.7622	0.2874	FLB(2)
0.6893	0.2863	FCC(2)
0.6791	0.3569	FCC(3)
0.9192	0.3696	FED(2)
0.4871	0.4167	FED(3)
-0.6669	0.3796	FCR(2)
-0.5413	0.3470	FCR(3)

For the single carriageway equation 3.74 therefore becomes the predictive model

$$A_3 = e^{-0.1617} \; K^{1.138} \; e^{(\Sigma a_i x_i)} \qquad (4.84)$$

where A_3 is the predicted RTAs on the single carriageway for the period under study, K is the travel in vehicle-kilometres, the coefficients a_i and the independent variables x_i are chosen from Table 4.3. The effects of the bottom classes are included in the constant term. The independent variables that were found to be reasonably related to RTAs (Table 4.3) were:

FJ(2): 3-7 junctions per kilometre,

FJ(3): >7 junctions per kilometre,

FLB(2): <28% lorries and buses,

FLB(3): >28% lorries and buses,

FCC(2): 5%-10% cracking and crazing,

FCC(3): >10% cracking and crazing,

FED(2): 30%-60% edge spalling,

FED(3): >60% edge spalling,

FCR(2): 800-3099m horizontal curve radius,

FCR(3): >3100m horizontal curve radius.

Equation 4.84 was found to have S.D/d.f of 1.42.

4.4 Data Appraisal

At the national level it was found that the collection of some of the data began only in 1960 and 1973. This had a definite effect on the calibration of the models developed in this study.

Further there were other extrenous factors that led to flactuations in RTA trends. These, among others were the emergency in the early 1950s during the struggle for independence, independence and the ensuing socio-economic and political development in the 1960s and onward, the matatu legislation of 1973, the oil crisis of the early 1970s, the subsequent coffee boom of the middle and late 1970s, the ban on vehicle importation of the early 1980s and the subsequent ban on night driving by heavy vehicles. Modulating the above was the road safety improvement measures started in the early 1980s to date. Nonetheless, the data available were of good quality and acceptable.

At the micro level on the roads, the location of RTA spots during coding was affected by missing files or files pending in court, stored away or destroyed at the expiry of certain periods of time. Nonetheless, these difficulties and the inadequacy of information contained in the Police Form P41 were solved by the assistance of the local police officers. It is generally believed that there is under-reporting of RTAs in Kenya and elsewhere. Further, it is not mandatory to report to the police RTAs involving property damage only (the practice of reporting stopped in 1973 in Kenya). Despite these shortcomings the data is considered and has been shown to be of good quality or at least reasonable in deriving RTA patterns in

CHAPTER 5 - DISCUSSION

5.1 Road Traffic Prediction

Firstly, from the models 4.1, 4.2 on human population growth in Kenya, it was found that human population is increasing rapidly. The prediction models obtained in this study were found to be a good fit for Kenyan data since the slope of observed versus the predicted regression line was almost ideal (i.e. unity) and the intercept nearly zero.

Due to rapid population increase, a high temple of socio-economic development and increased travel, road traffic is likely to increase rapidly. The annual rate of population increase was found to be 3.8%- 4.2%. The high variant growth by United Nation is an over-prediction.

On the assumption that past trends can be used to predict future motor vehicle levels, assuming the trends to continue into the future, it was found that road vehicles are increasing at an annual rate of 6.5%. The predictive models 4.3, 4.4 developed for the data analysed were found to be a good fit judging from the slope and the intercept (Fig.4.3). The prediction was equally consistent as shown by the correlation coefficient. It is worth noting that despite using two different limits for the number of motor vehicles, the results of the two predictions agree closely.

The level of motorization was found to be increasing at an annual rate of 2.8%. The predictive model 4.5 was found to be of good fitness, consistency and calibration (Fig.4.4).

The increase in motor vehicles involved in RTAs was found to be 3.6% per annum which is growing approximately as Kenya's human population increase. The predictive model 4.6 fitted observed data well. The logistic curve was found to be suited in predicting data related to population, vehicle fleet and motorization.

The predictive model for the growth in the composition of cars and utilities was (4.7) found to be the best compared to the ones for buses/lorries/taxis and the one for motorcycles. The model for cars and utilities was nearest to the ideal line (Fig.4.35) and was very consistent (r = 0.91). The slope for the model for buses/lorries/taxis was greater than 1 (1.158). Although this may be considered acceptable the data had very considerable scatter (r = 0.38). The slope for the model for motorcycles was found to be acceptable (1.123) and the scatter (r = 0.63) much better than that for buses/lorries/taxis. The standard error of the model for cars and utilities was greater however, than for the other two classes. The logarithmic curve was found to be the growth curve suited to describe growth in vehicle composition.

In this study it has been demonstrated that harmonic analysis techniques can be used to predict average vehicle flow per hour at a given time of the day, even with traffic counts taken at 4 hourly intervals (six-ordinate scheme). In fact, for lower accuracy predictions no data smoothing is necessary as the standard errors remain virtually the same. Data smoothing considerably improves the calibration of the model. On the dual carriageway both the smoothed and unsmoothed data models 4.10, 4.11 were found to be of good fitness judging by their slopes and intercept (Fig.4.7). They were also consistent, with r=0.93 and 0.91 respectively. The standard errors were large and this may be due to the fact that a lower number of ordinate scheme was used as well as the variations in traffic with time. A lower number ordinate scheme will skip some data points which have high variation leading to over/under estimation. Therefore, using a 12 or 24 ordinate scheme is likely to improve the model. The models 4.12, 4.13 developed for predicting traffic on a low trafficked single carriageway were found to be of very good fit as the slope was very nearly ideal (Fig.4.9). The prediction was very consistent (r = 0.94) for both models and the standard errors were equal. The models for unsmoothed and smoothed data made almost identical predictions because traffic variation on the single carriageway was low. This implies, therefore, that the interval could be increased from 4 hourly for the traffic counts, as long as some points around the peak flow are observed, and still get good predictions.

All the models discussed above were found to be significant at the 5 per cent level which is the level of statistical significance usually accepted.

5.2 National Road Traffic Accidents Prediction

In this study it was found that injury RTAs are increasing with time at the rate of 3.7% per annum. This is growing at the same rate as that of vehicles involved in RTAs.
The logistic curve

$$A_{p_1} = \frac{8049}{1 + 1.984\ e^{-0.137t}}$$

was found to be a good fit for the data observed. Although the slope of the regression curve was good (0.946) the intercept did not pass through zero (Fig.4.10). This suggests that the model could be improved by calibration. This is likely to have happended because these data, unlike other RTA data that were collected since 1949,were first recorded in 1960. It is likely that earlier data included also non-injury RTAs. However, the prediction was consistent (r=0.91). The standard error was large (1394). The significance level was found to be 5 per cent. The model may be improved in calibration by data improvement as well as choice of limit. In relation to motorization, injury RTAs were found to increase slowly in the initial stages of motorization, rising sharply, levelling off and falling. The model was found to be the cubic polynomial (4.15)

$$A_{P_2} = 6.6981\times10^{-8}(V/P)-0.82263376(V/P)^2$$

$$+ 270.438684V/P-15342.4929.$$

The slope for the prediction line for this model was acceptable (1.135) and the consistency good (r=0.92) (Fig.4.11). The standard error was large (1259) and the level of significance was found to be 10 per cent. This was considered acceptable. Data smoothing by moving averages as before improved the shape of the function curve. Although the curve shows that RTAs will be zero at a level of motorization between 250 and 260 vehicles per 10^4 persons this is not likely to be the case. What is more likely to be the case is that as the effects of rapid motorization balance out with those of road safety improvements the curve will stabilize at some level in future.

Injury RTAs per vehicle were found to be decreasing with motorization increase and the relationship described by a cubic polynomial (4.16)

$$(A/V)_p = 0.656x10^{12}(V/P)^3 - 0.00000484(V/P)^2$$

$$+ 0.001059V/P - 0.0183.$$

The calibration of the predictive model was almost ideal with slope equal to 1.246 and intercept -0.009 (Fig.4.12). The prediction was consistent although there was some scatter (r=0.8). The standard error was small (0.0034) and with the level of significance of 5 per cent. The data were of good quality and data smoothing improved the shape of the curve. However, as earlier mentioned injury RTA data were limited to the period 1960-83 which was a shortcoming for long-term prediction purposes.

It was found that injury RTAs per 10^6 vehicle-kilometres were decreasing at an annual rate of 1.6% with time. Therefore, as travel increases and therefore exposure to risk increases and RTAs per vehicle decrease this trend is likely. The logistic model was found to fit these data with slope of prediction line of 0.89, intercept of 0.168 and some scatter (r = 0.82). The standard error was small (0.195). To improve the prediction a model relating this variable with motorization was developed (4.18)

$$(A/K)_{P_2} = 0.2728\text{x}10^{-10}(V/P)^3 - 0.00019613(V/P)^2 + 0.042285(V/P) - 0.6774$$

which had a better slope (0.956), a smaller intercept (0.082) and standard error smaller (0.146). The scatter however, was more considerable (r=0.76) but both models, were significant at 5 per cent. Therefore, the cubic polynomial function can predict injury RTAs per vehicle-kilometre as a function of motorization. The data smoothing could be improved by removing the cyclic variation observed through decomposition of the series.

In this study the analysis showed that casualties from RTAs can be predicted by the logistic model (4.19)

$$C_{P_1} = \frac{14749}{1 + 3.772\, e^{-0.137t}}.$$

Casualties were found to be increasing with time at the rate of 5.6% per annum. The prediction was very near the ideal since the slope was 1.014 and the intercept of 204 was small compared to the standard error of 3137 which is somewhat large. However, the consistency of prediction was good as there was small scatter (r=0.93). The cubic polynomial prediction model 4.20 improved the prediction (slope = 1.09) but the intercept dropped) (-733). Whilst the consistency remained the same (r=0.93) the standard error dropped (2690). Therefore, with the significance level for both models of 5 per cent, the models were considered acceptable. The logistic model could be improved by improving the limit and extending the data. The data recording on casualties like that of injury RTAs begins in 1960. The calibration therefore can be improved.

Casualties per RTA were found to be increasing at the rate of 1.9% per annum (similar to that of casualties per 10^4 vehicles).

The prediction was near the ideal (1.219) but the intercept was not near zero (-0.304) (Fig.4.15). The calibration could be improved through revision of limit and data extension and smoothing. The scatter was acceptable (r=0.87). The standard error was small (0.159) and the model significant at 5 per cent level. Considering the limitation in data the model was acceptable. This result confirms that found by Jacobs and Hutchinson [1] for Kenya (an increase of 60% between 1961-1971).

It was found that casualties per RTA decrease with increase in motorization. The cubic polynomial model (4.22)

$$(C/A)_{P_2} = 0.11831 \times 10^{-10} (V/P)^3 - 0.00015 (V/P)^2 + 0.04492 V/P - 1.7667$$

fitted the data with reasonable accuracy. Although the calibration of the model could be improved, the predicted data was scattered around the ideal line (slope = 1.355, intercept = -0.488) (Fig.4.16). The consistency was fair (r=0.84) and the standard error small (0.146). Again, as observed earlier the curve is not likely to decrease to zero but rather it is likely to stabilize at some point in the future. The relationship described by the model was found to be significant at 5 per cent level. Therefore, the predictive model is acceptable.

This study showed that casualties per 10^4 vehicles is increasing at the rate of 1.7% per annum (Fig.4.17) (Similar to casualties per RTA). After data smoothing variation were still afflicting the shape of the curve. The logistic curve (4.23) was much flatter. The predicted data werescattered around the ideal curve with slope = 0.713 and intercept of 145. The calibration could be improved by removal of the variations and revision of limit. The scatter was considerable (r = 0.52) but the standard error small considering the variation in the series

(72.47). The model was found to be significant at the 5 per cent level.

It was further found that casualties per 10^4 vehicles are decreasing with increase in motorization. The cubic polynomial (4.24)

$$(C/V)_{P_2} = 8.8191\text{x}10^{-8}(V/P)^3 - 0.04464166(V/P)^2$$

$$+ 12.597057 V/P - 337.6139$$

was a good fit for this data. The prediction was near the ideal (slope = 1.022, intercept =-8.841) (Fig.4.18). Although there was scatter in the predicted data (r = 0.79) it was found that the accuracy of prediction was good. The calibration was therefore acceptable. The standard error (71.44) improved only slightly above the logistic model. The cubic model was found to be significant at 5 per cent level.

During the study it was found that data on RTA deaths can be definitely fitted by a logistic curve (4.25)

$$D_{P_1} = \frac{1720}{1 + 22.889\ e^{-0.174t}}$$

to show the trend in road deaths over time. It was further found that RTA deaths in Kenya are increasing at a high rate of 7.4% per annum nearly twice the increase in population. The predictive model was very near the ideal (slope = 0.994 and intercept = -22) (Fig.4.19). The consistency of prediction was good (r =0.97). The standard error was found to be somewhat large (553). The level of significance was found to be 5 per cent and therefore the prediction is reasonable.

It was further found that road deaths in Kenya will first increase, stabilize and then begin to decrease with motorization. The cubic polynomial (4.26)

$$D_{P_2} = 229.7235-11.960418 V/P+0.14040617 (V/P)^2 + 0.18958x10^{-6} (V/P)^3$$

was found to be a very reasonable fit for this trend. Predictions for Kenyan data were also made using Smeed's equation (2.2) [2] and the results compared in Table 5.1. The Agoki formula came nearest to the ideal (Fig.4.20) observed = predicted line. The consistency in prediction is of the same quality.

TABLE 5.1 COMPARISON OF OBSERVED AND PREDICTED RTA DEATHS IN KENYA

Formula	Units	Regression		Correlation	Determination	Standard
		Slope	Intercept	Coefficient, r	Coefficient, r^2	Error
Agoki	Deaths	1.009	-10	0.97	0.94	545
Smeed	Deaths	1.751	-459	0.96	0.93	310

Although the Smeed formula had a lower standard error, the slope and intercept suggest that the calibration could be improved. The Smeed formula over-predicts for lower rates of death and at higher rates it under-predicts. Smeed formula correctly predicts at around 500 deaths.

The study showed further, that deaths per 10^4 persons in Kenya increase slowly at first, then sharply, stabilize, and then may start to fall slowly. The cubic polynomial (4.27)

$$(D/P)_{P_1} = 1.9788 \times 1^{-10} (V/P)^3 + 0.00001494 (V/P)^2 + 0.007762 V/P - 0.4127$$

was found to be a good fit for Kenyan data. Predictions were also made on the same data using Smeed formula (2.3) [3] and Jacobs and Hutschinson formula (2.4)[1]. The comparison of the three formulae is shown on Table 5.2.

TABLE 5.2 COMPARISON OF OBSERVED AND PREDICTED RTA DEATHS PER 10^4 PERSONS

Formula	Units	Regression		Correla. Coeffi., r	Determin. Coeffi., r^2	Std. Error
		Slope	Inter.			
Agoki	D/P	0.923	0.054	0.93	0.87	0.31
Smeed	D/P	4.809	-2.545	0.91	0.83	0.06
Jacobs & Hutchinson	D/P	3.550	-1.172	0.92	0.85	0.08

Again, the Agoki formula (Fig.4.21) came nearest to the ideal observed = predicted line although it had highest standard error. All formulae have the same consistency in predicting data but the slopes and intercepts of the Smeed, Jacobs and Hutchinson formulae suggest that calibration is needed. Jacobs and Hutchinson formula predict Kenyan data correctly around D/P = 0.4 and the Smeed formula at D/P = 0.6. All models are significant at 5 per cent level.

It was further found that RTA deaths per 10^4 vehicles in Kenya rose slowly at first, rapidly and are likely to stabilize in future and drop as motorization increases. Again, the cubic polynomial function (4.28)

$$(D/V)_{p_1} = 1.4218\text{x}10^{-8}(V/P)^3 - 0.00022871(V/P)^2$$

$$+ 0.577548V/P - 5.4171$$

was found to be a good fit for the data for Kenya.

Again, the model derived in this study (Fig.4.22) was compared with those developed by Smeed (2.1) [1] and Jacobs and Hutchinson (2.5) [1]. The comparison of the three formulae is shown on Table 5.3.

TABLE 5.3 COMPARISON OF OBSERVED AND PREDICTED RTA DEATHS PER 10^4 VEHICLES

Formula	Units	Regression		Correla.	Determ.	Std
		Slope	Intercept	Coeffi.,r	Coeffi.,r^2	Error
Agoki	D/V	0.769	13	0.77	0.59	15
Smeed	D/V	-0.876	111	-0.70	0.49	12
Jacobs & Hutchinson	D/V	-2.013	151	-0.72	0.51	5

Again, the Agoki formula came nearest to the ideal prediction line. The Agoki and Smeed formulae had the same order of standard error and Jacobs and Hutchinson had the smallest standard error. The slopes and intercepts of the Smeed, Jacobs and Hutchinson formulae suggest strongly a need for their calibration. The Agoki formula could be improved in calibration particularly with improved data reporting and keeping for both road deaths and vehicle fleet and of course more accurate population census and prediction (although this is not critical considering the trend prediction for population discussed earlier). All models were statistically significant at the 5 per cent level.

With respect to deaths per 10^6 vehicle-kilometres the analysis revealed an increasing trend with time at the rate of 1.8% per annum, a rate similar to that shown by casualties per RTA. The data was fitted using the logistic curve model 4.29 and the prediction proved consistent although there was some scatter (r=0.84). The prediction was near the ideal line (slope = 0.864, intercept = 0.032) (Fig.4.23). The standard error was small (0.060) and with a significance level of 5 per cent the prediction is reasonable. Despite data smoothing the curve was still afflicted with flactuations. This difficulty may be overcome if data were available for decomposition of this time series. With further data smoothing calibration might be improved.

As seen in earlier trends, deaths per 10^6 vehicle-kilometres has risen slowly at the start, sharply then stabilized before beginning to drop. On a long term basis this trend is to continue. A cubic polynomial (4.30) fitted the curve with a somewhat poorer fit than the logistic curve. Although the data were predicted around the ideal line the slope was only 0.763. The intercept was good (0.053) (Fig.4.24) and comparable to the previous model. The standard error was equally small (0.059). The calibration could be improved by more accurate data on vehicle-kilometres. The amount of travel is somewhat difficult to observe or predict with great accuracy. The model was nonetheless, significant at the 5 per cent level. This model is reasonable for prediction.

RTA injuries were found to be increasing with time at the rate of 5.8% per annum. This is about the same rate as for the increase in casualties. This would

imply that they are of a greater influence in the growth of casualties than do deaths. The trend was fitted by the logistic curve (4.31) for predicting the trend in the growth of injuries. The prediction was found to be nearly ideal (slope = 1.045, intercept = -171) (Fig.4.25). The prediction was consistent (r = 0.97) but the standard error large (3430). The cubic polynomial (4.32)

$$I_{P_2} = 1.2305\text{x}10^{-6}(V/P)^3 + 0.25629308(V/P)^2$$

$$+ 60.580992 V/P - 4849.778$$

predicted the data satisfactorily and indicated that injuries have tended to increase with motorization. The prediction was still near the ideal line with slope = 0.961 but the intercept nearly trebled shifting to 344. The prediction remained consistent (r = 0.94) and the standard error dropped somewhat (3144). Data smoothing is likely to improve the calibration of the model. Both models were found to be significant at 5 per cent level and accordingly were accepted as predicting the number of injuries from RTAs.

With respect to injuries per 10^4 persons it was found that the trend was an increasing one with time at the rate of 5.2% per annum. The prediction model (4.33) found to predict this trend was the logistic curve. The prediction was very nearly ideal (slope=1.047 intercept = -0.149) (Fig.4.26). The prediction was consistent (r = 0.91) and the standard error small. With a significance level of 5 per cent, this prediction model was accepted. The data after smoothing was found to be still with variations which would imply a need for further smoothing to improve the calibration of the model. The reporting of injury data is likely to have affected the shape of the curve. A polynomial function (4.34) of the third degree was found to fit the same data in relation to motorization. It was found that injuries per 10^4 persons increases slowly initially, rapidly next then stabilizes before starting to fall as motorization increases. The prediction was near ideal (slope = 0.885, intercept = 0.764) (Fig.4.27). The consistency was fair (r = 0.87) and the standard error small (1.742). The two models were significant at 5 per cent level. The polynomial model had a better curve shape meaning that the data smoothing was very effective.

Injuries per 10^4 vehicles was found to grow at a rate of 1.8% per annum. It was observed that the smooth data curve (4.35) was flatter than some of the earlier curves. This implies that injuries per 10^4 vehicles are stabilizing with time as borne out by the growth rate and the fact that the predictions were scattered around the centre of the prediction line. The prediction was found to be fairly close to the ideal line (slope = 0.734, intercept = 117) (Fig.4.28). The prediction was not very consistent as the scatter was very considerable (r = 0.44). The standard error was not large considering the scatter. The model was statistically significant at 5 per cent level. The slope, the intercept and the scatter suggest that the model could be improved. This might be done by further data smoothing and the revision of the limit. The variation in injuries per 10^4 vehicles was found to fit the cubic polynomial function (4.36) with motorization as the independent variable. It was further found that even for Kenya as motorization increases injuries per 10^4 vehicles decreases, a finding which is at variance with the earlier finding by Jacobs and Hutchinson [1]. Their finding was based on data limited to only 10 years (1961-71). Therefore, it is to be noted that for both national and international comparisons long term trends based on records kept for a considerable period are more reliable for studying RTA patterns of different countries . The predictive model was nearly ideal (slope = 1.103, intercept = -55) (Fig.4.29). The standard error of 56 was comparable to that obtained for the logistic model, for this phenomenon, above. The model was significant at 5 per cent level. This model is quite suited for prediction and therefore acceptable.

In this study it was further found that injuries per 10^6 vehicle-kilometres are increasing with time at the rate of 2.4% per annum. Further, that the trend can be described by the logistic curve (4.37). The prediction was close to ideal (slope = 0.924, intercept = 0.084) (Fig.4.30). However, the scatter was considerable (r = 0.69). The standard error was small (0.239). It was further found that as motorization increases injuries per 10^6 vehicle-kilometres decrease the trend was described by the cubic polynomial function (4.38). The prediction was very nearly ideal (slope = 1.02, intercept = -0.052) (Fig.4.31). The scatter of r = 0.77 showed that the prediction was not very consistent. The standard error of 0.242 was rather large for the phenomenon being predicted but comparable to the previous logistic model. Both models were significant at 5 per cent level. The trend revealed that injuries per 10^4 vehicle-kilometres have stabilized and are decreasing. Both models could be improved in terms of calibration by further data smoothing and observation of more reliable data on vehicle-kilometres.

The severity index was found to be increasing with time at the rate of 3.0% per annum. The predictive model 4.39 was found to be the logistic curve but with a flatter shape. There appeared to be fluctuations even after data smoothing. This led to a rather considerable scatter in the prediction (r=0.53). The slope was 0.643, the intercept was 3.9 (Fig.4.32) and the standard error 1.65. The predictions are reasonable but the slope and intercept suggested necessary improvement in the calibration. The model was found to be significant at 5 per cent level.

It was found that severity index increases slowly with motorization and then rapidly. The cubic polynomial function (4.40) was found to fit the data. The prediction was fairly close to the ideal (slope =0.833, intercept = 1.655) (Fig.4.33). The scatter had lessened (r = 0.63) compared to that of the logistic prediction. The standard error was 1.508 rather like that of the logistic model. Both models were found to be significant at 5 per cent level. The severity indices for various classes of road users were analysed. Due to lack of sufficient data no meaningful functional relations either with time or motorization were suitable. But the analysis revealed that the severity index of pedestrians was positively correlated with motorization. Therefore, pedestrians would seem to be the main category of road users affecting severity index in RTAs. The finding by Jacobs and Hutchinson that the lower the vehicle ownership level, the greater the severity index is contradicted by the finding in this study.

The percentage distribution of RTAs by day and night in Kenya was found to be described by a logarithmic trend curve (4.41)

$$\left((\%)_{A_d} \right)_p = 81.073 - 5.656 \quad \ell nt$$

over time. This curve was significant at 5 per cent level and for the data observed the prediction was about the ideal line (slope = 0.754, intercept = 17.004) (Fig.4.34).

Due to flactuations remaining in the smoothed data there was much scatter (r=0.45). The standard error was 4.674 which is considered reasonable. The trend revealed that the day proportion is decreasing whilst the night proportion is increasing with a tendency to stabilize at around 50%. Nonetheless about 2/3 of RTAs in Kenya are still occurring during the day in line with the proportion of day traffic. Therefore, equal efforts in reducing RTAs should be exerted to both day as well as night RTAs.

The percentage RTA responsibility of various classes of vehicles was found to be described by the logarithmic trend (4.42-4.47) curve over time. The results for the various classes of vehicle type are summarized in Table 5.4. It was found that the prediction for pedal cyclists responsibility came nearest the ideal line. The prediction for pedal cyclists responsibility was the most consistent with some scatter however (r = 0.76). The others had reasonable calibration but with considerable scatter. When responsibility and composition (Fig.4.35-4.38) distribution were compared it was found that cars and utilities were responsible for RTAs in about the same proportion as their composition. Indeed their responsibility was just below the composition. Not surprisingly, buses, lorries and taxis were found to be responsible for nearly twice as much as their composition with an increasing tendency in their RTA involvement. Their composition was found to be stable. Because this class of vehicles carries passengers it has agreat effect on casualty, injury, death and RTA rates. Concerted efforts in RTA reduction should therefore be directed towards this class of vehicles as there is much potential for safety improvement. Although motorcycles were involved in RTAs more than their composition initially the stabilizing tendency was found to reveal that they are being involved in RTAs less than their composition. The responsibility by handcarts and animals as well as by pedal cyclists has remained more or less constant in recent years.

TABLE 5.4 COMPARISON OF OBSERVED AND PREDICTED PERCENTAGE RTA RESPONSIBILITY

Vehicle Type	Units	Regression		Correlation Coefficient, r	Determination Coefficient, r^2	Standard Error	Significance Level
		Slope	Intercept				
Cars, Utilities	%	0.787	14.661	0.43	0.18	1.590	5
Buses, Lorries, Taxis	%	0.767	5.894	0.53	0.29	2.190	5
Motorcycles	%	0.868	0.727	0.30	0.09	0.453	10
Pedal cyclists	%	0.979	0.040	0.76	0.57	1.655	5
Handcarts & animals	%	0.596	0.983	0.15	0.02	0.331	25
Pedestrians & Pass.	%	0.736	7.496	0.53	0.28	7.498	5

TABLE 5.5 COMPARISON OF OBSERVED AND PREDICTED % DISTRIBUTION OF PERSONS KILLED

Road user	Units	Regression		Correlation Coefficient, r	Determination Coefficient, r^2	Standard Error	Significance Level
		Slope	Intercept				
Drivers	%	3.147	-30.145	0.45	0.45	0.398	10
Motorcyclists	%	0.630	0.884	0.36	0.13	1.303	20
Pedestrians	%	0.925	3.197	0.45	0.20	1.484	10
Passengers	%	1.389	-11.236	0.21	0.04	0.319	30
Pedal cyclists	%	0.420	3.161	0.38	0.15	2.235	20

Of great concern was the finding that pedestrian and passenger responsibility is continuing to increase despite growth in motorization. Measures in safety improvement for these unprotected class of road users has not kept pace with increased travelling. This is yet another class of road users with much potential for RTAs reduction. Efforts should be directed towards this group both in terms of education as well as design for pedestrian facilities on Kenyan roads and changes in transportation of passengers. The models were found to predict responsibility and composition reasonably well. Their slopes and intercept indicate that their calibration could be improved. There was much fluctuation in motorcycle, buses/lorries/taxis and pedestrian/passenger data, which if smoothed out could greatly improve the calibration of predictive models related to these categories of road users.

The growth in percentage distribution of those killed and injured above 16 years of age was found to be logarithmic (4.49). However, the prediction of data for the distribution of those killed was not found to be statistically significant. The distribution predictive model for those injured was however, found to be significant at 20 per cent. These data had only been observed for a decade and it is not valid to extend them beyond a decade for long term extrapolative purposes. Nonetheless, they are useful in indicating short term trends. The prediction for the distribution of those injured came nearer the ideal (slope = 0.856, intercept = 13.117) (Fig.4.39). There was considerable scatter (r = 0.40). The standard error was small (1.808). If the data is extended for this model it could prove useful for predictive purposes. More useful information on age distribution could be gained if age grouping of those killed and injured was widened much in line with the grouping used in the analysis for the dual as well as the single carriageways data.

The percentage distribution of those persons killed in RTAs in Kenya was found to be described by the logarithmic trend curve (4.50-4.54) over time. The results for the various road user categories are summarized in Table 5.5. Since these predictions were about the ideal line all the results could be accepted as indicative of the distribution characteristics of those killed. Because data was of short duration it was found that it had very considerable scatter even after smoothing. For indicative purposes the levels of significance found were reasonable. Hence, judging the models by slope and intercept criteria revealed that the prediction for pedestrians came nearest the ideal line, followed by that for passengers and then the one for motorcyclists.

In terms of trends it was found that they were all stable. However, it was observed that nearly 80% of those killed are pedestrians and passengers followed by 14% as drivers. Therefore, in order to reduce RTAs efforts should be directed towards drivers as they have responsibility for themselves as well as for passengers (35% of total killed). Therefore, drivers were found to be potentially responsible for nearly 49% of those killed whereas pedestrian have a share of 45%. This result indicates that concerted efforts in road safety improvements should be directed towards the drivers and pedestrians. Again, passenger transportation is another area of potential improvement if RTA deaths are to be reduced. This confirms earlier predictions by responsibility distribution. For long term predictions these data need to be extended by further observations and subsequent recalibration. This may be said to be true of all the predictive models obtained in this study.

Finally, for the national RTA trends in Kenya, the percentage distribution of those persons injured in RTAs was found to be described by the logarithmic trend curve (4.55-4.59) over time. The results for the various road user categories are summarized in Table 5.6. It was found that the prediction for motorcyclists and pedal cyclists were not statistically significant. Again, since all the predictions were about the ideal line (i.e. they all intersected the ideal line at least) they could be accepted as indicative of the distribution characteristics of those injured. The prediction that came nearest the ideal line was that for drivers (slope 1.516, intercept = -8.112) (Fig.4.41). It however requires further calibration after data extension. The scatter was found to be considerable (r = 0.59). The standard error lay between those models found to be statistically significant. Again, for purposes of RTAs reductions efforts should be directed towards driver training, retraining and education. Also efforts should be directed towards passenger carrying regulations particularly for public transport vehicles like matatus and the buses as well as open lorries.

5.3 Prediction of Effect of Road Factors on Road Traffic Accidents

In this study it was found that the effect of longitudinal gradient on RTAs can be predicted by a quadratic polynomial function. Predictions were also made on the same data using Silyanov formula (2.14) [4] and compared (Table 5.7). For both upgrade and downgrade data the Agoki formulas (4.60, 4.61)

TABLE 5.6 COMPARISON OF OBSERVED AND PREDICTED % DISTRIBUTION OF PERSONS INJURED

Road User	Units	Regression		Correlation Coefficient, r	Determination Coefficient, r^2	Standard Error	Significance Level
		Slope	Intercept				
Drivers	%	1.516	- 8.112	0.59	0.35	1.650	5
Motorcyclists	%	0.052	4.202	-0.02	0	0.673	NONE
Pedal cyclists	%	0.057	6.175	-0.01	0	0.529	NONE
Pedestrians	%	0.486	10.677	0.30	0.09	3.460	20
Passengers	%	3.448	-127.706	0.22	0.05	0.268	30

TABLE 5.7 COMPARISON OF OBSERVED AND PREDICTED RTAs PER 10^6 VEHICLE KILOMETRES

Formula	Units	Regression		Correlation Coefficient, r	Determination Coefficient, r^2	Standard Error	Significance Level
		Slope	Intercept				
Agoki (Upgrade)	RTAs/10^6V-K	0.811	0.455	0.68	0.46	0.651	20
Silyanov (Upgrade)	RTAs/10^6V-K	0.025	1.956	0.02	0	0.565	NONE
Agoki (Downgrade)	RTAs/10^6V-K	1.018	-0.095	0.97	0.94	0.853	5
Silyanov (Downgrade)	RTAs/10^6V-K	-1.180	3.584	-0.97	0.97	0.738	5

$$(a_g)_{p_1} = 0.9866 + 1.10666g - 0.18401g^2$$

$$(a_g)_{p_2} = 2.993 + 0.11g - 0.05165g^2$$

came nearer the ideal observed = predicted line. The slopes and intercepts for the Silyanov formula suggest that they need recalibration if they are to interpret Kenyan or similar data. The Agoki formula for downgrade gradients came nearest the ideal line and therefore can be used in predicting the effect of gradient on RTA occurrence. The Agoki formula for upgrade gradient is a good fit also (slope = 0.811, intercept = 0.455) (Fig.4.47, 4.48) but the prediction is not as consistent as that for downgrade. It has scatter (r = 0.68) and the level of significance of 20 per cent. This could be acceptable since RTAs are dependent on many causative factors. Silyanov [4] found out that the number of RTAs increased continuously with increase in grade particularly being sharp at 3 per cent. The majority of the vehicles from Silyanov's result were moving downwards. In this study it was found that for upgrade gradients 3 per cent had the worst RTA incidence. For the downgrade the worst gradients are ones less than 3 per cent. The general finding was that flatter grades were more RTA prone than steeper ones. The reason for this may lie in the fact that the steeper the gradient the more careful and alert the drivers become. On the upgrade vehicular speeds reduce with increase in gradient thus better holding possibilities and better control of vehicles is enhanced. Design criteria [14] recommend maximum ranges of gradient for flat country as 3-5 per cent, rolling country as 4-7 per cent and mountainous as 7-10 per cent. These ranges fall largely in the decreasing section of the models developed in this study. This implies that the design of flatter gradients than 3 per cent is crucial to safety particularly when combined with other factors of sight distance and horizontal alignment. Further, attempts to achieve grades less than 3 per cent imply increase in construction costs which must be justified by increased traffic safety due to reduced RTAs.

The effect of sight distance on RTAs was also found to be predictable by a quadratic polynomial function. The comparison of prediction performance qualities of the models developed in this study was made with that of Silyanov (Table 5.8). The Agoki formulae (4.62, 4.63)

$$(a_s)_{P_1} = -8.745 + 0.07981S - 0.000136\ S^2$$

$$(a_s)_{P_2} = -1.8551 + 0.03467S - 0.00006\ S^2$$

TABLE 5.8 COMPARISON OF OBSERVED AND PREDICTED RTAs/10^6 VEHICLE - KILOMETRES

Formula	Units	Regression		Correlation Coefficient, r	Determination Coefficient, r^2	Standard Error	Significance Level
		Slope	Intercept				
Agoki (Nairobi-to-Thika CWY)	RTAs/10^6V-K	0.723	0.826	0.83	0.69	0.996	5
Silyanov (Nairobi-to-Thika CWY)	RTAs/10^6V-K	-1.734	5.609	0.85	0.72	0.424	5
Agoki Thika-to-(Nairobi CWY)	RTAs/10^6V-K	0.550	1.057	0.74	0.55	0.441	5
Silyanov (Thika-to-Nairobi CWY)	RTAs/10^6V-K	-0.473	3.463	0.59	0.35	0.326	5

TABLE 5.9 COMPARISON OF OBSERVED AND PREDICTED RTAs/10^6 VEHICLE KILOMETRES

Formula	Units	Regression		Correlation Coefficient r	Determination Coefficient r^2	Standard Error	Significance Level
		Slope	Intercept				
Agoki	RTA/10^6V-K	0.883	1.603	0.88	0.78	1.317	5
Silyanov	RTAs/10^6V-K	15.92	-11.293	0.88	0.78	0.073	5

came nearer the ideal line but the consistency, though better than in Silyanov's, showed scatter. Silyanov's formulae are unsuited for predicting the study data and judging from the slopes and intercept (4.49, 4.50) they need recalibration. The Nairobi-to-Thika carriage-way model had the highest standard error. Silyanov found that RTAs occurred on road sections where sight distance was less than 300 metres. In this study it was found that sections with 300 metres experience the worst RTA occurrence. RTAs were found to decrease for shorter or longer distances than 300m. The possible explanation here is that at distances greater than 300 drivers have a greater chance of avoiding a RTA and at distances less than 300m drivers are more careful and speeds are more moderate since other limiting factors such as gradient and curvature come into play. Design standards [14, 16] recommend minimum sight distances, on level roads in Kenya for design speeds 60-120 kph, ranging from 80-310 metres. These standards are comparable to those used in Great Britain. USA and Australia have lower standards. From this study it can be seen that where roads have many sections which fall within this range RTAs increase with sight distance to reach a maximum at 300m of sight distance for those sections between 300 and 500m RTAs decrease with increase in sight distance. The MOTC [14] standard specifying 300m sight distance for 120 k.p.h. for stopping and

60 k.p.h. for passing requires revision since at this level of sight distance the horizontal alignment as well as the vertical alignment appear to be contributing the most in worsening the safety situation.

In this study it was found that RTAs decrease with increase in carriageway width. A linear function (4.64)

$$(a_w)_{p_1} = 32.6439 - 4.2348W$$

was found to be describing this relationship. This finding was found to be consistent with that of Silyanov [4] where he observed that RTAs per vehicle-kilometre becomes markedly sharp when the width is less than 7 metres. The two models were compared (Table 5.9), Silyanov's equation being equation (2.12) [4].
The Agoki formula came nearer the ideal line than Silyanov's although Silyanov's had a much lower standard error. The consistency in prediction is comparable for both models. Silyanov's formula grossly under-predicts when used for Kenyan data.
The slope and intercept for Silyanov's formula prediction suggest improvement in calibration for Kenyan data. It is to be noted that the comparison shows that RTA rates on Kenyan roads are as high as 15 times the rates in Europe for which Silyanov developed the model. Alternatively seen, there is

potential for RTA reduction on Kenyan roads if carriageway widths are increased and present roadways routinely maintained including the shoulders.

On an urban and semi-urban dual carriageway, the effect of junctions per kilometre was found to be linear (4.65, 4.66).

$$(a_j)_{p_1} = 5.068 + 1.672j$$

$$(a_j)_{p_2} = 3.0099 + 2.9239j$$

RTAs per 10^6 vehicle-kilometres were found to increase with increase in number of junctions per kilometre. On the single carriageway rural road with a higher number of junctions and accesses per kilometre (than the dual carriageway urban and semi-urban road with control and restriction of access) it was found that the effect of junctions is non-linear. It was found to be of a quadratic polynomial function (4.75)

$$(a_j)_p = 0.6668 + 1.1082j - 0.1288j^2$$

The prediction by the models developed in this study was compared with that of Jacobs formula (equation (2.9) [4]). Table 5.10 shows the comparison.

TABLE 5.10 COMPARISON OF OBSERVED AND PREDICTED RTAS/10^6 VEHICLE-KILOMETRES

Formula	Units	Regression		Correlation Coefficient, r	Determination Coefficient, r^2	Standard Error	Significance Level
		Slope	Intercept				
Agoki (Nairobi-to-Thika CWY)	RTAs/10^6V-K	1.001	-0.004	0.92	0.84	2.649	5
Jacobs (Nairobi-to-Thika CWY)	RTAs/10^6V-K	1.639	2.691	0.92	0.84	2.346	5
Agoki (Thika-to-Nairobi CWY)	RTAs/10^6V-K	0.970	-0.696	0.93	0.86	6.316	5
Jacobs (Thika-to-Nairobi CWY)	RTAs/10^6V-K	2.781	-1.808	0.808	0.93	2.578	5
Agoki (Kiganjo-Nanyuki Rd)	RTAs/10^6V-K	1.004	-0.009	0.98	0.96	0.642	5
Jacobs (Kiganjo-Nanyuki Rd)	RTAs/10^6V-K	-0.050	2.670	-0.19	0.04	2.498	NONE

Jacobs [4] found, for the Nairobi-Mombasa Road, that junctions per kilometre were the most significant independent variable. The critical coefficient (r^2) for the model for his data was found to be only 0.49 meaning that the model explained only 49 per cent of the variation. This is rather too low. He states that there were never more than two junctions per kilometre and hence an addition of one junction per kilometre led to RTA increase of over one RTA per 10^6 vehicle-kilometre. From Table 5.10 it is confirmed that junctions per kilometre are a very significant independent variable in relation to RTA causation. The models developed in this study were all significant at 5 per cent level. The prediction came very near the ideal. For all intents and purposes they could be said to be perfect. The slopes and intercepts for the Nairobi-to-Thika carriageway and the Kiganjo-Nanyuki Road together with their intercepts reveal that the models are very well calibrated. The worst condition on the single carriageway is 4 junctions. Thus RTAs per 10^6 vehicle-kilometres increase with increase in junctions per kilometre. After 4 junctions per kilometre they decrease with increase in junctions per kilometre. This is to be expected because the fewer the junctions the greater the mobility, free flow conditions and hence the higher the speed. The more the junctions the greater the restriction to flow,the slower the vehicle and the safer. With reference to the comparison of the observed and predicted data by Jacobs formula, noting that the slope of the prediction line is nearly zero it can be assumed to be parallel to the predicted axis. Therefore the prediction by Jacobs formula on the study data varies in the observed value (the RTAs/10^6 vehicle-kilometres axis) only to a great extent meaning that it is actually tracing out the locus of the effect of junctions on RTAs. Thus it confirms the finding that the relationship is quadratic. At 4 junctions per kilometre Nairobi-to-Thika carriageway has an RTA rate of nearly 12 RTAs per 10^6 vehicle-kilometres, the Thika-to-Nairobi carriage has 15 and the single carriageway has 3. Thus in relation to junctions the single carriageway low trafficked road is the safest. The two carriageways of the dual carriageway road can be said to be quite dangerous to the extent of 5 times. The reasons for this high rate on the dual carriageway is likely to be speed, poor visibility, poor illumination at night and the high level of traffic. The developed models may be said with all certainty to be predictive of the phenomenon of RTAs. Jacobs formula failed in predicting the study data.

