From Increasing to Decreasing Fatality Figures: Where is the Turning Point?

Csaba KOREN [a], Attila BORSOS [b]

[a,b] *Dept. of Transport Infrastructure, Szechenyi Istvan University, Gyor, Hungary*
[a] *E-mail: koren@sze.hu*
[b] *E-Mail: borsosa@sze.hu*

Abstract: Earlier research identified the following three stages of development in road safety. a) Declining road safety: Increasing fatality rate per population dominates due to growing traffic volume. b) Turning point: The road safety situation is quite bad; however, the trend is changing. c) Long-lasting improvement: In spite of further growth in traffic volumes, the fatality rate per population is decreasing. This paper looks at the turning point: when did individual countries reach this, what are the chances of other countries – especially in Asia – being still in the declining road safety stage.

Keywords: Road safety, trends, driving forces, Europe, Asia

1. INTRODUCTION

The macroscopic trends of road safety were analyzed by a number of authors since in 1949. R. J. Smeed published his formula for predicting road deaths as an empirical rule relating traffic fatalities to motor vehicle registrations and population (Smeed, 1949). His paper is mostly cited emphasizing that the increase of vehicle ownership leads to a decrease in fatalities per vehicle. This approach was further investigated recently for India by Ponnaluri (2012). Another interpretation of Smeed's formula is that the increase of vehicle ownership leads to an increase in fatalities per population and in the total number of fatalities. Fortunately, the increasing trend of the total number of fatalities started to change towards a decreasing trend in some countries starting in the 1960's.

2. EARLIER RESEARCH

Research carried out by Oppe (1991a, 1991b) found that the long-term development of traffic fatalities in the highly motorized countries follows a law-like pattern determined by the growth of motorization and the decline of the fatality rate per vehicle kilometre of driving.
Some models describing the changes in road fatalities use among other variables, vehicle kilometres travelled (VKT) and Gross Domestic Product (GDP). Kopits and Cropper (2005) found that the income level at which traffic fatality risk first declines is $8,600 (1985 international prices), regardless of how the time trends are specified. This is the approximate income level attained by countries such as Belgium, the United Kingdom, and Austria in the early 1970s, South Korea in 1994, and New Zealand in 1968.

Based on data of 139 countries from all over the world published by the World Health Organization (WHO, 2009/a) Koren and Borsos (2010b) did a cross-sectional analysis for the year 2007. It was shown that the Smeed interpretation is too pessimistic above 0.2-0.3 vehicles per population and that a proposed function can better describe the 3 phases of road safety trends: decline, turning and improvement (Figure 1).

