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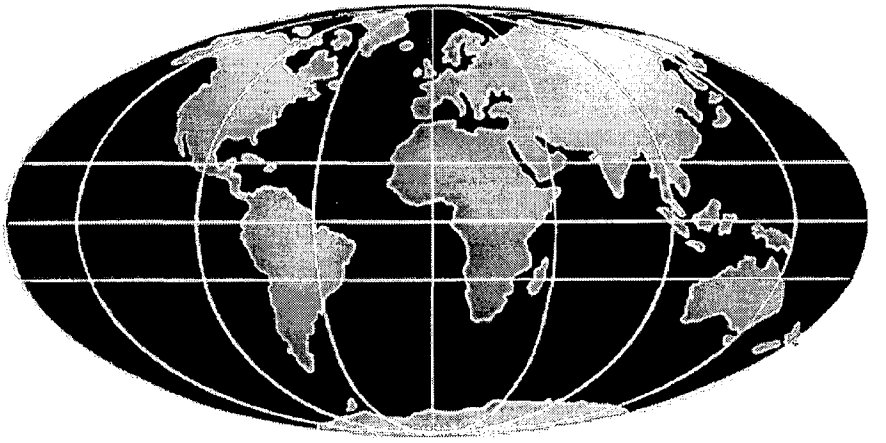

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FURTHER RESEARCH ON ACCIDENT RATES IN DEVELOPING COUNTRIES

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Abstract—Earlier studies have shown that by using cross-sectional data for a group of developing countries, a significant relationship can be established between fatality rates and vehicle ownership levels. This paper updates relationships established in earlier years and identifies whether or not the slope of the regression line has continued to increase (and suggests that for the group of countries as a whole, there is a worsening in the safety situation). Similar relationships are also established for casualty rates. A detailed analysis is made of the relationship between fatality rates and parameters which describe, in part, the social, physical and economic characteristics of the developing countries. These include vehicle ownership, gross national product per capita, road density, vehicle density (per kilometre of road), population per physician and population per hospital bed. Again, comparisons are made with results obtained on earlier studies.

1. INTRODUCTION

Research work by Jacobs *et al.*[1973,1977,1978] carried out by the Overseas Unit TRRL in recent years has shown that many developing countries have a serious road accident problem. Fatality rates (per licenced vehicle) are high in comparison with those in developed countries. While in Europe and North America the situation is generally improving, many developing countries have been experiencing a worsening situation.

In this paper earlier work on accident rates and trends carried out for 1958 to 1971 have been updated and comparisons are made of fatality and casualty rates for the year 1980 with those derived earlier. Also, trends in fatality rates over the period 1970–80 are compared with those established for the periods 1958–68 and 1961–71.

In addition, an analysis has been made of the relationships between fatality and casualty rates and parameters which describe in part, the social, physical and economic characteristics of selected developing countries. These include vehicle ownership, gross national product per capita, road density (per unit area of country), vehicle density (per kilometre of road), population per physician and population per hospital bed. Again, comparisons are made with results obtained in earlier studies.

The relationships derived are not used to predict future levels of death or injury rates in developing countries. Rather they are used to indicate how the relationships are changing over time, thus showing whether or not the safety problem is worsening or improving in the Third World. The relationships are also used to indicate whether or not a group of countries as a whole, those in the Middle East, for example, or developing as opposed to developed countries, have particularly high or low death rates. Results are also used to see whether or not social, economic or physical characteristics of the different countries can be related to fatality and casualty rates in developing countries. In this analysis developing countries have been taken as those with a gross national product (GNP) per capita (1980) of less than $1800.

2. DATA SOURCES

The basic data for the analyses in this study were obtained from published sources including the International Road Federation's publication, World Road Statistics[1981] and the United Nation's Statistical and Demographic year books[1981]. Information was also obtained from questionnaires sent by the Overseas Unit to individual countries and also from material published by the different countries themselves.

