GAP ACCEPTANCE CHARACTERISTICS AT A U-TURN SECTION IN BANGKOK

Ryoichi EBISAWA
Technical Staff, M. Eng.
Traffic Division of Metropolitan Police Department
Kasumigaseki 2-1-1, Chiyoda-ku, Tokyo, 100-0013, Japan
Tel:+81-3-3581-4321, Fax:+81-3-3581-4321
E-Mail: cdk19650@par.odn.ne.jp

Ian C. ESPADA
Graduate student, M. Eng.
Department of Civil Engineering, Graduate School of Engineering, University of Tokyo
7-3-1, Hongo, Bunkyo-ku, Tokyo, 113-8654, Japan
Tel:+81-3-5841-6118, Fax:+81-3-5841-8507
E-Mail: iespada@yahoo.com

Takashi NAKATSUJI
Associate Professor, Dr. Eng.,
Transportation and Traffic Systems, Graduate School of Engineering, Hokkaido University
Kita-13, Nishi-8, Kita-ku, Sapporo 060-8628, Japan
Tel:+81-11-706-6215, Fax +81-11-706-6216
Email: naka@eng.hokudai.ac.jp

Yordphol TANABORIBOON
Professor, Ph. D.,
School of Civil Engineering, Asian Institute of Technology
P.O. Box 4, Klongluang, Pathumthani 12120, Thailand
Tel:+66-2-524-5506, Fax+66-2-524-5509
Email: yord@ait.ac.th

Abstract: Unlike most cities, Bangkok's highway system depends heavily on at-grade U-turn intersection schemes. Thus, it is important to assess how U-turn vehicles interact with priority vehicles to improve designs and traffic controls at these sections as well as to justify the improvements to highway networks with U-turn sections. U-turn intersections generally operate at priority control. Gap acceptance function at normal priority intersections has been widely studied; however, little research has been conducted on U-turn intersections. Therefore, first of all, factors that affect the gap-acceptance function of U-turn drivers, needs to be identified and quantified to understand the U-turn phenomenon. In this study, the gap-acceptance function of a U-turn intersection in Bangkok was modeled as a binary choice problem. Eight explanatory variables are analyzed in an effort to identify and quantify variables that significantly affect gap acceptance at U-turn intersections.

Key Words: U-turn at Median, Gap acceptance, Traffic congestion, Binary Logit Model

1. INTRODUCTION

Bangkok's urban roads have uniquely developed dependence on the U-turn system due to the traditional use of *sois*. A *soi* is a local road connected to a major arterial in a T-configuration on one end and usually a dead end at the other. Later as traffic at the major road increased, the major arterials are physically divided by raised medians for safety and operational purposes. Since *sois* are closely spaced (approx. 100 m), it is then impractical to facilitate at-grade intersections for right turning traffic at every soi. Thus for a vehicle to turn right from a *soi*, it needs to turn left first then proceed to the nearest U-turn intersection. Obviously, U-turn intersections form bottlenecks of Bangkok traffic; thereby, are key elements in the performance of Bangkok's traffic system.

Despite popularity of the U-turn scheme in Bangkok, little is known on what influences traffic movement at these intersections. The gap acceptance function is the primary element that defines the way U-turn vehicles interact with a priority vehicle and is therefore a principal determinant in the analysis of U-turn movement. Thus, what factors and how they influence gap acceptance are key questions that needs to be addressed to fully analyze and understand traffic movement at these intersections.
U-turn intersections can be described as priority T-intersections with an angle of intersection of 180 degrees. However, maneuvers at U-turn intersections are different from those at standard 90-degree priority intersections. The gap acceptance has been studied by various

authors for 90-degree or close to 90-degree priority intersections (Daganzo; 1981, Mahmassani; 1981, Fitzpatrick; 1991, Hamed; 1997, Stan; 1997, Teply;1997, and Transportation Research Board; 1997). However, research on the gap acceptance function at U-turn sections has not gained much attention due to the unpopularity of such intersection configuration in most countries, except the study done by Al-Masaeid (1999), which analyzed the delay and capacity at U-turn sections.

