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The Future of Human Mobility

PREFACE

Dear Readers,

We trust you have a great year in 2015, and a happy beginning in the New Year 2016.

We truly apologize for the delay in the publication of these last two issues of 2015, the 3rd and 4th issues of Volume 6. Due to some technical glitches, our website was temporarily not available for a few weeks, but thanks to the dedicated work of our members, especially our webmaster team, Dr. Chalat Tipakornkiat, Assoc. Prof. Dr. Pawinee Iamtrakul and her hard working and able assistants, Chompoonut Kongphunphin, Puriched Kritayanukul, and Gussana Phromsonthi; we have now got it up and running again.

A big welcome to the September and December issues of Volume 6 of our online peer-reviewed International Journal of the Society of Transportation and Traffic Studies (JSTS). The 3rd issue consists of 5 interesting papers from various countries, India, Indonesia, Vietnam and Thailand. Four deal with the critical subject of road safety, two on road aspect and the others on human aspect. Another paper addresses the issue of school trips in Bangkok, a key parameter in the management of traffic congestion in Bangkok and other big cities.

The December issue comprises 5 papers which address different aspects of transportation. The paper from Latvia describes the long term performance of asphaltic mixes. The paper from Sri Lanka describes a new method for developing the driving cycle. Three papers from Thailand address the ongoing critical issue of road crashes which is arguably the number one public health issue for the country. One paper looks into the potential of defective motorcycles in causing road crashes. Another describes the use of Poisson and Binomial Regression Model in predicting road crashes on highway with a rest area. The final paper investigates the impact of road crashes as an important cause of household poverty and human trauma.

Again, we thank all authors who contribute to these issues of our journal and we express our gratitude to members of the International Editorial Board and reviewers for their valuable comments and continued supports. We trust our readers will enjoy and benefit from the articles in our online publication.

Again, a Happy and Safe New Year 2016 to everyone,

With Best wishes from all of us,

Professor Pichai Taneerananon
Chair of Editorial Board

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General Issue

PERFORMANCE EVALUATION OF DIFFERENT ASPHALT MIXES IN LONG-TERM OPERATION

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Abstract: Highway pavements have to withstand the traffic load under different seasonal and environmental conditions without excessive deformations (rutting and cracking). Either of these distress conditions can cause premature failure of the pavements. Hence, to reduce the possibility of forming such distresses in future, assessment of longevity of existing pavements is required. In 2001 eight experimental sections of road pavements (approximately 300 m each) were constructed using various asphalt concrete wearing course recipes on Riga bypass A4. Monitoring of these sections was performed during the following years. The structural condition of the sections has been continuously determined using Falling Weight Deflectometer (FWD) testing method. Measurements of skid resistance were performed using the Grip Tester. Surface texture and unevenness were characterized with the International Roughness Index (IRI) profilometer. Asphalt samples were cored from the asphalt for determining the performance properties in laboratory. This paper offers the assessment of changes and dynamics of performance of these different asphalt mixes during operation period of twelve years

Keywords: Road pavement A, Performance properties B, FWD C, Skid resistance D, Surface texture E

1. INTRODUCTION

A pavement's primary purpose is to provide a functional surface for a specific transportation need. The basic function is to withstand load, under different seasonal environmental conditions, without deforming or cracking. The function of the different layers in the pavement is to spread out the load on the surface and reduce its intensity with depth. Structural evaluation of pavement can be done in a number of different ways. In general, the deflection or the curvature of a pavement when subjected to a specific load is used for such measurement (Rajib B. Mallick and Tahar El-Korchi, 2009).

FWD is used by the road agencies for network level deflection survey for assessing the rate of pavement deterioration and to determine the timing for rehabilitation. Deflection basin parameters from FWD testing device are used extensively for assessing the structural integrity of a pavement and to back calculate the in situ layer moduli of a pavement. Pavement structural deformation is greatly dependent on the performance of the various pavement layers and the quality of the pavement subgrade (G. Chai, G. Lewer and G. Cancian, 2010).

Roughness of asphalt pavement affects the traffic safety, comfort of vehicle occupants and also generates dynamic load of heavy vehicles to give the pavement structure additional damage.

The pavement damage increases due to increase of IRI, and its increasing degree becomes more remarkable as travel speed is high (T. Kanai, K. Tomisawa and T. Endoh, 2010). Good skid resistance predominantly dependent upon the aggregate in the surfacing (Franēois de Larrard et al, 2008, T.Sofilic et al, 2010).

In recent years, many transportation agencies have started investigation the applicability of long term maintenance contracts, e.g. performance – specified maintenance contracts (PSMC) or performance – based warranty contracts. These maintenance contracts transfer the long – term responsibility for planning and executing maintenance work from agencies to contractors. The agencies are able to obtain better budget estimate, hedge the performance related risk, and reduce the cost of maintenance. And the contractors are able to implement innovative construction methods and management techniques to make a profit (Jih-Chiang Lee et al, 2013).

To assess serviceability of wearing courses of different asphalt mixes in conditions of specific traffic load, in 2001, 8 different mixtures of wearing course were built into the road A4 Baltezers – Saulkalne section 16.131 – 19.380 km. From 2001 until 2002, constant monitoring was performed to ascertain condition of these experimental mixes during operation:

- Visual assessment of condition;
- Measurements of skid resistance index of the surface with the Griptester equipment;
- Measurements of permanent deformation – ruts – with a laser profilometer (IRI);
- Measurements of surface evenness with a laser profilometer;
- Measurements of bearing capacity of the pavement (surface resilient modulus), performed with FWD;
- Borehole samples for laboratory testing to evaluate changes.

In the paper, the results of changes and dynamics of performance of different asphalt mixes during operation period of twelve years are presented, and suggestions to improve the current situation are also brought out.

2. CHARACTERIZATION OF TRAFFIC LOAD

Traffic intensity and axle load are one of the most important external factors influencing premature failure of the pavement. The traffic intensity and load data have been obtained from traffic statistic station, which is located at the Riga bypass A4 (Baltezers – Saulkalne). On figures 1 and 2 are shown traffic intensity and traffic content on Riga bypass A4.

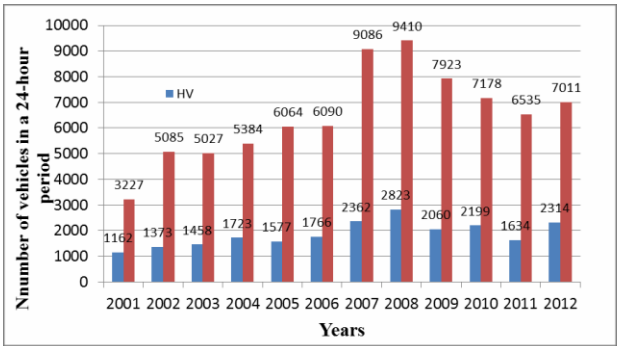

Figure 1. Traffic intensity on Riga A4 bypass

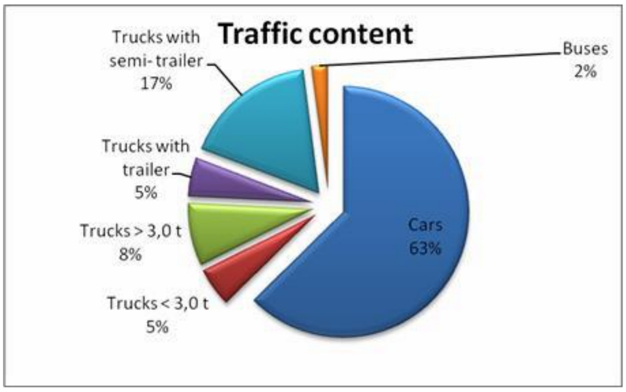

Figure 2. Traffic content on Riga A4 bypass

3. EXPERIMENTALN ROAD STRUCTURE

Experimental road constructions were prepared as follows. Reclaimed asphalt pavement (RAP) using cold recycling technology was constructed over an existing embankment soil. RAP, having layer thickness of 25cm, was treated with bitumen emulsion and Portland cement. Static deformation modulus of embankment and RAP sub-base layer were 170MPa and >170MPa respectively. Dense asphalt concrete AC 16 or stone mastic asphalt SMA 16 were used for asphalt pavement surface layer and ACb 32 was paved as base layer. Experimental road construction structure is shown in Figure 3.

4. EXPERIMENTAL ASPHALT CONCRETE MIXES

AC 16 and SMA 16 mixtures have been designed in accordance with Marshall Method by using unmodified bitumen B70/100 and aggregates (crushed granite, diabase and dolomite) of different origins. Aggregates were selected to contain the main natural stone materials which are conventionally used in asphalt concrete in Latvia. Properties of aggregates and bitumen have been investigated and their conformity to the technical specifications has been evaluated (Table 1 and Table 2).

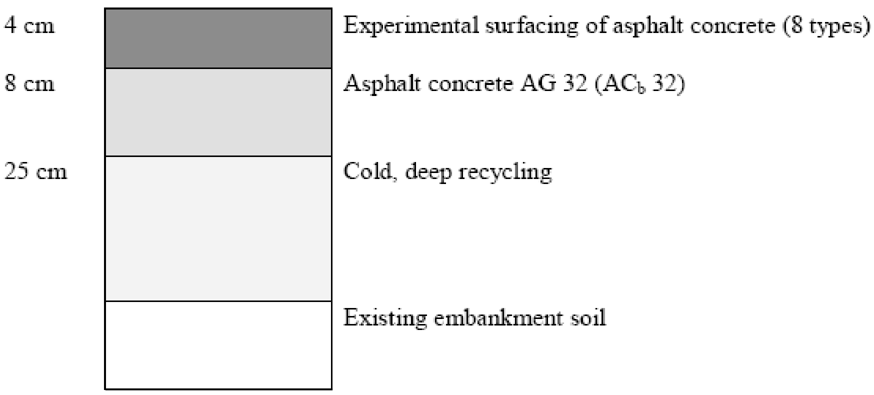

Figure 3. Experimental road structure

Table 1. Main properties of aggregates

No.	Aggregate		Properties: Micro-Deval value (M_{DE})	Properties: Nordic abrasion test (A_N)	Properties: Flakiness index (FI)	Properties: Los Angeles abrasion loss value (LA)	Mix No.
1.	Crushed "Lohja" (Finland)"	Granite Rudus"	88	-16.1	45.1	15	1, 7
2.	Crushed "Mikaševiči" (Belarus)	Granite	77	-22.5	47.3	16	8, 10, 12
3.	Crushed "Karlshamn" (Sweden)	Diabase	51 (-42%)	-9 (+44%)	52.5 (+11%)	15	11
4.	Crushed "Dolomitas" (Lithuania)"	Dolomite	50 (-35%)	-15 (+33%)	42.7 (+11%)	21	2, 9
Target value in accordance with technical requirements			-	14	15	20	

Table 2. Main properties of bitumen

No.	Bitumen	Initial in 2001: Penetration 25^0C [0.1mm]	Initial in 2001: Fraass breaking point [^{0}C]	Initial in 2001: Softening point [^{0}C]	Aging 163^0C: Change of mass [%]	Aging 163^0C: Penetration 25^0C [0.1mm]	Aging 163^0C: Softening point [^{0}C]	Aging 163^0C: Kinematic viscosity,	Mix No.: 1,2,7,8,9,,11,1	Mix No.: 10
1.	B70/100 "Nynas"	88	-16.1	45.1	0.14	60.2	51.0	287	x	
2.	B70/100 "Ķiriši"	77	-22.5	47.3	0.06	48.0	52.3	231		x
Recovered in 2012										
1.	B70/100 "Nynas"	51 (-42%)	-9 (+44%)	52.5 (+11%)	-	-	-	-	x	
2.	B70/100 "Ķiriši"	50 (-35%)	-15 (+33%)	42.7 (+11%)	-	-	-	-		x

The basic purpose of mix design is to select and combine the different components in such a way as to result in mix that has the most optimum levels of all relevant properties. Analysis of physical properties of asphalt concrete (the compaction degree), which is characterized by three volume parameters – voids (V), voids in mineral aggregate (VMA) and voids filled with bitumen (VFB) and two mechanical properties – compressive strength of specimens under the static load at temperature of 60^0C (Marshall stability) and displacement at the moment of specimen deterioration (Marshall flow), has been made for determination of optimum asphalt content.

In total eight (two SMA 16 and six AC 16) asphalt mixture have been designed in accordance with Marshal Method (Table 3).