3. TRENDS IN FATALITY RATES

In order to determine the changing patterns in fatality rates and also vehicle ownership levels with time, data were obtained on the vehicles, population and road accident fatalities for a number of developed and developing countries over the 10-year period 1970–1980. For the 10 year period, the percentage change per person in vehicles owned and change in fatalities per licenced vehicle and per head of population were calculated. Results are given in Table 1.

In almost all countries, as might be expected, there was an increase in the number of vehicles per person over the 10-year period. Some developing countries such as Turkey, Malaysia, Brazil and Jordan showed large increases, well over 100% in vehicle ownership levels.

In all developed countries but one (which was Spain, the poorest of the developed countries listed), there was a decrease in the number of fatalities per 10,000 persons. Conversely, of the 18 developing countries for which data were available, 15 showed an increase in the fatalities per 10,000 persons. Thus using this criterion as a measure of change, almost all developed countries show an improving situation over the given time period whilst most developing countries show a worsening situation. Calculations showed that in developing countries, the coefficient of rank correlation between changes in vehicles per person and fatalities per person were not significant, i.e. those countries with the largest increases in fatality rates were not necessarily those with the greatest increase in vehicle ownership.

Table 1 also shows changes in fatalities per licenced vehicle. This is perhaps a more meaningful indication of the accident situation in a group of countries since it takes into account

Table 1. Percentage change in vehicle ownership and fatality rates in (a) developing countries 1970–1980 and (b) in developed countries 1970–1980

(a)

	Vehs/10,000 Persons	Fats/10,000 Vehicles	Fats/10,000 Persons
Botswana	+180.3	−5.4	+165.2
Brazil	+174.8	−23.5	+112.5
Chile	+74.8	−57.6	−25.9
Colombia	+85.7	−13.8	+58.5
Ethiopia	+1.2	+4.9	+6.7
India	+89.0	+17.1	+126.7
Jordan	+309.4	−64.6	+45.5
Kenya	−18.8	+99.0	+61.9
Malaysia(w)	+174.2	+29.9	+325.9
Morocco*	+67.0	−24.2	+27.1
Niger	+112.0	−32.5	+42.9
Pakistan	+142.9	+36.7	+235.7
Senegal*	+26.0	+143.3	+84.4
South Africa	+91.5	−47.9	−0.3
Sri Lanka	+78.9	−20.7	+41.5
Thailand	+62.8	+42.2	+134.1
Tunisia	+77.1	+22.5	+115.3
Turkey*	+165.9	−64.7	−5.5

*1970 and 1980 figures not available, 1969 and 1979 used.

(b)

	Vehs/10,000 Persons	Fats/10,000 Vehicles	Fats/10,000 Persons
Australia*	+33.7	−36.0	−14.5
Belgium	+43.6	−44.4	−20.1
Denmark	−7.7	−40.2	−44.7
France	+29.4	−39.1	−21.0
Gt Britain	+22.0	−36.7	−23.0
Netherlands	+8.3	−46.8	−42.2
New Zealand	+36.3	−39.4	−17.5
Spain	+108.6	−47.5	+9.6
Switzerland	+50.5	−50.7	−25.9
United States	+29.4	−34.2	−14.9

*1970 and 1980 figures not available, 1969 and 1979 used.

the effect of varying levels of vehicle ownership on accident rate. An even better value to use would be the change in fatalities per million vehicle kilometres travelled, but since few developing countries operate trend censuses such data are unavailable.

It can be seen that all developed countries showed a decrease in fatalities per 10,000 vehicles whilst of the 18 developing countries, ten showed decreases whilst eight showed increases. Thus using fatalities per licenced vehicle as an indicator of trends, almost half the developing countries show a worsening situation. Comparing this result with that obtained for the period 1961–71 it is interesting to note that over the earlier period, about one-third of the developing countries showed increases in fatality rates again suggesting that the problem has increased in recent years.

4. FATALITY AND CASUALTY RATES 1980

4.1 *Fatality rates in developing countries*

Using data from 20 developed countries for road fatalities, vehicles and population for the year 1938 Smeed[1949] derived a relationship expressed by the equation

$$(F/V) = 0.0003(V/P)^{-0.66}$$

where F = fatalities from road accidents, V = number of vehicles in use, and P = population.