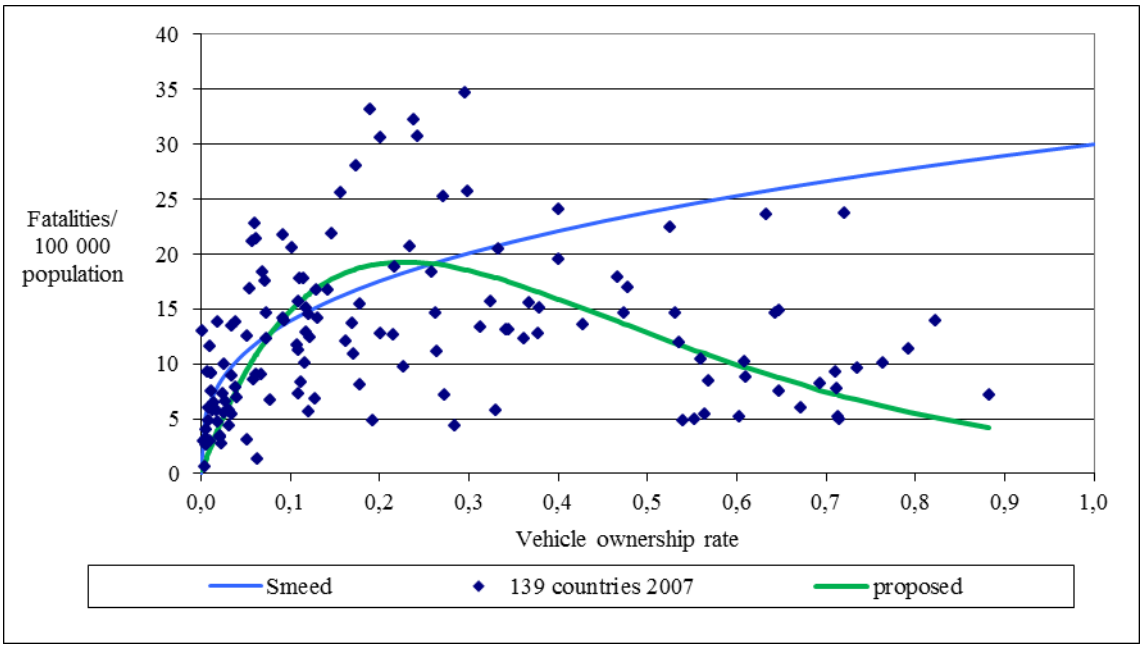

Figure 1. Two explanations for the relationship between vehicle ownership and fatality rate

For the description of the relation between vehicle ownership rate and fatalities per population the following model was proposed:

$$D/P = a \cdot N/P \cdot e^{-b \cdot N/P} \quad (1)$$

where

D is the number of annual road deaths
N is the number of registered vehicles and
P is population.

The change in the number of fatalities per population is influenced by the following driving forces:

- Increase in vehicle ownership rate goes together with an increase in accident exposure.
- Increase in vehicle ownership rate goes together with economic growth and technological development (better infrastructure, better equipped cars, better emergency services etc.).
- Social attitude against road safety changes (evaluation of accident costs, acceptance of restrictions, education, enforcement, etc.).

The combined impact of the three driving forces leads to the following three stages of development:

- Declining road safety: Increasing fatality rate per population dominates due to growing traffic volume, the economy is weak, and there is no social attention to road safety.
- Turning point: The road safety situation is quite bad; however, the economic performance makes the change possible, if there is adequate social and political will.
- Long-lasting improvement: The pace of economic and technological development as well as the change in social attitude is higher than the growth in traffic volume.

The term $a \cdot N/P$ expresses the growing exposure with the increase in the number of vehicles. While N/P is very low, $e^{-b \cdot N/P}$ is close to 1, so the first part of the formula, i.e. the growth in vehicle numbers is dominant.

The second part of the formula, $e^{-b \cdot N/P}$ is a negative exponential function, expressing that the growth of vehicle ownership generally goes together with the increase in vehicle and infrastructure safety as well as with an improvement in education and enforcement. Thus, with higher motorization rates the second term of the formula becomes dominant. In this part, N/P reflects the general development level of a country rather than the exposure.

The formula used is appropriate to describe the phenomenon that with low motorization the number of fatalities increases. Once reaching a certain threshold, the society chooses to devote and can afford more efforts to improve road safety.

Yannis et al. (2011a) examined the trends of road fatalities in several EU countries through motorized vehicle fleet and population. They used piece-wise linear regression models allowing for the simultaneous estimation of slopes and breakpoints. As a result of their research they defined the location of break points as well as the slopes of the connecting trends in each country and came to the conclusion that these break points and slopes vary among countries indicating different evolution patterns. Again using fatality rate and vehicle ownership data for 16 EU countries Yannis et al. (2011b) developed several models including simple non-linear models, their log-transformations and related autoregressive models.

Using the same model (Equation 1) Borsos et al. (2011) did a macroscopic analysis of long-term road safety trends in 26 countries. The research included a country-level (multiple years to estimate a curve for each country) (Figure 2) as well as a time-dependent (multiple countries to estimate a curve for each year) analysis using data of 45 years (1965-2009). The country-level analysis showed that the model can be fitted well for most countries.

