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Personal Risk – Is there a Turning Point?

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ABSTRACT

Reduction in road fatalities is measured by a reduction in personal risk, calculated by the ratio of the number of road deaths per 100,000 population. The objective of this study is to model personal risk, as a function of the motorization rate, calculated by dividing the number of vehicles per 1,000 population. A piecewise regression model is fitted to the data and both independent variables (motorization rate and turning point dummy variable) are significant in explaining the personal risk. A plot of personal risk as a function of the rate of motorization showed that there are two distinct trends of personal risk. From the early ‘70s throughout half part in the ‘90s, the coefficient of motorization rate is positive. This indicated that for every one unit increases in motorization rate, the personal risk is expected to increase by 0.026. When the motorization rate lapsed 363 vehicles per 1,000 population, the coefficient of motorization rate is negative, where personal risk is expected to decrease by 0.01. Thus, Malaysia road fatalities started to stabilize when the personal risk reached 29.77 deaths per 100,000 population and motorization rate at 363.11 vehicles per 1,000 population. The personal risk, considering the increment in exposures shows that it has reduced since the year 1996.

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1. Introduction

Malaysia experienced remarkable growth in country population, economy and industrialization, especially after the industrialization era started to set foot in the ‘80s. Time-series population figures indicated that the population grows between 2.0 - 2.6% annually in the period of three decades (1970-2005), and the figure dropped to less than 2% for the period after 1995 and to 1.3% in the year 2017. The number of population has increased from 10,881,800 in the year 1970 to almost 32,049,700 in the year 2017 (Department of Statistics Malaysia, 2017).

As the population grows, the rate of motorization increases to cater to the need for mobility. The number of cumulated registered vehicles increases from 669,294 vehicles in 1970 to over 17.9 million in 2008 (Sarani et al., 2009) and the annual growth was reported to be 8% annually from the year 1996-2005. The recent statistics showed the number of registered vehicles grows at a rate of 5% annually between 2010-2018.

Despite the positive impact of the remarkable expansion in population and motorization, Malaysia suffers from the burden of road deaths and injuries. In 2016, the Royal Malaysian Police reported that 7,152 deaths that were due to road crashes, involving 802,523 vehicles. The statistics increase drastically from 2014, where only 6,674 deaths were reported. Then, in the recent publication of this road accident statistics, the number of deaths reduced to 6,284 in 2018 (Royal Malaysian Police, 2018). It was forecasted that the number of road fatalities will reach 10,716 in the year 2020 if the business as usual (BAU) approach continues (Sarani et al., 2016). The increasing trend in the absolute number of road deaths is worrying.

The establishment of the Road Safety Research Centre (RSRC) in the year 1996 helped to lay a strong foundation for road safety research in the country. It is timely as the increment in motorization and exposures elevated the number of road fatalities and urged urgent attention. A death reduction target for the year 2000 was developed statistically. The statistical models consider two scenarios in predicting the number of fatalities; if business as usual (doing nothing), and if new road safety initiatives were introduced and intensified. Based on the model, a reduction of 30% in the number of road deaths was set. Under the target, a list of road safety initiatives and interventions were conducted (Sarani et al., 2009; Radin Sohadi, 2007) such as:

(i) The National Accident Database System
(ii) The Five Stages Road Safety Auditing
(iii) The National Blackspot Programs
(iv) Road Safety Research and Evaluation
(v) Conspicuity Initiatives for Motorcycles
(vi) National Targeted Road Safety Campaign
(vii) Revision of the Road Transport Act (1999 Revision)
(viii) Integrated Enforcement
(ix) New Helmet Standard MS1, 1996
(x) New Children’s Motorcycle Helmet Initiatives

Most of the initiatives and interventions brought in positive results of which 6,035 reported road deaths in the year 2000, 5 percent less than the target of 6,389 (Radin Sohadi, 2005).

Good road safety management, in terms of having a leading agency for road safety, is essential. The Cabinet Committee on Road Safety was established in the year 1990, and the Road Safety Department in the year 2004 (Eusofe & Evdorides, 2017) showed Malaysia's commitment to reducing injuries and fatalities on the road. The first Malaysia Road Safety Plan 2006-2010 under the Road Safety Department outlined more interventions and new target setting for Malaysia.

Figure 1 shows the statistics of road deaths, population and number of registered vehicles in the country from the year 1972-2018.