In this study, the gap acceptance function at a U-turn intersection in Bangkok was analyzed as a discrete choice problem. A pool of eight explanatory variables was investigated on their effect on gap acceptance probability. Estimation of coefficients was done using the maximum likelihood method. Because of the high percentage of motorcycles in Bangkok traffic, separate analysis was done for motorcycles and passenger cars. Base on statistical inference, variables that were significantly influential to the gap acceptance function at a U-turn intersection were identified.

2. GAP ACCEPTANCE AS A BINARY CHOICE MODEL

Assuming that decisions for gap acceptance is based on the comparison of the utility, U_{acc}, of acceptance and a threshold utility, U_{th}, value (Ben-Akiva; 1993). The probability of gap acceptance can thus be shown as:

$$\Pr(accept) = \Pr(U_{acc} \geq U_{th}) \tag{1}$$

Further assuming that the utility of drivers is random and the utility function can be expressed as:

$$U = V + \varepsilon \tag{2}$$

where V is the representative component of utility and ε is the random component or disturbances.
Eq. 1 can thus be reformulated as:

$$\begin{aligned}\Pr(accept) &= \Pr(V_{acc} + \varepsilon_{acc} \geq V_{th} + \varepsilon_{th}) \\ &= \Pr(\varepsilon_{th} - \varepsilon_{acc} \leq V_{acc} - V_{th})\end{aligned} \tag{3}$$

Assuming the logistic distribution with positive scale parameter, μ, for ε, Eq. 3 results in the binary logit model as Eq. 4.

$$\begin{aligned}\Pr(accept) &= \Pr(\varepsilon_{th} - \varepsilon_{acc} \leq V_{acc} - V_{th}) \\ &= \frac{1}{1 + \exp(-\mu V_{acc} + \mu V_{th})}\end{aligned} \tag{4}$$

Taking μV_{th} as a constant parameter and assuming the representative utility function, V, as a linear function of some explanatory variables, the binary logit model simplifies to

$$\Pr(accept) = \frac{1}{1 + \exp(-V)} \tag{5}$$

where V is the linear representative utility function

$$V = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n \tag{6}$$

and
$\beta_0, \beta_1, \beta_2, \beta_n$: constant parameters
X_1, X_2, X_n : explanatory variables

The use of a utility function in determining the probability of gap acceptance enables the systematic inclusion of more than one factor as well as to facilitate easy examination and quantification of the effect of explanatory variables on gap acceptance probability using the Newton-Raphson technique.

3. DATA COLLECTION

3.1 Site description

Data used to analyze the gap acceptance phenomenon at U-turn intersections was taken from an at-grade U-turn intersection at Paholyothin Highway, Bangkok. The study area is illustrated in FIGURE 1. The intersection is located at an urban area and caters to U-turn movement as well as to traffic to and from a minor road. The intersection has no traffic sign to regulate the U-turn traffic but is observed to be operating at yield control. The highway section is straight with approximately 0% grade. There are no pronounced obstacles in the vicinity of the U-turn intersection to obstruct sight distance.

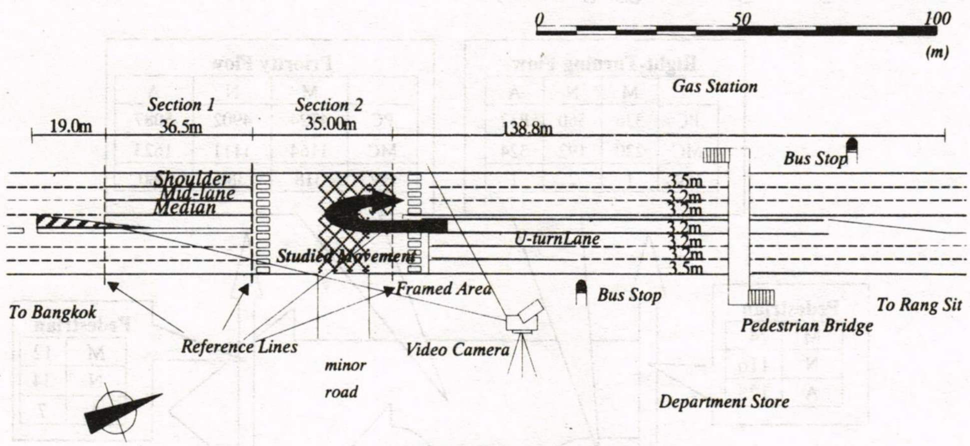


FIGURE 1. Study Area

The intersection was videotaped from a high vantagepoint on the 21 October 1997 for three 2-hour periods; namely, the morning period (08:45 to 10:45), the noon period (12:30 to 14:30) and the afternoon period (16:00 to 18:00). The video taping was done on a Tuesday with fair weather with all time periods having approximately the same lighting conditions.