Table 3. Asphalt concrete mixes

Recipe No.	Asphalt concrete mix type	No.	Mix content	Volume, %
1	AC 16	1.	Crushed granite “Lohja Rudus” fr. 8/16	14.3
		2.	Crushed granite “Lohja Rudus” fr. 6/12	31.5
		3.	Washed sand from quarry “Salenieki”	42.5
		4.	Filler “Brocēni”	7.1
		5.	Bitumen 70/100 “Nynas”	4.6
2	AC 16	1.	Crushed dolomite “Dolomitas” fr. 11/16	24.1
		2.	Crushed dolomite “Dolomitas” fr. 5/11	27.0
		3.	Washed sand from quarry “Salenieki”	38.5
		4.	Filler “Brocēni”	5.6
		5.	Bitumen 70/100 “Nynas”	4.8
7	AC 16	1.	Crushed granite “Lohja Rudus” fr. 8/16	14.3
		2.	Crushed granite “Lohja Rudus” fr. 6/12	13.3
		3.	Granite fines “Lohja Rudus” fr. 0/5	43.1
		4.	Filler “Brocēni”	4.5
		5.	Bitumen 70/100 “Nynas”	4.8
8	SMA 16	1.	Crushed granite “Mikaševiči” fr. 11/16	45.6
		2.	Crushed granite “Mikaševiči” fr. 5/11	27.5
		3.	Washed sand from quarry “Salenieki”	12.9
		4.	Filler “Brocēni”	8.3
		5.	Bitumen 70/100 “Nynas”	5.3
		6.	Celulose fibres	0.4
9	SMA 16	1.	Crushed dolomite “Dolomitas” fr. 11/16	45.2
		2.	Crushed dolomite “Dolomitas” fr. 5/11	29.0
		3.	Washed sand from quarry “Salenieki”	11.1
		4.	Filler “Brocēni”	8.3
		5.	Bitumen 70/100 “Nynas”	5.9
		6.	Celulose fibres	0.5
10	AC 16	1.	Crushed granite “Mikaševiči” fr. 11/16	24.8
		2.	Crushed granite “Mikaševiči” fr. 5/11	25.8
		3.	Washed sand from quarry “Salenieki”	37.5
		4.	Filler “Brocēni”	7.3
		5.	Bitumen 70/100 “Ķiriši”	4.6
11	AC 16	1.	Crushed diabase “Karlshamn” fr. 11/16	17.8
		2.	Crushed diabase “Karlshamn” fr. 8/11	21.4
		3.	Crushed diabase “Karlshamn” fr. 5/8	19.3
		4.	Washed sand from quarry “Salenieki”	30.2
		5.	Filler “Brocēni”	6.7
		6.	Bitumen 70/100 “Nynas”	4.3
12	AC 16	1.	Crushed granite “Mikaševiči” fr. 11/16	25.3
		2.	Crushed granite “Mikaševiči” fr. 5/11	18.8
		3.	Crushed granite “Mikaševiči” fr. 0/5	46.9
		4.	Filler “Brocēni”	4.7
		5.	Bitumen 70/100 “Nynas”	4.3

5. RESULTS

5.1 Skid Resistance

Skid resistance comes from a complex mechanism among the road surface, the tires, and the environment. Out of all the factors that affect the skid resistance of a surface, the texture is the only thing that can be controlled through engineering ways. Many studies which focused on the relationship between texture design and skid resistance showed that when the texture on the test surface is arranged orderly, its skid resistance will be affected by the shape, size and depth of the texture (Chai-Pei Chou and Ning Lee , 2013; T. F. Fwa et al, 2003). There are many types of skid resistance tester. Each of them obtains frictional values in completely different systems, and so far there are no reliable correlation equations to transform one system to another (A. E. Gendy and E. Shalaby, 2007).

Skid resistance values obtained from eight experimental sections are illustrated in Figure 5. Sections 1, 2, 9 and 10 showed the lowest skid resistance values – skid resistance index below 0.5. The results confirm strong relationship between pavement functional properties and aggregate properties: asphalt concrete mixes containing dolomite aggregate showed the lowest skid resistance, 0.2 (Sections 2 and 9), while sections containing crushed granite and diabase aggregates (7, 11 and 12) showed highest skid resistance value, 0.6. It is important to note that replacing fine crushed granite and diabase aggregates with washed natural sand caused significant drop in skid resistance: the index decreased from 0.6 (Section 7) to 0.4 (Section 1) and from 0.7 (Section 12) to 0.5 (Section 8).

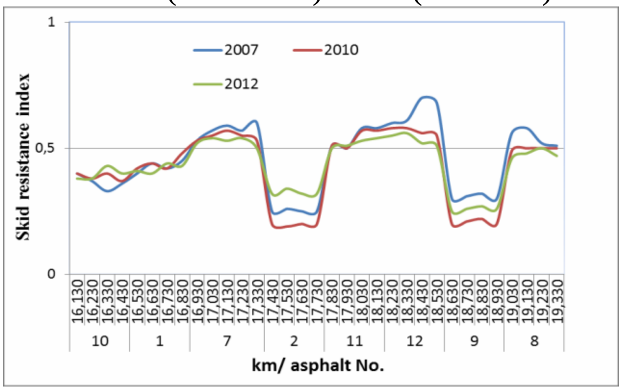

Figure 4. Diagram of skid resistance index

5.2 Load Bearing Capacity Of Pavement

A Falling Weight Deflectometer (FWD) equipment was used to assess the current structural pavement condition. The FWD applies a dynamic load on the pavement surface by dropping a weight that is transmitted through a circular loading plate. Such dynamic load simulates the effect of a wheel load on the pavement surface by generating temporally pavement deformations, which are recorded by sensors located radially at 2.5 m from the point of application of the load (S. M. Sargand et al, 2013). The magnitude of the impulse load transmitted by the FWD device to the pavement can vary from 30 kN to 250 kN by varying the weight and drop height (S. Sargand, 2002). The FWD testing method is widely used because is easy to implement, reliable, and cost-effective with respect to other methods (W. Edwards et al, 1989).

Measured surface deflections were used in back-calculating "effective" modulus of pavement layer witch are assumed to represent the in-situ strength or conditions of the layers after long term performance.

The Dynatest ELMOD 5 computer program, developed by Dynatest, was used as the back-calculation procedure in this study. ELMOD analyzes the pavement response from the by determining the modulus, stress and strain of each significant layer.

The load level used for the FWD drops was 50kN, which corresponds to a load pressure of approximately 750 kPa. Seismic geophones which monitor the deflections were placed at 0 mm, 200 mm, 300 mm, 450 mm, 600 mm, 900 mm, 1500 mm, 1800 mm and 2100 mm offsets to measure the full pavement deflection basin. The testing was performed at ambient temperatures of 10^{0}C to 11^{0}C. Figure 5 show modulus of elasticity for surface layers of experimental sections. The mean value of elasticity modulus for experimental sections is approximately 1000MPa. However, it is important to note that modulus of elasticity for the same experimental section changed significantly. This may be caused by inhomogeneity of bituminous and unbound layers.

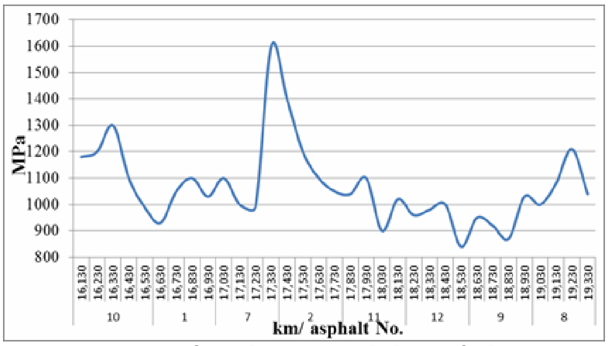

Figure 5. Surface layer modulus of elasticity

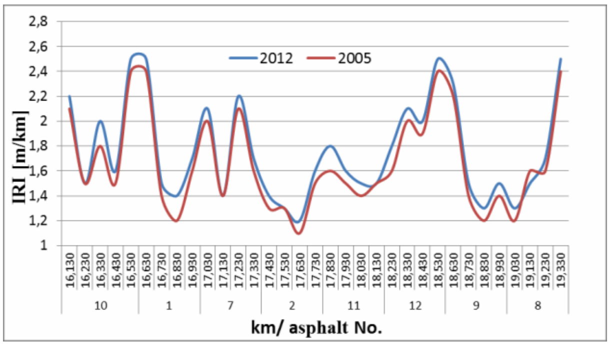

Figure 6. Road surface evenness

5.3 Pavement Surface Evenness

Pavement surface roughness is a major concern associated with driving quality. Furthermore, pavement roughness indicates pavement surface deformation, which may affect pavement drainage, drive safety, etcetera (Jyh-Dong Lin et al, 2003). Since pavement roughness causes an increase in vertical stress received by pavement and the aggravation of pavement fatigue, pavement roughness certainly accelerates pavement distress deterioration. Any pavement distresses will also result in a deterioration of the pavement roughness index value. Thus, the above shows that pavement distress and pavement roughness have a mutually causal relationship, affecting one another in both directions (M. S. Janoff et al, 1985). The International Roughness Index (IRI) is the roughness index most commonly obtained from measured longitudinal road profiles. The roughness measurement is performed by the Roughness Subsystem, which consists of a roughness computer, laser SDP software, the accelerometer, and the roughness lasers.

The IRI results are shown on figure 6. The two experimental sections (10 and 9) in which asphalt concrete mixes contain dolomite and granite aggregates with washed natural sand showed the highest surface evenness mean value: 1.9m/km for Section 10 and 2.3m/km for Section 9. However, IRI values within the same experimental sections changed significantly.

5.4 Laboratory Testing

A wheel tracking apparatus was used to simulate the effect of traffic and to measure the plastic deformations of the borehole asphalt concrete samples. Tests were performed according to standard EN 12697-22 method B (wheel tracking test with small size device in air). This test method is designed to repeat the stress conditions observed in the field and therefore can be categorized as simulative. The resistance of asphalt mixture to permanent deformation is assessed by measuring the rut depth and its increments caused by repetitive cycles (26.5 cycles per minute) under constant temperature at 60°C. The rut depths are monitored by means of two linear variable displacement transducers (LVDTs), which measure the vertical displacements of each of the two wheel axles independently as rutting progresses (V. Haritonovs et al, 2013).

According to research of number of scientists, ruts with the depth of ≥ 13mm become dangerous, when the vehicle speed exceeds 80km/h (S. Erkens, 2002). Rutting measurement results illustrated in figure 7 show that only in Sections 1 and 10 ruts deeper than 13mm developed. Crushed granite and diabase aggregates were replaced with washed natural sand in these sections.

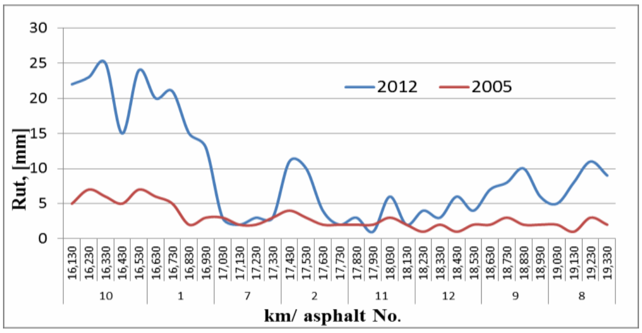

Figure 7. Rut depth

6. CONCLUSIONS

Indexes of performance properties of these experimental mixes, as well as, other results were used for development of "Road Specifications 2012" and "Road Specifications 2013".

Results of performance of the experimental pavement sections of a wearing course were taking into consideration when defining the following qualitative parameters and requirements:

- evenness of a wearing course (IRI) when defining different values in projects of periodic maintenance and new construction sites;
- skid resistance values in different levels of traffic intensity;
- resistance to permanent deformations (WTSAIR) in different levels of traffic intensity;
- resistance to wear from studded tyres of aggregates used in a base course (also in surface dressing)

The results demonstrated a strong relationship between functional properties of pavement and aggregates. Asphalt concrete mixes containing dolomite aggregate showed the lowest skid resistance while mixtures containing crushed granite and diabase aggregates had the highest skid resistance. It was found that replacing fine crushed granite and diabase aggregates with washed natural sand caused skid and rut resistance to drop significantly. However, the performance characteristics within the same experimental sections changed significantly. This is likely to be caused by the inhomogeneity of bituminous and unbound layers.

7. ACKNOWLEDGEMENT

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MOTORCYCLE DEFECTS ON MOTORCYCLE SAFETY IN THAILAND

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ABSTRACT:

This paper presents a review of past research works that examined factors affecting motorcycle safety, focusing on: human errors, infrastructure defects, vehicle defects and their interaction which contribute to motorcycle crashes, with the aim of highlighting the need for more research on the effect of motorcycle defects safety. Overview of the global motorcycle crash situation was conducted using data and various information sources. Non-English publications on motorcyclists and motorcycles were consulted. Sources of motorcycle accident information in Thailand included those of the Royal Thai Police, Department of Land Transport, and Road Accident Victims Protection. Key words used in the search included motorcycle safety, motorcycle crash/accident, motorcycle stability/balance, motorcycle defects, and motorcyclist. The results show that human errors, speeding, alcohol impairment, disregard of traffic laws, and inexperience are the most common factors involved in a motorcycle crash. Although vehicle defects such as defective components played a relatively small part of all the factors affecting motorcycle crash, but the effect was significant and increasing. One finding was clear from the review, very few research works have been done on the mechanism of motorcycle crashes due to motorcycle defects, especially those involving light weight motorcycle (101-125 cc) which is the most popular model in Thailand. Thus the study of the influence of the motorcycle and its components on a crash is needed. The outcomes of the research will help identify safer motorcycle components, including betters tire size, anti-lock braking system, crash bar, stability control system, and personal protective equipment.

Keywords: Motorcycle Crash, Motorcycle Safety, Motorcycle Defects, Motorcycle Stability, Motorcyclist

1. INTRODUCTION

Road crash data over the past 7 years show that average number of motorcycle accidents was more than personal car accidents by almost 20% (Royal Thai Police, 2013). Since motorcycle can easily become unstable, good vehicle control skills of motorcyclists are necessary. Road infrastructure elements such as road geometry, roadside installations, lighting and visibility, and pavement surface condition, if in poor conditions can increase the risk of motorcycle riding.

Although motorcycle seems to be a dangerous mode of transport, the use of motorcycle in Asian countries has been continuously increasing in popularity. The notable increase in motorcycle registrations has been reported in a number of countries in this region including Viet Nam, Malaysia, Indonesia and Thailand. The strong points of this mode of personal transport that make it more acceptable are economical vehicle, saving travel time, and ease of parking. The consequence of the popularity of this mode of transport means that road traffic accidents are increasing and currently users of motorcycles are the main fatalities globally.

In recent years, WHO announced that road traffic injuries was the eight leading causes of death and the leading cause of death in young people aged 15-29. Moreover, the statistical trend was predicted to rise to the fifth leading cause of death in 2030 (WHO, 2013).

The implementation of road safety strategies such as strengthening institutional capacity, improving road safety network, improving vehicle safety and developing better road user behaviors were driven to reduce the road traffic accident. However, on motorcycle characteristics, including its instability, lack of protection, and multitask controlling, and warning system, there is a need to address them as they can help improve safety of motorcyclists.

