

# **DEVELOPMENT OF MOTORCYCLE RUNNING SIMULATION MODEL UNDER MIXED TRAFFIC FLOW AND ITS VERIFICATION**

*Tetsuhiro ISHIZAKA, Nihon University, Japan*

*Atsushi FUKUDA, Nihon University, Japan*

## **ABSTRACT**

The objective of this study is to develop the motorcycle running simulation model under mixed traffic flow in Asian countries. The running behaviour of motorcycle was modelled by using the concept of the potential which show the topographical probability of motorcycle running on road. The running behaviour on the motorcycle running simulation model was verified in comparison with actual running behaviour under mixed traffic flow. It was concluded that the motorcycle running simulation model has been capable to demonstrate detailed running behaviour of motorcycle.

*Keywords: Motorcycle, Simulation model, Mixed flow*

## **INTRODUCTION**

Number of motorcycle is increasing because motorcycle as convenient and economy transport mode are widely used in developing countries. The advantages of usage of motorcycle are low initial and operation cost, narrow parking spaces, easy to driving and easy to threading among other passenger vehicles even if passenger car cannot run in traffic congestion. On the other hand, the number of passenger car is also increasing with rapid economic growth, consequently, motorcyclist have to drive on same lane with many other vehicles even they feel risk to traffic accident under mixed flow. In Thailand, motorcycle involved in traffic accident is equal to passenger car and its percentage is about 30% of all vehicles. The current situation is no desirable and should be improved.

To reduce traffic accidents of motorcycle, we have to conduct safety countermeasures in three perspectives: Riders, vehicles and road facilities. About the road safety countermeasures on rider and vehicle, it needs enough time to conduct these countermeasures in long time span. On the other hand, if the road safety countermeasures on road & environment such as traffic control devices and motorcycle lanes are installed,

effect of countermeasure is instantaneously provided to us but its effect is limited on installed road where countermeasure was installed.

In addition, many motorcycle as major transportation mode will continue to be used until next decades at least. We have to face traffic accident problems under the mixed flow in a short period. Therefore, some road safety countermeasures regarding road facilities have to be conducted because the road safety countermeasure rapidly contributes safety.

It is necessary to implement the road safety countermeasures such as waiting spot and signals for motorcycle-only and motorcycle lane to avoid collision between motorcycle and other vehicles. However, a methodology was still not developed to evaluate how these road safety countermeasures could be contributed to safety in developing countries. Micro simulation model is one of methodologies to evaluate how it can contribute safety. Micro simulation model which can simulate the motorcycle running behaviour for evaluation of safety is needed.

Therefore, the objective of this study is to develop of motorcycle simulation model and conduct simple verification of motorcycle running simulation model by comparing with actual traffic flow and simulated flow. The running behaviour of motorcycle was modelled by using the concept of the potential which show the topographical probability of motorcycle running on road.

## **LITERATURE REVIEW**

### **Motorcycle Running Behaviour**

Hyodo et al (2004) analyzed the traffic flow and traffic congestion under mixed traffic flow by image processing to evaluate traffic regulation in Ho Chi Minh City, Vietnam. The relationship between motorcycle speed and traffic volume was shown and the traffic flow was simulated by using VISSIM on which this relationship was inputted. Ioanna S. et al (2007) examine parameter of interaction related of motorcycle behaviour and other vehicles. This study also focuses interaction with other vehicle as a same as this study, however, the methodology to simulate motorcycle behaviour in simulation didn't be described on the paper.

Tien-Pen HSU (2004) considered that the traffic problem caused by the mixed traffic flow including motorcycle could not deal with it in the existing traffic analysis. PCU (passenger car unit) which is conventionally used when capacity of intersection and road is analyzed was not suitable for the present condition of mixed traffic flow. Therefore, the study proposed disarray index to evaluate motorcycle movement. The disarray index means average movement (meter) of lateral direction by 10 m of running direction movement. The disarray index was measured by observing actual traffic flow. The study concluded that disarray index depends on percentage of motorcycle of traffic volume. The disarray index exceeds 0.15 that means 1.5m movement of lateral direction per 10m when percentage of motorcycle is over 0.5 to 0.7. However, this study only considered movement of lateral direction and this disarray index was not classified by relative position of other vehicles. Therefore, the disarray index cannot be used to develop the motorcycle simulation model.