Using the same method as Smeed, Jacobs[1973,1977,1978] carried out analyses of fatality rates in developing countries for a number of different years 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 (significant at the 1% level) was derived of the form

$$(F/V) = 0.00036(V/P)^{-0.65}$$

which is very similar to that derived by Smeed suggesting that the situation in developed countries in 1938 is similar to that in developing countries in 1980. In terms of vehicle ownership and general approaches to the safety problem this may well be the case.

Since the number of developing countries (20) for which data were available was not high, the analysis was repeated for the most up to date year available, ranging from 1978 to 1980. In this instance information was obtained on 35 developing countries and the following equation derived:

$$(F/V) = 0.00039(V/P)^{-0.64}.$$

It can be seen that this relationship is very similar to that derived for 1980 data only.

The equation obtained using data for the year 1980 was now compared with that derived for developing countries for earlier years and results are shown in Fig. 1. It can be seen that from 1965 to 1971 the slope of the regression line remained the same with the regression constant increasing. In other words, the equation in 1971 suggested higher fatality rates than in 1968 or 1965 for the same level of vehicle ownership. The equation derived for 1980, however, has a different slope to that for earlier years and suggests that for countries with low levels of vehicle ownership fatality rates have increased whilst at higher levels they have decreased. Thus fatality rates for the countries at the "top end of the Third World scale," such as Chile, Brazil, Jordan and Turkey, have declined in relation to levels of vehicle ownership whilst in those (mainly African) countries at the opposite end of the spectrum, the reverse is true.

4.2 *Fatality rates in developed countries*

In order to determine whether the Smeed equation changed with time, an analysis was made [Jacobs and Fouracre, 1977] of the same group of countries used by Smeed and relationships derived for the years 1950, 1960 and 1970. It was found that there was relatively little variation

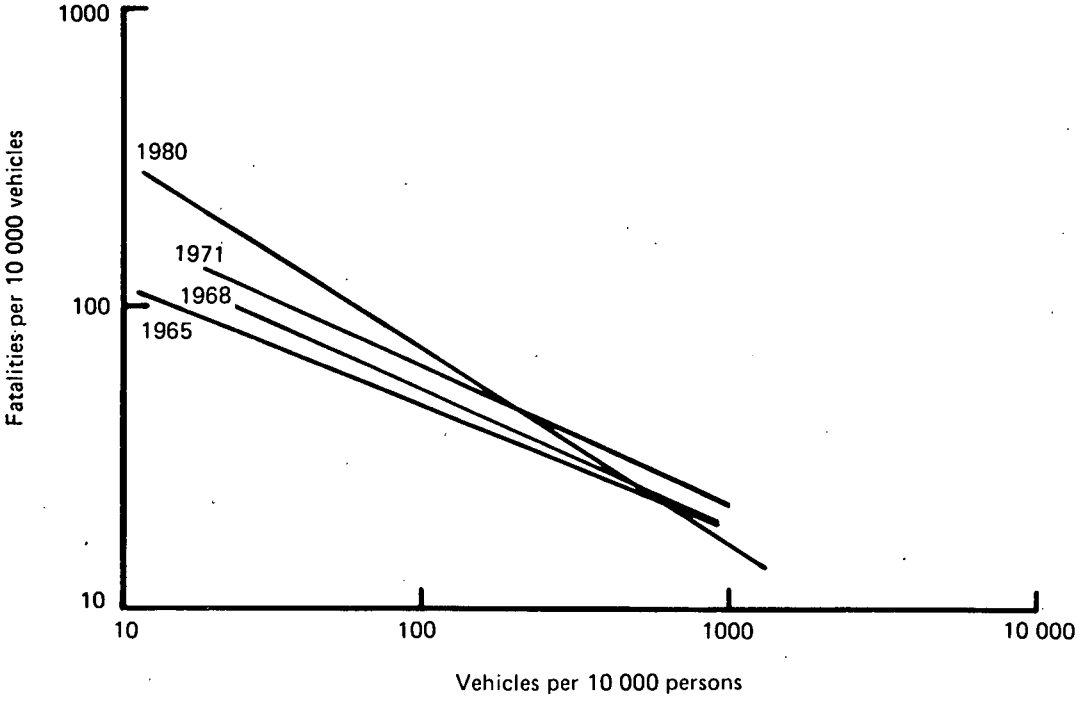

Fig. 1. Developing countries—fatality rates and vehicle ownership levels.

