Appendix III Article

"Epidemiological patterns of transport accident mortality in Thailand"

Title Page

Article title : EPIDEMIOLOGICAL PATTERNS OF TRANSPORT ACCIDENT MORTALITY IN THAILAND

Authors' names and institutional affiliations

Nuntaporn Klinjun,

Department of Mathematics and Computer Science, Faculty of Science and Technology, Prince of Songkla University, Pattani Campus,Thailand.

Office of Disease Prevention and Control 12, Songkhla Province, Thailand.

Apiradee Lim,

Department of Mathematics and Computer Science, Faculty of Science and Technology, Prince of Songkla University, Pattani Campus, 94000, Thailand.

Kanitta Bundhamcharoen,

International Health Policy Program, Ministry of Public Health, Nonthaburi.

A short running title

PATTERNS OF TRANSPORT ACCIDENT MORTALITY IN THAILAND

Correspondence

Apiradee Lim, Department of Mathematics and Computer Science, Faculty of Science and Technology, Prince of Songkla University, Pattani Campus, 94000, Thailand. Phone: +66 (0) 7333 1303 Fax: +66 (0) 7333 5130.

E-mail: api_45@hotmail.com

Keywords

Transport accidents, Mortality rate, Epidemiology, Poisson Regression

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 group and province-year group. Regression coefficients were used to classify mortality trends in 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 regions, lower-North region and Nakhon Ratchasima province in the Northeast region. The patterns of transport accident mortality rates were separated into nine groups. Increasing trends were found in three provinces in the North region, four provinces in the Central and Eastern region and five provinces in the South region. The nine models of this study can be used for forecasting the transport accident mortality rate in Thailand and planning appropriate responses.

Keywords: Transport accidents, Mortality rate, Epidemiology, Poisson Regression

INTRODUCTION

Transport accident deaths, especially road traffic accident deaths have long been recognized as a major public health problem causing a substantial burden on health care systems globally, notably 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. Moreover, they have a substantial impact on both the household income and the national economy, including loss of productivity, expenses of prolonged medical care, and funeral costs or rehabilitation (Nantulya and Reich, 2003). A survey in 2011 in 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, 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 is preventable and trends can be reduced (WHO, 2013).

Thailand is classified as a middle income country in the South-East Asian region (WHO, 2013). A 2011 survey of 182 countries reported that Thailand had the third highest road traffic accident mortality burden and the highest of 11 countries in the South-East Asia region 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-wheelers (WHO, 2013). A study of traffic accident costs in Thailand in 2004 estimated that the economic loss due to traffic accidents was 204,050 million Baht (approximately 5,101 million US$) or between 3.9 and 4.7 million Baht 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 on this transport accident burden accurate epidemiological informationon patterns and trends is essentially. At present Thai VR has good coverage capturing around 95% of deaths in the country since the mid-1990s (Prasartkul and Vapattanawong, 2006). Cause of death recording however is of low value in health planning as ill-defined deaths comprise up to 40% of deaths. To attempt to address this problem an ongoing process of 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; Kinijun *et al*, 2014). This study together with previous analysis by the same researchers (Kinijun *et al*, 2014) uses the results of these investigations.

Consequently, the study aimed to explore patterns of transport accident mortality rate in Thailand between 2004 and 2009 and assess severity levels and trend directions of transport accident mortality rates in each province.

MATERIALS AND METHODS

Data sources and management

The two main data sources used in this study are the estimated number of transport accident deaths in Thailand between 2004 and 2009, and population denominators. Transport accident death estimates were derived from Thai Vital Registration (VR) records which were then adjusted to reduce the proportion of illand wrongly defined caused of death using VA. The methods for this adjustment process have been reported elsewhere (Klinjun *et al*, 2014).

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

The population denominators separated by gender, age group, year and province were obtained from the 2000 population and housing census by 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 fitted a statistical model 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.