The effect of horizontal curves was found to be non-linear. The upgrade curves affected the occurrence of RTAs as a cubic polynomial function, while the effect of downgrade curves was of a quadratic nature. The two models developed in this study were compared with Silyanov's model (equation (2.13) [4]. Table 5.11 depicts the comparison. The Agoki formulae (4.67, 4.68)

$$(a_R)_{P_1} = 3.346 - 0.0009R + 0.77x10^{-7}$$

$$- 1.361x10^{-12}R^3$$

$$(a_R)_{P_2} = 6.8699 - 0.0031R + 0.000\ 000397R^2$$

came nearest to the ideal in terms of prediction. In particular the prediction by the model developed from upgrade data (the cubic function) predicts well but has some scatter (r = 0.67) (Fig.4.55). The standard errors are reasonable. The formula by Silyanov could be improved in terms of calibration. Silyanov formula predicts data for downgrade curves in Kenya judging by the slope and intercept. However it tends to under-predict and could be improved by calibrating the intercept in particular. Silyanov found that the most dangerous horizontal curves were those of less than 500 metres. By Silyanov's formula (2.13) this radius gives a rate of 2 RTAs per 10^6 vehicle-kilometres. Using this rate on the models developed here implies that for downgrade gradient curves the most dangerous are those less

TABLE 5.11 COMPARISON OF OBSERVED AND PREDICTED RTAs PER 10^6 VEHICLE-KILOMETRES

Formula	Units	Regression		Correlation Coefficient, r	Determination Coefficient, r^2	Standard Error	Significance Level
		Slope	Intercept				
Agoki (Upgrade)	RTAs/10^6V-K	1.011	-0.055	0.67	0.44	0.509	5
Silyanov (Upgrade)	RTAs/10^6V-K	0.194	2.112	0.37	0.14	1.467	20
Agoki (downgrade)	RTAs/10^6V-K	0.844	0.555	0.88	0.77	1.909	5
Silyonav (downgrade)	RTAs/10^6V-K	0.827	2.270	0.73	0.53	1.625	5

TABLE 5.12 COMPARISON OF OBSERVED AND PREDICTED RTAs PER 10^{-6} VEHICLE-KILOMETRES

Formula	Units	Regression		Correlation Coefficient, r	Determination Coefficient, r^2	Standard Error	Significance Level
		Slope	Intercept				
Agoki-Kiganjo/ Nairobi-to-Thika	RTAs/10^6V-K	0.966	0.065	0.97	0.94	0.937	5
Jacobs-Kig./ Nbi-Tka	RTAs/10^6V-K	0.415	0.126	0.95	0.90	2.132	5
Silyanov-Kig/ Nbi-Tka	RTAs/10^6V-K	6.782	-1.351	0.96	0.93	0.132	5
Agoki-Kig/ Tka-Nbi	RTAs/10^6V-K	0.921	0.110	0.96	0.91	1.679	5
Jacobs Kig/ Tka-Nbi	RTAs/10^6V-K	0.669	-0.635	0.92	0.84	2.220	5
Silyanov-K ig/ Tka-Nbi	RTAs/10^6V-K	10.969	-3.038	0.93	0.87	0.138	5

than 1500 metres and for upgrade those that are 2000 metres. This would seem to imply that drivers in Kenya take curves at higher speeds for the same curves taken in Europe. In fact curves less than 200 metres were found to be extremely dangerous particularly when occuring at crests. Design criteria [14] recommend for design speeds ranging between 40-120 kph curve radius ranges 60-1000m. Speeds of 90-100 k.p.h. require about 500m radius curves [14]. These speeds are the design range for the study roads. From this study it is seen that all these curves, particularly when negotiated at high speeds, lie in the RTA prone zone. It is not unthinkable to imagine that drivers in Kenya particularly with high powered engines negotiate curves at speeds much higher than 120 kph. As a measure for RTA reduction the models suggest that for downgrade curves it is RTA saving to design curves greater than 1500 metres. This would be true also for upgrade curves. For downgrade curves 4000 metre radius appeared to be the safest. Not surprisingly however after this radius RTAs begin to rise with increase in radius. The influence would seem to be that of high speeds and steeper gradients.

The effect of superelevation on RTAs was found to be virtually the same for upgrade as well as downgrade curves. It was found that RTAs decrease with increased superelevation. Taken on the face of it would seem to imply that small radii curves are safer. This would contradict the finding from horizontal curve effect. Rather, what is likely is that smaller radii curves are taken cautiously by drivers thus reducing RTAs on high superelevation curves. Further, an attempt to use larger radii for horizontal curves must take into consideration the cost implications versus the saving to be realized from a drop in RTAs particularly on curves. Quadratic polynomial functions were found to fit this effect of superelevation (4.69, 4.70),

$$(a_\alpha)_{p_1} = 2.2729 + 0.6\alpha - 0.098\alpha^2$$

$$(a_\alpha)_{p_2} = 1.0693 + 1.3132\alpha - 0.22\alpha^2.$$

The predictions were near ideal and consistent. The level of significance was 5 per cent and therefore the models were acceptable. The standard errors were small.

In this study it was found that whereas RTAs per 10^6 vehicle-kilometres increase with increase in vehicle flow (average vehicles per hour) the growth in RTAs follows the logistic curve (4.71, 4.72)

$$(a_q)_{P_1} = \frac{18.89}{1 + 24.128\, e^{-0.002q}}$$

$$(a_q)_{P_2} = \frac{24.55}{1 + 38.983\, e^{0.0003q}}$$

This was true for data from the single carriageway combined with each of the carriageways of the Nairobi-Thika Road. The models were compared with those of Jacobs (2.8) and Silyanov (2.11) [4] in Table 5.12. All the models were consistent in their prediction and significant at 5 per cent level. The Agoki and Silyanov formulae had lower errors than Jacobs formula. Of all the models the Agoki models came closest to the ideal line. Thus Jacobs formula that is linear over-predicts on the assumption that the effect of vehicle flow is linear, Silyanov's under-predicts as the non-linear quadratic function rises sharply. The Agoki formula predicts right rising slowly first then sharply to level off as traffic saturates. This finding fitted the logistic curve model. This finding was further enhanced by the fact that from harmonic analysis RTAs per 10^6 vehicle-kilometres and vehicle flow varied similarly with time of day to reach the peak i.e. at low traffic flow RTAs are low and reach peaks much the same way. These models were found to predict the phenomenon

TABLE 5.13 COMPARISON OF OBSERVED AND PREDICTED RTAS/10^6 VEHICLE - KILOMETRE

Formula	Units	Regression		Correlation Coefficient, r	Determination Coefficient, r^2	Standard Error	Significance level
		Slope	Intercept				
Nairobi-Tka Rd Unsmoothed	RTAs/10^6V-K	1.358	-0.026	0.77	0.59	0.201	5
Smoothed	"	0.979	-0.020	0.87	0.75	0.315	5
Kiganjo-Nyki Rd Unsmoothed	"	0.506	0.285	0.57	0.33	0.734	5
Smoothed	"	0.922	0.042	0.68	0.46	0.477	5

TABLE 5.14 COMPARISON OF OBSERVED AND PREDICTED RTAs/10^6 VEHICLE-KILOMETRES

Formula	Units	Regression		Correlation Coefficient, r	Determination Coefficient, r^2	Standard Error	Significance Level
		Slope	Intercept				
Rutting	RTAs/10^6V-K	0.998	0.006	0.94	0.88	0.785	5
Cracking	"	0.998	0.005	0.50	0.25	0.428	10
Potholes	"	0.999	0	0.84	0.70	0.318	5
Edge Spalling	"	1.001	0.002	0.92	0.84	1.018	5

well and therefore were found acceptable.

The variation of mean RTAs per 10^6 vehicle-kilometres, for both carriageways, was found to vary harmonically with time of the day (4.74, 4.81).

$$(a/K)_{P_2} = 0.538-0.267 \cos t-0.085 \cos 2t+0.033 \cos 3t$$

$$- 0.319 \sin t - 0.095 \sin 2t,$$

$$(a/K)_{P_4} = 0.704-0.456 \cos t-0.02 \cos 2t+0.01 \cos 3t$$

$$- 0.446 \sin t + 0.172 \sin 2t.$$

The comparison of the predictions for unsmoothed and smoothed data for the two study roads is shown in Table 5.13.

The formulae obtained after data smoothing by the moving averages technique improved both the calibration and prediction consistency particularly for low volume flow roads. For both study roads models developed using smoothed data came nearer the ideal line. The standard errors also dropped after data smoothing although the level of significance remained unchanged. The models were accepted for prediction.

Using data from the single carriageway the effect of pavement defects was found to be significant. The

The comparison of the prediction models is tabulated in Table 5.14. The effects were found to be non-linearly related to RTA occurence and the quadratic function gave the best fit. The prediction that came nearest the ideal (4.76 - 4.79, Fig.4.69 - 4.72) observe = prediction line was found to be that of edge spalling. Edge spalling, rutting, and potholes (together with patches, depressions and upheaval) were found to be more significant (5 per cent level) than cracking and crazing (significant at 10 per cent). Overally, rutting, cracking and potholes behave in the same manner in their effect on RTA occurrence. At the initial stages they have a reducing effect on RTA rates. After a minimum is reached they tend to increase the incidence of RTAs as they rise. Edge spalling acts in a counter manner to rutting, cracking and potholes. RTAs increase with increasing edge spalling to reach a maximum and then decrease with further increase in edge spalling. It is to be noted that for newly surfaced roads, when these independent variables are zero, driving speeds are considerably higher than after pavement defects have taken their toll. At this stage any small rutting causes the greatest rise in RTA occurence (4 RTAs per 10^6 vehicle-kilometres), followed by cracking and potholes (3 RTAs/10^6 vehicle-kilometres) then edge spalling (nearly 1 RTA per 10^6 vehical-kilometres).

The former three then have a decreasing effect and edge spalling which trigers RTAs predominates up to a level when it is nearly 40% causing as high as 4 RTAs per 10^6 vehicle-kilometres. At 100% edge spalling the road becomes virtually unpaved hence speeds reduce and consequently RTAs reduce. Maintenance criteria for paved roads [5] considers for all road bases that for no cracks, rutting of less then 10mm the pavement is good and acceptable. It should be noted that at this stage RTAs are at a level of 3 RTAs per 10^6 vehicle-kilometres. On the basis of the same criteria rutting of less than 25mm without cracks is critical. From this study, at this critical value rutting has the minimum effect and RTAs are more influenced by the other pavement defects. On the basis of the same criteria reconstruction is recommended when the rate of potholes is more than 40 per 100 metres. If this is considered to be equivalent to 100% potholes then patching and overlaying is recommended at 15-40 holes per 100 metres. Taking the lower limit (15) patching commences at 38% potholes. At this stage, from the analysis in this study, this pavement defect is already contributing close to 5 RTAs per 10^6 vehicle-kilometres. Therefore poor road maintenance has a considerable effect on RTA rates. A reduction in RTAs could be obtained by proper road maintance coupled with speed regulatory and related safety enforcement measures. These models are reasonable in their predictions and therefore acceptable.

5.4 Generalised Linear Models

5.4.1 Dual Carriageway

The two models developed for the dual carriageway indicated that on an interactive basis junctions per kilometre, the percentage of heavy vehicles, horizontal radius and superelevation have a far greater influence on RTAs than longitudinal gradient and sight distance. The first model further showed that the effect of superelevation depends on horizontal curve radius as would be expected. For the first model (equation 4.82)

$$A_1 = e^{-0.09198} K^{0.7248} e^{(\Sigma a_i x_i)}$$

S.D./d.f was found to be 1.81. This value is reasonably close to 1 and therefore the model is quite reasonable in predicting RTAs.

The second model developed for straight sections (equation 4.83)

$$A_2 = e^{-0.6274} K^{0.7532} e^{(\Sigma a_i x_i)}$$

was found to have S.D./d.f. = 1.79. This is quite a good model as S.D./d.f. is also tending to 1. Junctions and heavy vehicles increase RTA risk. Horizontal radius has the following effect on risk:

for radius 300m the effect = exp.(67.36x $\frac{1}{300}$ = 1.24,

for radius 3000m the effect =exp.(67.36x $\frac{1}{3000}$= 1.02

for straight section the effect = 1.00, for example.

The risk decreases as the radius increases.

The result is very interesting and is in the direction one could imagine.

5.4.2 Single Carriageway

The model developed for the single carriageway (equation 4.84) indicated that on an interactive basis the best variables that had any meaning when considering RTAs were junctions per kilometre, heavy vehicles, crazing and cracking, edge spalling and horizontal curve radius. Potholes, patches, depressions and upheavals as well as rutting did not have as significant an influence on RTAs.

Considering equation 4.84

$$A_3 = e^{-0.1617} K^{1.138} e^{(\Sigma a_i x_i)}$$

and the parameters in Table 4.3, given that the effect of 3 or less junctions per kilometre is 1.00 (bottom value), the effect for 3-7 junctions per kilometre was found to be 2.26 (exp.(00.8154)) and that for 7 or more junctions 1.45 (exp.(0.3817)). This means that risk increases 2.26 if junctions are in the second class and 1.45 if in the third class. For lorries and buses the risk decreases from 1.00 (for <28%) to 0.47 (for >28%). This would imply that there is not much variation and there are correlations. Therefore more data is required to be able to see the real effect. For crazing and cracking, if the effect for the first level of <5% is 1.00, for 5%-10% being exp(0.6893) which is 1.99 and for the third level of >10% being exp(0.6791) which is 1.92, this would mean that risk increases about 1.9 if crazing and cracking is above or equal to 5%. Similarly for edge spalling if the effect for the class <29% is 1.00 (bottom class) and that of 30%-60% 2.51 (exp(0.9192)) and that of >60% 1.63 (exp(0.4871)) then risk increases for edge spalling for the two classes in the order of 2.51 and 1.63 respectively. For horizontal curve radius if the risk is 1.00 for radius <799m then for 800-3099m is 0.51 (exp(0.3796)) and for >3100m is 0.58 (exp(0.3470)) meaning that when the radius is above 799m the risk is about 0.5 times compared with the radius below 800m. The model for the single carriageway (equation 4.84) had S.D/d.f. of 1.42. This model is quite good since 1.42 is close to 1 and therefore quite acceptable in finding out the effect of various independent variables on RTAs.

CHAPTER 6 - CONCLUSIONS

The objectives of this study were: to study road traffic accidents (RTAs) in Kenya and determine where possible their fundamental characteristics and causal factors related to their occurrence, to develop predictive models for Kenya at the National (macro) level to be used for the monitoring of RTAs and the performance of safety improvement programmes and lastly to develop predictive models for some selected Kenyan roads at the road (micro) level to assist in the proper understanding of the behaviour of RTAs in relation to the design elements. The results of this study indicated that:

1) RTA phenomenon lends itself to mathematical modelling and in particular the characteristic patterns of RTAs in different countries, and in particular Kenya, can be predicted provided long term accurate data for the particular country in question exist. At the macro level the logistic model is well suited in predicting the growth of RTAs with time, the logarithmic trend curve is well suited in predicting the growth in the distribution of RTA responsibility and involvement while the polynomial function is suited in predicting the trend of RTAs in relation to motorization. At the macro level

the Smeed relationships and those developed later by Jacobs and Hutchinson do not satisfactorily predict RTA phenomena in Kenya. The corresponding models developed in this study performed best overall. To predict RTA deaths the formula developed in this study as follows was (equation (4.26)):-

$$D_{P_2} = 229.7235 - 11.960418\ {}^{V}/_{P} + 0.14040617({}^{V}/_{P})^2 + 0.18958\text{x}10^{-6}({}^{V}/_{P})^3$$

with $r=0.97, r^2=0.94$, slope = 1.009, intercept =-10 which is better than Smeed's formula (2.2)

$$D = 0.0003\ (VP)^{\frac{1}{3}}$$

with $r=0.96$, $r^2=0.93$, slope=1.751 and intercept=-459. To predict RTA deaths per 10^4 persons the formula developed from the (equation (4.27)

$$(D/P)_{P_1} = 1.9788\text{x}10^{-10}(V/P)^3 + 0.00001494(V/P)^2 + 0.007762\ V/P - 0.4127$$

with $r=0.93, r^2=0.87$, slope=0.923, intercept=0.054, which is better than both Smeeds formula (2.3)

$$D/P = 0.0003(V/P)^{\frac{1}{3}}$$

with $r=0.91$, $r^2=0.83$, slope=4.809, intercept=-2.545

and Jacobs and Hutchinson's formula (2.4)

$$D/P = 0.00077(V/P)^{\frac{3}{5}}$$

with $r=0.92$, $r^2=0.85$, slope=3.550 and intercept =-1.172. To predict RTA deaths per 10^4 vehicles the model developed here as the equation (4.28)

$$(D/V)p_1=1.4218\times10^{-8}(V/P)-0.00022871(V/P)^2 + 0.577548\ V/P - 5.4171$$

with $r=0.77$, $r^2=0.59$, slope=0.769, intercept=13, is again better than both Smeed's formula (2.1)

$$D/V = 0.0003\ (V/P)^{-\frac{2}{3}}$$

with $r=-0.70$, $r^2=0.49$, slope=-0.876, intercept=111

and Jacobs and Hutchinson's formula (2.5)

$$D/V = 0.00077\ (V/P)^{-\frac{2}{5}}$$

with $r=-0.72$, $r^2=0.51$, slope=-2.013 and intercept=151.

2. At the micro level polynomial functions of the first, second and third degree were found to be suited in predicting the effects of road factors on RTA rates, the logistic curve is well suited in predicting the growth of RTAs in relation to vehicle flow whilst the variations in RTAs and vehicle flow with time of day can be predicted by harmonic functions. The models developed

in this study gave highest correlation between predicted and actual values. The relationships developed by Silyanov and later by Jacobs do not satisfactorily predict RTA phenomena on Kenyan roads. In particular to predict the effect of upgrade and downgrade gradients respectively, the models developed in this study viz,

$(a_g)_{P_1} = 0.9866 + 1.10666g - 0.18401g^2$ (for upgrades)

with r=0.68, r^2=0.46, slope=0.811, intercept=0.455 and $(a_g)_{P_2}$=2.993 + 0.11g - 0.05165g^2(for downgrades)

with r=0.97, r^2=0.94, slope=1.018,intercept=-0.o95, were better than Silyanov's formula (2.14)

$a_g = 0.265 + 0.105g + 0.0229g^2$

with r=0.02, r^2=0, slope=0.025, intercept=1.956 for upgrades and r=-0.97,r^2=0.94, slope=-1.180 and intercept=3.584 for downgrades. To predict the effect of sight distance one of the models developed in this study viz.

$(a_s)_{P_1}$ =-8.75 + 0.079 815 - 0.0001365^2

with r=0.83, r^2=0.69, slope=0.723, intercept=0.826 performed better than Silyanov's formula (2.15)

$$a_d = 1/(0.200 + 0.00111d + 0.0000009d^2)$$

with r=0.85, r^2=0.72, slope=-1.734 and intercept=5.609. To predict the effect of carriageway width the model developed from this study, viz.

$$(a_w)_{p_1} = 32.6439 - 4.2348W$$

with r=0.88, r^2=0.78, slope=0.883,intercept=1.603 performed better than Silyanov's formula (2.12)

$$a_w = 1/(0.173W - 0.21)$$

with r=0.88, r^2=0.78, slope=15.92 and intercept=-11.293. To predict the effect of junctions using the model developed from the single carriageway data viz,

$$(a_j)_p = 0.6668 + 1.1082j - 0.1288j^2$$

with r=0.98, r^2=0.96, slope=1.004, intercept=-0.009, performed better than Jacob's formula (2.9)

$$a_j = 1.45 + 1.02j$$

with r=-0.19, r^2=0.04, slope=-0.050 and intercept=2.670. To predict the effect of horizontal radius the model developed in this study for upgrade curves viz.

$$(a_R)_{p_1} = 3.346 - 0.0009R + 0.77\times10^{-7}R^2 - 1.361\times10^{-12}R^3$$

with $r=0.67$, $r^2=0.44$, slope=1.011, intercept=-0.055, performed better than Silyanov's formula (2.15)

$$a_R = 0.647 + 723/R - 649.5/R^2$$

with $r=0.37$, $r^2=0.14$, slope=0.194 and intercept=2.112. To predict the effect of vehicle flow one of the models developed in this study, viz,

$$(a_q)_{P_1} = \frac{18.89}{1 + 24.128e^{-0.002q}}$$

with $r=0.97$, $r^2=0.94$, slope=0.966, intercept=0.065, performed best compared with Jacobs formula (2.8)

$$a_q = 0.116 + 0.009q$$

with $r=0.95$, $r^2=0.90$, slope=0.415, intercept=0.126 and Silyanov's formula (2.11)

$$a_q = 0.256 + 0.000408q + 1.36\text{x}10^{-7}q^2$$

with $r=0.96$, $r^2=0.93$, slope=6.782 and intercept = -1.351.

3. RTAs do not occur by chance but are causally related to some characteristic factors on the road environment, vehicle or road user. Further, that these relationships can be described by mathematical models.

4. Generalized linear models are very beneficial when trying to study the various effects of traffic and geometrical design elements on RTAs. Further, that the interactions between various variables may be determined from these models. With increased data availability such models can be improved in order to form predictive models for a wider range of road and traffic conditions.

5. There is potential for RTA reduction in any country, and in particular Kenya, and the performance of improvement schemes can be monitored by predictive models similar to those developed in this study.

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NOTATIONS

A_o	observed number of RTAs
A_{p_1}	predicted number of RTAs by the logistic curve model
A_{p_2}	predicted number of RTAs as a function of motorization
$(A/K)_o$	observed RTAs per 10^6 vehicle - kilometres
$(A/K)_{p_1}$	predicted RTAs per 10^6 vehicle - kilometres by the logistic curve model
$(A/K)_{p_2}$	predicted RTAs per 106^6 vehicle - kilometres as a function of motorization
$(A/V)_o$	observed RTAs per motor vehicle
$(A/V)_p$	predicted RTAs per motor vehicle as a function of motorization
C_o	observed number of casualties i.e. sum of injured and killed
C_{p_1}	predicted casualties by the logistic curve model
C_{p_2}	predicted casualties as a function of motorization
$(C/A)_o$	observed casualties per RTA
$(C/A)_{p_1}$	predicted casualties per RTA by the logistic curve model
$(C/A)_{p_2}$	predicted casualties RTA as a function of motorization
$(C/V)_o$	observed casulties per 10^4 vehicles

$(C/V)_{p_1}$ predicted casualties per 10^4 by the logistic curve model

$(C/V)_{p_2}$ predicted casualties per 10^4 as a function of motorization

D_o observed RTA deaths

D_{p_1} predicted deaths by the logistic curve model

D_{p_2} predicted deaths as a function of motorization

$(D/K)_o$ observed deaths per 10^6 vehicle - kilometres

$(D/K)_{p_1}$ predicted deaths per 10^6 vehicle - kilometres by the logistic curve model

$(D/K)_{p_2}$ predicted deaths per 10^6 vehicle - kilometres as a function of motorization

$(D/P)_o$ observed deaths per 10^4 persons (population)

$(D/P)_{p_1}$ predicted deaths per 10^4 persons as a function of motorization

$(D/P)_{p_2}$ predicted deaths per 10^4 persons by Jacobs & Hutchinson Formula

$(D/P)_{p_3}$ predicted deaths per 10^4 persons by Smeed formula

$(D/V)_o$ observed deaths per 10^4 vehicles

$(D/V)_{p_1}$ predicted deaths per 10^4 vehicles as a function of motorization

$(D/V)_{p_2}$ predicted deaths per 10^4 vehicles by Jacobs & Hutchinson formula

$(D/V)_{p_3}$ predicted deaths per 10^4 vehicles by Smeed formula

H_o	observed human population
H_{p_1}	predicted human population by high growth by logistic curve model
H_{p_2}	predicted human population by low growth by logistic curve model
I_o	observed injuries from RTAs
I_{p_1}	predicted injuries by the logistic curve model
K	vehicle - kilometres (amount of travel as measured by products of vehicle flow and distance travelled)
$(I/K)_o$	observed injuries per 10^6 vehicle - kilometres.
$(I/K)_{p_1}$	predicted injuries per 10^6 vehicle - kilometres by the logistic curve model
$(I/K)_{p_2}$	predicted injuries per 10^6 vehicle - kilometres as a function of motorization
$(I/P)_o$	observed injuries per 10^4 persons
$(I/P)_{p_1}$	predicted injuries per 10^4 persons by the logistic curve model
$(I/P)_{p_2}$	predicted injuries per 10^4 persons as a function of motorization
$(I/V)_o$	observed injuries per 10^4 vehicles
$(I/V)_{p_1}$	predicted injuries per 10^4 vehicles by the logistic curve model
$(I/V)_{p_2}$	predicted injuries per 10^4 vehicles as a function of motorization

$(V_A)_o$ observed RTA vehicles

$(V_A)_p$ predicted RTA vehicles by the logistic curve model

V_o observed registered vehicles

V_{p_1} predicted registered vehicles by high growth by logistic curve model

V_{p_2} predicted registered vehicles by low growth by logistic curve model

$(V/P)_o$ observed vehicles per 10^4 persons (motorization)

$(V/P)_p$ predicted motorization by logistic curve model

ρ_o observed severity index (deaths/casualties as a percentage)

ρ_{p_1} predicted severity index by logistic curve model

ρ_{p_2} predicted severity index as a function of motorization

$\left((\%)A_d\right)_o$ observed percentage of RTAs occurring during daylight hours

$\left((\%)A_d\right)_o$ predicted percentage of RTAs occurring during daylight hours

$\left((\%)BLT\right)_o$ observed percentage composition of buses, lorries and taxis

$\left((\%)BLT\right)_p$ predicted percentage composition of buses, lorries and taxis

$\left((\%)_{b\ell T'}\right)_o$	observed percentage responsibility of buses, lorries and taxis
$\left((\%)_{b\ell T'}\right)_p$	predicted percentage responsibility of buses, lorries and taxis
$\left((\%)_{CU}\right)_o$	observed percentage composition of cars and utilities
$\left((\%)_{CU}\right)_p$	predicted percentage composition of cars and utilities
$\left((\%)_{cu}\right)_o$	observed percentage responsibility of cars and utilities
$\left((\%)_{cu}\right)_p$	predicted percentage responsibility of cars and utilities
$\left((\%)_{b'}\right)_o$	observed percentage responsibility of pedal cyclists
$\left((\%)_{b'}\right)_p$	predicted percentage responsibility of pedal cyclists
$\left((\%)_{ha}\right)_o$	observed percentage responsibility of handcarts and animals
$\left((\%)_{ha}\right)_p$	predicted percentage responsibility of handcarts and animals
$\left((\%)_{wp}\right)_o$	observed percentage responsibility of pedestrians and passengers
$\left((\%)_{wp}\right)_p$	predicted percentage responsibility of pedestrians and passengers
$\left((\%)_{M}\right)_o$	observed percentage composition of motorcycles
$\left((\%)_{M}\right)_p$	predicted percentage composition of motorcycles

$\left({}^{(\%)}D_{16+}\right)_o$ observed percentage of those killed above age 16

$\left({}^{(\%)}D_{16+}\right)_p$ peredicted percentage of those killed above age 16

$\left({}^{(\%)}D_{B'}\right)_o$ observed percentage distribution of pedal cyclists killed

$\left({}^{(\%)}D_{B'}\right)_p$ predicted percentage distribution of pedal cyclists killed

$\left({}^{(\%)}D_{D'}\right)_o$ observed percentage distribution of drivers killed

$\left({}^{(\%)}D_{D'}\right)_p$ predicted percentage distribution of drivers killed

$\left({}^{(\%)}D_{M}\right)_o$ observed percentage distribution of motor cyclists killed

$\left({}^{(\%)}D_{M}\right)_p$ predicted percentage distribution of motor cyclists killed

$\left({}^{(\%)}D_{P}\right)_o$ observed percentage distribution of passengers killed

$\left({}^{(\%)}D_{P}\right)_p$ predicted percentage distribution of passengers killed

$\left({}^{(\%)}D_{W}\right)_o$ observed percentage distribution of pedestrians killed

$\left({}^{(\%)}D_{W}\right)_p$ predicted eprcentage distribution of pedestrians killed

$\left({}^{(\%)}I_{16+}\right)_o$ observed percentage of those injured above age 16

$\left({}^{(\%)}I_{16+}\right)_p$ predicted percentage of those injured above age 16

$\left({}^{(\%)}I_{B'}\right)_o$ — observed percentage distribution of pedal cyclists injured.

$\left({}^{(\%)}I_{B'}\right)_p$ — predicted percentage distribution of pedal cyclists injured

$\left({}^{(\%)}I_{D'}\right)_o$ — observed percentage distribution of drivers injured

$\left({}^{(\%)}I_{D'}\right)_p$ — predicted percentage distribution of drivers injured

$\left({}^{(\%)}I_{M}\right)_p$ — observed percentage distribution of motor cyclists injured

$\left({}^{(\%)}I_{M}\right)_p$ — predicted percentage distribution of motor cyclists injured

$\left({}^{(\%)}I_{P}\right)_o$ — observed percentage distribution of passengers injured

$\left({}^{(\%)}I_{P}\right)_p$ — predicted percentage distribution of passengers injured

$\left({}^{(\%)}I_{W}\right)_o$ — observed percentage distribution of pedestrians injured

$\left({}^{(\%)}I_{W}\right)_p$ — predicted percentage distribution of pedestrians injured

$(a_C)_o$ — observed RTAs/10^6 vehicle-km associated with cracking and crazing

$(a_C)_p$ — predicted RTAs/10^6 vehicle-km associated with cracking and crazing

$(a_E)_o$ — observed RTAs/10^6 vehicle-km associated with edge spalling

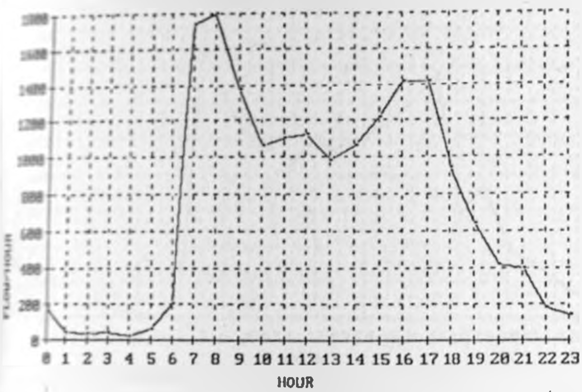
$(a_E)_p$ — predicted RTAs/10^6 vehicle-km associated with edge spalling

$(a_g)_o$	observed RTAs/10^6 vehicle-km associated with longitudinal gradient
$(a_g)_p$	predicted RTAs/10^6 vehicle-km associated with longitudinal gradient
$(a_j)_o$	observed RTAs/10^6 vehicle-km associated with junctions per km
$(a_j)_p$	predicted RTAs/10^6 vehicle-km associated with junctions per km
$(a/K)_o$	observed RTAs/10^6 vehicle-km on a road section
$(a/K)_p$	predicted RTAs/10^6 vehicle-km on a road section
$(a_p)_o$	observed RTAs/10^6 vehicle-km associated with potholes, upheavals and depressions
$(a_p)_p$	predicted RTAs/10^6 vehicle-km associated with potholes, upheavals and depressions
$(a_q)_o$	observed RTAs/10^6 vehicle-km associated with vehicle flow per hour
$(a_q)_p$	predicted RTAs/10^6 vehicle-km associated with vehicle flow per hour
$(a_R)_o$	observed RTAs/10^6 vehicle-km associated with horizontal curve radius
$(a_R)_p$	predicted RTAs/10^6 vehicle-km associated with horizontal curve radius
$(a_{r'})_o$	observed RTAs/10^6 vehicle-km associated with rutting
$(a_{r'})_p$	predicted RTAs/10^6 vehicle-km associated with rutting

$(a_s)_o$	observed RTAs/10^6 vehicle-km associated with sight distance
$(a_s)_p$	predicted RTAs/10^6 vehicle-km associated with sight distance
$(a_W)_o$	observed RTAs/10^6 vehicle-km associated with road width
$(a_W)_p$	predicted RTAs/10^6 vehicle-km associated with road width
$(a_\alpha)_o$	observed RTAs/10^6 vehicle-km associated with superelevation
$(a_\alpha)_p$	predicted RTAs/10^6 vehicle-km associated with superelevation
C	pavement cracking and crazing (%)
E	pavement edge spalling (%)
g	Longitudinal gradient (%)
j	junctions per km
P	potholes in pavement (%)
q	vehicles/hour
r'	pavement rutting (mm)
R	horizontal curve radius (m)
S	sight distance (m)
t	time (hours, years etc)
α	superelevation (%)
r	correlation coefficient
r^2	coefficient of determination (critical coefficient)
$S_{y.x}$	standard error of estimate
e	base for natural logarithms

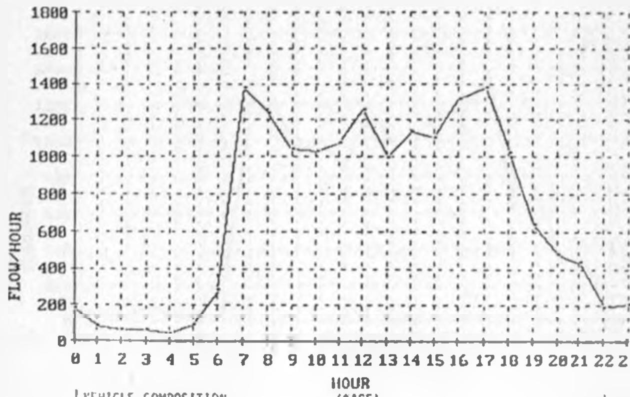
APPENDIX A.1

MANUAL TRAFFIC COUNT AT MUTHAIGA 30TH-31ST OCTOBER



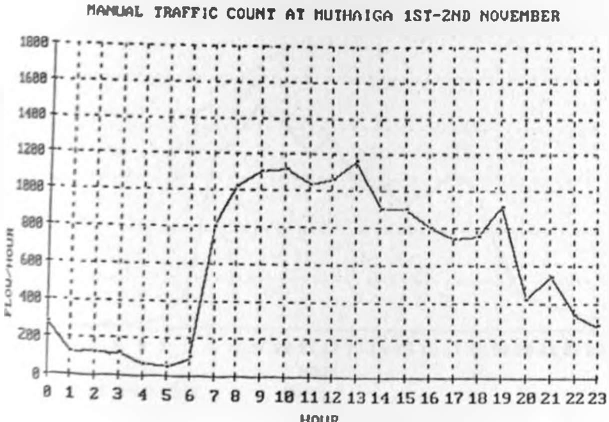
VEHICLE COMPOSITION		(%AGE)		
P			L	
12542/17782 : 70.5%			1986/17782 : 11.2%	
B			M	
925/17782 : 5.2%			2330/17782 : 13.1%	
NIGHT TRAFFIC (7.00 pm - 6.30 am)				
P	L	B	M	VEHICLES
1881	185	111	151	2328
%AGE 80.8%	7.9%	4.8%	6.5%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
1881	185	111	151	2328
%AGE 10.6%	1.0%	0.6%	0.8%	13.0%

MANUAL TRAFFIC COUNT AT MUTHAIGA 31ST OCT-1ST NOV



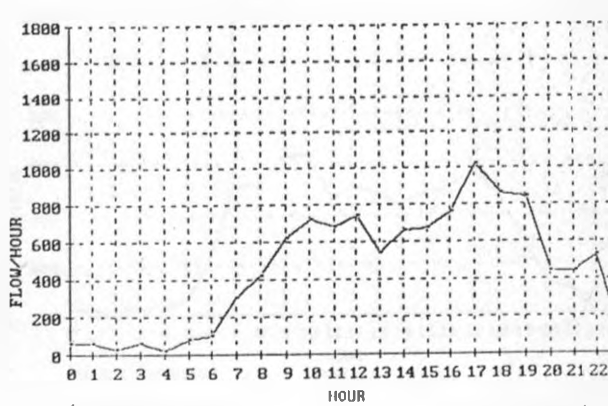
VEHICLE COMPOSITION		(%AGE)		
P			L	
12234/16707 : 73.2%			1687/16707 : 10.1%	
B			M	
635/16707 : 3.8			2151/16707 : 12.9%	
NIGHT TRAFFIC (7.00 pm - 6.30 am)				
P	L	B	M	VEHICLES
2117	173	126	140	2556
%AGE 82.8%	6.8%	4.9%	5.5%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
2117	173	126	140	2556
%AGE 12.7%	1.0%	0.75%	0.84%	15.3%

MANUAL TRAFFIC COUNT AT MUTHAIGA 1ST-2ND NOVEMBER



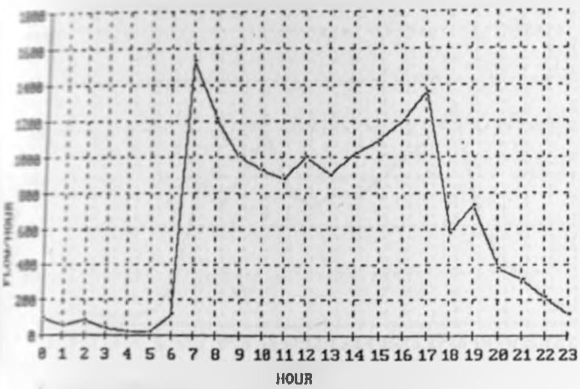
VEHICLE COMPOSITION		(%AGE)		
P			L	
11090/14900 : 74.4%			1141/14900 : 7.7%	
B			M	
768/14900			1901/14900 : 12.7%	
NIGHT TRAFFIC (7.00 pm - 6.30 am)				
P	L	B	M	VEHICLES
2875	134	182	193	3384
%AGE 85%	4%	5.3%	5.7%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
2875	134	182	193	3384
%AGE 25.9%	11.6%	23.7%	10.1%	22.6%

MANUAL TRAFFIC COUNT AT MUTHAIGA 2ND-3RD NOVEMBER



VEHICLE COMPOSITION		(%AGE)		
P			L	
8234/10939 : 75.3%			470/10939 : 4.3%	
B			M	
786/10939 : 4.3%			1449/10939 : 13.2%	
NIGHT TRAFFIC (7.00 pm - 6.30 am)				
P	L	B	M	VEHICLES
2185	144	242	240	2811
%AGE 77.8%	5.1%	8.6%	8.5%	100%
NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
2185	144	242	240	2811
%AGE 26.5%	30.6%	30.3%	16.3%	25.6%

MANUAL TRAFFIC COUNT AT MUTHAIGA 3RD-4TH NOVEMBER



VEHICLE COMPOSITION (%AGE)

P	L
11092/15081 : 73.6%	1621/15081 : 10.7%
B	M
728/15081 : 4.8%	1640/15081 : 10.9%

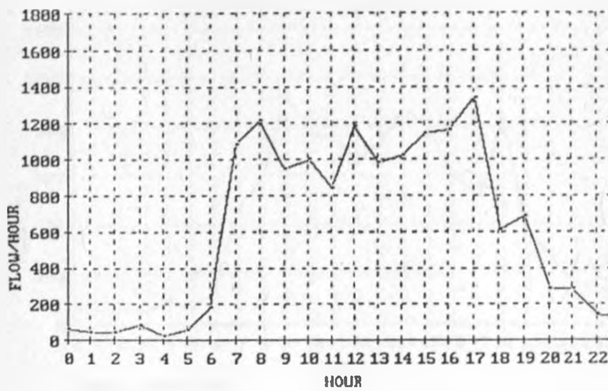
NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHICLES
1723	187	151	127	2188
%AGE 78.7%	8.5%	7.0%	5.8%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
1723	187	151	127	218
%AGE 15.6%	11.6%	21.1%	7.7%	14.6%

MANUAL TRAFFIC COUNT AT MUTHAIGA 4TH-5TH NOVEMBER



VEHICLE COMPOSITION (%AGE)

P	L
10471/14609 : 71.7%	1594/14609 : 10.9%
B	M
791/14609 : 5.4%	1753/14609 : 12.0%

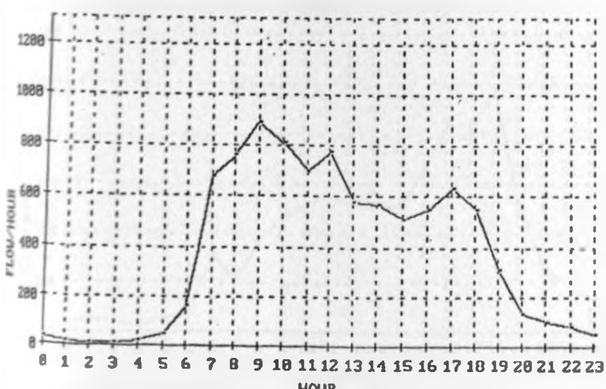
NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHICLES
1558	166	122	120	1966
%AGE 79.3%	8.4%	6.2%	6.1%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
1558	166	122	120	1966
%AGE 14.9%	10.4%	15.4%	6.9%	13.5%

MANUAL TRAFFIC COUNT AT RUIRU 29TH-30TH OCTOBER



VEHICLE COMPOSITION (%AGE)