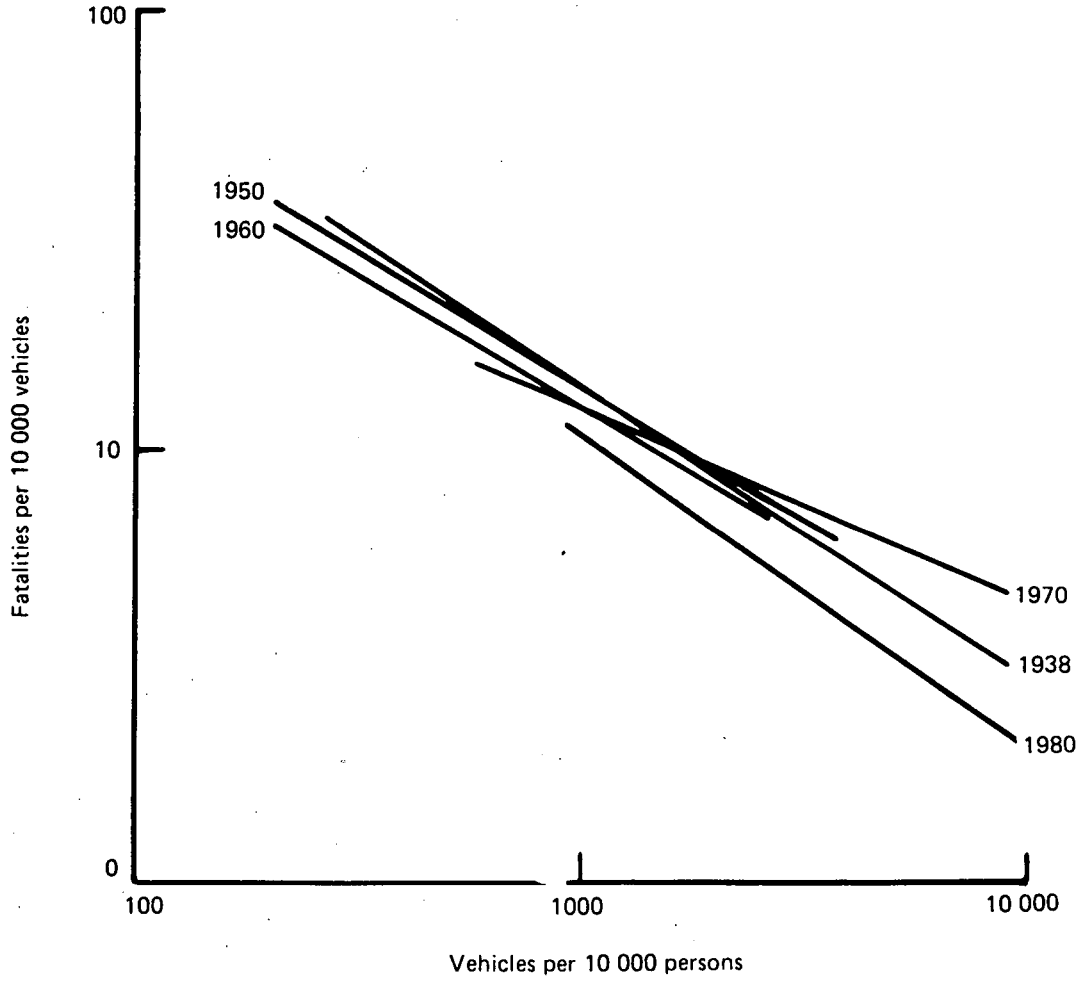

Fig. 2. Developed countries—fatality rates and vehicle ownership levels.

in the equation over the period 1938 to 1970. The analysis has now been repeated for the year 1980 and the equation derived was of the form

$$(F/V) = 0.00021(V/P)^{-0.72}.$$

Figure 2 shows this equation together with those for the earlier years. It can be seen that fatality rates for given levels of vehicle ownership are markedly lower in 1980 than in earlier years. This suggests that in the developing world as a whole, fatality rates, for a given level of vehicle ownership, have tended to increase over time, whereas in Western Europe and North America, there has been an overall decrease.

