Study on Filipino Driver Reaction Time

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Abstract – *Driver perception and brake reaction time (PBRT) is an important parameter in highway design and traffic flow analysis. PBRT can be divided into two main components namely (1) perception time, and (2) braking reaction time. In highway design, it is an important parameter in calculating sight distance for geometric design, to ensure road safety. In traffic flow analysis, specifically in microscopic traffic modeling, car-following models typically involve the specification of driver reaction time to replicate the trajectories of vehicles that travel along the highway. Driver reaction time is determined using two approaches: one is by designing and implementing a field experiment, and the other is by parameter estimation using genetic algorithm of vehicle trajectory data using an assumed car-following model. Result shows that Filipino driver reaction time is approximately 1.6 sec using field observation, and 1.5 using numerical estimation from trajectory data. The paper briefly discusses implication of these values on sight distance determination and its application in microscopic traffic flow analysis.*

Keywords—driver reaction time, local driving behavior, perception and braking time, car-following

I. INTRODUCTION

1.*1 Perception and Brake Reaction Time*

Driver perception and brake reaction time (PBRT) is an important parameter in highway design and traffic flow analysis. PBRT can be divided into two main components namely (1) perception time, and (2) braking reaction time. Perception time is defined to be the time it takes for the responder to perceive that an incident, say a traffic signal indication or sudden presence of road obstruction, has occurred and to decide upon a response. On the other hand, braking reaction time corresponds to the time it takes for the responder to lift his foot from the accelerator and apply the brakes. Driver error is a common cause of road accidents, and such errors could be associated with driver reaction time.

In highway geometric design, PBRT is used in calculating the required adequate stopping sight distance (SSD) to ensure that the horizontal and vertical alignment, particularly at sections with curvature, are safe for road users. For instance, the American Association of State Highway and Transportation Officials or AASHTO, recommends a value of 2.5s in calculating sight distances [1]. In traffic signal design, a driver's PBRT is used to estimate the time allotted for yellow light signal. Driver PBRT can be also used in crash probability estimation., Underestimating PBRT used in road design increases the risk of accidents for motorists and pedestrians, while overestimating it increases unnecessary roadway construction costs.

In microscopic traffic flow analysis, *car-following models* typically involve the specification of driver reaction time to replicate the trajectories of vehicles that travel along the highway. Car following involves the influence of a car's kinematics to the trajectory of a following vehicle in the same lane. Various concepts had been formulated to model car-following behavior. These include the *stimulus response theory*, which claims that the kinematics of a vehicle depend on the amount of stimuli received by the driver; the *safe distance theory*, wherein the main consideration is a maintained threshold distance between two consecutive vehicles; the *psychophysical theory*, which considers the acceleration of the leading vehicle as a stimuli; the *optimum velocity theory*, which claims that the driver behavior is affected by the difference between the optimum velocity and the current velocity; and the *trajectory based model*, in which the following vehicle's trajectory is taken as a translation in space time of the leading vehicle's trajectory.

The *Krauss car-following model*, as an illustration, is a combination of the stimulus response model and the safe distance model. It is presented as follows:

$$v_{safe} = v_{n-1} + \frac{g(t) - v_{n-1}(t)T}{\frac{v_n(t) + v_{n-1}(t)}{2b} + T} \tag{1}$$

$$g(t) = x_{n-1}(t) - x_n(t) - s$$

$$v_{des} = \min\{v_n(t) + a\Delta t, v_{safe}, V\}$$

$$v_n(t + \Delta t) = \max\{0, v_{des} - \epsilon at\}$$

In Equation 1, v_{safe} is the safe car-following velocity; n and $n-1$ are subscripts for the following and followed cars, respectively; a is the maximum vehicle acceleration; b is the maximum vehicle deceleration; T is the driver reaction time; $g(t)$ is called the gap function, a parameter that influences the safe velocity; v_{des} is the desired velocity, which makes use of the safe velocity as a parameter along with the maximum velocity due to the acceleration after the time interval Δt and the maximum allowed velocity; and ϵ_{at} is the stochastic parameter, which is a measure of driver sporadic and irrational driving behavior. Krauss model is a time-step model that returns values of velocity at equally spaced time intervals Δt.

