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The Study of Kinematic Features and Characteristics of Motorcyclists Under Normal Traffic Conditions on Highways in Thailand

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***Abstract*:** *The paper presents an analysis of riding behaviour of motorcyclists under normal traffic conditions on highways in Thailand. Traffic flow were recorded from roadside using video camera. The stream of data was subsequently analyzed by image processing technique using Autoscope traffic analysis tool. The analysis results show that on average a motorcyclist travels with speed 62.40 km/h. The proportion of motorcyclists are similar in lanes 1, 2 and 3. The majority of riders with one passenger are found in lane 1. With regard to riding solo, there is a significant difference of average speeds between helmeted and non-helmeted motorcyclists. In addition, there is a significant difference of average speed across engine power of motorcycles as well. The average spacing from the leading vehicle and lateral distance from a vehicle in an adjacent lane are 26.06 and 1.91 m, respectively. These main findings might contribute to traffic safety management for policy maker and academic research.*

Keywords: *Motorcycle, riding behaviour, kinematic feature, operating speed, safety.*

1. Introduction

More than 1.2 million people died each year on the world's road, making road traffic injuries are the leading cause of death globally. Most of these deaths are in low and middle income countries where rapid economic growth has been accompanied by increased motorization and road traffic injuries (WHO, 2013). Thailand is one of Southeast Asian countries where there was a significant of number of traffic accidents. According to the National Statistical Office of Thailand, there were totally 62,922 cases of road traffic accidents resulted 7,994 fatalities; 3,666 serious injuries and 18,037 slight injuries in 2013 (NSO, 2015).

As a mean of transport, a motorcycle is both inexpensive and easy to use, whether in the heavy traffic of large cities or in the countryside. Similar to other Southeast Asian countries, motorcycle is the primary mean of transportation in Thailand. According to the statistics from the Department of Land Transport (DLT), there were more than 37 million vehicles registered in Thailand by November, 2016. About 56% of all registered vehicles were motorcycles. Furthermore, 20,426 cases of traffic accidents were caused by motorcycles which was the highest proportion as compared to other type of vehicles. The National Statistical Office of Thailand also reported that speed limit violation was the highest factor in 17.29 percent of all cause of the accident by a person (43,193 cases) in 2013. So far, it can be seen that the road accident is mainly caused by motorcyclists; thus, this

present paper focuses on the study of characteristics and riding behaviour of motorcyclists under normal traffic conditions on some Thai highways.

2. Literature Review

Various studies have been conducted previously on the operating speed. These studies vary in terms of factors influencing the operating speed. Shbeeb et al. (2004) explored factors affecting drivers' speeds and/or lane change choice. They found that there was a significant difference between driver's speed-choice which could be attributed to the lane position. Lane-change possibility was found to be significantly related to speed limit violation regarding the observation made on the left lane. Similarly, Balakrishnan and Sivanandan (2015) studied the influence of lane and vehicle subclass on free-flow speed. The results showed that there was a significant difference in free flow speed among vehicle subclasses. The results also indicated that among two-wheelers, there was distinct average free flow speed. In addition, under the mixed traffic condition, the change in speed with traffic volume was less for small sized vehicles such as 2 and 3-wheelers and higher for big sized vehicle like big car and heavy vehicles (Dhaniya and Chandra, 2013). Due to a large number of motorcycle in developing countries, Minh et al. (2005) studied the characteristics of motorcycle traffic regarding speed-flow relationship and headway analyses. The results indicated that there was a statistically significant difference of mean speeds across locations due to site and traffic characteristics.

In addition to road and traffic characteristics, driving characteristics are also found as factors effecting choice of speed. For instance, Williams et al. (2006) determined the characteristics of speeder. It was found that speeders were younger, more likely to drive newer vehicles and sport utility vehicles, and less likely to drive minivans. There was no statistically significant relationship between speeding and vehicle size or having a valid license. However, Harrison et al. (2000) found a relationship between vehicle ownership and observed speed, where those not driving their own vehicle were more likely to have been travelling excessively fast. In addition, the speed choice was found to be affected by route familiarity; namely, speed increases with the repetition of travels on the same route. Familiar drivers seemed to be at the same time more unfocused on the driving task. On the other hand, aggressive drivers showed greater speed increasing rates than the cautious drivers (Colonna et al., 2016).