This paper provides a review of comprehensive research works that addressed the issue of motorcycle safety. Both qualitative and quantitative studies were analyzed. Key elements contributing to motorcycle crashes: human errors, infrastructure defects and vehicle defects and their interaction were described in some detail.

2. MAGNITUDE OF THE PROBLEM

The most vulnerable road user group in Thailand and most Asian countries is motorcycle users. The statistics of WHO (see Figure 1) shows that four Asian countries (Vietnam, Malaysia, Indonesia, and Thailand) have more than one motorcycle for every four people. There were nearly 300,000 fatalities as a result of motorcycle crashes in 2010; seventy-eight percent of which occurred in Asian countries. Figure 2 shows that Thailand has the highest fatality rate of 28 per 100,000 populations, nearly twice that of Lao, Vietnam and Malaysia (Nguyen, 2013).

The estimated road traffic death rate in Thailand has been recently published by the University of Michigan which shows the rate at 44 per 100,000 populations, the world's second highest, using the 2008 data (Sivak and Schoettle, 2014). However, according to the 2013 WHO report, using the 2010 data, the rate for Thailand was 38.1 per 100,000 populations which ranked third in the world (WHO, 2013); there is a slight improvement, but the figure is still far too high compared to its ASEAN members. Details of ASEAN fatality rate in the WHO 2013 report are shown in Table 1; and the University of Michigan 2008 statistics are given in Table 2. The Thai fatality rate, in comparison, was more than 46 percent higher than that of Malaysia with similar income level and more than some 7 times higher than that of Singapore.

The trend of road traffic crashes in Thailand is shown in Figure 3 using the police data (Royal Thai Police, 2013). It can be seen that in the period between 2006 and 2012, a downward trend was recorded in the number of motorcycle and personal car accidents. The sharp drop started in 2009 to 2011 and then remained stable in the year after. For the past three years, 2010-2012, motorcycle crashes have fluctuated between 54-35% of the total crashes. On average there were about 85,000 road traffic accidents and motorcycle crash proportion was about 54% or 49,000 cases. Significantly, of all the road users killed or injured, about 80 percent involved motorcycle users (Rungpueng et al., 2012).

Additionally, data from the Road Accident Victims Protection (RVP, 2013) gave details of the claims involving motorcycle users from 2011 to 2013 as shown in Figure 4. There was a fluctuation in the total number of injuries consisted of slightly, moderate and serious injury, with more than 200,000 per year. The number of fatality during in 2011 to 2012 leveled off at about 8,000 cases before declining to nearly 6,000 in 2013. Fatality numbers were on average 7,400 cases per year or roughly 20 Thai motorcyclists die on the road traffic accident every day.

In spite of the high rate of motorcycle fatalities, registered numbers of Thai motorcycles have been increasing with over 1 million units sold annually; the cumulative numbers are almost 20 million vehicles in 2012. Furthermore, Department of Land Transport's statistics (see Figure 5) show the high popularity of the 125 cc model. This model has been closely associated with motorcycle fatalities and injuries in Thailand. The high rate of motorcycle fatalities and the high demand of motorcycle usage make it challenging to reduce the number of fatalities.

However, this serious situation should be looked at under the limitations of the present road safety regulations, traffic laws, medical care, road design and motorcycle design. An effective system for improving road safety should be established by integrating all angles. For example, the authorities should evaluate the failing factors. The existing related traffic rules and regulations should be analyzed and improved.

3. THE CAUSE

Road crashes are a result of at least one of the 3 elements: human errors, infrastructure defects and vehicle defects, however, these elements often form a chain of events leading to a crash. For example, the combination of a defective road surface and poor rider handling ability or unstable motorcycle can increase the potential of crashes. To effectively respond to the cause of road traffic crashes, research is needed to gain a better understanding and evaluate the effectiveness of the implementation of road safety actions. The starting step should be to study what have been done in this area. Therefore, the following sections provide a detailed literature review relating to human errors, infrastructure defects and vehicle defects.

3.1 HUMAN ERRORS

Motorcycle riders are considered the most crucial component in motorcycle riding. Among three influencing factors of traffic accident; human errors, infrastructure defects and vehicle defects, Hurt who carried out an in-depth investigation into 900 motorcycle accidents and reviewed 3,600 traffic accident reports of motorcycle accidents found that the common contributing factor of all motorcycle collisions in Los Angeles during 1975-1980 was the human fault (Hurt et al., 1981). As motorcycle riders often appeared inconspicuous in traffic, and motor vehicle drivers failed to detect them, this led to many right-of-way accidents involving motor vehicles and motorcyclists. A decade later, the circumstances of US motorcycle accidents were remarkably different.

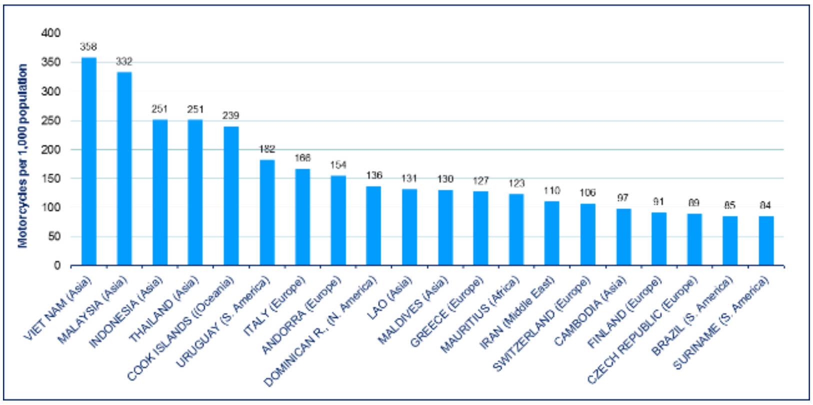

Figure 1. The leading 20 countries with high number of motorcycles per 1,000 population (Source: Nguyen, 2013, compiling from WHO 2013 data)

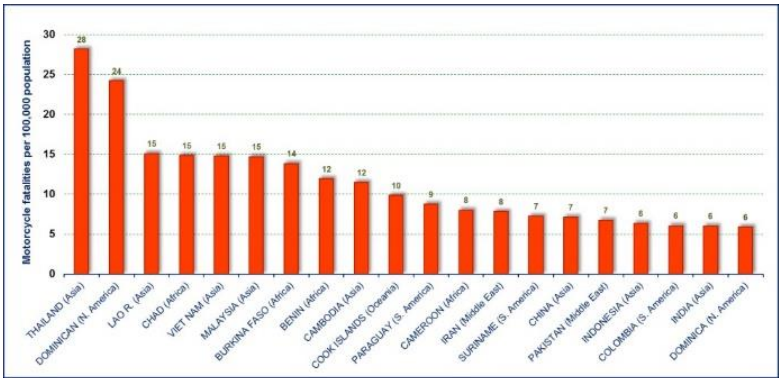

Figure 2. Twenty countries with the highest rate of motorcycle death per 100,000 population (Source: Nguyen, 2013 compiling from WHO 2013 data)

Table 1. ASEAN Road Traffic Deaths and Fatality Rate

Country	Income Level	Reported number of road traffic death	Estimated road traffic death rate per 100,000 population
Brunei Darussalam	High	46	6.8
Cambodia	Low	1,816	17.2
Indonesia	Middle	31,234	17.7
Lao People's Democratic Republic	Middle	767	20.4
Malaysia	Middle	6,872	25.0
Myanmar	Low	2,463	15.0
Philippines	Middle	6,739	9.1
Singapore	High	193	5.1
Thailand	Middle	13,365	38.1
Viet Nam	Middle	11,859	24.7

Source: Compiled from (WHO, 2013)

Table 2. Fatality Rate per 100,000 population from Road Crash (Sivak and Schoettle, 2014)

Rank	Country	Rate
1	Namibia	45
2	Thailand	44
17	Malaysia	30
	Global average	18
170	Singapore	6

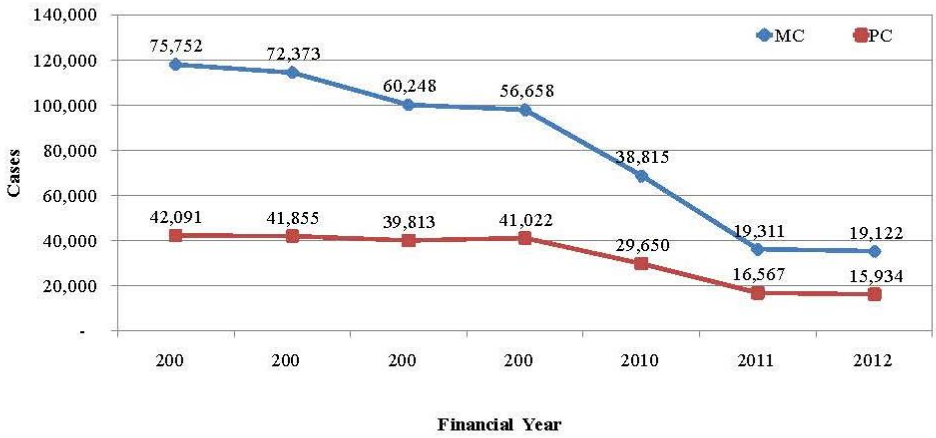

Figure 3. Road Traffic Crash Situation in Thailand (Royal Thai Police, 2013)

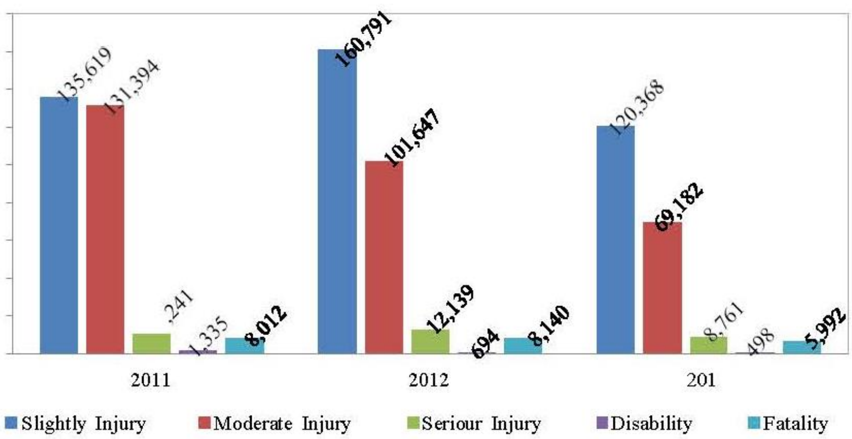

Figure 4. Claims Involving Motorcycle Users (RVP, 2013)

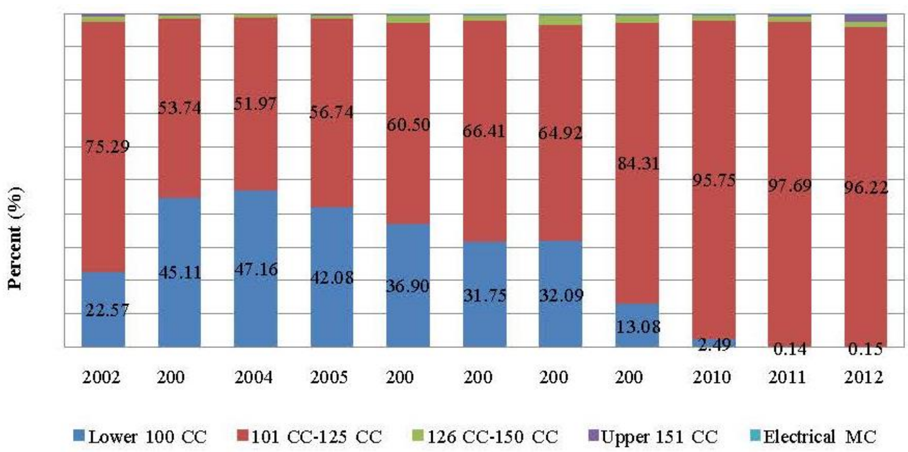

Figure 5. Percentage of Each Type of Registered Motorcycles (Department of Land Transport, 2013)

A study reported that over the period of 1996-2006 the numbers of motorcycle fatality in USA had doubled and also the major contribution factors were human errors. Speeding and high alcohol level in blood hit the peak of motorcycle crash causation (Padmanaban and Eyges, 2009).

Along with human errors in motorcycle crashes in USA, the European research team, The Motorcycle Accident In-Depth Study (MAIDS) found similar contributing human failures involving powered-two wheeler (PTW) accidents in Europe. These failures were categorized as (1) perception failure, (2) comprehension failure, (3) decision failure and (4) reaction failure. Approximate 37 % of PTW collisions were caused by human errors (ACEM, 2006).

For the motorcycle accident situation in South East Asia, the trend in fatality rate in motorcycle accident in Malaysia has continued to grow since early 0's. Careless driving was the biggest proportion of driver's faults that affected fatality rate of motorcycle crashes. It was noticeable that a violation to traffic light by motorcycle riders had increased about threefolds (MIROS, 2011a and 2011b).

To increase the depth of understanding of motorcycle crash characteristics in Thailand, since the early of 2000s a number of related research works have been conducted to identifying human factors associated with motorcycle crash causation. The key finding by Rojviroon was that young motorcycle riders had poor safe driving behavior (Rojviroon, 2006). Their habit of poor driving need to be improved. Some similar results were reported regarding poor riding. A study by Ngamsom et al. shows that the young motorcyclists in the 18-35 age group tend to violate traffic laws more than other age groups (Ngamsom et al., 2011). Moreover, it was stated that a key risk element, the inexperience of riders, would seem a primary contributing factor to motorcycle crashes (Pibool and Taneerananon, 2012).

In addition, Kasantikul found that alcohol was a major cause of motorcycle crashes (Kasantikul et al., 2005). Most of alcohol effects were evident in the "loss of control" motorcycle crashes resulting in run-off the road or single vehicle crash. Contrary to conventional findings, Saisama found that most of shuttle-motorcycle riders obeyed the traffic laws, gave responsible services to their customers and possessed acceptable behaviors regarding, emotional control, awareness of protective behaviors against accidents from motorcycle riding (Saisama, 2005).