Hashino et al (2004) examined lateral movement of motorcycle to verify relationship between motorcycle and other vehicle by observing traffic flow in Hatyai and Bangkok. Hashino clarified the lateral movement by the factors: motorcycle speed, bus stop, street-parking

vehicle, no of lane and lane width. The motorcycle ratio is critical important factor to describe motorcycle running behaviour under mixed flow.

### Existing Model for Motorcycle

To develop motorcycle simulation model from an aspect that it is important to consider existence of motorcycle to verify road safety in Japan, Inagaki and Uchida [6] tried to input the evaluation of accident involved by left-turn vehicle or right-turn vehicle to simulation model.

When an motorcycle was shown like Figure. 1 which considers the situation of avoiding collision to street-parking vehicle, Uchida examined the motorcyclist's psychological pressure by observation of the relationship the lateral interval "d" to the street-parking vehicle when motorcycle pass through side of street-parking vehicle, and the distance "l" from the position where motorcycle changes running direction to street-parking vehicle. The study called the psychological pressure the psychological potential that means risk of accident when motorcyclist feels based on situation around motorcycle. And it psychological potential means the topographical probability of motorcycle running on road. Its probability density function which is a function of distance from street-parking vehicle shows in Figure 2.

However, this study verified only the potential of motorcycle which passes through side of street-parking vehicle and the other potential didn't be verified. Because the motorcycle running behaviour which would be focused in this study didn't be verified, the other potential has to be verified.

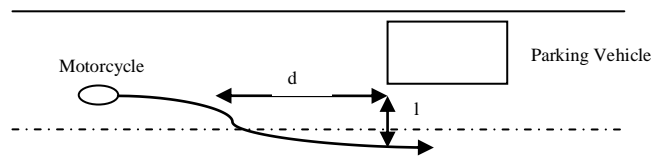


Figure 1- Motorcycle behaviour in passing parking vehicle

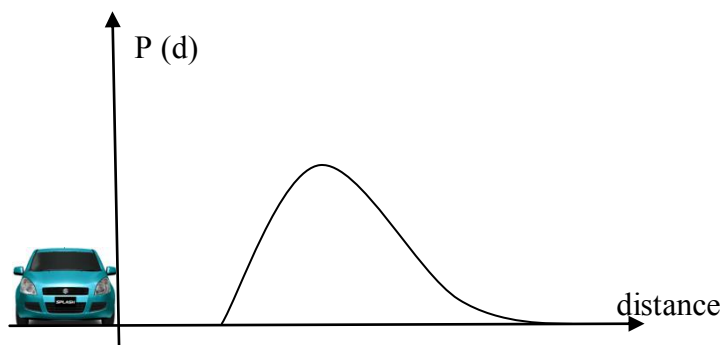


Figure 2- Probability density function of motorcycle running

## Running Direction of Motorcycle

There are a few previous studies about running direction of motorcycle. Therefore, this study picked up pedestrian behaviour which has similar behaviour of motorcycle.

Morishita (1995) conduct evacuation model by using microscopic proximity on cellular automaton in the emergency case in large shopping center. One of the features of cellular automaton can express by models that can be mathematically difficult to state, especially people can take advantage of its features to model. As a result, the number of entrances to the area where the accused and the relationship between time and was able to confirm qualitatively.

## MOTORCYCLE RUNNING BEHAVIOUR TO CONSIDER IN SIMULATION MODEL

### Classification of Running Behaviour

This study classified motorcycle running behaviour into three behaviours by observing traffic flow in Chiang Mai and Bangkok as follow:

Running behaviour 1

Motorcycle changes car-following to overtaking among other vehicles

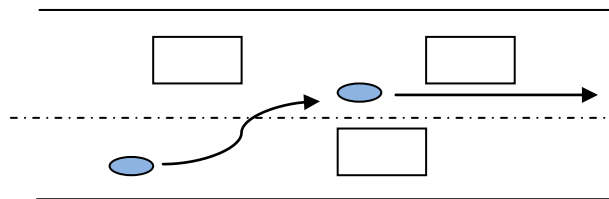


Figure 3 - Running Behaviour 1

Running behaviour 2

Motorcycle overtakes among vehicles

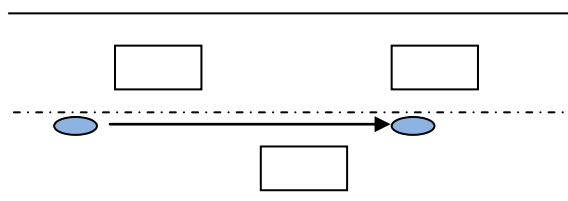


Figure 4 - Running Behaviour 2

Running behaviour 3

Motorcycle follows ahead car on next lane after overtaking ahead vehicle on same lane