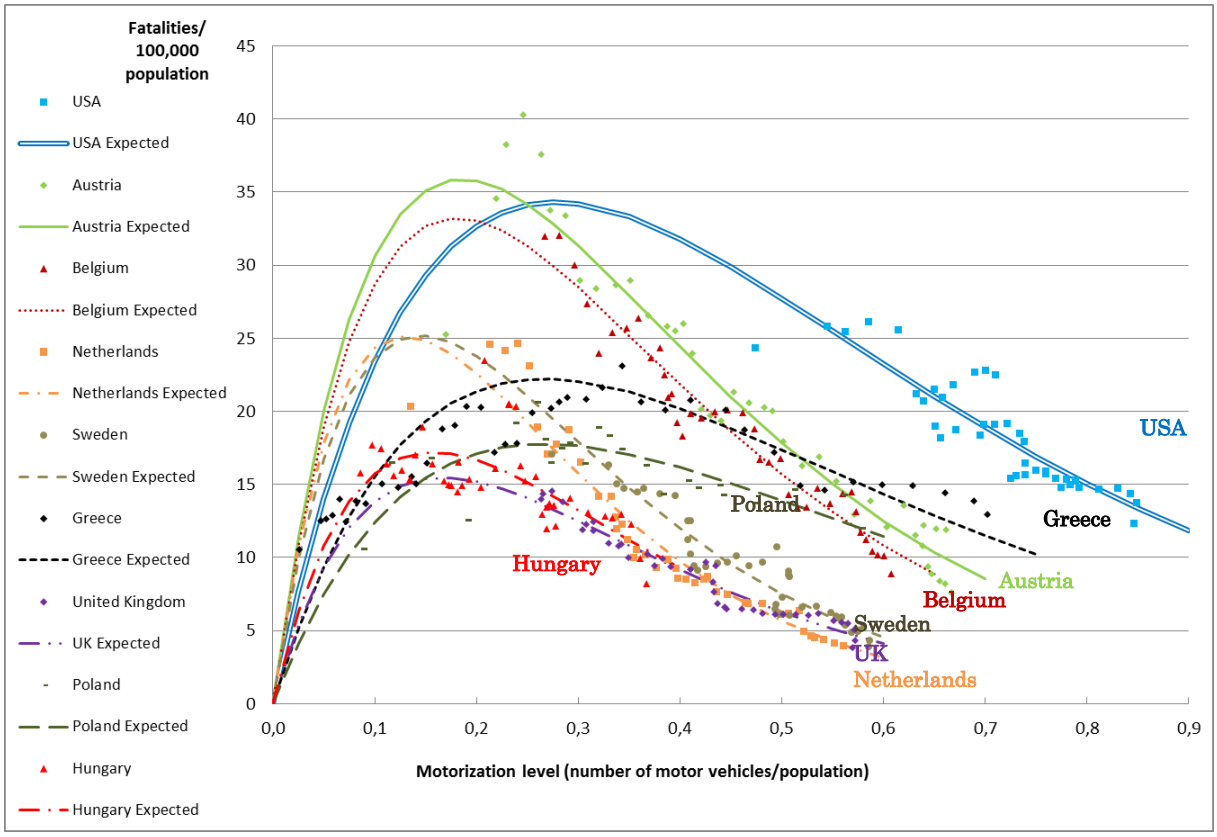

Figure 2. Fatality rates vs. motorization level and fitted curves in selected countries

This conclusion led the authors to further investigate the effect of time on road safety trends. In Koren & Borsos (2012) it was investigated, whether latecomers, i.e. countries which reach a certain level of development later than some others, can have safety benefits from being late. The analysis showed that Member States joining the EU after 2004 (the so-called New Member States) reached the 0.2 car ownership level 15-25 years later compared to those already being a member (the so-called Old Member States), as this growth strongly depends on the economic potential of a country. The situation proves to be much better with the safety figures where the backlog of the new countries is only 5-10 years. This is due to the free movement of goods, the international exchange of experiences, road design and safety improving solutions and the social attitude towards safety.