From the literatures, it can be concluded that most young motorcycle riders in Thailand have been riding without proper concern of and awareness of road safety. It was suggested that education and the safety riding program should be used to bridge the safety gaps for motorcyclists in order to reduce the motorcycle related injuries and fatalities (Woratanarat et al., 2013). Even though there were many attempts to deal with the human factors in motorcycle crashes, however, it is still a great challenge facing the country as the registered number of motorcycles continue to increase (Figure.6). More research in this area is still needed to effectively deal with the situation for the clear purpose of saving the life of motorcycle users.

The summary of available literatures was shown in Table 3 with respect to the behavioral of young motorcyclists, senior motorcyclists, shuttle-motorcycle riders and safe riding motorcycle instructors. It is evident that the experimental research on Thai motorcyclist behaviors is an under-research issue. The larger proportion of research was conducted on the survey and correlation analysis. There were a several behaviors topic such as attitude on safe riding, receptiveness to traffic law, risk and violent patterns.

Table 3. Summary of literature on human error factor involving in a motorcycle crashes

Authors	Title	Method/ Study design	Sample Size	Main Findings
ChoonWah Yuen et al. (2013)	*Investigation on Motorcyclist Riding Behaviour at Curve Entry in Down Slope Terrain*	Measure the variables related to riding behaviour of young	39	▸When riding to curve, ▸speed was reduced by applying higher brake
Kasantikul et al., 2005	*The Role Of Alcohol in Thailand Motorcycle Crashes*	On-scene, in-depth investigation and reconstruction	1082	▸Alcohol was the most ▸frequent cause of motorcycle crashes
Ngamsom et al., 2011	*Study of Motorcycle Driver Characteristics on Traffic Law Violation*	Interview of motorcyclists;	8285	▸Young motorcyclists ▸(aged 15-35) were not strictly obeying traffic ▸laws
Pibool and Taneerananon, 2012	*A Study of Crash Risk of Motorcyclists*	Analysis of collected field data and secondary data collected by police station and hospital	440	▸91 percent of ▸motorcycle crash were consequence of human errors ▸Road defects ▸contributed to 39 percent of motorcycle crashes ▸18 percent of motorcycle defects led to motorcycle crashes
Rojviroon, 2006	*Psychological and Safety Belief Factors Related to Safety Behavior In Motorcycle Driving of The Young*	Interview young student 10th-12th grade school level	375	▸Intention, carefulness, ▸good habit were main factors and could be ▸described as safe driving behavior about 62.48%
Saisama, 2005	*Protective Behaviors Against Accident in Shuttle- Motorcycle Riding in District of Mueang Nakhon Pathom Province*	Interview of shuttle-motorcycle riders	364	▸The shuttle-motorcycle ▸riders had an average knowledge of traffic law and high protective behaviors was high
Woratanarat et al., 2013	*Safety Riding Program and Motorcycle-Related Injuries in Thailand*	Interview of participants of safety riding program	3250	▸Motorcycle-related ▸injury could be reduced ▸by a safety riding program with 30% of license ▸course and 29% of ▸instruction course, respectively

3.2 INFRASTRUCTURE DEFECTS

Providing a safe road is a government responsibility. In terms of roadway or infrastructure safety, the impacts of roadway barrier or median on safety of motorcycle riders were higher than other automobile occupants. Even though they were designed to protect road users from road hazards, inadequate provisions of these safety devices had contributed to many roadside fatalities. In his in- depth investigations into roadside safety of highways in South Thailand, Somchainuek came to the conclusion that in thirty percent of the roadside crashes, the victims were killed by hitting roadside trees in clear zone, and motorcycle's involvement was three percent. (Somchainuek et al., 2012, 201)

Another study conducted in Australia and New Zealand show that the major causes of motorcyclist deaths involving roadside barriers were inappropriate speed and high level of alcohol or drug impairment (Jama et al., 2011). They found that single vehicle crash of a young male rider resulted in the most frequent fatality; and proposed that special consideration in the road design, especially at bends could help significantly reduce the number of motorcycle crashes on bends.

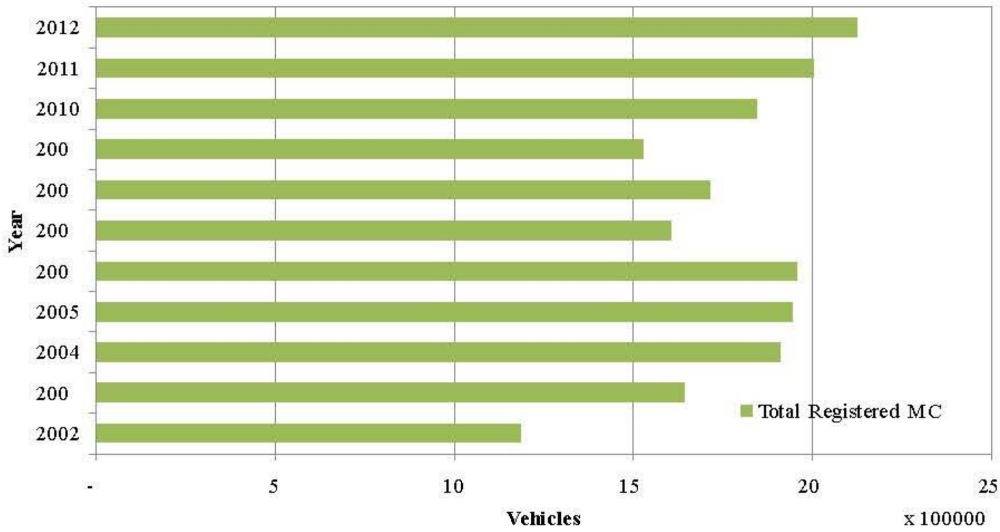

Figure 6. Registered Motorcycles (Department of Land Transport, 2013)

3.3 VEHICLE DEFECTS

Increasing vehicle safety is one of the five pillars of actions in the WHO global plan for decade of action for road safety 2011-2020. While the main thrust of vehicle safety is currently focused on the implementation of vehicle crash avoidance technologies; very few research and development are focused on the motorcycle. This is unfortunate given the fact that the motorcycle is used extensively worldwide, and particularly in Asian region where it outnumbers cars and pick-ups by several folds.

Study by Kasantikul show that about 12.5 percent and 25 percent of motorcycle crashes in Bangkok and five upcountry provinces were single vehicle collision respectively. The highest crash types were rear-ending, falling on the roadway and running off the road, respectively (Kasantikul, 2001a, 2001b). The scooters or light weight motorcycles with engine capacity between over 50 cc to under 250 cc were the most common motorcycle involved in crashes. While a number of factors contributed to these crashes, motorcycle defects, especially stability of the motorcycle was identified as a main impact factor (ACEM, 2006). Similarly, vehicle defects influencing motorcycle crashes were found to be substantial at 18 % (Pibool and Taneerananon, 2012). It is fair to say that these small motorcycles had less stability control systems and other safety instruments than those with larger engines e.g. Heavy Scooter over 250 cc, Sports Motorcycle and Touring Motorcycle with engine around 1000 cc. or more.

The stability of a motorcycle is influenced by inertia, gyroscopic effects, and righting effect due to trail and centrifugal force. While the motorcycle mass and velocity have significant impact on inertia effect, a study has shown that the moment of inertia of the wheel, steering moment, roll moment and yaw moment were particularly crucial components of gyroscopic effects (Cocco, 2004). In order to achieve stability, a motorcycle needed to have the control of driving dynamic properties at a lateral acceleration force greater than the available friction (Seiniger et al., 2012).

To identify dynamic instability conditions of motorcycle, roll angle, yaw angle and pitch or steering angle were normally used (Nenner et al, 2008, Ghosh and Mukhopadhyay, 2009, Chelli et al., 2010, Jamieson et al., 2013). Roll angle (see Figure 7) in particularly was a vital parameter with strong influence on the motorcycle stability. The degree of the angle normally depended on lateral acceleration and gravitational force of a motorcycle. Friction forces between the tire and road surface play an important role in motorcycle lateral acceleration. A flip-over of the two wheel vehicles could easily occur whether a small perturbation of a roll momentum was generated (Seiniger et al., 2010).

All dynamical parameters such as the wobble oscillations could be characterized by steering torque, steering angles and vehicle speed. Besides, the value of frequency and damping of motorcycle could generally express its stability. These normally can be measured by using appropriate sensors (Seiniger et al., 2010). Therefore, the experimental design and methodology on riding test need to be carefully considered for getting accurate data.

Many research works on motorcycle stability were conducted on larger machines such as HONDA CBR 1100XX, high performance sports motorcycle and BMW F800S (Jamieson et al., 2013, Cheli et al., 2010, Seiniger et al., 2010). However, there are very few research works on scooters or light weight motorcycles like the popular models in Thailand. It is important to gain good understanding of the stability of light weight motorcycle as in Thailand's model; in addition, other motorcycle defects which could potentially lead to motorcycle crashes should be investigated as a means to reducing motorcycle users' fatalities. To this end, an instrumented motorcycle should be the first priority option as it can help provide a strong, precise and consistent method in collecting essential data, as suggested by Yuen (Yuen et al., 2013).

Figure 8 displays the road traffic accident statistics happened in Thailand during the period of 2006 to 2010. The data was compiled from four main causes that initiate the accidents: (1) speeding, (2) alcohol, (3) vehicle defects, and (4) improper passing. Overall, it can be seen that the speeding was the most threat, except for the years of 2011 and 2012 that the highest number of accidents were caused by the vehicle defects. When considering for the whole period, it is clearly seen that from the years 2006 to 2010 the annual accidents caused by the vehicle defects were just approximately 1,100. Then, it was dramatically increased to about 12,000 for the years 2011 and 2012. This abnormal trend led the authors to further investigate the matter. It was found that, after discussing with the personnel responsible for compiling the data, there were some changes with respect to the definitions of vehicle defect thereby generating the very unusual data. As such, this particular cause should be further studied and clarified. Regarding the improper passing, it was observed that the annual accidents caused by this were relatively consistent. For the alcohol, however, the data shows the very scattered trend.

Table 4 summarizes studies of motorcycle stability both experimental testing and simulation modeling. The studies by Cheli and Seiniger focused on preventive systems (Advanced Driver Assistance System) and active safety system (Motorcycle Anti-Lock Brake Systems) for motorcycle. The simulation modeling focused motorcycle stability control. There are comparatively few experimental studies on small engine capacity motorcycles like the light weight motorcycle or scooter widely used in Thailand in attempts to examine the stability during all riding conditions.

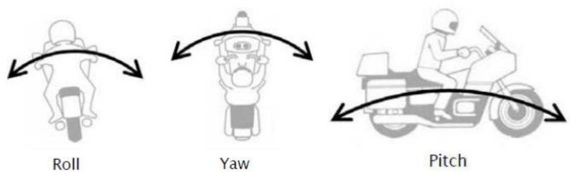

Figure 7. Roll, Yaw and Pitch (Jamieson et al., 2013)

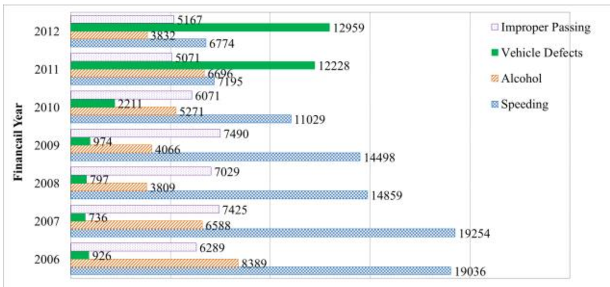

Figure 8. Four Major Causes of Thai Road Traffic Accidents (Royal Thai Police, 2013)

Table 4. Studies investigating the stability of motorcycle

Authors	Title	Method/ Experiment/ Vehicle	Performance Measure	Main Findings
Cheli et al. (2010)	*Motorcycle Dynamic Stability Monitoring During Standard Riding Conditions*	a high performance sports motorcycle	▸ steering angle ▸ lateral acceleration	▸ Advanced Driver ▸ Assistance System (ADAS) able to identify a dynamic instability of a generic motorcycle
Ghosh and Mukhopadhyay (2009)	*Stability Analysis of a Two-wheeler during Curve Negotiation under Braking*	Study the response of roll angle by using the simulation	▸ Root locus at various speeds under different ▸ braking conditions ▸ roll angle	▸ The roll behavior deteriorate with the ▸ applying of braking force ▸ during a turn ▸ The increased mass of motorcycle and the ▸ reducing of front wheel trail ▸ could lead to more unstable condition of motorcycle
Jamieson et al. (2013)	*Stability of motorcycles on audio tactile profiled (ATP) roadmarkings*	Full-scale physical test with HONDA CBR 1100XX and simulation modeling with PC-Crash	▸ vertical rear wheel load ▸ vertical accelerations of the front & rear wheel ▸ pitch, roll, and yaw ▸ longitudinal (x-axis), lateral (y-axis), and ▸ vertical (z-axis) ▸ accelerations	▸ No evidence refers that ▸ ATP roadmarkings create any instability matter for motorcycle
Nenner et al. (2008)	*Robust Stabilization of an Unmanned Motorcycle*	Develop an equation of motion for a motorcycle and design a robust cascade control using A 50 cc scooter with automatic variable transmission as the experimental system	▸ throttle ▸ brake force ▸ roll angle ▸ roll rate ▸ steering angle ▸ 24 physical properties of ▸ motorcycle	▸ The simulation model of unmanned motorcycle using a ▸ robust cascade feedback ▸ controller could be stabilized the motorcycle for velocity ranging from 2 m/s to 6.5 m/s.
Seiniger et al., 2010	*Perspectives for motorcycle stability control systems*	Detect critical driving situation of Motorcycle Anti-Lock Brake Systems of BMW F800S	▸ ▸ throttle ▸ ▸ brake force ▸ ▸ roll angle ▸ ▸ roll rate ▸ ▸ steering angle ▸ ▸ 24 physical properties of ▸ motorcycle	▸ ▸ Motorcycle Anti-Lock Brake ▸ Systems (ABSs) have a positive effect on motorcycle and have the potential to reduce motorcycle fatalities ▸ ▸ Vehicle dynamics control systems will be possible ▸ device for common
Zhang et al. (2011)	*Balance Control and Analysis of Stationary Riderless Motorcycles*	Analysis and estimated the domain of attraction (DOA) by using the Rutgers autonomous motorcycle	▸ ▸ attitude rates and acceleration ▸ ▸ steering angle ▸ ▸ roll and yaw angle	▸ ▸ The balancing control of stationary motorcycle is quite ▸ hard due to the DOA estimate is small.

