EPIDEMIOLOGICAL PATTERNS OF TRANSPORT ACCIDENT MORTALITY IN THAILAND

Nuntaporn Klinjun[1,2], Apiradee Lim[1] and Kanitta Bundhamcharoen[3]

[1]Department of Mathematics and Computer Science, Faculty of Science and Technology, Prince of Songkla University, Pattani Campus, Pattani; [2]Office of Disease Prevention and Control 12, Songkhla; [3]International Health Policy Program, Ministry of Public Health, Nonthaburi, Thailand

Abstract. This study aimed to explore patterns of transport accident mortality in Thailand between 2004 and 2009. Vital Registration (VR) data were obtained from the Thai Ministry of Public Health and corrected causes of death were derived from Verbal Autopsy (VA) data collected in 2005. A total of 136,164 deaths were analyzed. Poisson regression was used for identifying mortality patterns with respect to gender-age groups and province-year groups. Regression coefficients were used to classify mortality trends for the 76 provinces. The estimated number of transport accident deaths was 2.2 times higher than VR records. The mean estimated transport accident mortality rate was 34.5 per 100,000 population. The estimated transport accident mortality rates were highest among males aged 20-29 years and in the central region, lower northern region and Nakhon Ratchasima Province in the northeastern region. The patterns of transport accident mortality rates were separated into nine groups. Increasing trends were found in three provinces in the northern region, four provinces in the central and eastern regions and five provinces in the southern region. Nine models developed for these nine groups may be helpful for estimating future transport accident mortality rates in Thailand and developing appropriate responses.

Keywords: transport accidents, mortality rate, epidemiology, poisson regression, Thailand

INTRODUCTION

Transport accident deaths, especially road traffic accident deaths, have long been recognized as a major public health problem causing a substantial burdens to health care systems globally and especially in low-income and middle-income countries (WHO, 2007, 2009, 2013). These accidents have a direct impact on human physical and mental health, quality of life and property. They can have a substantial impact on both household income and the national economy, including loss of productivity, expenses for prolonged medical care and rehabilitation costs or funeral (Nantulya and Reich, 2003). A survey in 2011 of 182 countries reported that road traffic mortality rates in middle-income and low-income countries were 20.1 and 18.3 per 100,000 population, respectively,

Correspondence: Apiradee Lim, Department of Mathematics and Computer Science, Faculty of Science and Technology, Prince of Songkla University, Pattani Campus, Pattani 94000, Thailand.
Tel: +66 (0) 73 331303; Fax: +66 (0) 73 335130
E-mail: api_45@hotmail.com

but only 8.7 per 100,000 population in high-income countries (WHO, 2013). Evidence from many high-income countries shows that road traffic mortality and morbidity are preventable and trends can be reduced (WHO, 2013).

Thailand is classified as a middle income country in Southeast Asia (WHO, 2013). A 2011 survey of 182 countries reported that Thailand had the third highest road traffic accident mortality burden and the highest of the 11 countries in Southeast Asia with a rate of 38.1 per 100,000 population (WHO, 2013). In 2010, 74% of these road accident deaths involved riders of motorized 2-or 3-wheel vehicles (WHO, 2013). A study of traffic accident costs in Thailand for 2004 estimated the economic loss due to traffic accidents was THB 204,050 million (approximately USD 5,101 million) or between THB 3.9 and 4.7 million per fatality (Department of Highways and Faculty of Engineering, 2007). At present, Thailand has a substantial road traffic accident burden. However, since 2003 various concerned agencies have begun efforts to address these problems (Tanaboriboon and Satiennam, 2005).

In order for Thai agencies to take effective and efficient action to aleviate this transport accident burden accurate epidemiological information on patterns and trends is essentially. At present Thai vital registration (VR) has good coverage capturing about 95% of deaths in the country since the mid-1990s (Prasartkul and Vapattanawong, 2006). Cause of death recording, however, is of low value for health planning as ill-defined deaths comprise up to 40% of deaths reported. To address this problem an ongoing process of verbal autopsy (VA) and other investigative techniques have been carried out by the Thai Ministry of Public Health and other collaborators to obtain more accurate estimates of causes of death in Thailand (Pattaraarchachai *et al*, 2010; Polprasert *et al*, 2010; Porapakkham *et al*, 2010; Rao *et al*, 2010; Klinjun *et al*, 2015). This study together with a previous analysis by the same researchers (Klinjun *et al*, 2015) uses the results of these investigations.