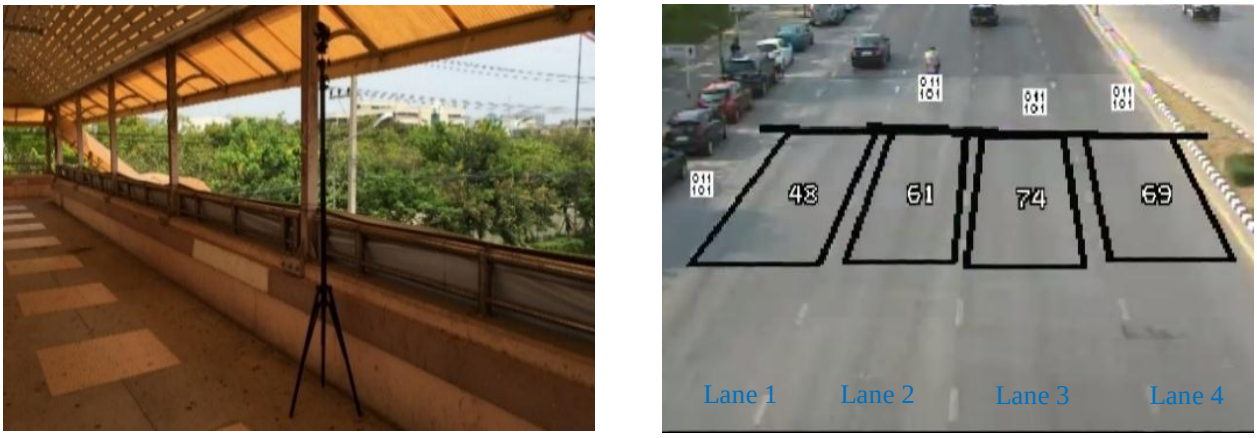
Vehicle characteristics are identified to influence operating speed (Brundell-Freij and Ericsson, 2005; Liu, 2007). A study by Fildes et al. (1991) found that type of vehicle being driven was associated with excessively slow travel speeds in rural, but not urban areas. Those driving vans and light commercial vehicles were more likely to be very slow travellers than were passenger car drivers. However, there was no statistical difference in travel speed behaviour between the different categories of passenger cars. In addition, Jevtić et al. (2015) examined the difference in the distribution of the speeds of different motorcycle styles and the difference in the distribution of speeds of particular motorcycle styles and cars. The results showed that the mean speeds significantly differed among motorcycle styles. Moreover, the research found that the speed of motorcycles without license plates were significantly greater than the speed of motorcycles with license plates.

3. Methods

The traffic flow data is collected by using video image processor (VIP) combining with roadside observation. A video recording camera is mounted on a pedestrian overpass and aims in the middle lanes to record the flow of vehicles during evening peak hours (4:00 pm – 6:00 pm). In addition, a roadside observation is conducted to observe the characteristics of motorcyclists and motorcycles. The study section is selected to avoid congestion or traffic control which impact traffic flow and travel speed. The weather was clear and the visibility was good.

The recorded video stream is then run through Autoscope Pn-520, a video image processor system. This technology not only provides the traffic parameters of individual vehicles but also allows users to combine the characteristics of motorcyclist and motorcycle obtained by roadside observation. On the other hand, there is no effect of speed collector into driver's behaviour. In addition, this method allows users to play the recorded video

repetitively. It can avoid the recollection of field data, manage time more efficiently and control the expenses under the budget. Figure 1 shows mounting video camera and Autoscope video screen for data collection.