4.3 *Fatality rates in Middle Eastern countries*

A comparison was also made of fatality rates in developing countries as a whole with those in the Middle East. Many Middle Eastern countries in fact lie somewhere between developed and developing countries in that average GNP/capita values are often high but they are "developing" in the sense that their infrastructure is still being developed. Figure 3 shows values of fatality rates and vehicle ownership levels for a number of such countries together with the regression line derived for developing countries for the year 1980.

It can be seen that almost all Middle Eastern countries lie above the regression line. This suggests that in relation to their levels of vehicle ownership they have high fatality rates. Of the 12 Middle Eastern countries, eight in fact lie outside the 95% confidence limits of the regression line. Table 2 shows the actual values of the fatality rates for these countries and compares these values with what might be "expected" from their vehicle ownership levels if their fatality rates actually lay on the regression line. Results are given in Table 2.

It can be seen that countries such as Qatar, Libya and Saudi Arabia have extremely high fatality rates in comparison with other Third World countries. These countries have high levels of both Gross National Product (GNP) per capita and vehicle ownership and it may have been more appropriate to compare their fatality rates with the regression line derived for developed, as opposed to developing, countries. Had this been done then "expected" values would have been even lower and differences between actual and expected values even greater.

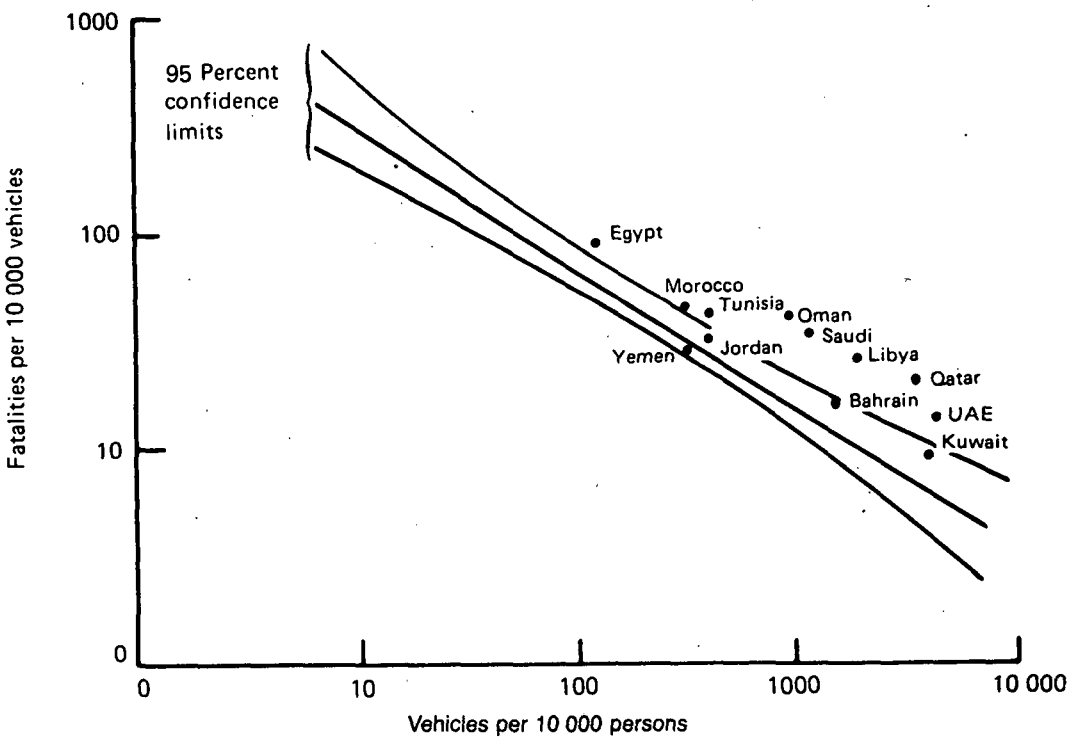

Fig. 3. Fatality rates in middle eastern countries—1980.