Vehicles are classified into car (PC), motorcycle (MC) and heavy vehicle (HV). Cars are defined to include passenger cars, pick-up trucks, station wagon and other vehicles with similar acceleration characteristics. Motorcycles include all motorized vehicles with two wheels. And, heavy vehicles include all vehicles with long wheelbase and low acceleration characteristics. Turning volumes and pedestrian traffic at the intersection for each time periods is shown in FIGURE 2, where the time periods are abbreviated as M, N and A for morning, noon, and afternoon time periods, respectively.

Using 1/100-second accuracy in video timing the following variables are derived from videotape.

- Crossing time of every priority vehicle on the three reference lines
- U-turning vehicle type
- Priority vehicle lane orientation
- Number of gaps rejected by the lead U-turn driver
- Accept or reject for all gaps
- Priority vehicle type
- Waiting time, which is defined as the time the U-turn vehicle is in queue

- Parallel stopping, which is defined as the situation at which two or more U-turn vehicles stop at the head of the U-turn lane

From the crossing time at reference lines the speed is measured between contiguous reference lines and the time interval. The acceleration is then derived using the following equations

$$a_{ij} = \frac{v_{2,ij} - v_{1,ij}}{t_{ij}} \tag{7}$$

where

a_{ij} = Acceleration of j-th priority vehicle for i-th U-turn vehicle
$v_{1,ij}$, $v_{2,ij}$ = Speed of j-th priority vehicle for i-th U-turn vehicle in section 1 and 2
t_{ij} = Travel time of j-th priority vehicle for i-th U-turn vehicle between section1 and 2

For passenger car, almost 500 U-turn vehicles was observed deciding to accept or reject a total of nearly 5,000 gaps during any time period. The data sample for each time period is considered large enough for disaggregate analysis.

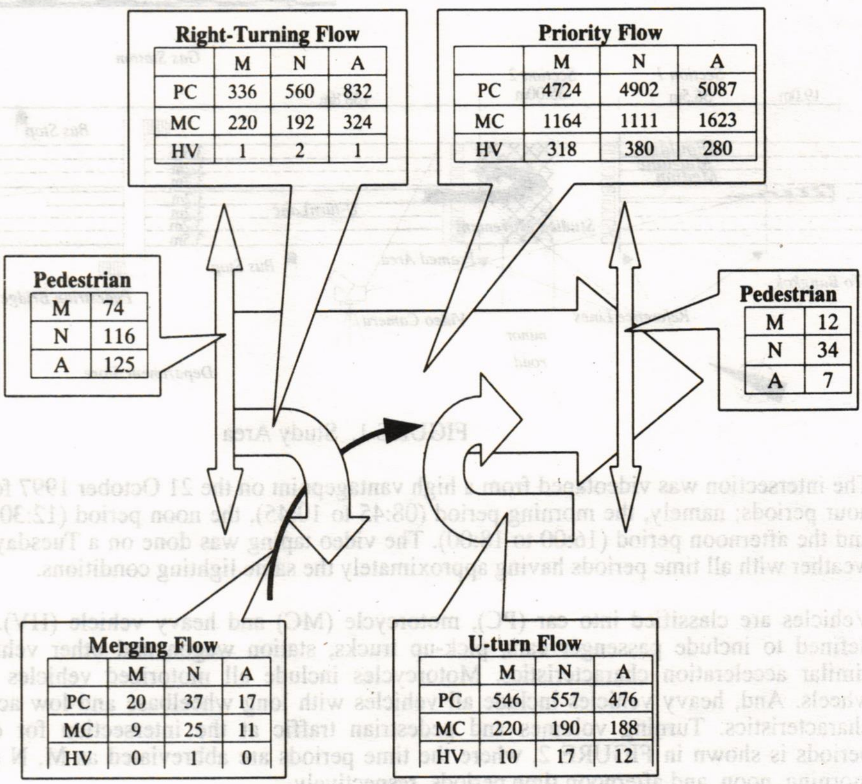


FIGURE 2. Turning Movement of Vehicular and Pedestrian Traffic at the U-turn Intersection

Pedestrian traffic was considered to be small enough and tends to cross the street when the traffic was at standstill, that is, there were few conflicts between U-turning vehicles and pedestrians. Thereby, their effect was excluded in the analysis. Also the merging flow was small enough to be neglected. Further, the number of HV U-turning vehicles was insufficient for analysis; thus, they were also excluded from the analysis.

