Road fatalities in Brunei

by Mohammed Ohidul Haque, PhD (Sydney), Professor of Applied Statistics and Econometrics, International Institute of Business and Social Studies (IIBASS), 9 Collier Court, Burwood, Victoria 3125

Abstract

This paper investigates the pattern of road fatalities in Brunei. Road fatalities reached a peak in 1993 when 79 people died on the roads. Various road safety initiatives were then taken to reduce the road toll; this worked well and reduced road fatalities until 2003, when they began to increase. This implies that there has been a recent change in the pattern of road fatalities in Brunei. This has been verified by testing long-term and short-term regression coefficients. The coefficient of a policy variable, lax enforcement of traffic laws, indicates that road fatalities are increasing due to non-implementation of traffic laws, together with a larger number of young drivers and new vehicle registrations.

In recent years Brunei's road fatality rates have not been significantly different from those in Victoria (Australia), and they are significantly lower than in Malaysia and Singapore. Brunei can thus be considered a model for the trajectory of road safety in South-East Asian countries. There is further scope to reduce road fatalities if Brunei introduces and implements additional effective road safety strategies incorporating the Safe System approach to road safety, together with enforcing the existing road safety measures more strictly.

Keywords

Road fatalities, Lax enforcement of traffic laws, Young drivers, Statistical models, Trajectory of road safety, Brunei

Introduction

Brunei is a small country with a population of approximately 400,000. In 2008, there were 780 vehicles per 1000 population, which can be considered very high. Brunei has a good road network system, which has helped to achieve lower fatality rates since 1995 compared to other South-East Asian countries. It has taken various road safety initiatives, dating back to 1924, to reduce the road toll [1].

There are many factors responsible for road crashes, viz., humans, vehicles, roads, environments and a random factor [2]. Car crashes probably happen due to a bad alignment of these factors. Initially, this study reviews the literature discussing possible factors related to crash fatalities, and those factors for which data are available are then used to test the situation in Brunei.

Background literature

An increase in the number of vehicles on the roads has been shown to increase the number of crashes and fatalities (see La Torre et al. [3] and many others). In his seminal work in 1975, Peltzman [4] analysed road fatalities incorporating many variables, among which speed, alcohol, income, youth and trend are important. Many other studies that incorporated a large number of safety, socio-economic, environmental and other policy variables, such as Long [5], Shibata and Fukuda [6], and Shankar and Mannering [7], have been undertaken since then. Soderlund and Zwi [8] found that increasing population density was associated with a proportionately greater number of traffic deaths among the young and elderly. Ayvalik [9] and Nguyen and Nguyen [10] used trend variables and found that road fatalities decreased over time.

Loeb and Gilad [11] and Loeb [12] used policy and many other variables to analyse the causes of road fatalities, while Haque [13, 14], Wibowo [15] and others showed that drivers aged less than 25 years constitute the highest number of fatal crashes and deaths. Besides these, Joksch [16], Partyka [17], Wagenaar [18], Loeb [19] and Haque [13, 14] used macroeconomic variables such as employment and unemployment to explain road fatalities.

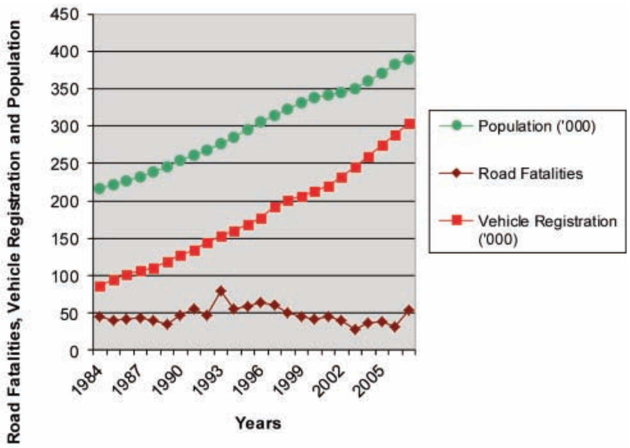
Smith [20] examined the effects of weather and climate on road crashes and inferred that wet days were associated with higher numbers of crashes. Owens and Sivak [21] showed that night-time fatality rates adjusted to mileage averaged three times higher than daytime rates. Jung et al. [22] analysed the effects of rainfall on single-vehicle crashes and found that rainfall intensity, wind speed, roadway terrain, driver's gender and safety belt usage were the most significant factors. Siddiqui et al. [23] investigated light conditions and pedestrian injuries and found that relative to dark conditions without street lighting, daylight reduces the odds of a fatal injury by 75% and 83% at mid-block locations and intersections, respectively.

Chang and Yeh [24] compared fatality risk factors between motorcyclists and non-motorcyclists and found that on average motorcyclists had approximately three times more fatality risk than non-motorcyclists after adjusting for driving mileage. Motorcycle fatalities are generally very high in most developing countries. For example, in 2008, 60% of Malaysia's total road fatalities were motorcyclists [25]. In fact it is a major challenge for most developing countries to reduce motorcyclists' fatalities. Besides these, there are many other studies on road fatalities, among which Dissanayake and Lu [26], O'Donnell and Connor [27] and Savolainen and Ghosh [28] can be mentioned.

Road crash trends in Brunei

To improve safety on public roads, road safety practitioners/researchers should collect appropriate road crash/casualty data, which is not an easy task. However, road fatality data collected by police is widely accepted in almost all countries in the world, although police fatality data are not immune from criticism. Collecting road fatality data is not a major problem, since most deaths occur on the spot or in hospitals, where data are accurately collected and recorded. The Royal Brunei Police Force collects road crash, fatality and other casualty data, which are reported in the *Brunei Darussalam statistical yearbook* [29]. This also provides other data, including various socio-economic, environmental and demographic data. All these data are used extensively for this study.

