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MODELLING ROAD ACCIDENT FATALITIES IN THAILAND AND OTHER ASIAN COUNTRIES

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ABSTRACT: Modelling was conducted of road accident fatalities (RAFs) in Thailand and other Asian countries. Based on a cross-sectional analysis in 2013, an Asian model of predicted RAFs (per population) as a function of motorization (registered vehicles per capita) was developed. In addition, an Asian RAFs (per vehicles) prediction model was also developed. Increasing motorization corresponded with lower estimated RAFs per 10,000 vehicles. Also, the Thailand RAFs (per population) prediction model was achieved based on the limited time series analysis utilizing the 3 RAFs database sources. The motorization could potentially be adapted to estimate the RAFs per 100,000 population in Thailand. Based on the Thailand RAFs prediction model and the predicted motorization in 2020, the estimated RAFs per 100,000 population will be 3 times greater than the targeted one. This means that Thailand will not be able to achieve the United Nations Sustainable Development Goal (SDG) for global road safety issues.

Keywords: Road Accident Fatalities, Modelling, Fatalities per Vehicle, Fatalities per Population, Asian countries.

1. INTRODUCTION

In 2015, UNDP formally announced 17 Sustainable Development Goals (SDGs) with 169 targets aiming to establish an equilibrium among economy, society and environment elements for sustainable development and encouraging appropriate actions during the coming 15 years [1]. Two SDGs directly related to global road safety issues include SDG 3: "*Ensure healthy lives and promote well-being for all at all ages*" with Target 3.6: "*By 2020, halve the number of global deaths and injuries from road traffic accidents*"; and SDG 11: "*Make cities and human settlements inclusive, safe, resilient and sustainable*" with Target 11.2: "*By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons*" [2]. These SDGs and their associated targets were established to encourage and stimulate both developed and developing countries to combat the global RAFs crisis.

Based on 182 countries in 2010, Thailand was the third worst ranked country (with 38.1 fatalities per 100,000 population) in the world [3] and based on 180 countries in 2013, Thailand was ranked second (with 36.2 fatalities per 100,000 population) [1]. This situation clearly indicates that Thailand has one of the most harmful road transport systems in the world. Taneerananon and Klungboonkrong [4] estimated the total economic burden of road accidents in Thailand to be over US$12,000 billion (3 percent of Gross Domestic Product (GDP)) annually. Following the UN decade of action for road safety commitment (from 2011 to 2020), Thailand has set up the target of 10.0 RAFs per 100,000 population by 2020. This challenging target is well matched with SDG 3 (Target 3.6) [2]. To achieve the target, a greater understanding of the high death rates is required so mitigating actions can be proposed and implemented. At a strategic level, an important consideration is to understand the relationship between RAFs, population size and vehicle numbers and extent of motorization.

The main objectives of this research were as follows: (i) to model and analyze the relationship between RAF rates (RAFs per 100,000 population), RAF risk (RAFs per 10,000 vehicles) and motorization (registered vehicles per capita) in some Asian countries and (ii) to model the RAFs as a function of motorization in Thailand.

2. LITERATURE REVIEWS

At the macroscopic level, the associations between RAFs, population, vehicles, number of trips, distance traveled, a distance of travel per vehicle, and income level has been explored extensively in several studies. The general conclusion is that low-income countries encounter greater road safety risks than high-income countries

[5]. It has been widely recognized that RAF risk (RAFs per 100,000 population) declines as income level (GNI per capita) increases [6]. In Asian countries, RAFs per 100,000 population showed no correlation with Gross National Income (GNI) per capita [4], [7], [8], [9]. Based on the Global Burden of Disease Study [10] and a WHO report [3], similar findings were recently observed [11]. However, the number of RAFs per 10,000 vehicles could illustrate a relatively high correlation with both GNI per capita as well as the number of registered vehicles per 1,000 population [4], [5], [7], [8], [9], [12], [13], [14].