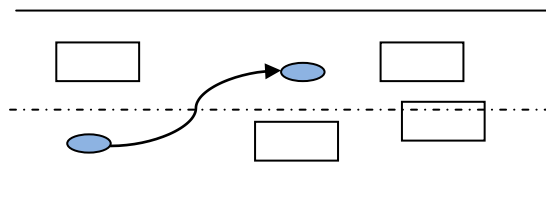


Figure 5 - Running Behaviour 3

## Field Observation

Based on above literate review, it was cleared that motorcycle ratio in traffic flow was important index to classify the motorcycle behaviour. Traffic flow was classified into free flow and congested flow and traffic phenomenon under these flows were examined by conducting field observation of actual traffic flow in Chiang Mai and Bangkok. The field observation was conducted by video shooting to traffic flow from pedestrian bridges. Total ten hours is recorded by video. Free flow and congested flow was chosen in movies of Chiang Mai and Bangkok.

### Free Flow

As a result of observation of traffic flow of a road in Chiang Mai, traffic volume and the frequency of by each behaviour is summarized on table 1 and Figure 6. The frequency by each behaviour was counted on 100 m road section. There was almost no rapid alternation of speed and this traffic flow is recognized as free flow. As shown in table 1 and Figure 6, it turned out that motorcycle running behaviour 1 has accounted for many rates. In free flow, frequency of running behaviour 1 is higher than behaviour 2 and behaviour 3.

Table 1 - Observed Traffic Volume of Free Flow in Chiang Mai

		Obsearvation time period(min)					average per five min.	average per ten min.
		15~16	16~17	17~18	18~19	19~20		
		20~21	21~22	22~23	23~24	24~25		
traffic volume (vehicle/time period)	Motorcycle	42	35	34	32	28	171	348
		41	20	49	33	34	177	
	Other Vehicles	56	52	44	28	14	194	478
		71	24	77	43	69	284	
frequency by each behavior (vehicle/time period/100m)	Behavior 1	5	3	2	1	7	18	39
		5	5	6	1	4	21	
	Behavior 2	1	1	2	2	0	6	16
		3	2	1	2	2	10	
	Behavior 3	1	1	0	2	0	4	13
		3	0	1	3	2	9	

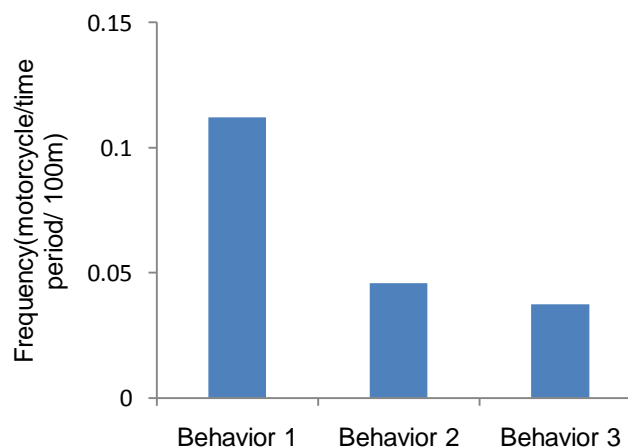


Figure 6 - Frequency of each behaviour

### Congested Flow

Rama I road in Bangkok was selected as observation site of congested traffic flow. Frequency of each running behaviour and traffic volume is shown in table 2 and Figure 7. It is difficult for motorcycle to change a lane and thread among other vehicles like behaviour 1 or 3 under congested flow. Therefore, running behaviour 2 of passing among other vehicles occupied high percentage of all behaviours.

Table 2 - Observed Traffic Volume of Congested Flow in Bangkok

		Obsearvation time period(min)					total per five min.	total per ten min.
		15~16	16~17	17~18	18~19	19~20		
		20~21	21~22	22~23	23~24	24~25		
traffic volume (vehicle/time period)	Motorcycle	32	37	23	33	47	172	353
	Other Vehicles	29	31	39	38	44	181	
	Behavior 1	40	53	51	45	45	234	451
		45	36	41	46	49	217	
frequenc y by each behavior (vehicle/time period/100m)	Behavior 1	5	6	6	3	2	22	53
		7	3	11	3	7	31	
	Behavior 2	10	10	16	20	27	83	136
		9	6	12	13	13	53	
	Behavior 3	4	7	4	5	3	23	37
		3	1	3	5	2	14	