The patterns of road fatalities from 1984 (when Brunei became independent) to 2007 (when the latest completed road casualty data were available), together with population and vehicle registrations, are presented in Figure 1. It is clear that road fatalities have decreased since 1993, except in recent years, despite a significant increase in population and vehicle registration.



Source: Data compiled by Royal Brunei Police Force and taken from Brunei Darussalam statistical yearbook: 1996/97-2008 [29]

Figure 1. Road fatalities, vehicle registrations and population in Brunei: 1984-2007

Brunei undertook various road safety measures, and introduced and implemented many road safety initiatives, after road fatalities climbed to 79 (the highest ever in Brunei) in 1993. This was very high for a country that, at that time, had a population of 276,300. Brunei's road fatalities have decreased since 1993, except in recent years, as reflected by various media reports [30] and as can be seen from Figure 1.

Many important factors appear to have significantly reduced road fatalities in Brunei, among which are better road design and vehicle construction; medical advancement and improved medical facilities; better driving, education and road safety awareness among road users; and implementation of some effective road safety measures. Other factors, such as media publicity and road safety techniques such as clearly delineated road surface markings and road signage, have also helped to reduce fatalities. In Brunei, place names and directions are clearly written in each lane of the road at major intersections and roundabouts, so that drivers and riders can see them from a long distance and head towards their destination without difficulty.

Aims of this research

The main aim of this study was to investigate the change in the pattern of road fatalities in Brunei. More specifically, it investigated the following hypotheses:

- that the annual rate of road fatalities has decreased in Brunei since 1993
- that during recent years, lax enforcement of traffic laws is to blame for the rise in annual road fatalities
- that the proportion of road fatalities per vehicle in Brunei is similar to that of Victoria, Australia.

Brunei has achieved a lot in road safety and it can be considered a model for the trajectory of road safety in South-East Asian countries, which can be tested through the above hypotheses.

Brunei crash data - International comparisons

From 1995 to 2007, most countries experienced decreased road fatalities, even though the world saw a rapid increase in economic development and a greater number of cars. These decreased road fatalities were also observed in Brunei and surrounding countries in the region. Table 1 presents road fatalities per 10,000 vehicles in Australia, Brunei, Malaysia and Singapore. It shows that Brunei's road fatalities have reduced from 3.46 per 10,000 vehicles in 1995 to 1.78 in 2007.

Table 1. Road fatality rates per 10,000 vehicles for various countries: 1995 – 2007[a]

	Road fatalities per 10,000 vehicles			
Year	Countries			
	Australia	Brunei	Malaysia	Singapore
1995	1.5	3.46	8.4	3.59
1996	1.4	3.60	8.20	3.4
1997	1.21	3.18	7.37	3.8
1998	1.23	2.49	6.28	3.2
1999	1.18	2.18	5.83	2.9
2000	1.24	1.92	5.69	3.1
2001	1.34	2.04	5.17	2.7
2002	1.16	1.72	4.90	2.8
2003	0.94	1.14	4.90	3.0
2004	0.96	1.39	4.52	2.7
2005	0.95	1.38	4.18	2.3
2006	0.90	1.11	3.98	2.4
2007	0.87	1.78	3.70	2.6

[a]*Sources:*

Victorian (Australian) data are supplied by VicRoads [31]

Brunei data are compiled by the Royal Brunei Police Force and taken from the *Brunei Darussalam statistical yearbook*: 1996/97-2007 [29]

Malaysian data are taken from Global Road Safety Partnership (GRSP), 2005 [25]

Singapore data are from *Monthly digest of statistics Singapore*, May 2008, and *TP road traffic accidents in Singapore*, 2005 [32]

Table 2. Estimated percentages of types of vehicles registered in various countriesa

	Countries			
Road user Groups	**Australia 2004**	**Brunei 2004**	**Malaysia 2005**	**Singapore 2008**
Cars and car derivatives	79.0	92.0	43.6	64.0
Goods vehicles and buses	18.0	5.0	5.6	17.0
Motorcycles and scooters	3.0	3.0	47.8	16.0
Other vehicles	< 1.0	<1.0	3.0	3.0

[a]*Sources:*

Australian Bureau of Statistics, Survey of Motor Vehicles Use Cat. No. 9208.0; all trucks included [34]

Brunei data are taken from ADB – ASEAN report (2005) [35]. They are based on an average of 2002-04.

Malaysian figures are based on JKR, 2005 taken from Mohd. Erwan (2007); Road Safety Annual Report [33]

Singapore figures are based on *Monthly digest of statistics Singapore*, March 2010; Singapore Department of Statistics [32]

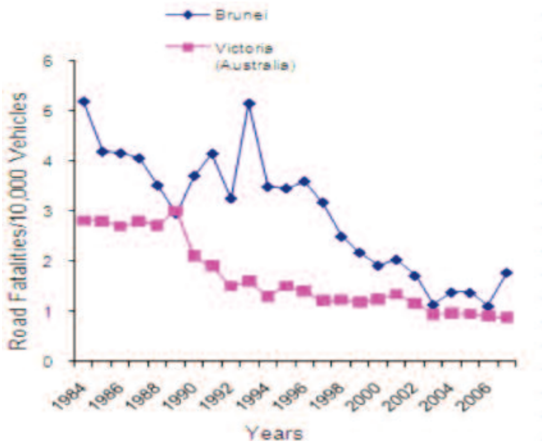
These figures are much lower than for Singapore and Malaysia. The difference between Brunei, and Malaysia and Singapore, could be due to differences in the vehicle mix. From Table 2, it can be seen that Malaysia and Singapore have 47.8% and 16.0% unprotected motorcycles and scooters on the road, respectively, compared to only 3.0% in both Australia and Brunei. As a result, there were 58% and 47.7% motorcyclist and pillion road fatalities in Malaysia and Singapore, compared to 15% and 11% in Australia and Brunei, respectively. Pedestrian and bicycle fatalities were highest in Singapore, compared to the very low number and percentage in Brunei, because most people in Brunei drive safer modern cars [31-35].