Koren and Borsos (2010a) also looked at the road safety trends of a few Asian countries in general. The present paper investigates the turning point in the fatality rate and attempts to forecast the tipping point in countries that have not reached it yet.

3. TURNING POINTS IN EUROPE, NORTH AMERICA AND AUSTRALIA

The turning points in road safety were defined as the years with the highest fatality rate per population. In order to compare European countries, the following data were collected:

- Year when reaching the highest fatality rate
- Fatality rate in that year
- Car ownership level in that year.

In Table 1 countries are ranked according to the year when they reached the peak in fatalities per population. Sweden and the UK were the first to turn the trend downwards in the sixties. Then in and around 1970 a number of countries reached their turning points (Norway, Italy, Denmark, Germany, the Netherland, Belgium, Austria, France and Finland). A similar big wave came around 1990 with the East European countries to follow. The time distance between the first and the last country in this table is more than 30 years.

If we look at the car ownership levels of countries in the year when they started to turn the trend downwards, the average is 0.19, the range between 0.13 and 0.31, the relative standard deviation being at 23%. This definite range confirms the assumption that a certain motorization level, a related economic strength and certain knowledge about road traffic in the society are needed to stop the increasing accident figures.

Another column in Table 1 shows the highest road fatality rates reached in each country. These figures show and average about 24 fatalities per 100 000 population, the range being between 15 and 33. The relative standard deviation of these figures is 26%, which means that the differences among countries concerning their “tolerance threshold” to accept road deaths were similar to the differences among their car ownership levels.

Table 1. Data of the turning points in selected European countries

Country	Year	D/P peak (fatalities / 10^5 population)	N/P (cars/person)
Sweden	1964	17.0	0.216
United Kingdom	1966	15.0	0.210
Norway	1970	14.5	0.180
Italy	1970	20.5	0.189
Denmark	1970	24.6	0.218
Germany	1970	27.2	0.194
Netherland	1970	24.5	0.195
Belgium	1970	30.5	0.213
Austria	1970	33.0	0.160
France	1970	32.5	0.233
Finland	1972	24.8	0.176
Portugal	1980	30.2	0.129
Bulgaria	1990	17.9	0.152
Spain	1990	23.3	0.309
Hungary	1990	23.4	0.187
Slovenia	1990	25.9	0.294
Poland	1991	20.7	0.159
Lithuania	1991	29.5	0.143
Greece	1991	31.3	0.154
Czech Republic	1994	15.8	0.234
Slovakia	1998	15.2	0.222
average		23.7	0.198
standard deviation		6.2	0.046
relative st. deviation		26%	23%

Concerning the peak fatality rates of these countries, Figures 3 and 4 show that it was neither influenced by the year when they reached this peak, nor by the car ownership level in that year.