4. FUTURE WORKS

The general question considered here is: Do the Thai light weight motorcycles or scooters have different safety standards to similar models in other countries? Hence, the author's future work will involve in-depth review of related research works in order to investigate critical factors in motorcycle crash causation. Focus will be given to the vehicle factors that dominate the motorcycle stability.

Experiments will be conducted to examine the potential dynamic properties of motorcycle on its stability. These comprise two parts: the subsystem and the whole vehicle. For the first part, the effect of wheel/tire combination on the gyroscopic moment will be investigated using the pendulum method. For the second part, riding tests will be conducted to determine the stability. The strength run test and the slalom test with instrumented motorcycles will be verified in order to measure the frequency and damping of the motorcycles. The expected outcome of this study will help create better understanding of key factors influencing motorcycle stability.

5. DISCUSSION AND CONCLUSIONS

It is obviously clear that most studies on motorcycle safety, particularly in Thailand, have focused more on motorcycle rider's behavior aspect than other elements of motorcycle crashes. These elements, road infrastructure defects and vehicle defects are significant in the chain of events leading to motorcycle crashes. They should be strongly considered and addressed in order to enable systemic elimination of all risks causing motorcycle crashes. As it has been noted, the current research works in Thailand do not touch on the stability aspect of light weight motorcycles that are widely used in Thailand and neighboring countries. Therefore it is essential to conduct more research into the stability of motorcycle and its impacts on motorcycle crashes. Physical and riding tests should be employed. The installation of motorcycle with powerful measuring devices such as sensors, accelerometers, gyroscope and also data loggers are required for measuring the dynamical parameters related to motorcycle stability. This research tool can provide the consistent and accurate data. The results that proved by riding experiment have permitted both researchers and designers to investigate, to compare, and to develop new safety devices or systems; which is not only for racing motorcycles but it is also for typical scooters and light weight motorcycles that are popular in Thailand and other Asian countries.

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ROAD CRASHES: IMPACTS ON POVERTY AND HUMAN DIGNITY

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ABSTRACT:

The new UN 2030 Agenda for Sustainable Development has put forward 17 Goals and 169 targets. Of the 17 new sustainable development goals that set out to end all forms of poverty, promote prosperity and people's well-being while protecting the environment by 2030; poverty eradication is the overarching number 1 goal of the agenda. However, a negative force working against this goal is the sudden poverty caused by road traffic crashes. While the annual economic loss from road crashes for Thailand is immense, amounting to some 3% of GDP or close to 500,000 Million Baht, it is at the household level that human poverty takes its toll. It is the families of the deaths, and the disabilities who are most impacted and are vulnerable to a life of sudden poverty. The paper gives examples where grave consequences of a road crash led to dire financial situation, human traumatic experiences including divorce, depression and suicide. It recommends that government should increase the social security fund contribution so that the fund could adequately supports the victims of road crashes, and that an income insurance policy be introduced in Thailand.

KEYWORDS: Road crashes, Poverty, Human Traumas, Road Deaths, Disabilities

1. INTRODUCTION

1.1 The UN 2030 Agenda For Sustainable Development

The new 17 Goals and 169 targets of the Agenda have been set to commence on 1 January 2016 and will guide all actions and decisions of countries and the UN over the next15 years. In the document, adopted by 193 countries on 25th of September 2015, it has been declared that the overarching number one goal is the eradication of poverty in all forms and dimensions, all agreed that poverty is the greatest global challenge and an indispensable requirement for sustainable development (UN, 2015). For the sake of completion, all the goals are listed below:

1) End poverty in all its forms everywhere
2) End hunger, achieve food security and adequate nutrition for all, and promote sustainable agriculture
3) Attain healthy life for all at all ages
4) Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
5) Achieve gender equality and empower all women and girls
6) Ensure availability and sustainable management of water and sanitation for all
7) Ensure access to affordable, reliable, sustainable, and modern energy services for all
8) Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
9) Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
10) Reduce inequality within and among countries
11) Make cities and human settlements inclusive, safe, resilient and sustainable
12) Ensure sustainable consumption and production patterns
13) Take urgent action to combat climate change and its impacts
14) Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15) Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
16) Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
17) Strengthen the means of implementation and revitalize the global partnership for sustainable development

It is common knowledge that the poor, the weak and the vulnerable are often marginalized and exploited. The above declaration called for the empowerment of these people which include all children, youth, persons with disabilities, for this group of people in particular, the UN document states that more than 80 per cent live in poverty. The first author has studied the impact of transport on improving poverty situation of villages in Thailand, but the study only focused on the provision of infrastructure (Taneerananon, 2015). However, few studies have been conducted on sudden poverty brought about by a road crash which could result in the death of the family breadwinner, or in permanent disabilities that prevent the bread winner from carrying working as before. This aspect will be further described.

The global awareness of gravity of road traffic injury situation was raised with the publication of WHO/World bank World Report on Traffic Injury Prevention in 2004 (WHO, 2004). After some 7-year lapse, the Decade of Action for Road Safety 2011-2020 was launched in 2011 by the UN, but no specific target for road fatalities was set, until now. In the 2030 Agenda, under Goal number 3, “Ensure healthy lives and promote wellbeing for all at all ages” a global target has been set for the first time thus “By 2020, halve the number of global deaths and injuries from road traffic accidents” This is an ambitious target but important for countries to take urgent action to achieve the target. For Thailand as other low and middle income countries, the urgency for action could not be overstated.

2. GLOBAL IMPACT OF ROAD SAFETY

2.1 Global Status Report On Road Safety 2015

WHO has published a Global Status Report on Road Safety in 2015; the report states that the global number of road traffic fatalities has plateaued at about 1.25 million deaths with the number of deaths in high income countries decreasing and those in low and middle income countries increasing (WHO, 2015a). For 10 ASEAN countries, the number of road deaths and death rate are shown in Table 1. It is seen from the table that Thailand has the highest number of estimated road deaths at 24,237 and the highest death rate at 36.2 deaths per 100,000 populations, followed by Vietnam and Malaysia at 24.5 and 24.0 respectively. The high rate places Thailand at number 2 in the world ranking of fatality rate. Common to most ASEAN countries, riders and passengers of motorized 2-or 3-
.
wheelers make up the highest percentage of road user deaths, for Thailand, the figure is 72.8 %, and well over 50 % for other countries as shown in Table 1.

2.2 The Impact Of Road Crashes On Thailand

Table 2 summaries the road fatality statistics for Thailand. It is seen that there is a large discrepancy between the reported and the WHO estimated number of road deaths; the main reason appears to be the time period when a death is recorded, the police are likely to record death at the crash scene or a day or two after the crash while WHO practice is to record death within 30 days of the event. Table 2 also shows the estimated GDP loss of 3%, citing a study by Taneerananon in 2009. For 2014, Thailand GDP was estimated at 404.6 billion US$ in 2014 (World Bank, 2015), at 3% of GDP, the economic loss to the nation would be 12100 million US$ or about 440,000 million Baht. A hefty national loss that needs to be urgently addressed; however, at the household level, the loss to individual family is more traumatic and requires government action

Table 1. Road traffic death rate for ASEAN countries

Country	General Information	Road traffic deaths				Road user death (%)					World Ranking
	Population numbers for 2013	Reported number of road traffic deaths	Modelled number of road traffic deaths: Point estimate	Modelled number of road traffic deaths: 95% Confidence Interval	Estimated road traffic death rate per 100,000 population	Drivers/ Passengers of 4-wheeled vehicles	Drivers/ Passengers of motorized 2-or 3-wheelers	Cyclists	Pedestrians	Other or unspecified user	
Thailand	67,010,502	13,650	24,237	-	36.2	13	72.8	2.3	8.1	3.8	2
Viet Nam	91,679,733	9,845	22,419	-	24.5	-	-	-	-	-	41
Malaysia	29,716,965	6,915	7,129	6,050-8,209	24.0	23.7	62.1	2.2	6.6	5.5	52
Myanmar	53,259,018	3,612	10,809	8,790-12,829	20.3	26	23	9	26	16	67
Cambodia	15,135,169	1,950	2,635	2,150-3,120	17.4	8.5	70.4	2.3	12.7	6.1	83
Indonesia	249,865,631	26,416	38,279	32,079 - 44,479	15.3	6.0	36.0	2.0	21.0	35.0	95
Lao People's Democratic Republic	6,769,727	908	971	795-1,147	14.3	18.7	66.9	2.7	9.6	2.1	100
Philippines	98,393,574	1,469	10,379	-	10.5	25.3	52.5	2	19	1.1	122
Singapore	5,411,737	159	197	-	3.6	17.5	45.6	9.4	26.9	0.6	169
Brunei Darussalam	No data										

Source: modified from WHO Global Status Report on Road Safety 2015(WHO, 2015a)

Table 2. Road Traffic Fatalities and Estimated GDP loss

DATA	
Reported road traffic fatalities (2012)	14 059[c] (79% M, 21% F)
WHO estimated road traffic fatalities	24 237
WHO estimated rate per 100 000 population	36.2
Estimated GDP lost due to road traffic crashes	3.0%[d]

[C] Bureau of Policy and Strategy, Office of Permanent Secretary, Ministry of Public Health. Defined as unlimited time period following crash.

[D] 2009, Dr. Pichai Thaneerananon, PhD. "Traffic Accident Costing in Thailand 2004".

Source: WHO Global Status Report on Road Safety 2015 (WHO, 2015a)

3. THE HUMAN DIMENSION OF ROAD CRASH

As mentioned above some 24000 Thais die from road crashes annually; in addition, from estimate made in a Department of Highways' traffic accident cost study, about 15000 people would become disabled as a result (Department of Highway, 2007). Most of the people with disabilities are in the 19 - 35 age group which is the working age. A consequence of the crash is that, an employer will terminate his /her employment within one year by paying the following compensation: For the first 3 months, the affected employee will get the same salary as before, for the 4th to 6th month the person will get 75% of the salary, the 7th -9th month, 50% and the 10th-12th month 25%; then the employment is terminated. This is affected by the employee voluntarily submitting a resignation letter. In case where the affected employee worked for a company which operates under the government Social Security system, the affected person will get a disability compensation, amount to 50% of the final salary but not exceeding 7500 Baht (208 US $) per month for a period of 15 years. This period has, in 2014, been extended to a lifetime of the affected employee. This Social Security compensation is a result of the monthly contribution by an employer of 5% of the employee's salary to the fun, with a maximum set at 750 Baht, the amount is matched by government contribution to the fund. It is seen that an affected employee with a monthly salary of 15000 baht (416 US$) stands to lose 50% of his or her monthly salary. For an affected person with salary greater than n 15000 Baht, the income loss is clearly greater than 50%. As an example, a typical bank worker with a salary of 30,000 Baht will get the same monthly 7500 Baht from the Social Security fund; the loss of income in this case would be 22,500 Baht or 75%, a drastic loss brought about by a road crash. For the road crash victims whose work are outside the Social Security system, the government gives out a monthly 'survival' support of 800 Baht. It is obvious that the sudden loss of income as a consequence of road crash as mentioned above presents an immense challenge for affected individuals, their families and the society as a whole that needs to be addressed at a national level.

3.1 The human trauma

The problem faced by the crash victim does not end with the loss of his or her income. As in the aftermath of any physically-disabling event, affected individuals will not be able to help themselves for some times if not permanently thus requiring someone to help them in their daily life. If the person can afford it, it is possible to hire a professional helper at a rate of 15000 Baht/month. But interview with affected people indicated that most could not afford this amount (Thongchim, 2015) thus necessitate help from family members, either a wife or husband for married couples or parents and relatives. This further exacerbates the already dire financial situation of the affected family as another income earner has to leave his/her job to care for the victim. One of the grave consequences of the loss of income which creates shortfall in household expenses is the resulting divorce. Study by KOTI shows that divorces (or separations) among crash victims are as high as 37 percent after a road crash, compared to a 5 percent divorce rate for non-victims of road crashes (Sung, 2015). For Thailand case, the ensuing divorce rate is huge and especially acute among people with injured spinal cord from road crashes where the rate is 70-80% of all the road crash victims (Thongchim, 2015), The divorce usually happens within one year of the crash. This is because road crash is an unexpected event for both the victims and their carers who often are spouse, parents and relatives; these are the people who inevitably have to bear the brunt of the consequence.

3.2 A real life case

A married woman aged 40 with two teen age children was sitting in the back of a pick-up truck when it ran off the road. She suffered a spinal cord injury as a result. The injury disabled her from walking and she was confined to a wheelchair. She could no longer work in a factory, so she became unemployed. After 6 months, her husband divorced her and remarried. She became very stressed and took an over doze of medicine in order to kill herself. Fortunately, neighbours found her and took her to hospital which saved her life. However, later on, she suffered from depression which required medical treatment. During this period of treatment, she was cared for by her 70 year-old father who also had to look after her two children who were starting their tertiary education. After almost two years, she and her family had finally got back into the main stream of life, with her doing a community job and supported by a company's CSR project.