Victoria, a state in Australia, has a comparable vehicle-to-population ratio to Brunei, and it would be appropriate to compare road fatality rates between Victoria and Brunei rather than comparing Brunei with Singapore and Malaysia, both of which have lower vehicle-population ratios. Figure 2 presents the road fatality rates per 10,000 vehicles from 1984-2008, and it clearly shows that the road fatality rates in Brunei were always higher than in Victoria. A similar picture is observed for the fatality rates per 100,000 population. However, population proportion tests based on Z-statistic indicate that in recent years, these differences are not statistically significant.

Brunei crash data – Linear regression analysis

Many methods can be used to analyse road fatalities. For example, Xin Pei et al. [36] used a joint-probability model for analysing car crash prediction. Kim et al. [37] and Milton et al. [38] used the mixed logit models to analyse pedestrian injury and highway crash severities, respectively. Ma et al. [39] used a multivariate Poisson regression model for predicting crash counts, using Bayesian methods, and Malyshkina and Mannering [40] analysed crash-injury severities using Markov switching multinomial models. Besides these, Carlo et al. [41], Leveson [42], Anastasopoulos and Mannering [43] and others also used a number of techniques to analyse road crashes/fatalities.

However, because of data limitations in this study, we used the regression method. The regression model is good to identify the factors that are responsible for road fatalities and to test changes in road fatality patterns. Previously, many authors such as Haque [13, 14], Loeb [19], Partyka [17] and Evens and Graham [44] have used the regression method to analyse road fatalities.



[a]*Sources:*

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Victorian (Australian) data are supplied by VicRoads [31]

Figure 2. Road fatalities per 10,000 vehicles in Brunei and Victoria, Australia: 1984-2007[a]

Specification of the functional form is important to determine the factors that are responsible for road fatalities. There is no unique functional form that can satisfy all the desired properties. Therefore, options are given to the researchers to choose the functional form to analyse road fatalities. A linear function is often taken as a first approximation to a class of regular curve. Haque [13, 14], Loeb [19] and Partyka [17] all used linear functional form to investigate the relationship between road fatalities and various socio-economic variables, which were also used for this analysis.

Long-term road fatality analysis

In this study the Ordinary Least Square (OLS) method has been used to estimate a linear regression model. The number of road fatalities is used as the dependent variable, while the number of vehicles ('000), fuel sales for cars (proxy for travel exposure), total improved road length, total population ('000), people aged between 18 to 24 years, yearly number of rainy days, average number of bright hours per day, gross domestic product, number of employed and unemployed persons, number of new vehicles registered and a trend variable from 1993 to 2007 are used as independent variables to analyse road fatalities in Brunei. Justification for using these variables is given below.

From Figure 1, it is clear that both the population and the number of vehicles have increased in Brunei over time. It is expected that these will continue to rise with economic growth, which will increase the risk of crashes and fatalities, as indicated in the 2005 ADB-ASEAN report [35].

Another ADB-ASEAN report also pointed out that the numbers of young drivers are expected to rise in Brunei. It is estimated that in 2007, approximately 80% of the people aged between 18 to 24 years in Brunei held driving licenses [29, 45]. Furthermore, in 2008 their involvement in road fatalities was more than 41%, even though they represented less than 14% of the total population [29]. Hence, there is enough justification to investigate this group for the analysis. Fuel sale is used as a proxy for vehicle mileage travel, which is also expected to grow with the increase in population and number of vehicles. Rain is very frequent in Brunei and makes the roads hazardous in wet conditions, especially on highways. All of these factors can lead to an increase in road crashes and fatalities.

Brunei is developing faster than many developing countries; its per capita GDP is increasing at a rapid pace, and its economic condition is much better than in surrounding countries. Hence, road fatalities are likely to fall as GDP grows, due to the use of more modern and safer cars.

At present, Brunei has more improved road length, in the sense that many ill-maintained and unimproved one-way roads have been converted to two-way roads, additional two-way roads have been built, and many black spots and roadside obstacles have been eliminated. This is also expected to reduce road crashes and fatalities. In addition, lower unemployment numbers may lead to a higher number of road fatalities and vice versa (see Haque [13, 14], Loeb [19], Partyka [17]). A yearly trend variable is used to cover the combined effects of all the road safety measures implemented so far to reduce the road toll.

In addition to the above variables, we also investigated the effect of average bright hours per day on road fatalities in Brunei. Most of the days in Brunei are bright, but sometimes due to cloudiness or rain, the bright daylight hours are cut short. Hence, vehicles are more likely to be involved in crashes on those days with shorter hours of bright light. Obben [46] used some of these variables to analyse road casualties in Brunei.

To see the impact of non-implementation of traffic laws in recent years (2004-2007), a dummy variable was created: NITL = 1 (for 2004 to 2007) if traffic laws are not fully implemented and NITL = 0 (1993 – 2003) if traffic laws are fully implemented. From Figure 1, it is clear that road fatalities were decreasing from 1993 to 2003 when only 23 people died on the roads in Brunei. Road fatalities then began to increase from 2004 when 36 people died. This is the beginning of the recent increasing trend, which continues up to 2007 (most recent available fatality data).