P	L
3998/9034 : 44.3%	2789/9034 : 30.9%
B	M
534(9034 : 5.9%	1713/9034 : 18.9%

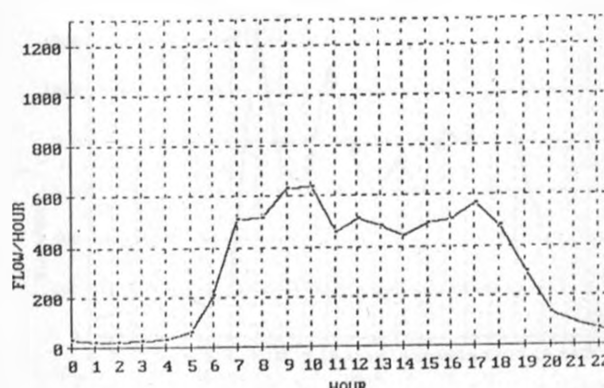
NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHICLES
598	189	52	67	906
%AGE 66.0%	20.9%	5.7%	7.4%	100% -

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
598	189	52	67	906
14.8%	6.7%	9.4%	3.9%	10%

MANUAL TRAFFIC COUNT AT RUIRU 30TH-31ST OCTOBER



VEHICLE COMPOSITION (%AGE)

P	L
4031/7228 : 55.8%	1789/7228 : 24.8%
B	M
470/7228 : 6.5%	938/7228 : 12.9%

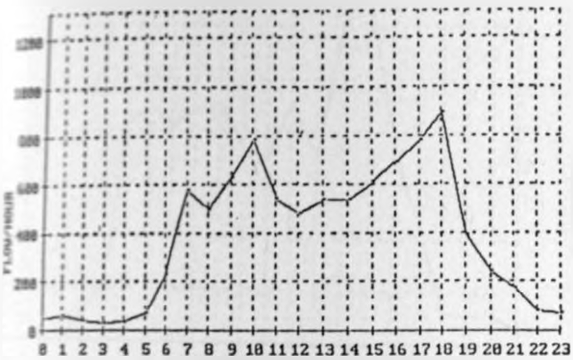
NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHICLES
564	223	89	51	927
%AGE 60.8%	24.1%	9.6%	5.5%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
564	223	89	51	927
14.0%	12.5%	19.2%	5.4%	12.9%

MANUAL TRAFFIC COUNT AT RUIRU 31ST OCT-1ST NOV



VEHICLE COMPOSITION (%AGE)

P 5288/9145 : 57.8 — L 1878/9145 : 20.6

B 534/9145 : 5.8 — M 1445/9145 : 15.8

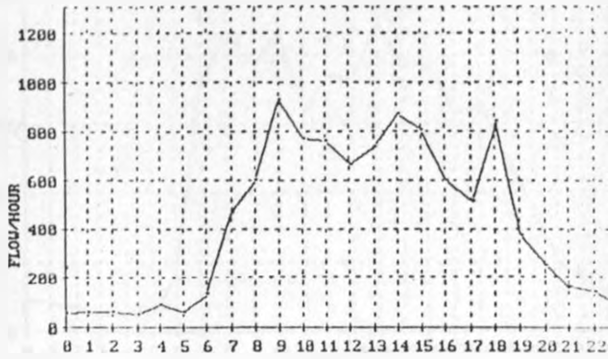
NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHICLES
850	246	120	104	1320
%AGE 64.4%	18.6%	9.1%	7.9%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
850	246	120	104	1320
%AGE 16.2%	13.1%	23.4%	7.3%	14.6%

MANUAL TRAFFIC COUNT AT RUIRU 1ST-2ND NOVEMBER



VEHICLE COMPOSITION (%AGE)

P 5812/10099 : 57.6% — L 1462/10099 : 14.5%

B 632/10099 : 6.2% — M 2493/10099 : 21.7%

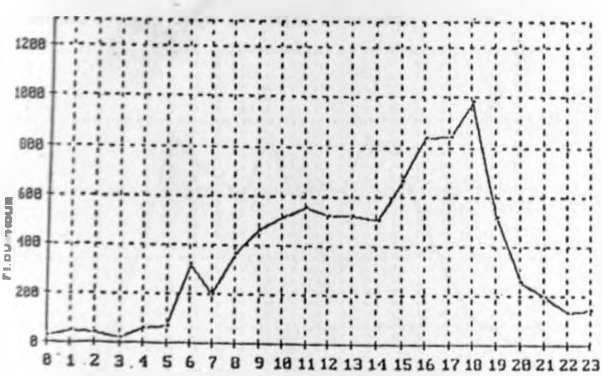
NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHICLES
1132	60	124	51	1467
%AGE 77.2%	10.9%	8.5%	3.4%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
1132	160	124	51	1467
%AGE 18 9%	10.8%	19.1%	2.3%	14.4%

MANUAL TRAFFIC COUNT AT RUIRU 2ND-3RD NOVEMBER



VEHICLE COMPOSITION (%AGE)

P 5546/8649 : 64.1% — L 640/8649 : 7.4%

B 717/8649 : 8.3% — M 1746/8649 : 20.2%

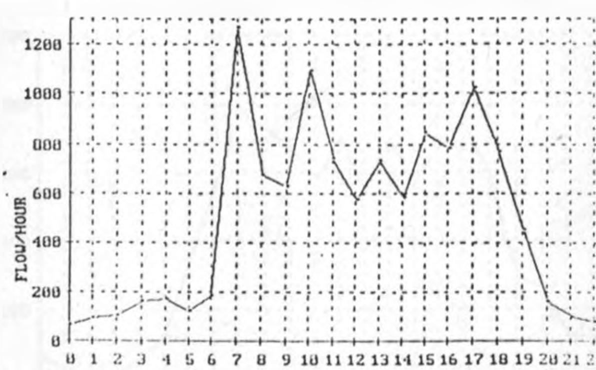
NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHICLES
1157	166	137	84	1544
%AGE 74.9%	10.8%	8.9%	5.4%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
1157	166	137	84	1564
%AGE 21.1%	26.6%	19.2%	4.9%	18.3%

MANUAL TRAFFIC COUNT AT RUIRU 3RD-4TH NOVEMBER



VEHICLE COMPOSITION (%AGE)

P 5929/11407 : 52.0% — L 2015/11407 : 17.7%

B 874/11407 : 7.6% — M 2589/11407 : 22.7%

NIGHT TRAFFIC (7.00 pm - 6.30 am)

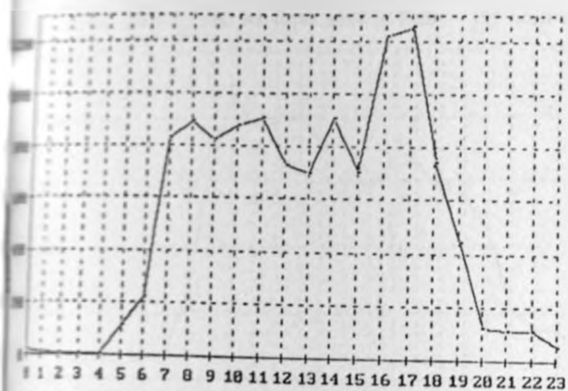
P	L	B	M	VEHICLES
919	530	146	75	1670
%AGE 55.0%	31.8%	8.7%	4.5%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
919	530	146	75	1670
%AGE 15.4%	26.3%	16.6%	2.9%	14.6%

A.1/3

MANUAL TRAFFIC COUNT AT RUIRU 4TH-5TH NOVEMBER



VEHICLE COMPOSITION (%AGE)

P	L
6048/11580 : 52.3%	2004/11589 : 17.3%
B	M
966/11580 : 8.3%	2562/11580 : 22.1%

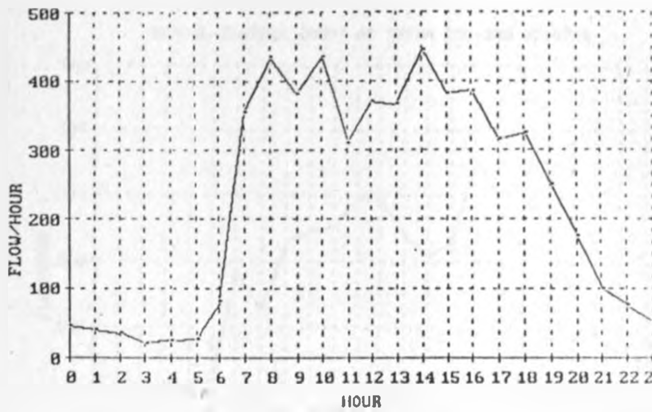
NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHICLES
[illegible]	240	115	68	1111
%AGE 6.9%	21.6%	10.4%	6.1%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
[illegible]	240	115	68	1111
%AGE 11.4%	12.1%	12.0%	2.7%	9.6%

MANUAL TRAFFIC COUNT AT THIKA 1ST-2ND SEPTEMBER



VEHICLE COMPOSITION (%AGE)

P	L
%AGE 2631/5483 : 48.0%	1175/5483 : 21.4%
B	M
%AGE 731/5483 : 13.3%	946/5483 : 17.3%

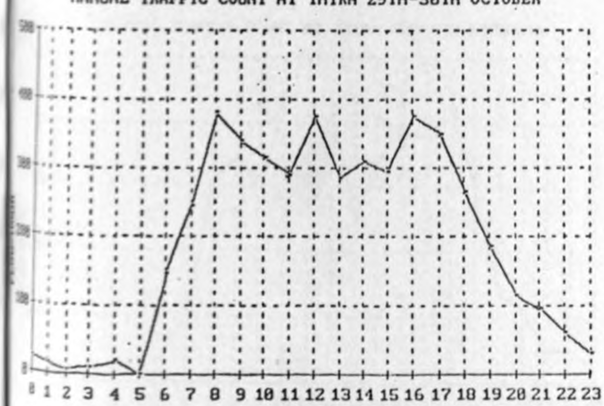
NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHICLES
583	138	88	88	897
%AGE 65%	15%	10%	10%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
583	138	88	88	897
%AGE 22.1%	13.0%	14.0%	10.0%	162%

MANUAL TRAFFIC COUNT AT THIKA 29TH-30TH OCTOBER



VEHICLE COMPOSITION (%AGE)

P	L
2390/4601 : 52%	1078/4601 : 23.4%
B	M
508/4601 : 11.0%	625/4601 : 13.6%

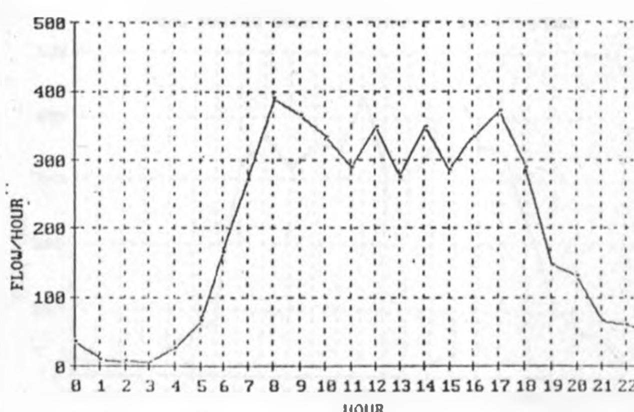
NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHICLES
405	146	62	40	653
%AGE 62.0%	22.3%	9.5%	6.2%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
405	146	62	40	653
17.0%	14%	12.2%	6.2%	14.3%

MANUAL TRAFFIC COUNT AT THIKA 30TH-31ST OCTOBER



VEHICLE COMPOSITION (%AGE)

P	L
2383/4694 : 51%	1199/4694 : 25%
B	M
499/4694 : 11%	613/4694 : 13%

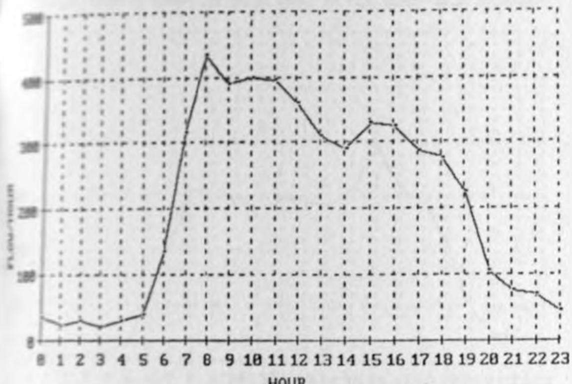
NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHICLES
381	162	69	58	670
%AGE 57%	24%	10%	9%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

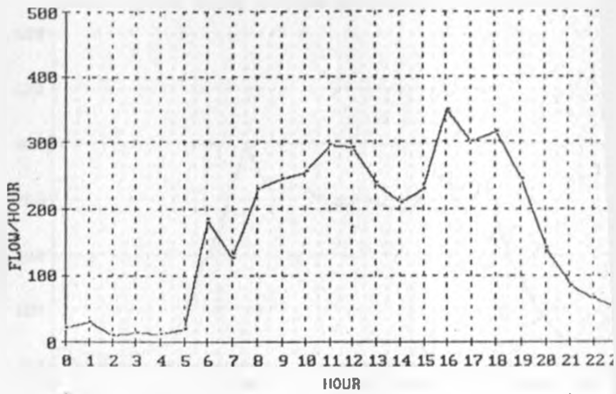
P	L	B	M	VEHICLES
381	162	69	58	670
16%	13%	14%	10%	14%

MANUAL TRAFFIC COUNT AT THIKA 31ST OCTOBER - 1ST NOVEMBER



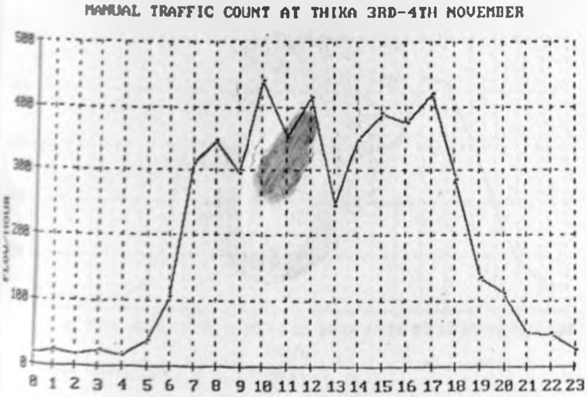
VEHICLE COMPOSITION (%AGE)				
P			L	
2386/4973 : 48.0%			1251/4973 : 25.2%	
B			M	
605/4973 : 12.1%			731/4973 : 14.7%	
NIGHT TRAFFIC (7.00 pm - 6.30 am)				
P	L	B	M	VEHICLES
455	156	88	64	763
%AGE 60%	20%	12%	8%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
455	156	88	64	763
19%	12.4%		9%	15.3%

MANUAL TRAFFIC COUNT AT THIKA 2ND-3RD OCTOBER



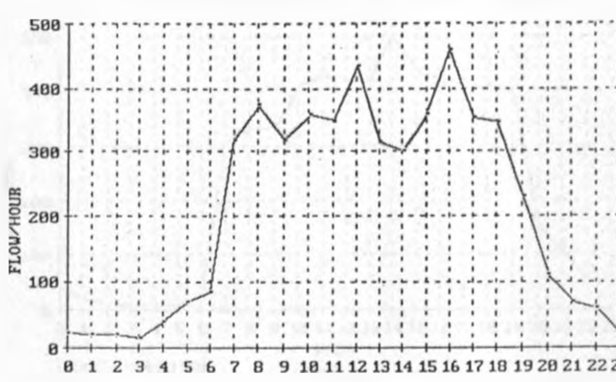
VEHICLE COMPOSITION (%AGE)				
P			L	
1938/4057 : 47.8%			640/4057 : 15.8%	
B			M	
702/4057 : 17.3%			777/4057 : 19.1%	
NIGHT TRAFFIC (7.00 pm - 6.30 am)				
P	L	B	M	VEHICLES
492	87	104	122	805
%AGE 61%	11%	13%	15%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
492	87	104	122	805
%AGE 26.0%	16.0%	17.2%	19.4%	20.2%

MANUAL TRAFFIC COUNT AT THIKA 3RD-4TH NOVEMBER



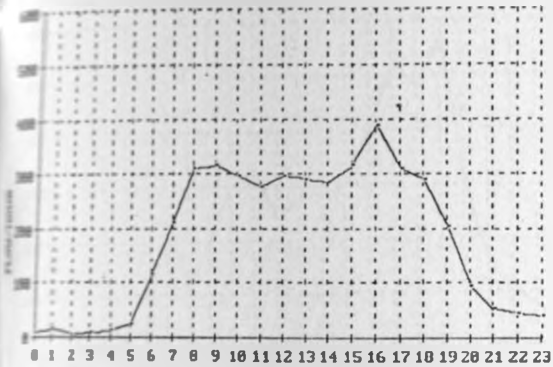
VEHICLE COMPOSITION (%AGE)				
P			L	
2154/4855 : 44.4%			1198%4855 : 24.7%	
B			M	
661/4855 : 4855			842/4855 : 17.3%	
NIGHT TRAFFIC (7.00 pm - 6.30 am)				
P	L	B	M	VEHICLES
315	132	61	44	552
%AGE 57%	24%	11%	8%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICELS
315	132	61	44	552
%AGE 14.4%	11%	9.2%	4%	11.3%

MANUAL TRAFFIC COUNT AT THIKA 4TH-5TH NOVEMBER



VEHICLE COMPOSITION (%AGE)				
P			L	
2160/5109 : 42.3%			1232/5109 : 24.1%	
B			M	
759/5109 : 14.9%			958/5109 : 18.7%	
NIGHT TRAFFIC (7.00 pm - 6.30 am)				
P	L	B	M	VEHICLES
382	154	90	100	726
%AGE 53%	21%	12%	14%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
382	154	90	100	726
%AGE 18%	13%	12%	10%	14.2%

MANUAL TRAFFIC COUNT AT BLUE POST HOTEL 29TH-30TH OCTOBER



VEHICLE COMPOSITION (%AGE)

P 2543/4301 : 59.1% | L 812/4301 : 189%

B 278/4301 : 6.5% | M 668/4301 : 15.5%

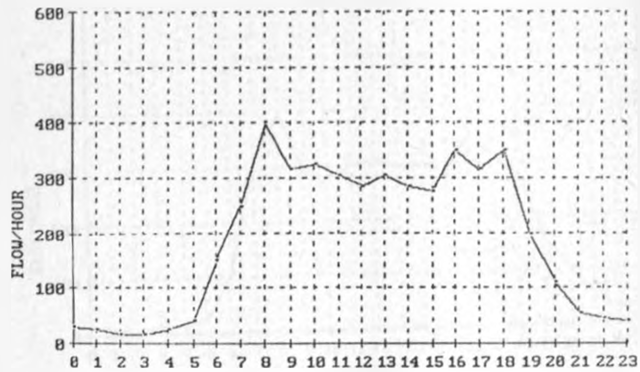
NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHICLES
369	132	31	64	596
%AGE 61.9%	22 2%	5.2%	10.7%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
369	132	31	64	596
4.5%	16.3%	11.3%	9.6%	13.9%

MANUAL TRAFFIC COUNT AT BLUE POST HOTEL 30TH-31ST OCTOBER



VEHICLE COMPOSITION (%AGE)

P 2593/4657 : 55.7% | L 1082/4657 : 23.2%

B 224/4657 : 4.8% | M 758/4657 : 16.3%

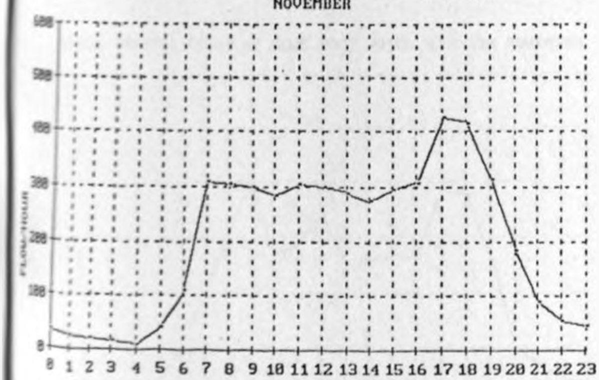
NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHICLES
430	221	38	89	778
%AGE 55.3%	28.4%	4.9%	11.4%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
430	221	38	89	778
16.5%	21.01%	17.1%	11.8%	13.9%

MANUAL TRAFFIC COUNT AT BLUE POST HOTEL 31ST OCTOBER - 1ST NOVEMBER



VEHICLE COMPOSITION (%AGE)

P 3011/4814 : 62.5% | L 804/4814 : 16.7%

B 249/4814 : 5.2% | M 750/4814 : 15.6%

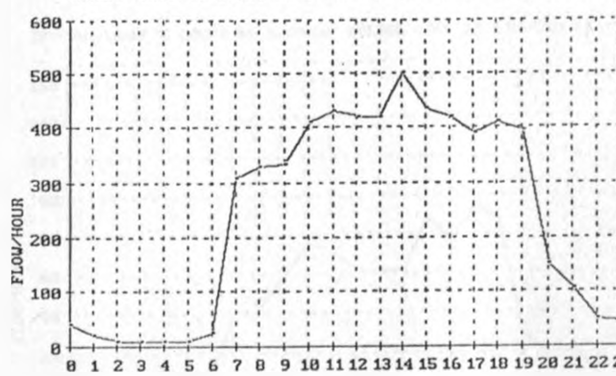
NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHICLES
585	182	42	68	877
%AGE 66.7%	20.8%	4.8%	7.7%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
585	182	42	68	877
19.4%	22.2%	20.2%	8.9%	18.1%

MANUAL TRAFFIC COUNT AT BLUE POST HOTEL 1ST-2ND NOVEMBER



VEHICLE COMPOSITION (%AGE)

P 3927/6099 : 64.4% | L 618/6099 : 10.1%

B 338/6099 : 5.6% | M 1216/6099 : 19.9%

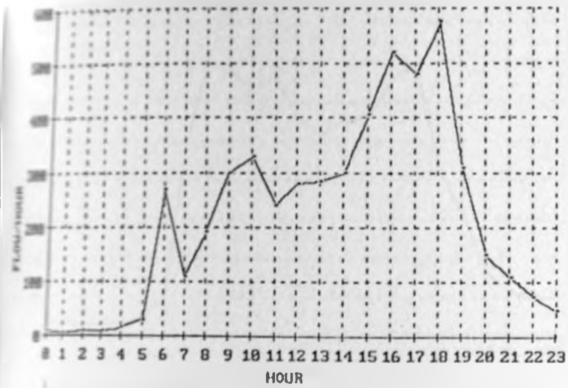
NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHICLES
673	124	65	108	970
%AGE 69.4%	12.8%	6.7%	11.1%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
673	124	65	108	970
%AGE 17.1%	19.8%	19.1%	8.7*	15.8%

MANUAL TRAFFIC COUNT AT BLUE POST HOTEL 2ND-3RD NOVEMBER



VEHICLE COMPOSITION (%AGE)

P 3392/5199 : 64.4%
B 315/5199 : 6.1%
L 352/5199 : 6.8%
M 1140/5199 : 21.9%

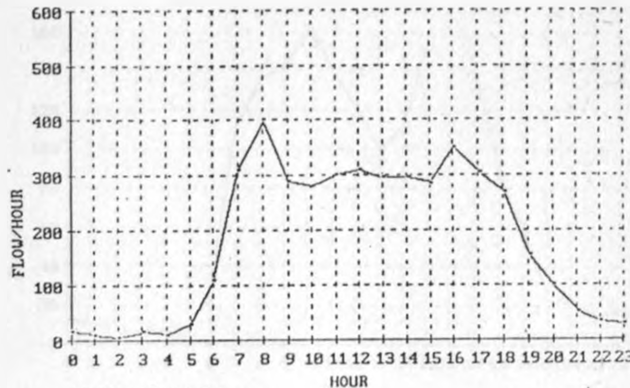
NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHICLES
701	114	41	156	1012
%AGE 69.3%	11.3%	4.0%	15.4%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHILCES
701	114	41	156	1012
%AGE 21%	34.8%	13.1%	14.1%	21.9%

MANUAL TRAFFIC COUNT AT BLUE POST HOTEL 3RD-4TH NOVEMBER



VEHICLE COMPOSITION (%AGE)

P 2543/4301 : 59.1%
B 240/4301 : 5.5%
L 686/4301 : 15.9%
M 832/4301 : 19.3%

NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHILCES
309	129	28	41	507
%AGE 60.9%	25.4%	5.5%	8.2%	100%

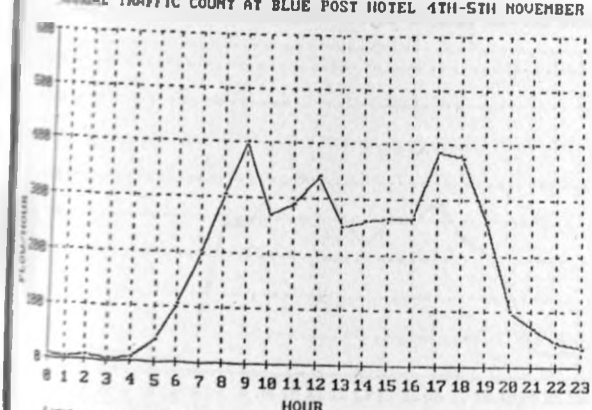
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
309	129	28	41	507
%AGE 12%	18.5%	11.6%	4.8%	11.6%

A.1/7

APPENDIX A.2

MANUAL TRAFFIC COUNT AT BLUE POST HOTEL 4TH-5TH NOVEMBER



VEHICLE COMPOSITION (%AGE)

P 2604/4346 : 59.9%
B 5/4346 : 5.4%
235/4346 : 5.4%
L 766/4346 : 17.6%
M 741/4346 : 17.1%

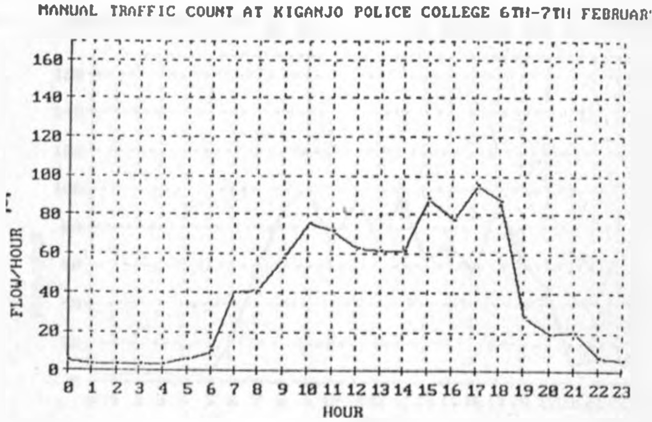
NIGHT TRAFFIC (7.00 pm - 6.30 am)

P	L	B	M	VEHICLES
385	148	39	72	664
%AGE 59.8%	22.9%	6.1%	11.2%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
385	148	39	72	644
%AGE 14.8%	19.6%	16.5%	9.8%	14.8%

MANUAL TRAFFIC COUNT AT KIGANJO POLICE COLLEGE 6TH-7TH FEBRUAR



VEHICLE COMPOSITION (%AGE)

P	L	B	M	VEHICLES
652	153	15	101	921
70.8%	16.6%	1.6%	11.0%	100%

NIGHT TRAFFIC (6.00 pm - 6.00 am)

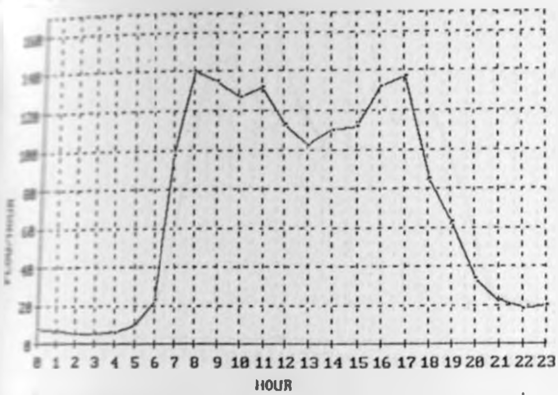
P	L	B	M	VEHICLES
131	28	4	29	192
68.2%	14.6%	2.1%	15.1%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
20.1%	18.3%	26.7%	28.7%	20.8%

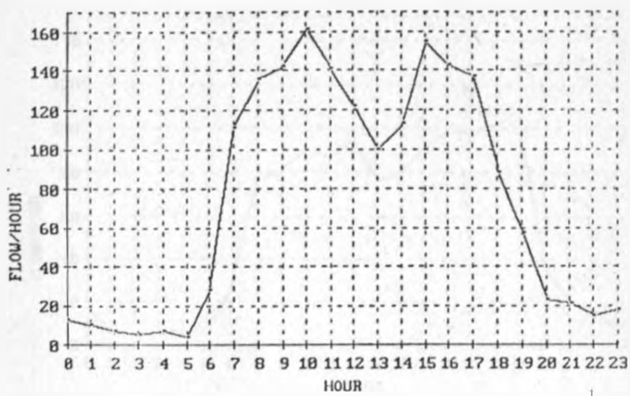
A.2/1

MANUAL TRAFFIC COUNT AT KIGANJO POLICE COLLEGE 1ST-2ND FEBRUARY



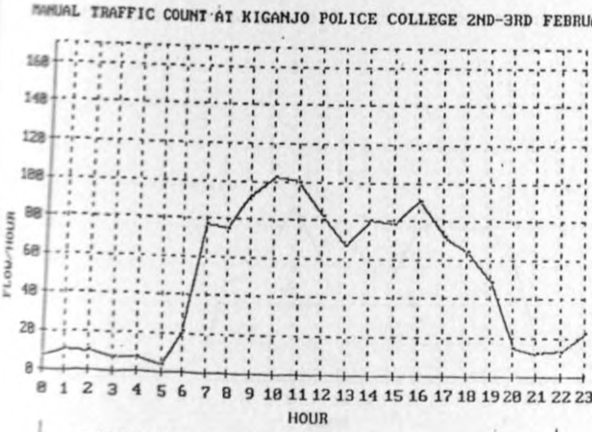
VEHICLE COMPOSITION		(%AGE)		
P	L	B	M	VEHICLES
968	409	52	202	1631
59.4%	25.0%	3.2%	12.4%	100%
NIGHT TRAFFIC (6.00 pm - 6.00 am)				
P	L	B	M	VEHICLES
201	55	7	16	279
72.1%	19.7%	2.5%	5.7%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
20.8%	13.4%	13.5%	7.9%	17.1%

MANUAL TRAFFIC COUNT AT KIGANJO POLICE COLLEGE 22ND-23RD JANUAR



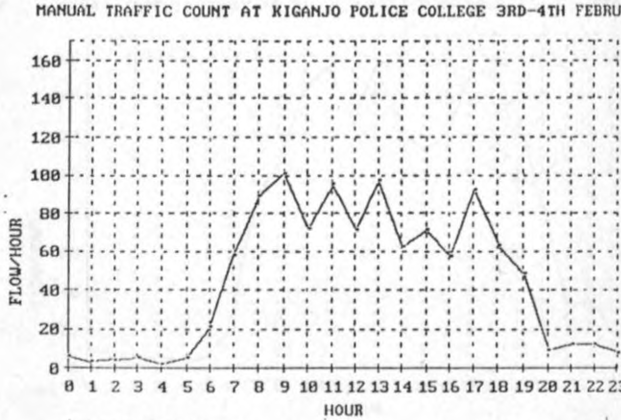
VEHICLE COMPOSITION		(%AGE)		
P	L	B	M	VEHICLES
893	479	58	223	1653
54.0%	29.0%	3.5%	13.5%	100%
NIGHT TRAFFIC (6.00 pm - 6.00 am)				
P	L	B	M	VEHICLES
189	40	9	26	264
71.6%	15.2%	3.4%	9.8%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
21.2%	8.4%	15.5%	11.7%	16.0%

MANUAL TRAFFIC COUNT AT KIGANJO POLICE COLLEGE 2ND-3RD FEBRUARY



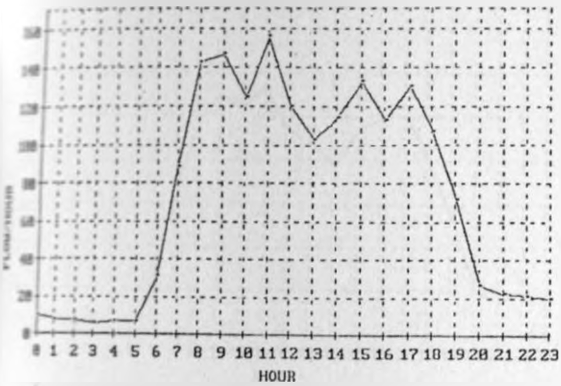
VEHICLE COMPOSITION		(%AGE)		
P	L	B	M	VEHICLES
733	330	14	70	1147
63.9%	28.8%	1.2%	6.1%	100%
NIGHT TRAFFIC (6.00 pm - 6.00 am)				
P	L	B	M	VEHICLES
172	36	1	13	222
77.5%	16.2%	0.4%	5.9%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
23.5%	10.9%	7.1%	18.6%	19.4%

MANUAL TRAFFIC COUNT AT KIGANJO POLICE COLLEGE 3RD-4TH FEBRUA



VEHICLE COMPOSITION		(%AGE)		
P	L	B	M	VEHICLES
662	332	6	64	1064
62.2%	31.2%	0.6%	6.0%	100%
NIGHT TRAFFIC (6.00 pm - 6 am)				
P	L	B	M	VEHICLES
131	32	4	12	179
73.2%	17.9%	2.2%	6.7%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
19.8%	9.6%	66.7%	18.8%	16.8%

MANUAL TRAFFIC COUNT AT KIGANJO POLICE KOLLEGE



VEHICLE COMPOSITION (%AGE)

P	L	B	M	VEHICLES
968	486	52	202	1708
56.7%	28.5%	3.0%	11.8%	100%

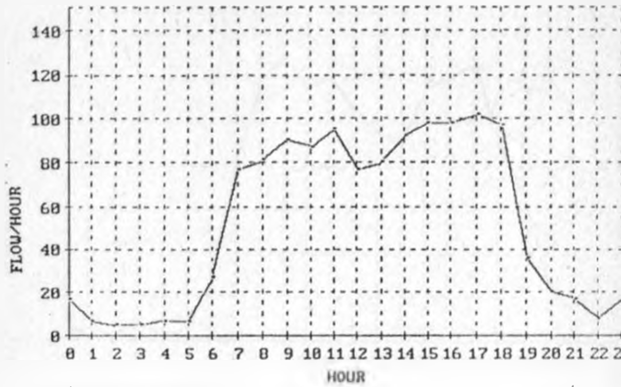
NIGHT TRAFFIC (6.00 pm - 6.00 am)

P	L	B	M	VEHICLES
228	44	13	26	311
73.3	14.1%	4.2%	8.4%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
23.6%	9.1%	25.0%	12.9%	18.2%

MANUAL TRAFFIC COUNT AT KIGANJO KENO 2ND-3RD FEBRUARY



VEHICLE COMPOSITION (%AGE)

P	L	B	M	VEHICLES
761	302	48	118	1229
61.9%	24.6%	3.9%	9.6%	100%

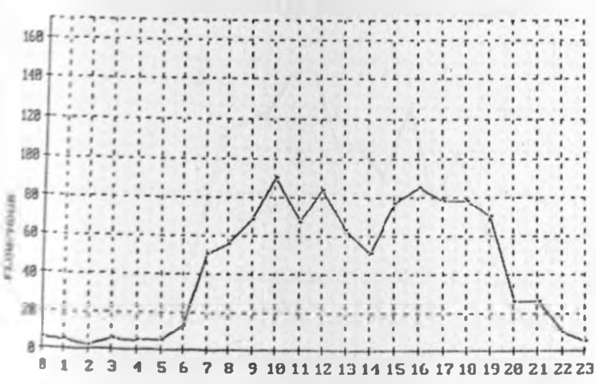
NIGHT TRAFFIC (6.00 pm - 6.00 am)

P	L	B	M	VEHICLES
161	41	11	16	229
70.3%	17.9%	4.8%	7.0%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
21.2.%	13.6%	22.9%	13.6%	18.6%

MANUAL TRAFFIC COUNT AT KIGANJO POLICE COLLEGE 4TH-5TH FEBRUARY



VEHICLE COMPOSITION (%AGE)

P	L	B	M	VEHICLES
639	296	19	78	1032
61.9%	28.7%	1.8%	7.6%	100%

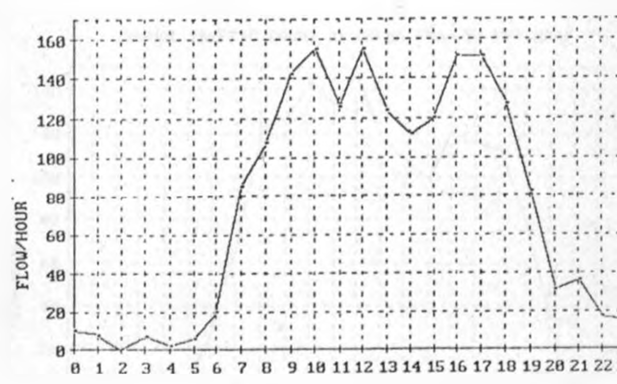
NIGHT TRAFFIC (6.00 pm - 6.00 am)

P	L	B	M	VEHICLES
201	39	3	11	254
79.1%	15.4%	1.2%	4.3%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
31.5%	13.2%	15.8%	14.1%	24.6%

MANUAL TRAFFIC COUNT AT KIGANJO POLICE KOLLEGE 4TH-5TH FEBR



VEHICLE COMPOSITION (%AGE)

P	L	B	M	VEHICLES
1026	453	64	250	1793
57.2%	25.3%	3.6%	13.9%	100%

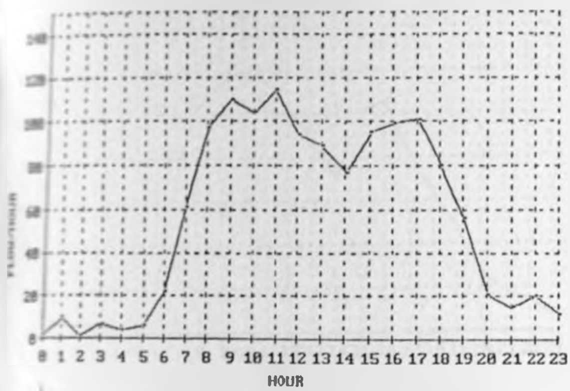
NIGHT TRAFFIC (6.00 pm - 6.00 am)

P	L	B	M	VEHICLES
249	54	12	29	344
72.4%	15.7%	3.5%	8.4%	100

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

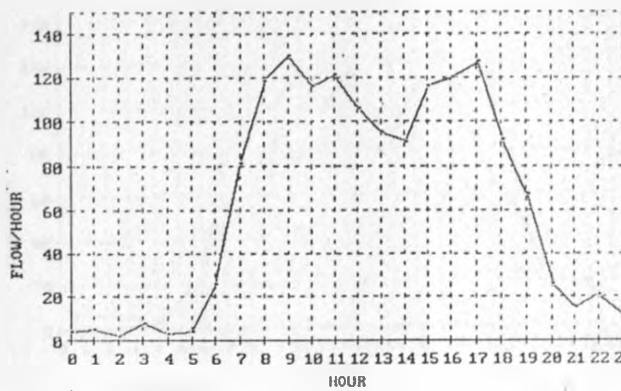
P	L	B	M	VEHICLES
24.3%	11.9%	18.8%	11.6%	19.2%

MANUAL TRAFFIC COUNT AT KIGANJO KCC 3RD-4TH FEBRUARY



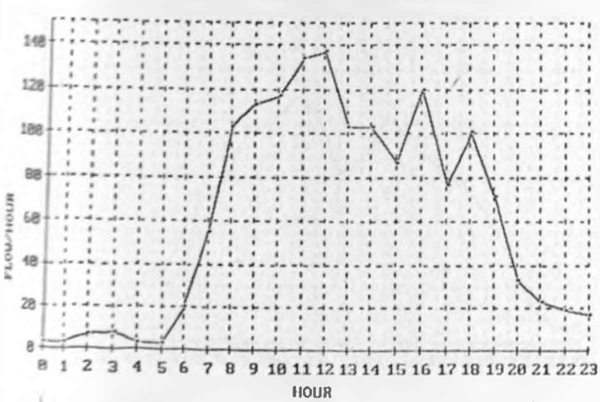
VEHICLE COMPOSITION		(%AGE)		
P	L	B	M	VEHICLES
[illegible]	306	43	126	1286
63.1%	23.8%	3.3%	9.8%	100%
NIGHT TRAFFIC (6.00 pm - 6.00 am)				
P	L	B	M	VEHICLES
175	37	11	9	232
75.4%	16.0%	4.7%	3.9%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
21.6.%	12.1%	25.6%	7.1%	18.0%

MANUAL TRAFFIC COUNT AT KIGANJO KCC 3RD-4TH FEBRUARY



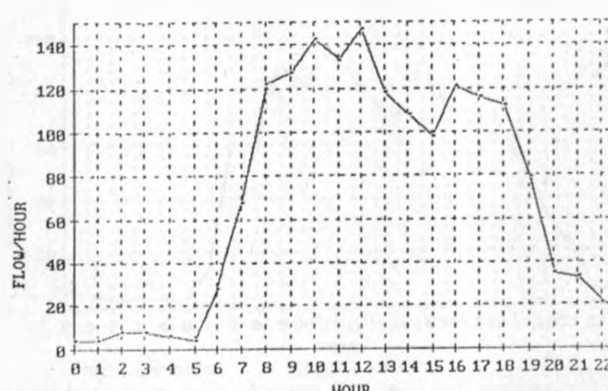
VEHICLE COMPOSITION		(%AGE)		
P	L	B	M	VEHICLES
901	434	49	130	1514
59.5%	28.7%	3.2%	8.6%	100%
NIGHT TRAFFIC (6.00 pm - 6.00 am)				
P	L	B	M	VEHICLES
192	47	13	12	264
72.7%	17.8%	4.9%	4.6%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
21.3%	10.8%	26.5%	9.2%	17.4%

