FACTORS AFFECTING ROAD FATALITY RATES IN DEVELOPING COUNTRIES

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Abstract:

The primary thrust of this paper is to show how motorization rates in the context in the low levels of vehicle ownership affect the nature of the accident problem in developing countries. Analysis based on time-series & cross sectional data is used to investigate the effect of rapid increase in motorization levels on road fatality rates. Regression analysis is carried out to quantify separately the dependence of the fatality rate per licensed vehicle on the parameters. An interpretation of the probable cause of variability between the slopes of the relations is offered.

1. Introduction

Statistical analysis of road accident is a subject for scientific research throughout the world. Worldwide between 15 to 20 million people have died and hundreds of millions have been permanently injured in road accidents since the beginnings of the motorized society earlier this century. For at least 50 years, the developed nations have recognized motor vehicle accidents as both a major health and serious economic drain on society. Prior to the 1970's literature on statistical analysis of road accidents .. virtually unavailable; the literature has been slowly growing since that time *(Shah, 1994, Lavis, 1993)*.

Research work carried out by the overseas unit of the Transport and Road Research Laboratory (TRRL). U.K., in recent years has shown that many developing countries already have a serious road accident problem *(Jacobs and Bardsley, 1974)*. Fatality rates per licensed vehicle are high in comparison with those in developed countries (Jacobs and Hutchinson, 1973; Jacobs and Fouracre, 1977) and whereas in Europe and North America the situation is generally improving, many developing countries face worsening situation *(Jacobs and Hards, 1977)*.

In comparison with developed countries, fatalities rates have been shown to be high in selected urban and rural areas in Africa, Asia and Caribbean even when factors such as road geometry, vehicle type and vehicle and pedistrian flows are taken into account *(Jacobs, 1976; Jacobs and Sayer, 1977)*

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It has been estimated that over 300,000 persons die and 10 to 15 million persons are injured every single year in road accidents allover the world. By the early 1970s, developing countries were becoming aware that they, too faced a growing road safety problem when motor vehicle accidents emerged as a leading cause of injury and health.

Motor vehicle related fatality rates, per person as well as per vehicle, in developing countries usually exceed those of the developed countries. This phenomenon is particularly evident among oil producing nations with shockingly high rates reported from Arab Gulf states and Nigeria ***(Mekky, 1985; Bayoumi, 1981; Eid, 1980; Mekky, 1984)***.

Alarming increase have been noted through the world; Thailand, Chile, Zambia, Greece and Pakistan are examples. In developed countries the motor vehicle fatality rates have been falling over time, while many developing countries particularly those with very low vehicle ownership rates, are exhibiting high and increasing per motor vehicle fatality rates ***(Choovravech, et al 1980; Emenalo, 1977; Hundal, 1985)***.

Limited epidemiological studies have been conducted in developing countries. These studies although hampered by lack of data, have described considerable differences in driving environments, as well as road user and vehicle populations among countries and over time within a country. Marked differences were described in the population of accident involved-road users and vehicles and the environmental conditions under which accidents occur.

Fatality rates per vehicle vary from country to country. Fatality rates in developing countries tend to be high often as much as 20 times greater than the rates for the contrast to per vehicle fatality rates, population fatality rates appear to be much lower for less developed countries than for more developed countries. Over time, the population death rate, appears to increase with the number of vehicles registered. The fatalities per population in many developing countries have not yet stabilized in a number of developing countries studied by Marchetti, ***(1984)***.

2. The Model

The model developed by Smeed (Smeed, 1949; Smeed, 1968) has production factors population (P) and number of motor vehicles (N). The final product is fatalities (D). The model itself is similar to the Cobb-Douglas production function ***(Baumol, 1972)*** and is of a form

$$D = AN^{1/3}, P^{2/3}$$

A is a constant of technology, which has, on average, remained constant over a wide verity circumstances, It can be seen that the production factor vehicles has a relatively low weight (a power of 1/3 compared with population, 2/3). This probably contributes to the accuracy of the model over a wide range of situation, since wide changes in the number of vehicles have much less effect then corresponding changes in the population numbers.