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

For this model, λ_{jt} is the mean of the Poisson distribution giving the estimated number of transport accident deaths for 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 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 whether the Poisson coefficients (i.e. high, medium, low). The coefficients of the province-year determinant of each province from the Poisson model were calculated to analyze trend direction of 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:

$$y = a + bx \qquad \ldots.. \quad (2)$$

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

We grouped transport accident mortality rates from each province by 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 of (1) high mortality rate and fast decreasing trend (2) high mortality rate and slow decreasing trend (3) high mortality rate and slow increasing trend (4) medium mortality rate and fast decreasing trend (5) medium mortality rate and slow decreasing trend (6) low mortality rate and flat trend (7) low mortality rate and fast decreasing trend (8) low mortality rate and fast increasing trend and (9) low mortality rate and slow decreasing trend.

The nine groups were fitted the transport accident mortality rates by Poisson regression model. For each group, the model was formulated as follows:

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

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 groups combinations and 6 years.

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.

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

RESULTS

Preliminary results

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

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 results

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

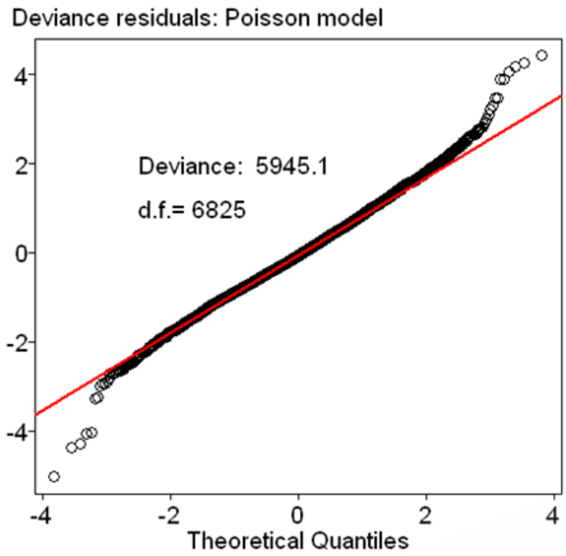

Fig 1−Residuals plot of transport accident deaths for all ages in Thailand, 2004 to 2009

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 high (>3.5), medium (3.0-3.5) and low (< 3.0) transport accident mortality rates. The regression coefficients show a trend of transport accident mortality rate for each province which could be classified into three subgroups, which are decreasing (-2 to -11), flat and unchanging (-1 to 0) and increasing (1 to 5).