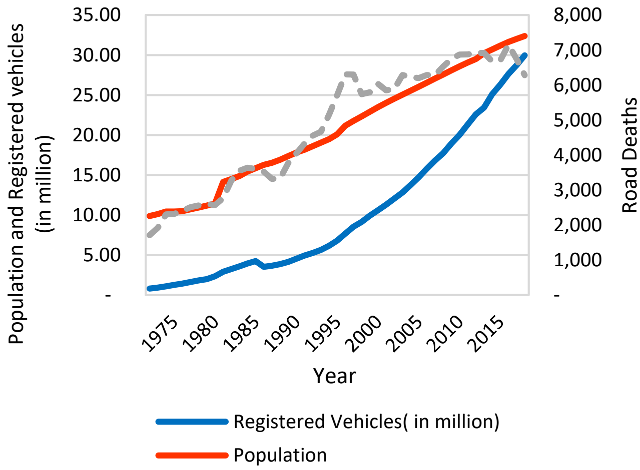

Figure 1: Number of population, registered vehicles, and road deaths

The establishment of the Malaysian Institute of Road Safety Research (MIROS) in the year 2007 elevates the magnitude of road safety research in planning and conducting road safety interventions. Among the notable intervention and initiatives are an automated enforcement system (AWAS), a new car assessment program (ASEAN NCAP), an international road assessment program (iRAP) and an extension of road safety education to secondary schools (RSE) and other various programs (Ishak & Syed Mohamed Rahim, 2020), to name a few.

An automated enforcement system (AWAS) was fully implemented in the year 2013, specifically to deter road users from speeding and red-light running. The intervention started with 14 locations throughout Peninsular Malaysia, with speed limit compliance increased to 90% after installation, as compared to the average of 60% before (Syed Mohamed Rahim et al., 2014).

The New car assessment program for Southeast Asian Countries (ASEAN NCAP) was established in the year 2011 to elevates the safety of vehicles in the ASEAN region. Under the program, new vehicles were tested for Adult Occupants Protection (AOP) and Child Occupant Protection (COP) by star rating, with 5 stars provides the highest standard of safety, before it enters consumers' market (MIROS, n.d.).

Another notable milestone for road safety in Malaysia is the establishment of the International Road Assessment Program (iRAP) Centre of Excellence at MIROS. Through this opportunity, the Malaysian Government has set up a policy that 75% of travel on 3-star or above in the year 2020 (MIROS, 2017).

The cost of keeping the road safe for everyone is not cheap. After spending billions on road safety, it is reasonable to reflect on whether all the initiatives were fruitful, or if the number of fatalities is stagnant, or if there is a reduction. In other words, a long-term trend analysis is crucial. Measuring road safety progress by looking at the reduction absolute number of road deaths alone, might not be fair, as one needs to consider the rapid growth in population and motorization. Hence, this paper highlights the long-term trend of Malaysia road fatalities in measuring road safety progress, considering population and motorization. Personal risk is modeled by incorporating a motorization rate and an indicator variable, that is represented by a breakpoint dummy. Accordingly, the objectives of this study are two-fold;

(i) to investigate whether there is a change in the long-term trend in personal risk; and
(ii) to determine what year of trend changes, if any.

2. Method

2.1. Data Source

This study utilizes time-series data for the population, the number of registered vehicles, and the number of road deaths for the year 1972 – 2018. The number of road fatalities was gathered from Annual Road Accidents Statistics Malaysia produced by Traffic Division, Royal Malaysia Police. The number of cumulated registered vehicles was obtained from the Road Transport Department and the number of populations is collected from the Statistics Department Malaysia.

In measuring long-term progress, a personal risk usually is used instead of the absolute number of road deaths. Personal risk is calculated by dividing the number of deaths per 100,000 population. It is also known as deaths per 100,000 population statistics. Motorization rate, on the other hand, is calculated as the number of vehicles owned per 1,000 population.

2.2. Piecewise Regression Model

A regression equation approximates the true relationship between variables. A simple relationship between x and y may be well represented by linear regression. However, a complex approximating function like piecewise-linear regression is also required, especially when a relationship between a response variable, y changes at different ranges of x, different linear relationships occur. In these cases, a single linear model may not provide an adequate description and a nonlinear model may not be appropriate either.

Piecewise linear regression is a type of regression that allows for more than one regression line to be fitted for a different range of x. The different range of x acts as breakpoint(s), which is differentiated by variation in slopes. The breakpoint(s) could be identified manually, if it is obvious, or could be obtained through segment counts detection. In this paper, a manual breakpoint is identified through graphical analysis (refer to Figure 2). The segmented regression analysis was run using IBM SPSS Statistics 20.