The Cobb-Douglas production function is a first order homogenous function, and has a number of properties which have a direct complication on its use in relation to the number of fatalities. A proportionate increase (λ) in both the population and the number of vehicles will cause a corresponding increase (λ) in the number of fatalities.

If

$$N_{t+1} = \lambda N_t \text{ and } P_{t+1} = \lambda P_t$$

then

$$D_{t+1} = (\lambda N_t)^{1/3} (\lambda P_t)^{2/3} = \lambda A N_t^{1/3} P_t^{2/3} = \lambda D_t$$

Asuming that N and P are independent variables, and since the partial derivatives are

$$\partial D/\partial N = 1/3 \quad A N^{1/3-1} P^{2/3} = 1/3 \ (D/N)$$

and

$$\partial D/\partial P = 2/3 \ A N^{1/3} \ P^{2/3-1} = 2/3 \ (D/N)$$

It will be noticed that

$$N(\partial D/\partial N) + P(\partial D/\partial P) = N1/3(D/N) + P2/3(D/P) = D$$

It follows that on average the contribution of each additional vehicle to the number of fatalities is proportional to the number of fatalities per vehicle, and the contribution of each additional unit of proportional to the number of fatalities per population. This means that D/N and D/P characterize the proportional contribution of vehicles and population to the number of fatalities.

The general form of the model becomes

$$F/V = a(V/P)^b$$

Where

F = fatalities from road accidents in a country.
V = no, of motor vehicles in use.
P = population of a country

3. Comparison of Fatality Rates

The most frequentl, used measures to compare the accident situation across the countries include motor vehicle related fatality rates per head of population and per registered vehicles. These measures are developed for Pakistan and Kuwait and are used in comaprison with other countries to show the relative road fatality situation in Pakistan. Motor vehicle fatality rates for the countries over time are examined for trends. This is accomplished by placing the Pakistan accident situation in the context of other countries on the basis of vehicle and population fatality rates.

One way of achieving this by regressing fatality rates (per vehicle) on motorization levels (F/V Vs V/P) for many countries in a certain year, using standard regression techniques; then the regression line should represent the best estimate of the mean value of F/V given a specific value of V/P. comparing any countries with that average implies taking V and P into consideration simultaneously and is expected to offer a tool for comparison better then those which depend upon one factor (P or V) only.

In this paper analysis based on time series and cross-sectional data is used to investigate the effects of rapid increase in motorization levels on road fatality rates. Relation for developed countries is derived and compared with that of some developed countries during the years 1982. Relation for Pakistan is also derived and compared with that of Kuwait, when the motorization levels and rates are comparable.

The results are summarized in table 1.

TABLE 1: Results of the model – $F/V = a(V/P)^b$

Countries	a	b	r^2	t-value	Results
Developed and Developing	0.000265	–0.743	0.800	–9.930	**significant**
Developing	0.000553	–0.531	0.830	–7.220	**significant**
Developed	0.000313	–0.225	0.060	–0.850	**insignificant**
Pakistan (1974 - 91)	0.000125	–0.773	0.670	–5 110	**significant**
Kuwait (1969 - 83)	0.000402	–0.772	0.920	–13.920	**significant**

In all above relations significant levels is 5%

Table 1 shows that the model gives fairly a good fit ($r^2 = 0.80$) for the cross sectional data of developed and developing countries. In order to derive a linear relationship, the logarithmic values of the motorization levels for years 1982.