Smeed [14] developed two statistical equations for forecasting the RAF rates (RAFs per 100,000 population and RAFs per 10,000 registered vehicles) in 20 developed countries as a function of motorization (registered vehicles per capita). Smeed's equations are as follows: (i) $D/P = \alpha(N/P)^{\beta}$ and (ii) $D/N = \mu(N/P)^{\Omega}$ where D is the number of RAFs, N is a number of registered vehicles, P is the population and α, β, μ Ω are constant parameters. Smeed [14] concluded that increasing motorization would result in the reduction of RAFs per 10,000 vehicles and the enhancement of RAFs per population and the total number of RAFs. Adams [17] suggested that although the parameters of Smeed's model (equation (i)) do not perfectly match the observed data of all countries, Smeed's model can generally capture the relationship between RAF rates and their exposure. It was also pointed out that social learning experiences can also contribute towards future RAF rate decreases.

In 1985, Andreassen [18] argued that Smeed's model could not be applied universally due to unique differences within countries regarding socio-economic status, road infrastructure conditions and motorization. Importantly Smeed's model was not based on time-dependent data (considering RAF data from several countries at taken from one particular year). Andreassen [18] then proposed a modification of Smeed's model as follows: $D = \alpha N^{\beta} P^{\mu}$ where D is the number of RAFs, N is a number of registered vehicles, P is the population size and α, β μ are constant parameters. Valli [19] developed road accident prediction models (in terms of a total number of accidents, injuries, and fatalities) as a function of registered vehicles and population in India during 1970 and 2001 based on Smeed's and Andreassen's models. Valli [19] found that both Smeed's and Andreassen's models performed well based on the direct comparisons between the modeled and observed values. Korkmaz and Akgungor [20] recently developed road accident prediction models (in terms of a number of accidents, injuries, and fatalities) by applying a differential evolution algorithm based on the Smeed and Andreassen model in the city of Ankara in Turkey. They found that Andreassen's model statistically and technically performed better than the Speed model. Agus [21–23] found that Andreassen's model [18] could not be adapted to predict the number of RAFs in Indonesia, because of the unique distinction of the size of the population, regional physical characteristics and road infrastructure of Indonesia.

Koren and Borsos [5] noted that at the beginning of the 1960's, increasing total RAFs began to shift to a declining trend in several countries and after 1966, the RAF values estimated by Smeed's model continued to increase, while total actual RAFs were gradually declining. Smeed's predicted RAF was approximately four times greater than the real observed value in 2000. Kopits and Cropper [6] noticed that there was a threshold income level for a country where RAFs would start to decline. Several research studies attempted to comprehend, analyze and model the rise and fall trends in RAF rates as a function of both motorization and income levels [6], [24], [25].

In the time when Smeed's RAF predictions were rising, actual observed RAFs were declining [26]. Koren and Borsos [12] pointed out that Smeed's equation (i) did not fit well with the RAFs per 100,000 population data estimated by the WHO [16] in 2007. Koren and Boss [5] conducted a macroscopic RAF pattern analysis for 26 countries in a time series fashion and found that the relationship between the RAFs per population and the motorization (registered vehicles per capita) could be portrayed as an inverted U-shaped curve. Subsequently, Koren and Borsos [12] proposed a new equation to capture the relationship between RAFs per 100,000 population and motorization in 139 countries in 2007. Koren and Borsos's equation is: $D/P = \alpha N/P\ e^{-\beta N/P}$ where D is the number of RAFs, N is a number of registered vehicles, P is a number of population and α β are constant parameters. At low levels of motorization, with increases in the number of registered vehicles per capita, the RAFs per 100,000 population also rise. Eventually, the RAFs per 100,000 population reach a maximum value termed the "turning point". Beyond the turning point, as the motorization increases, the RAFs per 100,000 population gradually commence a decline. Koren and Borsos [12] also found that beyond the turning point, as motorization increases, RAFs per vehicle will decrease. Similar trends could also be observed in several studies [11], [13], [26].