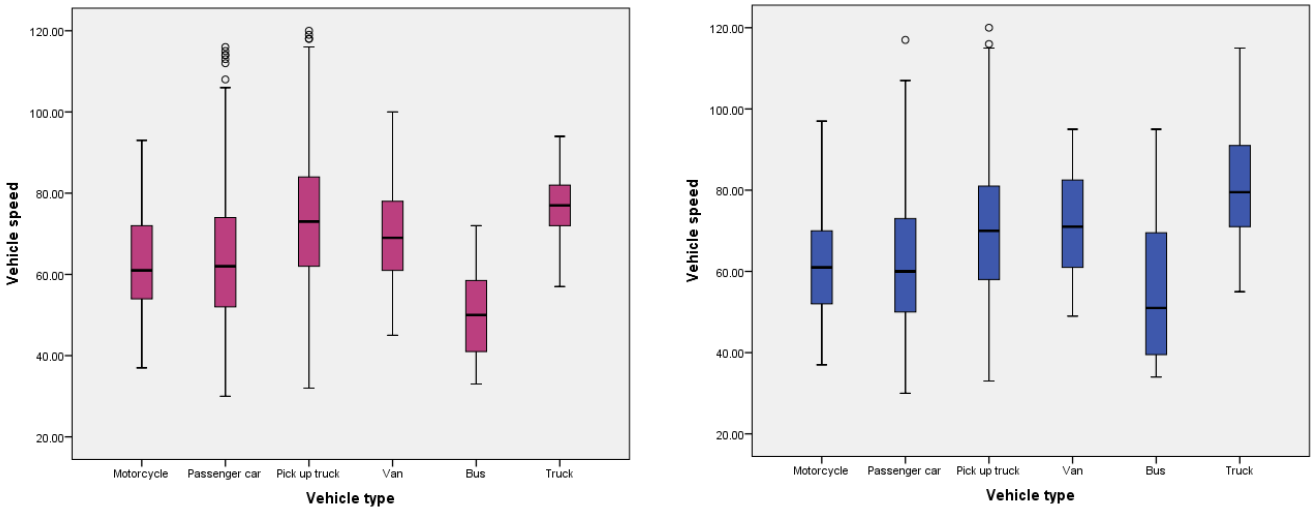


(a) Mounting video camera (b) Autoscope video player interface

Fig. 1: Tools for Data Collection

4. Study Area Description

The field data survey was conducted on a section of a main highway in Nakhon Pathom province, Thailand. The number of detected vehicles are 2,341 and 2,438 vehicles during 4:00 - 5:00 pm and 5:00 - 6:00 pm, respectively. 67.90% of overall vehicles are passenger cars, following by pick-up trucks (19.08%). Motorcycles contributes to 9.04% of total traffic flow. These percentages show that private vehicles are still predominant on Thai highways and more public transport services should be introduced.



(a) 4:00-5:00 pm (b) 5:00-6:00 pm

Fig. 2: Vehicle Speed across Vehicle Types (km/h)

Figure 2 depicts the box plot of speeds across vehicle types. All vehicle speeds are reasonably symmetric excepts for bus speeds at 5:00 - 6:00 pm. Moreover, there are few outliers at the speeds of passenger cars and pick-up trucks for both time periods. The minimum speed is 30 km/h whereas the maximum speed is 120 km/h. The median speeds of passenger cars and motorcycles are similar at 60 km/h. Trucks operate at the highest speed across vehicle types based on the highest median of box plot and followed by pick-up trucks. It is found that buses have the lowest median speed which explained by picking up and dropping off passengers.

TABLE I: Description of Operating Speeds (km/h) across Characteristics of Motorcyclists and Motorcycles

Description	Frequency (%)	Mean	S.D	CV	Max	Min
Gender						
Male	420 (97.22%)	62.57	12.32	19.68%	97	37
Female	12 (2.78%)	56.41	7.03	12.46%	67	44
Helmet use						
Yes	393 (90.97%)	62.87	12.28	19.53%	97	37
No	39 (9.03%)	57.65	10.95	18.99%	88	39
Motorcycle occupancy						
Riding solo	322 (74.53%)	63.62	12.02	18.89%	97	37
Riding with pillion	105 (24.30%)	58.47	12.06	20.62%	89	37
Riding with product	5 (1.17%)	66.20	15.49	23.39%	84	52
Engine power						
110cc	216 (50.00%)	59.68	10.91	18.28%	97	37
125cc	203 (46.99%)	64.71	12.93	19.98%	95	38
≥ 150cc	13 (3.01%)	71.46	11.05	15.46%	93	51
Lane position						
Lane 1	123 (28.47%)	51.73	7.94	15.34%	78	37
Lane 2	127 (29.39%)	60.13	8.30	13.80%	89	43
Lane 3	125 (28.93%)	67.59	9.39	13.89%	93	42
Lane 4	57 (13.21%)	79.08	7.83	9.90%	97	61
Total	**432 (100%)**	**62.40**	**12.24**	**19.61%**	**97**	**37**