Probably due to this change in trend, the Asian Development Bank (ADB) investigated the road safety situation in Brunei in 2004 and indicated that Brunei needed to: (i) review laws and compliance in the general population, (ii) improve law enforcement through more and better equipment and training, and (iii) monitor law compliance for drivers under the age of 25 years [35]. For this reason, 2004 was used as the beginning year of non-implementation of traffic rules for our study.

Figure 1 clearly shows that the data are non-stationary. To reconfirm this, the Augmented Dickey-Fuller (ADF) test was carried out, which shows that the data are non-stationary and therefore have unit root. The behaviour of the autocorrelation (ACF) also indicated that the data are non-stationary. To make the data series stationary we have differenced the data both at seasonal and non-seasonal levels before estimating the parameters of the model. Stationary data series means a stable (no ups and downs) data series, which is smooth and does not have high variations from previous observations. Stationary data are essential for accurate model estimation and prediction.

The SPSS computer software package was used to estimate various statistics and parameters of the model. The Durbin-Watson DW-statistic showed no problem of autocorrelation. The model was also tested for heteroscedasticity according to the procedure given in Glejser [47], and again no evidence of this problem was found. Multicollinearity was highly pronounced among some independent variables for the original observations. In order to avoid this problem, we re-ran the regression after withdrawing some variables that were related to each other.

We then selected only the following important variables, and the final long-term estimated regression coefficients (both standardised and un-standardised) for road fatalities in Brunei are presented in Table 3. The p-values of the different estimated parameters of the model are given in the last column. Unstandardised estimated regression coefficients are generally reported instead of standardised coefficients, because a change in standard deviation in one variable can make similar change in other predictors. However, it removes the 'scale of unit' and allows ordering the importance of various independent variables, which are included in the model.

The summary statistics indicate that the model explains road fatalities very well. The F-statistic shows that there exists a very high significant association between road fatalities and all the independent variables considered in our model, except Vehicles and Rainy Days. The coefficient of determination, adj-R^2 = 0.908 which is very high, indicates that the fit of the model is very good.

Table 3. Estimates of multiple regression coefficients

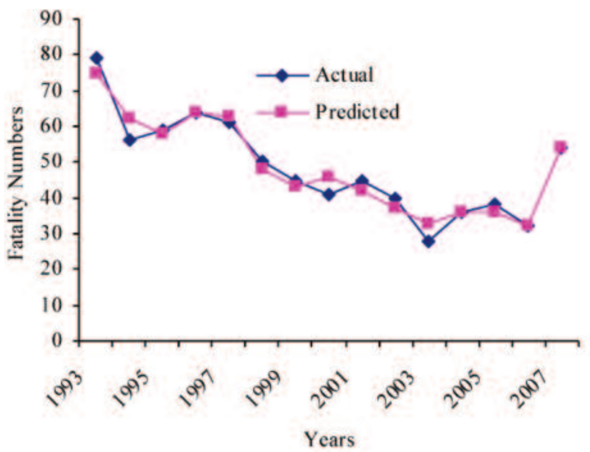
Independent variables	Unstandardised coefficients	Standardised coefficients	p-values
Constant	-72.468	-	0.001
Trend	12.580	9.45	0.000
Age 18-24 Years	6.781	4.03	0.001
New Vehicles Registered	1.544	0.98	0.035
NITL	2.010	1.07	0.047
Unemployment	-0.180	-0.145	0.050
Vehicles	2.054	1.85	0.570
Rainy Days	0.021	0.018	0.720
$F_{6,8}$ = 20.190; DW-statistics = 2.72 and Adj-R^2 = 0.908			

Source: Data compiled by Royal Brunei Police Force and taken from *Brunei Darussalam statistical yearbook*: 1996/97 – 2007 [29]

Plots of residuals against time showed that all important variables are taken care of in the model. This implies that not many separate additional factors would contribute in reducing road toll. Hence, a package of road safety measures is suggested for implementation to further reduce road fatalities in Brunei. The coefficients of all the independent variables of the estimated model have expected signs, and their interpretations are given below.

- **– 12.580 Trend** means that there will be a significant reduction of 12.58 road fatalities every year due to the introduction of a number of road safety laws, police initiatives, better road and motor vehicle design and construction, medical advances and better medical facilities for road victims, and public road safety awareness and care in driving vehicles, provided other factors remain constant.
- **+ 6.781 Age 18-24 Years ('000)** means that there would be a significant expected 6.781 more road fatalities if there were an increase of 1000 people aged 18-24 years in Brunei. From vital statistics it is observed that there is an annual increase of approximately 1500 people aged between 18 to 24 years, indicating that every year Brunei would expect 6.781 x 1.5 = 10.17 additional road fatalities due to the increase in the number of young people, which is observed from the normal expected behaviour (not by a chance factor) of the young people as road users, if other factors remain constant.
- **+ 1.544 New Vehicles Registered ('000)** means that there would be a significant expected 1.544 more road fatalities for an increase of 1000 new vehicles registered in Brunei, if other factors remain constant. At present, there is an average yearly increase of 15,000 new registered vehicles in Brunei, which can increase 1.544 x 15 = 23 more road fatalities per year due to new vehicles registered.
- **+ 2.010 NITL** means that there was a significant increase of 2.01 more fatalities in each year from 2004 to 2007 due to non-implementation, compared to full implementation, of traffic laws in Brunei if other factors remain constant.
- **– 0.180 Unemployed ('000)** means that there would be a significant expected 0.18 fewer road fatalities if there were 1000 more unemployed people in Brunei, provided other factors remain constant. Currently, the unemployment number is quite stable in Brunei and hence the number of road fatalities is not expected to change due to the unemployment factor.
- **+ 2.054 Vehicles ('0000)** means that there would be an insignificant increase of 2.054 road fatalities for an increase of 10,000 more vehicles on roads in Brunei.
- **+ 0.021 Rainy Days** means that there would be an insignificant expected increase of 0.02109 more road fatalities, if there were one more rainy day in a year in Brunei, provided other factors remain constant.