Speeds of priority vehicles had a mean of 50 kph with a standard deviation of 12 kph. Acceleration data of priority vehicles indicated a mean of 0 m/s^2 with a standard deviation of

0.5 m/s^2 or 1.8kph/s. A 0m/s^2 mean acceleration shows that priority vehicles were not significantly affected by the U-turning vehicles and that reverse priority was not apparent in the data. A statistical test indicated that the speed and acceleration data followed closely the normal distribution. Also, the speed and acceleration data of priority vehicles was considered to cover a wide enough range of values with 95% of the speed data between 26 kph and 74 kph and 95% of the acceleration data between -3.5 kph/s to +3.5 kph/s.

Observation of U-turning vehicles indicated that PC and HV vehicles started off from the U-turn lane and crosses the median lane and mid-lane to merge with the priority stream at the shoulder lane. MC vehicles generally followed the same U-turn path but occasionally merges with the priority stream at the median lane and mid-lane. Also, Both PC and MC vehicles tended to encroach into the median lane while waiting for a suitable gap at the head of the U-turn lane. Analysis of waiting time at the U-turn lane showed that the 50^{th} percentile values of the three time periods was between 18 to 20 seconds and the 85^{th} percentile values was between the 33 and 40-second range.

4. VARIABLE SELECTION

4.1 Model Structure

The gap acceptance probability curve is formulated using the binary logit model with the utility function assumed to be linear to simplify the analysis. The applied pool of explanatory variables is as follows.

- Gap (sec) - defined as the time between the crossing of a major stream vehicle (or the arrival of a U-turn vehicle) and the crossing of the next major stream vehicle regardless of lane orientation.
- Priority vehicle - defined as the vehicle that comes first to the stop line.
- Speed of priority vehicle (kph)
- Acceleration, *acc*, of priority vehicle (m/s^2)
- Type of priority vehicle
  - ✓ MC - motorcycle
  - ✓ PC - passenger car
  - ✓ HV - heavy vehicle
- Driving lane of priority vehicle
  - ✓ Lane 1 (shoulder lane)
  - ✓ Lane 2 (mid-lane)
  - ✓ Lane 3 (median lane)
- Waiting time, *wait* (sec)
- Number of rejected gaps
- Existence of parallel stopping vehicle

Variables such as priority vehicle type, parallel stopping and lane orientation are not readily applicable into the model due to its qualitative nature. Thus, the qualitative variables are treated as dummy variables with the following property:

$$X_{ij} = \begin{cases} 1 & \text{if item } i \text{ is category } j \\ 0 & \text{otherwise} \end{cases} \tag{8}$$

4.2 Correlation between Variables

The data was first tested on correlation. The correlation table for the noontime period is shown in TABLE 1. The other two time periods have similar correlation tables. All variable pairs except waiting time and number of rejected gaps exhibited low correlation at all three time periods. In the selection process, when one of the variable pair with high correlation is accepted, the other variable is automatically eliminated from the analysis.

TABLE 1. Correlation of Variables for the Noontime Period

	Type of U-turn vehicle	Gap	Number of rejected gaps	Waiting time	Speed	Acceleration	Parallel stopping
Type of U-turn vehicle	1						
Gap	.05	1					
Number f rejected gaps	.18	.07	1				
Waiting time	.19	.07	**.98**	1			
Speed	.04	.12	.12	.09	1		
Acceleration	.00	.11	.06	.05	.04	1	
Parallel stopping	.33	.02	.21	.21	.04	.04	1

4.3 Stepwise Selection

The selection process started with one-variable logit models, pairing each explanatory variable to a constant term to form the utility function. Parameters for each model were then optimized using the maximum likelihood method. Then the variable of the model that exhibited the best goodness-of-fit was adopted. Also, variables that were insignificant at 90% confidence interval were eliminated from the analysis. The selection process was then repeated using a two variable logit model with a constant term, by pairing the adopted explanatory variable and each variable left in the pool. The process was continued until a maximum of 5 explanatory variables was selected or until the pool of variables was used up. The selection process was conducted on MC and PC vehicle type separately for the three time periods. From the selected variables of each time period, the best combination of explanatory variables was chosen based on the goodness-of-fit, significance of variables and consistency.