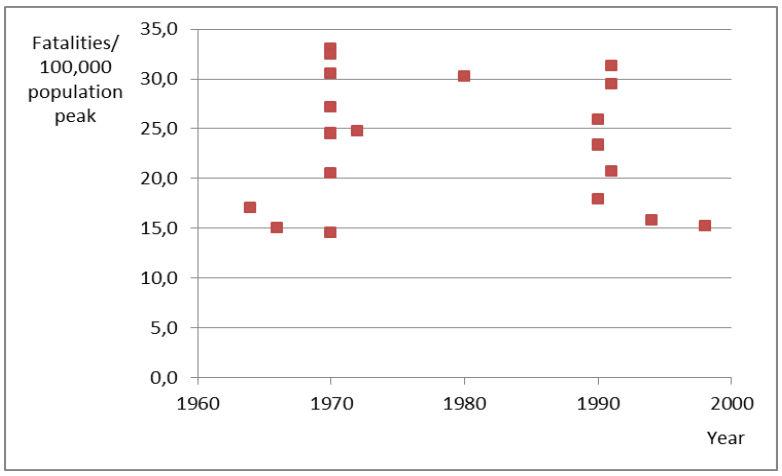

Figure 3. Peaks of the fatality rate by years in selected European countries

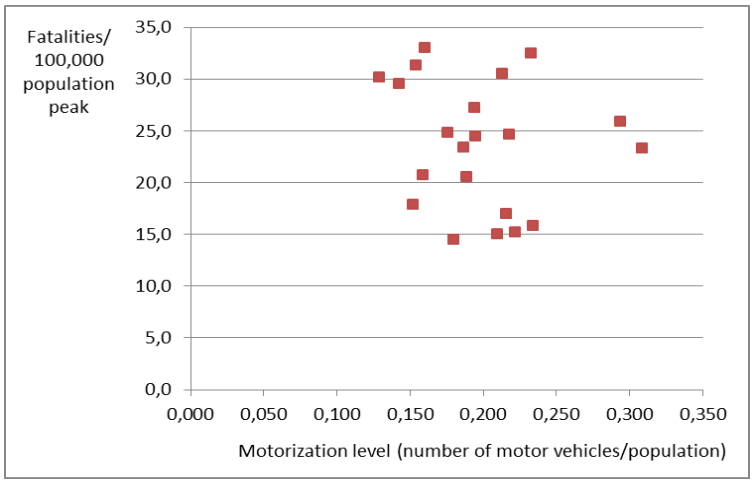

Figure 4. Peaks of the fatality rate by motorization levels in selected EU countries

As far as the turning point is concerned, in North America, Australia and New Zealand the picture is quite similar to those European countries that passed their highest fatality rates at the beginning of the 1970s (Table 2). It should be noted, though, that their motorization level at that point was on average twice as much as that of their European counterparts. Furthermore, their highest fatality rates were all higher than the European average but all within the European range.

Table 2. Data of the turning points in North America, Australia and New Zealand

Country	Year	D/P peak (fatalities / 10^5 population)	N/P (cars/person)
AUS	1970	30.4	0.381
USA	1972	26.1	0.586
CAN	1973	30.4	0.461
NZ	1973	27.9	0.475

4. TURNING POINTS IN ASIA

Asian data were collected from several sources, which contained longer or shorter time series (Mohan, 2009, Park, 2008, Traffic Bureau, National Police Agency Japan, 2008, Zhao, 2009, Ministry of Transportation and Communication, Taiwan, R.O.C, 2013). In some Asian countries a significant gap was found between fatality figures from police data and medical death reports. The WHO (2009/b) estimated real fatality figures in Bangladesh, India, Myanmar 1.5-7 times higher than the reported ones. Hu, Baker and Baker (2010) showed a similar situation by comparing road traffic mortality rates from police-reported data and death registration data in China.

There have already been efforts to predict the future trends. Rohayu et al. (2012) looked at the Malaysian fatality figures and used various modeling techniques to predict fatality figures by 2020. They arrived at the conclusion that the best model for predicting Malaysian road fatalities is ARIMA as it takes into account the previous observation and the past errors to observe patterns and make predictions. They predicted that the number of

fatalities will continue to increase up to 8,760 (year2015) and 10,716 (year 2020). The authors also pointed out that there have been several turning points in the past; however, these were based on absolute figures of fatalities, not on fatality rates.

The Asian countries show a very much dispersed picture in terms of fatality rates and their trends. In Figure 5 fatality rate versus motorization level is plotted for a few selected Asian countries, whereas Figure 6 shows the evolution of fatality rates over time.

Some countries are in a declining road safety situation, where an increasing fatality rate per population due to growing traffic volume dominates. Fatalities of low vehicle ownership countries (e.g. China, India) are still low but unfortunately rapidly increasing. Countries with medium vehicle ownership (like Thailand, Malaysia) have quite high fatality rates but these seem to be already decreasing. In these countries, the high share of two-wheelers contributes to the high fatality figures.