We then checked the robustness of our results, meaning whether the estimated parameters of our model differ significantly due to a small change in our data series. This has been examined by re-running a regression without the observations of 1993 and 1994. The results obtained from this new regression were not significantly different from the results of our estimated regression model, presented in Table 3. This shows that our results presented in Table 3 are fairly robust. On the whole, there is good agreement between the actual and fitted road fatality numbers, which can also be seen from Figure 3.



Source: Data compiled by Royal Brunei Police Force and taken from *Brunei Darussalam statistical yearbook*: 1996/97 – 2007 [29]

Figure 3. Long-term road fatality model for Brunei: 1993-2007

Short-term road fatality analysis

A short-term model was then considered to see the recent pattern of road fatalities in Brunei. This is because recent variation in the number of road fatalities can be better understood by incorporating all the current events, including road safety activities. Recent monthly data can be used to show the current pattern of road fatalities. Here we used monthly road fatality data available from January 2007 to July 2008 as a dependent variable, and the number of vehicles and trend as independent variables. In order to avoid seasonality, which is common in monthly road fatality data due to a number of identified factors (traffic volumes for a certain month, weather, darkness, etc.) and unidentified factors, we smoothed the monthly data by a moving average method using 12 points.

The same OLS method was used to estimate the parameters for the short-term linear regression model. Significant variables of the final estimated model are presented below with t-values given in parentheses.

$$\textbf{Fatalities} = \underset{(4.28)}{\mathbf{22.315}} + \underset{(3.72)}{\mathbf{0.710}}\ \textbf{Vehicles ('000)} + \underset{(5.23)}{\mathbf{0.163}}\ \textbf{Trend}$$

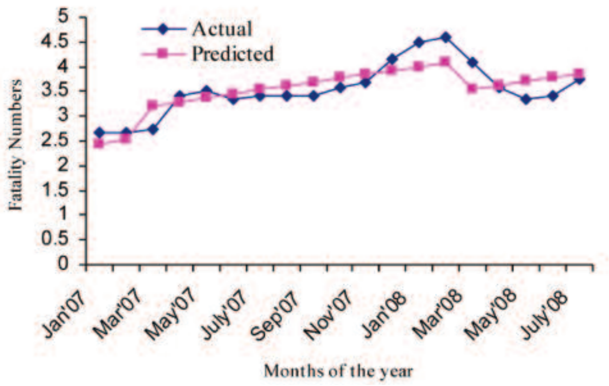
$F_{2, 16} = 16.60$; Adj-$R^2 = 0.668$; DW-statistic = 1.50

The above estimated short-term model shows that the regression coefficient of the Vehicles variable has an expected positive sign, but the regression coefficient for the Trend variable has a positive rather than a negative sign, which was observed earlier in the long-term model (Table 3). This shows that a change of pattern of road fatalities occurred in Brunei from 2004. The summary statistics indicate that, overall, the short-term model fits well for our data, which can also be seen from Figure 4. The interpretations of the estimated regression coefficients of the short-term model can be explained in a similar way to the long-term model and are provided below.

- **+ 0.710 Vehicles (‘000)** means that there would be a significant monthly average increase of 0.710 road fatalities for an additional monthly increase of 1000 vehicles in Brunei, provided other factors remain constant. Currently, on average, 1200 vehicles per month are added to the roads and hence 0.71 x 12 = 8.5 more fatalities are expected per year due to the Vehicles factor, which is higher than the long-term yearly figure observed from Table 3.
- **+ 0.163 Trend** means that there would be a significant monthly average increase of 0.16 fatalities, indicating that there is an upward trend of fatalities in recent months provided other factors remain constant, which is consistent with media reports (see the *Brunei Times*, 9 January, 6 and 27 February, and 16 March 2009 [30]).

This is in contrast to the long-term road fatality model (Table 3), which showed a negative coefficient for the Trend variable. This means that road fatalities have increased in recent months in Brunei, confirming that there is a change in the pattern of road fatalities in Brunei; a decreasing road fatality trend has now changed to an increasing trend, probably due to non-implementation of traffic laws, which can also be seen from the positive coefficient of the NITL variable (Table 3).

It is confirmed from recent media reports that road crash fatalities have increased in recent years and months. The Brunei government should now make sure that all traffic laws are fully implemented, in order to return the recently increasing trend to the more normal long-term decreasing trend, so that Brunei continues to have lower numbers and rates of road fatalities in future years.



Source: Data compiled by Royal Brunei Police Force and taken from *Brunei Darussalam statistical yearbook*: 1996/97 – 2007 [29]

Figure 4. Short-term road fatalities with seasonally adjusted monthly data: January 2007 - July 2008

Discussion

It can be seen from this study that road fatalities have reduced significantly in Brunei since 1993, except in recent years, even though the numbers of people and vehicles have increased significantly during this period. However, when we compare road fatality rates per 10,000 vehicles in Brunei and Australia (Figure 2), it is clear that Brunei’s road fatality rate was consistently higher than Australia’s. This indicates that there is significant scope to reduce road fatalities in Brunei. To make a significant improvement in road safety, we must first identify the causes of road fatalities. Most road crashes happen due to multiple causes (see Treat et al. [48], Rumar [49], Harry and Reagan [50] and others).