Table 2. Comparison of actual and "expected" values of fatality rates in Middle Eastern countries

Country	Actual Value	Expected Value	Percentage Difference
Bahrain	16.1	11.5	+40
Egypt	91.7	61.6	+49
Jordan	33.0	27.5	+20
Kuwait	8.9	6.2	+71
Libya	33.3	14.0	+138
Morocco	42.3	33.6	+26
Oman	38.5	19.4	+98
Qatar	17.9	7.0	+156
Saudi Arabia	35.7	17.0	+110
Tunisia	39.2	29.3	+34
U.A.E.	14.0	7.6	+84
Yemen	30.1	33.9	−11.2

4.4 *Casualty rates*

In the same way that relationships were established between fatality rates and levels of vehicle ownership, attempts were also made to correlate casualty rates (i.e. casualties per 10,000 vehicles) and fatality indices (i.e. the proportion of persons injured who are actually killed) with levels of vehicle ownership. Earlier attempts [Jacobs and Hutchinson, 1973; Jacobs and Fouracre, 1977] to relate casualty rates to vehicle ownership levels were not successful but data on 20 developing countries for the year 1980 gave the following relationship (significant at the 1% level)

$$(C/V) = 0.00626(V/P)^{-0.49},$$

where C = number of persons injured and V and P are as before.

Although a significant relationship was established it should perhaps be stressed that because accident reporting systems are not very well developed in Third World countries, statistics on casualties are not reliable, far less so in fact that those on persons killed.

4.5 *Fatality indices*

Similarly, a significant relationship (at the 5% level) was established between fatality indices and vehicle ownership levels of the form

$$FI = 4.0(V/P)^{-0.27}$$

where FI = fatality index (i.e. proportion of all persons injured who are killed) and V and P are as before.

This equation is very similar to that established for the same parameters for the year 1968 and shows that as vehicle ownership levels increase, the proportion of persons injured who are killed also decreases. Thus those countries with the highest fatality indices are those with the lowest vehicle ownership levels. Fatality indices range from about 5% in some countries to over 30% in others. The high values in some of these countries must, in part, be due to the considerable under reporting of non-fatal accidents.

For comparative purposes a similar analysis was made of fatality indices on developed countries and an equation (significant at the 1% level) was derived of the form

$$FI = 411.0(V/P)^{-0.58},$$

where FI, V and P are as above.

An equation for the two groups of countries are given in Fig. 4. It can be seen that fatality indices in developed countries are much lower than in the developing world and range from 6 to 2.5%. Earlier work [Jacobs and Hards, 1978] showed that high fatality indices can be related to a lack of medical facilities in developing countries. A similar analysis of 1980 data (see next section) shows this again to be the case.