Consequently, this study aimed to explore patterns of transport accident mortality rates in Thailand between 2004 and 2009 and assess severity levels and trends in transport accident mortality rates for each province.

MATERIALS AND METHODS

Data sources and management

The two main data sources used in this study were the estimated number of transport accident deaths in Thailand between 2004 and 2009, and population denominators. Transport accident death estimates were derived from Thai VR records, which were then adjusted to reduce the proportion of ill and wrongly defined causes of death using VA. The methods for this adjustment process have been reported elsewhere (Klinjun *et al*, 2015).

The estimated number of transport accident deaths in Thailand from 2004 to 2009 was then separated by gender-age groups and province-year groups. Genders were combined with age groups to produce 16 gender-age groups (two genders each with eight age groups). Provinces of residence were combined with years to produce 456 province-year groups (76 provinces each for the six years studied).

The population denominators separated by gender, age group, year and province were obtained from the 2000 population and housing census by the

National Statistical Office, Ministry of Information and Communication Technology, Thailand.

Transport accident deaths were defined according to the International Statistical Classification of Diseases and Related Health Problems (ICD-10) categories V01 to V99 (WHO, 2004).

Statistical methods

We used a statistical model fitted to the estimated transport accident mortality rates in Thailand for gender-age groups and province-year groups from 2004 to 2009. The model is a simple generalized linear model based on the Poisson distribution as follows:

$$\log(\lambda_{jt}/P_{jt}) = \mu + \beta_j + \gamma_t \qquad \text{..... (1)}$$

For this model, λ_{jt} is the mean of the Poisson distribution giving the estimated number of transport accident deaths for the gender-age group (j) (j=1, 2,…, 16) and province-year (t) (t=102004, 112004,…, 962009). P_{jt} is the corresponding population at risk in 100,000s and the terms β_j and γ_t represent the gender-age group and province-year, respectively. μ is a constant encapsulating the overall incidence. The model thus has 7,296 cells (16 x 456) corresponding to 16 gender-age groups combinations and 456 province-year groups.

The estimated transport accident mortality rates were then classified into three groups according to the Poisson coefficients (*ie*, high, medium, low). The coefficients of the province-year determinant for each province from the Poisson model were calculated to analyze trends in transport accident mortality.

Then, a simple linear regression model was used for fitting the association between the coefficients of the province-year determinant and years in each province as follows:

$$y = a + bx \qquad \text{..... (2)}$$

Where y is the coefficient of the province-year determinant for each province, a is the intercept, b is the slope or regression coefficient and x is year from 2004 to 2009.

We grouped transport accident mortality rates for each province using the slope of the simple linear regression models into nine groups. We used corresponding colors: (1) red, (2) brown, (3) blue, (4) pink, (5) chocolate, (6) yellow, (7) cyan, (8) green and (9) orange to show the provinces with (1) high mortality rate and a rapid decreasing trend, (2) high mortality rate and slowly decreasing trend, (3) high mortality rate and slow increasing trend, (4) medium mortality rate and rapidly decreasing trend, (5) medium mortality rate and slow decreasing trend, (6) low mortality rate and unchanging trend, (7) low mortality rate and rapidly decreasing trend, (8) low mortality rate and rapidly increasing trend and (9) low mortality rate and slowly decreasing trend. The nine groups were fitted to the transport accident mortality rates with the Poisson regression model. For each group, the model was formulated as follows:

$$\log(\lambda_{jt}/P_{jt}) = \mu + \beta_j + \gamma_t \qquad \text{..... (3)}$$

Here λ_{jt} is the mean of the Poisson distribution giving the estimated number of transport accident deaths per 100,000 population (P_{jt}) for gender-age group (j) (j=1, 2,…, 16) and year (t) (t=2004, 2005,…, 2009). The model thus has 96 cells (16 x 6) corresponding to 16 gender-age group combinations for the 6 years of the study.