4.4 Selected Variables

The results of the selection process for PC and MC are summarized in TABLE 2 and TABLE 3, respectively. The variable in each column represents the variable that was newly selected in each process. The results show that gap is the most influential factor for both PC and MC. This is intuitively reasonable as drivers naturally base their gap acceptance decision on the time available for maneuver. For PC, acceleration of the priority vehicle is the next most influential factor. No other explanatory variable is accepted in all time periods except gap and acceleration. Thus, gap and acceleration is considered the best combination of explanatory variables to explain the gap acceptance decisions of PC.

TABLE 2 Stepwise Selection Process and the Adjusted Likelihood Ratio ρ^2 for PC

	1st variable	2nd variable	3rd variable	4th variable	5th variable
Morning period	gap 0.874	acc 0.891	wait 0.897	parallel 0.898	
Noon period	gap 0.848177	acc 0.867	wait 0.877	speed 0.879	HV 0.882
Afternoon period	gap 0.856	acc 0.881	lane3 0.889	speed 0.895	

The results for MC also indicate the same consistency in the selection of gap and acceleration of the priority vehicle in the three time periods. Acceleration is the second selected variable in the evening period and the third selected variable in the morning and noon period. In the morning and noon periods waiting time and parallel stopping is selected before acceleration but both variables were not consistently accepted in all time periods. Thereby, the gap-acceleration model is considered best in defining the probability of gap acceptance of drivers of MC.

TABLE 3. Stepwise Selection Process and the Adjusted Likelihood Ratio ρ^2 for MC

	1st variable	2nd variable	3rd variable	4th variable	5th variable
Morning period	gap 0.751	wait 0.762	acc 0.770	MC 0.779	speed 0.782
Noon period	gap 0.719	parallel 0.725	acc 0.731	MC 0.732	speed 0.733
Afternoon period	gap 0.738	acc 0.752	wait 0.758	PC 0.762	lane3 0.763

5. PROPOSED MODEL

Base on the variable selection, the combination of a constant term, gap and acelration provides the best model for both PC and MC vehicle types and has the following form:

$$\Pr(accept) = \frac{1}{1 + \exp[-(V)]} \tag{8}$$

where

$V = \beta + \beta_g \times gap + \beta_a \times acc$

β, β_g, β_a = model parameters or coefficients

Using the maximum likelihood method, the model parameters are determined for each time period and are summarized in TABLE 4. The coefficients derived are reasonable in their nature: The positive coefficient for gap means that the larger the gap, the more the chance of U-turning. Similarly, the negative coefficient for acceleration guarantees that the probability of gap acceptance decreases with the acceleration increasing. The selected variables exhibit high significance with confidence intervals better than 99% for both PC and MC in all time periods.

TABLE 4. Recommended Model for All Time Periods

		morning		noon		afternoon	
		coefficient	t-statistics	coefficient	t-statistics	coefficient	t-statistics
PC	Constant term	-8.189	-17.396	-7.228	-21.327	-6.709	-18.290
PC	Gap	1.898	16.004	1.662	18.481	1.716	16.359
PC	Acceleration	-1.697	-7.225	-1.750	-8.390	-1.928	-8.742
PC	ρ2 (adjusted)	0.891		0.867		0.881	
MC	constant term	-5.279	-19.989	-5.137	-19.277	-4.563	-17.671
MC	gap	1.471	15.718	1.475	14.340	1.353	14.442
MC	acceleration	-1.087	-4.541	-0.797	-3.468	-1.232	-5.354
MC	ρ2 (adjusted)	0.759		0.724		0.752	

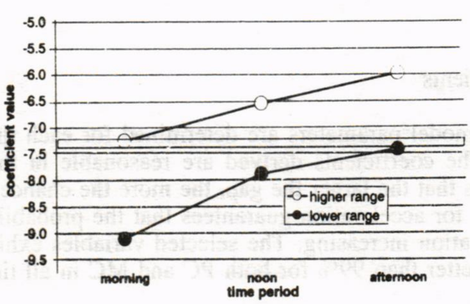
The next step would then be to determine the recommended value of coefficients for each of the explanatory variable. Using a confidence interval of 95%, the range of feasible values of each coefficient is determined for each time period. The results are shown in FIGURE 3 and FIGURE 4 for PC and MC respectively. The shaded region in FIGURE 3 and FIGURE 4 indicate intersection of the range of feasible values of parameters for the corresponding explanatory variable.