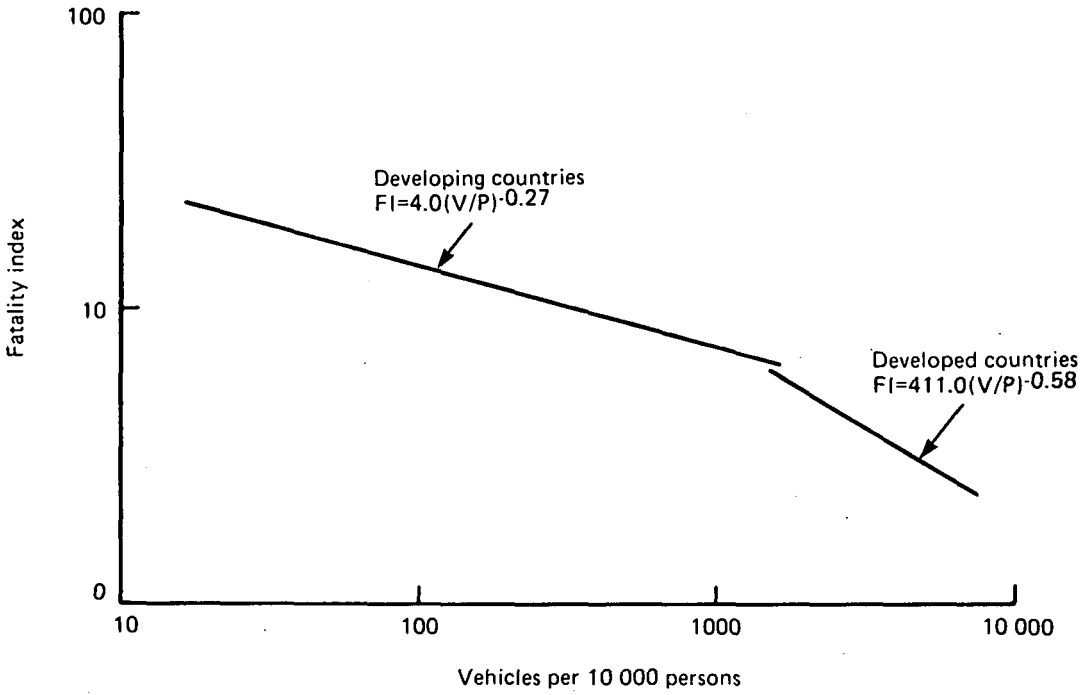

Fig. 4. Fatality indices and vehicle ownership levels in developed and developing countries—1980.

5. FACTORS AFFECTING FATALITY AND CASUALTY RATES

In the preceding section, fatality and casualty rates in different countries were found to be closely related to the levels of vehicle ownership existing in these countries. However, it should not be implied that variation in fatality rates, either in different countries or in any one country over time, can be "explained" simply by the level of vehicle ownership. In order to see whether these relationships could be expanded, the fatality and casualty rates and fatality indices in a group of countries were regressed against a range of parameters that describe, in part, the social, physical and economic characteristics of the country. Simple regression analysis was used to relate separately the logarithmic values of fatality rates, casualty rates (per licenced vehicle) and fatality indices in the 20 developing countries (1980) to the parameters given in Table 3. Results of the analysis are also given.

Fatality and casualty rates were found to decrease with increasing vehicle ownership and vehicle density (per length of road). Fatality rates were further related to GNP/capita (decreasing with increasing GNP) and to the population per hospital bed. In the latter case, fatality rates increased as the population per hospital bed increased, i.e. as medical facilities worsened. It is reasonable to deduce that in a number of Third World countries, fatality rates could be reduced by improving available medical facilities.

With the analysis of factors affecting fatality indices, the most significant relationship was found to be with population per physician. Thus the proportion of persons injured in road accidents who die as a result of the accident could be reduced in developing countries by improved medicine facilities. Other factors significantly related to fatality indices were vehicle ownership and GNP/capita.

The above results show how factors acting independently are related to fatality and casualty rates and fatality indices in the different countries. In order to determine the effect of these factors acting together, a multiple regression analysis was carried out. The equation derived with variables significant at the 5% level were

$$(\log)\ \text{Fats/veh} \times 10^4 = 3.153 - 0.649\ (\log)\ \text{vehs/pers} \times 10^4),$$

$$(\log)\ \text{Cas/veh} \times 10^4 = 3.765 - 0.492\ (\log)\ \text{vehs/pers} \times 10^4,$$

$$(\log)\ \text{Fat/Index} = 0.940 - 0.00001\ (\log)\ \text{pop}n\text{/physician}).$$

Table 3. Dependent variable 1.—(log) fatality rate (fatalities per vehicle × 10^4)