Using sum contrasts (Venables and Ripley, 2002; Tongkumchum and McNeil, 2009), we obtained adjusted mortality rates and corresponding confidence intervals for comparing them with the overall mean.

Table 1
Transport accident deaths and transport accident mortality rates by year.

Year	Estimated population (All ages)	Reported total deaths	Transport accident		
			Reported deaths (VR)	Estimated deaths (VA)	Estimated mortality rate
2004	64,533,735	366,712	10,969	22,644	35.1
2005	65,101,369	393,354	10,914	23,689	36.4
2006	65,574,251	389,583	10,393	23,462	35.8
2007	66,041,268	393,116	10,051	22,637	34.3
2008	66,481,676	397,256	9,707	21,958	33.0
2009	66,902,853	393,877	9,499	21,774	32.5

Statistical modeling and graphical presentations were carried out using R statistical software (R Core Team, 2013).

RESULTS

Preliminary results

Of the 2,333,893 total deaths recorded in the VR system, 61,533 (2.6%) were reported as transport accident deaths. After adjustment using the VA this number increased to 136,164 (5.8%) transport accident deaths. The estimated transport accident mortality rates by year are shown in Table 1.

Statistical modeling results

Fig 1 shows the plots of deviance residuals versus normal quantiles from the Poisson model after fitting the Poisson regression model containing additive effects associated with the gender-age groups and province-year groups. The Poisson regression provides a reasonably good fit because the standardized residuals were clustered around a straight line in the deviance residual plots, with less than 5% departing from the straight line.

Fig 2 shows the patterns of the Poisson coefficients, which varied substantially by province-year between 2.5 to 4.0. These were then classified into three main groups for transport accident mortality rates: high (>3.5), medium (3.0-3.5) and low (< 3.0). The regression coefficients show the trend for the transport accident mortality rate for each province, which can be classified into three subgroups: (1)

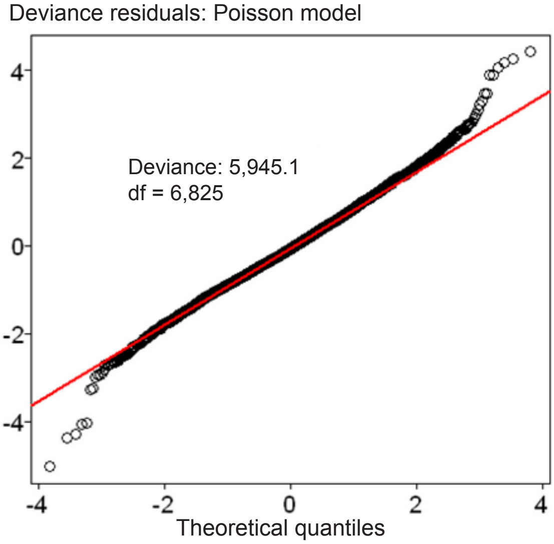

Fig 1–Residuals plot of transport accident deaths for all ages in Thailand, 2004 to 2009. df, deegree of freedom.

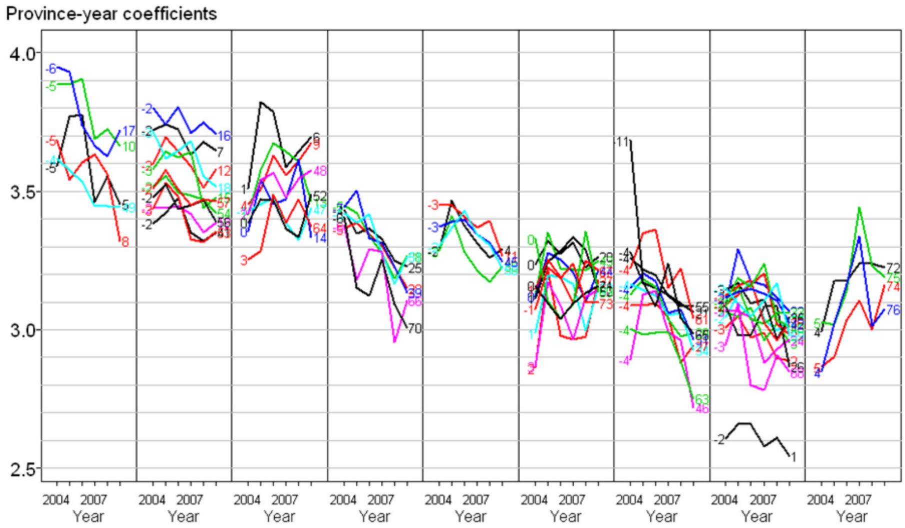

Fig 2–The Poisson coefficients and the regression coefficient of the province-year for each province from 2004 to 2009.

decreasing (-2 to -11), (2) unchanging (-1 to 0) and (3) increasing (1 to 5).