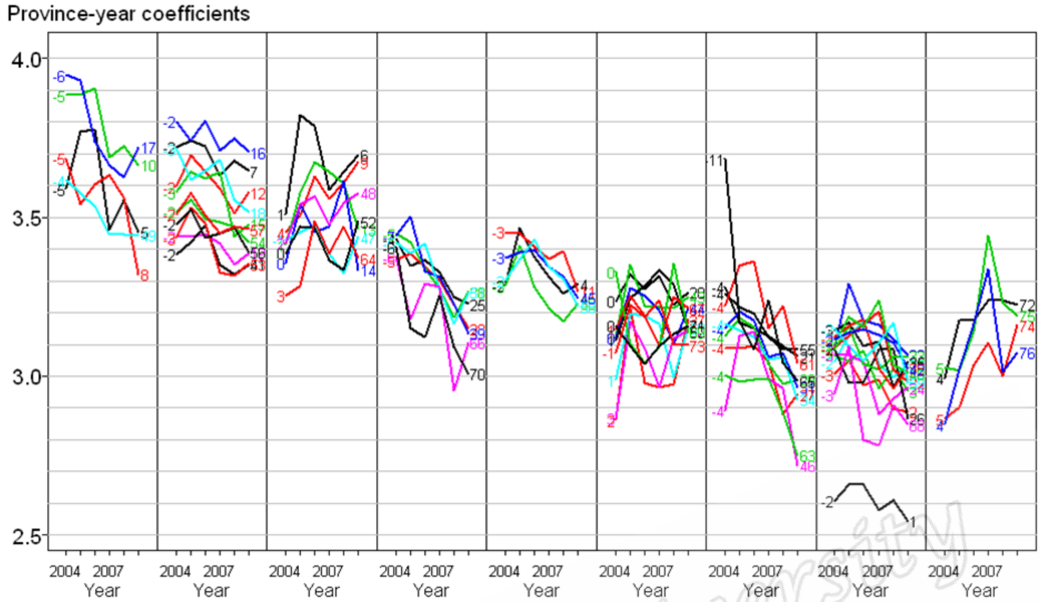

Fig 2−The Poisson coefficients and the regression coefficient of the province-year for each province from 2004 to 2009.

Geographical variation is displayed in Fig 3 as a thematic map using the colours of the nine region-year groups. Group 1, high mortality rate and fast decreasing trend (red colour) consists of five provinces, four in the Central and Eastern region and one in the North region. Group 2, high mortality rate and slow decreasing trend (brown colour) consists of 11 provinces, seven in the Central and Eastern region, three in the North region and one in the Northeast region. Group 3, high mortality rate and slow increasing trend (blue colour) consists of eight provinces, four in the Central and Eastern region, three in the North region and one in the South region. Group 4, medium mortality rate and fast decreasingtrend (pink colour) consists of seven provinces, three in the North region, two in the Northeast region and two in the South region. Group 5, medium mortality rate and slow decreasing trend (chocolate colour) consists of five provinces, three in the Central and Eastern region, one in the North region and one in the Northeast region. Group 6, low mortality rate and flat trend (yellow colour) consists of 25 provinces, 10 in the Northeast region, five in the North region, five in the Central and Eastern region and five in the South region. Group 7, low mortality rate and fast decreasing trend (cyan colour) consists of 10 provinces, five in the Northeast region, two in the Central and Eastern region and two in the South region and one in the North region. Group 8, low mortality rate and fast increasing trend (green colour) consists of four provinces in the South region. Group 9, Bangkok has a low mortality rate and slow decreasing trend (orange colour). These models provided a satisfactory fit, as shown in Fig 4.

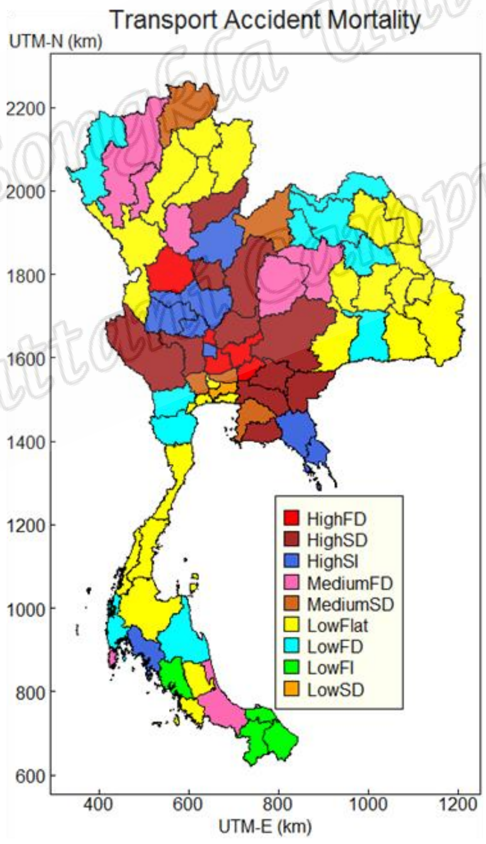

Fig 3−Geographical variation of the pattern of transport accident deaths from the Poisson model.