MANUAL TRAFFIC COUNT AT CHAKA 5TH-6TH FEBRUARY



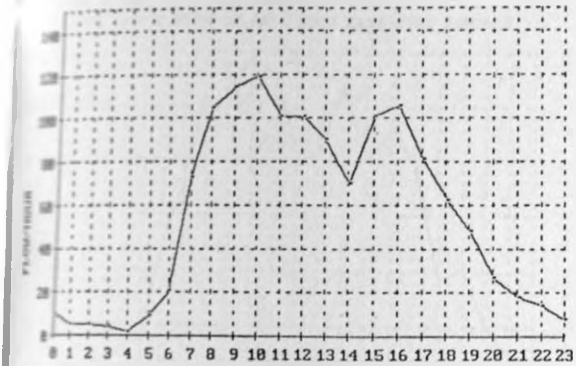
VEHICLE COMPOSITION		(%AGE)		
P	L	B	M	VEHICLES
[illegible]	322	51	169	1459
62.8%	22.1%	3.5%	11.6%	100%
NIGHT TRAFFIC (6.00 pm - 6.00 am)				
P	L	B	M	VEHICLES
213	38	7	38	296
72.0%	12.8%	2.4%	12.8%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
23.3%	11.8%	13.7%	22.5%	20.3%

MANUAL TRAFFIC COUNT AT CHAKA 5TH-6TH FEBRUARY



VEHICLE COMPOSITION		(%AGE)		
P	L	B	M	VEHICLES
1026	375	49	187	1637
62.7%	22.9%	30%	11.4%	100%
NIGHT TRAFFIC (6.00 pm - 6.00 am)				
P	L	B	M	VEHICLES
250	40	7	38	335
74.6%	11.9%	2.2%	11.3%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
24.4%	10.7%	14.3%	20.3%	20.5%

MANUAL TRAFFIC COUNT AT CHAKA 7TH-8TH FEBRUARY



VEHICLE COMPOSITION (%AGE)

P	L	B	M	VEHICLES
751	336	55	147	1289
58.2%	26.1%	4.3%	11.4%	100%

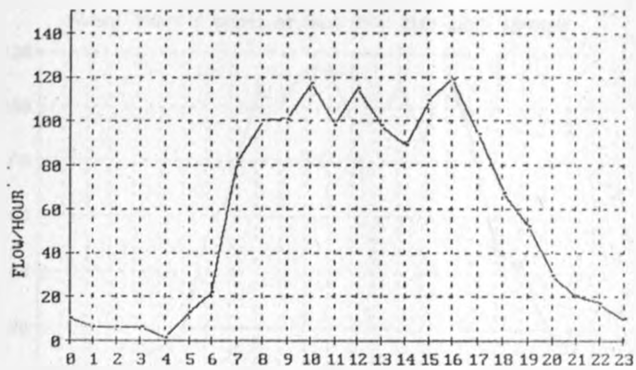
NIGHT TRAFFIC (6.00 pm - 6.00 am)

P	L	B	M	VEHICLES
140	40	11	21	212
66.0%	18.9%	5.2%	9.9%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
18.6%	11.9%	20.0%	14.3%	16.4%

MANUAL TRAFFIC COUNT AT CHAKA 7TH-8TH FEBRUARY



VEHICLE COMPOSITION (%AGE)

P	L	B	M	VEHICLES
805	358	56	153	1372
58.7%	26.1%	4.1%	11.1%	100%

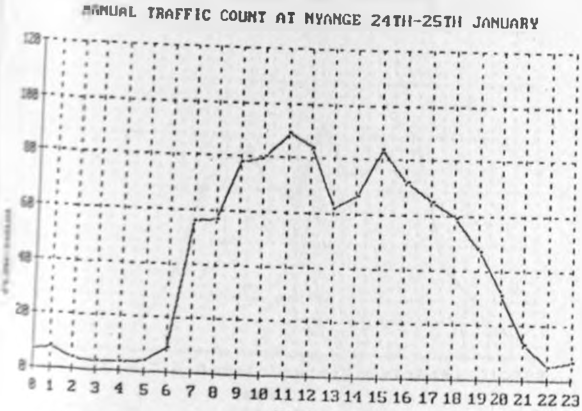
NIGHT TRAFFIC (6.00 pm - 6.00 am)

P	L	B	M	VEHICLES
163	42	12	23	240
67.9%	17.5%	5.0%	9.6%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
20.2%	11.7%	21.4%	15.0%	17.5%

MANUAL TRAFFIC COUNT AT NYANGE 24TH-25TH JANUARY



VEHICLE COMPOSITION (%AGE)

P	L	B	M	VEHICLES
565	261	40	121	987
57.2%	26.4%	4.1%	12.3%	100%

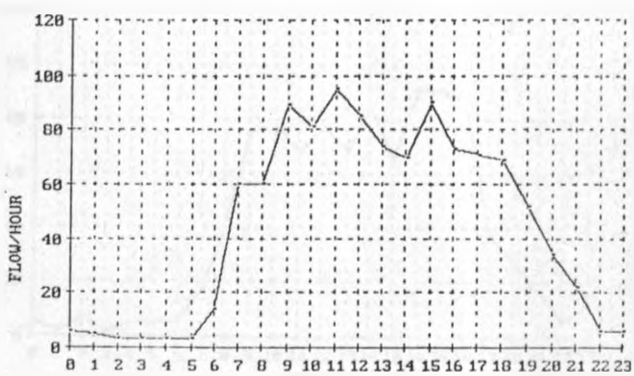
NIGHT TRAFFIC (6.00 pm - 6.00 am)

P	L	B	M	VEHICLES
128	35	7	21	191
67.0%	18.3%	3.7%	11.0%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
22.7%	13.4%	17.5%	17.4%	19.4%

MANUAL TRAFFIC COUNT AT NYANGE 24TH-25TH JANUARY



VEHICLE COMPOSITION (%AGE)

P	L	B	M	VEHICLES
602	279	40	144	1065
56.5%	26.2%	3.8%	13.5%	100%

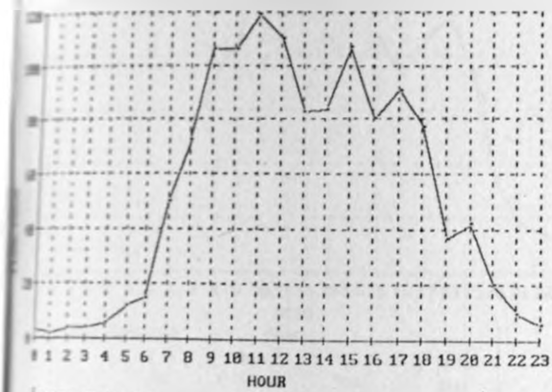
NIGHT TRAFFIC (6.00 pm - 6.00 am)

P	L	B	M	VEHICLES
152	37	5	21	215
70.7%	17.2%	2.3%	9.8%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

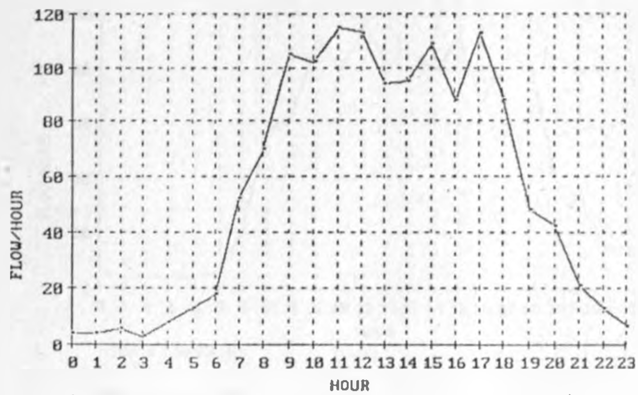
P	L	B	M	VEHICLES
25.2%	13.3%	12.5%	14.6%	20.2%

MANUAL TRAFFIC COUNT AT NARO MORU 21ST-22ND JANUARY



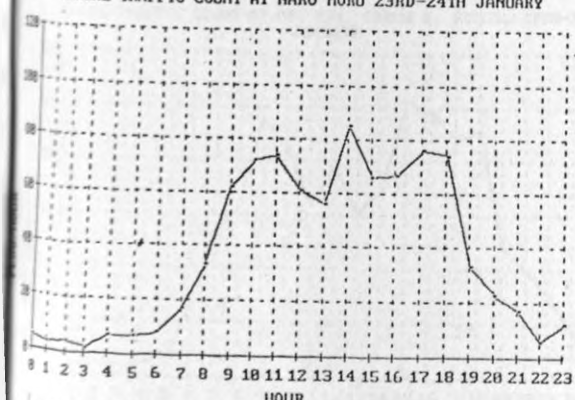
VEHICLE COMPOSITION		(%AGE)		
P	L	B	M	VEHICLES
743	321	41	134	1239
60.0%	25.9%	3.3%	10.8%	100%
NIGHT TRAFFIC (6.00 pm - 6.00 am)				
P	L	B	M	VEHICLES
155	51	6	14	226
68.5%	22.6%	2.7%	6.2%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
20.9%	15.9%	14.6%	10.4%	18.2%

MANUAL TRAFFIC COUNT AT NARO MORU 21ST-22ND JANUARY



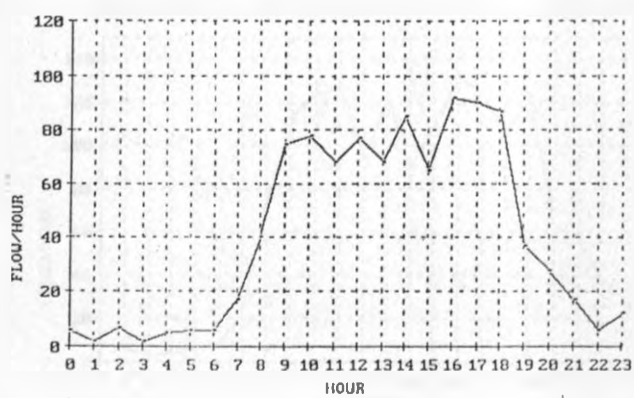
VEHICLE COMPOSITION		(%AGE)		
P	L	B	M	VEHICLES
833	317	45	137	1332
62.5%	23.8%	3.4%	10.3%	100%
NIGHT TRAFFIC (6.00 pm - 6.00 am)				
P	L	B	M	VEHICLES
183	53	6	16	258
70.9%	20.5%	2.3%	6.2%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
22.0%	16.7%	13.3%	11.7%	19.4%

MANUAL TRAFFIC COUNT AT NARO MORU 23RD-24TH JANUARY



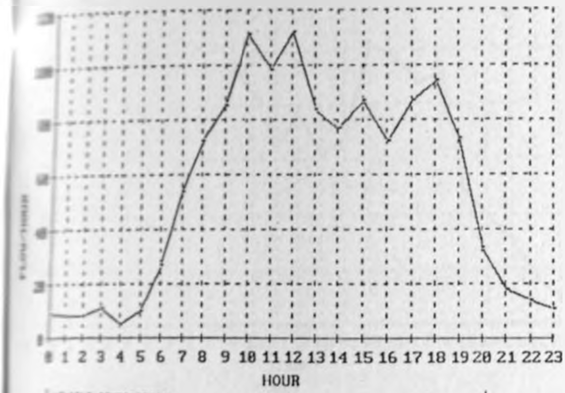
VEHICLE COMPOSITION		(%AGE)		
P	L	B	M	VEHICLES
555	128	41	141	865
64.2%	14.8%	4.7%	16.3%	100%
NIGHT TRAFFIC (6.00 pm - 6.00 am)				
P	L	B	M	VEHICLES
145	19	8	20	192
75.5%	9.9%	4.2%	10.4%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
26.1%	14.8%	19.5%	14.2%	22.2%

MANUAL TRAFFIC COUNT AT NARO MORU 23RD-24TH JANUARY



VEHICLE COMPOSITION		(%AGE)		
P	L	B	M	VEHICLES
647	124	41	171	983
65.8%	12.6%	4.2%	17.4%	100%
NIGHT TRAFFIC (6.00 pm - 6.00 am)				
P	L	B	M	VEHICLES
165	20	8	23	216
76.4%	9.3%	3.7%	10.6%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
25.5%	16.1%	19.5%	13.5%	22.0%

MANUAL TRAFFIC COUNT AT NARO MORU 25TH-26TH JANUARY



VEHICLE COMPOSITION (%AGE)

P	L	B	M	VEHICLES
779	283	57	130	1249
62.4%	22.6%	4.6%	10.4%	100%

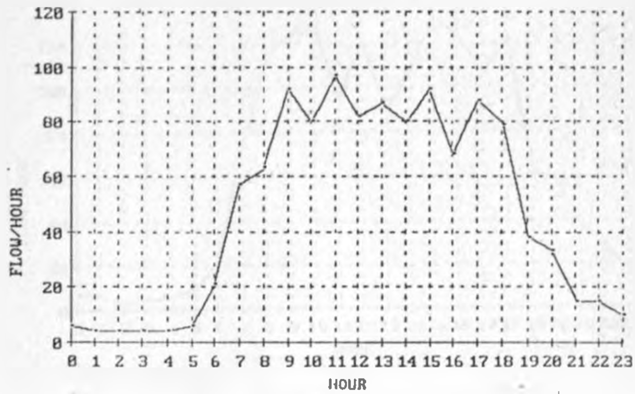
NIGHT TRAFFIC (6.00 pm - 6.00 am)

P	L	B	M	VEHICLES
220	52	9	13	294
74.8%	17.7%	3.1%	4.4%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
28.2%	18.4%	15.8%	10.0%	23.5%

MANUAL TRAFFIC COUNT AT NARO MORU 25TH-26TH JANUARY



VEHICLE COMPOSITION (%AGE)

P	L	B	M	VEHICLES
654	289	38	128	1109
59.0%	26.1%	3.4%	11.5%	100%

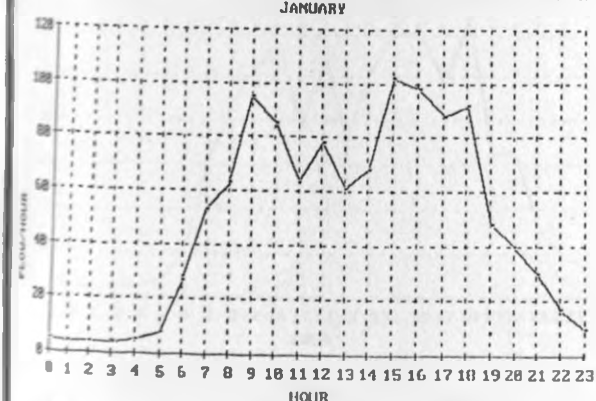
NIGHT TRAFFIC (6.00 pm - 6.00 am)

P	L	B	M	VEHICLES
146	37	7	23	213
68.5%	17.4%	3.3%	10.8%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
22.3%	12.8%	18.4%	18.0%	19.2%

MANUAL TRAFFIC COUNT AT MOI EQT. GIRLS S. SCHOOL 27TH-28TH JANUARY



VEHICLE COMPOSITION (%AGE)

P	L	B	M	VEHICLES
738	262	45	88	1133
[illegible]	23.1%	4.0%	7.8%	100%

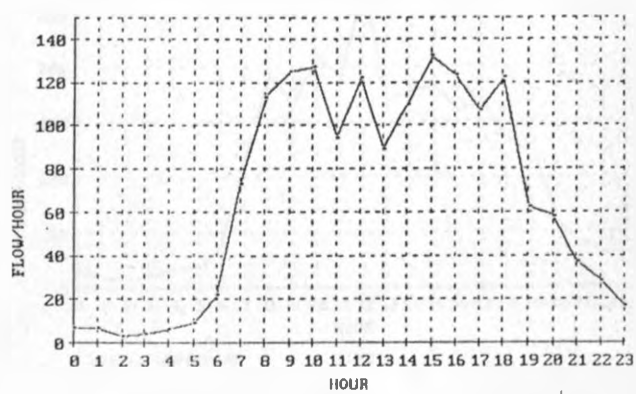
NIGHT TRAFFIC (6.00 pm - 6.00 am)

P	L	B	M	VEHICLES
198	47	8	7	260
76.1%	18.1%	3.1%	2.7%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
[illegible]	17.9%	17.8%	8.0%	22.9%

MANUAL TRAFFIC COUNT AT SILVERBECK HOTEL 27TH-28TH JANUARY



VEHICLE COMPOSITION (%AGE)

P	L	B	M	VEHICLES
1087	350	40	96	1573
69.1%	22.3%	2.5%	6.1%	100%

NIGHT TRAFFIC (6.00 pm - 6.00 am)

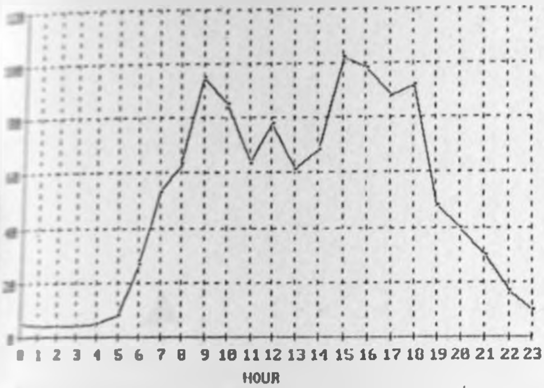
P	L	B	M	VEHICLES
282	51	7	7	347
81.3%	14.7%	2.0%	2.0%	100%

%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC

P	L	B	M	VEHICLES
25.9%	14.6%	17.5%	7.3%	22.1%

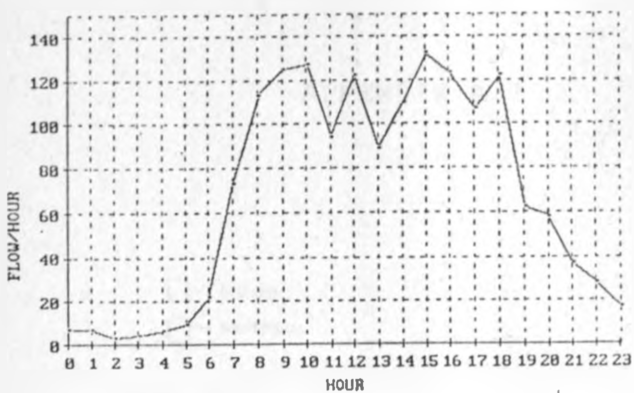
A.2/7

MANUAL TRAFFIC COUNT AT MOI EQT. GIRLS S. SCHOOL 27TH-28TH JANUARY



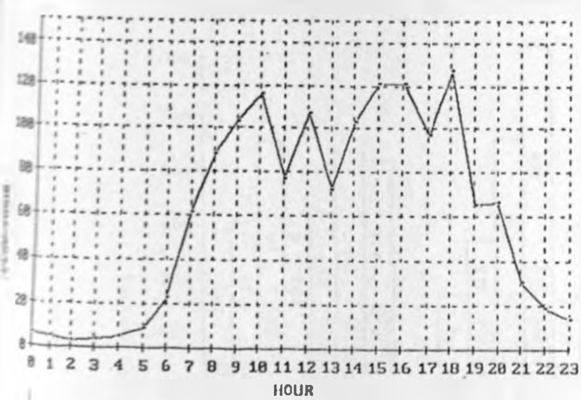
VEHICLE COMPOSITION		(%AGE)		
P	L	B	M	VEHICLES
738	262	45	88	1133
65.1%	23.1%	4.0%	7.8%	100%
NIGHT TRAFFIC	(6.00 pm - 6.00 am)			
P	L	B	M	VEHICLES
198	47	8	7	260
76.1%	18.1%	3.1%	2.7%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
26.8%	17.9%	17.8%	8.0%	22.9%

MANUAL TRAFFIC COUNT AT SILVERBECK HOTEL 27TH-28TH JANUARY



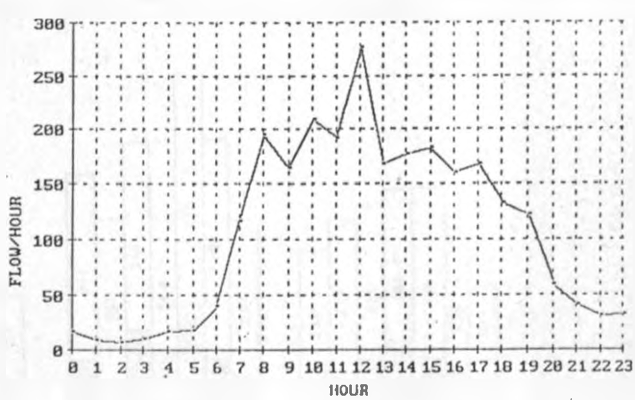
VEHICLE COMPOSITION		(%AGE)		
P	L	B	M	VEHICLES
1087	350	40	96	1573
69.1%	22.3%	2.5%	6.1%	100%
NIGHT TRAFFIC	(6.00 pm - 6.00 am)			
P	L	B	M	VEHICLES
282	51	7	7	347
81.3%	14.7%	2.0%	2.0%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
25.9%	14.6%	17.5%	7.3%	22.1%

MANUAL TRAFFIC COUNT AT SILVERBECK HOTEL 27TH-28TH JANUARY



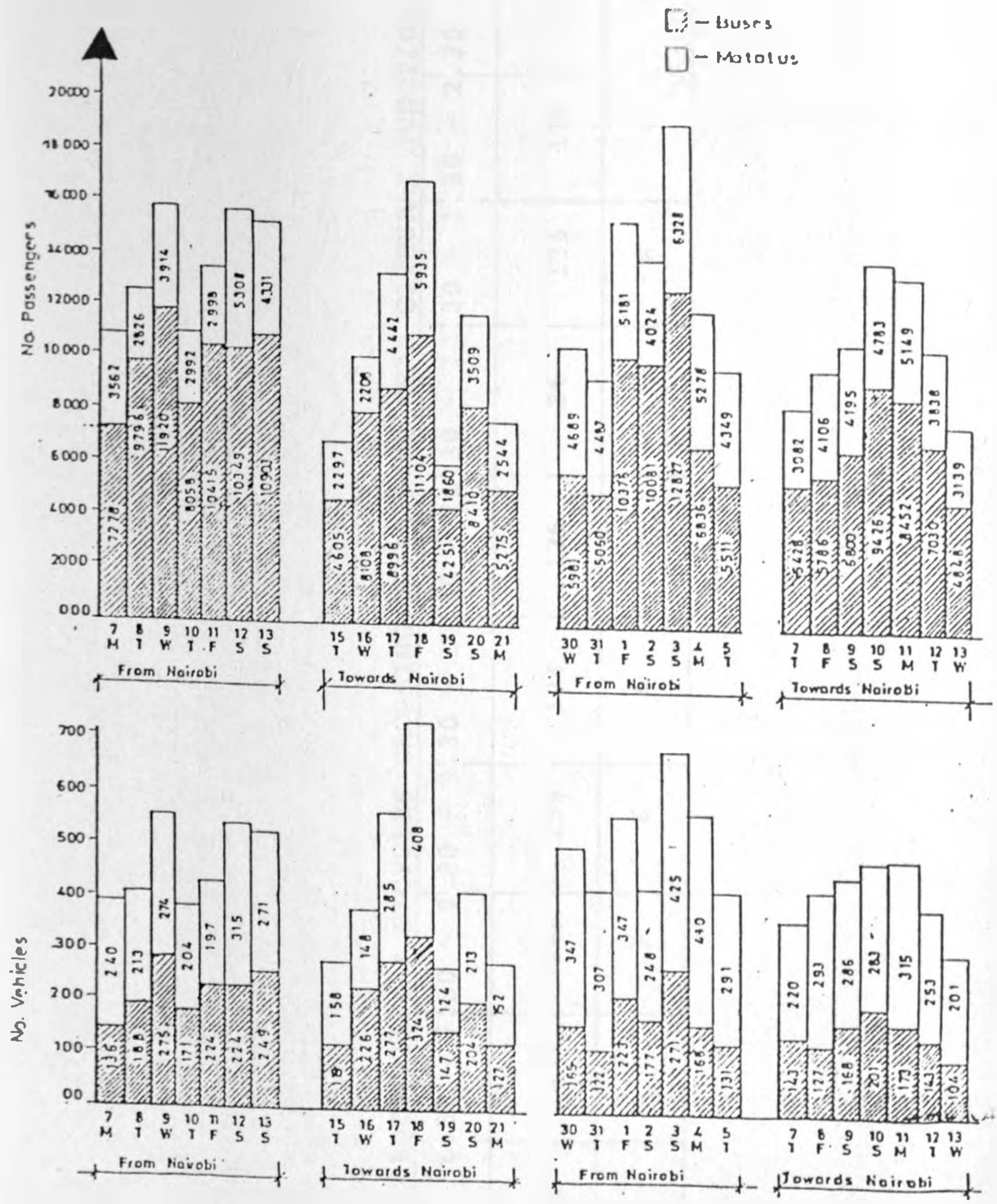
VEHICLE COMPOSITION		(%AGE)		
P	L	B	M	VEHICLES
971	311	43	109	1434
67.7%	21.7%	3.0%	7.6%	100%
NIGHT TRAFFIC	(6.00 pm - 6.00 am)			
P	L	B	M	VEHICLES
263	65	8	5	351
74.9%	18.5%	2.3%	4.3%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
27.1%	20.9%	18.6%	13.7%	24.5%

MANUAL TRAFFIC COUNT AT NANYUKI TOWN HALL 26TH-27TH JANUARY



VEHICLE COMPOSITION		(%AGE)		
P	L	B	M	VEHICLES
1881	405	69	176	2531
74.3%	16.0%	2.7%	7.0%	100%
NIGHT TRAFFIC	(6.00 pm - 6.00 am)			
P	L	B	M	VEHICLES
406	60	16	17	499
81.4%	12.0%	3.2%	3.4%	100%
%AGE NIGHT TRAFFIC / 24 HOURS TRAFFIC				
P	L	B	M	VEHICLES
21.6%	14.8%	23.2%	9.7%	1.9%

APPENDIX A.3



Public Transportation Usage Registration Near Safari Park 7:7 - 21:7:80.

Public Transportation Usage Registration East of Ruiru 30.7 - 13:8:80.

PEDESTRIANS & BICYCLES CROSSING THIKA ROAD NEAR GITH

TIME	6.30 - 7.30	7.30 - 8.30	8.30 - 9.30	9.30 - 10.30	10.30 - 11.30	11.30 - 12.30	12.30 -
PEDESTRIANS	337	298	139	124	126	86	13
BICYCLES	6	9	6	4	7	3	8

APPENDIX A.5

POLICE 41

THE KENYA POLICE—TRAFFIC DEPARTMENT

Charge Reg. No. ....

ACCIDENT REPORT

Acc. Reg. No. ....

O.B. No. ....

Reporting Officer .... Division .... Station ....

Location of Accident ....

....

Highway Authority ....

Date .... Day .... Time ....

	Types of Vehicles concerned	Registration Numbers	Names and Addresses of Owners and/or Drivers (state which)	Brief details of damage
1				
2				
3				

	If in order state "Yes" If endorsed or not in order give details overleaf 1.	2.	3.
Certificate of Competency			
Driving Licence			
Road Tax			
Insurance			
T.L.B. Licence			
P.S.V. or Taxi Licence			

Name and Address of injured persons	Class of person	Age	Sex	Fatal Serious Slight	From Vehicle No.	Tribe or Nationality

Class of Person: "P" Pedestrian. "D" Driver. "MC" Motor Cyclist. "PS" Passenger. "C" Cyclist. "PP" Pillion Passenger. "O.P." Other Person. In Case of Fatal Accident give Date of Death.

Names and Addresses of witnesses.—

....

Nationality or Tribe of vehicle driver primarily responsible ....

ROAD SURFACE Tarmac/Murram/Unmade, Wet, Dry. Speed limit of .... m.p.h.
Street lighting—Yes/No

Apparent Cause Code No .... Special Features if any ....

Are Court proceedings Contemplated—Yes No
When a Police vehicle is involved, this form must be despatched to the Commissioner of Police and the Divisional Transport Officer within 24 hours. (P.T.O.)

Items of Accident (Prepare sketch plan on separate sheet of paper).

Remarks of Investigating Officer.

Has a notice of intended prosecution been served against either driver and, if so, on whom: __________

____

____

____

Date of serving: ____________________

Action taken

(Police accidents only)

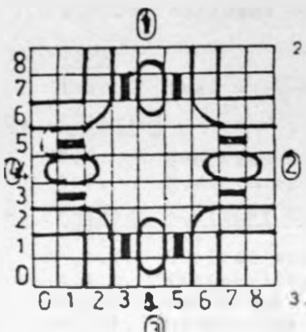
		Date
Despatched to Commissioner of Police		__________
,, ,, P.P.O.	Through D.T.O.	__________
,, ,, Divisional Officer		__________

Date ____________________

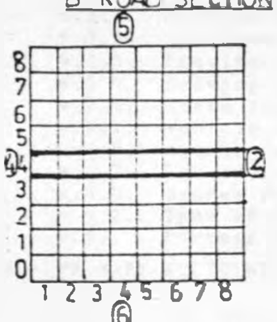
____
Officer in charge Police Station

GPK (I)

A. NODE



B. ROAD SECTION



RECONSTRUCTED SCENE	
ELEMENT	MAKE
FIRST	
SECOND	

1. GENERAL

1.1. Type of form
1.2. Police Station
1.2.3. Accident report reg. number
1.2.4. Classification of the road

2. TIME, PAVEMENT, LIGHT & WEATHER CONDITION

2.1.1. Day of week
2.1.2. Year
2.1.3. Month
2.1.4. Day of month
2.1.5. Time of day
2.2. Pavement
2.3. Road surface condition
2.4. Weather condition
2.5. Light condition

3. LOCATION

3.1. Accident location
3.2.1. Node I
3.2.2. Node II/other locations
3.3.1. Alignment
3.3.2. Sight obstruction
3.3.3. Pedestrian/bicycle crossing
3.3.4. Bus-stop/railway crossing
3.3.5. Access

4. PRIMARY ACCIDENT SPOT

5. THE FIRST ELEMENT INVOLVED IN THE ACCIDENT

5.1. Type of 1st element in the accident involvement
5.2. Maneuvre
5.3. Direction of travel
5.4.1. Changes in cross-section
5.4.2. Changes caused by road inventory
5.4.3. Changes in traffic environment
5.4.4.1. Type of disturbing traffic element
5.4.4.2. The traffic element's maneuver
5.4.4.3. Direction of travel
5.5.1. Traffic violation
5.5.2. Medical/Psyco-condition
5.5.3. Socio. aspects of the traffic violation
5.5.4. Vehicle failure, load, passenger
5.6.1. Secondary accident element
5.6.2. Type of collision obstruction
5.6.3. Secondary spot of collision

6. THE SECOND ELEMENT INVOLVED IN THE ACCIDENT

6.1. Type of 2nd element in the accident involvement
6.2. Maneuvre
6.3. Direction of travel
6.4.1. Changes in cross-section
6.4.2. Changes in road inventory
6.4.3. Changes in traffic environment
6.4.4.1. Type of disturbing traffic element
6.4.4.2. The traffic element's maneuvre
6.4.4.3. Direction of travel
6.5.1. Traffic Violation
6.5.2. Medical/Psycho.-condition
6.5.3. Socio. Aspects of traffic violation
6.5.4. Vehicle failure, load, passenger
6.6.1. Secondary accident element
6.6.2. Type of collision obstruction
6.6.3. Secondary spot of collision

7. INJURIES, PROPERTY DAMAGES

7.1. The degree of injury
7.2. Number of injured persons
7.3. Number of vehicles damaged.

8. TYPE OF ACCIDENT

UNIVERSITY OF NAIROBI DEPARTMENT OF CIVIL ENGINEERING	KENYA POLICE TRAFFIC DEPARTMENT	ACCIDENT DATA FORM A.	G.S.O. AGOKI	NO.
		ROAD NAME:	ROAD NUMBER:	
		DATE:		

1. GENERAL

1.1. Type of form — 2
1.2.1. Police Station
1.2.2. Accident report reg. number

2. TIME

Year — Year when accident occurred

3. LOCATION

3.1. Junction detail
3.2. Road category

4. PRIMARY ACCIDENT ELEMENT 1 (DRIVER1)

4.1.1. Sex
4.1.2. Marital status
4.1.3. Nationality/race/tribe
4.1.4. Age Group
4.1.5. Occupation
4.2. Degree of injury
4.3.1. Driving experience
4.3.2. Frequency of accident involvement
4.3.3. Previous court conviction
4.3.4. Driving speed prior to accident
4.3.5. Speed limit
4.4.1. Vehicle registration number
4.4.2. Age of vehicle,
4.4.3. Pre accident defect
4.4.4. Degree of damage
4.4.5. Type of damage
4.5. Purpose of trip

5. PRIMARY ACCIDENT ELEMENT 2 (DRIVER2)

5.1.1. Sex
5.1.2. Marital Status
5.1.3. Nationality/race/tribe
5.1.4. Age group
5.1.5. Occupation
5.2. Degree of injury
5.3.1. Driving experience
5.3.2. frequency of accident involvement
5.3.3. Previous court conviction
5.3.4. Driving speed prior to accident
5.3.5. Speed limit
5.4.1. Vehicle registration number
5.4.2. Age of vehicle
5.4.3. Pre-accident defect
5.4.4. Degree of damage
5.4.5. Type of damage
5.5. Purpose of trip

6. OTHER INJURED PERSONS

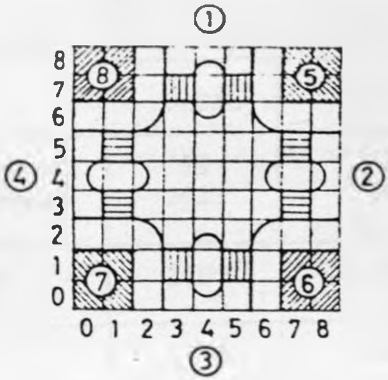
6.1. Accident element type
6.2. Driver/Passenger/pedestrians Sex
6.3. Driver/Passenger/Pedestrians age group
6.4. Marital status
6.5. Nationality/race/tribe
6.6. Occupation
6.7. Degree of injury
6.8. Purpose of trip

7.1. Accident element type
7.2. Drive/Passenger/Pedestrian, Sex
7.3. Driver/Passenger/Pedestrian, age group
7.4. Marital Status
7.5. Nationality/race/tribe
7.6. Occupation
7.7. Degree of injury
7.8. Purpose of trip

8.1. Accident element type
8.2. Driver/Passenger/Pedestrian Sex
8.3. Driver/Passenger/Pedestrian Age group
8.4. Marital status
8.5. Nationality/race/tribe
8.6. Occupation
8.7. Degree of inury
8.8. Purpose of trip

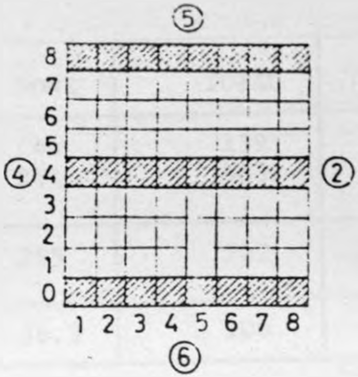
UNIVERSITY OF NAIROBI DEPARTMENT OF CIVIL ENGINEERING	KENYA POLICE TRAFFIC DEPT.	ACCIDENT DATA FORM B	G.S.O. AGOKI	NO.
		ROAD NAME:	ROAD NUMBER:	
		DATE:		

- 361 -



8	Roadside
6	Footpath
6	Parking place, shoulder
5	Carriageway/traffic lane
3	Carriageway

CODING FOR RTA LOCATION



2	Parking place, shoulder
1	Footpath
0	Roadslide
99	Unknown

NAIROBI - THIKA ROAD RTAS DISTRIBUTION BY LO

LOCATION	SEVERITY OF INJURY			
	FATAL	SERIOUS	SLIGHT	NONE
Junctions	29	27	39	44
Sections	101	106	145	211
Total	130	133	184	255
%	18.6	18.9	26.2	36.3

NAIROBI - THIKA ROAD DISTRIBUTION OF RTAS IN

TYPE	SEVERITY OF INJURY		
	FATAL	SERIOUS	SL
1. Vehicle-vehicle in same direction	2	7	
2. Head-on collision	1	1	
3. Turning from same direction	0	0	
4. Turning from opposite direction	0	0	
5. Crossing without turning	1	0	
6. Crossing with turning	0	0	
7. Pedestrian crossing carriageway	25	7	
8. Pedestrian walking along	7	0	
9. Vehicle turns off the road	5	9	
0. Other types	10	11	
TOTAL	51	35	
%	25.5	17.5	

KIGANJO-NANYUKI ROAD: DISTRIBUTION OF RTAs BY DAY AND NIGHT

TYPE	DAY	NIGHT	TOTAL	%
1: Vehicle-vehicle in same direction	12	1	13	13.8
2: Head-on collision	12	8	20	21.3
3: Turning from same direction	2	0	2	2.1
4: Turnign from opposite direction	1	0	1	1.1
5: Crossing without turning	1	0	1	1.1
6: Crossing with turning	2	0	2	2.1
7: Pedestrian crossing carriageway	9	3	12	12.7
8: Pedestrian walking along the road	3	0	3	3.2
9: Vehicle turns off road	14	6	20	21.3
0: Other types	14	6	20	21.3
TOTAL	70	24	94	100
	74.5	25.5	100	

KIGANJO-NANYUKI ROAD: SEX DISTRIBUTION OF DRIVERS, PEDESTRIANS AND CYCLISTS INVOLVED IN RTAs

SEX	ELEMENTS			
	FIRST	SECOND	TOTAL	%
Irrelevant (animals)	0	3	3	1.8
Unknown	6	5	11	6.7
Male	94	48	142	87.1
Female	1	6	7	4.3
Total	101	62	163	100
%	62.0	38.0	100	

DISTRIBUTION OF RTAS BY TYPE : NAIROBI - THIKA ROAD

APPENDIX A.11

TYPE	SEVERITY OF INJURY					
	FATAL	SERIOUS	SLIGHT	NONE	TOTAL	%
1. Vehicle-vehicle in same direction	14	23	53	176	266	37.9
2. Head-on collision	3	3	1	2	8	1.1
3. Turning from same direction	1	3	4	10	18	2.6
4. Turning from opposite direction	0	0	0	2	2	0.3
5. Crossing without turning	2	3	7	9	21	3.0
6. Crossing with turning	1	3	5	3	12	1.7
7. Pedestrian crossing carriageway	57	33	19	1	110	15.7
8. Pedestrian walking along	11	7	6	0	24	3.4
9. Vehicle turns off the road	16	33	52	31	132	18.8
0. Other types	25	26	37	21	109	15.5
TOTAL	130	133	184	255	702	100

KIGANJO-NAYUKI ROAD: DISTRIBUTION OF RTAs BY TYPE

APPENDIX A.12

TYPE	SEVERITY OF INJURY			TOTAL	%
	FATAL	SERIOUS	SLIGHT		
1. Vehicle-vehicle in same direction	4	3	6	13	13.7
2. Head-on collison	5	10	5	20	21.3
3. Turning from same direction	1	1	0	2	2.1
4. Turning from opposite direction	0	1	0	1	1.1
5. Crossing without turning	1	0	0	1	1.1
6. Crossing with turning	0	2	0	2	2.1
7. Pedestrian crossing carriageway	5	7	0	12	12.8
8. Pedestrian waling along the road	0	1	2	3	3.2
9. Vehicle turns off the road	4	8	8	20	21.3
0. Other types	5	12	3	20	21.3
TOTAL	25	45	24	94	100

1948	0	5.251120	.	5.199167	5.240178	.	.
1949	1	.	5.489	5.400955	5.243358	.	.
1950	2	.	5.579	5.609661	5.633720	.	.
1951	3	.	5.669	5.825452	5.840789	.	.
1952	4	.	5.760	6.048491	6.055000	.	.
1953	5	.	5.851	6.278941	6.276563	.	.
1954	6	.	5.948	6.516960	6.505693	.	.
1955	7	.	6.048	6.762704	6.742609	.	.
1956	8	.	6.993	7.016326	6.987533	.	.
1957	9	.	7.209	7.277972	7.240690	.	.
1958	10	.	7.432	7.547785	7.502307	.	.
1959	11	.	7.880	7.825900	7.772616	.	.
1960	12	.	8.115	8.112446	8.051849	.	.
1961	13	.	8.352	8.407545	8.340241	.	.
1962	14	8.636263	.	8.711310	8.638030	.	.
1963	15	.	8.847	9.023844	8.945455	.	.
1964	16	.	9.104	9.345242	9.262756	.	.
1965	17	.	9.385	9.675586	9.590173	.	.
1966	18	.	9.643	10.014948	9.927946	.	.
1967	19	.	9.948	10.363386	10.276319	.	.
1968	20	.	10.209	10.720944	10.635530	.	.
1969	21	10.942706	.	11.087655	11.005817	.	.
1970	22	.	11.247	11.463533	11.387421	.	.
1971	23	.	11.694	11.848578	11.780574	.	.
1972	24	.	12.091	12.242773	12.185511	.	.
1973	25	.	12.504	12.646083	12.602459	.	.
1974	26	.	12.935	13.058455	13.031642	.	.
1975	27	.	13.413	13.479816	13.473281	.	.
1976	28	.	13.853	13.910076	13.927589	.	.
1977	29	.	14.348	14.349121	14.394773	.	.
1978	30	.	14.875	14.796821	14.875033	.	.
1979	31	15.427000	.	15.253021	15.368559	.	.
1980	32	.	16.053	15.717547	15.875524	16.440	16.491
1981	33	.	16.500	16.190202	16.396130	.	.
1982	34	.	17.100	16.670768	16.930509	.	.
1983	35	.	18.784	17.159005	17.478616	.	.
1984	36	.	.	17.654652	18.041194	.	.
1985	37	.	.	18.157426	18.617759	20.154	20.207
1986	38	.	.	18.667023	19.208520	.	.
1987	39	.	.	19.183119	19.813863	.	.
1988	40	.	.	19.705366	20.433577	.	.
1989	41	.	.	20.233404	21.096762	.	.
1990	42	.	.	20.766848	21.716581	23.811	25.032
1991	43	.	.	21.305299	22.379931	.	.
1992	44	.	.	21.848239	23.057847	.	.
1993	45	.	.	22.395535	23.750303	.	.
1994	46	.	.	22.946442	24.457250	.	.
1995	47	.	.	23.500600	25.178616	.	.
1996	48	.	.	24.057539	25.914305	.	.
1997	49	.	.	24.616779	26.664193	.	.
1998	50	.	.	25.177831	27.428134	.	.
1999	51	.	.	25.740201	28.205951	.	.
2000	52	.	.	26.303389	28.997445	31.125	38.550
2001	53	.	.	26.866893	29.802385	.	.
2002	54	.	.	27.430209	30.620515	.	.
2003	55	.	.	27.992836	31.451551	.	.
2004	56	.	.	28.554271	32.295179	.	.
2005	57	.	.	29.114020	33.151058	.	.
[illegible]	58	.	.	[illegible]	[illegible]	.	.
[illegible]	59	.	.	[illegible]	[illegible]	.	.
[illegible]	60	.	.	[illegible]	[illegible]	.	.
[illegible]	61	.	.	[illegible]	[illegible]	.	.