In microscopic traffic flow modelling, calibration of these model parameters is necessary before the microscopic model could be practically applied in traffic flow analysis. The interest in this paper is estimating the driver reaction time T along with other parameters in the Krauss model. Among several parameter estimation (i.e. calibration) techniques, the genetic algorithm is considered in this paper.

1.2 Rationale and Objective

PBRT is an important parameter that describes driver characteristic and may vary from country to country. It is needed in calculating and determining values for several highway design controls that are essential in ensuring the safety of road users. Design of Philippine highways adopts foreign highway design guidelines, largely AASHTO guidelines, including the assumption of PBRT equal to 2.5s for stopping sight distance. There had been no research that validates if this assumed value is indeed applicable to Filipino drivers. There is a need to determine PBRT for Filipino drivers.

This study seeks to determine PBRT of Filipino drivers using two approaches. The first approach involves designing a methodology for field measurement of PBRT, while the second approach involves numerical estimation of driver reaction time using vehicle trajectory data used in car-following analysis.

1.3 Limitation of the Study

The field experiment designed and implemented to measure the PBRT, and the road section footage for the car-following analysis had been limited to a signalized intersection approach and a mid-block section, respectively, in the city of Metro Manila. Observations at these single locations would not be able to reflect regional differences in driver behavior. Nevertheless, the results shall be assumed to be indicative of the Filipino driver behavior. Also, the reaction time variation by demographic type of driver is not considered in this study.

II. REVIEW OF RELATED LITERATURE

2.1 Driver Reaction Time

Related studies that attempted to determine PBRT in various countries used different procedures and yielded varying values of PBRT [2,7,8,14,15]. Comparison of the PBRT values from these studies shall later be summarized and discussed in Section 5.

Methodologies employed to determine PBRT could be summarized into three main approaches: (1) controlled road study wherein the driver rides a test car, accompanied by an observer, and drives it into a series of obstacles that are set on a predefined test track; (2) simulator research, wherein a virtual reality test is given to the driver and the driver's response times to obstacles are measured by an observer; and (3) naturalistic observation, wherein a video observation of the actual traffic is recorded and analyzed.

The study by Olson and Sivak [2] in the University of Michigan measured the PBRT of unalerted drivers to *surprise*, *expected*, and *unexpected* obstacles for different age groups. They found that the 95th percentile perception reaction time is 1.6 seconds for unexpected obstacles and that reaction times are basically the same for age groups in both surprise and alerted conditions.

The PBRT was measured by an observer who accompanied the driver using a stopwatch. The driver is tasked to alert the data collector when the obstruction had been seen. This method is considered unideal due to introduction of possible bias from the driver's unusual state of alertness due to the knowledge that a test is being performed.

In the study by D'Aaddario [3] where the effect on PBRT of repeated exposure to hazardous scenarios was investigated, the expected decrease in PBRT was observed and were significantly evident in the perception times. The simulated pedestrian hazard registered shorter PBRT. However, for hazards coming from the side, the driver PBRT were higher at first, but decreased on the next drive trials because the drivers became more cautious of hazards coming from their peripheral. The brake reaction time was found to be 1.3s which is the average of measurements from two driving simulators for unexpected obstacles.

The study by Jurecki and Stanczyk [4] tested driver response to certain traffic accident by simulation and explored three methods for determining PBRT. The three methods were by *simple psychological stand* which is the experimental measurement of reaction time by the testing the driver's reaction to light or sound by pressing a key, *traffic simulation*, and *controlled track experiment*. It was found that there was no correlation between the results of the experiment on the track and that the simple psychological stand was not a reliable reaction time of drivers.

Setti and Grakha [5] characterized the PBRT at high-speed intersections with a minimum of 64 km/h design speed. The computation of the yellow light time depended on the PBRT and the researchers wanted to validate the 1 second PBRT at the 85th percentile. The authors recommended setting 1.0s for traffic signal design. For experiment procedure it was recommended that the time of arrival of cars at the intersection for measuring PBRT should be between 2.2s to 4.4s.