Geographical variation is shown in Fig 3 as a thematic map using the colors of the nine region-year groups. Group 1, with a high mortality rate and a rapidly decreasing trend (red) consists of five provinces: four in central and eastern and one in nothern Thailand. Group 2, with a high mortality rate and a slowly decreasing trend (brown) consists of 11 provinces: seven in central and eastern, three in nothern and one in northestern Thailand. Group 3, with a high mortality rate and a slowly increasing trend (blue) consists of eight provinces: four in central and eastern, three in northern and one in southern Thailand. Group 4, with a medium mortality rate and a rapidly decreasing trend (pink) consists of seven provinces: three in northern, two in northeastern and two in southern Thailand. Group 5, with a medium mortality rate and a slowly decreasing trend (chocolate color) consists of five provinces: three in central and eastern, one in northern and one in northeastern Thailand. Group 6, with a low mortality rate and an unchanging trend (yellow) consists of 25 provinces: 10 in the northeastern, five in the northern, five in central and eastern and five in southern Thailand. Group 7, with a low mortality rate and a rapidly decreasing trend (cyan) consists of 10 provinces: five in the northeastern, two in central and eastern, two in southern and one in northern Thailand. Group 8, with a low mortality rate and a rapidly increasing trend (green) consists of four provinces in southern Thailand. Group 9, consists of Bangkok with a low mortality rate and slowly decreasing trend (orange). These models provided a satisfactory fit (Fig 4).

Fig 5 shows confidence intervals for transport accident mortality rates from the Poisson regression model based on sum contrasts for gender-age groups and region-year groups. The mean estimated transport accident mortality rate for Thailand (during 2004 - 2009) was 34.5 per 100,000 population (red line). The estimated transport accident mortality

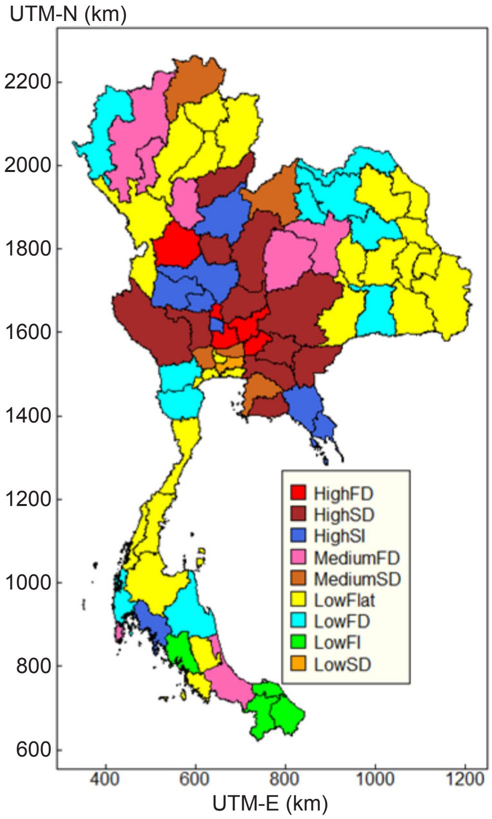

Fig 3–Geographic variation in transport accident deaths from the Poisson model. FD, Fastly decreasing trend; SD, Slowly decreasing trend; SI, Slowly increasing trend; FI, Fastly increasing trend; UTM-N, Universal Transverse Mercator-North; UTM-E, Universal Transverse Mercator-East.

rate for males older than nine years was significantly higher than for females and the overall mean. Males aged 20-29 years had the highest mortality rate. For the region-year groups, groups 1, 2, 3 and 5 had higher transport accident mortality rates than the average during 2004 - 2009. Group 4 had a higher mortality rate than the average for 2004-2007 and Group 8 had a higher mortality rate than the average for 2007. For all the years studied, the lowest transport accident mortality rate was found in Group 9 and the highest found in Group 1.