Rumar [49] used American and British crash reports as data and found that 57% of crashes were due solely to the driver factor, 27% to combined roadway and driver factors, 6% to vehicle and driver factors, 3% solely to roadway factors, 3% to combined roadway, driver and vehicle factors, 2% solely to vehicle factors, and 1% to combined roadway and vehicle factors. Analysing these reports he found that driver error, intoxication and other human factors contribute wholly or partially to about 93% of crashes, which is consistent with the earlier finding of Treat et al. [48].

Therefore, to achieve a significant reduction in road fatalities, Brunei should now adopt the new Safe System approach to road safety, which emerged initially from the Netherlands' Sustainable Safety Approach in the 1990s and later resurfaced from Sweden's Vision Zero road fatalities (see National Road Safety Council [51] and Langford [52]). Subsequently, this new Safe System approach to road safety has been adopted by many countries around the world (see Langford [52], Peden et al. [53] and International Transport Forum [54, 55]).

The new Safe System approach to road safety aims to avoid deaths and serious injuries by reducing crash forces. It advocates that crash forces remain below a threshold level, so that they cannot cause any serious injuries to the human body in the event of road crashes. It allows for human error, irrespective of the level of education and compliance in obeying traffic laws, rather than blaming the road users for crashes.

This Safe System approach deals with road and vehicle designs and travel speed; it recognises that there will always be some crashes, but it tries to avoid deaths and serious injuries by reducing crash forces to a level that the human body can tolerate without any serious injuries. The main goal of the Safe System approach is to eliminate deaths and injuries by allowing for human error, lowering crash forces to those that the human body can tolerate and minimising unsafe road user behaviour. It is a shared responsibility among road and vehicle designers and users at local, regional and national levels.

In this respect, it promotes a comprehensive approach to road safety that involves identifying the interactions between the road user, the vehicle and the road environment, i.e., the potential areas of intervention. This approach recognises that the human body is highly vulnerable to injury and that humans make mistakes. A safe road traffic system is therefore one that accommodates and compensates for human vulnerability and fallibility, which is shown diagrammatically in WHO's [56] *Global status report on road safety*.

Brunei could reduce road fatalities further by adopting this new Safe System approach to road safety, and could make a successful road safety strategy more effective by introducing and implementing the following important road safety initiatives:

- setting appropriate safety speed limits and monitoring and punishing offenders
- setting lower speed limits near schools, colleges, and shopping and community centres
- using movable speed cameras for detecting driving speeds at different locations
- legislating and enforcing lower driving speeds at night and during darker hours, particularly for young drivers
- adopting and implementing laws related to drugs, alcohol, etc.
- adopting and implementing laws related to fatigue
- using red light cameras for the detection of light violation offenders
- introducing a demerit point system to deter traffic offences
- educating traffic offenders who accumulate certain demerit points
- making and maintaining better roads and vehicles for safe driving
- developing a better public transport system to reduce car use.

Conclusions and limitations

In this study we investigated road fatalities in Brunei and found that road fatalities have significantly declined since 1993 (the worst road safety year), even though the population and the number of vehicles have increased manyfold. Thus, Brunei has achieved an impressive record of road safety during the last couple of decades. Furthermore, the study shows that Brunei has the lowest fatality rate per 10,000 vehicles compared to Malaysia and Singapore, and possibly to most South-East Asian countries.

However, when we compared road fatality rates with Australia, we found that Brunei's road fatality rate was consistently higher, even though not that significant from 2004 to 2007. Therefore, Brunei can be seen as the trajectory of road safety in South-East Asian countries. We believe that there is scope to reduce road fatalities in Brunei, similarly to Australia, if Brunei were to introduce and implement some of Australia's successful road safety strategies [57] and adopt the new Safe System approach to road safety.

On the whole, this study has attempted to underpin the causes of road fatalities in Brunei. It introduced a number of road safety, socio-economic, environmental and demographic variables and inferred that young drivers (80% of people aged between 18-24 years have driving licenses in Brunei), new vehicle registration and non-implementation of traffic laws are the main causes of road fatalities in Brunei.

The model developed can measure the effects of various factors on road fatalities, which can assist policy makers to take necessary actions in order to reduce road fatalities. It can also forecast the road fatalities for future years based on predicted changes in the economy, various road safety measures, and socio-demographic and environmental factors.

This is the most comprehensive study of the kind yet attempted to analyse road fatalities in Brunei. Thus, it can help policy makers to take necessary decisions on how to use limited funds to achieve the maximum benefit for the community. Generalisation of our model is straightforward, and many explanatory variables can be incorporated to explain road fatalities without any difficulties. It is recommended that this type of statistical model should be used to analyse road fatalities in other countries.

There are several limitations for our study. First, most data are taken from the *Brunei Darussalam statistical yearbook* [29], which may be subject to criticism, because these data are compiled for general use. Second, a general Box-Cox type function should be tried to predict road fatality numbers more accurately in Brunei. Due to unavailability of longer monthly data for a number of important variables, we used only Vehicles and Trend as independent variables for our short-term model; these are neither enough nor complete. Thus, our short-term results may be subject to criticism, but are still good enough to show the start of an increasing road fatality pattern from the beginning of 2004, following a downward trend.

The present analyses also did not consider road fatalities for specific road user groups, viz., pedestrians, motorcyclists, bicyclists and novice drivers, who face different risks of death on the roads. For that reason the new Safe System approach, which allows for human error and tries to avoid death and serious casualties due to road crashes, should be adopted by Brunei. This is because many countries have made significant improvement in road safety by adopting the Safe System approach. More details on the Safe System approach can be found in WHO's [56] *Global status report on road safety*.