Note: S.D: standard deviation, CV: coefficient of variation, Max: maximum, Min: minimum

The total of 432 motorcyclists are extracted from recorded video from the study site. Table I depicts the overall descriptive statistics of motorcycle speeds. It is found that over 97% of motorcyclists are male which implies that Thailand women are not familiar with riding motorcycles. The difference of means of some motorcyclists' characteristics and riding behaviour are analysed by independent samples T-test and analysis of variance (ANOVA). The results are summarized in Tables II and III.

TABLE II: Summary of Independent Samples T-Tests for Mean Speed (km/h) With 95% Confidence Level

Variables	Group	Degree of freedom	Difference mean	T-value	Sig.
Motorcycle speed of riding solo	Helmet use	325	6.865	2.764	0.006
Motorcycle speed of 110cc engine power	Helmet use	214	0.712	0.264	0.792
Motorcycle speed of 125cc engine power	Helmet use	201	10.463	3.614	0.000

TABLE III: Summary of ANOVA Tests for Mean Speed (km/h) With 95% Confidence Level

Variables	Degree of freedom		Mean square		F-value	Sig.
	Between group	Within group	Between group	Within group		
Motorcycle speed across lane positions	3	428	11,298.032	71.822	157.307	0.000
Helmeted motorcyclist speed across motorcycle occupancies	2	390	1,133.966	145.738	7.781	0.000
Motorcycle speed across motorcyclist groups	2	102	453.657	139.401	3.254	0.043
Motorcycle speed across engine powers	2	429	1,876.051	141.915	13.220	0.000

5. Riding Behaviour

5.1. Speed and Lane Position

There are totally 5 lanes which consist of one parking lane and four traffic lanes, as shown in Fig. 1 (b). The mean speed of motorcyclists is 62.40 km/h. The maximum and minimum speeds of motorcyclists are 97 km/h and 37 km/h, respectively. It is found that the number of motorcyclists in lane 4 are lowest while on average there are 125 motorcycles on lanes 1, 2 and 3. It might be explained by riders' safety perspective.

Moreover, the results show that there is a statistically difference of average motorcycle speeds across lane positions (ANOVA, $F_{0.05,3,428} = 157.307$, $p = 0.000$). Based on the results, the research suggests to introduce a lane splitting of motorcycles along with satisfactory posted speed. Motorcyclists should be restricted to move on a certain lane (for instance, left lane only) or lanes which not only improves traffic flow but also reduce the percentage of vehicle collisions.

5.2. Speed and Helmet Use

More than 90% of all motorcyclists wearing helmet during their trips which implies that most riders appear to obey the helmet law. The average speed of helmeted motorcyclists is 62.87 km/h while it is 57.65 km/h for those riders who do not wear helmet. The highest speeds are 97 and 88 km/h for helmeted and non-helmeted motorcyclists, respectively. Both helmeted and non-helmeted motorcyclists travel less than 40 km/h at low speed. All motorcyclists tend to wear helmet if they ride and carry products in the back.

Regarding riding solo, there is a significant difference of mean speeds between helmeted and non-helmeted motorcyclist ($t_{0.05,325} = 2.764$, $p=0.006$). It implies that those helmeted motorcyclists tend to ride at higher speed which resulting to have higher risk of accident. Possibly, riders might believe in helmet efficacy to reduce head injury and mortality which lead them to speeding. The results will be useful for road speed management strategies. Moreover, the results can be employed to design road campaign which illustrate how fast helmeted motorcyclists ride along the road. Similarly, in terms of helmet use, there is a statistically significant difference of mean speeds among riding solo, riding with product and riding with one passenger (ANOVA, $F_{0.05,2,390} = 7.781$, $p = 0.000$).