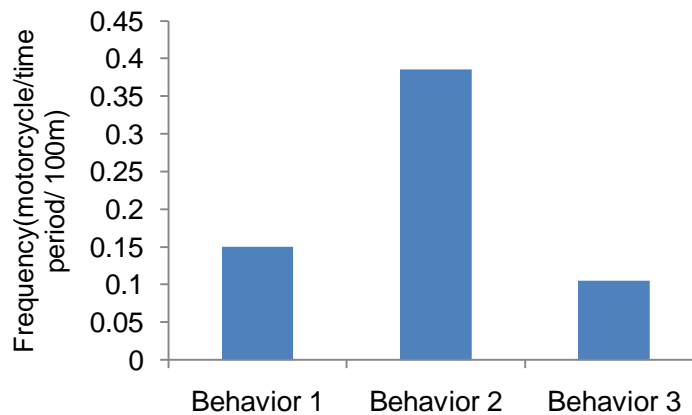


Figure 7 - Frequency of each behaviour

## DEVELOPMENT OF MOTORCYCLE RUNNING SIMULATION MODEL

### Proposal of Motorcycle Running Simulation Model

In the previous chapter, frequency of each behaviour is different by traffic flow: free flow or congested flow. Especially, the field observation revealed that frequency of behaviour 1 and 2 were influenced by free/congested flow, in other words, headway of other vehicles. And more, it was clearly that almost motorcycle disregarded traffic lane. This study described that the motorcycle running behaviours under mixed traffic flow couldn't be adapted into existing car-following model for car.

Therefore, this study proposes the motorcycle simulation model which can simulate the motorcycle running Behaviours by dynamically deciding the position, direction and speed of motorcycle.

### **Concept of the Motorcycle Simulation Model**

The study applied the concept of potential model of Inagaki and Uchida (2004) to the motorcycle running simulation model. However, Uchida considered the influence to motorcyclist from only on street-parking vehicles. Therefore, this study considered the three type of potential as shown in Figure 8. Three types of potentials is defined as lateral direction, vertical direction and among vehicles. The potential curve of lateral direction is connected between side edges of vehicle or road side. The potential curve of vertical direction is connected between front or rear side of vehicles and intersection. The potential curve among vehicles is connected between vehicles including motorcycle.

### **Calculation of Potential**

The potential of between following vehicle  $V_f$  and leading vehicle  $V_l$  expresses by the logarithmic curve which shows potential  $d_f(i, j)$  of  $V_f$  by a formula (1), and shows potential  $d_l(i, j)$  of  $V_l$  by a formula (2). Figure 9 shows the method of calculation for potential of running direction. Finally, the potential between following vehicle and leading vehicle is calculated by averaging  $d_f(i, j)$  and  $d_l(i, j)$ . The adjustment parameter is used to adjust potential value. In this study, by changing the adjustment parameter, the frequency of each running Behaviour can be controlled. Same calculation is conducted for other two potential. However, the adjustment parameter is defined for each potential. Finally, the average of three potential values is used for motorcyclist to decide direction and speed like image of Figure 10.

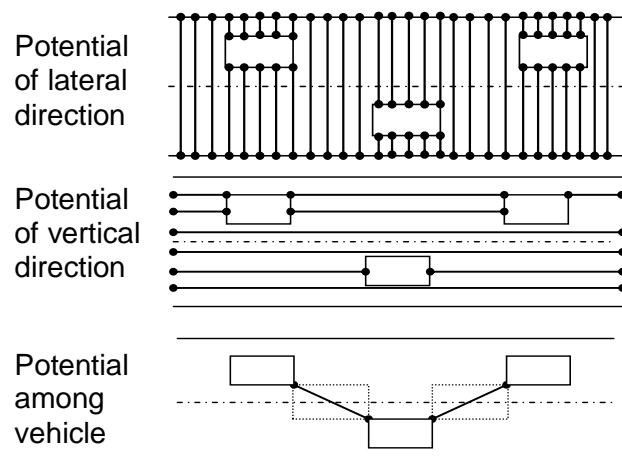


Figure 8 - Three types of Potential

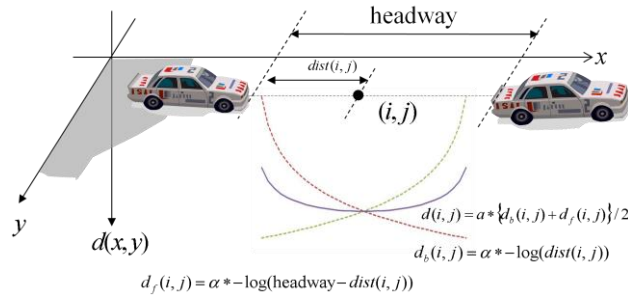


Figure 9 - Concept of Potential Model

$$d_f(i, j) = \alpha_{rd} * -\log(\text{headway} - \text{dist}(i, j)) \quad (1)$$

