CHAPTEIR 2
ROAD TRAFFIC ACCIDENT STUDIES IN DIFFERENT COUNTRIES

2.1 INTRODUCTION

Road traffic accident scene is found to have an increasing trend with varying degree of severity mainly influenced by road network characteristics, road user behaviour and environmental factors. The road accident analyses made in different countries are reviewed. Basic structure of various models built to study accident scene in different countries making use of one or more variables are presented broadly under the following groups - based on population and vehicle ownership; based on econometric and social variables; based on traffic volume, road geometry and speed. Grouping has been primarily done taking the major factors in to account.

2.2 MODELS BASED ON POPULATION AND VEHICLE OWNERSHIP

Srinivasan and Mahesh Chand [1986] related accidents with population. According to them, \( A = 12.45 \times \text{Exp}(0.003803 \times P) \), where \( A \) = Number of accidents [in 1000] in a year, and \( P \) = Population in million in year considered. Victor [1990] used simple regression approach to analyse the available data for India and concluded that the number of road accident casualties was linearly related with population, \( C = 0.221 + 0.000546 \times P \) where \( C \) = total casualties in million, \( P \) = population in million.

Based on the past trend, an attempt had been made to work out a relation between fatalities and motor vehicle population [Kadiyali and Venkatesan, 1984]. An equation of the form \( D = KV^n \) where \( D \) was the number of deaths per 10,000 vehicles, \( K \) and \( n \) were constants and \( V \) was the number of vehicles per 1000 population, was tried. Studies made by Mohan [1982], Jacobs and Bardsley [1977], and Jacobs [1982] showed that highway fatality rates per thousand vehicles and injury rates for a given rate of traffic flow were generally higher in poor countries as compared to relatively more industrialized ones. Jacobs [1982] also showed that gross fatality rates for the same level of vehicle ownership in developing countries increased over the period 1965 -
1978. The rising death toll was causing concern in India. The remedial actions suggested gave a great deal of importance to driver error, safety propaganda and stricter licensing of drivers. However, effectiveness of these measures in developing countries had rarely been studied scientifically [Aiyaswamy et al., 1982]. Srinivasan and Mahesh Chand [1986] linked accidents with number of vehicles in India. According to them, 

\[ A = 68.58 \exp(0.000176V) \] 

where \( A \) = Number of accidents [in 1000] in a year, and \( V \) = Number of Vehicles [in 1000] in year considered. Victor [1990] used simple regression to analyse the available data for India and concluded that the number of road accident casualties was linearly related with the growth of motorized vehicles, 

\[ C = 0.047 + 0.0186 M \quad [R^2 = 0.99]; \quad C = 0.026 + 0.00485 S \quad [R^2 = 0.99]; \] 

where \( C \) = total casualties in million, \( M \) = total motorized vehicles in million and \( S \) = total slow moving vehicles in million.

Smeed [1949] used data for road fatality, population and vehicles in use for the year 1938 from 20 developed countries and derived the relationship: 

\[ F = 0.0003 \left( \frac{V}{P^2} \right)^{1.3} \] 

where \( F \) = road fatalities; \( V \) = number of vehicles in use and \( P \) = population. Data were then obtained for Britain for the years 1909 - 1938 and the vehicles per 10,000 persons and fatalities per 10,000 vehicles were calculated [Jeffcoate, 1958]. During this period vehicle ownership levels in Britain were similar to those of the developing countries for 1968, with vehicle ownership rising from 33 vehicles per 10,000 persons in 1909 to 670 vehicles per 10,000 persons in 1938. Fatalities per 10,000 vehicles were calculated and the relationship plotted on the same graph as the data for the developing countries. It was seen that all the points lie within the 90 per cent confidence limits and were fairly close to the line. This implied that the fatality rates experienced in the developing countries in 1968 were not dissimilar to those experienced by Britain in her early stages of road transport development. In fact, the majority of the points for Britain lay above the line, indicating that for a given vehicle ownership although the fatality rates were higher in Britain during these years than in the developing countries in 1968. Thus, although the fatality rates in developing countries appear to be high, it would seem that Great Britain, in the early stages of her road transport development, had equally high rates. A similar analysis found that the relationship between fatalities per vehicle and vehicles per person in the U.S. for 1912 - 1967 was comparable with that for various countries of the world for 1967 [Dondanville, 1970]. Jacobs and Hutchinson [1973], Jacobs and Fouracre [1977], and Jacobs and Hards [1978] carried out analyses of fatality rates in developing countries and established significant relationships between fatality rates and levels of vehicle ownership. The analysis was repeated for the year 1980 using data from 20 developing countries and a relationship was derived of the form, 