YEAR	TIME	VEHICLES
1949	0	.030014
1950	1	.035408
1951	2	.039900
1952	3	.044170
1953	4	.043939
1954	5	.049778
1955	6	.056861
1956	7	.063626
1957	8	.067670
1958	9	.073358
1959	10	.077669
1960	11	.089505
1961	12	.084540
1962	13	.087130
1963	14	.087073
1964	15	.092581
1965	16	.098258
1966	17	.103175
1967	18	.109439
1968	19	.113329
1969	20	.124348
1970	21	.137271
1971	22	.149750
1972	23	.159969
1973	24	.164222
1974	25	.184086
1975	26	.199715
1976	27	.203446
1977	28	.213451
1978	29	.225447
1979	30	.232189
1980	31	.240435
1981	32	.246132
1982	33	.247162
1983	34	.250919
1984	35	.
1985	36	.
1986	37	.
1987	38	.
1988	39	.
1989	40	.
1990	41	.
1991	42	.
1992	43	.
1993	44	.
1994	45	.
1995	46	.
1996	47	.
1997	48	.
1998	49	.
1999	50	.
2000	51	.
2001	52	.
2002	53	.
2003	54	.
2004	55	.
2005	56	.
2006	57	.
2007	58	.
2008	59	.

AGOKI1	AGOKI2	YEAR	TIME	MOTORIZA	MOV.AVER	AGGLIFRE
.036600	.036680	1949	0	.00547	.	.00725
.039026	.039097	1950	1	.00635	.	.00744
.041612	.041671	1951	2	.00688	.00678	.00764
.044367	.044415	1952	3	.00767	.00736	.00784
.047304	.047339	1953	4	.00751	.00797	.00804
.050433	.050454	1954	5	.00837	.00841	.00825
.053766	.053773	1955	6	.00940	.00875	.00847
.057318	.057309	1956	7	.00910	.00923	.00869
.061102	.061076	1957	8	.00939	.00952	.00891
.065132	.065089	1958	9	.00987	.00985	.00914
.069425	.069364	1959	10	.00986	.01005	.00938
.073997	.073918	1960	11	.01103	.01019	.00962
.078865	.078769	1961	12	.01012	.01019	.00986
.084048	.083935	1962	13	.01009	.01025	.01011
.089566	.089438	1963	14	.00984	.01014	.01037
.095440	.095297	1964	15	.01017	.01025	.01063
.101692	.101537	1965	16	.01047	.01044	.01090
.108345	.108181	1966	17	.01070	.01069	.01112
.115423	.115255	1967	18	.01100	.01093	.01146
.122953	.122786	1968	19	.01110	.01127	.01175
.130962	.130803	1969	20	.01136	.01170	.0120[illegible]
.139478	.139336	1970	21	.01221	.01214	.01234
.148532	.148418	1971	22	.01281	.01255	.01265
.158157	.158082	1972	23	.01323	.01312	.01296
.168384	.168366	1973	24	.01313	.01366	.01328
.179251	.179307	1974	25	.01423	.01403	.01360
.190792	.190945	1975	26	.01489	.01438	.01394
.203047	.203324	1976	27	.01469	.01478	.01427
.216057	.216488	1977	28	.01494	.01494	.01462
.229962	.230485	1978	29	.01516	.01496	.01497
.244508	.245365	1979	30	.01504	.01501	.0153[illegible]
.260039	.261132	1980	31	.01493	.	.0157[illegible]
.275503	.277989	1981	32	.01492	.	.01607
.295847	.295647	1982	33	.01450	.	.01646
.312428	.314816	1983	34	.01336	.	.01684
.331992	.334961	1984	35	.	.	.01724
.352695	.356349	1985	36	.	.	.01764
.374593	.379052	1986	37	.	.	.01805
.397740	.405142	1987	38	.	.	.01847
.422196	.428693	1988	39	.	.	.01890
.448020	.455900	1989	40	.	.	.01933
.475271	.484532	1990	41	.	.	.01977
.504008	.514981	1991	42	.	.	.02022
.534291	.547239	1992	43	.	.	.02067
.566180	.581395	1993	44	.	.	.02114
.599735	.617552	1994	45	.	.	.02161
.635013	.655805	1995	46	.	.	.02209
.672072	.696260	1996	47	.	.	.02257
.710966	.739020	1997	48	.	.	.02306
.751748	.784193	1998	49	.	.	.02357
.794468	.831889	1999	50	.	.	.02407
.839169	.882220	2000	51	.	.	.02459
.885895	.935296	2001	52	.	.	.02511
.934631	.991233	2002	53	.	.	.02564
.985558	1.050143	2003	54	.	.	.02616
.033551	1.112139	2004	55	.	.	.026[illegible]
[illegible]	[illegible]	2005	56	.	.	[illegible]
[illegible]	[illegible]	2006	57	.	.	[illegible]
[illegible]	[illegible]	2007	58	.	.	[illegible]
[illegible]	[illegible]	2008	59			[illegible]

APPENDIX A.

A.13/3

YEAR	TIME	RTAVEHIC	MOVINGAV	AGOKI
1960	0	2788	.	2106
1961	1	2377	.	2217
1962	2	2469	2494	2335
1963	3	2385	2445	2458
1964	4	2450	2458	2588
1965	5	2542	2554	2725
1966	6	2445	2703	2868
1967	7	2947	2786	3020
1968	8	3129	2987	3179
1969	9	2869	3342	3346
1970	10	3546	3686	3522
1971	11	4217	3999	3706
1972	12	4668	4301	3901
1973	13	4695	4582	4105
1974	14	4379	4660	4319
1975	15	4751	4633	4545
1976	16	4605	4819	4782
1977	17	4536	5187	5031
1978	18	5625	5093	5292
1979	19	6216	5302	5567
1980	20	4485	5591	5855
1981	21	5648	5738	6158
1982	22	5981	.	6476
1983	23	6362	.	6809
1984	24	.	.	7159
1985	25	.	.	7526
1986	26	.	.	7910
1987	27	.	.	8314
1988	28	.	.	8736
1989	29	.	.	9190
1990	30	.	.	9644
1991	31	.	.	10130
1992	32	.	.	10639
1993	33	.	.	11171
1994	34	.	.	11729
1995	35	.	.	12312
1996	36	.	.	12921
1997	37	.	.	13558
1998	38	.	.	14224
1999	39	.	.	14919
2000	40	.	.	15644
2001	41	.	.	16401
2002	42	.	.	17190
2003	43	.	.	18013
2004	44	.	.	18870
2005	45	.	.	19762
2006	46	.	.	20691
2007	47	.	.	21657
2008	48	.	.	22661
2009	49	.	.	23704
2010	50	.	.	24735

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YEAR	TIME	RTAS	MOVAVERA	AGOKI
1960	0	4101	.	2698
1961	1	3573	.	2948
1962	2	3595	3708	3207
1963	3	3578	3600	3474
1964	4	3693	3655	3746
1965	5	3562	3813	4020
1966	6	3847	4000	4295
1967	7	4387	4101	4566
1968	8	4511	4421	4833
1969	9	4196	4860	5093
1970	10	5163	5305	5344
1971	11	6042	5761	5583
1972	12	6613	6171	5810
1973	13	6799	6446	6024
1974	14	6250	6547	6224
1975	15	6534	6414	6409
1976	16	6548	6447	6581
1977	17	5949	6807	6737
1978	18	6956	6732	6880
1979	19	8049	6873	7010
1980	20	6162	.	7128
1981	21	7250	.	7233
1982	22	7524	.	7328
1983	23	8023	.	7413
1984	24	.	.	7488
1985	25	.	.	7556
1986	26	.	.	7615
1987	27	.	.	7668
1988	28	.	.	7715
1989	29	.	.	7756
1990	30	.	.	7792
1991	31	.	.	7824
1992	32	.	.	7852
1993	33	.	.	7876
1994	34	.	.	7896
1995	35	.	.	7917
1996	36	.	.	7934
1997	37	.	.	7948
1998	38	.	.	7961
1999	39	.	.	7972
2000	40	.	.	7982
2001	41	.	.	7990
2002	42	.	.	7998
2003	43	.	.	8004
2004	44	.	.	8010
2005	45	.	.	8015
2006	46	.	.	8019
2007	47	.	.	8023
2008	48	.	.	8026
2009	49	.	.	8029
2010	50	.	.	8032

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YEAR	MOTORIZA	OBSERVED	MODEL	AGOKI
1960	110.29	.04582	.	.03962
1961	101.22	.04226	.	.03930
1962	100.88	.04126	.04206	.03928
1963	98.42	.04109	.04015	.03904
1964	101.69	.03989	.03916	.03934
1965	104.69	.03625	.03892	.03952
1966	106.99	.03729	.03866	.03960
1967	110.01	.04009	.03743	.03963
1968	111.00	.03980	.03771	.03962
1969	113.63	.03374	.03832	.03954
1970	122.05	.03761	.03857	.03885
1971	128.05	.04035	.03888	.03795
1972	132.30	.04134	.03892	.03709
1973	131.33	.04134	.03794	.03730
1974	142.31	.03395	.03624	.03439
1975	148.59	.03272	.03353	.03208
1976	146.20	.03187	.03143	.03231
1977	149.39	.02775	.03158	.03189
1978	151.54	.03086	.03016	.03104
1979	150.40	.03469	.02968	.03149
1980	149.77	.02563	.	.03174
1981	149.17	.02946	.	.03198
1982	145.70	.03020	.	.03325
1983	133.58	.03797	.	.03680
1984	172.40	.	.	.02041
1985	176.40	.	.	.01739
1986	180.50	.	.	.01515
1987	134.70	.	.	.01218
1988	189.00	.	.	.00895
1989	193.30	.	.	.00555
1990	197.70	.	.	.00188
1991	202.20	.	.	.
1992	206.70	.	.	.
1993	211.40	.	.	.
1994	215.10	.	.	.
1995	220.90	.	.	.
1996	225.70	.	.	.
1997	230.60	.	.	.
1998	235.70	.	.	.
1999	240.70	.	.	.
2000	245.90	.	.	.
2001	251.10	.	.	.
2002	256.40	.	.	.
2003	261.80	.	.	.
2004	267.20	.	.	.
2005	272.80	.	.	.
2006	278.30	.	.	.
2007	284.00	.	.	.
2008	289.70	.	.	.
2009	295.50	.	.	.
2010	301.40	.	.	.

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YEAR	TIME	OBSERVED	MODEL	AGOKI1	AGOKI2
1960	0	1.833	.	1.689	1.061
1961	1	1.691	.	1.677	1.593
1962	2	1.650	1.702	1.663	1.592
1963	3	1.644	1.654	1.648	1.585
1964	4	1.596	1.579	1.632	1.594
1965	5	1.450	1.552	1.615	1.600
1966	6	1.491	1.551	1.596	1.602
1967	7	1.603	1.499	1.576	1.601
1968	8	1.592	1.560	1.555	1.600
1969	9	1.350	1.563	1.532	1.595
1970	10	1.504	1.546	1.508	1.562
1971	11	1.614	1.539	1.482	1.521
1972	12	1.654	1.543	1.455	1.484
1973	13	1.654	1.570	1.427	1.493
1974	14	1.358	1.423	1.397	1.368
1975	15	1.309	1.285	1.365	1.271
1976	16	1.287	1.268	1.332	1.290
1977	17	1.110	1.270	1.297	1.263
1978	18	1.234	1.194	1.261	1.227
1979	19	1.388	1.135	1.224	1.246
1980	20	1.025	.	1.186	1.256
1981	21	1.178	.	1.146	1.266
1982	22	1.210	.	1.106	1.320
1983	23	1.279	.	1.065	1.471
1984	24	.	.	1.023	.783
1985	25	.	.	.981	.679
1986	26	.	.	.938	.565
1987	27	.	.	.900	.442
1988	28	.	.	.853	.309
1989	29	.	.	.811	.168
1990	30	.	.	.769	.017
1991	31	.	.	.728	.
1992	32	.	.	.687	.
1993	33	.	.	.648	.
1994	34	.	.	.609	.
1995	35	.	.	.572	.
1996	36	.	.	.536	.
1997	37	.	.	.502	.
1998	38	.	.	.469	.
1999	39	.	.	.437	.
2000	40	.	.	.407	.
2001	41	.	.	.378	.
2002	42	.	.	.351	.
2003	43	.	.	.325	.
2004	44	.	.	.301	.
2005	45	.	.	.278	.
2006	46	.	.	.257	.
2007	47	.	.	.237	.
2008	48	.	.	.219	.
2009	49	.	.	[illegible]	.
2010	50	.	.	.193	.

1949	0	713.67	.	363.38	817.73
1950	1	341.16	.	371.93	282.04
1951	2	357.27	405.57	380.47	317.59
1952	3	325.56	335.36	388.98	365.88
1953	4	290.18	360.37	397.46	356.62
1954	5	362.61	383.22	405.88	403.96
1955	6	466.22	399.85	414.26	452.17
1956	7	471.51	427.29	422.57	439.51
1957	8	408.75	436.99	430.80	451.59
1958	9	427.36	345.68	438.96	470.92
1959	10	411.10	441.02	447.02	470.38
1960	11	481.20	457.06	454.99	508.82
1961	12	476.70	481.47	462.85	480.18
1962	13	488.92	505.14	470.60	478.96
1963	14	549.42	504.53	478.23	469.85
1964	15	529.48	506.69	485.74	481.84
1965	16	478.13	517.55	493.13	492.00
1966	17	487.52	509.11	500.37	499.25
1967	18	543.22	502.00	507.48	509.04
1968	19	507.20	519.38	514.45	510.75
1969	20	[illegible]	536.13	521.27	517.52
1970	21	565.01	559.11	527.94	535.03
1971	22	571.29	591.60	534.46	543.64
1972	23	655.13	607.33	540.62	547.81
1973	24	[illegible]	590.67	547.03	547.00
1974	25	[illegible]	593.49	553.08	551.24
1975	26	[illegible]	560.55	559.98	546.63
1976	27	525.36	514.21	564.71	549.02
1977	28	[illegible]	526.63	570.29	548.27
1978	29	437.97	517.02	573.71	546.48
1979	30	535.55	504.56	580.98	547.48
1980	31	[illegible]	.	586.03	547.99
1981	32	[illegible]	.	591.04	548.43
1982	33	[illegible]	.	595.93	550.38
1983	34	[illegible]	.	600.48	548.74
1984	35	.	.	604.98	507.74
1985	36	.	.	[illegible]	495.83
1986	37	.	.	613.53	482.24
1987	38	.	.	617.59	466.71
1988	39	.	.	621.51	449.13
1989	40	.	.	625.30	430.00
1990	41	.	.	628.95	408.67
1991	42	.	.	632.47	385.07
1992	43	.	.	635.86	359.67
1993	44	.	.	639.12	331.20
1994	45	.	.	642.27	300.77
1995	46	.	.	645.29	257.66
1996	47	.	.	648.20	232.49
1997	48	.	.	651.00	174.47
1998	49	.	.	653.69	152.62
1999	50	.	.	656.28	109.35
2000	51	.	.	658.76	61.97
2001	52	.	.	661.14	12.19
2002	53	.	.	663.43	.
2003	54	.	.	665.63	.
2004	55	.	.	667.73	.
2005	56	.	.	[illegible]	.
2006	57	.	.	[illegible]	.
2007	58	.	.	[illegible]	.
[illegible]	[illegible]	.	.	[illegible]	.
[illegible]	[illegible]	.	.	[illegible]	.
[illegible]	[illegible]	.	.	[illegible]	.
.	.	.	.	.	

YEAR	TIME	DEATHS
1949	0	148
1950	1	159
1951	2	162
1952	3	157
1953	4	150
1954	5	186
1955	6	288
1956	7	302
1957	8	268
1958	9	282
1959	10	303
1960	11	332
1961	12	329
1962	13	394
1963	14	548
1964	15	521
1965	16	552
1966	17	559
1967	18	596
1968	19	670
1969	20	750
1970	21	944
1971	22	1046
1972	23	1331
1973	24	1402
1974	25	1251
1975	26	1338
1976	27	1640
1977	28	1560
1978	29	1588
1979	30	1662
1980	31	1413
1981	32	1720
1982	33	1462
1983	34	1515
1984	35	.
1985	36	.
1986	37	.
1987	38	.
1988	39	.
1989	40	.
1990	41	.
1991	42	.
1992	43	.
1993	44	.
1994	45	.
1995	46	.
1996	47	.
1997	48	.
1998	49	.
1999	50	.
2000	51	.
2001	52	.
2002	53	.
2003	54	.
2004	55	.
2005	56	.
2006	57	.
2007	58	.
2008	59	.
2009	60	.
2010	61	.
		.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.	72	290	1949	54.60	148	.	[illegible]	290
.	85	310	1950	63.46	159	.	36	310
155	100	326	1951	68.77	148	155	71	326
163	118	341	1952	76.68	157	163	138	341
189	139	344	1953	75.09	150	189	123	344
217	163	362	1954	83.68	186	217	212	362
239	190	383	1955	94.01	288	239	346	383
265	222	438	1956	90.98	302	265	303	438
289	258	456	1957	93.86	268	289	344	456
297	298	478	1958	98.70	282	297	417	478
303	343	507	1959	98.56	303	303	415	507
328	393	542	1960	110.29	332	328	619	542
381	449	542	1961	101.22	329	381	458	542
425	509	560	1962	100.88	394	425	452	560
469	574	569	1963	98.42	548	469	413	569
515	642	592	1964	101.69	521	515	466	592
555	714	616	1965	104.69	552	555	517	616
580	798	637	1966	106.99	559	580	559	637
625	862	664	1967	110.01	596	625	613	664
704	937	683	1968	111.00	670	704	632	683
801	1011	738	1969	113.63	750	801	684	739
948	1081	777	1970	122.05	944	948	862	777
1095	1150	821	1971	128.05	1046	1095	1001	821
1215	1215	859	1972	132.30	1331	1215	1105	858
1294	1274	685	1973	131.33	1402	1294	1081	895
1412	1329	940	1974	142.31	1351	1412	1372	940
1458	1380	990	1975	148.89	1338	1458	1562	990
1495	1424	1018	1976	148.30	1640	1495	1545	1018
1558	1465	1059	1977	149.39	1560	1558	1577	1059
1573	1500	1104	1978	151.54	1598	1573	1642	1104
1539	1532	1142	1979	150.40	1562	1589	1607	1142
.	1559	1197	1980	149.77	1413	.	1539	1187
.	1583	1219	1981	149.17	1720	.	1570	1219
.	1603	1250	1962	145.70	1462	.	1468	1250
.	1620	1337	1983	133.52	1515	.	1136	1337
.	1635	1429	1984	172.40	.	.	2342	1429
.	1646	[illegible]	1965	[illegible]	.	.	2490	1489
.	1657	1557	1986	180.50	.	.	2546	1557
.	1669	1615	1987	184.70	.	.	2312	1615
.	1677	1682	1988	189.00	.	.	2986	1682
.	1683	1751	1989	193.30	.	.	3165	1751
.	1689	1822	1990	197.70	.	.	3354	1822
.	1694	1896	1991	202.20	.	.	3553	1896
.	1698	1972	1992	206.70	.	.	3758	1972
.	1702	2051	1993	211.40	.	.	3978	2051
.	1704	2132	1994	216.10	.	.	4204	2132
.	1707	2215	1995	220.90	.	.	4441	2215
.	1709	2301	1996	225.70	.	.	4685	2301
.	1711	2390	1997	230.60	.	.	4940	2390
.	1712	2481	1998	235.70	.	.	5213	2481
.	1713	2575	1999	240.70	.	.	5488	2575
.	1715	2671	2000	245.90	.	.	5781	2671
.	1715	2770	2001	251.10	.	.	6082	2770
.	1716	2871	2002	256.40	.	.	6397	2871
.	1717	2975	2003	261.30	.	.	6725	2975
.	1717	3081	2004	267.20	.	.	7062	3081
.	1718	3190	2005	272.50	.	.	7420	3190
.	1718	3301	2006	278.30	.	.	7760	3301
.	[illegible]	3414	2007	[illegible]	.	.	8162	3414
.	[illegible]	[illegible]	2008	[illegible]	.	.	8553	[illegible]
.	[illegible]	[illegible]	2009	[illegible]	.	.	[illegible]	[illegible]
.	[illegible]	[illegible]	2010	[illegible]	.	.	9365	[illegible]
.	.	.	.	.	.	.	.	.

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YEAR	MOTORIZA	DPERFERS	MOVINGAV	AGOKI	JACOBS	SMEED
1949	54.68	.270	.	.056	.338	.529
1950	63.46	.285	.	.140	.370	.555
1951	68.77	.286	.274	.192	.388	.570
1952	76.68	.273	.283	.270	.414	.592
1953	75.09	.256	.321	.254	.409	.587
1954	83.68	.313	.350	.342	.437	.609
1955	94.01	.476	.370	.449	.468	.633
1956	90.98	.432	.394	.417	.459	.626
1957	93.86	.372	.409	.448	.468	.633
1958	98.70	.379	.395	.499	.482	.644
1959	98.56	.385	.388	.498	.482	.643
1960	110.29	.409	.405	.625	.515	.668
1961	101.22	.394	.453	.526	.489	.649
1962	100.88	.456	.490	.523	.488	.648
1963	98.42	.619	.526	.496	.481	.643
1964	101.69	.572	.563	.531	.491	.650
1965	104.69	.589	.592	.564	.499	.656
1966	106.99	.580	.599	.589	.506	.661
1967	110.01	.599	.622	.622	.514	.667
1968	111.00	.656	.672	.633	.517	.669
1969	113.63	.685	.735	.662	.525	.674
1970	122.05	.839	.835	.758	.548	.691
1971	128.05	.894	.928	.827	.564	.702
1972	132.30	1.101	1.000	.876	.575	.710
1973	131.33	1.121	1.032	.865	.572	.708
1974	142.31	1.044	1.090	.995	.600	.727
1975	148.89	.998	1.087	1.075	.617	.738
1976	148.30	1.184	1.076	1.068	.615	.737
1977	149.39	1.087	1.083	1.081	.618	.739
1978	151.54	1.063	.283	1.107	.623	.742
1979	150.40	1.077	1.031	1.093	.621	.741
1980	149.77	.380	.	1.086	.617	.739
1981	149.17	1.042	.	1.078	.618	.736
1982	145.70	.555	.	1.036	.609	.733
1983	133.58	.807	.	.891	.578	.712
1984	172.40	.	.	1.371	.674	.775
1985	176.40	.	.	1.422	.683	.781
1986	180.50	.	.	1.475	.692	.787
1987	184.70	.	.	1.532	.702	.793
1988	189.00	.	.	1.589	.712	.799
1989	193.30	.	.	1.647	.721	.805
1990	197.70	.	.	1.707	.731	.811
1991	202.20	.	.	1.769	.741	.817
1992	206.70	.	.	1.832	.751	.823
1993	211.40	.	.	1.898	.761	.830
1994	216.10	.	.	1.964	.771	.836
1995	220.90	.	.	2.033	.782	.842
1996	225.70	.	.	2.103	.792	.848
1997	230.60	.	.	2.174	.802	.854
1998	235.70	.	.	2.249	.913	.860
1999	240.70	.	.	2.324	.823	.806
2000	245.90	.	.	2.402	.834	.872
2001	251.10	.	.	2.481	.844	.878
2002	256.40	.	.	2.563	.855	.885
2003	261.80	.	.	2.647	.866	.891
2004	267.20	.	.	2.732	.876	.897
2005	272.80	.	.	3.021	.887	.903
2006	278.30	.	.	2.909	.898	.909
2007	284.00	.	.	3.001	.909	.915
2008	289.70	.	.	3.095	.920	.921
2009	295.50	.	.	3.191	.931	.927
2010	301.40	.	.	3.290	.942	.934

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YEAR	MOTORIZA	DPERVEHI	MOVINGAV	AGOKI	JACOBS	SMEED
1949	54.68	49.30	.	25.48	61.85	96.65
1950	63.46	44.90	.	30.32	58.28	87.52
1951	68.77	41.50	41.06	33.22	56.43	82.96
1952	76.68	35.50	38.68	37.53	54.03	77.15
1953	75.09	34.10	39.82	36.67	54.48	78.23
1954	83.68	37.40	41.02	41.32	52.17	72.78
1955	94.01	50.60	41.84	46.87	49.80	67.35
1956	90.98	47.50	42.70	45.25	50.46	68.84
1957	93.86	39.60	43.02	46.79	49.83	67.42
1958	98.70	38.40	40.32	49.37	48.84	65.20
1959	98.56	39.00	38.60	49.30	48.87	65.26
1960	110.29	37.10	39.72	55.52	46.72	60.55
1961	101.22	38.90	44.62	50.71	48.35	64.11
1962	100.88	45.20	48.08	50.53	48.41	64.26
1963	98.42	62.90	51.90	49.22	48.89	65.32
1964	101.69	56.30	54.96	50.96	48.26	63.91
1965	104.69	56.20	56.82	52.56	47.70	62.69
1966	106.99	54.20	56.06	53.77	42.29	61.79
1967	110.01	54.50	56.36	55.37	46.76	60.65
1968	111.00	59.10	59.38	55.89	46.60	60.29
1969	113.63	60.30	62.50	57.28	46.16	59.36
1970	122.05	68.80	68.24	61.69	44.86	56.59
1971	128.05	69.80	73.50	64.82	44.01	54.81
1972	132.30	83.20	76.12	67.02	43.44	53.63
1973	131.33	85.40	75.76	66.52	43.57	53.89
1974	142.31	73.40	77.92	72.18	42.19	51.09
1975	148.89	67.00	75.84	75.55	41.43	49.56
1976	148.30	80.60	72.84	75.25	41.70	49.70
1977	149.39	78.30	72.48	75.81	41.38	49.46
1978	151.54	70.40	70.84	76.90	41.14	48.99
1979	150.40	71.60	63.70	76.32	41.27	49.24
1980	149.77	58.80	.	76.06	41.34	49.37
1981	149.17	69.90	.	75.69	41.40	47.51
1982	145.70	59.00	.	73.92	41.79	50.29
1983	133.58	60.40	.	67.68	43.27	53.29
1984	172.40	.	.	87.43	39.07	44.95
1985	176.40	.	.	89.42	38.72	44.27
1986	180.50	.	.	91.46	38.38	43.60
1987	184.70	.	.	93.54	38.01	42.93
1988	189.00	.	.	95.67	37.66	42.28
1989	193.30	.	.	97.79	37.32	41.65
1990	197.70	.	.	99.93	36.99	41.03
1991	202.20	.	.	102.1	36.66	40.42
1992	206.70	.	.	104.3	36.34	39.83
1993	211.40	.	.	106.6	36.01	39.24
1994	216.10	.	.	108.9	35.70	38.67
1995	220.90	.	.	111.2	35.38	38.11
1996	225.70	.	.	113.4	35.08	37.56
1997	230.60	.	.	115.8	34.78	37.03
1998	235.70	.	.	118.2	34.48	36.49
1999	240.70	.	.	120.6	34.19	35.99
2000	245.90	.	.	122.9	33.90	35.48
2001	251.10	.	.	125.4	33.62	34.99
2002	256.40	.	.	127.9	33.34	34.50
2003	261.80	.	.	130.4	33.06	34.03
2004	267.20	.	.	132.9	32.79	33.57
2005	272.30	.	.	135.4	32.52	33.10
2006	278.30	.	.	137.9	32.26	32.67
2007	284.00	.	.	140.5	32.00	32.23
2008	289.70	.	.	143.1	31.75	31.80
2009	295.50	.	.	145.5	31.50	31.39
2010	[illegible]	.	.	148.3	31.25	30.98

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YEAR	MOTORIZA	DPERVEHK	MOVINGAV	AGOKI11	AGOKI12
1949	54.68	.1972	.	.1006	.1139
1950	63.46	.1796	.	.1204	.1211
1951	68.77	.1662	.1644	.1323	.1284
1952	76.68	.1428	.1548	.1498	.1359
1953	75.09	.1366	.1594	.1463	.1436
1954	83.68	.1495	.1642	.1652	.1514
1955	94.01	.2026	.1674	.1877	.1593
1956	90.98	.1899	.1708	.1812	.1672
1957	93.86	.1584	.1721	.1874	.1752
1958	98.70	.1538	.1613	.1979	.1831
1959	98.56	.1560	.1545	.1976	.1909
1960	110.29	.1484	.1590	.2226	.1987
1961	101.22	.1557	.1785	.2033	.2064
1962	100.88	.1809	.1924	.2025	.2139
1963	98.42	.2517	.2076	.1973	.2212
1964	101.69	.2251	.2198	.2043	.2284
1965	104.69	.2247	.2272	.2107	.2353
1966	106.99	.2167	.2242	.2156	.2420
1967	110.01	.2178	.2274	.2220	.2484
1968	111.00	.2365	.2375	.2242	.2540
1969	113.63	.2413	.2500	.2297	.2605
1970	122.05	.2751	.2730	.2474	.2661
1971	128.05	.2794	.3045	.2599	.2714
1972	132.30	.3328	.3045	.2688	.2764
1973	131.33	.3415	.3031	.2567	.2812
1974	142.31	.2936	.3117	.2373	.2857
1975	148.89	.2680	.3033	.2027	.2899
1976	148.30	.3224	.2914	.3015	.2938
1977	149.39	.2911	.2899	.3045	.2975
1978	151.54	.2817	.2834	.3060	.3010
1979	150.40	.2865	.2748	.3057	.3042
1980	149.77	.2351	.	.3045	.3071
1981	149.17	.2795	.	.3032	.3099
1983	133.58	.2415	.	.2714	.3149
1984	172.40	.	.	.3496	.3171
1985	176.40	.	.	.3570	.3191
1986	180.50	.	.	.3650	.3210
1987	184.70	.	.	.3740	.3227
1988	189.00	.	.	.3820	.3243
1989	193.30	.	.	.3900	.3257
1990	197.70	.	.	.3980	.3271
1991	202.20	.	.	.4070	.3283
1992	206.70	.	.	.4150	.3294
1993	211.40	.	.	.4240	.3305
1994	216.10	.	.	.4330	.3314
1995	220.90	.	.	.4420	.3323
1996	225.70	.	.	.4510	.3331
1997	230.60	.	.	.4600	.3338
1998	235.70	.	.	.4690	.3345
1999	240.70	.	.	.4780	.3351
2000	245.90	.	.	.4870	.3357
2001	251.10	.	.	.4950	.3362
2002	256.40	.	.	.5050	.3366
2003	261.80	.	.	.5150	.3371
2004	267.20	.	.	.5240	.3374
2005	272.30	.	.	.5340	.3378
2006	278.30	.	.	.5430	.3381
2007	284.00	.	.	.5530	.3384
2008	289.70	.	.	.5627	[illegible]
2009	295.50	.	.	.5740	[illegible]
2010	301.40	.	.	.5830	.3392
.	.	.	.	.	.

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YEAR	MOTORIZA	OBSDRTAS	MOVAVERA	AGOKI
1960	110.29	4101	.	4478
1961	101.22	3573	.	3603
1962	100.88	3595	3708	3568
1963	98.42	3578	3600	3305
1964	101.90	3693	3655	3652
1965	104.69	3562	3813	3954
1966	106.99	3847	4000	4175
1967	110.01	4387	4101	4453
1968	111.00	4511	4421	4541
1969	113.63	4196	4860	4766
1970	122.05	5163	5305	5411
1971	128.05	6043	5761	5799
1972	132.30	6613	6171	6038
1973	131.33	6737	6446	5996
1974	142.31	6250	6547	6484
1975	148.89	6534	6414	6687
1976	148.30	6543	6447	6671
1977	149.39	5949	6807	6700
1978	151.54	6756	6732	6749
1979	150.40	8049	5373	6724
1980	149.77	6122	.	6709
1981	149.17	7250	.	6694
1982	145.70	7534	.	6597
1983	133.58	8023	.	6104
1984	172.40	.	.	5821
1985	176.40	.	.	5785
1986	180.50	.	.	6670
1987	184.70	.	.	6545
1988	189.00	.	.	6336
1989	193.30	.	.	6196
1990	197.70	.	.	5971
1991	202.20	.	.	5706
1992	206.70	.	.	5411
1993	211.40	.	.	5065
1994	216.10	.	.	4684
1995	220.90	.	.	4255
1996	225.70	.	.	3791
1997	230.60	.	.	3277
1998	235.70	.	.	2700
1999	240.70	.	.	2093
2000	245.90	.	.	1417
2001	251.10	.	.	698
2002	256.40	.	.	.
2003	261.80	.	.	.
2004	267.20	.	.	.
2005	272.60	.	.	.
2006	278.30	.	.	.
2007	284.00	.	.	.
2008	289.70	.	.	.
2009	295.30	.	.	.
2010	301.40	.	.	.

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YEAR	TIME	CASUALTI	MOVAVERA	AGOKI1	AGOKI2
1960	0	4307	.	3123	6172
1961	1	4030	.	3474	4532
1962	2	4260	4457	3851	4467
1963	3	4784	4535	4253	3989
1964	4	4902	4754	4680	4621
1965	5	4698	5091	5128	5182
1966	6	5125	5254	5595	5596
1967	7	5945	5530	6078	6124
1968	8	5599	6141	6573	6293
1969	9	6282	6827	7075	6730
1970	10	7756	7744	7580	8027
1971	11	8555	8824	8083	8856
1972	12	10528	9675	8579	9395
1973	13	10997	10048	9065	9276
1974	14	10540	10719	9535	10506
1975	15	9621	10729	9987	11115
1976	16	11909	10504	10418	11065
1977	17	10577	11346	10825	11158
1978	18	9874	11502	11207	11334
1979	19	14749	11294	11562	11242
1980	20	10403	.	11891	11190
1981	21	10867	.	12194	11139
1982	22	13840	.	12470	10832
1983	23	13526	.	12722	9549
1984	24	.	.	12950	12510
1985	25	.	.	13135	12605
1986	26	.	.	13340	12747
1987	27	.	.	13505	12752
1988	28	.	.	13652	12757
1989	29	.	.	13784	12722
1990	30	.	.	13900	12643
1991	31	.	.	14003	12518
1992	32	.	.	14095	12349
1993	33	.	.	14175	12124
1994	34	.	.	14246	11350
1995	35	.	.	14309	11520
1996	36	.	.	14363	11137
1997	37	.	.	14412	10697
1998	38	.	.	14454	10191
1999	39	.	.	14491	9619
2000	40	.	.	14524	8976
2001	41	.	.	14552	8273
2002	42	.	.	14577	7494
2003	43	.	.	14599	6638
2004	44	.	.	14618	5716
2005	45	.	.	14635	4692
2006	46	.	.	14649	3619
2007	47	.	.	14662	2437
2008	48	.	.	14673	1182
2009	49	.	.	14683	.
2010	50	.	.	14691	.

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YEAR	TIME	CASPERTA	MOVAVERA	AGOKI
1960	0	1.10	.	1.14
1961	1	1.10	.	1.18
1962	2	1.20	1.20	1.21
1963	3	1.30	1.24	1.25
1964	4	1.30	1.28	1.29
1965	5	1.30	1.32	1.32
1966	6	1.30	1.30	1.35
1967	7	1.40	1.34	1.38
1968	8	1.20	1.38	1.41
1969	9	1.50	1.40	1.44
1970	10	1.50	1.44	1.47
1971	11	1.40	1.52	1.49
1972	12	1.60	1.56	1.52
1973	13	1.60	1.56	1.54
1974	14	1.70	1.64	1.56
1975	15	1.50	1.68	1.58
1976	16	1.80	1.64	1.60
1977	17	1.80	1.66	1.61
1978	18	1.40	.	1.63
1979	19	1.80	.	1.64
1980	20	1.70	.	1.66
1981	21	1.80	.	1.67
1982	22	1.30	.	1.68
1983	23	1.70	.	1.69
1984	24	.	.	1.70
1985	25	.	.	1.71
1986	26	.	.	1.72
1987	27	.	.	1.72
1988	28	.	.	1.73
1989	29	.	.	1.74
1990	30	.	.	1.74
1991	31	.	.	1.75
1992	32	.	.	1.75
1993	33	.	.	1.76
1994	34	.	.	1.76
1995	35	.	.	1.76
1996	36	.	.	1.77
1997	37	.	.	1.77
1998	38	.	.	1.77
1999	39	.	.	1.77
2000	40	.	.	1.78
2001	41	.	.	1.78
2002	42	.	.	1.78
2003	43	.	.	1.78
2004	44	.	.	1.78
2005	45	.	.	1.79
2006	46	.	.	1.79
2007	47	.	.	1.79
2008	48	.	.	1.79
2009	49	.	.	1.79
2010	50	.	.	1.79

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YEAR	MOTORIZA	CASPERTA	MOVAVERA	AGOKI
1960	110.29	1.10	.	1.36
1961	101.22	1.10	.	1.24
1962	100.88	1.20	1.20	1.24
1963	98.42	1.30	1.24	1.20
1964	101.69	1.30	1.28	1.25
1965	104.69	1.30	1.32	1.29
1966	106.99	1.30	1.30	1.32
1967	110.01	1.40	1.34	1.36
1968	111.00	1.20	1.38	1.37
1969	113.63	1.50	1.40	1.40
1970	122.05	1.50	1.44	1.48
1971	129.05	1.40	1.52	1.53
1972	132.30	1.60	1.56	1.55
1973	131.33	1.60	1.56	1.55
1974	142.31	1.70	1.64	1.59
1975	148.89	1.50	1.68	1.60
1976	146.30	1.30	1.64	1.60
1977	149.39	1.80	1.66	1.60
1978	151.54	1.40	1.50	1.60
1979	150.40	1.80	1.50	1.60
1980	149.77	1.70	.	1.60
1981	149.17	1.80	.	1.60
1982	145.70	1.80	.	1.59
1983	133.58	1.70	.	1.56
1984	172.40	.	.	1.52
1985	176.40	.	.	1.49
1986	180.50	.	.	1.45
1987	184.70	.	.	1.41
1988	189.00	.	.	1.37
1989	193.30	.	.	1.31
1990	197.70	.	.	1.18
1991	202.20	.	.	1.11
1992	206.70	.	.	1.11
1993	211.40	.	.	1.03
1994	216.10	.	.	.94
1995	220.90	.	.	.84
1996	225.70	.	.	.73
1997	230.60	.	.	.62
1998	235.70	.	.	.49
1999	240.70	.	.	.36
2000	245.90	.	.	.21
2001	251.10	.	.	.06
2002	256.40	.	.	.
2003	261.80	.	.	.
2004	267.20	.	.	.
2005	272.80	.	.	.
2006	278.30	.	.	.
2007	284.00	.	.	.
2008	289.70	.	.	.
2009	295.50	.	.	.
2010	301.40	.	.	.