It is thus recommended that Brunei should adopt the new Safe System approach to road safety, which builds on the existing road safety system, but adopts a new approach in managing the entire road safety system with shared responsibilities by road and vehicle designers and road users. Thus, all people living in Brunei should share overall responsibilities and accountabilities for road safety, and should aim to achieve zero road fatalities in future years.

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References

1. National Road Safety. Enactment No. 12 of 1954. Brunei: Department of Land Transport, 1954.
2. Haight FA. Problems in estimating comparative costs of safety and mobility. Journal of Transport Economics and Policy 1994; 28:7-30.
3. La Torre G, Beeck EV, Quaranta G, Mannocci A, Ricciardi W. Determinants of within-country variation in traffic accident mortality in Italy: A geographical analysis. International Journal of Health Geographics 2007; 6: 49.
4. Peltzman S. The effects of automobile safety regulations. Journal of Political Economy 1975; 83:677-725.
5. Long J. Regression models for categorical and limited dependent variables. Thousand Oaks, CA: Sage Publications, 1997.
6. Shibata A, Fukuda K. Risk factors of fatality in motor vehicle traffic accidents. Accident Analysis and Prevention 1994; 26:391-97.
7. Shankar V, Mannering F. An exploratory multinomial logit analysis of single-vehicle motorcycle accident severity. Journal of Safety Research 1996; 27:183-94.
8. Soderlund N, Zwi AB. Traffic-related mortality in industrialized and less developed countries. Bulletin of the World Health Organisation 1995; 73:175-82.
9. Ayvalik C. Determinants of motor vehicle fatalities and fatality rates: Some preliminary findings for Illinois. Ankara: Gazi University, 2002. Viewed 17 February 2011. http://www.trafik.gov.tr/icerik/bildiriler/c5-44.pdf.
10. Nguyen DT, Nguyen A. Toward a macroscopic model of road fatalities in Queensland. Nathan: Griffith University, 2008. Viewed 19 February 2011. http://www98.griffith.edu.au/dspace/bitstream/10072/24868/1/54425_1.pdf
11. Loeb PD, Gilad B. The efficacy and cost effectiveness of motor vehicle inspection: A state specific analysis using time series data. Journal of Transport Economics and Policy 1984; 18:145-164.
12. Loeb PD. The efficacy and cost effectiveness of motor vehicle inspection using cross sectional data: An econometric analysis. Southern Economic Journal 1985; 52:500 09.
13. Haque MO. Road safety: Data collection, analysis, monitoring and countermeasure evaluations with cases. New York: University Press of America, 2009.
14. Haque MO. Unemployment and road fatalities. International Journal of Transport Economics 1993; 20:175-95.
15. Wibowo K. The facts of young drivers' highway accidents and fatalities in the United States. Centre for Economics and Development Studies Working Paper No. 199901. Bandung, Indonesia: Padjadjaran University, 1999.
16. Joksch HC. The relation between motor vehicle accident deaths and economic activity. Accident Analysis and Prevention 1984; 16:207-10.
17. Partyka SC. Simple models of fatality trends using employment and population data. Accident Analysis and Prevention 1984; 16:211-22.
18. Wagenaar AC. Effects of macroeconomic conditions on the incidence of motor vehicle accidents. Accident Analysis and Prevention 1984; 16:191-205.
19. Loeb PD. The determinants of automobile fatalities: with special consideration of policy variables. Journal of Transport Economics and Policy 1987; 21:279-87.
20. Smith K. How seasonal and weather conditions influence road accidents in Glasgow. Scottish Geographical Journal 1982; 98:103-14.
21. Owens DA, Sivak, M. Differentiation of visibility and alcohol as contributors to twilight road fatalities. Human Factors 1996; 38:680-89.
22. Jung S, Qin X, Noyce D. Rainfall effects on single-vehicle crash severities using polychotomous response models. Accident Analysis and Prevention 2010; 42:213-24.
23. Siddiqui N, Chu X, Guttenplan M. Crossing locations, light conditions and pedestrian injury severity. Transportation Research Record 2006; 1982:141-49.
24. Chang H, Yeh T. Risk factors to driver fatalities in single vehicle crashes: Comparisons between non-motorcycle drivers and motorcyclists. Journal of Transportation Engineering 2006; 132:227-36.
25. International Cooperative Research Activity (ICRA). Inter-regional valuation of road casualties and exploration of social attitudes of road casualty reduction in Southeast Asian Countries, Thailand, Malaysia and Indonesia. Kuala Lumpur: East Asia Society for Transportation Studies, 2008. Viewed 19 February 2011. http://www.easts.info/activities/icra/2007/ICRA-2007-Dilun.pdf.
26. Dissanayake S, Lu J. Analysis of severity of young driver crashes – Sequential binary logistic regression modelling. Transportation Research Record 2002; 1784:108-114.
27. O'Donnell C, Connor D. Predicting the severity of motor vehicle accident injuries using models of ordered multiple choice. Accident Analysis and Prevention 1996; 28:739-53.
28. Savolainen P, Ghosh I. Probabilistic models of motorcyclists' injury severities in single- and multi-vehicle crashes. Accident Analysis and Prevention 2008; 39:955-63.
29. Brunei Darussalam statistical yearbook. Economic Planning and Development (JPKE), Prime Minister's Office. Brunei: Department of Statistics.
30. Brunei Times. August 2008 – May 2009.
31. VicRoads. Victorian road accident data base. Kew: VicRoads, 2008
32. Monthly digest of statistics Singapore. TP road traffic accidents in Singapore. Singapore: Traffic Police Department, 2008.