\[ (F/V) = 0.00036(V/P)^{0.65} \]
where $F =$ road fatalities; $V =$ number of vehicles in use and $P =$ population. This was very similar to that derived by Smeed suggesting that the situation in developed countries in 1938 was similar to that in developing countries in 1980. Jacobs and Hutchinson [1973] carried out a similar analysis using data from a group of developing countries for the year 1968 and derived the relationships, $(F/P) = 0.00077 (V/P)^{0.60}$ and $(F/V) = 0.00077 (V/P)^{0.40}$. This implied that a country doubling its vehicle ownership would have 52 percent more fatalities per person and 24 percent fewer fatalities per vehicle. In order to determine whether the Smeed equation had changed with time, the same group of countries used by Smeed for 1938 were taken and relationships derived for the years 1950, 1960 and 1970. The equations derived were, $F/V = 0.00034 (V/P)^{0.38}$ [for 1950]; $F/V = 0.00034 (V/P)^{0.60}$ [for 1960]; $F/V = 0.00039 (V/P)^{0.56}$ [for 1970]. There was little variation in the equations over the 20 year period. A study in Greece showed that the application of Smeeds Equations gave an estimation of fatalities 32 per cent less than the observed ones [Pitsira et.al, 1982]. Hence the constants had been modified to give a better fit for the period 1963-1976. Kadiyali and Venkatesan [1984] studied the trend of road accidents in India over the period 1960 - 1980 and fitted the equation, $D = 91.5147V^{0.2475}$ where $D =$ number of deaths per 10,000 vehicles and $V =$ number of vehicles per 1000 population. Andreassen [1985] had said that Smeed [1949] established only an apparent relationship. He argued that the relationship found by Smeed between these variables was spurious, and that the Smeed equation was based on an analysis of 20 countries for one year of data [1938]. He concluded that Smeeds findings should not be used as a basis for comparing road accident death rates for different countries at different levels of motorization. Satyamurthy et.al, [1991] analysed the road accident rates in Bangalore City using data from 1963 - 1980 and fitted the relationship $D/P = 0.00056 (N/P)^{0.56}$ where $D/P$ was the fatality rate based on population and $N/P$ was the vehicle ownership based on population. Using data for the period 1981 - 1987 they fitted relationship, $D/P = (129.0428 N^{0.972})/P$ where $D/P$ was the fatality rate based on population, $N$ was the number of vehicles registered and $P$ was the population. Rajendra Prasad [1992] studied accident scene in Delhi by considering fatality rates based on population as a function of vehicle ownership based in population. He also built a linear relation between fatality rate based on registered motor vehicles and vehicle ownership based on population.

Victor [1990] studied the accidents in India using a simple regression model, $C = -0.061 + 0.143L$ where $C =$ total casualties [killed and injured] in million and $L =$ total road length in million km. Rajendra Prasad [1992] built a multiple linear regression model using number of fatal accidents in Delhi as dependent variable and number of registered motor vehicles and road length as
independent variables. Fieldwick and Brown [1987] used the data for 20 European Countries and the U.S. for the year 1984 to fit the equation, \( D = 0.00097215 \) \((P^{1.02192}\cdot U^{1.78634}\cdot R^{1.062236})\), where \( D \) = number of fatalities; \( P \) = population in million; \( U_r \) = urban speed limit in kilometres per hour [kmph] and \( R_u \) = rural speed limit in kmph. It was demonstrated that speed limits, and particularly those posted for urban areas, had a considerable effect on safety. It was estimated that reducing the rural speed limit from 100 to 90 kmph and the urban limit from 60 to 50 kmph would reduce fatalities and casualties by up to one-third. It was concluded that speed limit was a powerful safety tool available to governments, but as was demonstrated by the wide disparity in rural speed limits in different countries, the relationship between speed limits and safety was not yet fully recognized. The above models considered the details of the accidents recorded in a city or region or state as a whole and analysed the same with the total population and number of vehicles in use and hence the models were aggregate in nature. The road fatalities in a country or city can not be explained through one or two factors. The above forms of equations can not be a completely satisfactory predictor of changes in fatalities over time since only one or two parameters are involved. Further the models had not taken care of changes in vehicle composition the distribution of traffic, pedestrian influence, segregation measures, pedestrian facilities, road alignment, disturbance due to side streets, road geometrics, mixed traffic and interaction among various modes.