In Table 1, related studies are categorized under the type of obstacle and the driver's expectation of the obstacle. This is to determine which type of study would allow the driver to exhibit a more natural and unbiased reaction. As an overall assessment, the unbiased alertness and realistic driving conditions are observed in *naturalistic observation* types of studies.

In designing the appropriate field measurement methodology for this study, the following additional points were noted:

- Naturalistic observation of driver reaction to the onset of the yellow light is the kind of study that would match the objective of measuring the PBRT of Filipino Drivers.
- One type of stimulus that drivers commonly react to is traffic signal. The yellow light phase (amber phase) is a standard 3 seconds and is computed based on the AASHTO standard PBRT, which is 2.5 seconds. Some studies have considered the onset of yellow light as the chosen stimulus to react to and are conducted to investigate the validity of the 2.5 standard PBRT.
- Normal daily traffic must be observed, therefore reaction to surprise obstacles such as stray pedestrians or accident inducing situations may be present.

Table 1. Comparison of PBRT Methodologies

	CONTROLLED ROAD STUDY		SIMULATOR RESEARCH		NATURALISTIC OBSERVATION	
General Description	Obstacles set in test track. Driver in a test car with accompanying observer.		Computer based driving simulator/ set-up. Virtual Reality.		Video observation of traffic.	
Related Studies	Olson and Sivak (1986) [2]	Setti and El-Shawarby (2006) [5]	D'Addario (2014) [3]	Sena, et.al (2014) [6]	Fu, Zhang, Bie, Hu (2015) [7]	Goh and Wong (2004) [8]
PBRT measured *As One* or *In Components*	In Components	In Components	In Components	In components	As One	As one
Obstacle	Road Obstruction	Yellow signal without countdown timer	Left turn, Right Incursion, Pedestrian	Brake lights of car in front	Yellow signal with and without countdown	Yellow Signal
Driver expectation to obstacle	Expected, Unexpected and Surprise	Unexpected	Expected, Unexpected and Surprise	Unexpected	Expected and Unexpected	Unexpected
Driver behavior factors						
Natural level of alertness						
Realistic driving environment						
Remarks	Behavioral Studies		Focused on driver neurological activity and reaction		Considers impact of actual traffic situation	
	Measured PBRT is smaller		Measured PBRT is smaller		Yields more accurate PBRT	

2.2 Car-following Models and Vehicle Trajectory Data

Ranjitkar, Nakatsuji, and Kawamua [9] experimented on the different types of car-following models and focus on their advantages and disadvantages. Using trajectory data from 10 different drivers, acceleration, velocity and position or gap predictions were obtained from eight calibrated models: two stimulus response models, two safe distance models, two psychophysical models, one optimum velocity model and one trajectory-based model.

From F-test and T-test, and using percentile errors as performance index, the stimulus response and safe distance models performed better than the other models, with low percentile errors for speed and accelerations. Larger percentile errors were obtained from gaps and acceleration values.

Ossen S., and Hoogendoorn, S. [10] differentiated various techniques of obtaining trajectory data for calibration of car following models. Among the methods mentioned were equipping vehicles with GPS, aerial observation through helicopter or building, and the use of driving simulators. Aside from advantages in availability, aerial observation proved convenient in terms of flexibility of approach, sample size, and representativeness of the sample. Though it presented disadvantages and inconvenience in the length of the observed stretched of traffic, this factor can easily be adjusted with some modifications of the method.

Kesting and Treiber [11] proposed a methodology in which the trajectory data were obtained from real traffic situations, followed by getting the initial values of the observed trajectory data. These initial values were then in turn used as inputs for the model. The predictions of the model were then compared to the actual conditions by statistical fit. Using their values of fitness, genetic algorithm was used to determine the set of parameters that best fits the actual traffic.