5.3. Speed and Motorcyclist Group

The motorcyclists are classified into three main groups. The first group represents both rider and passenger wearing helmet during their travel. The second group is for riders wearing helmet with non-helmeted passenger. Finally, the last group is neither rider nor passenger wearing helmet.

There are totally 105 motorcyclists who rode motorcycles with one passenger. However, only 28 motorcyclists are found in group 1. The motorcyclists in group 2 contribute more in the traffic stream. There are totally 14 motorcyclists in group 3. Based on the results, it implies that there is still a limit of understanding about helmet benefits among motorcycles' passengers. Therefore, there is a need to enforce helmet law toward both rider and passenger.

The results also show that all three motorcycle groups prefer to travel on lane 1 which are possibly explained by safety perception. However, there is no presence of motorcycle group 3 in lane 4 which implies that this motorcycle group may be aware of other vehicles operating at the higher speed in lane 4. The mean speed of motorcyclist groups 1, 2 and 3 are 63.25 km/h, 56.41 km/h, and 58.21 km/h, respectively. However, there is no statistically difference on motorcycle speeds among these three groups at 5% significance level (ANOVA, $F_{0.05,2,102} = 3.254$, $p = 0.043$).

5.4. Speed and Engine Power

In the present research, motorcycle is classified into three main groups based on its engine power. The 110cc motorcycle contributes predominantly at 50.00%, followed by 47.00% of 125cc motorcycle. Only 3.00% of high engine power motorcycle are found in the study area. The average speed of 110cc, 125cc and high engine power motorcycle are 59.68 km/h, 64.71 km/h and 71.46 km/h, respectively. The results also show that there is a

significant difference of mean speeds among these three types of motorcycles (ANOVA, $F_{0.05,2,429} = 13.220$, $p = 0.000$).

All non-helmeted motorcyclists are found in low engine power motorcycle (110cc and 125cc). On the contrary, all riders who travel with high engine power (⩾150cc) motorcycle tends to wear helmet which might be explained by safety conception. For 110cc motorcycles, the results show no statistically significant difference of mean speeds between helmeted and non-helmeted motorcyclists ($t_{0.05,214} = 0.264$, $p=0.792$). For 125cc motorcycles, helmeted motorcyclists ride faster than those who do not wear helmet ($t_{0.05,201} = 3.614$, $p=0.000$). For riding solo cases, the number of 110cc motorcycles is similar to 125cc motorcycles. However, riding with one passenger are not found in high engine power (⩾150cc) motorcycles. It implies that the motorcyclists on high engine power motorcycles prefer to ride alone.

5.5. Spacing from Leading Vehicle

Out of 432 motorcyclists, there are 326 motorcyclists who follow other vehicles in the same lane. The mean and standard deviation of spacing from leading vehicle are 26.06 m and 8.15 m, respectively. Based on the results, motorcyclists tend to keep at least 11 m from leading vehicle as a safety distance.

Regarding following the front vehicles, motorcyclists prefer to travel on lanes 1 and 2. Only 10.73% of 326 motorcyclists travel on lane 4 and the mean spacing from the leading vehicle is the highest at 29.42 m. The research also investigates the spacing from leading vehicle across lane positions. Based on Table IV, the results show that there is a significant difference of spacing from leading vehicle across lane positions (ANOVA, $F_{0.05,3,322} = 6.130$, $p = 0.000$). The results might be explained by the variation of speeds across lane positions.

TABLE IV: Summary of ANOVA Tests For Mean Spacing From Leading Vehicle (m) and Mean Lateral Distance From Vehicle In An Adjacent Lane (m) With 95% Confidence Level

Variables	Degree of freedom		Mean square		F-value	Sig.
	Between group	Within group	Between group	Within group		
Spacing from leading vehicle across lane positions	3	322	389.017	63.464	6.130	0.000
Lateral distance from vehicle in an adjacent lane across lane positions	3	235	0.061	0.333	0.183	0.908

5.6. Lateral Distance from Vehicle in an Adjacent Lane

There are totally 239 motorcyclists who travel along vehicle in an adjacent lane. The average and standard deviation of lateral distance from vehicle in an adjacent lane are 1.91 m and 0.57 m, respectively. The results also show that motorcyclist keeps at least 0.83 m of lateral distance from vehicle in an adjacent lane. This result can be used for road safety management such as general guidelines for lane splitting.