2.3 MODELS USING ECONOMETRIC AND SOCIAL VARIABLES

Using U.S. annual data Peltzman [1975] studied the effects of automobile safety regulation on accidents. He estimated a regression model in double-log form. The motor vehicle occupant deaths divided by the vehicle miles was the dependent variable. The cost of an accident, real earned income per adult of working age, consumption of distilled spirits per person, driving speed and ratio of 15 - 25 years old drivers to those of older drivers were used as independent variables. The estimated coefficient of income, alcohol, speed and driver age were positive and significant. The estimated coefficient of cost was negative. Joksch [1976] critiqued Peltzmanns study. He concluded that some of the variables used in the study, such as Peltzmanns measure for the cost of an accident and the standardized death rates, were arbitrarily chosen and were therefore potential sources of measurement error. Nelson [1976] claimed that Peltzman, by adhering so strongly to a particular hypothesis, did not pay sufficient attention to alternative hypotheses that may be equally consistent with Peltzmanns evidence. Crandall [1983] employed Peltzmanns basic formulation in conducting a cross-sectional analysis of highway deaths in the 50 states. The model he estimated was, \( D = f(I,Y,A,S,U,S1,M) \), where
D = highway death; I = income; Y = share of population that is 25 years old and under; A = alcohol consumption; S = speed; U = ratio of urban to total vehicle miles; S1 = safety regulation; M = vehicle miles. Kelley [1984] identified 14 annual independent variables as potential determinants of motor vehicle death rates. These variables are indicated in the following equation, \( D = f(P,R,R_1,P_1,T,R_2,L,P_2,P_3,P_4,M,P_5,C,Y) \), where D = death rate; P = population; R = ratio of rural to urban vehicle miles; R1 = average rural speed; P1 = percentage of male drivers in the driver population; T = total vehicles miles; R2 = registered vehicles; L = licensed drivers; P2 = domestic passenger cars in operation; P3 = ratio of domestic passenger cars to registered vehicles; P4 = ratio of passenger car vehicle miles to total vehicle miles; M = ratio of motorcycles to total vehicles; P5 = real personal income; C = apparent consumption of distilled spirits and Y = trend variable. Zlatoper [1984] used regression model, \( D = f(P,I,V,T,A,S,Y,S1,R,P1) \) where D = motor vehicle; P = the cost component of an accident that is typically insured; I = personal income; V = amount of driving; T = secular trend; A = alcoholic intoxication among drivers; S = driving speed; Y = young drivers; S1 = vehicle size; R = type of driving as measured by the ration of rural to urban vehicle miles; P1 = federally mandated vehicle safety standards.

Koshal [1976] used 1970 data for 48 contiguous states in U.S. and took total deaths divided by vehicle miles as dependent variable. Annual temperature, maximum speed limit, road capacity given by the ratio of lane miles of road to the area of the region, minimum age requirement for driving automobiles, percentage of male drivers to total drivers, percentage of urban population to total population were used as independent variable in double-log form. The estimated coefficients for capacity, driving age and urbanization were negative and significant. The coefficients for speed limit, temperature and percentage male drivers were positive and significant. Robertson [1977] used U.S. annual data and estimated a regression model in double-log form. Total motor vehicle deaths divided by vehicle miles was used as the dependent variable. Drivers income, trend, alcohol consumption, speed, drivers in the age group 15 - 24 as a percentage of all drivers involved in accidents and motor cycles as a percentage of all registered vehicles were used as independent variables.