As it has been previously mentioned the data presented here might not be in line with the actual figures. For instance, in Figure 5 two data rows are presented for China proving that the death registration and police-reported data significantly deviate from each other. In that case the latter one seems to be more reliable. Also, the vehicle ownership (an important predictor of fatalities) is prone to be flawed. Both in Thailand and in Taiwan there is a loop (Figure 5) in their time series indicating that vehicle registration data might have errors or that the registration methods changed over time.

Despite these data problems it can be pointed out that with growing motorization figures the fatality rates of Asian countries also follow more or less the bell-shaped curves described in Equation 1, although for some countries the range of data only represents a section of the curve.

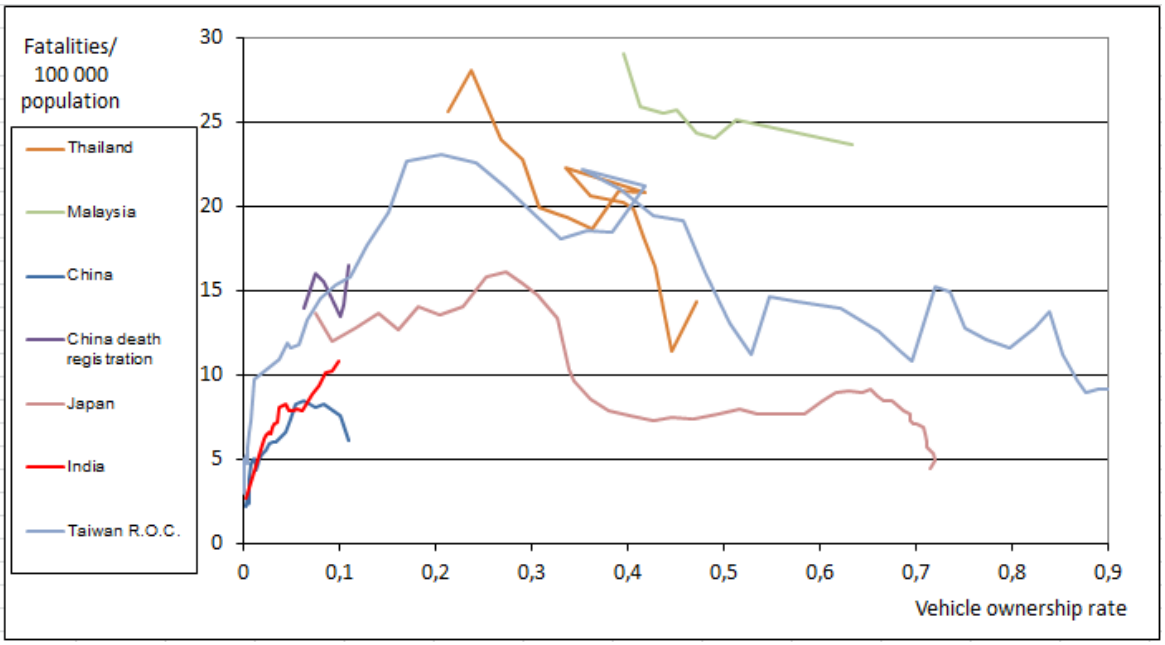

Figure 5. Fatality rates vs. motorization level in selected Asian countries

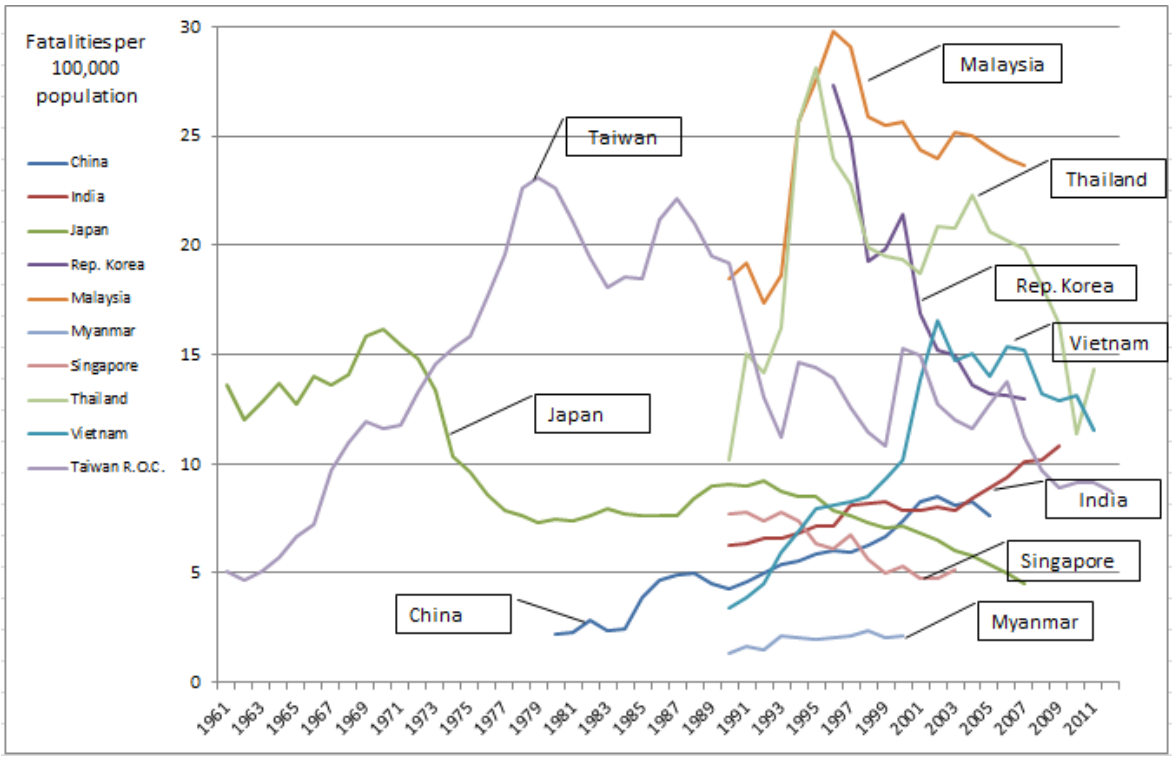

Figure 6. The evolution of fatality rates in selected Asian countries

Similarly to the previously mentioned cases, some Asian countries also passed their peak in fatality rates (Table 3). Japan and Taiwan ROC in the seventies, while Thailand, Malaysia and the Republic of Korea in the nineties. Their motorization level in the year of reaching the peak was higher than in Europe, although it has to be mentioned that for the Asian countries the high amount of two-wheelers was also included in the number of vehicles. The peak fatality rates in these countries were all within the European range.

Table 3. Data of the reported turning points in selected Asian countries