A detailed statistical notation on piecewise regression is written in Ryan & Porth (2007). In analyzing trends of road traffic fatalities in several EU countries, Yannis et al. (2011) investigated the development of personal risk against motorization rate over time, spanning 45 years period at the country level. Simultaneous estimation of broken-line regression models developed or piece-wise linear regression has been fitted in estimating slopes and breakpoints.

3. Results

For visualization purpose, personal risk and motorization rate is plotted over time (Figure 2). The motorization rate (in the orange line) is an increasing trend. On the other hand, personal risk has a gradual increment and slow decrease towards the end of the series. A plot of personal risk as a function of the rate of motorization is as in Figure 2.

The personal risk (in the blue line) resembles a curve with a maximum point. Before the year 2000, sometime between the year 1996-1997, personal risk has an upward trend and then changed its trend to a downward trend. The existence of two major trends here suggests that personal risk could be modeled using segmented regression, which is also called piecewise regression. On the other hand, the motorization rate continues to increase linearly over time.

Through graphical inspection and the maximum value of personal risk, a turning point was identified. The maximum value of personal risk was 29.77 deaths per 100,000 population, which occurred when the motorization rate was at 363.11 vehicles per 1,000 population. A breakpoint dummy is added to the models with a value of 1, for all periods after the turning point, and 0 for all periods before the turning point occurred.

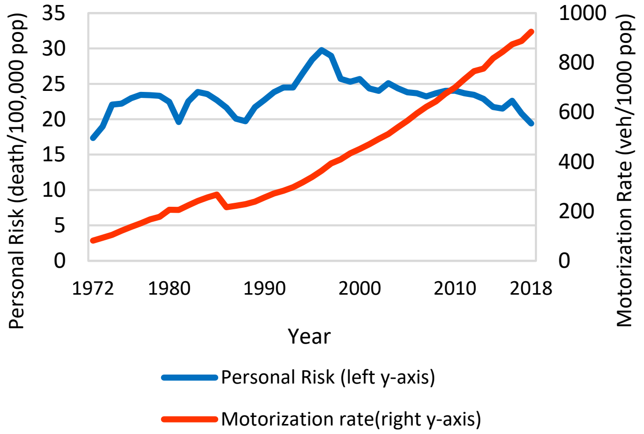

Figure 2: Plot of personal risk and motorization rate

Then, the piecewise regression model is fitted on the data. The model is assessed by the overall model fit (F-value), R-square value, and value of the coefficient of each variable. The piecewise regression model fits the data well, as indicated by the F-value for the overall model fit. F-value of 35.721 is greater than $F_{2,46,} = 3.20$ indicating that the null hypothesis of $H_0: \beta_1 = \beta_2 = 0$ is rejected. This concludes that either the motorization rate or the breakpoint dummy (or both) contributed significantly to the model.

R-square statistics that measure the variability of the dependent variable explained by the explanatory variables used in the model is 0.619. The R-square statistics of 0.619 indicate that 61.9% of the variability in personal risk, could be explained by motorization rate and breakpoint dummy.

When motorization rate $x_i \leq 363$

$$\hat{y} = \beta_0 + \beta_1 x_1 + \beta_2 (x_i - x^{(k)}) x_k \quad (1)$$

where $x^{(k)} = 363$ and $x_k = breakpoint\ dummy$

$$\hat{y} = 17.170 + 0.026x_1 - 0.036\,(x_i - 363)x_k \quad (2)$$

In modeling the first part of the personal risk, the equation is when breakpoint dummy, x_k equals to zero, equation (1) becomes

$$\hat{y} = 17.170 + 0.026x_1 \quad (3)$$

The first part of the model could be seen from 1972 to the early '90s. From the early '70s until the early '90s, the slope of personal risk is positive which indicated that personal risk is expected to increase as the motorization rate per 1,000 population increases. For every one unit increases in the motorization rate, the risk gets higher by 0.026 until the motorization rate was at 363 vehicles per 1000 population. That is the peak where personal risk changed its direction. Personal risk started at 17.33 deaths per 100,000 population in the year 1972 and reached 29 deaths per 100,000 population in the year 1996.

When motorization rate $x_i > 363$

The second part of the model, when breakpoint dummy, x_k equals to one which fit the line after the breakpoint becomes the following:

$$\hat{y} = 17.170 + 0.026x_1 - 0.036\,(x_i - 363) \quad (4)$$

which can be solved and simplified into equation (5)

$$\hat{y} = 30.238 - 0.01x_1 \quad (5)$$

When the motorization rate lapsed 363 vehicles per 1,000 population, the slope changed to negative, where personal risk is expected to decrease by 0.01. At this point, the personal risk was at 29.77 deaths per 100,000 population.