4. FACING UP TO THE NATIONAL CHALLENGE OF PREVENTING ROAD FATALITIES

With the recently adopted UN 2030 Agenda for Sustainable Development which has among its goals and target: "By 2020, halve the number of global deaths and injuries from road traffic accidents". This is an immense challenge for many countries, especially the low and middle income ones. Thailand, a middle income country, whose global fatality rate ranking is currently at number 2, a staggering 36.2 deaths per 100,000 population, faces a tremendous task of reducing its annual road deaths. Fortunately, to deal with this challenge, global organizations have helped develop "how to do it" manuals to address the key risk factors of road crashes. The partnership of the FIA Foundation for the Automobile and Society, the Global Road Safety Partnership, the World Health Organization and the World Bank have developed these manuals which are freely available (WHO, 2015b):

- Pedestrian manual
- Data systems
- Seat-belt manual
- Helmet manual
- Drinking and driving manual
- Speed manual
- Road safety management manual

Thailand would do well to seriously put these manual into practice. In addition, the country needs to look into measures that would help reduce the burden of sudden poverty from loss of income brought about by road crashes as the current safety net provided by government is far.from adequate. Among these measures are:

4.1 Increase the limit of social security fund contribution

The current limit of 15000 Baht is the basic minimum, 5 % monthly contribution by employer amounts to only 750 Baht per employee, this should be increased to reflect the current economic situation of the country. Higher matching contribution by the state should also be considered as this should be seen as direct support to the victims who had worked for the development of the nation, and clearly is not a handout.

4.2 Introduce income insurance

For professional people, government should look into getting insurance companies to introduce income insurance policy which has been available in many countries. This not only helps reduce the financial burden of government and society but also helps affected individuals and their families to live a life of dignity, as the policy will usually pay a monthly sum about the same as the prior salary of the insured person up until the age of 60 or 65.

5. CONCLUSIONS

Poverty has been and is still a major challenge for humanity; the UN has declared it as the number 1 goal of the 2030 Agenda for Sustainable Development. This paper describes how road traffic injuries can create sudden poverty for unprepared individuals as well as their household. The status of global, ASEAN and Thailand road safety situation has been described. It is seen that while the global situation in terms of road deaths has stabilized, the situation in ASEAN and Thailand still presents a challenge to governments. While the annual economic loss from road crashes for Thailand is immense, amounting to some 3% of GDP or close to 500,000 Million Baht, it is at the household level that human poverty takes its toll. The paper gives examples where grave consequences of a road crash led to dire financial situation, human traumatic experiences including divorce, depression and suicide. It recommends that government increase the social security fund contribution so that the fund could adequately support the victims of road crashes, and that an income insurance policy be introduced in Thailand so that adequate monthly income could be provided to the insured victim. This will ensure that the victims of road crashes can live their lives with dignity.

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ACCIDENT PREDICTION MODEL FOR HIGHWAYS WITH REST AREA BY USING POISSON AND BINOMIAL REGRESSION MODEL

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ABSTRACT:

Currently, rest area positively impacts on road users in terms of business points and information providers; however, the important task of rest area is reducing the number of road accident cause of fatigue. In the past, truck drivers in Thailand usually parked their vehicles on roadside or shoulder, which these harmful areas could generate road accidents when parked vehicles move out from the road shoulder to the travelled way. In Thailand, road accident situation is top 10 of the world. Research objectives consist of the determination of influencing factors that affect the road accident within upstream and downstream 16 km of rest areas in Thailand and built the accident prediction models. It was found out that main variables such as serviceability of rest areas and the number of the truck users in rest areas are significantly impacted into the accident prediction model. In summary, rest area could help to reduce the number of road accidents.

Keywords: Rest Area, Accident Prediction Model, Truck, Heavy Vehicle

1. INTRODUCTION

Rest area is the area for road users to rest, sleep, change driver, check goods and/or evaluate their vehicle (AASHTO, 2001). Rest area is the safety countermeasure which can reduce the number of accident, so agencies which related highways could primarily concern road safety. Not only road safety aspect, but rest area also generate revenue and provide information. Rest area is focused on the number of accident reduction related to fatigue; all roads could be provided rest area within an approximate distance. Fatigued drivers would avoid from main travelled way because of stress, especially a very high traffic volume on a road. From the study of National Cooperative Highway Research Program Report on Evaluation of Roadside Rest Areas by King (1989) which stated that interstate highways without rest areas, shoulder-related accidents increased to 52 %. AASHTO (2001) stated that the opportunity of a fatigue-related accident reduced 3.7% for drivers who utilized a rest area.

Fatigue is an important problem of a truck driver, in practice, at least 60% of truck drivers usually continue the work more than 12 hours, and it means that a truck driver works more than 70 hours per week. This work time period affects the rest time of a driver, fatigue could be occurred because of they have 7-8 hours per day. In U.S., at least 20% of accident is related to fatigue which occurred in midnight and 6 A.M. Above-mentioned, it conforms to a research in France that a fatigue-related accident and the overtime work is occurred in the midnight (European Transport Safety Council, 2001)

Banerjee et al (2009) stated that rest areas, which are a counter measure for fatigue, play a role in fatigue-related freeway collisions. Out of 2,203,789 total collisions occurring between 1995 and 2005, fatigue collisions accounted for more than 1.3 - 9.7 % of total collisions in California. It was also found that the number of collisions due to fatigue tended to decrease immediately downstream of rest areas, while suddenly increasing after about 30 miles from rest areas. This phenomenon is consistent with a possible assumption that drivers become significantly exhausted about 30 miles downstream of rest areas.

Garber and Wang (2004) concluded that the lack of sufficient rest areas are a cause of an accident, drivers' fatigue is a cause of truck accidents about 30-40 %. 31 Percent of fatalities is related with the fatigue because of insufficient rest period within 24 hours. In the past, truck drivers parked their trucks on shoulder or roadside, so the accident will occurred when vehicle move from shoulder/roadside to the travelled way. Blomquist et al. (2004) studied an approximate distance between rest areas, and it was found that 100 kilometers is an approximate distance between rest areas and a driver have to rest at least 10 min for every one work hour.

From accident statistic reports in Thailand, there was found that Thailand is top ranking countries by highest death rate in road accidents. Accident reports from 2009 - 2012 by Department of Highways in Thailand presented the severities, accident costs and hazardous areas. In Table 1, the number of accidents were 61,683, the number of fatalities were 7,101 and the number of injuries were 50,731.

In reports also presented that 18.7 % (11,549 accidents) of total number of accidents were related with goods transportation sectors for 5 years ago.

Table 1. Number of accident, number of fatality and number of injury on highways in Thailand

Items	Year				
	2008	2009	2010	2011	2012
Accident	14,336	13,673	12,054	10,607	11,013
Fatality	1,513	1,378	1,370	1,291	1,549
Injury	11,680	10,415	9,991	8,970	9,675

Source: Department of Highways, 2013

Considering in-depth analysis of these data, it was found that, 1/3 of accidents were occurred on truck vehicles such as 4 wheels pick-up, trailer, and less than 10 wheels truck respectively. In addition, the road accidents which occurred on a trailer have been increasing every year. From previous in-depth research in 2009, the number of accidents per 10,000 registered vehicles was Bangkok, southern, central, eastern, northern, and northeast respectively. Which the number of truck accidents were the highest in Northern. From these accident numbers, it presents the importance role of an overview of accidents such as statistic of fatalities and injuries that consist of regional statistic which there was the highest number of truck accident. So, reduction of the number of truck accidents by large rest area services are needed because it presented that a truck-related accidents were 1 of 3 of total accidents.

In study of rest area service, it should include an evaluation of fatigue-related accident, black spots, and accident rates near rest areas. In addition, a good design of a rest area is a part of aesthetic, and life quality of a community because of goods services, markets, tourism, data information services, and information transfer among drivers.

1.1 Objectives

1) To study influencing factors that related to road accidents near rest areas
2) To forecast an average number of road accidents by two cases such as the forced and unforced policy of a rest area service which included the accident reduction number by various size of rest areas

1.2 Research Assumptions

1) Rest area is a part of an accident reduction countermeasure.
2) Base prediction model is based on the accident data from Department of Highways in Thailand which occurred near four main rest areas
3) Base prediction model is based on the assumptions that customers or drivers who utilize the rest areas were unforced condition
4) The forced policy of a rest area is based on the traffic volume of heavy vehicle parking
5) The size of a rest area depends on number of stalls and customers/drivers
6) Accidents were collected within 16 kilometers of upstream and downstream of a rest area

1.3 Scope of Study

The relationships between road accidents and road physical factors and traffic volume factors to develop the accident prediction model of study areas which consist of four main rest areas of Department of Highways in Thailand. 16 kilometers of upstream and downstream of rest areas were study areas. Rest areas of Department of Highways consist of Khuntal (Highway no.11 section of Lampang-Chiang Mai, KM.33+420 – KM 33+577), Lam Takong (Highway no.2, section of Saraburi- NakonRatchasima, KM. 193+292 – 193-975), Chainat (Highway no.32, section Chainat intersection- Namsakon intersection,KM185+504 – 185+604), and Khao Po (Highway no.4, section Prajubkirikhun-Chumpon, KM431+400 – 432+ 200). All rest areas were opened in April 2002.

1.4 Research Methodology

Research methodology begins with the literature review in Thailand and international studies which consists of model formulation development and a factor-related accident. Five main steps of research methodology such as:

1) Literature review of factors and model formulation
2) Study of road accidents between 2000-2010 traffic volume and road geometry were reported by
3) Department of Highways in Thailand. 16 km of upstream and downstream were base data which will be developed to forecast the average number of accidents
4) Data analysis, data were separated by 75:25 which 75% of data is used to develop the prediction model, and 25% of data were used to validate the model. Model formulation was organized by three steps such as Pearson's correlation analysis among dependent variable and independent variables, and correlation among independent variables. Over dispersion test and models formulation based on Poisson regression model and Negative regression model
5) Goodness of fit is tested to select the approximate model
6) Conclusions

2. LITERATURE REVIEW

Author separated literature review in two parts such as the accident prediction model and factor analysis. In previous researches, various statistic models were used such as: Mohamed et al. (2000) used a negative binomial model to predict the road accident. Pongmesa (2002) used a multiple regression model, Poisson regression model, negative binomial regression model and log-normal regression model. Chao et al. (2009) and Littidej (2007) used Poisson regression model. Greibe (2003) developed an accident prediction by Poisson regression model in Italy. Dinu and Veeraragavan (2011) developed Poisson regression model to predict a road accident for two-lane highways. Jintawong (2004) compared a linear regression model, Poisson and negative binomial model; it was found that Poisson regression model is an approximate model to predict the road accident in case of non-overdisperson data. Lalita (2008) concluded that the prediction of number of accidents, injuries and accident costs is suitable with Poisson regression model, and the prediction of fatalities is suitable with the negative binomial model. In contrast with Thipwet (2012) studied the Poisson and negative binomial model and concluded that a negative binomial model is suitable with the prediction of the number of accidents and severities. Therefore, model selection is depended on Maximum Likelihood and a reasonable parameter of a variable (Ciro et al., 2007).

Variables in an accident prediction model could be separated in two parts such as traffic variables and road physical variables. Thipwet (2012) concluded both variables as shown in following:

- Traffic variables such as traffic volume, speed, percentage of passenger vehicles, percentage of two wheel vehicles, percentage of heavy vehicles.
- Physical variables such as road length, lane width, number of travelled lane, shoulder width, number of horizontal curve per road section, minimum radius of curve, slope, number of accessibility, number of vertical curves, median width, available of shoulder, median type, accessibility per kilometer, unsafe sight distance/percentage of banned overtake length time such as April in Thailand

3. MODEL DEVELOPMENT AND APPLICATION

Firstly, author applied the spatial analysis of the number of fatigue-related accidents and total accidents by Banerjee et al. (2009) to presents an overview of a countermeasure efficiency cause of a fatigue-related accident. Accident data since 2000-2010 were analyzed. Figure 1 and 2 present number of accidents in term of total number of accidents and fatigue-related accidents. 16 km of upstream and downstream were compared as same as the suggestion by Banerjee et al. (2009). Four rest areas of Department of Highways were utilized since 2002, number of accidents is reduced suddenly. An average number of accidents was 54.5 times per year before rest areas were opened, and an average number of accidents was 46.7 time per year after rest areas were opened. It could be implied that rest areas could reduce the accident 14.3%. It conforms with the fatigue-related accident that an average number of a fatigue-related accident before rest areas opened was 5 time per year, and an average number of a fatigue-related accident after rest areas opened was 4.2 times per year. It could be implied that 16% of an average fatigue-related accident is reduced by the counter measure of a rest area. Consideration of both number of an accident reduction were conformed with Banerjee et al.(2009) which rest areas can help to reduce a fatigue-related accident by 12.83%

Secondly, author formulated the accident prediction model, various variables were separated in two groups such as a dependent and independent variables. Influencing variables on an accident prediction is called independent variables, and an independent variable is a number of an average accident per year. The relation between an independent and dependent variables is described in an equation (1)
Model structures consist of Poisson and negative binomial regression model when an average variance of an accident or the variance of variables is overdispersion effect. TARC (2009) concluded that Poisson and negative binomial regression model were suitable with the accident prediction model because both statistic models can provide a zero value (non-accident) which Poisson regression model is a suitable model with a rarely accident, but negative binomial model is a suitable model which based on an average number is unequal to variance.

3.1 Model Formulation and Variables

Development of an accident prediction model, a dependent and independent variables were presented in Table 2. Both variables were described in following:

1) Increasing of Annual Average Daily Traffic (AADT) then an accident rate will increased.
2) Increasing of percent of heavy vehicle (HVVEH) then an accident rate will increased.
3) Increasing of number of light vehicle parking (LIGHTPARK) then an accident rate will increased.
4) Increasing of number of heavy vehicle parking (HVPARK) then an accident rate will reduced.
5) Increasing of number of total vehicle parking (TOTALPK) then an accident rate will reduced.
6) Available of a rest area on highway (REST) then an accident rate will reduced.
7) Narrow width of road (RDWD) then an accident rate will reduced.