III. FIELD MEASUREMENT OF PBRT

3.1 Field Measurement Methodology

3.1.1 Site Selection

For the field experiment, it was decided that PBRT would be measured using the turning of the traffic light from green, to yellow, and to red as triggers for driver perception and braking. Therefore, the selected site should be an approach to a signalized intersection.

Potential study sites inside a university campus (University of the Philippines Diliman campus) were considered for the study. Initially, a signalized intersection with countdown timer of was considered (Roces Avenue - Osmena Avenue intersection in front of the College of Engineering). The site was visited on a regular school day, both in the morning and in the afternoon. PBRT of drivers of cars passing thru the intersection was observed wherein the onset of yellow light was considered as the obstacle while the appearance of brake lights indicates the application of brakes However, it was noticed that some of the drivers tended to stop even before the onset of the yellow light signal which results to a negative value of PBRT. This is due to the presence of countdown timers, which implies that drivers anticipate the onset of yellow light since they have information on how much time is left on the green light signal. In this case, the onset of yellow light cannot be considered as the obstacle since some drivers start to brake prior to the onset of yellow signal. Therefore, it was decided to look for a signalized intersection without countdown timer.

A better site considered was the signalized intersection that does not have countdown timer (CP Garcia - P. Velazquez Street intersection in front of 'Bahay ng Alumni'). Again, the site was visited in the morning and in the afternoon of a regular school day and preliminary PBRT of the cars passing thru the intersection was observed. In this site, the researchers did not see any cars that stopped before the onset of yellow light with respect to the traffic signal. The area was then decided to be the final site for the data collection.

3.1.2 Field Observation

A video camera, placed on top of a tripod, was used to record the traffic situation on the signalized intersection of CP Garcia and P Velasquez streets. Only a certain distance from the intersection will be regarded as data collection area. The distance is calculated from the SSD formula (NCHRP [12]):

$$SSD = 0.278\ Vt + \frac{0.039\ V^2}{a} \tag{2}$$

The velocity, *V*, used is 61.56 km/hr which was obtained from doing a spot speed analysis prior to the video observation. Deceleration rate, *a*, is 3.4 m/s2 (NCHRP [12]) and brake reaction time, *t*, is the

AASHTO standard of 2.5s. The SSD computed was found to be 86.13m.

Criteria for selection of cars to be observed are as follows: (1) the subject car should eventually stop or slow down after the onset of yellow light; (2) the subject car should be within the stopping sight distance from the intersection when the yellow light flashes, and (3) there should be no other car or obstacle right in front of the car, that might have caused the subject car to stop or slow down.

In this experiment, the onset of yellow light is taken to be the obstruction/obstacle and the time of application of the brakes will be the time when brake light flashes from behind the car. Correspondingly, PBRT is taken to be the time difference from the time the yellow light indication appears to the time when the car's brake light becomes visible from the back of the car.

The time of data collection will be scheduled during times when the traffic flow is very smooth and/or when there is no traffic congestion (non-peak hours) to avoid the third condition stated earlier where drivers brake due to vehicles in front of them.

3.2 Data Analysis and Result

After 20 hours of field observation, a total of 98 valid samples (those that follow the conditions) were collected. The minimum value observed was 0.73s while the maximum value observed was 3.31s. From the histogram below (Figure 1), the 50th and 85th percentile of raw PBRT were found to be 1.63 and 2.72 seconds, respectively. The calculated standard deviation is 0.7s sec.