$$d_l(i, j) = \alpha_{rd} * -\log(\text{dist}(i, j)) \quad (2)$$

$$d_{rd}(i, j) = \{d_l(i, j) + d_f(i, j)\} / 2 \quad (3)$$

$$d(i, j) = \{d_{rd}(i, j) + d_{ld}(i, j) + d_{v2}(i, j)\} / 2 \quad (4)$$

Where

$d_f(i, j)$  : Potential at position (i,j) from following vehicles

$d_l(i, j)$  : Potential at position (i,j) from leading vehicles

$d_{rd}(i, j)$  : Average potential of both potential of running direction

$d_{v2}(i, j)$  : Average potential of both potential among vehicles by calculating with formula (1)

and (2),  $\alpha_{v2}$  is used instead of  $\alpha_{rd}$

$d_{ld}(i, j)$  : Average potential of both potential of lateral direction by calculating with formula

(1) and (2),  $\alpha_{ld}$  is used instead of  $\alpha_{rd}$

$d(i, j)$  : Average potential of both potential

*Headway* : Headway between following vehicle and leading vehicle

*dist(i, j)* : Distance from following vehicle

$\alpha_{rd}$ : Adjustment parameter for running direction

$\alpha_{ld}$ : Adjustment parameter for lateral direction

$\alpha_{v2}$ : Adjustment parameter among vehicles

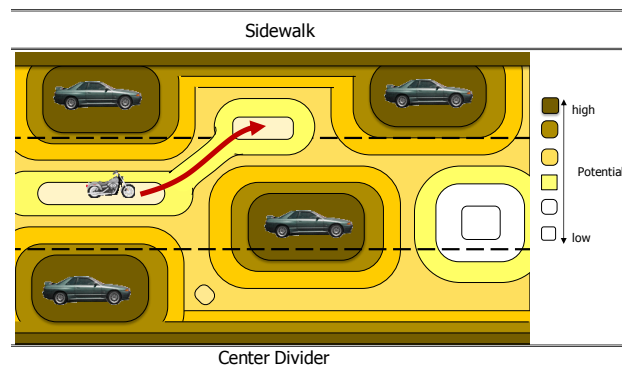


Figure 10 - Image of Potential

The motorcycle simulation model is defined as follows:

- The traffic lane as shown in Figure. 10 is described as three dimension, x axis indicates the running direction of motorcycle and other vehicle, y axis indicates the lateral direction (of lane width) and z axis means the potential which shown by  $d(x,y)$ .



- Potential is calculated by each cell which is 10 centimetre mesh.
- Three lanes with 3.5 m width
- Road length is 100m
- Running direction of motorcycle is a direction from motorcycle to the lowest potential
- Speed of motorcycle is decided by depth of potential which
- Time scan is 0.1 second.
- Potential  $d(i,j)$  is calculated by every time scan.
- The speed of other vehicles is fixed 40km/h because road length is very short.

## VERIFICATION OF MOTORCYCLE RUNNING SIMULATION MODEL

In this study, the verification of the developed motorcycle simulation model was conducted by checking whether each running behaviour would be demonstrated or not and whether totals traffic flow of motorcycle and other vehicle would be created.

### Demonstration of Motorcycle Running Behaviour

In this study, it was checked whether each running behaviour would be reproduced in the developed motorcycle simulation model based on the proposed concept. The sequence images of demonstrated running behaviour are shown in Figure.11, Figure.12 and Figure.13. The potential value illustrated the shade of colour: low potential is showed by white colour in these images. Based on the concept of motorcycle running Behaviour, motorcycle is due to run forward direction to lowest potential point. Consequently, it is recognized that the motorcycle shown by circle in these figure run like an actual motorcycle.