3. MODELING OF ROAD SAFETY STATUS IN ASIA

3.1 Modelling Road Accident Fatalities per Population in Asian countries

Based on the RAFs and other road safety-related data estimated in 2013 by WHO [1], RAFs and other related data for 43 Asian countries were analyzed and compared (as shown in Table 1). In Figure 1, for each Asian country, the estimated RAFs per 100,000 population showed a moderate correlation with motorization (registered vehicles per capita). The macroscopic statistics model developed by Koren and Borsos [5] was adopted to fit the estimated RAFs per 100,000 population against the motorization (vehicles per capita) data.

Based on the WHO estimated RAFs in 2013 [1], the new equation of D/P = 313.9 (N/P) $e^{-1.9(N/P)}$ (with $R^2 = 0.635$) was derived. The motorization (an independent variable in X-axis) can reasonably explain the RAFs rate (a dependent variable in Y-axis). As illustrated in Figure 1, at low motorization levels, as motorization increases, the RAF rate (RAFs per 100,000 population) will also rise. At the turning point, the maximum RAF rate of 23.6 is reached on the motorization of 0.20. Beyond the turning point, as the motorization increases, RAF rate will also gradually decline. In addition, based on the WHO reported RAFs in 2013 [1], the other new equation D/P = 135.0 (N/P) $e^{-3.5(N/P)}$ (with R^2 = 0.520) was obtained. A similar relationship between RAFs per 100,000 population and motorization as with the previous equation for WHO estimated RAF data is clearly illustrated. At the turning point, RAFs per 100,000 population is 14.2 and the associated motorization is 0.29. At low motorization levels from 0 to 0.60 vehicles per capita, the WHO estimated RAF equation is generally greater than the WHO reported RAF equation, while at motorization levels greater than 0.60 the two equations are relatively similar.

For most Asian countries, the reported RAFs were lower than the estimated one. Thailand showed the greatest discrepancy between the reported and the estimated RAFs per 100,000 population. Both the WHO estimated and reported RAFs per 100,000 population of Thailand in 2013 [1] were 36.2 and 20.4 respectively. These two values are much higher than both the modeled values based on the WHO estimated (14.3) and reported (12.1) data. This implies that the derived models may not be applicable to the RAF rate prediction model of Thailand. As shown in Figure 1, some countries (e.g., Israel (IL), Iran (IR), Lebanon (LB) and the Russian Federation (RU)) possess similar motorization but have very different RAFs per 100,000 population. In addition, the estimated RAFs per 100,000 population in some Asian countries (e.g. China (CN) and Thailand (TH)) were much greater than the reported ones. This situation clearly indicated that there are critical problems in the quality of the road safety database systems in many Asian countries. It should be noted that international comparisons of Asian countries' RAFs per 100,000 population characteristics were difficult and complex. This is because these Asian countries were uniquely distinct in terms of geographical conditions, road infrastructure and land use characteristics, vehicle fleet composition, socio-economic situation, road use culture and behaviors, RAF definitions and the systems to report and record RAFs.

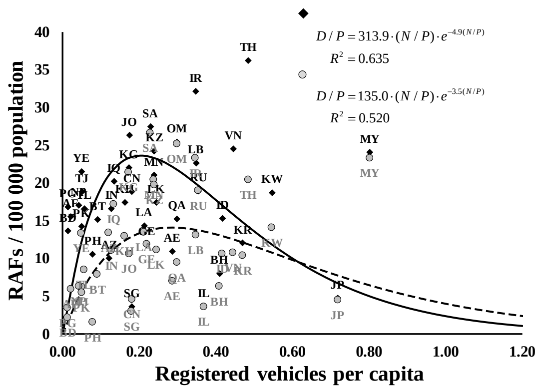

Fig.1 Relationship between RAFs per100,000 population and motorization among Asian countries in 2013

3.2 Modelling Road Accident Fatalities per Vehicle in Asian Countries

Vehicle-kilometers of travel on the road networks of each country would be an ideal measure of road accident exposure, however, the information is only available in some developed countries [5]. Although the number of registered vehicles is less suitable than vehicle-kilometers, it is capable of gauging the levels of motorization of each country. Hence, the RAFs per 10,000 registered vehicles are determined in this section. Smeed [14] found that increasing motorization would lead to the reduction of RAFs per 10,000 vehicles. As shown in Figure 2, Smeed's equation (ii) was adopted to fit the estimated RAFs per 10,000 vehicles on the Y-axis and the motorization (registered vehicles per capita) on the X-axis.