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YEAR	TIME	INJURIES	MOVINGAV	ABOKI1	ABOKI2
1949	0	1994	.	1033	.
1950	1	1049	.	1155	27
1951	2	1231	1336	1291	529
1952	3	1281	1261	1441	1303
1953	4	1125	1524	1606	1145
1954	5	1619	1817	1786	2015
1955	6	2363	2061	1984	3112
1956	7	2698	2406	2200	2784
1957	8	2498	2660	2434	3095
1958	9	2853	2983	2687	3627
1959	10	2890	3183	2959	3612
1960	11	3975	3457	3251	4951
1961	12	3701	3734	3562	3909
1962	13	3866	4032	3891	3871
1963	14	4236	4066	4238	3596
1964	15	4381	4220	4600	3962
1965	16	4146	4465	4978	4303
1966	17	4471	4633	5367	4567
1967	18	5089	4837	5767	4918
1968	19	5078	5370	6173	5034
1969	20	5399	5977	6585	5345
1970	21	6812	6799	6997	6364
1971	22	7509	7702	7408	7113
1972	23	9197	8460	7814	7654
1973	24	9595	8754	8212	7530
1974	25	9187	9306	8600	8966
1975	26	8283	9270	8975	9856
1976	27	10269	9008	9336	9775
1977	28	9017	9788	9680	9924
1978	29	8286	9928	10007	10221
1979	30	13087	10107	10315	10063
1980	31	8980	.	10605	9976
1981	32	11167	.	10874	9894
1982	33	12378	.	11125	9421
1983	34	13526	.	11356	7819
1984	35	.	.	11569	13218
1985	36	.	.	11764	13819
1986	37	.	.	11944	14442
1987	38	.	.	12106	15090
1988	39	.	.	12254	15763
1989	40	.	.	12388	16446
1990	41	.	.	12509	17154
1991	42	.	.	12618	17889
1992	43	.	.	12716	18633
1993	44	.	.	12804	19422
1994	45	.	.	12883	20223
1995	46	.	.	12954	21052
1996	47	.	.	13017	21893
1997	48	.	.	13073	22764
1998	49	.	.	13124	23684
1999	50	.	.	13169	24598
2000	51	.	.	13209	25563
2001	52	.	.	13245	26541
2002	53	.	.	13276	27553
2003	54	.	.	13304	28599
2004	55	.	.	13330	29659
2005	56	.	.	13352	30775
2006	57	.	.	13372	31867
2007	58	.	.	13389	33055
2008	59	.	.	13405	34240
2009	60	.	.	13419	35463
2010	61	.	.	[illegible]	[illegible]

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YEAR	TIME	INJPERVK	MOVINGAV	ABOKI1	ABOKI2
1949	0	664	.	347	205
1950	1	296	.	352	265
1951	2	316	364	358	298
1952	3	290	297	364	343
1953	4	256	321	370	335
1954	5	325	342	375	377
1955	6	416	358	381	420
1956	7	424	385	387	408
1957	8	369	394	392	419
1958	9	389	400	398	436
1959	10	372	402	404	435
1960	11	444	417	409	466
1961	12	438	437	415	443
1962	13	444	457	420	442
1963	14	487	453	425	435
1964	15	473	452	431	445
1965	16	422	456	436	453
1966	17	433	448	441	459
1967	18	465	441	446	466
1968	19	448	455	451	468
1969	20	434	469	456	473
1970	21	496	491	461	484
1971	22	501	518	466	488
1972	23	575	520	471	489
1973	24	584	504	476	489
1974	25	445	505	481	484
1975	26	415	474	485	476
1976	27	505	430	490	477
1977	28	421	454	494	475
1978	29	368	446	499	472
1979	30	564	436	503	474
1980	31	373	.	507	475
1981	32	454	.	511	476
1982	33	499	.	515	481
1983	34	539	.	519	489
1984	35	.	.	523	414
1985	36	.	.	526	398
1986	37	.	.	631	380
1987	38	.	.	535	360
1988	39	.	.	538	338
1989	40	.	.	542	314
1990	41	.	.	545	288
1991	42	.	.	548	259
1992	43	.	.	552	229
1993	44	.	.	555	195
1994	45	.	.	558	159
1995	46	.	.	561	120
1996	47	.	.	564	78
1997	48	.	.	567	34
1998	49	.	.	570	.
1999	50	.	.	573	.
2000	51	.	.	576	.
2001	52	.	.	578	.
2002	53	.	.	581	.
2003	54	.	.	583	.
2004	55	.	.	586	.
2005	56	.	.	588	.
2006	57	.	.	590	.
2007	58	.	.	593	.
2008	59	.	.	595	.
2009	60	.	.	597	.
2010	61	.	.	599	.

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YEAR	TIME	SEVINDEX	MOVINGAV	ABOKI1	ABOKI2
1949	0	6.9	.	8.5	12.1
1950	1	13.2	.	8.7	11.4
1951	2	11.6	10.9	8.9	11.0
1952	3	10.9	11.6	9.2	10.6
1953	4	11.8	11.1	9.4	10.7
1954	5	10.3	10.8	9.6	10.4
1955	6	10.9	10.6	9.7	10.3
1956	7	10.1	10.0	9.9	10.3
1957	8	9.7	9.8	10.1	10.3
1958	9	9.0	9.2	10.3	10.3
1959	10	9.5	8.8	10.5	10.3
1960	11	7.7	8.7	10.7	10.6
1961	12	8.2	9.2	10.9	10.4
1962	13	9.2	9.4	11.1	10.4
1963	14	11.5	10.2	11.2	10.3
1964	15	10.6	10.8	11.4	10.4
1965	16	11.7	11.0	11.6	10.4
1966	17	11.1	11.0	11.7	10.5
1967	18	10.1	11.4	11.9	10.6
1968	19	11.7	11.5	12.1	10.7
1969	20	12.2	11.7	12.2	10.8
1970	21	12.2	12.2	12.4	11.3
1971	22	12.2	12.4	12.5	11.7
1972	23	12.6	12.5	12.6	12.1
1973	24	12.7	12.8	12.8	12.0
1974	25	12.8	13.2	12.9	13.2
1975	26	13.9	13.6	13.0	14.0
1976	27	13.8	14.3	13.2	14.0
1977	28	14.7	14.0	13.3	14.1
1978	29	16.1	13.9	13.4	14.4
1979	30	11.3	13.8	13.5	14.2
1980	31	13.6	.	13.6	14.2
1981	32	13.3	.	13.7	14.1
1982	33	10.6	.	13.8	13.6
1983	34	10.1	.	13.9	12.3
1984	35	.	.	14.0	17.9
1985	36	.	.	14.1	18.7
1986	37	.	.	14.2	19.5
1987	38	.	.	14.3	20.4
1988	39	.	.	14.4	21.4
1989	40	.	.	14.4	22.5
1990	41	.	.	14.5	23.5
1991	42	.	.	14.6	24.7
1992	43	.	.	14.7	25.9
1993	44	.	.	14.7	27.3
1994	45	.	.	14.8	28.6
1995	46	.	.	14.8	30.1
1996	47	.	.	14.9	31.6
1997	48	.	.	15.0	33.2
1998	49	.	.	15.0	35.0
1999	50	.	.	15.1	36.7
2000	51	.	.	15.1	38.6
2001	52	.	.	15.2	40.6
2002	53	.	.	15.2	42.7
2003	54	.	.	15.2	44.8
2004	55	.	.	15.3	47.1
2005	56	.	.	15.3	49.5
2006	57	.	.	15.4	51.9
2007	58	.	.	15.4	54.5
2008	59	.	.	15.4	57.2
2009	60	.	.	15.5	[illegible]
2010	61	.	.	[illegible]	[illegible]

[illegible]	[illegible]	[illegible]	0.0	[illegible]	[illegible]
[illegible]	1	1195	.	1384	[illegible]
1951	2	1263	1455	1391	1173
1952	3	1160	1187	1419	1334
1953	4	1024	1282	1447	1303
1954	5	1301	1369	1475	1462
1955	6	1662	1432	1502	1623
1956	7	1696	1533	1530	1579
1957	8	1477	1576	1557	1621
1959	9	1556	1599	1534	1686
1959	10	1488	1610	1610	1685
1960	11	1776	1659	1637	1815
1961	12	1751	1747	1663	1713
1962	13	1775	1828	1689	1718
1963	14	1946	1811	1715	1683
1964	15	1893	1807	1740	1723
1965	16	1698	1824	1765	1758
1966	17	1733	1792	1790	1782
1967	18	1860	1762	1914	[illegible]
1968	19	1772	[illegible]	1533	1821
1969	20	[illegible]	[illegible]	[illegible]	[illegible]
1970	21	[illegible]	[illegible]	[illegible]	[illegible]
1971	22	[illegible]	2077	[illegible]	[illegible]
1972	23	2209	2125	1951	1950
1973	24	2337	2060	1952	1947
1974	25	1996	2062	1974	1964
1975	26	1659	1940	1995	1957
1976	27	2019	1767	2016	1953
1977	23	1689	2255	2036	1956
1978	29	1470	1782	2056	1951
1979	30	2256	1745	2075	1954
1980	31	1494	.	2074	1955
1981	32	1915	.	2112	1957
1982	33	1987	.	2130	1952
1983	34	2156	.	2142	1953
1984	35	.	.	2154	1830
1985	36	.	.	2181	1792
1986	37	.	.	2197	1745
1987	38	.	.	2213	1699
1988	39	.	.	2229	1642
1989	40	.	.	2243	1580
1990	41	.	.	2258	1512
1991	42	.	.	2272	1435
1992	43	0.0	.	2285	1353
1993	44	.	.	2299	1261
1994	45	.	.	2311	1162
1995	46	.	.	2324	1054
1996	47	.	.	2336	940
1997	48	.	.	2348	817
1998	49	.	.	2359	680
1999	50	.	.	2370	540
2000	51	.	.	2380	385
2001	52	.	.	2391	222
2002	53	.	.	2401	49.0
2003	54	.	.	2410	.
2004	55	.	.	2419	.
2005	56	.	.	2428	.
2006	57	.	.	2437	.
2007	58	.	.	2445	.
2008	59	.	.	2452	.
2009	60	.	.	2461	.
2010	61	.	.	2469	.

[illegible]	[illegible]	3633	.	[illegible]	2239
1950	5346	1880	.	1098	[illegible]
1951	6677	2171	2356	1663	2534
1952	7668	2224	2184	2451	2690
1953	7509	1923	2589	2298	2850
1954	8368	2722	2927	3094	3015
1955	9401	3907	3175	3951	3184
1956	9098	3858	3558	3711	3357
1957	9386	3465	3747	3940	3533
1958	9870	3838	3945	4304	3711
1959	9856	3668	4060	4294	3892
1960	1102	4898	4262	5079	4073
1961	1012	4431	4452	4485	4256
1962	1008	4476	4681	4461	4438
1963	9842	4788	4587	4284	4619
1964	1019	4812	4628	4517	4800
1965	1049	4427	4756	4722	4978
1966	1069	4637	4793	4873	5152
1967	1101	5116	4812	5062	5325
1968	1110	4974	5143	5122	5494
1969	1133	4934	5500	5277	5658
1970	1225	[illegible]	[illegible]	[illegible]	[illegible]
1971	1255	[illegible]	[illegible]	5795	[illegible]
1972	1320	7606	6837	6169	6122
1973	1313	7674	6861	6132	6265
1974	1421	6429	7059	6500	6403
1975	1489	6175	6795	6661	6535
1976	1420	7413	6374	6648	6661
1977	1499	6284	6785	6671	6781
1978	1514	5570	5550	6713	6895
1979	1500	8483	6540	6692	7003
1980	1497	5594	.	6679	7106
1981	1497	6758	.	6667	7202
1982	1450	7239	.	6586	7293
1983	1333	7613	.	6213	7378
1984	1720	.	.	6873	7456
1985	1760	.	.	6853	7533
1986	1800	.	.	6814	7603
1987	1840	.	.	6757	7669
1988	1890	.	.	6630	7730
1989	1930	.	.	6583	7787
1990	1970	.	.	6465	7840
1991	2020	.	.	6323	7989
1992	2060	0.0	.	6161	7935
1993	2110	.	.	5969	7977
1994	2160	.	.	5754	8017
1995	2200	.	.	5511	8053
1996	2250	.	.	5245	8087
1997	2300	.	.	4948	5118
1998	2350	.	.	4613	8147
1999	2400	.	.	4259	8174
2000	2450	.	.	3863	8198
2001	2510	.	.	3439	8221
2002	2560	.	.	2978	8242
2003	2610	.	.	2479	8261
2004	2670	.	.	1951	8279
2005	2720	.	.	1370	8296
2006	2780	.	.	769	8311
2007	2840	.	.	113	8325
2008	2890	.	.	.	8338
2009	2950	.	.	.	8349
2010	3010	.	.	.	[illegible]

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YEAR	TIME	VEHICLES	MCYCLES	PERCENT	MOVINGAC
1960	0	89505	4769	5.33	.	.
1961	1	84540	4600	5.44	.	5.3
1962	2	87130	4713	5.41	5.43	5.5
1963	3	87073	4736	5.44	5.54	5.6
1964	4	92581	5100	5.51	5.65	5.7
1965	5	98258	5793	5.90	5.77	5.8
1966	6	103175	6164	5.97	5.92	5.8
1967	7	109439	6593	6.02	6.10	5.9
1968	8	113328	7004	6.13	6.20	5.9
1969	9	124348	7970	6.41	6.31	6.0
1970	10	137271	8823	6.43	6.45	6.0
1971	11	149750	9774	6.53	6.30	6.0
1972	12	159969	10681	6.68	6.14	6.0
1973	13	164222	8966	5.46	5.99	6.1
1974	14	184086	10332	5.61	5.85	6.1
1975	15	199715	11312	5.66	5.70	6.1
1976	16	203446	11870	5.83	5.83	6.1
1977	17	214351	12763	5.95	5.96	6.2
1978	18	225447	13746	6.10	6.11	6.2
1979	19	232029	14573	6.28	6.27	6.2
1980	20	240435	15343	6.38	6.43	6.2
1981	21	246132	16345	6.64	6.55	6.2
1982	22	249162	16870	6.77	.	6.2
1983	23	250919	16823	6.70	.	6.2
1984	24	.	.	.	.	6.3
1985	25	.	.	.	.	6.3
1986	26	.	.	.	.	6.3
1987	27	.	.	.	.	6.3
1988	28	.	.	.	.	6.3
1989	29	.	.	.	.	6.3
1990	30	.	.	.	.	6.3
1991	31	.	.	.	.	6.3
1992	32	.	.	.	.	6.4
1993	33	.	.	.	.	6.4
1994	34	.	.	.	.	6.4
1995	35	.	.	.	.	6.4
1996	36	.	.	.	.	6.4
1997	37	.	.	.	.	6.4
1998	38	.	.	.	.	6.4
1999	39	.	.	.	.	6.4
2000	40	.	.	.	.	6.4
2001	41	.	.	.	.	6.4
2002	42	.	.	.	.	6.4
2003	43	.	.	.	.	6.4
2004	44	.	.	.	.	6.4
2005	45	.	.	.	.	6.5
2006	46	.	.	.	.	6.5
2007	47	.	.	.	.	6.5
2008	48	.	.	.	.	6.5
2009	49	.	.	.	.	6.5
2010	50	.	.	.	.	6.5

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TIME	Y	A	B	C	D	E	F	G	H	I	J
1960	0	89505	64594	7217	.	.	2788	1885	6761	.	.
1961	1	84540	64163	7590	.	7643	2377	1664	7000	.	7416
1962	2	87130	65673	7560	7476	7493	2469	1745	7068	7019	7283
1963	3	87073	65511	7524	7493	7405	2385	1680	7044	7107	7205
1964	4	92581	69357	7491	7423	7343	2450	1769	7220	7256	7150
1965	5	98258	71750	7302	7347	7295	2542	1831	7203	7292	7107
1966	6	103175	74697	7240	7264	7256	2445	1894	7746	7242	7072
1967	7	109439	73554	7178	7179	7222	2947	2135	7245	7178	7042
1968	8	113329	80556	7108	7116	7194	3129	2127	6798	7054	7016
1969	9	124349	87897	7069	7066	7168	2869	1979	6398	6922	6994
1970	10	127271	95573	6984	7026	7145	5546	2334	6582	6858	6973
1971	11	144750	104553	6737	7029	7125	4217	2988	7036	6884	6955
1972	12	[illegible]	111655	6760	7037	7106	4568	3233	6925	6963	6433
1973	13	[illegible]	115945	7121	7063	7057	4695	3252	6927	7082	6923
1974	14	[illegible]	130535	7113	7085	7073	4379	[illegible]	7217	7037	6909
1975	15	199715	142025	7111	7113	7033	4951	3540	7150	6951	6895
1976	16	209448	144490	7102	7102	7044	4605	3165	6373	6978	6883
1977	17	214251	152536	7116	7081	7031	4536	3011	6633	6881	6871
1978	18	[illegible]	159324	7067	7066	7013	5625	3888	6912	6714	6860
1979	19	[illegible]	162680	7011	7045	7007	6216	4246	5821	6716	6850
1980	20	240425	169153	7036	7024	6996	4435	2832	6314	6736	6840
1981	21	246132	172166	6995	7017	6985	5648	3889	6386	6690	6831
1982	22	[illegible]	174674	7010	.	6975	5981	4029	6736	.	6822
1983	23	[illegible]	176479	7033	.	6965	6362	4233	5585	.	6813
1984	24		.	.	.	6956	.	.	.	.	6805
1985	25	.	.	.	.	6947	.	.	.	.	6797
1986	26	.	.	.	.	6939	.	.	.	.	6790
1987	27	.	.	.	.	6931	.	.	.	.	6782
1988	28	.	.	.	.	6923	.	.	.	.	6775
1989	29	.	.	.	.	6915	.	.	.	.	6769
1990	30	.	.	.	.	6905	.	.	.	.	6762
1991	31	.	.	.	.	6901	0	.	.	.	6756
1992	32	.	.	.	.	6894	.	.	.	.	6750
1993	33	.	.	.	.	6887	.	.	.	.	6744
1994	34	.	.	.	.	6881	.	.	.	.	6738
1995	35	.	.	.	.	6875	.	.	.	.	6733
1996	36	.	.	.	.	6869	.	.	.	.	6727
1997	37	.	.	.	.	6863	.	.	.	.	6722
1998	38	.	.	.	.	6857	.	.	.	.	6717
1999	39	.	.	.	.	6851	0	.	.	.	6712
2000	40	.	.	.	.	6846	.	.	.	.	6707
2001	41	.	.	.	.	6841	.	.	.	.	6702
2002	42	.	.	.	.	6835	.	.	.	.	6697
2003	43	.	.	.	.	6830	.	.	.	.	6693
2004	44	.	.	.	.	6825	.	.	.	.	6689
2005	45	.	.	.	.	6820	.	.	.	.	6684
2006	46	.	.	.	.	6816	.	.	.	.	6680
2007	47	.	.	.	.	6811	.	.	.	.	6676
2008	48	.	.	.	.	6807	.	.	.	.	6672
2009	49	.	.	.	.	6802	.	.	.	.	6668
2010	50	.	.	.	.	6798	.	.	.	.	6664

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YEAR	TIME	RTAS	DAYRTAS	PERCENT	MOVINGAV	AGOKI
1960	0	4102	3125	76.18	.	.
1961	1	3573	2730	76.41	.	81.07
1962	2	3595	2647	73.63	74.67	77.15
1963	3	3578	2616	73.11	73.94	74.86
1964	4	3693	2734	74.03	73.20	73.23
1965	5	3562	2583	72.52	73.11	71.97
1966	6	3847	2798	72.73	73.33	70.94
1967	7	4387	3209	73.15	72.82	70.07
1968	8	4511	3349	74.24	72.46	69.31
1969	9	4196	3000	71.50	71.89	68.65
1970	10	5163	3648	70.66	70.61	68.05
1971	11	6042	4222	69.88	69.64	67.51
1972	12	6613	4415	66.76	62.57	67.02
1973	13	6789	4710	69.36	61.84	66.57
1974	14	6250	2261	36.18	61.20	66.15
1975	15	6534	4379	67.02	61.33	65.76
1976	16	6534	4357	66.68	60.11	65.39
1977	17	5949	4010	67.41	65.55	65.05
1978	18	6956	4402	63.26	66.36	64.72
1979	19	8049	5099	63.35	66.13	64.42
1980	20	6162	4381	71.10	66.43	64.13
1981	21	7250	4748	65.49	67.59	63.85
1982	22	7524	5186	68.93	.	63.59
1983	23	8023	5544	69.10	.	63.34
1984	24	.	.	.	.	63.10
1985	25	.	.	.	.	62.87
1986	26	.	.	.	.	62.64
1987	27	.	.	.	.	62.43
1988	28	.	.	.	.	62.23
1989	29	.	.	.	.	62.03
1990	30	.	.	.	.	61.83
1991	31	.	.	.	.	61.65
1992	32	.	.	.	.	61.47
1993	33	.	.	.	.	61.30
1994	34	.	.	.	.	61.13
1995	35	.	.	.	.	60.96
1996	36	.	.	.	.	60.80
1997	37	.	.	.	.	60.65
1998	38	.	.	.	.	60.50
1999	39	.	.	.	.	60.35
2000	40	.	.	.	.	60.21
2001	41	.	.	.	.	60.07
2002	42	.	.	.	.	59.93
2003	43	.	.	.	.	59.80
2004	44	.	.	.	.	59.67
2005	45	.	.	.	.	59.54
2006	46	.	.	.	.	59.42
2007	47	.	.	.	.	59.30
2008	48	.	.	.	.	59.18
2009	49	.	.	.	.	59.06
2010	50	.	.	.	.	58.95

YEAR	TIME	TOTELEME	PEDALCYC	PERCENT	MOVINGAV	AGOKI
1960	0	3515	429	12.20	.	.
1961	1	3473	398	11.46	.	11.75
1962	2	3595	340	9.46	10.59	10.36
1963	3	3578	374	10.45	9.84	9.54
1964	4	3693	346	9.37	9.02	8.97
1965	5	3564	302	8.47	8.63	8.53
1966	6	3991	293	7.34	7.87	8.16
1967	7	4321	324	7.50	7.55	7.85
1968	8	4511	302	6.69	7.30	7.58
1969	9	4103	319	7.77	7.24	7.35
1970	10	5163	372	7.21	6.92	7.14
1971	11	6042	425	7.03	7.01	6.95
1972	12	6623	392	5.92	6.55	6.77
1973	13	6789	484	7.13	6.07	6.61
1974	14	6250	342	5.47	5.65	6.46
1975	15	6534	312	4.78	6.45	6.33
1976	16	6548	325	4.96	6.94	6.20
1977	17	5703	565	9.91	6.73	6.07
1978	18	6956	665	9.56	6.57	5.96
1979	19	8049	356	4.42	6.65	5.85
1980	20	6162	246	3.99	5.76	5.75
1981	21	7122	383	5.38	4.75	5.65
1982	22	7524	410	5.45	.	5.56
1983	23	8023	363	4.52	.	5.47
1984	24	.	.	.	.	5.38
1985	25	.	.	.	.	5.30
1986	26	.	.	.	.	5.22
1987	27	.	.	.	.	5.15
1988	28	.	.	.	.	5.08
1989	29	.	.	.	.	5.01
1990	30	.	.	.	.	4.94
1991	31	.	.	.	.	4.87
1992	32	.	.	.	.	4.81
1993	33	.	.	.	.	4.75
1994	34	.	.	.	.	4.69
1995	35	.	.	.	.	4.63
1996	36	.	.	.	.	4.57
1997	37	.	.	.	.	4.52
1998	38	.	.	.	.	4.46
1999	39	.	.	.	.	4.41
2000	40	.	.	.	.	4.36
2001	41	.	.	.	.	4.31
2002	42	.	.	.	.	4.26
2003	43	.	.	.	.	4.22
2004	44	.	.	.	.	4.17
2005	45	.	.	.	.	4.13
2006	46	.	.	.	.	4.08
2007	47	.	.	.	.	4.04
2008	48	.	.	.	.	4.00
2009	49	.	.	.	.	3.95
2010	50	.	.	.	.	3.91

TIME	Y	A	B	C	D	E	F	G	H	
1960	0	3515	129	367	.	.	169	481	.	.
1961	1	3473	84	242	.	353	614	1768	.	7
1962	2	3595	90	250	271	325	696	1936	1717	13
1963	3	3578	93	260	242	309	791	2211	1981	16
1964	4	3693	88	238	357	297	809	2191	2092	19
1965	5	3564	79	222	349	288	641	1799	2146	21
1966	6	3991	325	814	345	281	928	2325	2135	23
1967	7	4321	92	213	339	275	953	2206	2102	24
1968	8	4511	108	239	330	270	972	2155	2189	25
1969	9	4103	84	205	200	265	831	2025	2254	26
1970	10	5162	92	175	211	261	1152	2233	2521	27
1971	11	6042	101	167	222	257	[illegible]	3352	2812	28
1972	12	6622	177	267	243	233	1560	2537	2716	29
1973	13	6789	193	292	241	250	2114	3114	2813	30
1974	14	6250	193	309	238	247	1379	3038	2949	31
1975	15	6534	112	171	231	244	1797	2750	2575	31
1976	16	6548	99	151	214	242	2166	3303	4051	32
1977	17	5703	132	231	234	239	3233	5669	4022	32
1978	18	6956	143	206	245	237	3320	5492	3771	33
1979	19	8049	329	409	250	225	2253	2723	3751	33
1980	20	6162	139	226	235	233	901	1462	3263	342
1981	21	7122	127	176	242	231	2267	3211	2835	346
1982	22	7524	116	154	.	229	2429	3228	.	350
1983	23	8023	196	244	.	227	2563	3350	.	354
1984	24	.	.	.	.	226	.	.	.	357
1985	25	.	.	.	.	224	.	.	.	362
1986	26	.	.	.	.	224	.	.	.	365
1987	27	.	.	.	.	221	.	.	.	369
1988	28	.	.	.	.	219	.	.	.	372
1989	29	.	.	.	.	218	.	.	.	375
1990	30	.	.	.	.	217	.	.	.	378
1991	31	.	.	.	.	215	.	.	.	381
1992	32	.	.	.	.	214	.	.	.	384
1993	33	.	.	.	.	213	.	.	.	387
1994	34	.	.	.	.	212	.	.	.	390
1995	35	.	.	.	.	211	.	.	.	392
1996	36	.	.	.	.	209	.	.	.	395
1997	37	.	.	.	.	208	.	.	.	397
1998	38	.	.	.	.	207	.	.	.	400
1999	39	.	.	.	.	206	.	.	.	402
2000	40	.	.	.	.	205	.	.	.	404
2001	41	.	.	.	.	204	.	.	.	407
2002	42	.	.	.	.	203	.	.	.	409
2003	43	.	.	.	.	202	.	.	.	411
2004	44	.	.	.	.	201	.	.	.	413
2005	45	.	.	.	.	200	.	.	.	417
2006	46	.	.	.	.	200	.	.	.	419
2007	47	.	.	.	.	199	.	.	.	421
2008	48	.	.	.	.	198	.	.	.	423
2009	49	.	.	.	.	197	.	.	.	423
2010	50	.	.	.	.	196	.	.	.	425

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TIME	Y	A	B	C	D	E	F	G	H	IU	J
1973	0	1402	1222	8716	.	.	9595	8871	9245	.	.
1974	1	1352	1183	8750	.	8605	9187	8439	9186	.	9101
1975	2	1338	1145	8558	8424	8405	8283	7553	9119	8937	8930
1976	3	1640	1388	8463	8370	8288	10269	9268	9025	8905	8830
1977	4	1560	1191	7635	8253	8205	9017	7313	8110	8754	8759
1978	5	1588	1341	8445	7707	8141	10856	9865	9087	8572	8704
1979	6	[illegible]	1357	9165	[illegible]	8066	13087	11029	8427	8556	8659
1980	7	1413	[illegible]	8627	[illegible]	8044	8990	7922	8211	8707	8621
1981	8	1720	1491	[illegible]	[illegible]	[illegible]	11157	9787	8943	8657	8530
1982	9	1462	1244	8509	.	7971	12378	10773	8867	.	8559
1983	10	1515	1300	8561	.	7941	12526	11961	8843	.	8533
1984	11	.	.	.	.	7913	.	.	.	.	8509
1985	12	.	.	.	.	7888	.	.	.	.	8488
1986	13	.	.	.	.	7865	.	.	.	.	8468
1987	14	.	.	.	.	7844	.	.	.	.	8450
1988	15	.	.	.	.	7824	.	.	.	.	8433
1989	16	.	.	.	.	7805	.	.	.	.	8417
1990	17	.	.	.	.	7786	.	.	.	.	8402
1991	18	.	.	.	.	7771	.	.	.	.	8388
1992	19	.	.	.	.	7756	.	.	.	.	8374
1993	20	.	.	.	.	7741	.	.	.	.	8362
1994	21	.	.	.	.	7727	.	.	.	.	8350
1995	22	.	.	.	.	7714	.	.	.	.	8338
1996	23	.	.	.	.	7701	.	.	.	.	8327
1997	24	.	.	.	.	7689	.	.	.	.	8317
1998	25	.	.	.	.	7677	.	.	.	.	8307
1999	26	.	.	.	.	7663	.	.	.	.	8297
2000	27	.	.	.	.	7655	.	.	.	.	8288
2001	28	.	.	.	.	7644	.	.	.	.	8279
2002	29	.	.	.	.	7634	.	.	.	.	8270
2003	30	.	.	.	.	7624	.	.	.	.	8262
2004	31	.	.	.	.	7615	.	.	.	.	8254
2005	32	.	.	.	.	7606	.	.	.	.	8246
2006	33	.	.	.	.	7597	.	.	.	.	8238
2007	34	.	.	.	.	7589	.	.	.	.	8231
2008	35	.	.	.	.	7580	.	.	.	.	8224
2009	36	.	.	.	.	7572	.	.	.	.	8217
2010	37	.	.	.	.	7564	.	.	.	.	8210

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YEAR	TIME	DEATHS	MCYCLIST
1973	0	1402	24
1974	1	1351	17
1975	2	1338	15
1976	3	1640	28
1977	4	1560	21
1978	5	1588	21
1979	6	1662	24
1980	7	1413	123
1981	8	1720	45
1982	9	1462	36
1983	10	1515	31
1984	11	.	.
1985	12	.	.
1986	13	.	.
1987	14	.	.
1988	15	.	.
1989	16	.	.
1990	17	.	.
1991	18	.	.
1992	19	.	.
1993	20	.	.
1994	21	.	.
1995	22	.	.
1996	23	.	.
1997	24	.	.
1998	25	.	.
1999	26	.	.
2000	27	.	.
2001	28	.	.
2002	29	.	.
2003	30	.	.
2004	31	.	.
2005	32	.	.
2006	33	.	.
2007	34	.	.
2008	35	.	.
2009	36	.	.
2010	37	.	.

PCENTMC	MOVINGAM	AGOKIM	PEDALCYC	PCENTPCY	MOVINGAP	AGOKIP
1.71	.	.	129	9.20	.	.
1.26	.	-.80	72	5.33	.	10.40
1.12	1.43	.96	103	7.70	8.02	8.28
1.71	1.35	1.68	130	7.93	6.98	7.05
1.35	1.39	2.19	155	9.94	6.87	6.17
1.32	2.90	2.59	64	4.03	5.56	5.49
1.44	3.09	2.91	79	4.75	4.83	4.93
8.70	3.31	3.18	15	1.13	3.98	4.46
2.62	3.45	3.42	74	4.30	4.20	4.06
2.46	.	3.63	83	5.68	.	3.70
2.05	.	3.82	78	5.15	.	3.38
.	.	3.99	.	.	.	3.09
.	.	4.14	.	.	.	2.82
.	.	4.23	.	.	.	2.59
.	.	4.42	.	.	.	2.35
.	.	4.54	.	.	.	2.14
.	.	4.65	.	.	.	1.94
.	.	4.76	.	.	.	1.76
.	.	4.86	.	.	.	1.59
.	.	4.96	.	.	.	1.42
.	.	5.05	.	.	.	1.26
.	.	5.14	.	.	.	1.12
.	.	5.22	.	.	.	.97
.	.	5.30	.	.	.	.84
.	.	5.37	.	.	.	.71
.	.	5.45	.	.	.	.58
.	.	5.52	.	.	.	.46
.	.	5.58	.	.	.	.35
.	.	5.65	.	.	.	.24
.	.	5.71	.	.	.	.13
.	.	5.77	.	.	.	.03
.	.	5.83	.	.	.	.
.	.	5.89	.	.	.	.
.	.	5.94	.	.	.	.
.	.	5.99	.	.	.	.
.	.	6.05	.	.	.	.
.	.	6.10	.	.	.	.
.	.	6.14	.	.	.	.

YEAR	TIME	DEATHS	PEDESTRI	PERCENT	MOVINGAV	AGOKI	PASSENGE	PERCENTP	MOVINGAG	AGOKI2
1973	0	1402	597	42.58	.	.	445	31.74	.	.
1974	1	1351	528	39.08	.	39.74	487	36.05	.	34.24
1975	2	1338	591	44.17	41.12	41.14	454	33.93	34.74	34.54
1976	3	1640	650	39.63	42.17	41.96	601	36.65	34.84	34.72
1977	4	1560	626	40.13	42.56	42.54	551	35.32	34.67	34.84
1978	5	1588	760	47.86	42.17	43.00	512	32.24	34.83	34.94
1979	6	1662	682	41.03	43.68	43.36	585	35.20	34.48	35.02
1980	7	1413	596	42.18	44.52	43.68	491	34.75	34.57	35.09
1981	8	1720	812	47.21	43.41	43.95	600	34.88	36.16	35.14
1982	9	1462	648	44.32	.	44.18	523	35.77	.	35.20
1983	10	1515	641	42.31	.	44.40	609	40.20	.	35.24
1984	11	.	.	.	.	44.59	.	.	.	35.26
1985	12	.	.	.	.	44.77	.	.	.	35.32
1986	13	.	.	.	.	44.93	.	.	.	35.35
1987	14	.	.	.	.	45.08	.	.	.	35.39
1988	15	.	.	.	.	45.22	.	.	.	35.44
1989	16	.	.	.	.	45.35	.	.	.	35.44
1990	17	.	.	.	.	45.47	.	.	.	35.47
1991	18	.	.	.	.	45.59	.	.	.	35.50
1992	19	.	.	.	.	45.70	.	.	.	35.52
1993	20	.	.	.	.	45.80	.	.	.	35.54
1994	21	.	.	.	.	45.90	.	.	.	35.56
1995	22	.	.	.	.	45.99	.	.	.	35.58
1996	23	.	.	.	.	46.08	.	.	.	35.60
1997	24	.	.	.	.	46.17	.	.	.	35.62
1998	25	.	.	.	.	46.25	.	.	.	35.64
1999	26	.	.	.	.	46.33	.	.	.	35.66
2000	27	.	.	.	.	46.41	.	.	.	35.67
2001	28	.	.	.	.	46.48	.	.	.	35.69
2002	29	.	.	.	.	46.55	.	.	.	35.70
2003	30	.	.	.	.	46.62	.	.	.	35.72
2004	31	.	.	.	.	46.69	.	.	.	35.73
2005	32	.	.	.	.	46.75	.	.	.	35.75
2006	33	.	.	.	.	46.81	.	.	.	35.76
2007	34	.	.	.	.	46.87	.	.	.	35.77
2008	35	.	.	.	.	46.93	.	.	.	35.79
2009	36	.	.	.	.	46.99	.	.	.	35.80
2010	37	.	.	.	.	47.04	.	.	.	35.81

TIMT	Y	A	B	C	D	E	F	G	H	I
1973	0	9595	2082	2170	.	.	4758	4959	.	.
1974	1	9187	1975	2150	.	2964	4997	5439	.	5209
1975	2	8283	1695	2046	2504	2637	4266	5150	5242	5234
1976	3	10269	2635	2566	2457	2446	5625	5487	5342	5249
1977	4	9017	3228	3530	2443	2310	4666	5175	5241	5260
1978	5	10856	2112	1945	2346	2205	5924	5457	5146	5268
1979	6	13087	2720	2078	2243	2118	6459	4935	5150	5275
1980	7	8990	1404	1562	1886	2046	4203	4675	5313	5280
1981	8	11167	2287	2048	1865	1983	6151	5508	5417	5285
1982	9	[illegible]	2223	1776	.	1927	[illegible]	5782	.	5299
1983	10	13526	2487	1839	.	1977	[illegible]	5901	.	5293
1984	11	.	.	.	.	1832	.	.	.	5297
1985	12	.	.	.	.	1791	.	.	.	[illegible]
1986	13	.	.	.	.	1754	.	.	.	[illegible]
1987	14	.	.	.	.	1719	.	.	.	5306
1988	15	.	.	.	.	1686	.	.	.	5308
1989	16	.	.	.	.	1656	.	.	.	5311
1990	17	.	.	.	.	1627	.	.	.	5313
1991	18	0	.	.	.	1600	.	.	.	5315
1992	19	.	.	.	.	1574	.	.	.	[illegible]
1993	20	.	.	.	.	1550	.	.	.	[illegible]
[illegible]	[illegible]	.	.	.	.	[illegible]	.	.	.	[illegible]
[illegible]	[illegible]	.	.	.	.	[illegible]	.	.	.	[illegible]
[illegible]	[illegible]	.	.	.	.	[illegible]	.	.	.	[illegible]
[illegible]	[illegible]	.	.	.	.	[illegible]	.	.	.	[illegible]
1998	25	.	.	.	.	1445	.	.	.	5327
1999	26	0	.	.	.	1426	.	.	.	5328
2000	27	.	.	.	.	1409	.	.	.	5330
2001	28	.	.	.	.	1391	.	.	.	5331
2002	29	.	.	.	.	1375	.	.	.	5332
2003	30	.	.	.	.	1359	.	.	.	5334
2004	31	.	.	.	.	1343	.	.	.	5335
2005	32	.	.	.	.	1328	.	.	.	5336
2006	33	.	.	.	.	1314	.	.	.	5337
2007	34	.	.	.	.	1300	.	.	.	5338
2008	35	.	.	.	.	1286	.	.	.	5339
2009	36	.	.	.	.	1273	.	.	.	5340
2010	37	.	.	.	.	1260	.	.	.	5341

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YEAR	TIME	INJURIES	DRIVERS	PERCENT	MOVINGAV	AGOKI
1973	0	9595	2607	27.17	.	.
1974	1	9187	2464	26.82	.	19.19
1975	2	8283	1251	15.10	18.66	17.63
1976	3	10269	1124	10.95	16.69	16.72
1977	4	9017	1196	13.26	14.43	16.07
1978	5	10856	1879	17.31	14.54	15.57
1979	6	13087	2035	15.55	15.53	15.16
1980	7	8990	1403	15.61	15.64	14.81
1981	8	11167	1776	15.90	14.97	14.51
1982	9	12378	1712	13.83	.	14.24
1983	10	13526	1890	13.97	.	14.01
1984	11	.	.	.	.	13.79
1985	12	.	.	.	.	13.60
1986	13	.	.	.	.	13.42
1987	14	.	.	.	.	13.23
1988	15	.	.	.	.	13.09
1989	16	.	.	.	.	12.95
1990	17	.	.	.	.	12.81
1991	18	.	.	.	.	12.68
1992	19	.	.	.	.	12.56
1993	20	.	.	.	.	12.45
1994	21	.	.	.	.	12.34
1995	22	.	.	.	.	12.23
1996	23	.	.	.	.	12.13
1997	24	.	.	.	.	12.04
1998	25	.	.	.	.	11.94
1999	26	.	.	.	.	11.86
2000	27	.	.	.	.	11.77
2001	28	.	.	.	.	11.69
2002	29	.	.	.	.	11.61
2003	30	.	.	.	.	11.53
2004	31	.	.	.	.	11.46
2005	32	.	.	.	.	11.39
2006	33	.	.	.	.	11.32
2007	34	.	.	.	.	11.25
2008	35	.	.	.	.	11.19
2009	36	.	.	.	.	11.12
2010	37	.	.	.	.	11.06

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TIMT	Y	A	B	C	D	E	F	G	H	I
1973	0	9595	278	289	.	.	704	734	.	.
1974	1	9187	193	613	.	222	563	613	.	484
1975	2	8283	169	204	334	300	539	651	514	534
1976	3	10269	340	331	339	346	535	521	538	563
1977	4	9017	211	234	292	379	316	350	509	584
1978	5	10836	540	313	423	404	501	554	582	600
1979	6	13087	537	410	433	42[illegible]	615	471	684	613
1980	7	5990	752	636	460	442	1136	1264	647	624
1981	8	11167	414	371	461	437	539	483	629	634
1982	9	12378	455	368	.	470	576	465	.	643
1983	10	13526	433	320	.	482	628	464	.	650
1984	11	.	.	.	.	493	.	.	.	657
1985	12	.	.	.	.	503	.	.	.	663
1986	13	.	.	.	.	512	.	.	.	669
1987	14	.	.	.	.	520	.	.	.	675
1988	15	.	.	.	.	528	.	.	.	680
1989	16	.	.	.	.	535	.	.	.	684
1990	17	.	.	.	.	342	.	.	.	689
1991	18	.	.	.	.	548	.	.	.	693
1992	19	.	.	.	.	554	.	.	.	697
1993	20	.	.	.	.	560	.	.	.	700
1994	21	.	.	.	.	566	.	.	.	704
1995	22	.	.	.	.	571	.	.	.	707
1996	23	.	.	.	.	576	.	.	.	.
1997	24	.	.	.	.	581	.	.	.	.
1998	25	.	.	.	.	586	.	.	.	.
1999	26	.	.	.	.	590	.	.	.	719
2000	27	.	.	.	.	594	.	.	.	722
2001	28	.	.	.	.	598	.	.	.	725
2002	29	.	.	.	.	602	.	.	.	727
2003	30	.	.	.	.	606	.	.	.	730
2004	31	.	.	.	.	610	.	.	.	732
2005	32	.	.	.	.	613	.	.	.	734
2006	33	.	.	.	.	617	.	.	.	737
2007	34	.	.	.	.	620	.	.	.	739
2008	35	.	.	.	.	624	.	.	.	741
2009	36	.	.	.	.	627	.	.	.	743
2010	37	.	.	.	.	630	.	.	.	745

APPENDIX A.14

A.14/1

HOURS	OBSDFLOW	MODFLOW	AGOKI1	AGOKI2
0	240	177	240	177
1	70	123	114	39
2	60	53	-10	-61
3	30	43	-55	-67
4	40	63	40	63
5	120	.	286	321
6	260	.	627	647
7	1180	880	764	950
8	1200	1147	1200	1147
9	1060	1087	1287	1203
10	1000	1003	1245	1143
11	950	1007	1146	1040
12	1070	973	1070	973
13	900	983	1064	986
14	980	1020	1116	1070
15	1180	1107	1170	1173
16	1160	1227	1160	1227
17	1340	1133	1054	1191
18	900	960	870	1065
19	640	680	665	888
20	500	707	500	707
21	980	580	405	554
22	260	487	362	430
23	220	240	321	310

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HOURS	OBSDFLOW	MODLFLOW	AGOKI1	AGOKI2
0	7	10	7	10
1	6	5	4	6
2	2	3	2	2
3	1	4	2	1
4	9	7	9	7
5	11	.	22	21
6	18	.	41	40
7	45	47	60	61
8	78	78	78	78
9	112	106	92	90
10	127	119	102	98
11	117	121	111	[illegible]
12	120	115	120	115
13	107	110	130	[illegible]
14	104	116	138	[illegible]
15	136	124	140	[illegible]
16	132	141	132	141
17	154	142	114	123
18	140	116	89	96
19	54	78	62	66
20	39	41	37	41
21	31	27	23	24
22	12	20	14	16
23	17	12	10	12

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GRADIENT	GRADIEN1	RTA1	RTA2	OBSERVED	PRED1	PRED2
.5	.5	.53	2.73	1.41	1.49	.32
2.1	2.1	2.73	1.11	1.92	2.50	.57
3.9	3.9	1.80	0.0	3.34	2.50	1.02
5.0	5.6	1.67	.	1.67	1.92	1.36
6.0	.	.49	2.65	1.57	1.00	1.72

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DOWNGRAD	MODGRADE	RTA1	RTA2	MODRTA	OBSRTAS	AGOKI	SILYANOV
.4	.4	.52	5.45	2.99	2.99	3.03	.31
.8	.8	.49	6.28	3.39	3.39	3.05	.36
1.7	1.7	.49	5.91	3.20	3.20	3.03	.51
1.8	1.8	.49	5.00	2.75	2.75	3.02	.53
2.0	2.0	2.73	.	2.73	2.73	3.01	.57
2.9	2.9	.49	4.71	2.60	2.60	2.80	.76
3.8	3.8	.	2.73	2.73	2.73	2.67	.99
8.0	8.0	.	.49	.49	.49	.57	2.57

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RTA1	RTA2	RTA3	RTA4	RTA5	MODELRTA	MODELSD	OBSERSD	OBSERRTA	AGOKI	SILYANOV
.49	.53	.	.	.	.	.	150	.51	.17	2.59
.91	1.06	1.11	1.48	2.61	.	.	175	1.43	1.06	2.37
1.06	2.22	2.94	.	.	1.41	187.5	200	2.07	1.78	2.18
.49	.53	.91	3.33	7.64	.	.	225	2.58	2.33	2.02
2.35	2.50	2.73	2.90	.	2.67	237.5	250	2.62	2.71	1.87
.49	.53	.98	1.06	1.11	.	.	275	3.17	2.92	1.74
2.50	2.73	9.09	10.0	.	.	.	.	.	.	.
1.11	1.18	1.82	1.67	2.12	2.87	287.5	300	2.45	2.96	1.63
2.61	2.65	3.33	3.45	4.50	.	.	.	.	.	.
.49	.53	.59	.83	.91	2.30	362.5	400	2.07	1.42	1.27
1.04	1.18	1.67	1.76	1.82	.	.	.	.	.	.
1.48	2.12	2.35	2.46	1.11	.	.	.	.	.	.
2.50	3.33	3.64	4.12	4.71	.	.	.	.	.	.
4.17	5.29	5.56	8.89	9.17	.	.	.	.	.	.