The area of intersection of coefficient ranges defined for each explanatory variable in FIGURE 3 and FIGURE 4 is then hypothised as the range wherein the common estimate is located. The recommended coefficient is simply taken as the mid-range value. The resulting recommended coefficients are summarized in TABLE 5.

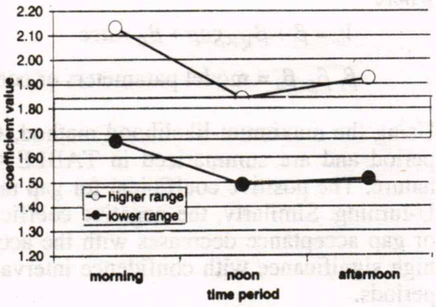
Comparison of the coefficients of PC and MC indicate that the coefficients of PC and MC are different at 95% confidence interval. This indicates that the gap acceptance behavior of PC drivers is different from those of MC drivers.

FIGURE 5 illustrates the proposed gap acceptance model with acceleration taken as constant. Models with constant acceleration values of –2, 0 and + 2m/s^2 are shown for comparison. From FIGURE 5, the 50 percentile accepted gap at –2 m/s^2, 0 m/s^2 and +2 m/s^2 priority vehicle acceleration is 1.0, 4.25 and 6.25 seconds for PC respectively and 1.0, 3.5 and 4.9 seconds for MC respectively. Thus the results show that drivers of MC tend to be more aggressive than drivers of PC. The high maneuverability and high acceleration properties of motorcycles can explain such tendencies.

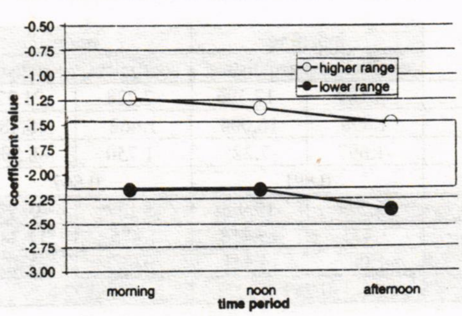
FIGURE 6 illustrates the recommend gap acceptance model for U-turn intersection when gap is taken to be constant. Constant gap values of 1 to 7 seconds are graphed for comparison. Here, it is shown that accelerating priority vehicles causes U-turn vehicles to exercise greater caution and that drivers of PC are more sensitive to acceleration of a conflicting vehicle than drivers of MC.