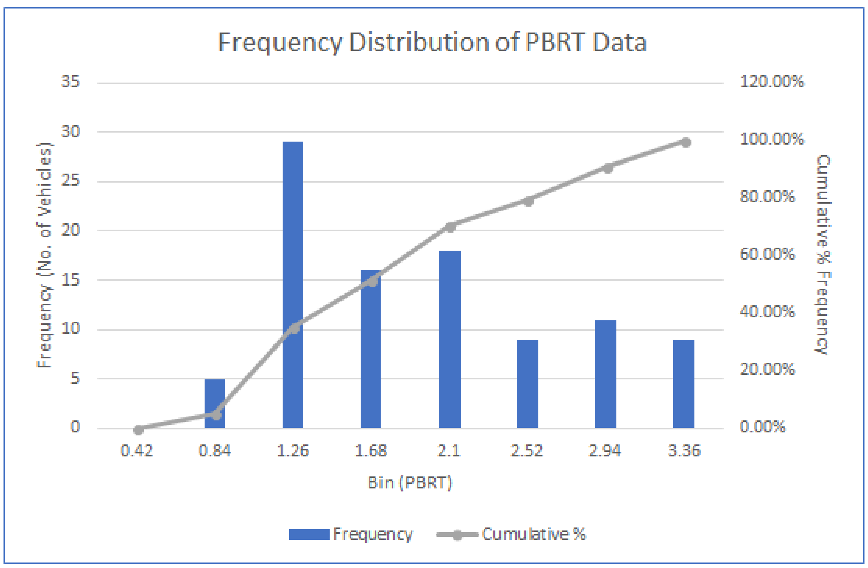

Figure 1. Histogram of frequency distribution of Perception and Brake Reaction Times

IV. ESTIMATION USING CAR-FOLLOWING TRAJECTORY

4.1 Methodology for Estimation Using Car-following Model

4.1.1 Vehicle Trajectory Data Collection Gathering Using Video

The selected study area is along Coronado Street, Mandaluyong City. This area was selected because it provides the biggest visible road span from the camera among the considered places, with the chosen high rise building as a vantage point having about 44 floors (about 140 meters above the ground). The result is a clear view of a length of road in which vehicles cover between 8 to 15 seconds, enough to capture car position, velocity and acceleration.

On the top floor of the said building, the camera was mounted such that the plane of view is parallel to the road. This is because mounting the camera not oblique with respect to the road imposes parallax distortion, increasing errors in spacing between the vehicles. With the plane of view parallel to the road, the true length of the road can be preserved, and any length measured along it will also be the actual length.

The video footage was taken on two Sundays, on March 22, 2015 and on March 29, 2015. This choice of time provides a free flow for the traffic, not too crowded as to make the consecutive frames of the video almost identical, and not too clear for the vehicles to traverse the road span in a very short period of time, rendering the video useless. This makes the car following phenomenon more observable and making distances vary freely over time, resulting to the coverage of data being more general with respect to car kinematics.

4.1.2 Video Data Processing

The video was separated into frames, 1 frame per second, JPG format using a video separation software. The resolution of the video was conserved in the images. Using the scaling software *Brava!*, the distances and gaps between vehicles are measured by associating a fixed distance between preset markers in the frame with known length. The software automatically scales this known distance if a new length is to be measured.

Since time interval between frames are known, the velocity and acceleration of vehicles can easily be determined by the central difference formulas.

Adopting the methodology described by Kesting and Treiber [11], ten pairs of vehicles were selected among the obtained 8 video footages. The choice of pairs of vehicles are based on the clarity of the distance between vehicles and the observability of the phenomenon of car following. The same measurements mentioned above were done with these ten pairs.

4.1.3 Parameter Estimation of Reaction Time T Using Genetic Algorithm

Genetic algorithm (GA) is used to estimate reaction time T in the Krauss car-following model (see Equation 1), simultaneously with other model parameters like maximum acceleration a, and maximum deceleration b. Parameters are estimated by comparing actual data with model predictions using candidate parameter values using a specified objective function to statistically test the “fitness” of the systematically generated parameter set (or “individuals”). The general procedure employed to implement GA in this study is as follows:

1. Select arbitrary sets of model parameter values (*individuals*)
2. Measure *fitness* of individual by comparing simulated car-following speeds with actual observed trajectory speeds. The objective function (error) minimized for this purpose is shown below:

$$F_{mix}\left[s^{sim}\right] = \sqrt{\frac{1}{\langle |s^{data}| \rangle} \langle \frac{\left(s^{sim} - s^{data}\right)^2}{|s^{data}|} \rangle} \tag{3}$$

3. Individual with lowest error is retained, and remaining individuals are paired and combined to form new set of *individuals*
4. New *individuals* are subjected to another generation of simulation; fitness is checked again.
5. Process is repeated until only a single *individual* (the best fit) remains.