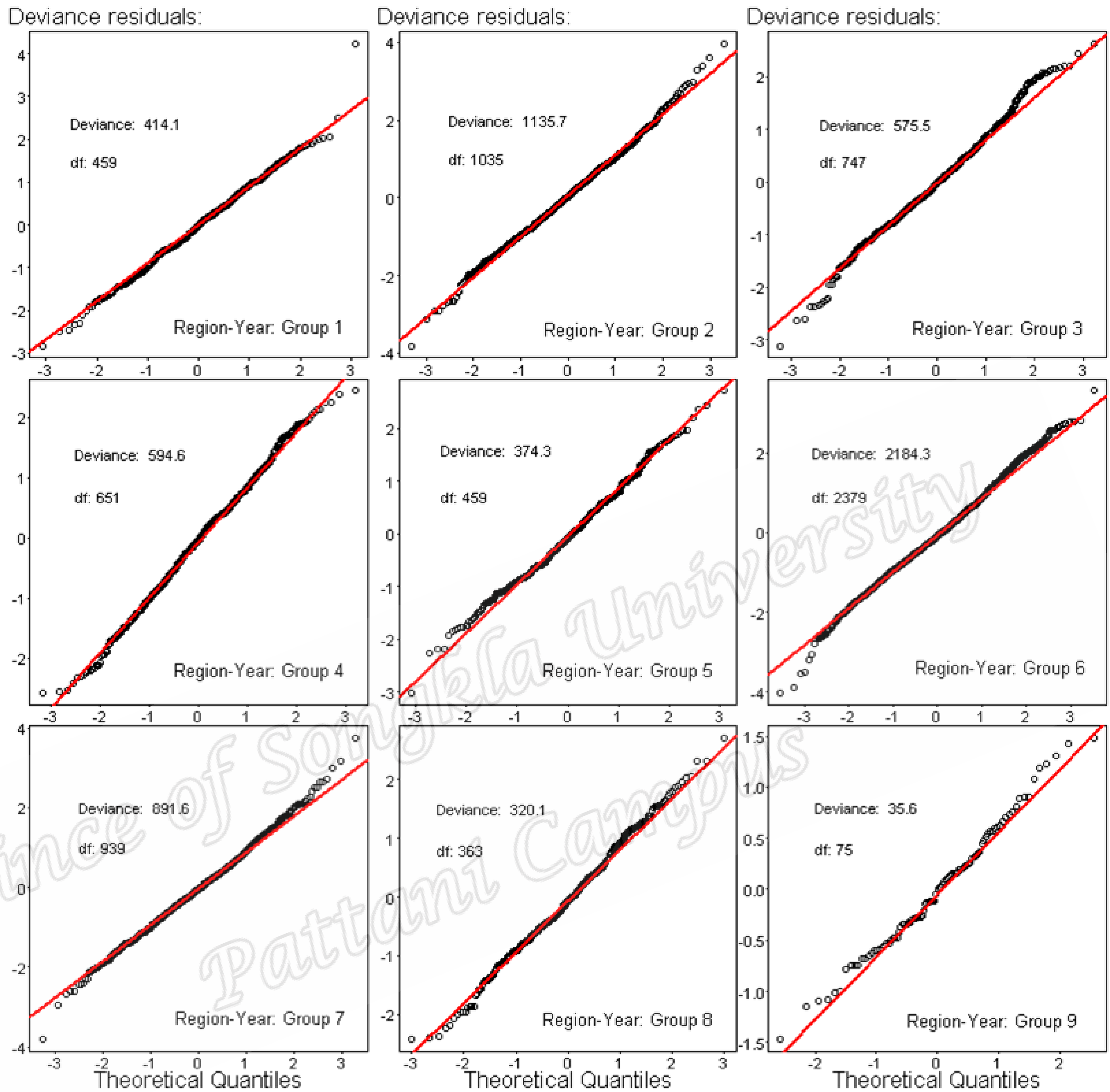

Fig 4−Residuals plot of transport accident deaths from the nine region-year groups.