Country	Year	D/P peak (fatalities / 10^5 population)	N/P (vehicles/person)
Japan	1970	16.2	0.273
Taiwan R.O.C.	1979	23.1	0.206
Thailand	1995	28.1	0.237
Malaysia	1996	29.8	0.370
Rep. Korea	1996	27.3	0.378
Vietnam	2002	16.6	0.013 ?
China	2002	8.5	0.060 ?

Police report data from China and Vietnam show that these countries have already passed their peak fatality rates. However, looking at the figures of all the countries mentioned before, it seems quite unlikely that any country can turn its upward trend in fatality rates at a motorization level lower than 0.2 vehicles per person. Furthermore, the authors do not expect that a country can avoid reaching the 15 fatalities per 100,000 population peak, but 20 would be a better estimate. This estimate is valid for all the countries who did not reach their peak fatality rate yet.

Having laid down all the reasoning above it is hoped that a similar model to Equation 1 might be used for Asian countries as well. However, it has to be considered that data inconsistencies cause fluctuations in the time series which hinders rigorous analysis from a statistical point of view. Secondly, the motorization boom is yet to come in some countries (e.g. India, China) which makes for the model difficult to behave well. Using Equation 1 in a linearized form and interpreted as a simple linear regression model curves are fitted for a few selected Asian countries in Figure 7. It should be noted that in countries that are undoubtedly over the tipping point (for instance Japan and Taiwan) the proposed bell-shaped curve can be used with a good fit (R^2 values: Taiwan 0.96; Japan 0.93; Thailand 0.91; Malaysia 0.93). A detailed model description can be found in Borsos et al. (2012).