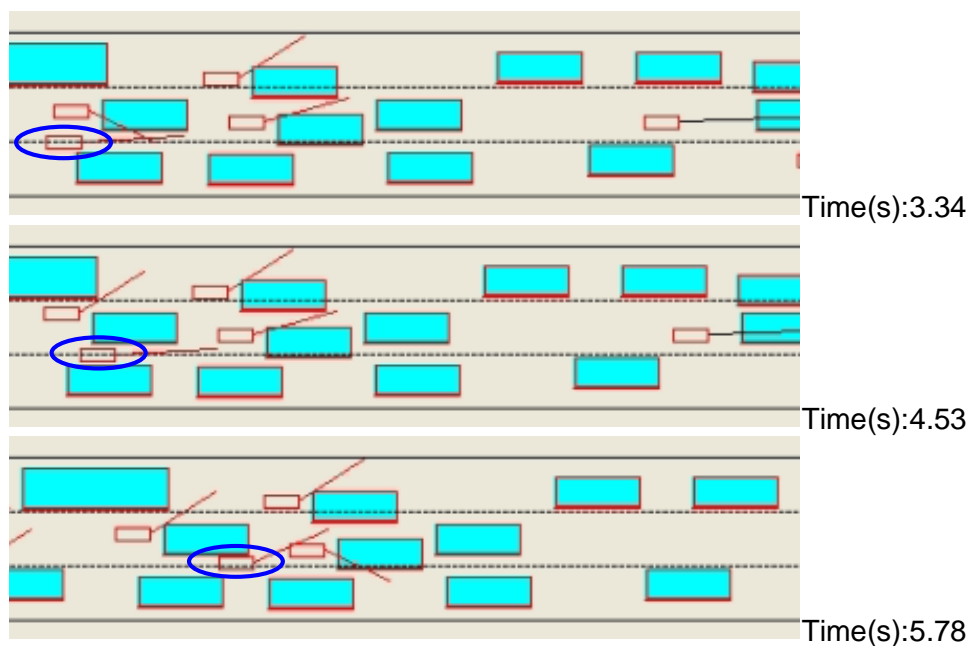


Figure11 - Verification of Running Behaviour 1

(Motorcycle changes car-following to overtaking among other vehicles)

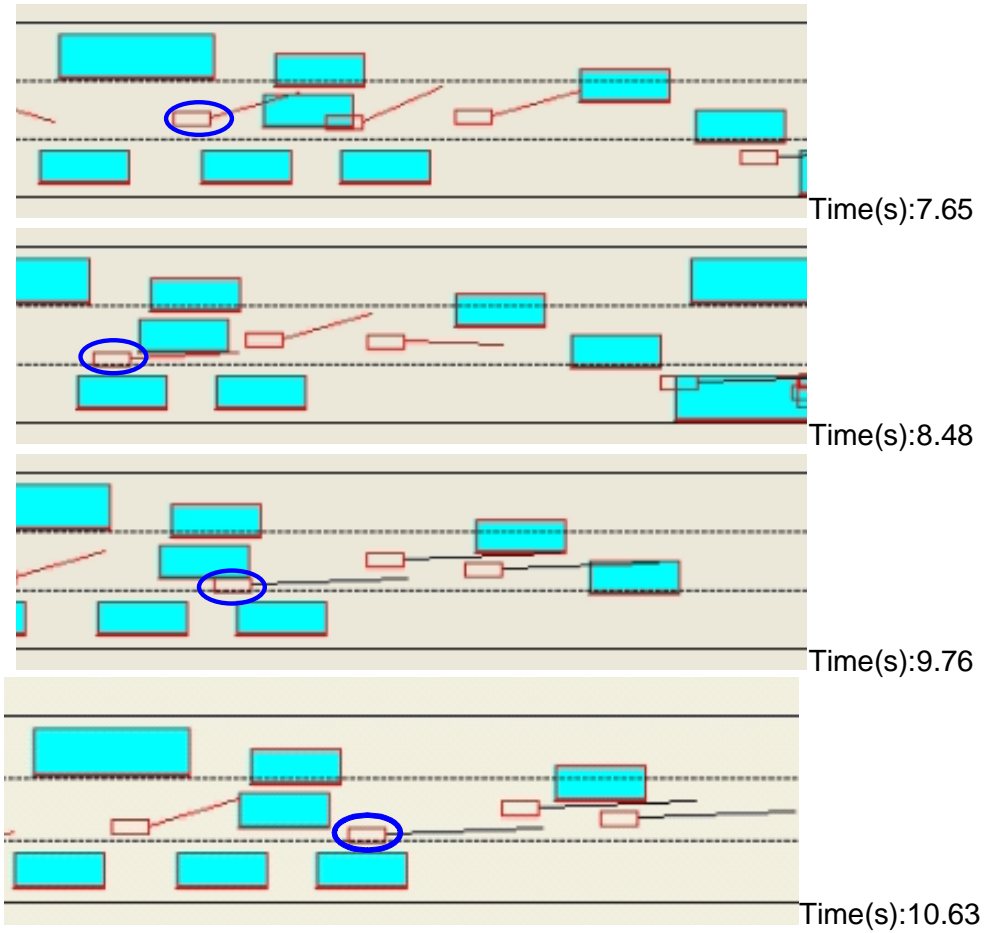


Figure 12 - Verification of Running Behaviour 2  
(Motorcycle overtakes among vehicles)