Shown on Table 2 below are the prescribed range of values of the parameter in the car following model presented in Equation 1. With Table 2 as guide, the initial values for the genetic algorithm were randomly chosen and combined to form the initial set of individuals to be used in the genetic algorithm

Table 2. Guide on initial values for genetic Algorithm *(Source: Ranjitkar et al. [9])*

Parameter	
Reaction Time *T*	0.5 to 3 sec
Maximum acceleration *a*	1.5 m/sec^2
Maximum deceleration *b and b**	-3 to -4.5 m/sec^2
Maximum desired speed *V*	20 to 25 m/sec
Jam headway *s*	7.5 m
Minimum desired spacing *S*	10 to 50 m

Additionally, the values for the car length is set to be 4.6 m, the value for the maximum velocity is 100 kph, and the random number ϵ is chosen to be 0.5, the expected value from the range of values 0 – 1, assuming equal probability for each value.

The genetic algorithm could be easily executed using spreadsheet analysis. The actual velocity of the preceding car, the position of the preceding car, the actual velocity of the following car, the position of the following car, and the parameter values for each individual were used. Using the Krauss Car Following Model formula (Equation 1), the velocity of the following car was predicted with only the values at t = 0 given. These values were then compared with the actual values by calculating the mixed error.

The process above were done for each set of observed vehicle pairs (or referred hereafter as 'individual') and the individual with the lowest mixed error were retained. The remaining individuals were paired and averaged and used for the next iteration along with the retained individual. The process is then repeated 5 times, arriving at a single set of individuals, for a single car pair.

The individual obtained from each car pair were collected and averaged. The result is taken as the calibrated parameters for the Krauss Car Following Model.

4.2 Analysis and Estimation Result

The following parameter values were obtained.

Table 3. Result of Parameter Estimation

Maximum Acceleration	1.034 m/s^2 (roughly 3.7 kph/s)
Maximum Deceleration	3.805 m/s^2 (roughly 14 kph/s)
(Driver) Reaction Time	**1.532 sec**

To evaluate the precision of the obtained measurements, the values of parameters for each of the car pairs were plotted. Figure 2 below shows the plot.

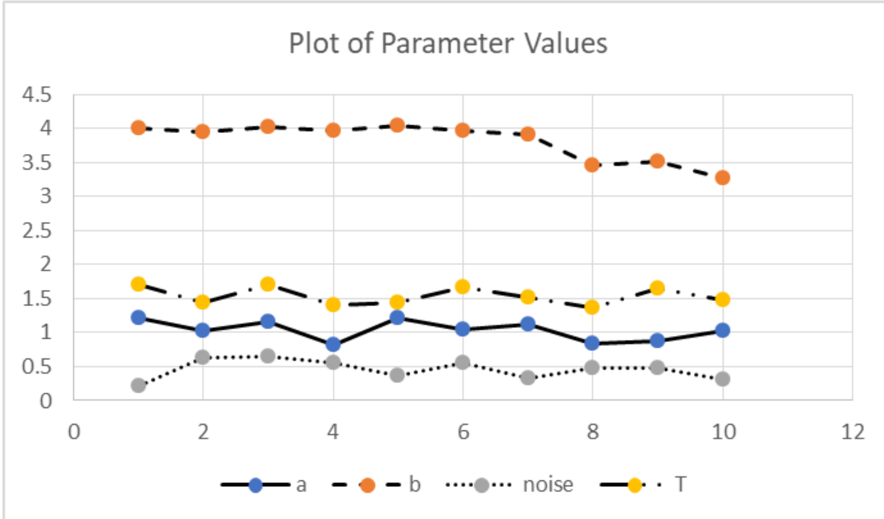

Figure 2. Plot of the values obtained for the parameters for each vehicle pair.