33. Erwan M. Development of unsignalised intersection analysis procedure for the Malaysian highway capacity manual. Master thesis. Kuala Lumpur, Malaysia: University of Science and Technology, 2007.
34. Australian Bureau of Statistics. Survey of motor vehicles use, Australia: 12 months ended 31 October 2007, Cat. No. 9208.0. Canberra: Australian Bureau of Statistics, 2007.
35. ADB-ASEAN Regional Road Safety Program. National road safety action plan in Brunei Darussalam. Manila: Asian Development Bank, 2005.
36. Xin P, Wong SC, Sze NN. A joint-probability approach to crash prediction models. Accident Analysis and Prevention 2011; in press, available online 11 January 2011; Journal homepage: www.elsevier.com/locate/aap
37. Kim JK, Ulfarsson G, Shankar V, Mannering F. A note on modelling pedestrian injury severity in motor vehicle crashes with the mixed logit model. Accident Analysis and Prevention 2010; 42:1751-58.
38. Milton J, Shankar V, Mannering, F. Highway accident severities and the mixed logit model: An exploratory empirical analysis. Accident analysis and Prevention 2008; 40:260-66.
39. Ma J, Kockelman KM, Damien P. A multivariate Poisson-regression model for prediction of crash counts by severity, using Bayesian methods. Accident Analysis and Prevention 2008; 40:964-75.
40. Malyshkina N, Mannering F. Markov switching multinomial model: An application to accident-injury severities. Accident Analysis and Prevention 2009; 41:829-38.
41. Carlo GP, Victoria G, Shlomo B. Mapping patterns of pedestrian fatal accidents in Israel. Accident Analysis and Prevention 2011, in press, available online 8 January 2011; Journal homepage: www.elsevier.com/locate/aap
42. Leveson N. A new accident model for engineering safer systems. Safety Science 2004; 42: 247-70.
43. Anastasopoulos PC, Mannering F. An empirical assessment of fixed and random parameter logit models using crash- and non-crash-specific injury data. Accident Analysis and Prevention 2011; in press, available online 8 January 2011; Journal homepage: www.elsevier.com/locate/aap
44. Evens W, Graham JD. Traffic safety and business cycle. Alcohol, Drugs and Driving 1988; 4:31-38.
45. ADB-ASEAN Regional Road Safety Program. National road safety action plan (2005 – 2010) AP1 Road Safety Action Plan in Brunei Darussalam. National Road Safety Council of Brunei Darussalam. Manila: Asian Development Bank, 2004.
46. Obben J. Towards the explanation and abatement of road casualties in Brunei – A contribution from the toolkit of economists. Tinjauan 1998; 2:39-59.
47. Glejser H. A new test for heteroscedasticity. Journal of the American Statistical Association 1969; 64:316-23.
48. Treat JR, Tumbas NS, McDonald ST, Shinar D, Hume RD, Stangifar RL, Castellan NJ. Causal factor tabulation and assessments: DOT HS-805 085. Institute for Research in Public Safety, Indiana University, 1977.
49. Rumar K. The value of perceptual and cognitive filters in observed behaviour: In Evans L, Schwing RC. (eds.). Human behaviour and traffic safety; London: Plenum, 1985.
50. Harry L, Reagan JA. Interactive highways design model: Accident predictive module. Public Roads 1995. 59(2).
51. National Road Safety Council. Road safety fact sheet NRSC2, Safe System approach. Perth: C-MARC, 2010. Viewed 14 February 2011. http://nrsc.atcouncil.gov.au/Files/NRSC2safe_system.pdf.
52. Langford J. C-MARC Fact Sheet No. 1 Towards Zero: Understanding a Safe System approach to road safety. Perth: C_MARC, 2009. Viewed 19 February 2011. http://C_Marc.curtin.edu.au/local/docs/CMARC%20Fact%20Sheet%201%20Towards%20Zero.pdf.
53. Peden M, Scurfield R, Sleet D, Mohan D, Hyder AA, Jarawan E. (eds.). World report on road traffic injury prevention. Geneva: World Health Organization, 2004.
54. International Transport Forum. Towards Zero: Ambitious road safety targets and the Safe System approach. Geneva: OECD, 2008.
55. International Transport Forum. IRTAD road safety 2009 annual report. Geneva: International Traffic Safety Data and Analysis Group (OECD), 2009.
56. WHO. Global status report on road safety: Time for action. Geneva: Department of Violence & Injury Prevention & Disability (VIP) - World Health Organization, 2009. Viewed 12 February 2011. www.who.int/violence_injury_prevention
57. Australian Transport Council. National road safety action plan 2005 to 2006. Canberra: Australian Transport Council, 2004. Viewed 19 February 2011. http://www.atcouncil.gov.au/documents/files /ACTION_PLAN_05_06.pdf

Understanding speeding in school zones in Malaysia and Australia using an extended Theory of Planned Behaviour: The potential role of mindfulness

by S. Abdul Hanan, M.J. King and I.M. Lewis, Centre for Accident Research and Road Safety- Queensland (CARRS-Q), Queensland University of Technology

Email: suhaila.abdulhanan@qut.edu.au

Abstract

Speeding in school zones is a problem in both Malaysia and Australia. While there are differences between the countries in terms of school zone treatments and more generally, these differences do not explain why people choose to speed in school zones. Because speeding is usually an intentional behaviour, the Theory of Planned Behaviour (TPB) has been used to understand speeding and develop interventions; however, it has limitations that can be addressed by extending the model to incorporate other constructs. One promising construct is mindfulness, which can improve the explanatory value of the TPB by taking into account unintentional speeding attributable to a lack of focus on important elements of the driving environment. We explain what mindfulness is (and is not), how it can assist in providing a better understanding of speeding in school zones, and how it can contribute to the development of