Fig 5 shows confidence intervals of transport accident mortality rates from the Poisson regression model based on sum contrasts by gender-age group and region-year group. The mean of estimated transport accident mortality rates in Thailand (2004 to 2009) was 34.5 per 100,000 population (red line). The estimated transport accident mortality rates in males older than nine years were significantly higher than those in 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 rate than the average in 2004 to 2009. Group 4 had a higher mortality rate than the average from 2004 to 2007 while group 8 had a higher mortality rate than the average in 2007. For all years, the lowest transport accident mortality rate was found in group 9 and the highest mortality rate was found in group 1.

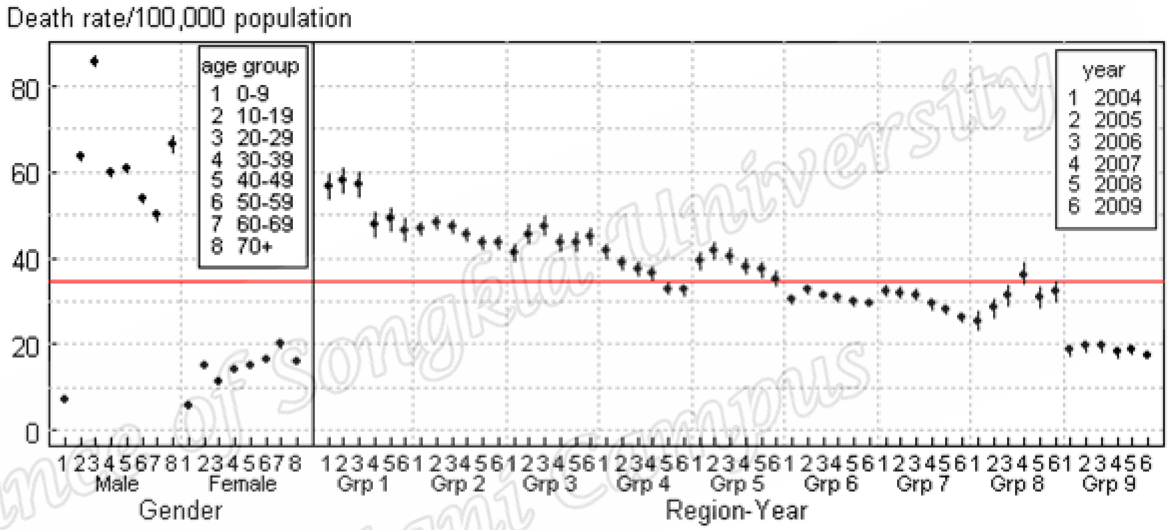

Fig 5−Confidence intervals of estimated transport mortality rates by gender-age group and the region in 2004 to 2009.

DISCUSSION AND CONCLUSION

This study identified patterns of transport accident mortality rates in Thailand for the period of 2004 to 2009 revealing both the severity of the mortality rate and trends in that mortality rate. VR data estimate that between 2004 and 2009, 61,533 Thai people died in transport accidents. After adjusting to reduce the number of ill-defined deaths this number rose 2.1-2.3 times to total 136,164 over the six year-period. This result is similar to previous reports in Thailand which found that road traffic accident deaths between 1999 and 2005 were twice as high as VR data (Tangcharoensathien *et al*, 2006; Porapakkham *et al*, 2010).

The highest transport accident mortality rates occurred mostly in the lower Northern provinces, most of the Central and Eastern provinces except Bangkok and surrounding provinces, one province in the North-east and one in the South. Meanwhile, Bangkok had the lowest transport accident mortality rate in Thailand. This is consistent with results from the Thai Roads Foundation (2011) which reported that in the same time period as this study the highest road accident mortality rates were in the Central and Eastern region and the lowest rate was in Bangkok. Furthermore, the Thai Roads Foundation and Thailand Accident Research Center (2011) have reported that 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 the reports from The Thai Roads Foundation (2011), which reported Bangkok had the lowest rate of car, pick-up truck or 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 behaviors like helmet use, seat belt use, drink-driving 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 observing helmet use and seat belt use in 30 provinces of Thailand year 2010. This research found that the highest helmet use both in drivers (93%) and passengers (45%) and the highest seat belt use both in drivers (85%) and in front-seat passengers (64%) were found in Bangkok. This is because the traffic rules are enforced more in Bangkok than other provinces in Thailand.