A.14/6

RTA1	RTA2	RTA3	RTA4	RTA5	RTA6	RTA7	MODELRTA	MODELSD	OBSSD	OBSDRTAS	AGOKI	SILYANOV
.49	.53	.83	1.11	2.95	3.33	4.24	2.01	150.0	150	2.01	1.99	2.59
3.53	6.28	7.39	8.18	.	.	.	.	.	.	.	.	.
.52	1.04	2.94	5.45	.	.	.	2.94	237.5	250	2.48	3.03	1.87
.91	.98	1.57	1.67	2.50	3.71	8.89	.	.	275	2.89	3.11	1.74
1.18	1.67	1.82	4.17	4.55	4.71	.	.	.	300	3.02	3.10	1.63
.49	.83	.91	1.05	1.57	1.67	1.76	.	.	325	2.48	3.03	1.52
2.09	2.22	3.53	4.71	3.18	8.18	.	3.04	337.5	.	.	.	.
.49	1.76	5.29	.	.	.	.	.	.	375	2.51	2.64	1.35
.49	.52	.53	.59	1.76	2.61	2.95	2.60	400.0	400	2.60	2.34	1.27
1.82	.83	1.67	2.35	2.50	3.53	3.94	.	.	.	.	.	.
3.33	3.64	4.17	4.55	.	.	.	.	.	.	.	.	.

A.14/7

RTA1	RTA2	RTA3	MODELRTA	MODELWID	OBSDWIDT	OBSEDRTA	AGOKI	SILYANOV
7.59	.	.	.	.	5.80	7.59	8.08	1.26
8.47	.	.	8.03	5.82	5.84	8.47	7.91	1.25
8.12	.	.	.	.	5.92	8.12	7.57	1.23
8.32	.	.	.	.	5.99	8.32	7.28	1.21
9.17	.	.	7.19	6.00	6.08	9.17	6.90	1.20
7.67	.	.	.	.	6.28	7.67	6.05	1.14
6.42	.	.	5.84	6.33	6.42	6.42	5.46	1.11
5.76	.	.	.	.	6.48	5.76	5.20	1.10
1.67	7.49	8.62	.	.	6.51	5.93	5.08	1.09
6.34	.	.	5.00	6.53	6.55	6.34	4.91	1.08
5.91	.	.	.	.	6.56	5.91	4.86	1.08
5.83	.	.	.	.	6.58	5.83	4.78	1.08
3.82	5.09	6.13	.	.	6.60	5.01	4.69	1.07
4.73	5.83	.	.	.	6.62	5.28	4.61	1.07
5.82	.	.	.	.	6.65	5.82	4.48	1.06

A.14/8

RTA1	RTA2	RTA3	RTA4	RTA5	MODELRTA	OBSEDJNS	OBSEDRTA	AGOKI	JACOBS
.91	1.67	2.73	9.17	.83	5.88	0	5.88	5.07	1.45
2.50	4.17	10.00	20.90	.	.	.	.	.	.
1.11	7.50	7.27	6.67	10.59	6.80	1	6.80	6.74	2.47
2.62	11.82	.	.	.	.	.	.	.	.
1.11	3.33	3.64	5.00	5.24	7.28	2	7.28	8.41	3.49
6.36	7.78	9.85	13.26	17.27	.	.	.	.	.
3.45	7.06	9.41	15.76	.	8.92	3	8.92	10.08	4.51
5.00	10.00	24.55	.	.	13.18	4	13.18	11.76	5.53

A.14/9

RTA1	RTA2	RTA3	RTA4	RTA5	RTA6	RTA7	MODELRTA	OBSEDJNS	OBSEDRTA	AGOKI	JACOBS
2.09	2.50	3.53	3.64	4.17	5.00	.	3.49	0	3.49	3.01	1.45
1.82	3.64	6.40	6.89	5.88	6.67	4.55	5.79	1	5.79	5.93	2.47
6.36	7.88	7.78	.	.	.	.	.	.	.	.	.
1.11	2.72	5.83	5.45	4.44	8.37	12.94	8.47	2	8.47	8.86	3.49
16.47	18.89	.	.	.	.	.	.	.	.	.	.
5.42	5.76	5.83	.	.	.	.	.	3	5.67	11.78	4.51
14.40	.	.	.	.	.	.	14.40	4	14.40	14.71	5.53
.	.	.	.	.	.	.	.	5	.	17.63	6.55
20.91	.	.	.	.	.	.	20.91	6	20.91	20.55	7.57

A.14/10

UPODRADI	MODRADIU	RTA1	RTA2	MODELRTA	OBSDRTAS	AGOKI	SILYANOV
130	130	2.94	.	2.94	2.94	3.23	6.17
470	405	2.50	.	3.11	2.50	2.93	2.18
500	.	3.71	.	.	3.71	2.91	2.09
600	610	2.65	4.92	3.11	3.79	2.03	1.85
620	.	1.76	.	.	1.76	2.81	1.81
920	920	2.73	.	2.73	2.73	2.58	1.43
1037	1144	2.73	.	2.27	2.73	2.49	1.14
1250	.	1.82	.	.	1.82	2.34	1.22
1500	1500	1.67	2.22	1.94	1.94	2.16	1.13
2000	2000	1.76	.	1.76	1.76	1.83	1.08
2500	2500	1.67	.	1.67	1.67	1.55	.94

A.14/11

DOWNGRAD	MODRADIU	RTA1	RTA2	MODELRTA	OBSEDRTA	AGOKI	SILYANOV
130	130	6.23	.	6.23	6.23	6.48	6.17
340	340	5.91	.	5.91	5.91	5.87	2.77
590	590	7.27	4.71	5.99	5.99	5.19	1.87
600	600	4.71	.	4.71	4.71	5.16	1.85
900	905	3.64	5.00	4.32	4.32	4.41	1.45
910	.	.83	5.45	.	3.14	4.39	1.44
1980	1980	2.23	.	2.23	2.23	2.32	1.01
3200	3200	2.46	.	.	2.46	1.06	.87
5000	5500	2.50	2.22	1.92	2.36	1.37	.79
6000	.	1.05	.	.	1.05	2.65	.77

A.14/12

UPGSUPER	MODELSUP	RTA1	RTA2	RTA3	OBSEDRTA	AGOKI
.2	.	2.73	.	.	2.73	2.39
.6	.6	2.12	2.73	2.60	2.43	2.60
.8	.	2.94	.	.	2.94	2.69
2.7	2.9	2.94	.	3.20	2.94	3.19
3.2	.	3.79	.	.	3.79	3.20
4.5	4.7	3.14	2.93	.	3.14	3.00
5.0	.	2.73	.	.	2.73	2.84

A.14/13

DOWNSUPE	MODELSUP	RTA1	RTA2	MODELRTA	OBSEDRTA	AGOKI
0.0	0.0	1.05	.	1.05	1.05	1.07
2.4	.	.49	4.02	.	2.25	2.95
2.6	2.5	.49	5.91	3.13	3.20	2.99
3.0	.	4.02	2.09	.	3.06	3.02
3.8	3.4	3.79	1.82	2.80	2.81	2.88
4.2	4.2	1.47	3.79	2.63	2.63	2.70
4.5	4.5	1.47	3.79	2.63	2.63	2.51

A.14/14

RTA1	RTA2	RTA3	RTA4	RTA5	MODELRTA	MODELFLO	OBSFLOW	OBSDRTAS	AGOKI	JACOBS	SILYANOV
.80	.	.	.	.	.80	80	80	.80	.88	.84	.29
.29	3.71	.57	.	.	.	.	302	1.52	1.33	2.83	.39
.29	.57	1.14	2.00	4.86	.	.	417	1.77	1.65	3.87	.45
.29	.57	1.14	6.57	.	2.04	464	475	2.14	1.83	4.39	.48
.86	2.00	2.29	.	.	.	.	500	1.72	1.91	4.62	.49
2.00	.	.	.	.	.	.	509	2.00	1.94	4.70	.50
1.71	.	.	.	.	.	.	537	1.71	2.04	4.95	.51
2.00	.	.	.	.	.	.	622	2.00	2.37	5.71	.56
.29	.57	1.43	8.00	.	.	.	641	2.57	2.45	5.89	.57
.29	.57	2.86	6.29	.	2.80	667	667	2.50	2.57	6.12	.59
3.14	.	.	.	.	.	.	779	3.14	3.11	7.13	.66
3.71	.	.	.	.	3.71	840	840	3.71	3.44	7.68	.69
3.14	4.57	4.86	.	.	4.19	1000	1000	4.19	4.43	9.12	.80

A.14/15

RTA1	RTA2	RTA3	RTA4	RTA5	MODELRTA	MODFLOW	OBSDFLOW	OBSDRTAS	AGOKI	JACOBS	SILYANOV
.80	.	.	.	.	.80	80	80	.80	.76	.84	.29
.49	2.00	.	.	.	.	.	302	1.24	1.35	2.83	.39
.29	.86	2.57	3.14	.	.	.	417	1.72	1.81	3.87	.45
.29	.49	.57	1.71	2.57	.	.	.	.	.	.	.
3.14	6.57	.	.	.	1.85	464	475	2.19	2.09	4.39	.48
.86	1.71	2.57	3.14	.	.	.	500	2.07	2.22	4.62	.49
2.29	.	.	.	.	.	.	537	2.29	2.43	4.95	.51
.29	.86	5.43	6.57	.	3.19	627	628	3.29	2.98	5.71	.56
1.14	4.86	.	.	.	.	.	641	3.00	3.12	5.89	.57
.29	3.43	5.14	4.57	.	.	.	667	3.36	3.32	6.12	.59
2.86	.	.	.	.	3.49	723	779	2.86	4.29	7.13	.66
.29	7.14	9.14	.	.	6.17	920	840	5.52	4.91	7.68	.69
5.71	6.86	.	.	.	.	.	1000	6.29	6.83	9.12	.80

A.14/16

HOURS	TOTRTAS	OBSEDRTA	MODELRTA	AGOKI1	AGOKI2
0	9	.164064	.218736	.164064	.218736
1	6	.109368	.115440	.070451	.099420
2	4	.072912	.060744	.010700	.021971
3	0	0.0	.048600	.007880	.004586
4	4	.072912	.054696	.072912	.054696
5	5	.091140	.	.197020	.162901
6	12	.218760	.	.351902	.303610
7	27	.492192	.437520	.498586	.443270
8	33	.601584	.552960	.601584	.552950
9	31	.565128	.656280	.642035	.619436
10	44	.802104	.704680	.623767	.649190
11	41	.510432	.686640	.569667	.663463
12	28	.510432	.686640	.510432	.686640
13	44	.802104	.601560	.471350	.733950
14	27	.492192	.710952	.463273	.804318
15	46	.838560	.692712	.481294	.881430
16	41	.510432	.941856	.510432	.941857
17	68	1.239624	1.014768	.534226	.963380
18	58	1.057320	1.184928	.541346	.942294
19	69	1.257840	.935784	.527358	.874635
20	27	.492192	.772032	.492192	.772032
21	31	.565128	.455736	.436535	.645828
22	17	.309912	.419280	.360633	.505532
23	21	.382824	.285600	.266831	.359536

A.14/17

TOTJUNCT	RTA1	RTA2	RTA3	RTA4	RTA5	RTA6	RTA7	RTA8	MODELRTA	AGOKI	JACOBS
1	1.13	1.21	2.27	2.43	.	.	.	.	1.76	1.65	2.47
2	1.01	.86	1.13	4.29	2.57	2.43	3.64	2.27	2.20	2.37	3.49
3	.86	3.64	2.43	2.27	6.03	1.13	.	.	2.73	2.83	4.51
4	.76	1.13	6.86	3.40	.	.	.	.	3.04	3.04	5.53
5	1.53	2.27	4.93	.	.	.	.	.	2.91	2.98	6.55
6	.86	2.27	5.33	.	.	.	.	.	2.84	2.68	7.57
7	2.27	.	.	.	.	.	.	.	2.27	2.11	8.59
8	1.13	.	.	.	.	.	.	.	1.13	1.29	9.61

.14/18

HOURS	TOTRTAS	OBSEDRTA	MODELRTA	AGOKI1	AGOKI2
0	0	0.0	.237824	0.0	.237824
1	3	.535103	.178368	-.055103	.061794
2	0	0.0	.297279	.016508	-.078071
3	2	.356735	.178368	.123864	.112945
4	1	.178368	.237823	.178367	-.059456
5	1	.178368	.	.159599	.078880
6	1	.178368	.	.136977	.277131
7	1	.178368	.297280	.230995	.500483
8	3	.535103	.416191	.535103	.713471
9	3	.535103	.713470	1.044534	.888976
10	6	1.070205	.654014	1.636599	1.013925
11	2	.356735	1.248573	2.118374	1.090005
12	13	2.318779	1.129561	2.318778	1.129660
13	4	.713470	1.426941	2.175313	1.149367
14	7	1.248573	1.070205	1.767172	1.182895
15	7	1.248573	1.129661	1.275482	1.176799
16	5	.891838	1.486397	.891838	1.189118
17	13	2.318779	1.426941	.724844	1.190936
18	6	1.070205	1.545852	.754861	1.167629
19	7	1.248573	1.070205	.859411	1.112601
20	5	.891838	.713470	.891838	1.010749
21	0	0.0	.416191	.766736	.881414
22	2	.356735	.178368	.503813	.650657
23	1	.178368	.178368	.207798	.454423

A.14/21

RUTTING	RTA1	RTA2	RTA3	RTA4	RTA5	RTA6	RTA7	RTA8	RTA9	RTA10	RTA11	RTA12	OBSEDRTA	AGOKI
0	2.27	2.29	5.38	6.66	.	.	.	.	.	.	.	.	4.20	4.11
5	1.01	2.29	6.86	.	.	.	.	.	.	.	.	.	3.39	3.33
10	.86	1.09	1.13	1.21	2.43	2.57	3.64	6.07	.	.	.	.	2.38	2.71
15	.76	.86	1.09	1.13	1.21	1.53	2.27	3.46	3.64	4.29	4.93	6.03	2.60	2.27
20	.86	1.13	1.21	2.27	2.43	.	.	.	.	.	.	.	1.58	1.99
25	.86	1.21	2.27	2.46	3.40	.	.	.	.	.	.	.	2.04	1.68
30	.86	1.13	1.21	2.27	3.64	.	.	.	.	.	.	.	1.82	1.94
35	1.13	4.29	.	.	.	.	.	.	.	.	.	.	2.71	2.17
40	2.27	.	.	.	.	.	.	.	.	.	.	.	2.27	2.57
45	1.13	2.27	6.07	.	.	.	.	.	.	.	.	.	3.16	3.13
50	2.27	5.38	.	.	.	.	.	.	.	.	.	.	3.83	3.87

A.14/22

CRACKING	RTA1	RTA2	RTA3	RTA4	RTA5	RTA6	RTA7	RTA8	RTA9	RTA10	RTA11	RTA12	OBSEDRTA	AGOKI
0.0	.76	.86	1.01	1.13	1.21	2.27	2.43	3.64	4.29	5.38	6.07	6.86	2.99	2.74
1.2	.86	1.21	2.27	2.46	3.64	4.29	4.93	5.38	6.03	6.07	.	.	2.06	2.39
5.0	.86	1.13	1.21	2.27	2.43	2.46	2.57	.	.	.	.	.	1.84	2.12
7.5	1.09	1.13	1.53	2.27	.	.	.	.	.	.	.	.	1.51	1.95
10	1.13	2.27	.	.	.	.	.	.	.	.	.	.	1.70	1.86
15	2.27	3.40	3.64	.	.	.	.	.	.	.	.	.	3.10	1.95
25	2.27	3.40	.	.	.	.	.	.	.	.	.	.	2.84	3.16

A.14/23

POTHOLES	RTA1	RTA2	RTA3	RTA4	RTA5	RTA6	RTA7	RTA8	OBSEDRTA	AGOKI
0.0	.86	1.21	2.46	4.29	6.03	.	.	.	2.97	2.80
1.2	.86	1.21	2.43	4.93	5.38	.	.	.	2.96	2.73
2.5	1.07	2.36	3.64	.	.	.	.	.	2.36	2.67
3.5	2.27	.	.	.	.	.	.	.	2.27	2.63
5.0	.66	1.13	1.21	2.27	2.29	2.43	5.38	6.86	2.80	2.58
7.5	.86	1.13	2.27	2.43	2.57	6.07	.	.	2.56	2.55
10.0	1.21	2.27	3.64	.	.	.	.	.	2.37	2.56
12.5	2.27	2.43	3.40	.	.	.	.	.	2.70	2.62
15.0	1.09	1.53	2.27	3.64	6.07	.	.	.	2.92	2.74
17.5	1.13	4.93	.	.	.	.	.	.	3.03	2.90
20.0	2.27	3.64	.	.	.	.	.	.	2.96	3.10
25.0	3.64	.	.	.	.	.	.	.	3.64	3.67

A.14/24

EDGESPAL	RTA1	RTA2	RTA3	RTA4	RTA5	OBSEDRTA	AGOKI
0	.76	.86	1.09	1.53	2.43	1.33	1.43
5	.86	1.09	1.53	.	.	1.16	1.97
10	.86	4.29	4.93	.	.	3.36	2.46
20	3.40	.	.	.	.	3.40	3.25
25	3.64	.	.	.	.	3.64	3.56
30	2.27	2.57	4.93	5.38	.	3.78	3.81
60	1.13	2.27	3.64	6.03	6.86	3.99	4.05
80	1.13	1.21	6.07	.	.	2.80	3.04
90	1.01	1.13	3.64	.	.	1.92	2.17
100	.76	.86	1.13	1.21	2.27	1.44	1.08
.	2.43	.	.	.	.	.	.

1	2	MUTHAIGA	400	17782	598	16	3	5		1.5	-0.2	250
2	2	MUTHAIGA	400	17782	598	16	0	3		0.0	+0.4	250
3	2	MUTHAIGA	253	17782	598	16	5	1		1.0	-3.3	250
4	2	MUTHAIGA	231	17782	598	16	0	2		1.5	+1.5	250
5	2	MUTHAIGA	169	17782	598	16	0	0	312	4.0	-6.6	250
6	2	MUTHAIGA	142	17782	598	16	0	0	300	2.0	+3.0	250
7	2	MUTHAIGA	201	17782	598	16	0	2		1.0	-4.2	325
8	2	MUTHAIGA	398	17782	598	16	0	1		2.0	+6.6	325
9	2	UTALII	480	17782	598	16	0	7	600	4.0	+4.6	325
10	2	UTALII	309	17782	598	16	0	6	340	3.0	-5.1	325
11	2	UTALII	617	17782	598	16	2	6	3200	1.0	-0.6	325
12	2	UTALII	431	17782	598	16	5	5		1.0	+0.7	325
13	2	DRIVEIN	623	17782	598	16	3	5		1.0	-0.9	300
14	2	DRIVEIN	96	17782	598	16	0	0	700	2.0	+0.8	325
15	2	DRIVEIN	123	14609	464	15	0	0	2000	0.0	-0.3	300
16	2	DRIVEIN	1235	14609	464	15	3	4		1.5	+1.4	300
17	2	DRIVEIN	55	14609	424	14	0	0		0.5	-0.2	300
18	2	BREWERY	34	14609	486	14	0	1	110	2.0	+0.3	300
19	2	DRIVEIN	90	14609	486	14	0	2	1500	0.5	-1.0	300
20	2	BREWERY	102	14609	434	14	9	1	500	4.0	+1.2	300
21	2	DRIVEIN	314	14609	484	15	0	1		1.5	-1.1	300
22	2	BREWERY	537	14609	486	14	0	5		1.0	+6.0	400
23	2	BBU	199	14609	424	15	5	4	65	2.0	-1.1	300
24	2	BREWERY	146	14609	486	14	0	0	600	4.0	-6.0	400
25	2	BREWERY	84	14609	486	14	0	1	140	2.0	-2.6	300
26	2	BREWERY	138	14609	486	14	0	1		1.0	-6.0	400
27	2	BREWERY	57	14609	486	14	0	1	350	2.0	-1.5	300
28	2	BREWERY	131	14609	486	14	8	1	600	4.0	-6.0	300
29	2	BREWERY	526	14609	486	14	0	5		1.0	-7.0	400
30	2	BREWERY	372	12358	417	14	4	2		1.0	-0.7	300
31	2	BREWERY	398	14609	486	14	3	1	550	1.0	+3.5	300
32	2	SAFARIPK	641	12358	417	14	4	6		1.5	+2.0	325
33	2	BREWERY	545	12358	417	14	5	2		1.0	+3.0	300
34	2	ROYSAMBU	533	12358	417	14	0	1		1.0	+3.0	300
35	2	BREWERY	560	12358	417	14	0	2		1.0	+0.3	300
36	2	ROYSAMBU	73	10372	350	14	14	1	100	2.5	+1.4	325
37	2	BREWERY	330	12358	417	14	0	2	6000	1.3	-3.0	400
38	2	ROYSAMBU	594	10372	350	14	5	13		1.0	+2.0	325
39	2	SAFARIPK	749	12358	417	14	3	6		1.5	-0.7	400
40	2	ROYSAMBU	149	10372	350	14	0	1	450	4.5	+5.1	325
41	2	ROYSAMBU	286	12358	417	14	0	1	1250	1.5	-0.4	300
42	2	ROYSAMBU	326	10372	350	14	0	1		1.0	+2.2	325
43	2	ROYSAMBU	106	12358	417	14	0	2		1.5	-2.0	325
44	2	ROYSAMBU	1124	10372	350	14	3	7		0.5	+2.5	325
45	2	ROYSAMBU	83	12358	417	14	11	1	110	2.5	-0.4	325
46	2	ROYSAMBU	296	10372	350	14	0	2	620	4.0	+2.6	325
47	2	ROYSAMBU	119	12358	417	14	8	11	130	2.5	-1.2	325
48	2	ROYSAMBU	725	10372	350	14	1	8		0.5	+0.6	300
49	2	RUIRU	241	9592	254	26	4	2	5000	0.0	-2.5	275
50	2	RUIRU	124	9592	254	26	0	1	2500	3.0	+5.0	275
51	2	RUIRU	833	9592	313	26	0	3		0.0	0.4	275
52	2	RUIRU	965	9592	313	26	0	20		0.0	+2.3	275
53	2	RUIRU	507	9592	313	26	2	2	900	5.0	+1.6	275
54	2	RUIRU	189	9592	313	26	0	0	590	6.5	-0.6	275
55	2	RUIRU	143	9592	313	26	0	1		2.5	+6.0	275
56	2	RUIRU	219	9592	313	26	0	3	300	5.0	-2.4	275
57	2	RUIRU	[illegible]	9592	313	26	0	1	900	[illegible]	[illegible]	275
58	2	RUIRU	[illegible]	9592	313	26	7	2		2.5	[illegible]	275

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59	2	RUIRU	[illegible]	9592	312	26	1	2		2.0	-1.2	275
60	2	RUIRU	294	9592	313	26	4	2	900	5.0	-3.8	275
61	2	ROYSAMBU	102	10372	350	14	10	2	130	2.5	-1.2	325
62	2	GITHURAI	124	10045	340	14	0	2	2000	0.5	+2.8	300
63	2	ROYSAMBU	491	10372	350	14	0	2		2.0	-2.5	325
64	2	GITHURAI	218	10045	340	14	3	2		0.0	-2.0	300
65	2	ROYSAMBU	366	10372	350	14	0	1	900	4.5	-3.7	325
66	2	KAHAWA	4239	10045	254	14	2	14		0.5	+2.0	400
67	2	ROYSAMBU	1217	10372	350	14	0	8		1.5	+2.0	325
68	2	SUKARI	261	10045	254	14	0	4	900	4.0	-2.0	300
69	2	ROYSAMBU	288	10372	350	14	0	2	600	6.0	-2.0	325
70	2	SUKARI	803	10045	254	14	1	2		0.5	+0.4	300
71	2	ROYSAMBU	610	10372	350	14	2	7		1.5	-0.6	325
72	2	SUKARI	636	10045	254	14	0	1		1.5	-2.0	300
73	2	GITHURAI	170	10045	340	14	6	1	2000	1.5	-1.8	300
75	2	GITHURAI	606	10045	340	14	2	3	0	2.0	-5.0	300
77	2	KAHAWA	2537	10045	277	14	3	2		1.5	+1.0	275
79	2	SUKARI	182	10045	254	14	0	1	920	2.5	-1.9	275
81	2	SUKARI	64	10045	254	14	0	1		[illegible]	-2.0	[illegible]
82	2	SUKARI	151	10045	254	14	0	2	470	4.0	+4.0	300
83	2	SUKARI	299	10045	254	14	0	4		1.5	+0.9	300
84	2	RUIRU	722	9592	311	26	0	1		1.5	+[illegible].2	275
85	2	RUIRU	449	9592	311	26	0	2	2100	2.0	-1.0	300
86	2	RUIRU	222	9592	313	26	1	3	910	1.5	-0.4	275
87	2	RUIRU	233	9592	311	26	0	1		1.5	-0.5	300
88	2	RUIRU		9592	311	20	0	1	1592	1.5	+2.2	200
89	2	RUIRU	326	9592	311	26	3	3	3000	2.5	-2.0	300
90	2	RUIRU	537	9592	311	26	0	2		1.0	-1.4	300
91	2	JUJA	470	7208	270	21	0	2		0.0	-5.0	300
92	2	JUJA	641	7208	270	31	0	4		0.5	+5.0	200
93	2	JUJA	638	7208	270	31	2	3	920	5.0	+1.8	300
94	2	JUJA	1299	7208	270	31	2	5		0.5	+1.7	300
95	2	JUJA	1159	7208	270	31	1	6		0.5	-[illegible]	300
96	2	JUJA	516	7208	244	31	0	1	929	4.5	-0.6	285
97	2	JUJA	609	7208	244	31	1	3		0.0	+2.5	285
98	2	JUJA	160	7208	244	31	0	4		0.0	-1.5	285
99	2	JUJA	68	7208	244	31	0	1	920	4.5	+0.8	285
100	2	JUJA	191	7208	244	31	0	1	700	2.0	-3.0	285
101	2	JUJA	1322	7208	244	31	2	19		0.5	-0.4	285
102	2	JUJA	1135	7208	244	31	0	22		0.5	+0.9	285
103	2	JUJA	1083	7208	240	31	1	2		1.0	-0.7	285
104	2	JUJA	709	7208	240	31	1	2		1.0	-0.7	285
105	2	JUJA	218	7208	240	31	0	1	1250	0.5	-3.4	225
106	2	JUJA	204	7208	240	31	0	2	1250	0.5	+3.7	225
107	2	JUJA	532	7208	240	31	0	4		1.0	-5.9	225
108	2	JUJA	781	7208	240	31	0	8		2.5	+4.5	225
109	2	JUJA	919	7208	240	31	1	2		1.0	+2.5	225
110	2	THIKA	1448	4824	210	3	2	1		1.5	+3.0	225
111	2	THIKA	1744	4824	210	36	2	2		1.0	-4.0	225
112	2	THIKA	313	4824	210	36	0	1	1500	3.0	+4.6	225
113	2	THIKA	339	4824	210	36	0	5	1625	3.0	+4.6	225
114	2	THIKA	1134	4824	210	36	1	5		1.0	+5.0	225
115	2	THIKA	1429	4824	210	36	1	9		1.5	+1.5	225
116	2	THIKA	355	4824	260	36	3	2	5000	1.5	-0.2	265
117	2	THIKA	1676	4824	260	36	2	10		1.0	0.0	265
118	2	THIKA	1857	4824	260	36	2	5		1.0	+0.2	265
119	2	BLUEPOST	123	[illegible]	162	21	0	1	[illegible]	4.5	+1.5	300
120	2	BLUEPOST	[illegible]	[illegible]	162	21	[illegible]	1		[illegible]	[illegible]	300

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? $CAL %RE=(%YV-%FV)/%SQRT(%ULL)$
? $LOOK ONO S JPK LAB AR SUE %FV %RE PIT$
-- list truncated
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	ONO	S	JPK	LAB	[illegible]	SUE	%FV
1	1.000	2.34033	3.000	16.00	[illegible]	1.5000	4.5513
2	2.000	2.34033	0.000	16.00	[illegible]	0.0000	4.3771
3	3.000	1.80226	5.000	16.00	[illegible]	1.0000	3.7828
4	4.000	1.79129	0.000	16.00	[illegible]	1.5000	2.4132
5	5.000	1.47203	0.000	16.00	[illegible]	4.0000	1.7399
6	6.000	1.30469	0.000	16.00	[illegible]	2.0000	1.9767
7	7.000	1.65217	0.000	16.00	[illegible]	1.0000	[illegible]
8	8.000	2.33532	0.000	15.00	[illegible]	2.0000	[illegible]
9	9.000	2.52265	0.000	16.00	[illegible]	4.0000	[illegible]
10	10.000	2.08221	0.000	16.00	[illegible]	3.0000	3.0535
11	11.000	2.77374	2.000	16.00	[illegible]	1.0000	6.3583
12	12.000	2.41498	5.000	16.00	[illegible]	1.0000	5.9197
13	13.000	2.79141	3.000	15.00	[illegible]	1.0000	6.8071
14	14.000	0.91322	0.000	16.00	[illegible]	2.0000	1.2908
15	15.000	0.96450	0.000	15.00	[illegible]	0.0000	1.6062
16	16.000	3.34901	3.000	16.00	[illegible]	1.5000	9.7502
17	17.000	0.15765	0.000	16.00	[illegible]	0.5000	0.7972
18	18.000	0.58314	0.000	16.00	[illegible]	3.0000	1.4911
19	19.000	0.65213	0.000	14.00	[illegible]	0.5000	1.1578
20	20.000	0.80628	9.000	14.00	[illegible]	1.0000	1.8174
21	21.000	1.90171	0.000	16.00	[illegible]	1.5000	2.6225
22	22.000	2.52734	0.000	14.00	[illegible]	1.0000	4.2773
23	23.000	1.44562	5.000	16.00	[illegible]	2.0000	5.6038
24	24.000	1.13573	0.000	14.00	[illegible]	4.0000	1.1663
25	25.000	0.58314	0.000	14.00	[illegible]	2.0000	[illegible]
26	26.000	1.07957	0.000	14.00	[illegible]	1.0000	1.4575
27	27.000	0.19537	0.000	14.00	[illegible]	1.0000	0.7751
28	28.000	1.02752	8.000	14.00	[illegible]	1.0000	1.9487
29	29.000	2.68611	0.000	14.00	[illegible]	1.0000	4.3206
30	30.000	2.33587	4.000	14.00	[illegible]	1.0000	4.7059
31	31.000	2.13877	3.000	14.00	[illegible]	1.0000	4.3191
32	22.000	2.71958	4.000	14.00	[illegible]	1.5000	6.2249
33	33.000	1.82853	[illegible]	14.00	[illegible]	1.0000	3.9462
34	34.000	2.25408	0.000	14.00	[illegible]	1.0000	3.4817
35	35.000	1.67109	0.000	14.00	[illegible]	1.0000	2.6093
36	36.000	0.10025	14.000	14.00	[illegible]	2.5000	2.7860
37	37.000	1.78408	0.000	14.00	[illegible]	1.5000	[illegible]
38	38.000	2.19667	5.000	14.00	[illegible]	1.0000	4.8363
39	39.000	2.60239	3.000	14.00	[illegible]	1.5000	5.3246
40	40.000	0.81374	0.000	14.00	[illegible]	[illegible]	0.6911
41	41.000	1.64098	0.000	14.00	[illegible]	1.5000	2.1292
42	42.000	1.59669	0.000	14.00	[illegible]	1.0000	2.1281
43	43.000	0.64842	0.000	14.00	[illegible]	1.5000	0.7776
44	44.000	2.83447	3.000	14.00	[illegible]	[illegible]	7.1590
45	45.000	0.46232	11.000	14.00	[illegible]	2.5000	3.1475
46	46.000	1.50015	0.000	14.00	[illegible]	4.0000	1.5207
47	47.000	0.76411	8.000	14.00	[illegible]	2.5000	2.0755
48	48.000	2.39596	1.000	14.00	[illegible]	0.5000	4.4344
49	49.000	1.21641	4.000	26.00	[illegible]	0.0000	3.1711
50	50.000	0.55189	0.000	26.00	[illegible]	0.0000	1.6058
51	51.000	2.45664	0.000	26.00	[illegible]	0.0000	5.7133
52	52.000	2.60374	0.000	26.00	[illegible]	0.0000	6.2060
53	53.000	1.96012	2.000	26.00	[illegible]	5.0000	2.7746
54	54.000	0.97336	0.000	26.00	[illegible]	2.5000	0.9861
55	55.000	0.72882	0.000	26.00	[illegible]	2.5000	1.1085
56	56.000	1.11611	0.000	26.00	0.0011111	5.0000	1.2563

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57	57.000	1.36410	0.000	26.00	[illegible]	4.5000	1.6463
58	58.000	0.72204	7.000	26.00	[illegible]	2.5000	1.9982
59	59.000	2.38059	1.000	26.00	[illegible]	2.0000	4.7198
60	60.000	1.38058	4.000	26.00	[illegible]	5.0000	2.0808
61	61.000	0.43476	10.000	14.00	[illegible]	2.5000	2.6046
62	62.000	0.59804	0.000	14.00	[illegible]	0.5000	1.0992
63	63.000	2.00624	0.000	14.00	[illegible]	2.0000	2.5569
64	64.000	1.16225	5.000	14.00	[illegible]	0.0000	2.5051
65	65.000	1.71242	0.000	14.00	[illegible]	4.5000	1.6325
66	66.000	4.12960	2.000	14.00	[illegible]	0.5000	17.6274
67	67.000	2.99442	0.000	14.00	[illegible]	1.5000	5.7229
68	68.000	1.34228	0.000	14.00	[illegible]	4.0000	1.3134
69	69.000	1.47275	0.000	14.00	[illegible]	6.0000	1.1794
70	70.000	2.46611	1.000	14.00	[illegible]	0.5000	4.4749
71	71.000	2.22325	2.000	14.00	[illegible]	1.5000	3.7151
72	72.000	2.23295	0.000	14.00	[illegible]	1.5000	3.2251
73	73.000	0.91355	4.000	14.00	[illegible]	1.5000	1.9295
74	75.000	2.18464	3.000	14.00	[illegible]	2.0000	3.6586
75	77.000	3.61649	3.000	14.00	[illegible]	1.5000	11.4265
76	79.000	0.98176	0.000	14.00	[illegible]	2.5000	1.2887
77	81.000	-0.06336	0.000	14.00	[illegible]	0.0000	0.6852
78	82.000	0.85916	0.000	14.00	[illegible]	4.0000	0.9787
79	83.000	1.47485	0.000	14.00	[illegible]	1.5000	1.8221
80	84.000	2.31364	0.000	26.00	[illegible]	1.5000	4.4266
81	85.000	1.83863	0.000	26.00	[illegible]	2.0000	2.9771
82	86.000	2.23590	1.000	26.00	[illegible]	1.5000	4.8425
83	87.000	1.37706	0.000	26.00	[illegible]	1.5000	2.1853
84	88.000	0.00000	0.000	20.00	[illegible]	1.5000	0.7114
85	89.000	1.51851	3.000	26.00	[illegible]	2.5000	2.7540
86	90.000	2.10664	0.000	26.00	[illegible]	1.0000	4.0242
87	91.000	1.59861	0.000	31.00	[illegible]	0.0000	3.4472
88	92.000	1.90890	0.000	31.00	[illegible]	0.5000	4.0936
89	93.000	1.90421	3.000	31.00	[illegible]	5.0000	3.1827
90	94.000	2.61445	2.000	31.00	[illegible]	0.5000	8.0911
91	95.000	2.50119	1.000	31.00	[illegible]	0.5000	6.8970
92	96.000	1.69198	0.000	31.00	[illegible]	4.5000	2.3041
93	97.000	1.85769	1.000	31.00	[illegible]	0.0000	4.5130
94	98.000	1.93311	0.000	31.00	[illegible]	0.0000	4.4516
95	99.000	-0.33462	0.000	31.00	[illegible]	4.5000	0.5011
96	100.000	0.69815	0.000	31.00	[illegible]	2.0000	1.5115
97	101.000	2.63277	2.000	31.00	[illegible]	0.5000	8.2036
98	102.000	2.48026	3.000	31.00	[illegible]	0.5000	7.8780
99	103.000	2.43336	1.000	31.00	[illegible]	1.0000	6.1680
100	104.000	2.00973	1.000	31.00	[illegible]	1.0000	4.4931
101	105.000	0.83037	0.000	31.00	[illegible]	0.5000	1.9198
102	106.000	0.76399	0.000	31.00	[illegible]	0.5000	1.8262
103	107.000	1.72252	0.000	31.00	[illegible]	1.0000	3.3522
104	108.000	2.10645	0.000	31.00	[illegible]	2.5000	3.7318
105	109.000	2.26916	1.000	31.00	[illegible]	1.0000	5.4505
106	110.000	2.32222	2.000	30.00	[illegible]	1.5000	5.6299
107	111.000	2.50822	2.000	36.00	[illegible]	1.0000	7.8204
108	112.000	0.79049	0.000	36.00	[illegible]	3.0000	1.5169
109	113.000	0.87028	0.000	36.00	[illegible]	3.0000	1.6053
110	114.000	2.07779	1.000	36.00	[illegible]	1.0000	5.2497
111	115.000	2.30901	1.000	36.00	[illegible]	1.5000	5.8808
112	116.000	0.91640	3.000	36.00	[illegible]	1.5000	2.4231
113	117.000	2.48149	2.000	36.00	[illegible]	1.0000	7.6645
114	118.000	2.57100	2.000	36.00	[illegible]	1.0000	8.1990
115	119.000	1.09020	0.000	21.00	[illegible]	4.5000	1.1860
116	120.000	0.55222	4.000	21.00	[illegible]	2.0000	1.3861

A.15 (CONTD)