Based on the WHO estimated and reported RAFs in 2013 [1], two new equations D/N = 1.524 $(N/P)^{-1.022}$ (with R^2 = 0.73) and D/N = 1.546 $(N/P)^{-0.747}$ (with R^2 = 0.52) were obtained. The motorization (X-axis) demonstrates the RAFs per 10,000 vehicles. Both the WHO reported an estimated RAFs per 10,000 vehicles showed a reasonable correlation with the registered vehicles per capita. The greater the motorization, the lower the estimated RAFs per 10,000 vehicles. At low vehicles per capita, small changes in the motorization would rapidly decrease the estimated RAFs per 10,000 vehicles. Subsequently, as the motorization increases, the decreasing rate will gradually decline and approach zero. It has become clear that motorization increases at a much faster rate than the number of RAFs.

As the vehicles per capita increase, the discrepancy between the reported and estimated RAFs per 10,000 vehicles in Asian countries decline considerably.

Table 1 Road safety status of 43 Asian countries based on 2015 WHO report [1]

NO.	COUNTRY/ AREA	CODE	POPULATION NUMBERS FOR 2013	GNI PER CAPITA FOR 2013 IN US DOLLARS	INCOME LEVEL	NUMBER OF REGISTERED VEHICLES	ESTIMATED NUMBER OF ROAD TRAFFIC DEATHS	REPORTED NUMBER OF ROAD TRAFFIC DEATHS	ESTIMATED NUMBER OF ROAD TRAFFIC DEATHS RATE PER 100,000 PEOPLE	REPORTED ROAD TRAFFIC DEATH RATE PER 100,000 PEOPLE	ESTIMATED ROAD TRAFFIC DEATH RATE PER 1,000 VEHICLES	REPORTED ROAD TRAFFIC DEATH RATE PER 1,000 VEHICLES
1	AFGHANISTAN	AF	30,551,674	690	L	655,357	4,734	1,808	15.50	5.92	7.22	2.76
2	ARMENIA	AM	2,976,566	3,800	M	—	546	316	18.34	10.62	—	—
3	AZERBAIJAN	AZ	9,413,420	7,350	M	1,135,936	943	1,256	10.02	13.34	0.83	1.11
4	BAHRAIN	BH	1,332,171	19,700	H	545,155	107	83	8.03	6.23	0.20	0.15
5	BANGLADESH	BD	156,594,962	1,010	L	2,088,566	21,316	3,296	13.61	2.10	10.21	1.58
6	BHUTAN	BT	753,947	2,330	M	68,173	114	59	15.12	7.83	1.67	0.87
7	CAMBODIA	KH	15,135,169	950	L	2,457,569	2,635	1,950	17.41	12.88	1.07	0.79
8	CHINA	CN	1,385,566,537	6,560	M	250,138,212	261,367	62,945	18.86	4.54	1.04	0.25
9	CYPRUS	CY	1,141,166	25,210	H	644,068	59	44	5.17	3.86	0.09	0.07
10	GEORGIA	GE	4,340,895	3,570	M	951,649	514	514	11.84	11.84	0.54	0.54
11	INDIA	IN	1,252,139,596	1,570	M	159,490,578	207,551	137,572	16.58	10.99	1.30	0.86
12	INDONESIA	ID	249,865,631	3,580	M	104,211,132	38,279	26,416	15.32	10.57	0.37	0.25