Crandall and Graham [1984] used passenger car occupant deaths divided by the vehicle miles as dependent variable. Driver income, trend, alcohol, young drivers, safety regulation, rural to urban driving ratio, size of the vehicle and limited access were independent variables. In addition, Crandall used vehicle miles and trucks as independent variables and Graham used cost of accident and 55 mph speed limit as independent variables. Forester et.al, [1984] used U.S. annual data for 1952 - 1979.
Joksch [1984] considered the relationship between traffic deaths and industrial activity. He used U.S. annual data for the period 1930 - 1982 and estimated a regression model in linear form. The annual percentage change in the index of industrial production was the independent variable. Hedlund et al., [1984] examined why U.S. traffic fatalities in 1982 were dramatically less [14% lower] than the number of deaths in 1980. The authors concluded that among the factors considered, economic effects, realized through changes in vehicle miles travelled, apparently contributed the most to the drop in fatalities. Partyka [1984] considered the relationship between traffic deaths and employment and used U.S. annual data for 1960 - 1982 to estimate a regression model in linear form. Total traffic fatalities was used as dependent variable. Unemployed civilian workers, employed civilian workers, people not in labour force, oil embargo and 55 mph speed limit were the independent variables. Wagenaar [1984] studied the relationship between economic condition and accidents. He used monthly data from Michigan State for 1972 - 1982 and estimated linear regression model. The number of drivers of non commercial vehicles involved in injury accidents was the dependent variable. Unemployment rate of previous year, unemployment rate of the year considered and vehicle miles were the independent variables. Garbacz [1985] studied the effect of safety regulation on traffic deaths by estimating a regression model in double-log form using U.S. annual data for 1952 - 1982. The fatality rate defined as deaths per 100 million vehicle miles was the dependent variable. Disposable income per driver, cost of medical care and auto repair indices, human population in the age group of 16 to 24 divided by population aged above 24, consumption of alcohol per head, number of automobiles fitted with regulated safety equipment divided by the total automobiles, 55 mph speed limit and length of inter-state highways were the independent variables. Garbacz estimated separate regression models for fatality rates corresponding to three categories of highway deaths-total, occupant, and non occupant [pedestrian and pedal cycle].

Loeb [1985] used 1979 data for all 50 states and the District of Columbia in a linear regression model. The dependent variable was the level of fatalities. Independent variables representing income, level of education, vehicle inspection, population density, per cent of population between the ages of 25 and 44, and per cent of population between the ages of 45 and 64 were used. Asch and Levy [1987] developed a regression model, $F = f(M,S,V,I,E,Y,A,D,L)$, where $F$ = fatality rate; $M$ = percentage
of highway mileage classified as municipal; \( S \) = average driving speed on interstate rural highways; \( V \) = average vehicle size; \( I \) = per capita personal income; \( E \) = percentage of male drivers; \( Y \) = percentage of licensed drivers aged 15 - 24; \( A \) = average alcohol consumption; \( D \) = minimum legal driving age; \( L \) = minimum legal consumption age the estimates corresponding to \( M, A, S \) and \( D \) were consistently significant or near significant. Most of the econometric and social variables used in the above models were indirect in nature and cannot be considered as directly causing or influencing the occurrence of accidents. Further the models had not considered road geometries and did not make any allowance for changes in vehicle composition and traffic behaviour.