DISCUSSION

In this study we identified patterns in transport accident mortality rates and trends for Thailand during 2004 - 2009. The VR data estimate during 2004 - 2009, 61,533 Thai people died in transport accidents. After adjusting for the number of ill-defined deaths this number rose 2.1-2.3 times to a total of 136,164 deaths during the study period. This finding is similar to previous studies from Thailand which found road traffic accident deaths during 1999 - 2005 were twice as high as reported in the VR data (Tangcharoensathien *et al*, 2006; Porapakkham *et al*, 2010).

The highest transport accident mortality rates were mostly in lower northern provinces, most of the central and eastern provinces (except Bangkok) and surrounding provinces, one province in northeastern and one in southern Thailand. Bangkok had the lowest transport accident mortality rate in Thailand. This finding is similar to the results from the Thai Roads Foundation (2011) which reported during the same period the highest road accident mortality rates were in central and eastern region and the lowest rate was in Bangkok. The Thai Roads Foundation and Thailand Accident Research Center (2011) have reported the lower accident rate in Bangkok was a result of inequalities in transport resource allocation between the capital city and other provinces. This is supported by reports from The Thai Roads Foundation (2011), which reported Bangkok had the lowest rate of car, pick-up, truck, van and bus occupants per 10,000 registered vehicles by region between 2005 and 2008. Lower rates in Bangkok are also related to law enforcement of safety behavior, such as helmet use, seat belt use, drunk-driving