Mekky suggested that motorization rates affect the parameters of the model. Isolating the developing countries from developed countries, further increase the fitness ($r^2 = 0.83$) of the model. In all the investigated cases, using cross - sectional and time - series data, fatality rates decrease with the increase in motorization levels (V/P), though at different speeds. It is found that doubling the vehicle ownwership in Pakistan and Kuwait would result about 41.42% and 41.44% fewer fatalities pel vehicle. This is due to the similar slopes for both countries. The reasons associated with the decrease in vehicle fatality rates as motorization levels increase are decrease in the population of two wheeled traffic on the roads, a category of vehicles which has the highest accident rates which in turn be due to improved pedestrian facilties and an overatly tendency towards higher levels of road users education and training, better maintenance of vehicles and road system. The high fatality rates per vehicle and their relatively slow decrease with the increase in motorization levels in developing countries seem to be the dear price for the rapid motorization.

Motorization levels as an explanatory variable accounts for 67% to 92% of the variation in fatality rates in all cases except for developed countries where this relationship is insignificant. For developed countries factors other than motorization levels may also be used as a measure of exposure for comparison. For Pakistan case, motorization levels have significant effect on vehicle fatality rates across the years. This is the strongest measure of exposure and explained 92% of variation in fatality rates. It is concluded that motorization level is a powerful measure of exposure across developing countries and has significant effect on vehicle fatality rates.

Relationship between Fatality Rates and other Parameters

We have related the fatality rate per licensed vehicle to the motorization levels of developed and developing countries. The major drawback for such relationship could be that they recognized only a single explanatory variable (vehicle ownership) as affecting the fatality rate. Although the relationship could be used to compare the relative safety in different countries, vehicle ownership on its own cannot provide a satisfactory explanation of changes in fatality rates.

We find the relationship between fatality rate and other parameters that are believed to have some impact on fatalities in the country. In addition to vehicle ownership the parameters used are:

*. Population per hospital bed;

*. Population per doctor;

*. Gross National Product (GNP) per capita;

The reason for choosing these parameters is that they are believed to reflect some economic and health characteristics of the country. Regression analysis are carried out to quantify separately the dependence of the fatality reate per licensed vehicle on the parameters. The logarithmic values of the fatality rates per vehicle of Pakistan for 1981 - 91 are related to the parameters. The results of the analysis are summarized in Table 2.

TABLE 2: Dependent Variable - (log) fatality rate (fatalities per 10,000 vehicles)

Parameters	a	b	r	t-value	Results
(log) Vehicles per person	−1.528	−1.220	−0.956	9.78	significant
Population per hospital bed	−1.301	0.003	0.922	7.11	significant
Population per Doctor	2.733	0.002	0.895	6.00	significant
(log) Gross National Product (GNP) per capita.	29.105	−3.110	−0.944	−8.58	significant

In all above relations significance level is 5%.

The above results show that the fatality rates are found to:

(1) decrease with increasing vehicle ownerships;
(2) decrease with increasing GNP per capita;
(3) increase with population per doctor;
(4) increase with population per hopsital bed.

The results obtained indicate how economic and health parameters acting independently might affect the accident situation in the country. It is thus reasonable to reduce that road accident fatality rates could be reduced by improving the medical services available in the country.

TABLE 3: Computation of zero-order correlation for data.

	X_1	X_2	X_3	X_4
X_1	1.000			
X_2	−0.833	1.000		
X_3	−0.980	0.740	1.000	
X_4	0.988	−0.854	−0.971	1.000

X_1 = (log) vehicles per persons.
X_2 = population per hospital bed.
X_3 = population per doctor.
X_4 = (log) Gross National Product (GNP) per capita.

Table 3 shows the association between explanatory variables. Motorization level is negatively associated with population per hospital bed. Model shows that the greater motorization levels, the lower the fatality rates. Similarly increase in motorization levels result in decrease in population per hospital bed and population per doctor. As country becomes wealthier motorization levels and medical facilities all increased.

4. Association between Parameters

The purpose of regression analysis is to estimate the parameters dependency not interdependency relationship (Farrar and Glauber, 1967).