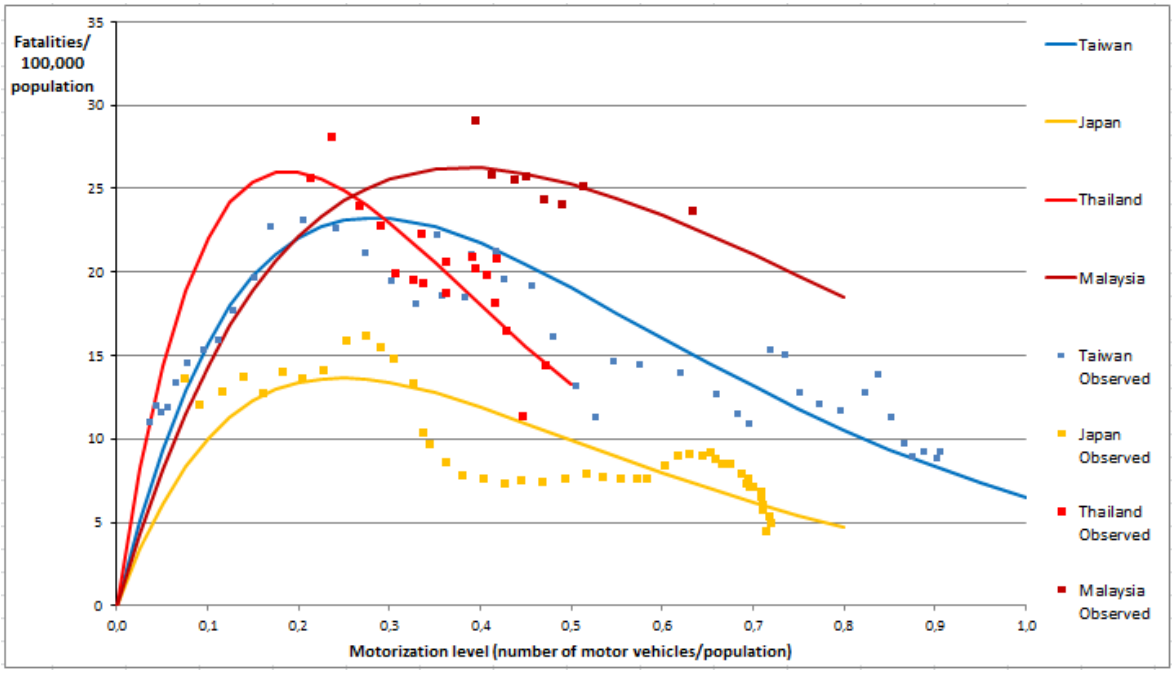

Figure 7. The evolution of fatality rates and fitted curves in selected Asian countries

5. CONCLUSIONS

It was found that due to several driving forces the following three stages of road safety development can be identified for all countries:

- Declining road safety: Increasing fatality rate per population dominates due to growing traffic volume, the economy is weak, and there is no social attention to road safety.
- Turning point: The road safety situation is quite bad; however, the economic performance makes the change possible, if there is adequate social and political will.
- Long-lasting improvement: The pace of economic and technological development as well as the change in social attitude is higher than the growth in traffic volume.

The year of the turning point differs considerably country by country. However the change does not happen below a certain level of motorization (about 0.20 to 0.30 vehicles per person), which indicates an economic potential and also a social embedment of motor transport. The height of the turning point in terms of fatality rate also differs from country to country (15 to 30 fatalities per 100,000 population), which may be related to the social attitude against losses of life. A coherent safety policy and its consequent implementation are essential to keep the actual fatality figures at the lower segment of this range.

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