The values when plotted approximates a horizontal line, showing the consistency of measurements being fixed on a single value. To evaluate the spread, the standard deviations of the parameter values are as follows:

a – 0.1492
b – 0.2792
noise – 0.144
reaction Time – 0.332

None of the parameters obtained exceeds a standard deviation of more than one unit. This shows that the values, even when obtained from different car pairs and different sets of initials values of parameters for the genetic algorithm, arrive and converge at a single value, the value that will reflect Filipino driving behavior.

To check for the accuracy of the parameter values, a pair of vehicles, different from the 10 pairs used in the genetic algorithm, were measured for the values of position and velocity. The initial values of the empirical data were then used as inputs in the model using the obtained parameters. The results were plotted in the graph below.

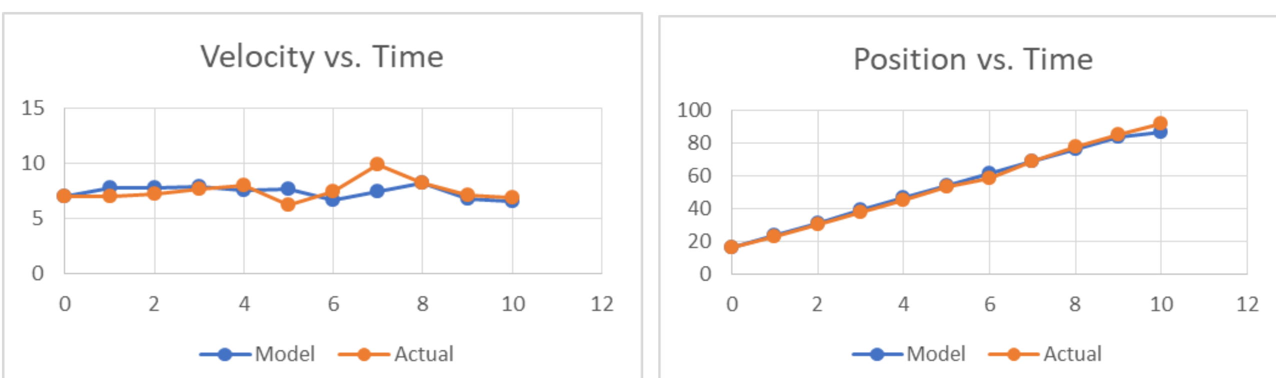

Figure 8. Validation plots
(Model vs. Actual Velocity-Time and Position-Time Plots for arbitrarily selected car pair)

Though the velocity values seem to diverge through time, the plots for the model and actual positions of the car pairs follow the same curvature, a proof that the car following model approximates driver behavior (a characteristic associated with the curvature of the plot), which is the main aim of traffic simulations. The nature of the model may explain the divergence of the position values itself, being more conservative and subjected to restrictions, such as the maximum velocity, the use of the minimum between the kinematics velocity and the safe velocity.

Also, the study area at the time of study is clear, making driving behavior tend to aggressiveness with respect to driving, making them go faster once they enter the area, resulting to a big increase in the change of position.

V. DISCUSSION

5.1 Implication on sight distance calculation for highway design

Sample calculation of stopping sight distance (SSD) for design was calculated using the result of this study (i.e. t = 2.722s instead of the AASHTO prescribed 2.5 sec). The calculations are shown below.

Table 4. Stopping Sight Distance sample calculations*

Design Speed, km/h	SSD, m (t=2.5s)	SSD, m (t=2.722s)	Difference, m	%
30	31.0	32.8	1.8	6%
40	45.8	48.2	2.4	5%
50	62.8	65.9	3.1	5%
60	82.2	85.9	3.7	5%
70	103.7	108.0	4.3	4%
80	127.5	132.5	5.0	4%
90	153.6	159.2	5.6	4%
100	181.9	188.1	6.2	3%
110	212.5	219.3	6.8	3%
120	245.3	252.7	7.4	3%

**For the case of G = 0%, f = 0.35 using the formula from Sigua (2008) [13]:*

$$SSD = \frac{vt}{3.6} + \frac{v^2}{2g(3.6^2)(f \pm G)}$$ *where v is speed in km/h, and t in sec.*

The sample computation illustrates that for purposes of highway geometric design control, adequate SSD criterion on local highways that were originally designed using the AASHTO prescribed 2.5s, should be increased by about 3% to 6%. However, this illustration is only for highways of zero grade, and assuming f=0.35. Similar computation could be done for varying cases of f and G.