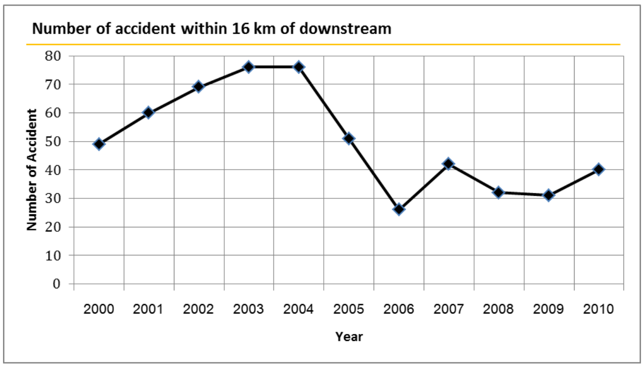

Figure 1. Number of accident within 16 km of downstream

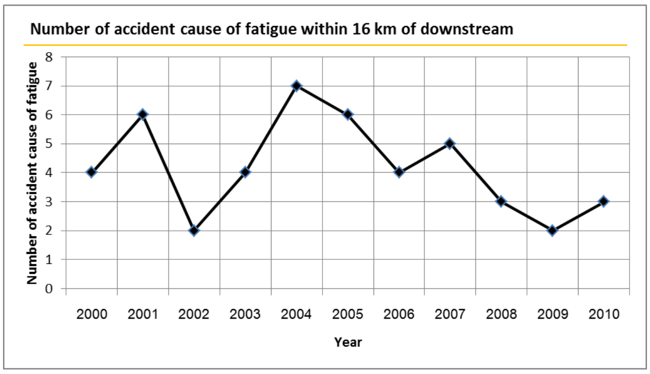

Figure 2. Number of accident cause of fatigue within 16 km of downstream

Descriptive statistics of both variables types were presented in Table 3. It shown that number of accidents of four rest areas were 148 times per year

$$Y = \exp(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n) \qquad (1)$$

Where
Y : Number of predicted accident per year
β_0 : Intercept constant of model
$\beta_1, \beta_2, \ldots, \beta_n$: Parameter of independent variables

Table 2. Description of variables

Variables		Descriptions
Response Variable (Dependent Variable)		
ACC		Number of accident per year
Explanation Variables (Independent Variables)		
Traffic Variable	AADT	Annual Average Daily Traffic (Vehicle per day)
	HVVEH	Percent of Heavy Vehicle
	LIGHTPARK	Number of Light Vehicle Parking (Vehicle per hour)
	HVPARK	Number of Heavy Vehicle Parking (Vehicle per hour)
	TOTALPK	Total Number of Parking (Vehicle per hour)
Physical Variables	REST	Rest Area Available (0 = Not available, 1 = available)
	RDWD	Road Width (meter)

Table 3. Statistic of response variable and explanation variables

Variables	Min	Max	Average	S.D.
Response Variable (Dependent Variable)				
Number of accident per year	20.00	504.00	147.97	109.71
Explanation Variables (Independent Variables)				
AADT	10,074	42,222	23,074	10,345
Heavy Vehicle (%)	20.69	38.18	26.46	4.61
Number of Light Vehicle Parking (%)	10.00	44.00	22.43	10.23
Number of Heavy Vehicle Parking (%)	12.00	61.00	32.48	15.41
Number of Total Vehicle Parking (Veh/hr)	24.00	100.00	58.83	26.64
Available of Rest Area	0	1	0.80	0.41
Road Width (m)	22.19	27.00	24.55	1.76

Table 4. Pearson Correlation between dependent and independent variables

Dependent \ Independent		REST	AADT	HVVEH	TOTALPK	HVPARK	LIGHTPARK	RDWD
ACC	Pearson Correlation	-.417**	-.126	-.367*	-.147	-.163	-.107	-.490**
	P-value	.005	.415	.014	.340	.290	.488	.001

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 5. Pearson Correlation among independent variables

Variables	REST	AADT	HVVEH	TOTALPK	HVPARK	LIGHTPARK	RDWD
REST	1	-.008	-.065	-.031	-.049	.012	.000
AADT	-.008	1	.153	.985**	.942**	.991**	.688**
HVVEH	-.065	.153	1	.307*	.448**	.034	.547**
TOTALPK	-.031	.985*	.307*	1	.985**	.953**	.749**
HVPARK	-.049	.942*	.448**	.985**	1	.889**	.786**
LIGHTPARK	.012	.991*	.034	.953**	.889**	1	.627**
RDWD	.000	.688*	.547**	.749**	.786**	.627**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 6. Accident Parameters estimation of Poisson regression analysis

Variables	Parameter
Intercept	8.848(0.000)
REST	0.641(0.000)
AADT	-
HVVEH	-
TOTALPK	-
HVPARK	-
LIGHTPK	-
RDWD	0.209(0.000)
Deviance/Degree of Freedom	10.647
Pearson Chi-Square	444.058
Log-Likelihoo	-320.081
Akaike's Information Criterion (AIC)	646.161

In parenthesis: P-value

Table 7. Accident Parameters estimation of Negative binomial regression analysis

Variables	Parameter
Intercept	4.119(0.000)
REST	0.709(0.078)
AADT	-
HVVEH	-
TOTALPK	-
HVPARK	-0.009(0.300)
LIGHTPK	-
RDWD	-
Deviance/Degree of Freedom	0.87
Pearson Chi-Square	22.249
Log-Likelihoo	-187.372
Akaike's Information Criterion (AIC)	380.745

In parenthesis: P-value

3.2 Correlation Analysis of Variables

Correlation analysis of related variables was presented in Table 4 and 5. Pearson's correlation analysis was tested among independent variables and a dependent variable. Significant coefficient of Pearson's correlation is implied that it has a significant impact on an average number of accidents coefficient values have two sides such as positive and negative side on a dependent variable. Correlation coefficient between independent variables and a dependent variable were shown in Table 4. Independent variables such as REST, RDWD and HVVEH were included in a model structure at0.01 and 0.05 significant.

4. MODEL CALIBRATION

Factor analysis in the model formulation was concluded by a commercial software in both of Poisson and negative binomial regression model. Log-Likelihood value by the Maximum likelihood estimator and reasonable sign of parameters were considered.

The accident prediction with Poisson regression model was presented in Table 6. It was found that Deviance/DF is 10.647 which over than 1.00, so it could be implied that Poisson regression is non-fit with these data because of overdisperson effect. Parameters form Poisson regression model have higher error which unacceptable.

Therefore, negative binomial regression model is shown in Table 7 with 70% of confidence. Table 7 shows reasonable sign of parameters form the negative binomial regression model. The model structure is shown in an equation 2

$$Y_{Accident} = Exp(4.119 - 0.709 \times REST - 0.009 \times HVPARK) \quad (2)$$

Where

$Y_{Accident}$: Number of predicted accident per year

$REST$: Rest Area Available (0 = Not available, 1 = available)

$HVPARK$: Number of Heavy Vehicle Parking (Vehicle per hour)

5. MODEL VALIDATION

Accident prediction model in an equation 2 was validated by separated data which it had 9.05 % error. The number of predicted accidents between forced and unforced policy of a rest area were considered, the different thing between forced and unforced policy is the number of heavy vehicle parking in rest areas. So, the number of heavy vehicle parking in case of forced policy is higher than unforced policy. It could be implied that the number of accidents in case of forced policy is less than another case. An average number of accidents are reduced 42% when highways provided a rest area. The large size of rest areas will reduce an average number of accidents 63% and the smaller size of rest areas will reduce an average number of accident 32%.

6. CONCLUSIONS AND RECOMMENDATIONS

From this study, the author focuses on the benefit of rest areas which could reduce the number of road accident especially available of rest area and heavy vehicle factor. Seven variables are tested by the goodness of fit method to select the approximate model. There found out that main variables that significantly effect on an average number of accidents consist of the availability of a rest area, which conforms with the study of Banerjee et al. (2009) that highways with an availability of a rest area, the average number of accidents within 16 kilometers will be reduced.

In previous research, it was found out that the relation between exits from parking places and accident risks seems to be an inverted. Roads with no accesses and roads with a large number of accesses have the lowest accident risk, while roads with a medium number of accesses have the highest accident risk (Greibe, 2003). Therefore, in this research expanded the findings from Greibe (2003). There was found out that large number of heavy vehicle parking will reduce the number of road accidents.

Finally, the suitable model to predict the accident is the negative binomial in this case because of the criterion of Log-Likelihood and overdisperson effect.

Author would like to purpose recommendations for the further research in this area of study such as:

1) In next research, the physical properties of highways and rest areas could be considered, for example: slope, number of horizontal curve, number of accessibility and connection to calibrate the prediction model.
2) Formulation of the flexible of model structures could be considered, for example: a flexible negative binomial regression model. In other word, the computer software could be considered also.
3) The validation and calibration of the accident prediction model for private or non-government rest areas could be considered.

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NEW METHODOLOGY FOR DEVELOPING DRIIVNG CYCLE(S) FOR SRI LANKA; CASE STUDY, COLOMBO, SRI LANKA

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ABSTRACT:

Even though driving cycles have been adopted around the world in different type of applications, the data needed for each steps is costly and time consuming. Majority of the Developing countries do not have systematic data bases for traffic related information such as origin-destinations, vehicle kilometers, average annual daily traffic etc. for majority of road links. Meager amount of available data is not sufficient to develop a driving cycle. Even though the data is collected, significant effort has to be made to construct a driving cycle that closely matches to the population data set. This paper gives simplified methodology for developing driving cycles using different approaches for route selection, data collection and cycle construction. For the route selection the available methods have been combined together and modified to suit for developing countries where no details traffic flow information will be available. Also a method was adopted for data collection by dividing selected routes in to links and grouped them according to daily traffic to optimize the cost for data collection. Road links were divided using physical junctions on the road and routes were selected using traffic generators and attracters combined with Origin Destination data. Also methodology was developed for synthesize data population using collected data from road links. Another issue for cycle construction is to construct a cycle which is close to population parameters. Using existing methods many cycles have to be constructed until the acceptable cycles is generated. New methodology has been adopted to develop driving cycle to match the population parameters and then to select data for driving cycle using Markov chain. As a case study Colombo, Sri Lanka has selected to apply the new approach of driving cycle construction for developing countries.

Keywords: Driving Cycle, Emission, Cycle construction

1. INTRODUCTION

World is moving towards sustainable transportation systems during the past few decades. Fuel efficiency and transportation emission are the main driving forces. Many methods have been adopted for developing emission inventories and estimating fuel economy and those can be divided in to two groups namely travel based models and fuel based models (Xiao, 2012). Fuel based methods are empirical methods which use results to model and predict the behavior (top to bottom approach) and travel based models use the data and develop a model to predict the behavior after analyzing the data (bottom up approach).

One of the widely used methods to model and predict the traffic behavior hence predicts fuel consumption and emission inventories is driving cycle. It can be categorized under travel based methods. Many countries have developed different methods for developing driving cycles and the comparison of existing driving cycles have been done previously and methods suitable for Sri Lankan conditions have been identified(Galgamuwa, 2014). Colombo, Sri Lanka was selected as a case study to develop a driving cycle where a basic driving cycle for a selected route has been developed (Gamalath, 2012). Due to lack of systematic traffic data, a new methodology was adopted for route selection and data collection hence the cycle construction methodology.

2. ROUTE SELECTION

Route selection is one of the major steps in developing driving cycles. The routes selected have to represent the traffic behavior of the area where the driving cycle is to be developed and if not the results obtain from the driving cycle will be deviate from its actual situation. When selecting routes consideration must be given to traffic flow, the other conditions with respect to traffic (spatial and temporal), land use, road type, topography, population density etc.(Tong and Hung 2010: Barrios, 2012).

A major problem in many developing countries is lack of systematic traffic related information. Hence it is difficult to use an advanced method such as Australia (Australian Composite Urban Emission Driving Cycle), Hong Kong driving cycle etc. Therefore a new method was adopted for Colombo after analyzing available traffic flow data. Traffic flow can be divided in to two categories namely intercity and intra city. Therefore the routes have to be selected for those two types separately.

2.1. Route Selection for Intercity Trips

Route selection for intercity trips were done using origin destination data (OD) and daily traffic flow data at 10 main entry points to city of Colombo. For the OD survey the locations were selected such that to cover the major corridors where the traffic fleet enters the Colombo. Selected ten locations are shown in figure 1 and names of those locations are given below

- Gamsabha Junction(Aththidiya road)
- Piliyandala
- Mattakkuliya (Canal Road)
- Grandpass (Negambo Road)
- Rajagiriya (Sri Jayawardanapura Mawatha)
- Kohuwela (Horana Road)
- High Level
- Dehiwala (Galle Road)
- Kelanithissa(Kandy road)
- Orugodawatta (Awissawella Road)

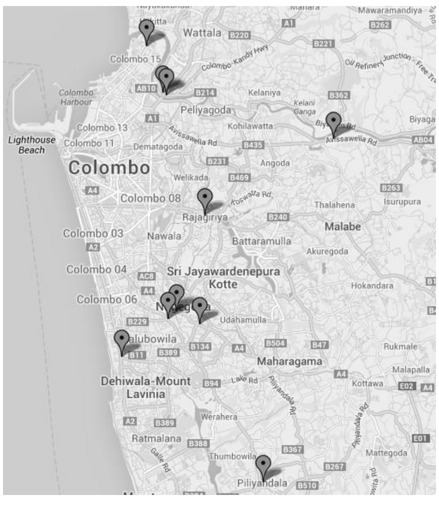


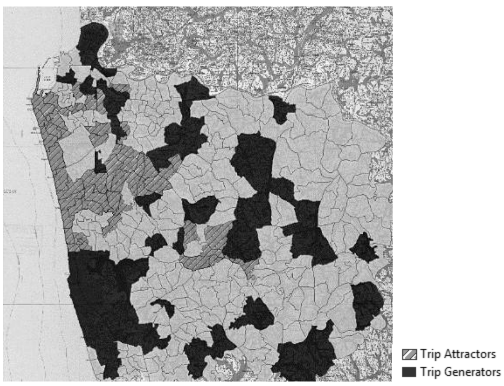
Figure 1. OD locations for Colombo

Data from OD surveys was analyzed. 57 routes were selected by considering the frequency (routes which accommodate more than 70% of the vehicle fleet which enter Colombo from respective corridor

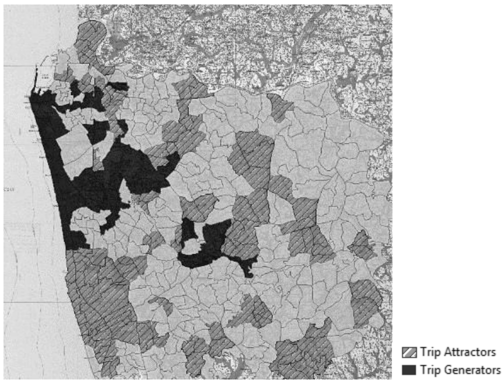
2.2. Route Selection for Intracity Trips

Even though the routes were selected for intercity trips based on OD data, it is difficult, costly and time consuming to carry out OD for intra city trips due to economical constrains. Hence the routes were selected considering traffic generators and traffic attractors.