2.4 MODELS USING TRAFFIC VOLUME, ROAD GEOMETRY AND SPEED

Vey [1937] plotted accident rates against Average Daily Traffic [ADT] on two-lane state highways in New Jersey. A curve fitted through the data showed the accident rate to rise from zero at zero traffic to maximum and then to decline. Belmont [1953] examined accident data from two-lane roads in California and compared accident rates per vehicle mile with hourly traffic volumes. Whilst the single-car accident rate tended to decrease with traffic, the head-on accident rate did not vary much with traffic volume, but multi-car and rear-end accident rates increased sharply until an hourly volume of 600-700 vehicles was reached. The total accident rate reached a peak of 80 per 100 million vehicle miles before declining. A study made on German Express ways revealed that the increase in accidents at a particular site had been largely caused by heavy vehicles [Bitzel, 1957]. Large-scale surveys of accident rates on roads in Belgium and France were reported respectively by Claes [1955] and Goldberg [1962]. Both studies showed some evidence of a U-shaped relationship between accident rates and traffic volumes. Billion and Parsons [1962] considered accidents on divided urban highways on Long Island, New York between 1955 and 1959 and concluded that accident rates increased with traffic volume. In a study of accident data on Californian freeways, Lundy [1965] regressed accident rates against Average Daily Traffic. The analyses showed the accident rate increasing with traffic. Thorson and Mouritsen [1971] fitted a wider variety of power curves to accident data from Denmark during 1962 to 1966; some curves showed a positive, and some a negative, relationship between accident rates and traffic volumes. Gwynn [1967] analysed accident data from a four-lane divided highway in New Jersey. The relationship between accident rates and hourly volumes did not emerge very clearly, but a U-shaped curve was suggested. Gwynn and Baker [1970] used data from New Jersey to conclude that the accident rate was
high at low volume of traffic. Using data from Germany, Brilon [1972] concluded that the relationship between total accidents and hourly volume was U-shaped. Yu [1972] fitted curves to accident data from highways in Virginia. The form of the curves showed that the single-vehicle accidents dominated at low flows and collisions became important at higher traffic volumes. Chatfield [1973] compared the different states of the U.S. and plotted the fatal accident rate against the 'travel density', which was actually the average traffic volume over the whole of the road network. Based on data from rural main roads in Sweden in 1962-64, Nilsson [1973] concluded that the single-vehicle accident rate decreased with Average Daily Traffic [ADT] and that the collision rate increased with ADT. The regression lines fitted control for roadways width and shoulder width in that different lines were calculated for the various width groupings. A later report by Nilsson [1974] did not distinguish between different types of accidents. Using the same data as the previous report, Nilsson carries out multiple regressions and correlation analyses [using both total and partial correlations]. The general trend exhibited by the results was that accident rates were correlated negatively with traffic volumes, but variables describing sight distance prove to be most closely correlated with accident rates. Mc Kerral [1962] studied the pattern of accident rates on roads of New South Wales and fitted a curve, \( y = a + bx + cx^2 \), where \( y \) = number of accidents per mile, \( x = ADT \), and \( a, b, \) and \( c \) constants. This study indicated an increase in accident rate with increase in traffic volume. Foldvary [1975 and 1976] used data from Queensland to conclude that the accident rates were high when the traffic was light. The analyses of Jacobs [1976] dealing with rural roads in Kenya and Jamaica indicated that there was a decrease in accident rate with increasing traffic volume. Avishai Ceder [1982] brought out that multi vehicle accident rate sharply increased with hourly flow. Turner and Thomas [1986] estimated the annual single vehicle injury accident per km. as - 0.605 + 0.059 Q, where Q is the two-way annual traffic volume [10^6 vehicles]. He also estimated the total annual multiple vehicle injury accidents per km. as - 0.0256 + 0.107 Q. Investigations on two lane rural roads have shown that the accident rate increases with volume up to 7000 vehicles per day and then decreases with further increases in volume. The comparison of results obtained from Kenya and Jamaica with those from developed countries has shown that at a flow level of 100 vehicles per hour, the accident rate in Kenya was over three times greater than in developed countries and the rate in Jamaica was almost five times greater [Jacobs, 1976 and Srinivasan, 1991b]. Simpson et.al, [1985] showed that accident rate tended to decline with ADT for British rural roads [of types S2 and WS2] although for any level of ADT there was a considerable variation in accident occurrence rates. The regression analyses of Crowther and Shumate [1964] were of a rather different
type to those described above. The dependent variable was accident density, but the independent variables were the number of headways less than 2 seconds and the number of meetings of vehicles. Rykken [1949] studied the effects of highway congestion on accidents. The congestion index was taken as the quotient of the 30th highest hourly traffic [per year] and the practical hourly capacity. He concluded that the number of accidents increased linearly with the congestion index. The rate of increase was greater than when the index exceeded unity. The implication was that, for a particular type of road, the accident rate remained constant until congested conditions were reached and then began to rise. Rajendra Prasad [1992] studied fatal accidents per km. in four lane roads of Delhi by using 16 hours traffic volume, speed, percentage of heavy fast vehicles, percentage of light fast vehicles and percentage of slow vehicles as independent variables. Moskowitz and Schaefer [1960] analysed accident rates on highways in California. They reached the rather unexpected conclusion that the forms of the relationship depended on the type of median. With traversable medians, the rate went up with increasing traffic, and the opposite was true for roads with non traversable medians. Scott [1986] studied British road accident data, after segregating by vehicle type, road class and built-up area using regression model. Belmont [1954] studied the effect of shoulder width on accidents in California. Square root of the number of accidents was the dependent variable. Square root of the vehicle miles and square root of the length of the road section were the independent variables.