13	IRAN	IR	77,447,168	5,780	M	26,866,457	24,896	17,994	32.15	23.23	0.93	0.67
14	IRAQ	IQ	33,765,232	6,720	M	4,515,041	6,826	5,789	20.22	17.14	1.51	1.28
15	ISRAEL	IL	7,733,144	33,930	H	2,850,513	277	277	3.58	3.58	0.10	0.10
16	JAPAN	JP	127,143,577	46,330	H	91,377,312	5,971	5,679	4.70	4.47	0.07	0.06
17	JORDAN	JO	7,273,799	4,950	M	1,263,754	1,913	768	26.30	10.56	1.51	0.61
18	KAZAKHSTAN	KZ	16,440,586	11,550	M	3,926,487	3,983	3,233	24.23	19.66	1.01	0.82
19	KUWAIT	KW	3,368,572	45,130	H	1,841,416	629	473	18.67	14.04	0.34	0.26
20	KYRGYZSTAN	KG	5,547,548	1,210	M	958,187	1,220	1,184	21.99	21.34	1.27	1.24
21	LAO PDR	LA	6,769,727	1,450	M	1,439,481	971	908	14.34	13.41	0.67	0.63
22	LEBANON	LB	4,821,971	9,870	M	1,680,011	1,088	630	22.56	13.07	0.65	0.37
23	MALAYSIA	MY	29,716,965	10,430	M	23,819,256	7,129	6,915	23.99	23.27	0.30	0.29
24	MALDIVES	MV	345,023	5,600	M	61,412	12	12	3.48	3.48	0.20	0.20
25	MONGOLIA	MN	2,839,073	3,770	M	675,064	597	579	21.03	20.39	0.88	0.86
26	NEPAL	NP	27,797,457	730	L	1,178,911	4,713	1,744	16.95	6.27	4.00	1.48
27	OMAN	OM	3,632,444	25,150	H	1,082,996	924	913	25.44	25.13	0.85	0.84
28	PAKISTAN	PK	182,142,594	1,360	M	9,080,437	25,781	9,917	14.15	5.44	2.84	1.09
29	PAPUA NEW GUINEA	PG	7,321,262	2,010	M	94,297	1,232	248	16.83	3.39	13.07	2.63
30	PHILIPPINES	PH	98,393,574	3,270	M	7,690,038	10,379	1,469	10.55	1.49	1.35	0.19
31	QATAR	QA	2,168,673	86,790	H	647,878	330	204	15.22	9.41	0.51	0.31
32	REPUBLIC OF KOREA	KR	49,262,698	25,920	H	23,150,619	5,931	5,092	12.04	10.34	0.26	0.22
33	RUSSIAN FEDERATION	RU	142,833,689	13,850	H	50,616,163	27,025	27,025	18.92	18.92	0.53	0.53
34	SAUDI ARABIA	SA	28,828,870	26,260	H	6,599,216	7,898	7,661	27.40	26.57	1.20	1.16
35	SINGAPORE	SG	5,411,737	54,040	H	974,170	197	159	3.64	2.94	0.20	0.16
36	SRI LANKA	LK	21,273,228	3,170	M	5,203,678	3,691	2,362	17.35	11.10	0.71	0.45
37	TAJIKISTAN	TJ	8,207,834	990	L	411,548	1,543	508	18.80	6.19	3.75	1.23
38	THAILAND	TH	67,010,502	5,340	M	32,476,977	24,237	13,650	36.17	20.37	0.75	0.42
39	TIMOR-LESTE	TL	1,132,879	3,940	M	63,553	188	96	16.59	8.47	2.96	1.51
40	UNITED ARAB EMIRATES	AE	9,346,129	38,360	H	2,674,894	1,021	651	10.92	6.97	0.38	0.24
41	UZBEKISTAN	UZ	28,934,102	1,880	M	—	3,240	2,231	11.20	7.71	—	—
42	VIETNAM	VN	91,679,733	1,740	M	40,790,841	22,419	9,845	24.45	10.74	0.55	0.24
43	YEMEN	YE	24,407,381	1,330	M	1,201,890	5,248	3,239	21.50	13.27	4.37	2.69