We define:

y^x as a sample of N observation on one dependent and n independent variables, each of which is normalized (by sample, size and standard deviation) to unit length $X^t X$ is zero order corrlecation matrix.

b as a vector of true coefficients.

u as a true error term, with distributional properties specified by the general linear model, and

σ_u^2 as the underlying population variances of u: and presume that y and x are related to one another through the linear form

$$y = Xb + u$$

Least-squares regression analysis leads to estimates

$$b^{\wedge} = (X^t X)^{-1} X^t Y$$

with variance-convariance matrix

$$V(b^{\wedge}) = \sigma_u^2 (X^t X)^{-1}$$

As interdependence among explantory variables x grows, the correlation matrix (X^tX) approaches singularity, and elements of the inverse matrix $(X^tX)^{-1}$ explodes. Perfect linear dependence within an independent variable set leads to a completely indeterminate set of parameter estimate $b^{\wedge}$. Diagonal elements of the inverse matrix $(X^tX)^{-1}$ that corresponds to linearly dependent members of X becomes infinite. Variance for the affected variables regression coefficients.

$$V(b^{\wedge}) = \sigma_u^2 (X^tX)^{-1}$$

also become infinite.

Farrar and Glauber has discussed a test for the pattern of interdependence within an independent variable set X in a manner, exactly analogous to the simple (zero-order) correlation coefficient, the statistics

$$t_{ij}(V) = \frac{r_{ij}.\,(N - N)^{1/2}}{(1 - r_{ij}^{2})^{1/2}}$$

is distributed as Student's with V = N-n degree of freedom where r_{ij} is the partial correlation coefficient between two variables holding the effect of other variables constant.

Computation of a First - order partial correlation

$r_{24.3} = 0.8424$ $r_{21.3} = -0.8053$

$r_{41.3} = 0.7655$ $r_{23.1} = 0.6934$

$r_{24.1} = -0.3627$ $r_{41.2} = 0.9609$

$r_{13.2} = -0.9770$ $r_{43.2} = -0.9688$

$r_{21.4} = -0.1338$ $r_{23.4} = 0.7174$

$r_{31.4} = -0.5593$ $r_{14.1} = -0.0898$

The second - order partial correlation is

$$r_{ij.kl} = \frac{r_{ij.k} - r_{il.k}\, r_{jl.k}}{(1 - r^{2}_{ij.k})^{2}(1 - r^{2}_{ji.k})^{2}}$$

TABLE 4: **Partial t_{ij} kl(7) = 1.895**

	X_1	X_2	X_3	X_4
X_1		−1.38	−2.39	0.75
X_2			3.32	−0.59
X_3				−6.66
X_4				

Table 4 gives the following conclusions; there is insignificant association between motorization levels and population per hospital bed; Gross National Product (GNP) and population per hospital bed. The association between motorization levels and population per doctor; population per doctor and population per hospital bed; GNP and population per doctor is significant.

5. Conclusions

The following conclusions are drawn:

General trands in fatality rates for developing and developed countries are discussed comparably. In general fatality rates per motor vehicle are high in the early stages of motorization and tend to decrease over time, whereas fatality rates per population are low in the early stages and increase over time, it is shown that log - linear version of Smeed's Model, which relates vehicle ownership to fatalities, fits reasonably well for developing countries. It provides a poor fit for the data from the developed countries. While there is most certainly a relationship between fatality rates and vehicle ownership, fatalities also present a good view of the road safety situation in developing countries. The effects of economic factors and health characteristics on fatality rates for Pakistan together with their inter-relationship are explored.

It is found that motorization levels had significant effect on vehicle fatality rates in developing countries, particularly for those, which are at the lower end of the per capita GNP. Economic factors and the health characteristics have significant effect on vehicle fatality rates in Pakistan. The fatality rates are decreasing with the increase in motorization levels though at different speeds. The reasons associated with this decrease in vehicle fatality rates are decrease in the population of two wheeled traffic on roads, a category of vehicle which has the highest accident, a fall in pedestrian casualty rates which in turn could be due to improved pedestrian facilties and an overall tendency towards higher level of road users education and training, a better maintenance of vehicle and road system.

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