a) constant term

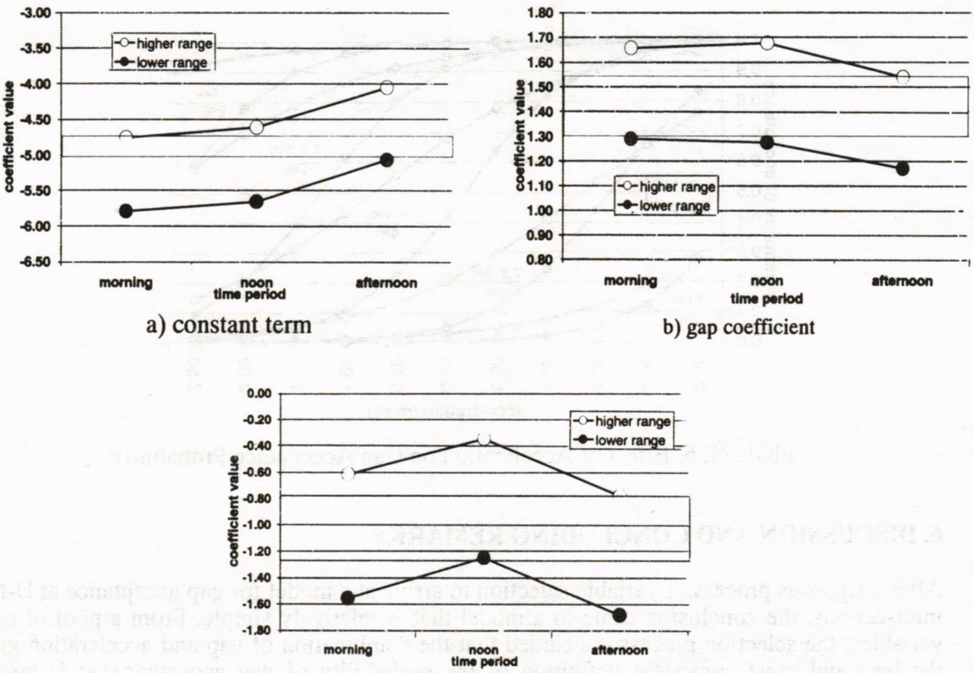


b) gap coefficient



c) acceleration coefficient

FIGURE 3. Resulting Intersection of Ranges for PC



a) constant term

b) gap coefficient

c) acceleration coefficient

FIGURE 4. Resulting Intersection of Ranges for MC

TABLE 5. Recommended Coefficients

	PC	MC
constant	-7.3475	-4.9149
gap	1.7517	1.4121
acceleration	-1.8262	-1.0144

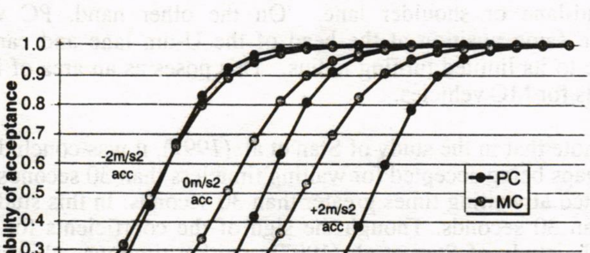


FIGURE 5. Effect of Gap on Gap Acceptance Probability

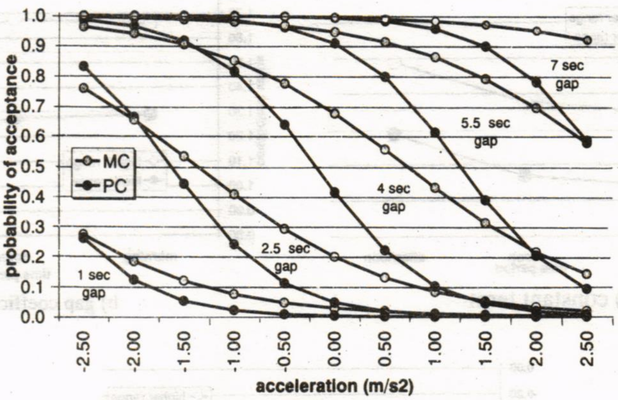


FIGURE 6. Effect of Acceleration on Gap Acceptance Probability

6. DISCUSSION AND CONCLUDING REMARKS

After a rigorous process of variable selection to arrive at a model for gap acceptance at U-turn intersections, the conclusion came to a model that is relatively simple. From a pool of eight variables, the selection process concluded that the combination of gap and acceleration gives the best and most consistent definition of the probability of gap acceptance of U-turning vehicles. The results are intuitively reasonable since drivers would tend to be more cautious if the gap is small and if the priority vehicle is accelerating. However, the rejection or the non-inclusion of the other variables considered in this analysis; namely, lane orientation, speed and vehicle type of priority vehicle, waiting of the U-turning vehicle, and parallel stopping, is contradictory to what is intuitively obvious. We expect drivers to exercise more caution when priority vehicles that are on the shoulder lane because of the extra distance required to traverse to the shoulder lane. The results, however, showed that U-turning drivers do not significantly differentiate the lane orientation of the conflicting priority vehicle. Similar arguments can be made with the speed and vehicle type of the priority vehicle, waiting time of the U-turning vehicle, and parallel stopping.
It is also observed that the gap acceptance models for MC exhibit much lower ρ^2 values than those for PC. This can be attributed to the tendency of MC vehicles to position themselves less consistently at the head of the U-turn lane and its ability to turn sharply to merge at the median lane, mid-lane or shoulder lane. On the other hand, PC vehicles position at approximately the same position at the head of the U-tun lane and can only merge at the shoulder lane due to its limited turning radius. This poses as an area of improvement of gap acceptance models for MC vehicles.