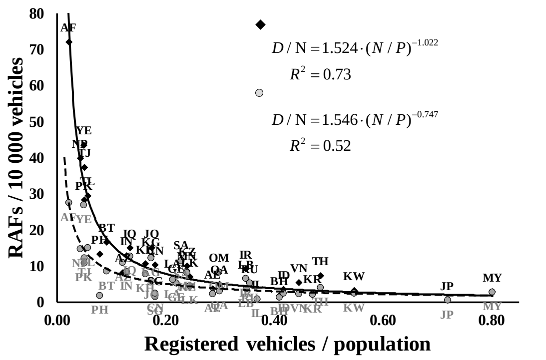

Fig.2 Relationship between RAFs per 10,000 vehicles and motorization

4. MODELING AND ANALYSIS OF ROAD SAFETY STATUS IN THAILAND

The road safety status in Thailand was analyzed from the recently published RAFs of Thailand based on the comprehensive and careful analysis of the three RAFs database systems including National Police Bureau (NPB), the Ministry of Public Health (MPH) and the Road Accident Victim Protection Company of Thailand (RAVPCT) [27].

4.1 Analysis of Road Accident Fatalities per population in Thailand

As shown in Figure 3, the changing trends of RAFs per 100,000 population derived from National Police Bureau (NPB), Ministry of Public Health (MPH) and Road Accident Victim Protection Company of Thailand (RAVPCT) database systems were different. This indicated that there have been serious problems regarding the quality and reliability of RAF database systems in Thailand.

Subsequently, the Ministry of Public Health (MPH) recently completed an important research study [27] by comprehensively and systematically incorporating, managing and analyzing the 3 RAFs database sources including in National Police Bureau (NPB), the Ministry of Public Health (MPH) and Road Accident Victim Protection Company of Thailand (RAVPCT). The main purpose of the study was to estimate the most scientific and systematic RAF values (from 2011 to 2016) based on the 3 RAF database systems. The individual identification numbers (13 digits) of deceased persons from road accidents in each year and other screening methods were adopted to eliminate duplicated counts [27].

As shown in Table 2, in 2013, the best estimated Thailand RAF of 21,221 derived from the 3 RAF database sources were much greater than the formally reported (to the WHO) RAF value of 13,650 [1]. This can potentially lead to the misunderstanding and underestimation of the actual effects of road accidents in terms of the road accident severity, the road accident related cost and other adverse impacts in Thailand. Consequently, a systematic standardized road accident database system is urgently needed in Thailand. Importantly, the best-estimated RAFs derived from the 3 RAF database sources were relatively comparable to those estimated values from WHO reports [1], [3]. These findings suggested that the WHO estimated RAF values were more reliable and realistic than the historically reported ones. Interestingly, from 2011 to 2015, the Thailand best estimated RAFs values gradually decreased from 21,996 to 19,960, respectively. However, in 2016, the RAFs values of 21,745 abruptly increased [31], [32]. In 2016, an increasing trend in RAFs can also be noticed in both MPH, NPB and RAVPCT database systems.

4.2 Modelling Road Accident Fatalities per Population in Thailand

Borsos et al. [13] conducted the time-series modeling of RAFs per 100,000 population as a function of motorization (vehicles per capita) for 26 countries during 1965 and 2009. All derived models illustrated the rise and decline patterns consistent with an inverted U-shaped curve. Borsos et al [13] concluded that the models can potentially be used to predict the RAFs per 100,000 population for most countries. The model was consequently selected to model the RAFs per 100,000 population as a function of motorization in Thailand based on the NPB database source during 1994 and 2016 (as shown in Figure 4). The derived RAF prediction model of Thailand is $D/P = 354.3\ (N/P)\ e^{-5.1(N/P)}$ (with $R^2 = 0.97$). Although RAF data from the traffic police database have been generally underreported, Mohan [7], [11] and many studies in the past [6], [28], [29], [30] adopted the RAFs derived from traffic police sources to prove the existence of the rise and decline pattern. Consequently, RAF data from the National Police Bureau (NPB) was used to develop the RAFs (per 100,000 population) prediction model as a function of motorization and illustrate the existence of the rise and decline pattern in Thailand. As shown in Figure 4, the derived RAFs prediction model for Thailand, the RAFs data from NPB (during 1994 and 2016) [27], the three RAFs database sources (during 2011 and 2016) [31] as well as WHO [1], [3] were plotted against the developed model. The RAFs per 100,000 population obtained from the NPB were reasonably well matched to the developed RAFs model. Both the RAFs per 100,000 population estimated by WHO [1], [3] in 2010 and 2013 and by the 3 database sources were much greater than Thailand modeled values. These findings suggested that the RAF prediction model is unreliable at predicting RAFs in Thailand.