The trend of mortality rate provides important information for transport accident prevention and control. Particularly noteworthy is, the directional trend of increasing mortality rate in two region-year groups consist of group 3 and group 8. These two groups consist of 12 provinces, three in the Northern region (Nakhon Sawan, Uthai Thani and Phisanulok provinces), four in the Central and Eastern region (Ang Thong, Chai Nat, Chanthaburi and Trat provinces) and five in the Southern region (Krabi, Trang, Pattani, Yala and Narathiwat provinces). Moreover, the adjusted result showed that four region-year groups maintained higher transport accident mortality rate than the overall mean (34.5 per 100,000 population) in 2009. Worse still, all region-year groups were higher than the target road accident death rate of 14.15 per 100,000 population in 2012 and of 10 per 100,000 population in 2020 (Thai Roads Foundation and Thailand Accident Research Center, 2011).

As well our study agrees with other research 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 in all age groups except those less than nine years old, where male and female rates were similar. The highest rate was found in 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 that the patterns of the transport accident mortality rates in Thailand year 2004 to 2009 could be separated into nine region-year groups for both severity levels and trend directions of mortality rates. The nine models form Poisson regression are appropriate model for analyze cause-specific mortality as transport accident mortality rates in Thailand in agree with a study Odton *et al* (2010). These results are useful for guiding health policy on the prevention of transport accident deaths in both national and local levels, such as legislation and enforcement of major road safety laws: helmet use, seat belt use, speed limit enforcement, drink-driving and education of road users. Thus, further study can use the nine models from this study for forecasting the transport accident mortality in 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. Prince of Songkla University, 2007. [Cited 2013 Oct 19]. Avaliable from: URL: 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-Pacific Journal of Public Health* 2014; 1-7. doi:10.1177/1010539514529810

Nantulya VM, Reich MR. Equity dimensions of road traffic injuries in low-and middle-income countries. *Injury Control and Safety Promotion* 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, Porapakkham Y, Pao-in W, Singwerathum N, Lopez AD. Cause-specific mortality patterns among hospital deaths in Thailand: validating routine death certification. *Population Health Metrics* 2010; 8: 1-12.

Polprasert W, Rao C, Adair T, Pattaraarchachai, J., Porapakkham, Y., Lopez, A.D. Cause-of-death ascertainment for deaths that occur outside hospitals in Thailand: application of verbal autopsy methods. *Population Health Metrics* 2010; 8: 1-15.

Porapakkham Y, Rao C, Pattaraarchachai J, Polprasert W, Vos T, Adair T, Lopez A D. Estimated causes of death in Thailand, 2005: implication for health policy. *Population Health Metrics* 2010; 8: 1-11.

Prasartkul P, Vapattanawong P. The completeness of death registration in Thailand: evidence from demograohic 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]. Avalable from: URL: 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. *Population Health Metrics* 2010; 8: 1-13.

Tanaboriboon Y, Satiennam T. Traffic accidents in Thailand. *IATSS Research* 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. KhonKaen. Thailand Road Safety Network, 2011. (in Thai). [Cited 2014 May 19]. Avalable from: URL: 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]. Avalable from: URL: http://trso.thairoads.org/resources/4803

Tongkumchum P, McNeil D. Confidence intervals using contrasts for regression model. *Songklanakarin J Sci Technol* 2009; 31: 151-156.

Venables W N, 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]. Avalable from: URL: http://www.who.int/violence_injury_prevention/ road_ safety_status/2013/ report/en