It is pertinent to note that in the study of Stan et al. (*1997*), it was concluded that waiting time tends for higher gaps being accepted for waiting time less than 30 seconds and tends for lower gaps being accepted at waiting times greater than 30 seconds. In this study, waiting times are generally less than 30 seconds. Though the sign of the coefficients for waiting time are in agreement with the study of Stan et al. (1997), waiting time was eliminated in the variable selection process.

Al-Masaeid (1999) analyzed the capacity at U-turn sections. He presented regression formulas for capacity, total delay, critical gap, and move-up time. For instance, the average total delay and conflicting traffic speed are adopted to describe the critical gap. However, The probability function is focused for neither passenger car nor motorcycle in the study.

The *Highway Capacity Manual* (HCM) provides the comprehensive procedures for estimating the capacity of unsignalized intersection. The procedures have greatly advanced for the last decade (Transportation Research Board; 1991, 1997). In the latest version (Transportation Research Board; 2000), the critical gap at unsignalized intersection accounts for geometric and traffic conditions, such as grade, the number of lanes, proportion of heavy vehicles, and vehicle movement. The capacity computed as the function of critical gap is further adjusted to consider the impedance by higher-priority vehicle movements, pedestrians, and so on. Thus, compared to the HCM model, the model proposed here is simplified. And the model is specific to U-turn sections whose traffic characteristics are similar to those of the measurement site. However, since the road network in Thailand is fundamentally based on U-turn scheme, the model should have a lot of chances to be applied for design and assessment of real road network systems.

With the proposed model for gap acceptance characteristics of U-turning vehicles, more rigorous study can be done on U-turn intersections in terms of its capacity and other performance indicators. The nature of the proposed gap acceptance model makes it ideal for use in dynamic analysis of U-turn intersections as in microscopic simulation analysis. The formulation of the proposed gap acceptance model for U-turn intersections is a step towards better understanding of the U-turn phenomenon.

ACKNOWLEDGMENT

A part of this study was conducted as the Research and Education Development Program (REDP) granted by Japanese Government at Asian Institute of Technology in Bangkok, Thailand.

REFERENCES

Hashem R. Al-Masaeid (1999) Capacity of U-Turn at Median Openings, **Institute of Transportation Engineers Journal**, June 1999, 28-34

Ben-Akiva, M. and Lerman, S. (1993) **Discrete Choice Analysis: Theory and Applications to Travel Demand**, The MIT Press, London.

Daganzo C.F. (1981) Estimation of Gap Acceptance Parameters Within And Across The Population From Direct Roadside Observation. **Transportation Research, Vol.15B**, 1-15.

Fitzpatrick K. (1991) Gaps Accepted at Stop-Controlled Intersections. **Transportation Research Record, 1303**, 103-112.

Hamed M. M. and Easa S. M. (1997) Disaggregate Gap-Acceptance Model for Unsignalized Intersection, **Journal of Transportation Engineering**, Vol.123, No.1, 36-42.

Mahmassani H. and Sheffi Y. (1981) Using Gap Sequences to Estimate Gap Acceptance Function. **Transportation Research, Vol.15B**, 143-148.

Stan, Teply, Mona I. Abou-Henaidy and Hunt J. D. (1997) Gap acceptance behavior-aggregate and logit perspectives: Part 2. **Traffic Engineering and Control, Vol.38, No.10**, 540-544.

Teply S., Abou-Henaidy M. I. and John Douglas hunt (1997) Gap acceptance behavior-aggregate and logit perspectives: Part 1. **Traffic Engineering and Control, Vol.38, No.9**, 474-482.

Transportation Research Board (1985, 1994, 1997, 2000) **Highway Capacity Manual, TRB Special Report 209**, Washington D.C..

Transportation Research Board (1991) Interim Materials on Unsignalized Intersection Capacity, **Transportation Research Circular 373**, Washington D.C.

Transportation Research Board (1997), Review of International Practices Used to Evaluate Unsignalized Intersections, **Transportation Research Circular 468**, Washington D.C.