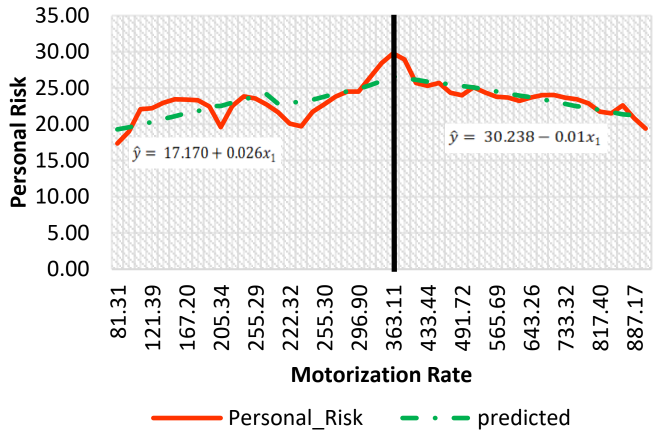

Figure 3: Plot of Personal Risk (Actual and Predicted)

Both the original and predicted trend of personal risk as a function of the motorization rate is presented in Figure 3. Two distinct trends were seen and a turning point was observed when the motorization rate was at 363 vehicles per 1,000 population. It is quite interesting to know what year it represented, as it showed changes in personal risk.

4. Discussion

A pattern of increasing personal risk until a point, when a structural bend is observed in the trend and a downward trend continues afterward were observed. Results showed that personal risk started at 17.33 deaths per 100,000 population, and continued with an increasing trend at the early series (1972-1996). The personal risk reached its peak when fatalities were at 29.77 death per 100,000 population. The plot of personal risk and motorization rate revealed that the turning point occurred when Malaysia had 363 vehicles per 1,000 population. The time when the turning point occurred is in the year 1996.

Yannis et al (Yannis et al., 2011) in analyzing macroscopic trends in road safety summarized the trends of road traffic fatalities in several EU countries. The Austrian and Belgian datasets are observed to have a peak (of more than 30 fatalities per 100,000 population) that occurred at about 230 and 245 vehicles per 1,000 population respectively. In the case of the Netherlands, the breakpoint was detected in the early 70s when the motorization rate was around 220. The secondary breakpoint was observed when the motorization rate reached a value of about 360, and respectively the personal risk was reduced to about 10 fatalities per 100,000 population. Greece on the other hand has a breakpoint at 325 vehicles per 1,000 inhabitants.

Piecewise regression also works for data that has several turning points. However, in this study, the author assumed that there is only one turning point in the personal risk series. Future works on detecting several turning points should be continued. The same methods could also be applied for detailed trend analysis for different road users and age groups.

One of the limitations of this kind of analysis is the availability of a long time series of data. For instance, the result presented in this study is based on a cumulated registered vehicle, collected and available since the establishment of the Road Transport Department. However, by using the cumulated registered vehicles, the statistics could contain all same vehicles from the year 1972 until now, and it might not represent the real motorization rate for the country. The authors suggest an extension of analysis using the number of active vehicles for better results.

5. Conclusion and Recommendations

Modeling personal risk as a function of the motorization rate in Malaysia revealed a few interesting findings. Personal risk or death per 100,000 population was calculated over time. On the same note, the motorization rate, calculated by dividing the number of cumulated registered vehicles per 1,000 population.

In this study, data from the year 1972 – 2018 is used. A plot of personal risk showed that the series is not linear, as it has its peak somewhere in the middle of the series. The trend of personal risk is increasing first, and then reached its peak and continue with a downward trend.

A statistical model based on segmented regression is developed. The statistical model showed that the motorization rate and the breakpoint dummy variables are both significant. The two variables explained 62% of the variation in personal risk. The model could be improved by adding more breakpoints dummy that represents changes in trend over time.

In conclusion, segmented regression used in modeling personal risk fits the data well. The presence of a turning point in the year 1996 might suggest that personal risk has reduced in the long term, which could imply an improvement in road safety in Malaysia. As the motorization rate continues to increase, personal risk has decreased from 29.77 deaths per 100,000 population in the year 1996 to 19.40 deaths per 100,000 in the year 2018. This might suggest that Malaysia road safety initiatives and interventions conducted are beneficial to the country.

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