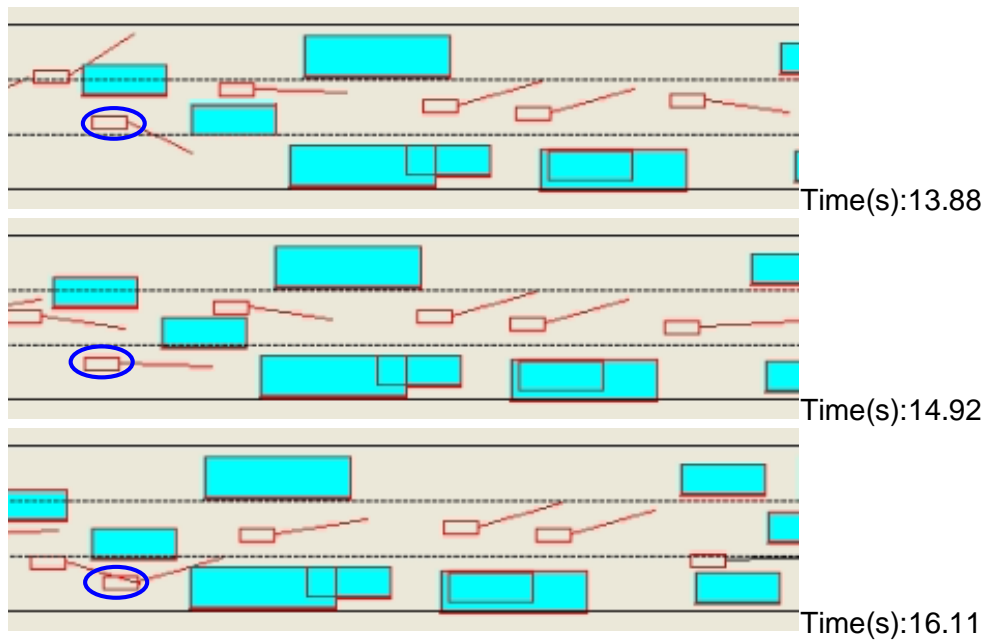


Figure.13 - Verification of Running Behaviour 3  
(Motorcycle follows ahead car on next lane after overtaking ahead vehicle on same lane)

## Comparison Simulated Traffic Flow with Observed Traffic Flow

This study tried to verify whether the traffic phenomenon of free flow of a road in Chiang Mai could be reproduced using the developed motorcycle simulation model. In addition, since the traffic phenomenon of a road in Chiang Mai was a free flow, it needed to set the parameter  $\alpha$  to demonstrate speed, number of vehicle and headway like the situation of Chiang Mai described in third chapter. Then, a parameter of setting which demonstrates free flow was estimated as follow:

$\alpha_{rd}$ : Adjustment parameter for running direction ( $\alpha=1$ )

$\alpha_{ld}$ : Adjustment parameter for lateral direction ( $\alpha=2$ )

$\alpha_{v2}$ : Adjustment parameter among vehicles ( $\alpha=5$ )

The frequency of each running Behaviour which counted on developed motorcycle simulation model was compared the observed value as shown in Figure 14. As the result, the both frequencies of each behaviour is recognized to be same tendency. It was concluded that the motorcycle running behaviour was able to be simulated using the developed motorcycle simulation model.