The research also investigates the lateral distance from vehicle in an adjacent lane across lane positions. As shown in Table IV, there is no significantly difference of lateral distance from vehicle in an adjacent lane across lane positions (ANOVA, $F_{0.05,3,235} = 0.183$, $p = 0.908$).

6. Conclusions

This research is conducted in response to the call for reduction of traffic road accidents by understanding the riding behaviour of motorcycle. The research presents comprehensive field data which has provided a real and reliable information to understand the samples by using advanced traffic data collection technology. Several useful outcomes have been highlighted. The average speed of motorcyclists is 62.40 km/h. The speeds are as high as 97 km/h and 88 km/h for helmeted and non-helmeted motorcyclists. The proportion of motorcyclists are similar in lanes 1, 2 and 3. Furthermore, it is found that there is a statistically difference of average motorcycle speeds across lane positions. Both helmeted and non-helmeted motorcyclists travel less than 40 km/h at low speed. Regarding riding solo, there is a significant difference of mean speeds between helmeted and non-helmeted motorcyclists. In the study zone, the results also show that there is a significant difference of motorcycle speeds among three different engine powers of motorcycles.

Regarding following the front vehicles, motorcyclists prefer to travel on lanes 1 and 2. The average and standard deviation of spacing from leading vehicle are 26.06 m and 8.15 m, respectively. Based on the results, motorcyclists tend to keep at least 11 m from leading vehicle as safety distance. In addition, the average and standard deviation of lateral distance from vehicle in an adjacent lane are 1.91 m and 0.57 m, respectively. The motorcyclists tend to keep at least 0.83 m of lateral distance from vehicle in an adjacent lane.

This research provides both added value to the scientific literatures in the field as well as practical implications. From a scientific point of view, this research is another research effort which highlights that advanced traffic data collection technology have not only been used for traffic management but also been utilized to study the human behaviour and traffic safety. The outcomes provide a more detailed and potentially more precise way for understanding riding behaviour of motorcyclists under normal traffic condition. In addition, the results of this study implies that motorcyclists riding behaviour varies across characteristics of motorcyclists, motorcycles and lane positions. These characteristics might be considered as factors influencing motorcycle speed and rider compliance to speed limits. These characteristics might also provide the data needed to develop a motorcycle experiment in simulators.

From a practical point of view, this research might be the special attention of police and law enforcement against speedy motorcyclists in Thailand and other countries in Southeast Asian region. Media campaigns for traffic safety targeting on speedy motorcyclists (helmeted motorcyclist, high engine power) might produce more effective results than on general motorcyclists. Several recommendations can be drawn from this research in order to strengthen motorcycle road safety. For example, setting a reduced speed limit of the right lane could be used to slow down the motorcycle speed. It also provides evidence for setting specific limit speed values for different lane positions. It is recommended that policymakers and road designers should use the information presented in this article to be more aware and be more equipped to deal with the characteristics of motorcyclist and motorcycle that impact on riding behaviour. Additionally, specialized training of high engine power motorcyclists may decrease the potential risk from improper speeding.

Although the findings from this study provide helpful information for speed traffic management and policy maker, it still has an awareness of several limitations. Further research is necessary to examine the riding behaviour under the free flow condition which more reflects the likelihood of speeding. In addition, other characteristics namely; female rider, riding with high engine power, number of passengers (more than two passengers on the motorcycle) or even riding with children should be more focused in future studies. The current data only covers four main traffic lanes on highway. This is something that could be further investigated for different numbers of traffic lanes, type of roads (arterial road/frontage road) or even different speed limits. The relationship between speed of motorcycle, motives of risky behaviour and the effects of other significant characteristics (age, experience, socio-demographic characteristics, life style, etc.) should be considered. The method should include direct measurements of the speed along with interviews of riders. These kinds of research would contribute better traffic safety theories and to guidelines for traffic practitioners.

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