Given the merits and rigorous precision of the model, this model was adopted and recalibrated against the best-estimated RAF values derived from the three RAF database sources of Thailand. The new RAF prediction model is $D/P = 254.68\ (N/P)\ e^{-2.676(N/P)}$ (with $R^2 = 0.93$). In this model, the motorization (registered vehicles per capita) can potentially be used to estimate the RAFs per 100,000 population in Thailand. Given the fact that there were limited RAF data (from the 3 data sources during 2011 and 2016) available, Thailand modified RAF model provided a better prediction. In addition, the modeled RAF values were also slightly lower than (but compatible with) the WHO estimated RAFs per 100,000 population in 2010 and 2013. It should also be noted that the current RAFs per 100,000 population in Thailand during 2011 and 2016 were clearly beyond the turning point (at 35.01 RAFs per 100,000 population and 0.37 vehicles per capita) and currently in a long-term declining trend period [5]. This suggests that Thailand has passed the maximum RAFs per 100,000 population (turning point) and reached a road safety situation such that as motorization (vehicles per capita) increases, the RAFs per 100,000 population decrease.

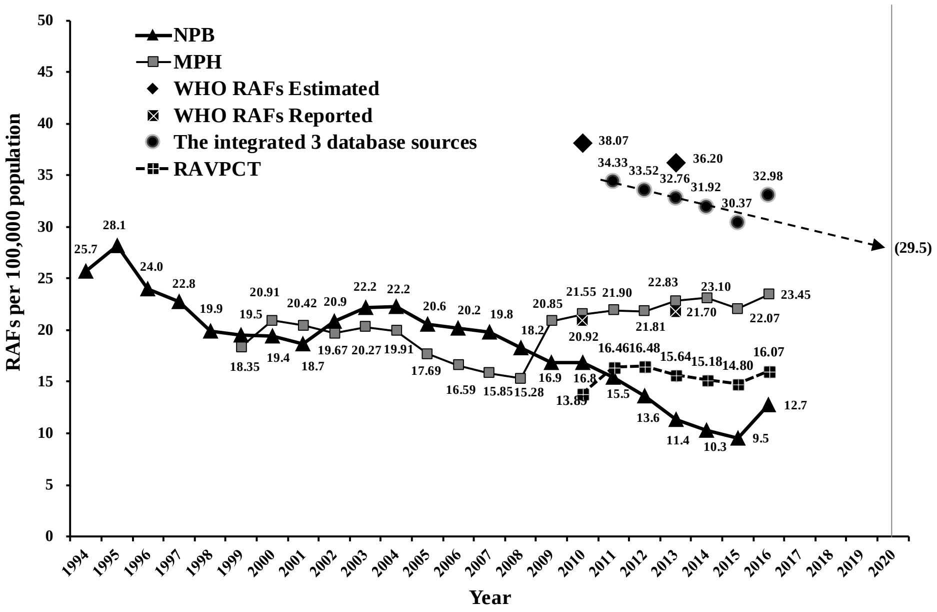

Fig.3 The Thailand RAFs prediction model as a function of motorization

Tab.2 Thailand estimated RAFs and RAFs per 100,000 population from 3 road safety database sources and WHO