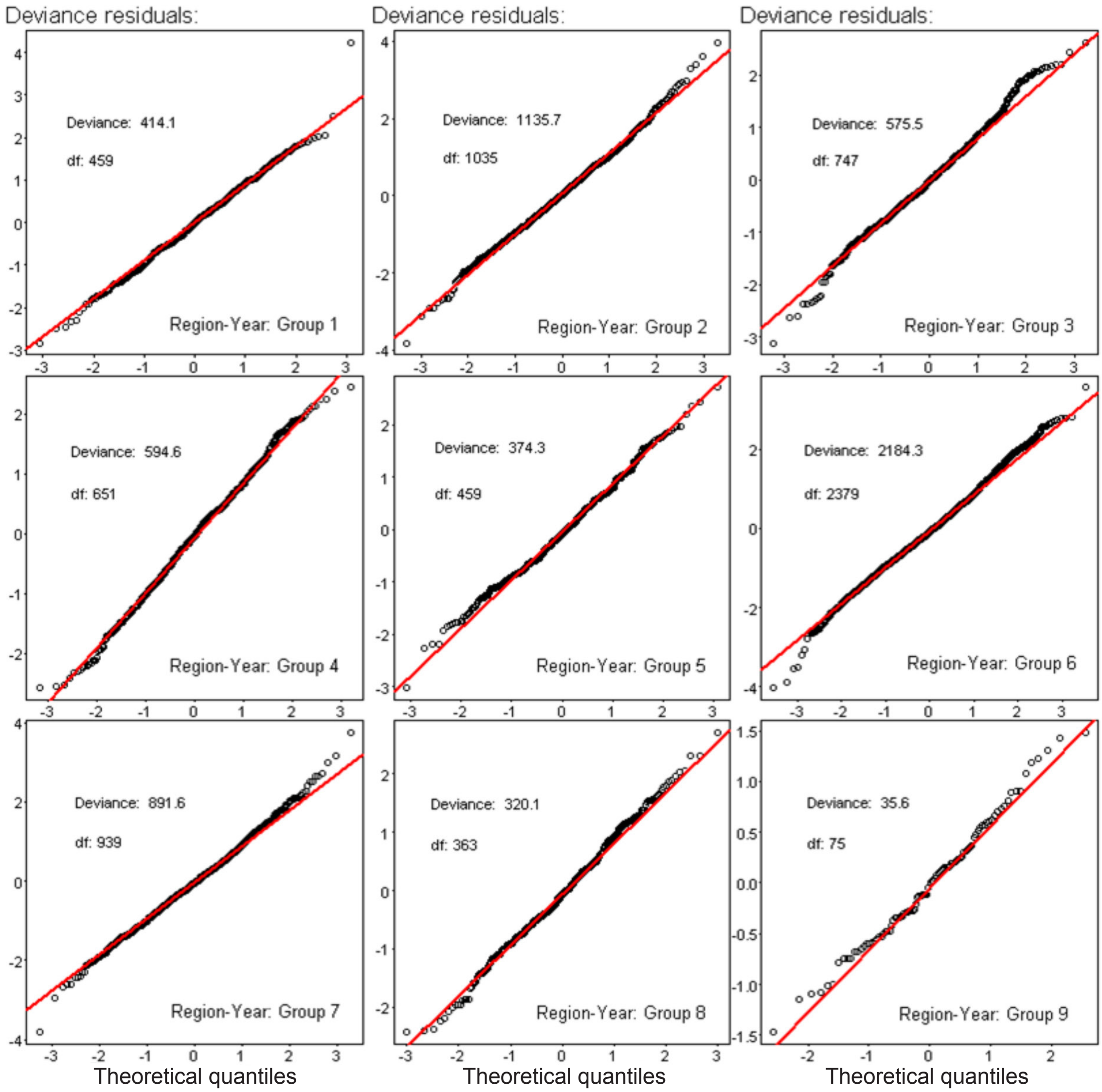

Fig 4–Residual plots of transport accident deaths for the nine region-year groups. df, degree of freedom.

and speed limits (WHO, 2013). This point is supported by the Thai Roads Foundation and Thailand Accident Research Center (2011), which showed the result of evaluating helmet use and seat belt use in 30 provinces of Thailand during 2010. This study found the highest helmet use both among drivers (93%) and passengers (45%) and the highest seat belt use both among drivers (85%) and front-seat passengers (64%) was in Bangkok. This is because traffic rules are better enforced in Bangkok than in the other provinces of Thailand.

The trend for mortality rate provides important information for transport accident prevention and control. Particu-

Fig 5–Confidence intervals for estimated transport mortality rates by gender-age group and region-year group.

larly noteworthy is the increasing trend in mortality rates in two region-year groups (Group 3 and Group 8). These two groups consist of 12 provinces, three in the northern (Nakhon Sawan, Uthai Thani and Phisanulok Provinces), four in central and eastern (Ang Thong, Chai Nat, Chanthaburi and Trat Provinces) and five in southern Thailand (Krabi, Trang, Pattani, Yala and Narathiwat Provinces). The adjusted results show the four region-year groups had higher transport accident mortality rates than the overall mean (34.5 per 100,000 population) during 2009. Worse still, all the region-year groups were higher than the goal road accident death rates of 14.15 per 100,000 population by 2012 and 10 per 100,000 population by 2020 (Thai Roads Foundation and Thailand Accident Research Center, 2011).

Our findings agree with other studies showing transport accident mortality rates vary by gender and age (Thai Roads Foundation, 2011; Thai Roads Foundation and Thailand Accident Research Center, 2011; WHO, 2013). In our study higher transport accident mortality rates were found among males of all age groups except those less than nine years old, where male and female rates were similar. The highest mortality rate was found among males aged 20-29 years old. This result agrees with previous Thai research which also found higher rates among males and particularly young adults (Thai Roads Foundation, 2011).

Our findings suggest the patterns in transport accident mortality rates for Thailand during 2004-2009 can be separated into nine region-year groups for both severity levels and trends in mortality rates. These nine models are appropriate for analyzing cause-specific mortality, such as transport accident mortality rates in Thailand, in agreement with a study by Odton *et al* (2010). These results are useful for guiding health policies regarding prevention of transport accident deaths at both national and local levels, such as legislation and enforcement of major road safety laws: helmet use, seat belt use, speed limit enforcement, drunk-driving and education for vehicle users. Further studies may use these nine models to help predict trends in transport accident mortality for Thailand.

ACKNOWLEDGEMENTS

We are grateful to Emeritus Professor Don McNeil for his helpful advice and suggestions and Matthew Kelly from the National Centre for Epidemiology and Population Health, the Australian National University for his editing and correction of the English in this manuscript. We also would like to thank the Thai Ministry of Public Health and the National Statistical Office of Thailand for providing mortality data. We thank the Graduate School, Prince of Songkla University for providing a scholarship for this research.