Using population data and land use pattern the trip generators and trip attractors have been identified according to the GN (Gramasewa Niladari) divisions (Smallest administrative areas for the population and household data is available) . Also according to the time of the day the generators and attractors changes. In Colombo, in the morning the residential areas generate traffic and commercial areas and schools attract the traffic. But in the evening the generators become attractors and attractors become generators. 52 trip attractors (Commercial and schools) and 116 trip generators have been identified in GND wise. Then the route network is laid on the map and routes were identified which connect trip generators and trip attractors using ArcGIS 10.2 software. 72 different routes were identified for intra city tips.



(a) In the morning



(b) In the evening

Figure 2. Trip generator and Trip attractors in different periods of the day

2.3. Routes Selected For Data Collection

After identified the routes for intercity (57 routes by analyzing OD data) and intra city trips (72 routes using Trip generators and attractors) the routes were laid on a same map. Then the superimposed road layer is divided in to route links using physical junctions. A Total of 121 route links were identified to use to collect speed time data in Colombo region using selected data collection method to synthesize the data population.

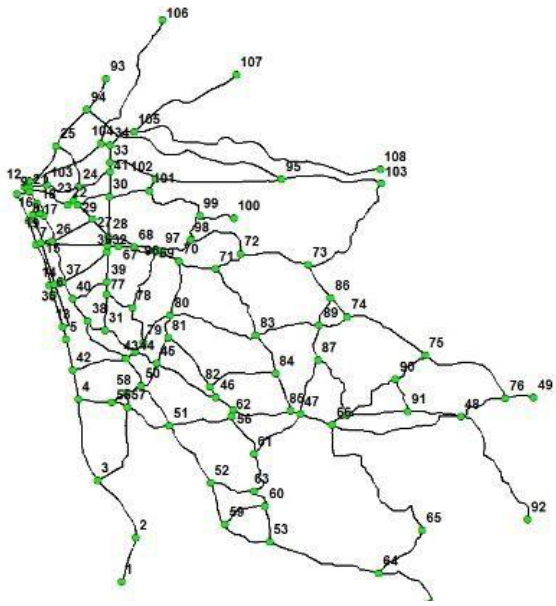


Figure 3. Selected route links for data collection

3. DATA COLLECTION

Data collection becomes a vital role because the quality of the output is directly influenced by the reliability, representativeness, homogeneousness and consistency of the data which have collected. Mainly there are two types of data collection methods namely, chase car method and on board measurement method (Tong et al., 2000). It is possible to combine above two methods to a one known as Hybrid method (Tong and Hung, 2010)

Considering the traffic behavior of the Colombo city and resource availability, on board measurement method was selected as a data collection method. Number of data samples required for each link was identified proportionate to the daily traffic estimates. The required numbers of samples were further divided in to time period of the day using hourly traffic volumes in corresponding routes. For that, the day was divided in to seven segments namely morning off peak, morning peak, inter peak 1, school peak, inter peak 2, evening peak and evening off peak. Then the routes were assigned in to five groups according to daily traffic by giving number 1 to the lowest daily traffic volume and number 5 to the highest daily traffic volume. Number of segments to be divided is decided by researcher from the knowledge of the area of concern. Simply it is to identify and grouped road links which have similar traffic characteristics and behavior. Further consideration was given the variation of traffic flow within the day. Because the time of the day affect the traffic flow in given road hence affect the speed time data collected in that road. Therefore seven segments defined used to select number of samples and selected samples are shown in table 1 it is given for minimum sample size which is one. (At least there should be one sample from each segment and the segment which has minimum traffic flow has number one as circled in the table 1)

Table 1. Sample distribution within the road groups and time of the day (for minimum sample size)

	Morning Off Peak	Morning Peak	Inter Peak1	School Peak	Inter Peak2	Evening Peak	Night Off Peak	Total
Road Group 1	2	3	3	2	1	3	2	16
Road Group 2	1	4	4	4	3	4	3	23
Road Group 3	5	7	4	4	4	8	3	35
Road Group 4	5	10	7	6	4	7	4	43
Road Group 5	10	15	8	11	15	15	12	86

4. CYCLE CONSTRUCTION

Method of cycle construction varies with the purpose of the driving cycle whether it is for estimation of emission inventories or estimation of fuel consumption or traffic engineering purposes. Each cycle construction method has its unique features to represent its' envisioned purpose (Galgamuwa, 2014). Model cycle construction is selected for this study as it can capture the each and every state of driving since it is used Markov model for segment and select data for developing driving cycle. In Modal cycle construction actual driving patterns are divided in to acceleration, deceleration, cruising and idling events. To construct the Driving Cycle Markov Chain theory is used hence assume that the likelihood of particular modal event depends only upon the pervious modal event (Lin and Niemeier, 2003). There are four basic steps for constructing driving cycle using Modal cycle construction method. (Dia et al 2008 cited Lin and Niemeier 2002)

1. Using maximum likelihood estimation on road data is partitioned into snippets of various duration based on acceleration.
2. Using maximum likelihood estimation snippets are assigned into modal bins considering variables such as average, minimum, and maximum speeds and acceleration rates.
3. Creates a transition matrix that contains the succession probabilities between different modes.
4. Cycle is constructed as a Markov chain

The method available considers the probability of state changes and then select data according to highest probability of state change from initial state. And then Speed acceleration frequency distribution is considered and select the best cycle which matches the population parameters. The available method has been modified by combining two matrices of probability of state changes and probability of state changes. Then it is not necessary to consider SAFD when selecting each and every data set for the driving cycle. The modified method is used to develop driving cycle for Colombo, Sri Lanka. Methodology for cycle construction is as below.

4.1. Defining the States Used in Transition Probability Matrix

According to the previous study done, states have been defined using speeds and accelerations and assigned them in to different modal bins. (Shi, 2011)

Table 2. Definition for the states used in transition probability matrix

	a≤-0.8	-0.8<a≤-0.1	-0.1<a≤0.1	0.1<a≤0.8	a>0.8
0<vm≤25	State 1	State 2	State 3	State 4	State 5
25<vm≤45	State 6	State 7	State 8	State 9	State 10
45<vm≤65	State 11	State 12	State 13	State 14	State 15
vm>65	State 16	State 17	State 18	State 19	State 20

State 0 – Idle v- Speed (km/h)

a- Acceleration (m/s^2)

4.2. Preparing the Transition Probability Matrix for State Changes

Then a transition probability matrix is prepared which represent the probability of mode changes from one state to another based on the Markov chain model. The sample of the matrix is shown in table 3.

4.3. Calculating the Proportions of States

Then calculate the time proportion of each twenty one states using population data set. Proportions calculated for state 0,1,2,3 …. n are defined as p0, p1, p2, p3…… pn respectively.

4.4. Calculating the Time for Driving Cycle from each Mode

Calculate the time in each state with in the driving cycle (time allocated for each state with in 1200s duration of driving cycle). The duration of the driving cycle is kept as 1200s to optimize the running cost of developed cycle on chassis dynamometer. Sample calculation is given in table 4.

In table 4, Xi is the time used for diving cycle from each mode. At the beginning Xi is equal to zero. But when the cycle is been constructed the time from each mode for the driving cycle is reduced. Then the probabilities for the driving cycle from each states are calculated as shown in the equation 1.

The probability for i^{th} state

Table 3. Transition probability matrix for state changes

States	0	1	2	3	4	5	6	7	8	9	10	11	…	…	…	17	18	19	20
0																			
1																			
2																			
…																			
…																			
19																			
20																			

Table 4: Time for driving cycle from each mode

State	Time for driving cycle from each mode	Probability of each state to driving cycle
0	$(1200\times p_0)-X_0$	P_0
1	$(1200\times p_1)-X_1$	P_1
2	$(1200\times p_2)-X_2$	P_2
19	$(1200\times p_{19})-X_{19}$	P_{19}
20	$(1200\times p_{20})-X_{20}$	P_{20}

Table 5. New transition probability matrix for state changes

State	0	1	2
0	0	$P_{0\to1}\times P_1$	$P_{0\to2}\times P_2$
1	$P_{1\to0}\times P_0$	0	$P_{1\to2}\times P_2$
2	$P_{2\to0}\times P_0$	$P_{2\to1}\times P_1$	0

Where $P_{i\to j}$ is the probability of state change from i^{th} state to j^{th} state

Note- When one mode is selected, the time allocated for the respective state is reduced hence the probabilities will decreased and it allow the states which haven't been selected previously or haven't been selected frequently to increase their probabilities. Then those states which have higher probability in new transition probability matrix for state changes will have higher chance of get selected for the driving cycle.

4.5. Developing New Transition Probability Matrix

After calculating the new probabilities of each driving mode (table 4) and prepare a transition probability matrix for new probabilities of state changes by multiplying probability of state changes column by probability of corresponding probability of state changes. Example for calculating new probabilities of state changes are shown in table 5

4.6. Data Selection Criteria

Initially a data set from state 0 is selected. Then the state which has higher probability from state 0 is selected according to the new transition probability matrix (Higher probability state from state 0 is in state 0 row). Then the new transition probability matrix is calculated according to new probabilities for each 21 states. Again the higher probability state was selected from current state (the highest probability of current state row in new transition probability matrix).Likewise the data is selected for the driving cycle until the time requirement is fulfill. (For each selection the new probabilities are calculated and update the new transition probability matrix)

5. CYCLE ASSESSMENT

Many parameters have been identified for cycle assessment in the literature according to purpose of the cycle construction. Out of those parameters ten parameters have been identified which will assess the emission related driving cycles.

1. Average speed of the entire driving cycle
2. Average running speed
3. Average acceleration
4. Average deceleration
5. Time proportions of driving modes for idling
6. Time proportions of driving modes for acceleration
7. Time proportions of driving modes for cruising
8. Time proportions of driving modes for deceleration
9. Root mean square acceleration (arms)
10. Positive kinetic energy (PKE)

After calculating the parameters for the population as well as for the candidate cycles, candidate cycle is selected as a driving cycle to represent on road traffic behavior of selected

road or region which has a lower Performance value where the definition of the Performance Value (PV) is given below.
PV= Summation of the percentage different of the candidate cycle with the population parameters

If developed candidate cycles have similar or approximately close PV values then the Speed Acceleration Frequency Distribution (SAFD) is considered. Then the Smallest Sum Square Difference (SSD) value is taken (summation of the different between SAFD of the population and candidate cycle) and the cycle which has minimum SSD value is taken as the Driving cycle for the road or that area.

6. DATA VALIDATION

Data validation is important to make sure that the data collected are true representatives of actual travel pattern in the area of concern. The following method was adopted for data validation.

First calculate the 10 parameters used for cycle assessment for the data population used for constructing candidate cycles. Then one continuous data set is collected using roads which covers major and minor roads and according to the road groups. Same parameters calculated for the population will be calculated for the collected data set using major and minor roads. Then compare with the population parameters. If the parameters calculated using dataset lies within the allowable range (15% upper limit and 5% lower limit) (Kamble, 2009) compared to the population parameters the population data set is considered as representative data set.

7. RECOMMENDATIONS

Since it consider speed acceleration probability distribution of the population when selecting data for candidate cycle the cycle represent the actual driving pattern in the area of concern. But if the driving behavior is uniform (if the state changes do not occur frequently) the cycle will deviate from population. Therefore this method is suitable for the areas where the uneven driving pattern occurs. If the method is used such areas where there are not much variation of speeds length of the driving cycle should be increase to minimize the error or states have to be define as accordingly.

The accuracy of the driving cycle depends on the data collected. It is advisable to use all routes selected and collect data proportionate to its daily traffic. If the time and the budget is limited collect data from the groups as given in the methodology but there the data validation should be done.

Parameters have to be selected carefully to assess the developed driving cycle because the predominant parameters are changed due to purpose of the driving cycle. The driving cycle constructed using this method might seem unrealistic than micro trip method since the data is selected using probabilistic method.(in micro trip method acceleration, cruising, deceleration and idling considers as one data set where in Modal cycle construction method divide those micro trip in to further states based on acceleration and average speeds). But it is proven that the new approach gives more accurate results than micro trip method (Using sample data set collected). Sometimes it might be difficult to run on chassis dynamometer (Old chassis dynamometer which cannot capture frequent fluctuations). Therefore results from this method must be analyzed carefully and smooth the cycle using statistical method such as time series analysis without deviating the parameters with population parameters.

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