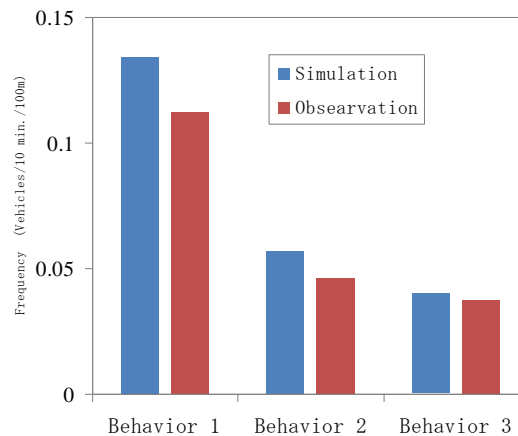


Figure.14 - Comparison with actual traffic flow (free flow)

To verify whether the traffic phenomenon of congested flow of a road in Bangkok, the adjustment parameter was adjusted as follows:

$\alpha_{rd}$ : Adjustment parameter for running direction ( $\alpha=1$ )

$\alpha_{ld}$ : Adjustment parameter for lateral direction ( $\alpha=7$ )

$\alpha_{v2}$ : Adjustment parameter among vehicles ( $\alpha=3$ )

Adobe adjustment parameter is suitable to demonstrate congested flow with these running Behaviour. The frequency of each behaviour is shown in Figure.15

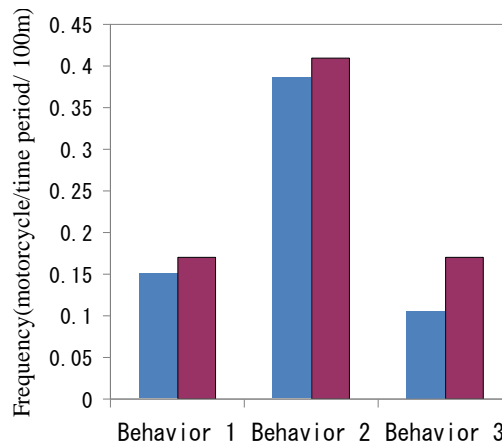


Figure.15 - Comparison with actual traffic flow (congested flow)

## CONCLUSION AND DISCUSSION

This study tried to develop the motorcycle simulation model which simulated motorcycle running behaviour in developing countries. To develop the model, this study conducted to classify into three motorcycle running behaviours and count it through the field observation. The frequency of each behaviour under free flow and congested flow was revealed. The motorcycle simulation model which can simulate three running behaviours of motorcycle was developed by authors. And the verification was conducted whether motorcycle running behaviour could be simulated. Consequently, it is concluded that developed motorcycle simulation model has possibility to simulate mixed traffic flow. However, this study is first trial to develop simulation model by using the concept of potential. Therefore, we need to improve the motorcycle simulation model.

The simulation model was verified under only two traffic flow. More kind of traffic flow should be examined and the relationship between adjustment parameter and traffic flow should be revealed. In further study, we try to simulate traffic flow around and at intersection. Finally, the motorcycle simulation model will be used to evaluate traffic safety countermeasures in developing countries.

## ACKNOWLEDGMENT

I would like to express my gratitude to the research foundation of Nihon University which supported this study.

## REFERENCES

- Yordphol T. and Thaned S. (2005) Traffic Accidents in Thailand, IATSS RESEARCH, Vol.29, No.1, pp.88-100
- Nobuyuki M., Tetsuro H., Youji T. and Megumi O. (2004) Analysis of Running Behaviour of mixed traffic flow with motorcycle by using microsimulation model and image processing, Proceeding of Traffic Engineering, Vol.24, pp.61-64.

- Ioanna S. and Dimitris S. (2007) Parameter related to modeling motorcycle movement, Transportation Research Board, CD-ROM.
- Toshio Y., Yashushi S. and Ryuichi K.(2004) Capacity Analysis of Mixed Traffic Flow with Motorcycles, IATSS Review, Vol.29, No.3, pp.188-198.
- Tien-Pen HSU (2004) Segregated Flow Concept for Motorcycle Traffic, IATSS Review, Vol.29, No.3, pp.199-208.
- Yoshihiko H. and Atsushi F. (2004) Study on Lateral Movement of Motorcycle under Mixed Traffic Flow in Developing Countries – Case Study of Bangkok and Hajai-, Master's thesis of Nihon University,
- Takeshi I., Takashi U., Yasuo H. and Nagayuki Y. (2004) The proposal of potential model to simulate motorcycle running Behaviour, Proceeding of Traffic Engineering, Vol.24, pp.1-4.
- Nobuaki M., Haruyuki N., Taro I. and Shinya F.(1995) Model of Lane changing at Expressway, Proceeding of Traffic Engineering, Vol.15, pp.17-20.
- L.W.Lan and C.W. Chang (2003) Motorbike's Moving Behaviour In Mixed Traffic: Particle-Hopping Model with Cellular Automata, Journal of the Eastern Asia Society for Transportation Studies, Vol.5, 2003, pp.23-37