Dart and Mann [1970] attempted to relate accident rates on rural highways of Louisiana to highway geometry. They employed 11 independent variables plus first order interactions formed as products of pairs of the original variables, and the dependent variable was the accident rate. Curiously, the most important predictor variables appear to be the first order interactions, several of which involve ADT as one of the constituent factors. Central Road Research Institute [1982] used accidents per km. per year as the dependent variable. Curvature, pavement width number of junctions per km. and ADT had been used as independent variables. Belmont [1956] took sections of uniform length of one mile. Grouping the data, he developed equations of the form, \( y = a + bs + cx + dsx \), where \( y \) was the number of accidents; \( s \) was the shoulder width; \( x \) was the ADT; and \( a, b, c \) and \( d \) were constants. The value of \( R^2 \) found was 0.946. The success of the studies of Belmont no doubt depended on the very careful selection of roads, excluding any sections with curves, structures or intersections. Head [1959] gave a large number of regression coefficients, obtained from data on state highways of Oregon, relating the accident rate to ADT and several design variables. Head began with 426 road sections and proceeds to divide his data into quite small groups of sections, as small as 2 or 3 in some cases. Schoppert [1957] analysed data from
the Oregon State Highways and develops simple regressions equations relating the numbers of accidents on mile sections of road to seven independent variables, including ADT. Different equations were calculated for different ADT ranges, so that the effect of traffic volume was given both in the equations themselves and in the differences between the various equations. The coefficients of ADT were all positive but not all significant. Rahim and Ashma [1992] studied accident data for a total of 51 improved sites. Multi variate regression analysis was used to developed predictive models to determine the accident frequency in both before and after improvement conditions. One linear and three multiplicative form models were used in the preliminary analysis. The general form of these models were as follows:- Linear model: \( A/M/Y = a + b_1(ADT) + b_2(W) + b_3(S) \)

Multiplicative models:
\( A/M/Y = a(ADT)^{b_1}(W)^{b_2}(S)^{b_3}; \)
\( A/M/Y = a(ADT)^{b_1}(b_2)W(b_3)S; \) and
\( A/M/Y = a(b_1)^{ADT}(b_2)W(b_3)S, \) where \( A/M/Y = \) accidents per mile per year; \( A = \) number of accidents at site in before or after period; \( M = \) length of the site in miles; \( Y = \) number of years in before or after period; \( ADT = \) average daily traffic; \( W = \) lane within feet; \( S = \) shoulder width and \( a, b_1, b_2 \) and \( b_3 = \) constants for each model. The general form of the linear and multiplicative models are similar to those used by Zegeer et.al, [1987]. Ng and Hauer [1989] analysed the same data used by Zegeer et.al, and concluded that under similar roadway and traffic conditions, different states have different number of accidents per mile per year. Thus they recommended that data from different states should not be combined for use in multi variate analyses. The variables strongly related to accident occurrence are average daily traffic [ADT], section length, lane and shoulder width, shoulder type, alignment grades, and side slope [Boyce et.al, 1988; Zegeer et.al, 1987; Foody and Long, 1974; Perchonok et.al, 1978; Cleveland and Kitmura 1978; Cleveland et.al, 1984; Maierle and Wolfgram 1988].