Years	3 RAFs Database source*	Number of Population (x 10^6)	RAFs per 100,000 population	WHO Reports [1], [3]			
				Reported		Estimated	
				RAFs	RAFs per 100,000 population	RAFs	RAFs per 100,000 population
2010	-	63.9	-	13,365	19.3	26,312	38.1
2011	21,996	64.1	34.3	-	-	-	-
2012	21,603	64.5	33.5	-	-	-	-
2013	21,221	64.8	32.8	13,650	20.4	24,237	36.2
2014	20,790	65.1	31.9	-	-	-	-
2015	19,960	65.7	30.4	-	-	-	-
2016	21,745	65.9	33.0	-	-	-	-

* The 3- Road Accident Fatalities Database sources including Road Accident Victim Protection Company of Thailand (RAVPCT), National Police Bureau (NPB) and Ministry of Public Health (MPH) [27]

Based on the historical records of the number of registered vehicles [33] and population [34] in Thailand during 1994 and 2016, the predicted motorization in 2020 (the end of the decade of action for road safety) will be 0.60 vehicles per capita. Based on the modified Thailand RAFs prediction model and the predicted motorization in 2020, the estimated RAFs per 100,000 population will be 30.68 that is three times greater than the targeted one (10.0 RAFs per 100,000 population). This means that Thailand is not able to achieve the UN SDG 3 and its associated target 3.6 [2].

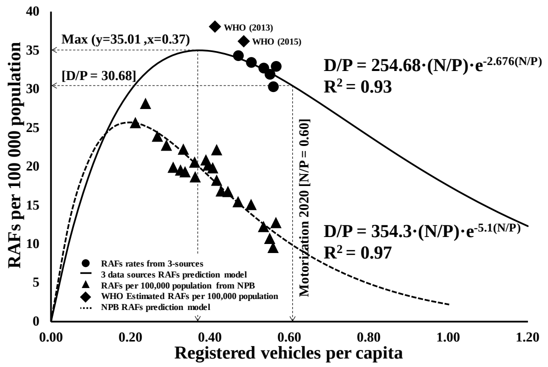

Fig.4 The Thailand RAFs prediction model as a function of motorization

5. CONCLUSIONS

Macro modeling of the RAF characteristics of Thailand and other Asian countries was conducted. The Asian (RAFs per population) prediction model of D/P = 313.9 (N/P) $e^{-1.9(N/P)}$ (with $R^2 = 0.625$) for 43 Asian countries was developed. This Asian RAFs prediction model is based on the cross-sectional modeling approach (using only one-year data from many countries). Another Asian RAF prediction models (RAFs per 10,000 vehicles) as a function of the motorization were also developed. The RAFs per vehicle prediction model of D/N = 1.524 $(N/P)^{-1.022}$ (with $R^2 = 0.73$) was derived. It was found that the greater the extent of motorization, the lower the estimated RAFs per 10,000 vehicles. Although the modeled Asian RAFs to a certain extent fitted to the estimated RAFs per 100,000 population data, the developed Asian RAFs prediction model could not properly be applied to RAF conditions in Thailand. Consequently, the Thailand RAF prediction model of D/P = 254.68 (N/P) $e^{-2.676(N/P)}$ (with $R^2 = 0.93$) was developed by using the limited estimated RAF data derived from three RAF database sources. Such RAF prediction models are fundamentally different from the previous RAFs prediction model developed for Asian countries. While the Asian RAFs prediction model is the cross-sectional based model, the Thailand RAFs prediction model is a time-series based model (considering many-years data for only one country). The developed model suggested that the current RAFs per 100,000 population of Thailand is clearly beyond the estimated turning point at 35.0 RAFs per 100,000 population and 0.37 vehicle per capita and is in the declining trend that is as the motorization increases, the RAFs per 100,000 population will decrease. The Thailand RAF prediction model is subsequently applied to predict the RAFs per 100,000 population of 30.7 in 2020. It is three times higher than the targeted one. On the basis of the macro analysis, it shows that Thailand will not be able to achieve the SDG target.

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