5.2 Comparison with other countries

Tables 5 and 6 show a comparison of the PBRT obtained from this study with measurements from related studies. It can be noted that the 85th-percentile PBRT is significantly greater than the values obtained in other researches.

The PBRT values obtained in this study suggests that Filipino drivers could be slower in perceiving obstacles or braking reaction time. Several reasons could explain this. Zhuk et al. [16] explained that poor acquisition of skill or lower driver competence, and exposure to complicated traffic situations that which requires a more complex response could result in longer PBRT.

Table 5. Comparison of reaction times with results from other studies

Study	Country	Perception and Brake Reaction Time / Driver Reaction Time (sec)	
		50^{th} Percentile	85^{th} Percentile
Fu, Zhang, Bie, Hu (2015) [7]	China	0.84	1.86
Olson and Sivak (1986) [2]	Michigan, United States	1.04	1.88
Johansson and Rumar (1971) [14]	Virginia, United States	0.85	1.24
Goh and Wong (2004) [8]	Singapore	0.85	1.08
This Study	Philippines	(a)* 1.63 (b)** 1.53	(a)* 2.722 -

**(a) – result of field measurement*
***(b) – result of estimation using car-following model*

Table 6. Perception and brake reaction time from various studies* [16]

Study	Perception and Brake Reaction Time / Driver Reaction Time (sec)	
	85^{th} Percentile	95^{th} Percentile
Gazis et al. (1960)	1.48	1.75
Wortman et al. (1983)	1.80	2.35
Chang et al. (1985)	1.90	2.50
Sivak et al. (1982)	1.78	2.40
This study	2.72	-

** summarized in a study by Layton and Dixon (2012) [15] that checks the validity of the 2.5 seconds design perception reaction time by AASHTO*

VI. CONCLUSION

For this study, the most ideal method of measuring driver reaction time is through naturalistic observation and a field methodology was designed and employed in this study to measure PBRT. Based on field measurement, the 50^{th} and 85^{th} percentile PBRT are determined to be 1.63s and 2.72, respectively. As a complementary analysis, numerical estimation for driver reaction time using a vehicle trajectory data and an assumed car-following model yielded 1.53s.

It is further observed that the 85th percentile PBRT in this study (2.72 sec) is higher in comparison with measurements done in other countries.

Additionally, the traffic flow for Filipino drivers can be approximated by the Krauss Car Following Model, using the following parameter values:

- Maximum acceleration – 1.034 m/s^2 (roughly 3.7 kph/s)
- Maximum deceleration – 3.80 m/s^2 (roughly 14 kph/s)
- Noise – 0.46
- Reaction time (PBRT) – 1.53s

These estimated driver behavior parameters are useful in calibrating microscopic traffic simulation modelling.

Output of this study could help in prescribing appropriate revisions in geometric design controls for Philippine roads, particularly the criteria on sight distances, thus ensuring that safety for road users. Obviously, longer PBRT would require longer adequate sight distances. With the estimated value of PBRT in this study, appropriate values of sight distance criteria for varying gradients and coefficients of friction could be determined.

Changes in existing highway geometry and designs of a new highway that satisfy the revised sight distance criteria may be costly. But safety should not be compromised. For existing highways, to offset reconstruction costs, introduction of less costly traffic control devices to control speed might be considered. The study did not include cost analysis, but from the sample computation showing a possible adjustment in SSD criteria by only +3-6%, the corresponding cost increase may not be too large.

For further research, the field observation procedure developed and employed in this study could be replicated in other locations to generate more data, thereby expanding the research to consider regional differences and effects of driver demographic factors.

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