? $LOOK ONO PIA %FV %RE RAD AR$

	ONO	PIA	%FV	%RE	RAD	AR
1	1.000	8.000	4.5613	1.610095	0.00	0.0000000
2	2.000	6.000	4.3771	0.775710	0.00	0.0000000
3	3.000	1.000	3.9828	-1.494617	0.00	0.0000000
4	4.000	3.000	2.4132	0.377714	0.00	0.0000000
5	5.000	0.000	1.7399	-1.319071	312.00	0.0032051
6	6.000	0.000	1.9707	-1.403818	300.00	0.0033333
7	7.000	2.000	2.3090	-0.203371	0.00	0.0000000
8	8.000	1.000	3.4215	-1.309108	0.00	0.0000000
9	9.000	7.000	3.4587	1.904148	600.00	0.0016667
10	10.000	6.000	3.0588	1.686172	340.00	0.0029412
11	11.000	6.000	6.3883	-0.145953	3200.00	0.0003125
12	12.000	5.000	5.9489	-0.389042	0.00	0.0000000
13	13.000	5.000	6.8071	-0.692635	0.00	0.0000000
14	14.000	0.000	1.2908	-1.136123	700.00	0.0014286
15	15.000	0.000	1.6062	-1.267349	2000.00	0.0005000
16	16.000	6.000	9.7502	-1.201023	0.00	0.0000000
17	17.000	0.000	0.7972	-0.892867	0.00	0.0000000
18	18.000	2.000	1.4941	0.413900	110.00	0.0090909
19	19.000	2.000	1.1578	0.752679	1500.00	0.0006667
20	20.000	1.000	1.8174	-0.606302	500.00	0.0020000
21	21.000	1.000	2.6285	-1.001916	0.00	0.0000000
22	22.000	5.000	4.2773	0.349434	0.00	0.0000000
23	23.000	4.000	5.6088	-0.679311	85.00	0.0117647
24	24.000	0.000	1.1663	-1.079956	[illegible]	0.0016667
25	25.000	1.000	1.4175	-0.350687	140.00	0.0071429
26	26.000	1.000	1.4375	-0.264926	0.00	0.0000000
27	27.000	1.000	0.7931	0,232339	350.00	0.0028571
28	28.000	1.000	1.9467	-0.679621	600.00	0.0016667
29	29.000	5.000	4.8206	0.081708	0.00	0.0000000
30	30.000	8.000	4.9857	1.347863	0.00	0.0000000
31	31.000	1.000	4.3191	-1.597057	850.00	0.0011765
32	32.000	6.000	6.2649	-0.105842	0.00	0.0000000
33	33.000	2.000	3.9482	-0.930456	0.00	0.0000000
34	34.000	1.000	3.4917	-1.330001	0.00	0.0000000
35	35.000	2.000	2.6093	-0.377172	0.00	0.0000000
36	36.000	1.000	2.7260	-1.045385	130.00	0.0076923
37	37.000	2.000	2.3259	-0.213717	6000.00	0.0001667
38	38.000	13.000	4.8663	3.712216	0.00	0.0000000
39	39.000	6.000	5.3246	0.292711	0.00	0.0000000
40	40.000	1.000	0.8911	0.115347	460.00	0.0021739
41	41.000	1.000	2.1793	-0.798857	1250.00	0.0008000
42	42.000	1.000	2.1221	-0.770272	0.00	0.0000000
43	43.000	2.000	0.9778	1.033700	0.00	0.0000000
44	44.000	7.000	7.1590	-0.059423	0.00	0.0000000
45	45.000	1.000	3.1475	-1.210471	110.00	0.0090909
46	46.000	2.000	1.5289	0.381017	620.00	0.0016129
47	47.000	11.000	2.8765	4.789709	130.00	0.0076923
48	48.000	8.000	4.4344	1.693253	0.00	0.0000000
49	49.000	2.000	3.1711	-0.657634	5000.00	0.0002000
50	50.000	1.000	1.0058	-0.005770	2500.00	0.0004000
51	51.000	3.000	5.9133	-1.198024	0.00	0.0000000
52	52.000	20.000	6.6060	5.211222	0.00	0.0000000
53	53.000	2.000	2.7746	-0.465012	900.00	0.0011111
54	54.000	0.000	0.9861	-0.993019	590.00	0.0016949
55	55.000	1.000	1.1083	-0.172930	0.00	0.0000000
56	56.000	3.000	1.2663	1.540700	900.00	0.0011111
57	57.000	1.000	1.6463	-0.503730	900.00	0.0011111

58	58.000	2.000	1.9902	0.006964	0.00	0.0000000
59	59.000	2.000	4.7198	-1.251906	0.00	0.0000000
60	60.000	2.000	2.0808	-0.056087	900.00	0.0011111
61	61.000	2.000	2.6046	-0.374626	130.00	0.0076923
62	62.000	2.000	1.0992	0.859801	2000.00	0.0005000
63	63.000	2.000	2.3589	-0.349376	0.00	0.0000000
64	64.000	2.000	2.5051	-0.319136	0.00	0.0000000
65	65.000	1.000	1.5023	-0.496892	900.00	0.0011111
66	66.000	14.000	17.6274	-0.863970	0.00	0.0000000
67	67.000	8.000	5.7229	0.931812	0.00	0.0000000
68	68.000	4.000	1.3124	2.346075	900.00	0.0011111
69	69.000	2.000	1.1794	0.755642	600.00	0.0016667
70	70.000	2.000	4.5749	-1.237157	0.00	0.0000000
71	71.000	7.000	3.7151	1.704254	0.00	0.0000000
72	72.000	1.000	3.2251	-1.237020	0.00	0.0000000
73	73.000	1.000	1.9293	-0.669071	2000.00	0.0005000
74	75.000	8.000	3.6586	2.269762	0.00	0.0000000
75	77.000	8.000	11.4235	1.014165	0.00	0.0000000
76	79.000	1.000	1.2337	-0.254482	460.00	0.0021739
77	81.000	1.000	0.6962	0.378837	0.00	0.0000000
78	82.000	2.000	0.9767	1.039402	470.00	0.0021277
79	83.000	4.000	1.8221	1.613910	0.00	0.0000000
80	84.000	1.000	4.4764	-1.628597	0.00	0.0000000
81	85.000	2.000	2.9771	-0.566274	3100.00	0.0003226
82	86.000	3.000	4.5425	-0.837295	910.00	0.0010989
83	87.000	1.000	2.1063	-0.802276	0.00	0.0000000
84	88.000	1.000	0.7114	0.343197	1592.00	0.0006281
85	89.000	3.000	2.7540	0.148256	3000.00	0.0003333
86	90.000	2.000	4.0242	-1.007043	0.00	0.0000000
87	91.000	2.000	3.4472	-0.779470	0.00	0.0000000
88	92.000	4.000	4.0906	-0.048682	0.00	0.0000000
89	93.000	3.000	2.1827	-0.102426	920.00	0.0010870
90	94.000	5.000	3.0911	-1.036711	0.00	0.0000000
91	95.000	6.000	2.8970	-0.341542	0.00	0.0000000
92	96.000	1.000	2.3041	-0.857143	929.00	0.0010764
93	97.000	3.000	4.3135	-0.712401	0.00	0.0000000
94	98.000	4.000	4.4516	-0.214050	0.00	0.0000000
95	99.000	1.000	6.5011	0.704757	920.00	0.0010870
96	100.000	1.000	1.1115	-0.416021	700.00	0.0014286
97	101.000	19.000	11.2036	3.769461	0.00	0.0000000
98	102.000	22.000	7.8780	5.031382	0.00	0.0000000
99	103.000	2.000	6.1480	-1.673246	0.00	0.0000000
100	104.000	2.000	4.4931	-1.172745	0.00	0.0000000
101	105.000	1.000	1.9198	-0.663343	1250.00	0.0003000
102	106.000	2.000	1.8262	0.128621	1250.00	0.0008000
103	107.000	4.000	[illegible]	0.353800	0.00	0.0000000
104	108.000	8.000	3.7318	2.209173	0.00	0.0000000
105	109.000	2.000	5.4505	-1.477958	0.00	0.0000000
106	110.000	1.000	5.6297	-1.951283	0.00	0.0000000
107	111.000	2.000	7.8204	-2.081313	0.00	0.0000000
108	112.000	1.000	1.5169	-0.419662	1500.00	0.0006667
109	113.000	5.000	1.6053	2.677374	1625.00	0.0006154
110	114.000	5.000	5.2497	-0.107001	0.00	0.0000000
111	115.000	9.000	5.8808	1.286247	0.00	0.0000000
112	116.000	2.000	2.4231	-0.271834	5000.00	0.0002000
113	117.000	10.000	7.6645	0.843396	0.00	0.0000000
114	118.000	5.000	8.1790	-1.117218	0.00	0.0000000
115	119.000	1.000	1.1860	-0.170804	900.00	0.0011111
116	120.000	1.000	1.3381	-0.272258	0.00	0.0000000

Note for Appendix A.15

1: Constant,
S: power to which travel is raised,
JPK: junctions per kilometre,
LAB: lorries and buses
FCR(2): horizontal radius (800-3200m),
FCR(3): horizontal radius (73200m),
FCR(1): SUE: horizontal radius (0-800m) and superelevation,
FCR(2). SUE: horizontal radius (800-3200m) and superelevation,
FCR(3). SUE: horizontal radius (>3200m) and superelevation,
AR: reciprocal of the horizontal radius,
SUE: superelevation

A.15(CONTD)

```
$UNITS 116
$DATA ONO LES ADT VEH LAL JEI I A RAD SUE GI
$FORMAT F3.0,12X,F4.0,1X,F5.0,1X,F3.0,1X,F2 ,1X,F2.0,
1X,F4.0,1X,F3.1,1X,F4.1,1X,F
$C AGOGIN 4AJOL DATA, NJORINTO ..., DATE
$C MLR 15.3.1988
$DIM 7$
$CAL A1=365*(LES/1000)
$CAL SUO=4*A1$
$CAL S=%LOG(SUO)$
$CAL B1=%IF(RAD>0,RAD,1)$
$CAL B2=1/B1$
$CAL AR=(B2/=1)*B2
$CAL ARA=10+GRA$
$FAC FJ 3$
$CAL FJ=1+%GE(JPK,3)+%GE(JPK,7)$
$CAL CR=(RAD-1)*10000+RAD$
$FAC FCR 3 FSU 2 FGR 3 FLB 3$
$CAL FCR=1+%GE(CR,800)+%GE(CR,3800)$
$CAL FSU=1+%GE(SUE,3.5)$
$CAL FGR=1+%GE(ARA,7)+%GE(ARA,13)$
$CAL FLB=1+%GE(LAB,20)+%GE(LAB,30)$
$YVAR PIA$ERROR P$LINK L$
$FIT :+S:+JPK:+LAB:+AR:+SUE+DISP D E $
$FIT S+JPK+FCR+FCR.SUE$DISP D E$
$C CAL %RE=(%YV-%FV)/%SQRT(SUO)$
$C LOOK ONO PIA %FV %RE FJ FLB FGR FLB FCR$
$RETURN $

$FIT :+S:+LAB:+JPK$DISP D E$
scaled deviance = 380.19 at cycle 4
           d.f. = 115

scaled deviance = 228.96 (change =  -151.2) at cycle 4
           d.f. = 114    (change =     -1  )

scaled deviance = 221.88 (change =   -7.07) at cycle 4
           d.f. = 113    (change =     -1  )

scaled deviance = 206.23 (change = -15.650) at cycle 4
           d.f. = 112    (change =     -1  )

Scaled deviance is  206.23  on  112 d.f.  from 116 observations
        change is  -15.65 for   -1 d.f.

         estimate        s.e.       parameter
    1     -0.8228       0.2232       1
    2      0.7636       0.06079      S
    3      0.02125      0.006199     LAB
    4      0.09371      0.02255      JPK
    scale parameter taken as  1.000

? $FIT +SUE$
scaled deviance = 201.02 (change =   -5.21) at cycle 4
           d.f. = 111    (change =     -1  )

? $DISP D E$
Scaled deviance is  201.020  on  111 d.f.  from 116 observations
        change is   -5.214 for   -1 d.f.

         estimate        s.e.       parameter
    1     -0.4976       0.2612       1
    2      0.7019       0.06597      S
    3      0.01941      0.006136     LAB
    4      0.09345      0.02269      JPK
    5     -0.1021       0.04583      SUE
    scale parameter taken as  1.000
```

A.15(CONTD)

```
? $FIT +SID$
scaled deviance = 200.63 (change =   -0.39) at cycle 4
          d.f. = 110     (change =   -1   )

? $FIT -SID+AR$
scaled deviance = 196.91 (change =   -3.73) at cycle 4
          d.f. = 110     (change =    0   )

? $DISP D E$
Scaled deviance is  196.908  on  110 d.f.   from  116 observations
        change is   -3.726 for    0 d.f.

        estimate        s.e.      parameter
   1    -0.6274       0.2716      1
   2     0.7532       0.07081     S
   3     0.02132      0.006333    LAB
   4     0.07437      0.02435     JPK
   5    -0.1213       0.04734     SUE
   6     67.36        31.50       AR
   scale parameter taken as  1.000

? $FIT -AR+FCR$
scaled deviance = 198.26 (change =   +1.35) at cycle 4
          d.f. = 109     (change =   -1   )

? $DISP D E$
Scaled deviance is  198.258  on  109 d.f.   from  116 observations
        change is   +1.350 for   -1 d.f.

        estimate        s.e.      parameter
   1    -0.2777       0.2984      1
   2     0.7330       0.07412     S
   3     0.02174      0.006450    LAB
   4     0.08607      0.02267     JPK
   5    -0.1278       0.05698     SUE
   6    -0.3608       0.2196      FCR(2)
   7    -0.3138       0.2305      FCR(3)
   scale parameter taken as  1.000

? $FIT +GRA$
scaled deviance = 197.02 (change =   -1.24) at cycle 4
          d.f. = 108     (change =   -1   )

? $FIT :+S:+JPK:+LAB:+SUE:+AR$DISP D E$
scaled deviance = 380.19 at cycle 4
          d.f. = 115

scaled deviance = 228.96 (change =  -151.2) at cycle 4
          d.f. = 114     (change =    -1  )

scaled deviance = 217.69 (change = -11.271) at cycle 4
          d.f. = 113     (change =   -1    )

scaled deviance = 206.23 (change = -11.452) at cycle 4
          d.f. = 112     (change =   -1    )

scaled deviance = 201.02 (change =   -5.21) at cycle 4
          d.f. = 111     (change =   -1   )

scaled deviance = 196.91 (change =   -4.11) at cycle 4
          d.f. = 110     (change =   -1   )

Scaled deviance is  196.908  on  110 d.f.   from  116 observations
        change is   -4.112 for   -1 d.f.

        estimate        s.e.      parameter
   1    -0.6274       0.2716      1
   2     0.7532       0.07081     S
   3     0.07437      0.02435     JPK
   4     0.02132      0.006333    LAB
   5    -0.1213       0.04734     SUE
   6     67.36        31.50       AR
   scale parameter taken as  1.000

? $FIT -SUE+GRA$
scaled deviance = 202.78 (change =   +5.87) at cycle 4
          d.f. = 110     (change =    0   )

? $FIT S+JPK+LAB:+AR$
scaled deviance = 206.23 at cycle 4
          d.f. = 112

scaled deviance = 203.88 (change =   -2.36) at cycle 4
          d.f. = 111     (change =   -1   )

? $DISP D E$
Scaled deviance is  203.878  on  111 d.f.   from  116 observations
        change is   -2.356 for   -1 d.f.

        estimate        s.e.      parameter
   1    -0.9721       0.2443      1
   2     0.8113       0.06629     S
   3     0.08006      0.02416     JPK
   4     0.02308      0.006367    LAB
   5     51.36        32.18       AR
   scale parameter taken as  1.000
```

A.15(CONTD)

```
? $FIT +AR+FCR:+FCR.SUE$
scaled deviance = 203.39 (change = -0.46) at cycle [illegible]
        d.f. = 110    (change =  -1   )

scaled deviance = 194.53 (change = -8.863) at cycle [illegible]
        d.f. = 107    (change =  -3   )

? $DISP D E$
Scaled deviance is  194.531  on  107 d.f.   from [illegible] observations
        change is  -8.863 for  -3 d.f.

        estimate       s.e.      parameter
  1    -0.09198      0.4942      1
  2     0.7248       0.07462     S
  3     0.08490      0.02295     JPK
  4     0.01904      0.006628    LAB
  5    -0.7595       0.5382      FCR(2)
  6    -0.2860       0.4984      FCR(3)
  7    -0.1692       0.1371      FCR(1).SUE
  8    -0.01629      0.08199     FCR(2).SUE
  9    -0.2639       0.09962     FCR(3).SUE
  scale parameter taken as  1.000

? $FIT -FCR.SUE+FCR.FSU$
scaled deviance = 199.89 (change =   +5.36) at cycle [illegible]
        d.f. = 108    (change =   +1   )

? $FIT +FSU$
scaled deviance = 199.89 (change =    0.00) at cycle [illegible]
        d.f. = 108    (change =    0   )

? $FIT :+S:+JPK:+LAB:+SID$
scaled deviance = 380.19 at cycle  4
        d.f. = 115

scaled deviance = 228.96 (change =  -151.2) at cycle  4
        d.f. = 114    (change =    -1  )

scaled deviance = 217.69 (change = -11.271) at cycle  4
        d.f. = 113    (change =  -1     )

scaled deviance = 206.23 (change = -11.452) at cycle  4
        d.f. = 112    (change =  -1     )

scaled deviance = 205.85 (change =   -0.38) at cycle  4
        d.f. = 111    (change =   -1    )

? $FIT -LAB$
scaled deviance = 215.37 (change =   +9.51) at cycle [illegible]
        d.f. = 112    (change =   +1    )

? $FIT :+S:+JPK:+LAB:+AR$DISP D E$FIT +SUE$
scaled deviance = 380.19 at cycle  4
        d.f. = 115

scaled deviance = 228.96 (change =  -151.2) at cycle [illegible]
        d.f. = 114    (change =    -1  )

scaled deviance = 217.69 (change = -11.271) at cycle [illegible]
        d.f. = 113    (change =  -1     )

scaled deviance = 206.23 (change = -11.452) at cycle [illegible]
        d.f. = 112    (change =  -1     )

scaled deviance = 203.88 (change =   -2.36) at cycle  4
        d.f. = 111    (change =   -1    )

Scaled deviance is  203.878  on  111 d.f.   from  116 observations
        change is   -2.356 for   -1 d.f.

        estimate       s.e.      parameter
  1    -0.9721       0.2443      1
  2     0.8113       0.06829     S
  3     0.08006      0.02416     JPK
  4     0.02308      0.006327    LAB
  5     51.36        32.18       AR
  scale parameter taken as  1.000

scaled deviance = 196.91 (change =   -6.97) at cycle [illegible]
        d.f. = 110    (change =   -1    )

? $DISP D E$
Scaled deviance is  196.903  on  110 d.f.   from  116 observations
        change is   -6.970 for   -1 d.f.

        estimate       s.e.      parameter
  1    -0.6274       0.2716      1
  2     0.7532       0.07081     S
  3     0.07437      0.02435     JPK
  4     0.02132      0.006343    LAB
  5     67.36        31.50       AR
  6    -0.1213       0.04734     SUE
  scale parameter taken as  1.000
```

1	2	KIGANJO	500	1023	43	38	4	3	609.6	+2.60	1.5	35.0	1.25	5.00
2	2	KIGANJO	500	1673	11	21	6	1		-0.30	0.0	45.0	2.50	3.50
3	2	KIGANJO	500	1673	71	27	6	5	914.4	-1.10	5.0	50.0	1.25	0.00
4	2	KIGANJO	500	1229	51	28	2	0	609.6	-1.40	5.0	7.5	0.00	1.25
5	2	KIGANJO	500	1229	51	28	2	0	914.4	+0.57	2.5	60.0	0.00	1.25
6	2	KIGANJO	500	1236	54	27	4	1		+1.30	5.0	85.0	0.00	0.00
7	2	KIGANJO	500	1266	54	27	4	8		-0.10	0.0	60.0	0.00	1.25
8	2	CHAKA	500	1509	63	32	0	1	609.6	-0.30	5.0	30.0	1.25	2.50
9	2	CHAKA	500	1506	63	28	6	1		-0.50	6.2	50.0	0.00	0.00
10	2	CHAKA	500	1375	57	29	2	0	1524.0	+1.50	7.3	20.0	0.00	1.25
11	2	BILIMANI	500	[illegible]	57	[illegible]	4	5		+5.30	22.5	50.0	0.00	0.00
12	2	BILIMANI	500	[illegible]	57	28	3	2		+3.[illegible]	7.3	30.0	1.25	2.50
13	2	[illegible]	500	[illegible]	[illegible]	32	3	2	609.6	[illegible]	25.0	50.0	5.00	12.50
14	2	[illegible]	500	[illegible]	[illegible]	28	[illegible]	[illegible]	1066.3	[illegible]	[illegible]	30.0	0.00	10.00
15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	12.3	[illegible]	10.00	1.25
16	2	GHAURIYA	500	[illegible]	44	30	0	0		-0.20	17.5	35.0	0.00	1.25
17	2	KARICHEN	500	1063	44	30	0	1		+1.10	25.0	5.0	3.75	3.75
18	2	KARICHEN	500	1063	44	30	0	0		+1.80	20.0	15.0	1.25	1.25
19	2	KARICHEN	500	1063	44	30	4	1		+1.30	17.5	50.0	2.50	50.00
20	2	KARICHEN	500	1063	44	30	4	[illegible]		+1.10	25.0	40.0	0.00	3.13
21	2	NYANGE	500	1065	44	30	6	0	914.4	-2.50	20.0	30.0	1.38	5.00
22	2	NYANGE	500	987	41	30	4	2	914.4	+3.50	10.0	50.0	0.00	1.25
23	2	NYANGE	500	987	41	30	2	2	502.9	+1.00	12.5	50.0	0.00	13.75
24	2	NYANGE	500	987	41	30	0	2	1524.0	+1.40	15.0	50.0	5.00	10.00
25	2	COISOI	500	987	41	30	0	0	1524.0	+2.50	12.5	90.0	11.25	1.25
26	2	COISOI	500	987	41	30	4	[illegible]		-1.00	20.0	50.0	0.00	23.75
27	2	COISOI	500	987	41	30	0	2	6096.0	-1.40	7.5	70.0	6.25	18.75
28	2	COISOI	500	987	41	30	0	1		+0.19	20.0	55.0	0.00	1.25
29	2	COISOI	500	987	41	30	0	0		+0.60	10.0	80.0	0.00	2.50
30	2	COISOI	500	987	41	30	0	0		+1.20	12.5	60.0	0.00	11.25
31	2	THUNGARE	500	987	41	30	4	0		+0.10	10.0	50.0	0.00	7.50
32	2	THUNGARE	500	987	41	30	4	[illegible]		+1.40	12.5	40.0	0.00	5.00
33	2	THUNGARE	500	987	41	30	[illegible]	0		+0.50	[illegible]	50.0	0.00	2.50
34	2	THUNGARE	500	987	41	30	[illegible]	0		[illegible]	15.0	55.0	0.00	6.25
35	2	THUNGARE	500	[illegible]	41	[illegible]	0	[illegible]		[illegible]	12.5	[illegible]	0.00	13.50
36	2	THUNGARE	500	1141	48	25	4	1	914.4	-1.95	17.5	50.0	2.50	3.73
37	2	THUNGARE	500	1141	48	25	0	0		+1.70	10.0	25.0	1.25	3.75
38	2	THUNGARE	500	1141	48	25	2	0	914.4	+0.90	17.5	30.0	3.75	8.75
39	2	THUNGARE	500	1141	48	25	0	0		-0.03	7.5	45.0	0.00	26.25
40	2	THUNGARE	500	1141	48	25	4	2		-0.80	17.5	60.0	0.00	5.00
41	2	AGUTHI	500	1141	48	25	2	3		-0.07	12.5	45.0	1.25	2.50
42	2	AGUTHI	500	1141	48	25	0	0		+0.60	22.5	95.0	0.00	1.25
43	2	AGUTHI	500	1141	48	25	0	0		+2.46	22.5	90.0	0.00	0.00
44	2	AGUTHI	500	1141	48	25	0	0		-1.15	6.2	65.0	2.50	12.50
45	2	AGUTHI	500	1141	48	25	2	1		+0.14	20.0	50.0	3.75	7.50
46	2	RUARE	500	1141	48	25	0	1		+2.24	7.5	60.0	2.50	2.50
47	2	RUARE	500	1141	48	25	0	0		+0.90	12.5	35.0	2.50	5.00
48	2	RUARE	500	1141	48	25	0	1		-1.20	12.5	55.0	5.00	15.00

APPENDIX A.16

9	2	RUARE	500	1141	48	25	0	4		-0.20	37.5	35.0	0.00	11.25
0	2	RUARE	500	1141	48	25	8	1		+5.60	10.0	90.0	3.75	2.50
1	2	NAROMORU	500	1141	48	25	8	1	304.8	+4.80	37.5	95.0	0.00	1.25
2	2	NAROMORU	500	1050	44	28	6	1	304.8	-2.70	10.0	70.0	0.00	1.25
3	2	NAROMORU	500	1050	44	28	4	1		+1.06	8.7	35.0	12.50	8.75
4	2	NAROMORU	500	1050	44	28	4	1	609.6	+3.10	25.0	15.0	18.75	12.50
5	2	NAROMORU	500	1050	44	28	2	3	3048.0	-0.56	10.0	72.5	6.25	6.25
6	2	NAROMORU	500	1050	44	28	2	2	3048.0	+2.70	12.5	50.0	10.00	11.25
7	2	MURIRO	500	1050	44	28	0	0	3048.0	-0.67	10.0	35.0	7.50	5.00
8	2	MURIRO	500	1050	44	28	4	1	3048.0	-2.37	20.0	40.0	6.25	2.50
9	2	MURIRO	500	1050	44	28	6	2	3048.0	-3.50	32.5	70.0	10.00	12.50
0	2	MURIRO	500	1050	44	28	4	2	3048.0	+1.29	32.5	35.0	6.25	13.[illegible]
1	2	MURIRO	500	1050	44	28	[illegible]	1	3048.0	-3.20	[illegible]	45.0	1.25	6.25
2	2	MURIRO	500	1050	44	28	4	0	3048.0	-4.46	18.7	60.0	3.12	6.25
3	2	MURIRO	500	1050	44	28	8	0		+4.46	22.5	35.0	5.50	5.[illegible]
4	2	BANTU	500	1050	44	28	2	[illegible]	457.2	-0.29	22.5	45.5	1.25	2.50
5	2	BANTU	500	1030	44	28	2	0	304.8	-2.02	15.0	90.0	1.25	5.00
6	2	BANTU	500	1050	44	28	2	0		-0.44	5.0	45.0	5.00	0.00
7	2	BANTU	500	1050	44	28	4	1		-3.03	40.0	60.0	5.00	5.00
8	2	BANTU	500	1050	44	28	2	1		-2.52	22.5	45.0	10.00	7.50
9	2	BANTU	500	1050	44	28	0	0		+0.15	5.0	75.0	7.50	5.10
0	2	BANTU	500	1202	50	28	6	0	1524.0	+2.84	52.5	25.0	5.00	6.25
1	2	BANTU	500	1202	50	26	2	0		-1.69	25.0	47.5	3.75	7.50
2	2	BANTU	500	1202	50	28	4	1	1524.0	+0.33	15.0	65.0	7.50	7.50
3	2	GWARA	500	1202	50	28	2	0	1524.0	+0.48	17.5	15.0	10.00	3.75
4	2	GWARA	500	1202	50	28	6	0		+0.67	20.0	25.0	5.00	6.37
5	2	GWARA	500	1202	50	28	0	0		+1.76	10.0	30.0	16.25	12.50
6	2	GWARA	500	1202	50	28	2	0		+0.39	47.5	60.0	17.50	16.25
7	2	GWARA	500	1202	50	28	0	2	3048.0	-4.03	37.5	35.0	7.50	10.00
8	2	GWARA	500	1202	50	28	2	0	3048.0	+6.53	15.0	85.0	12.50	6.25
9	2	GWARA	500	1202	50	28	2	0	3048.0	-1.99	27.5	62.5	10.00	3.75
0	2	GWARA	500	1202	50	28	6	0	3048.0	+1.40	15.0	70.0	2.50	[illegible]
	2	ICUGA	500	1202	50	28	8	2		+0.60	12.5	17.5	10.00	5.00
2	2	ICUGA	500	1202	50	28	2	0	3048.0	+1.25	10.0	[illegible]	1.25	1.25
3	2	ICUGA	500	1202	50	28	0	0		-0.14	37.5	80.0	3.12	10.[illegible]
4	2	ICUGA	500	1202	50	28	4	0	3048.0	-0.40	30.0	75.0	3.12	10.62
5	2	GATHERI	500	1202	50	28	2	1		+1.56	27.5	20.0	15.00	2.50
6	2	GATHERI	500	1202	50	28	4	1		+4.30	71.2	50.0	7.25	3.75
7	2	GATHERI	500	1202	50	28	4	2		+4.10	62.5	45.0	3.75	2.50
8	2	MOIEQUAT	500	1202	50	28	8	3		+1.20	45.0	40.0	15.62	5.00
9	2	MOIEQUAT	500	1434	60	25	12	0		+0.98	32.5	97.5	2.50	2.50
0	2	MOIEQUAT	500	1434	60	25	6	2		+5.36	25.0	50.0	0.00	2.50
	2	SILVERBE	500	1434	60	25	6	1		+5.00	12.5	65.0	1.25	0.00
2	2	SILVERBE	500	1573	65	25	4	3	914.4	+0.99	12.5	45.0	0.00	1.25
3	2	NANYUKI	500	1573	65	25	6	2		-0.86	12.5	20.0	2.50	8.75
4	2	NANYUKI	500	1573	65	25	2	1		-0.08	12.5	0.00	5.00	7.50
5	2	NANYUKI	500	2363	98	19	0	0		+0.57	5.0	0.00	2.50	5.00
6	2	NANYUKI	500	2363	98	19	0	3		+0.49	5.0	0.00	5.00	2.50

A.16 (CONTD)

number of units is 96

y-variate PIA
weight *
offset *

probability distribution is POISSON
link function is LOGARITHM
scale parameter is 1.000

terms = 1 + S + FJ + FLB + FCC + FED + FCR

-- list truncated

	OND	PIA	%FV	%RE	FJ	FLB	FCC	FED
1	1.000	3.000	1.6155	1.091537	2.000	2.000	1.000	2.000
2	[illegible]	[illegible]	[illegible]	[illegible]	2.000	[illegible]	[illegible]	2.000
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.000	1.000	2.000
4	4.000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.000	1.000
5	[illegible]	[illegible]	[illegible]	-0.541237	[illegible]	[illegible]	1.000	3.000
6	6.000	1.000	1.6947	[illegible]	2.000	1.000	1.000	3.000
7	7.000	9.000	1.6947	4.343487	2.000	1.000	1.000	3.000
8	8.000	1.000	1.1119	-0.105446	1.000	2.000	1.000	2.000
9	9.000	1.000	0.7451	0.056511	3.000	2.000	1.000	2.000
10	10.000	0.000	[illegible]	[illegible]	1.000	2.000	1.000	1.000
11	11.000	5.000	1.3155	3.211879	2.000	2.000	1.000	2.000
12	12.000	2.000	0.3822	1.558152	1.000	2.000	1.000	2.000
13	13.000	2.000	1.9932	0.004547	1.000	2.000	2.000	2.000
14	14.000	[illegible]	[illegible]	-1.077285	2.000	2.000	1.000	2.000
15	15.000	[illegible]	[illegible]	-1.071500	1.000	2.000	3.000	2.000
16	16.000	0.000	0.1735	-0.416495	1.000	2.000	1.000	1.000
17	17.000	1.000	0.1735	1.984493	1.000	2.000	1.000	1.000
18	18.000	0.000	0.1735	-0.416495	1.000	2.000	1.000	1.000
19	19.000	1.000	0.9830	0.017153	2.000	2.000	1.000	2.000
20	20.000	[illegible]	[illegible]	-0.991460	2.000	2.000	1.000	2.000
21	21.000	[illegible]	[illegible]	-0.749635	3.000	2.000	1.000	2.000
22	22.000	2.000	0.7951	[illegible]	2.000	[illegible]	1.000	2.000
23	[illegible]	[illegible]	[illegible]	[illegible]	1.000	[illegible]	1.000	2.000
24	24.000	2.000	[illegible]	1.551545	1.000	2.000	2.000	2.000
25	25.000	0.000	0.4504	-0.671094	1.000	2.000	3.000	3.000
26	26.000	0.000	0.9015	-0.949466	2.000	2.000	1.000	2.000
27	27.000	2.000	0.5159	2.066351	1.000	2.000	2.000	3.000
28	28.000	1.000	0.3989	0.951766	1.000	2.000	1.000	2.000
29	29.000	0.000	0.2589	-0.508843	1.000	2.000	1.000	3.000
30	30.000	0.000	0.2589	-0.508843	1.000	2.000	1.000	3.000
31	31.000	0.000	0.5852	-0.764959	2.000	2.000	1.000	3.000
32	32.000	0.000	0.9015	-0.949466	2.000	2.000	1.000	2.000
33	33.000	0.000	0.3989	-0.631576	1.000	2.000	1.000	2.000
34	34.000	0.000	0.3989	-0.631576	1.000	2.000	1.000	2.000
35	35.000	1.000	0.2589	1.456399	1.000	2.000	1.000	3.000
36	36.000	1.000	2.0097	-0.712249	2.000	1.000	1.000	2.000
37	37.000	0.000	1.0082	-1.004087	1.000	1.000	1.000	2.000
38	38.000	0.000	0.8893	-0.943004	1.000	1.000	1.000	2.000
39	39.000	[illegible]	1.0082	-1.004087	1.000	1.000	1.000	2.000
40	40.000	2.000	1.4790	0.428405	2.000	1.000	1.000	3.000
41	41.000	3.000	1.0082	1.983701	1.000	1.000	1.000	2.000
43	43.000	0.000	0.6544	-0.303965	1.000	1.000	[illegible]	[illegible]
44	44.000	0.000	0.6544	-0.808965	1.000	1.000	1.000	2.000
45	45.000	1.000	1.0082	-0.008158	1.000	1.000	1.000	2.000
46	46.000	1.000	0.6544	0.427181	1.000	1.000	1.000	3.000
47	47.000	0.000	1.0082	-1.004087	1.000	1.000	1.000	2.000
48	48.000	1.000	2.0087	-0.711706	1.000	1.000	2.000	2.000
49	49.000	4.000	1.0082	2.979631	1.000	1.000	1.000	2.000
50	50.000	1.000	0.9586	0.042295	3.000	1.000	1.000	2.000
51	51.000	1.000	1.6472	-0.504247	3.000	1.000	1.000	2.000
52	52.000	1.000	1.0788	-0.075910	2.000	2.000	1.000	3.000
53	53.000	1.000	1.9075	-0.657050	2.000	2.000	3.000	2.000
54	54.000	1.000	1.3072	-0.268668	2.000	2.000	3.000	1.000
55	55.000	3.000	0.4862	3.594866	1.000	2.000	2.000	3.000
56	56.000	2.000	0.7444	1.455196	1.000	2.000	3.000	2.000
57	57.000	0.000	0.7521	-0.867247	1.000	2.000	3.000	2.000
58	58.000	1.000	1.6593	-0.536744	2.000	2.000	3.000	2.000
59	59.000	2.000	[illegible]	[illegible]	2.000	2.000	[illegible]	[illegible]
60	60.000	2.000	1.6993	0.230270	2.000	2.000	2.000	[illegible]
61	61.000	1.000	[illegible]	0.158990	2.000	2.000	[illegible]	[illegible]
62	62.000	0.000	0.5533	-0.744167	2.000	2.000	1.000	[illegible]
63	63.000	0.000	0.6269	-0.791776	3.000	2.000	1.000	[illegible]
64	64.000	0.000	0.7354	-0.857565	1.000	2.000	1.000	[illegible]
65	65.000	0.000	0.4774	-0.690917	1.000	2.000	[illegible]	[illegible]
66	66.000	0.000	0.8527	-0.923423	1.000	2.000	3.000	2.000
67	67.000	1.000	1.2509	-0.224340	2.000	2.000	3.000	1.000
68	68.000	1.000	0.9440	0.169796	1.000	2.000	3.000	2.000
69	69.000	0.000	[illegible]	-0.743977	1.000	2.000	[illegible]	[illegible]
70	70.000	0.000	0.7907	-0.889190	2.000	2.000	2.000	[illegible]
71	71.000	0.000	0.4992	-0.706522	1.000	2.000	1.000	2.000
72	72.000	1.000	1.2369	-0.252871	2.000	2.000	2.000	[illegible]
73	73.000	0.000	[illegible]	-0.589455	1.000	2.000	3.000	1.000
74	74.000	0.000	0.8954	-0.946787	2.000	2.000	3.000	1.000
75	75.000	0.000	0.9844	-0.992163	1.000	2.000	3.000	2.000
76	76.000	0.000	0.6390	-0.799359	1.000	2.000	3.000	2.000
77	77.000	2.000	0.8772	1.198794	1.000	2.000	2.000	2.000
78	78.000	0.000	0.5636	-0.750730	1.000	2.000	3.000	3.000
79	79.000	0.000	0.5636	-0.750730	1.000	2.000	3.000	3.000
80	[illegible]	0.000	0.6459	-0.803675	2.000	2.000	1.000	[illegible]
81	81.000	2.000	0.5751	1.879050	3.000	2.000	3.000	1.000
82	82.000	0.000	0.2858	-0.534597	1.000	2.000	1.000	3.000
83	83.000	0.000	0.3966	-0.629794	1.000	2.000	2.000	1.000
84	84.000	0.000	0.6459	-0.803675	2.000	2.000	1.000	3.000
85	85.000	1.000	0.3926	0.969414	1.000	2.000	3.000	1.000
86	86.000	1.000	2.2477	-0.932202	2.000	2.000	2.000	2.000
87	87.000	2.000	1.1281	0.820865	2.000	2.000	1.000	2.000
88	88.000	3.000	1.4419	1.297544	3.000	2.000	3.000	2.000
89	89.000	0.000	1.2434	-1.115062	3.000	1.000	1.000	3.000
90	90.000	2.000	2.9554	-0.555744	2.000	1.000	1.000	2.000
91	91.000	1.000	1.9184	-0.663058	2.000	1.000	1.000	3.000
92	92.000	3.000	2.8962	0.061008	2.000	1.000	1.000	2.000
93	93.000	2.000	1.3095	0.603371	2.000	1.000	1.000	1.000
94	94.000	1.000	1.1545	-0.143755	1.000	1.000	2.000	1.000
95	95.000	0.000	0.9207	-0.959553	1.000	1.000	1.000	1.000
96	96.000	3.000	1.8345	0.860547	1.000	1.000	2.000	1.000

? $STOP

```
GLIM SESSION ENDS
C:\GLIM $UNITS 96
$DATA ONO LES ADT VPH LAB JFK PIA RAD LGR RUT EDS CRC FEA$
$FORMAT F3.0,12X,F3.0,1X,F4.0,1X,F3.0,1X,F2.0,1X,F2.0,1X,F2.0,
1X,F6.1,1X,F5.2,1X,F4.1,1X,F4.1,1X,F5.2,1X,F5.2$
$C AGOSIN BAJON DATA, AJOVIRTA AGGLIM, DATA AG01.DAT
$C MLR 9.3.1988
$DIN 7$
$CAL A1=365*(LES/1000)*ADT/1000000$
$CAL SUU=4*A1$
$CAL S=%LOG(SUU)$
$CAL B1=%IF(RAD>0,RAD,1)$
$CAL B2=1/B1$
$CAL AR=(B2/-1)*B2
$FAC FJ 3$
$CAL FJ=1+%GE(JFK,3)+%GE(JFK,7)$
$CAL CR=(RAD<1)*10000+RAD$
$FAC FCR 3 FED 3 FCC 3 FLB 2$
$CAL FCR=1+%GE(CR,800)+%GE(CR,3100)$
$CAL FED=1+%GE(EDS,30)+%GE(EDS,60)$
$CAL FCC=1+%GE(CRC,5)+%GE(CRC,10)$
$CAL FLB=1+%GE(LAB,28)$
$YVAR PIA$ERROR P$LINK L$
$FIT :+S:+FJ:+FLB:+FCC:+FED:+FCR$DISP D E M$
$CAL %RE=(%YV-%FV)/%SQRT(%WT)$
$LOOK ONO PIA %FV %RE FJ FLB FCC FED FCR$
$RETURN $
```

<u>Note for Appendix A.16</u>

1:	Constant
S:	to which travel is raised
FJ(2):	3-7 junctions per kilometer,
FJ(3):	> 7 junctions per kilometer,
FLB(2):	< 28% lorries and buses,
FLB(3):	> 28% lorries and buses,
FCC(2):	5%-10% cracking and crazing,
FCC(3):	>10% cracking and crazing,
FED(2):	30%-60% edge spalling,
FED(3):	>60% edge spalling,
FCR(2):	800-3099m horizontal curve radius,
FCR(3):	>3100m horizontal curve radius

GLIM

C:\GLIM>echo off

A.16 (CONTD)

```
GLIM 3.77 update 1 (copyright)1985 Royal Statistical Society, London

? $INPUT 9$
File name? AGGLIM
File name? AG01.DAT
scaled deviance = 157.69 at cycle  4
           d.f. =  95

scaled deviance = 149.88 (change =  -7.808) at cycle  4
           d.f. =  94    (change =  -1     )

scaled deviance = 138.32 (change = -11.566) at cycle  4
           d.f. =  92    (change =  -2     )

scaled deviance = 134.81 (change =  -3.505) at cycle  4
           d.f. =  91    (change =  -1     )

scaled deviance = 131.48 (change =  -3.336) at cycle  4
           d.f. =  89    (change =  -2     )

scaled deviance = 123.72 (change =  -7.754) at cycle  4
           d.f. =  87    (change =  -2     )

scaled deviance = 120.85 (change =  -2.869) at cycle  4
           d.f. =  85    (change =  -2     )

Scaled deviance is  120.85 [illegible]  85 d.f. [illegible] 9[illegible] observations
         change is   -2.869 for  -2 d.f.

         estimate        s.e.      parameter
   1     -0.1617       0.4770      1
   2      1.138        0.5950      S
   3      0.8154       0.8300      FJ(2)
   4      0.3817       0.4050      FJ(3)
   5     -0.7622       0.2874      FLB(2)
   6      0.6893       0.2863      FCC(2)
   7      0.6791       0.3569      FCC(3)
   8      0.9192       [illegible]  FED(2)
   9      0.4871       0.41[illegible]  FED(3)
  10     -0.5669       0.3796      FCR(2)
  11     -0.5413       0.3470      FCR(3)
  scale parameter taken as  1.000
```