REFERENCES

Department of Highways and Faculty of Engineering, Prince of Songkla University. Final report of the study of traffic accident costs in Thailand. Songkhla: Prince of Songkla University, 2007. [Cited 2013 Oct 19]. Avaliable from: http://siteresources.worldbank.org/INTTHAILAND/Resources/333200-1177475763598/Sep07-traffic_accident-full-report.pdf

Klinjun N, Lim A, Bundhamcharoen K. A logistic regression model for estimating transport accident deaths using verbal autopsy data. *Asia-Pac J Public Health* 2015; 27: 286-92.

Nantulya VM, Reich MR. Equity dimensions of road traffic injuries in low-and middle-income countries. *Inj Control Saf Promot* 2003; 10: 13-20.

Odton P, Choonpradub C, Bundhamcharoen K. Geographical variations in all-cause mortality in Thailand. *Southeast Asian J Trop Med Public Health* 2010; 41: 1209-19.

Pattaraarchachai J, Rao C, Polprasert W, *et al*. Cause-specific mortality patterns among hospital deaths in Thailand: validating routine death certification. *Popul Health Metr* 2010; 8: 1-12.

Polprasert W, Rao C, Adair T, Pattaraarchachai J, Porapakkham Y, Lopez AD. Cause-of-death ascertainment for deaths that occur outside hospitals in Thailand: application of verbal autopsy methods. *Popul Health Metr* 2010; 8: 13.

Porapakkham Y, Rao C, Pattaraarchachai J, *et al*. Estimated causes of death in Thailand, 2005: implication for health policy. *Popul Health Metr* 2010; 8: 1-14.

Prasartkul P, Vapattanawong P. The completeness of death registration in Thailand: evidence from demographic surveillance system of the Kanchanaburi project. *World Health Popul* 2006; 8: 43-51.

R Core Team. R: A Language and Environment for Statistical Computing (version 3.0.1). Vienna: R Foundation for Statistical Computing, 2013. [Cited 2013 Dec 1]. Available from: http://www.R-project.org

Rao C, Porapakkham Y, Pattaraarchachai J, Polprasert W, Swampunyalert N, Lopez AD. Verifying causes of death in Thailand: rationale and methods for empirical investigation. *Popul Health Metrs* 2010; 8: 11.

Tanaboriboon Y, Satiennam T. Traffic accidents in Thailand. *IATSS Res* 2005; 29: 88-100.

Tangcharoensathien V, Faramnuayphol P, Teokul W, Bundhamcharoen K, Wibulpholprasert S. A critical assessment of mortality statistics in Thailand: potential for improvements. *Bull World Health Organ* 2006; 84: 233-8.

Thai Roads Foundation. The statistical report of Thailand road accidents year 2009. Bangkok: Thai Road Foundation, 2011 (in Thai). [Cited 2014 May 19]. Available from: http://trso.thairoads.org/updates/4807

Thai Roads Foundation and Thailand Accident Research Center (TARC). Report road accidents in Thailand 2010. Bangkok: National Health Foundation, 2011. [Cited 2014 May 20]. Available from: http://trso.thairoads.org/ resources/4803

Tongkumchum P, McNeil D. Confidence intervals using contrasts for regression model. *Songklanakarin J Sci Technol* 2009; 31: 151-6.

Venables WN, Ripley BD. Modern applied statistics with S. 4th ed. New York: Springer-Verlag, 2002.

World Health Organization (WHO). International statistical classification of diseases and health related problems. Tenth revision, Volume 1. 2nd ed. Geneva: WHO, 2004.

World Health Organization (WHO). Preventing injuries and violence: a guide for ministries of health. Geneva: WHO, 2007.

World Health Organization (WHO). Global status report on road safety: time for action. Geneva: WHO, 2009.

World Health Organization (WHO). Global status report on road safety 2013: supporting a decade of action [online]. Geneva: WHO, 2013. [Cited 2014 May 19]. Available from: http://www.who.int/violence_injury_prevention/road_ safety_status/2013/report/en