Independent Variable	Regression Constant	Regression Coefficient	Correlation Coefficient	F-value	Significant at 5%
(log) vehicles per person × 10^4	3.153	−0.649	−0.908	84.13	Yes
Vehicles per 10 Km of road	1.928	−0.003	−0.650	13.15	Yes
(log) GNP/capita	3.562	−0.682	−0.552	7.88	Yes
Population per hospital bed	1.448	0.0002	0.462	4.87	Yes
Population per physical	1.540	0.0001	0.433	4.15	No
(log) road density (Km of road per Km^2)	1.400	−0.278	−0.355	2.59	No
Dependent variable 2.—(log) casualty rate (casualties per vehicle 10^4)					
(log) vehicles per person × 10^4	3.765	−0.492	−0.670	14.62	Yes
Vehicles per 10 Km of road	2.852	−0.002	−0.517	6.58	Yes
Population per physician	2.610	0.001	0.064	0.07	No
Population per hospital bed	2.547	0.0001	0.177	0.59	No
(log) road density (Km of road per Km^2)	2.551	−0.084	−0.105	0.20	No
(log) GNP/capita	3.430	−0.286	−0.225	0.96	No
Dependent variable 3.—(log) fatality index					
Population per physician	0.940	0.00001	0.572	8.25	Yes
(log) vehicles per person × 10^4	1.675	−0.268	−0.514	6.31	Yes
(log) GNP/capita	2.190	−0.411	−0.520	6.30	Yes
Population per hospital bed	0.915	0.0001	0.419	3.61	No
(log) road density (Km of road per Km^2)	0.840	−0.218	−0.430	3.86	No
Vehicles per 10 Km of road	1.107	−0.0007	−0.239	1.03	No

With fatality and casualty rates as dependent variables, the only significant variable to enter the multiple regression equation was vehicle ownership. With the fatality index as the dependent variable the only significant variable was population per physician. From Table 3 it can be seen that the three dependent variables were related separately to a number of the independent variables. In the multiple regression equation, however, only one parameter was found to enter each of the equations (at the 5% significance level). The reason for this is that the independent variables are themselves interrelated. Thus as a country develops, the GNP/capita, vehicle ownership, vehicle density, road density and level of medical facilities all increase. When carrying out the multiple regression analysis, the most significant factor (which was vehicle ownership in the case of fatality and casualty rates and population per physician in the case of the fatality index) enters the equation first. However, since this is closely related to the other independent variables it also "explains" most of the variation associated with these parameters which in the multiple regression analyses were found to be non-significant.

6. DISCUSSION

This paper has attempted to show how an analysis of fatality and casualty rates (both as absolute numbers and as trends over time) can be used to indicate the seriousness of the road safety problem in developing countries. A study of changes in fatality rates (i.e. fatalities per licenced vehicle) over the period 1970–80 showed that whilst nine out of ten developed countries showed decreases in fatality rates, almost half the developing countries showed increases. An earlier analysis (over the period 1961–71) showed that under one-third of the developing countries experienced increases in fatality rates. These results suggest that whereas the safety problem is generally improving in countries of Europe and North America, many developing countries show a worsening situation.

Cross-sectional analysis of data from 20 developing countries was used to derive Smeed-type equations relating fatality and casualty rates and fatality indices to levels of vehicle ownership for the year 1980. These equations have not been used in any predictive sense to forecast future numbers of deaths and injuries in the developing world. Rather, they have been used to show how fatality rates have increased over time in developing countries for any given level of vehicle ownership. They have also been used to show that the Smeed-type relationship for developing countries in 1980 differed from that for developed countries and that Middle Eastern countries

as a whole have relatively high fatality rates for their given levels of vehicle ownership. The results were also used to show that compared with developed countries, fatality indices were also high in the Third World. No doubt this is a reflection of the under reporting of the less serious accidents in these countries but a lack of medical facilities would also seem to be a contributory factor leading to high fatality indices.

Cross-sectional analysis was used to establish relationships between fatality and casualty rates and fatality indices and parameters that describe in part the social economic and physical characteristics of the developing countries. Results showed that vehicle ownership was still the dominating independent variable but also that fatality rates could be significantly related to parameters such as GNP/capita, vehicle density (per length of road) and population per hospital bed. The last named variable was also that most closely correlated with fatality indices in these countries.

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