Past studies indicated that the increased frequency of fixed object collisions is due to higher traffic volumes, greater number of road side objects, and closer distance of road side objects to the road [Zegeer and Parker, 1984; Kohuteck and Ross, 1978]. The most frequently hit objects include utility poles, trees, ditch embankments, sign posts, guardrails and fences, drainage facilities, and bridge structures [Tignor et.al, 1982; Zegeer et.al, 1987a]. Godwin [1984] examined the effects of changes in the rural speed limit in 10 countries and derived a relationship, \( F = 7.07 + 0.716 P \) where \( F = \) percentage change in fatality rate, \( p = \) change in posted rural speed limit [kmph]. He brought out that a reduction in the rural speed limit from 100 to 90 kmph reduced the fatality rate by 14.2 per cent. Fieldwick and De Beer [1987] analysed a monthly accident time series between January 1972 and December 1985 and identified and quantified a number of factors that influence the number
of accidents. One of these factors was the urban speed limit. It was estimated that a reduction in the urban speed limit from 60 to 50 kmph would reduce fatal accidents by 12.3 percent and injury accidents by 14.3 percent. In the same study, the fatality rates of 12 Western Developed countries were regressed against their urban and rural speed limits. The resulting equation was, \[ F = 0.14321 \text{ Ur} + 0.02788 \text{ Ex} - 7.47 \] where \( F \) = fatality rate [fatalities/10^8 vehicle km.], \( \text{ Ur} \) = urban speed limit [kmph], \( \text{ Ex} \) = rural express way speed limit [kmph]. It was estimated that a reduction in the urban speed limit from 60 to 50 kmph would reduce the fatality rate by 36.6 per cent. Imposing speed limits was supposed to be an effective measure which could reduce driver speeds and possibly reduce traffic accidents. From the enforcement point of view the accidents would be minimized, or at least reduced, if every driver obeyed the speed limits. In fact, it was repeatedly pointed out that a large number of drivers consistently commit speeding violations [Hauer et.al, 1982; Mostyn and Sheppard, 1980]. It was argued that a personal limit existed, or, in other words, that drivers were controlled by what they perceive to be a safe speed rather than the legal limit. It was further claimed that drivers were not convinced of any significant relationship between exceeding the speed limit and accidents, and that, therefore, they did not believe that it was important to keep the posted speed limit. Speed zoning on roads with high accident rates had in many cases yielded useful results. Speed limits also had been found to be useful in accident prevention. The 85 kmph speed limit which was originally imposed in the U.S.A. as a fuel economy measure, resulted in a reduction of 9000 road deaths during the first year. Srinivasan [1991b] observed that speed limits should be based on studies of the prevailing speeds, character of the road, the extent and character of development along the margins of the roadway and the accident history of the road. Lave [1985] measured the effects of both speeding and speed variance on the motor vehicle death rate. Using state averages for 1981 and 1982 as his data, he estimated least-square regressions for six different types of high-speed roads. To directly measure the effect of speed he employed the following model, \[ FR = a + b_1S + b_2V + b_3C + b_4H + e \] where \( FR \) = fatalities per 100 million vehicle miles; \( S \) = average speed; \( V \) = speed variance; \( C \) = speeding citations per driver; \( H \) = access to emergency medical care; and \( e \) = error term. Speed variance was approximated by the 85th percentile speed minus the average speed. Speeding citations were used as a measure for driver characteristics. The estimated coefficient for average speed was insignificant in all of the regression, suggesting that there was no discernible effect of speed on the fatality rate. In many of the regressions, the estimated coefficient for speed variance was positive and highly significant, indicating that greater speed variance causes more motor vehicle deaths. It had been demonstrated by Noguchi [1990] that the average free [natural] speeds tended to be well above the posted speed limits.
This was especially the case in urban areas, where the posted speed limits were rather low [40-60 kmph]. This tendency has also been reported elsewhere [Joselyn and Elston, 1970; Mostyn and Sheppard, 1980].

2.5 CONCLUSION

The models described above have taken into account one or few causative variables. Any one who is familiar with traffic conditions in Indian context would agree that a large number of physical, behavioural and traffic related variables would contribute the accident scene. Therefore any study on accident analysis should be comprehensive to take care of at least all the important variables associated with physical conditions, behavioural factors and traffic flow. This may include length and width of road section, presence of intersections and deflections in road alignment, index for disturbance due to entry from side streets, index for segregation of traffic flow moving in opposing directions, index for segregation of bicycles from other vehicles, index for the facilities provided to prevent pedestrians from using carriageway, average daily traffic of fast moving vehicles and slow moving vehicles, traffic composition, pedestrian behaviour, traffic density and traffic congestion.