Comparison of Simple Gap Acceptance Method and Gap Forcing Method in Estimating the Capacity of Single Lane Streams at Simple Intersections

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Abstract: The study is about comparison between methods of estimation of capacity of a single lane movement in a simple intersection. Two models are used in the estimation of the capacity namely the Simple Gap Acceptance Method and Gap Forcing Method. The data is obtained by running two simulation programs based on the two models. Results showed that there is a significant difference between the two capacity estimates indicating that estimating the capacity for a given stream can be potentially improved if gap forcing is taken into account.

keywords*: capacity, simple gap acceptance, gap forcing*

1. INTRODUCTION

The study is all about estimation of capacities of a given minor stream in the simple intersection. The study focuses on the simplest configuration of the intersection that consists only of one lane-one direction in the major stream and one lane-one direction in the minor stream. The results of this study will serve as the basis for further studies involving intersections and roundabouts that is characterized by more complex movements of vehicles resulting to additional number of conflicts of movements. The study is very valuable for as to date, guidelines used by the Philippines are based on experiences from other countries like the ones reflected contained in the US Highway Capacity manual. Traffic laws are being strictly applied in the United States than in our country and thus it can be assumed that drivers in our country tend to be more aggressive than those drivers in the US.

Different models of estimation are used for the capacity of streams in an intersection. Among them is the Simple Gap Acceptance Theory which is incorporated in the Highway Capacity Manual. Capacity obtained from Simple Gap Acceptance Theory is presented as a function of critical gap and follow-on-time and is used for capacity analysis and determination of levels of performance of intersections. Simple Gap Acceptance assumes that vehicles in the major streams have absolute priority over the vehicles in the minor streams and that the vehicles in the minor streams have to wait for suitable gaps in the major stream before they could cross the intersection. Vehicles in the major stream, therefore, will experience no delay. While this assumption likely applies well in the US due to their disciplined drivers, the applicability may not extend in our country's setting. In every intersection in the Philippines, gap forcing is prevalent due partly to the laxity of application of traffic laws. Quite possibly also, aggressiveness on the part of drivers in the minor streams results to this kind of observation and even due to the courtesy of drivers from the major stream giving way to drivers in the minor stream. Given the differences of driver behavior, a considerable discrepancy of results might be expected.

The estimated capacity resulting from the simple gap acceptance assumption results in an exponential curve which is a function of the critical gap data and the follow on time of the minor stream vehicles. The general appearance of the capacity curve for a roundabout is shown below.

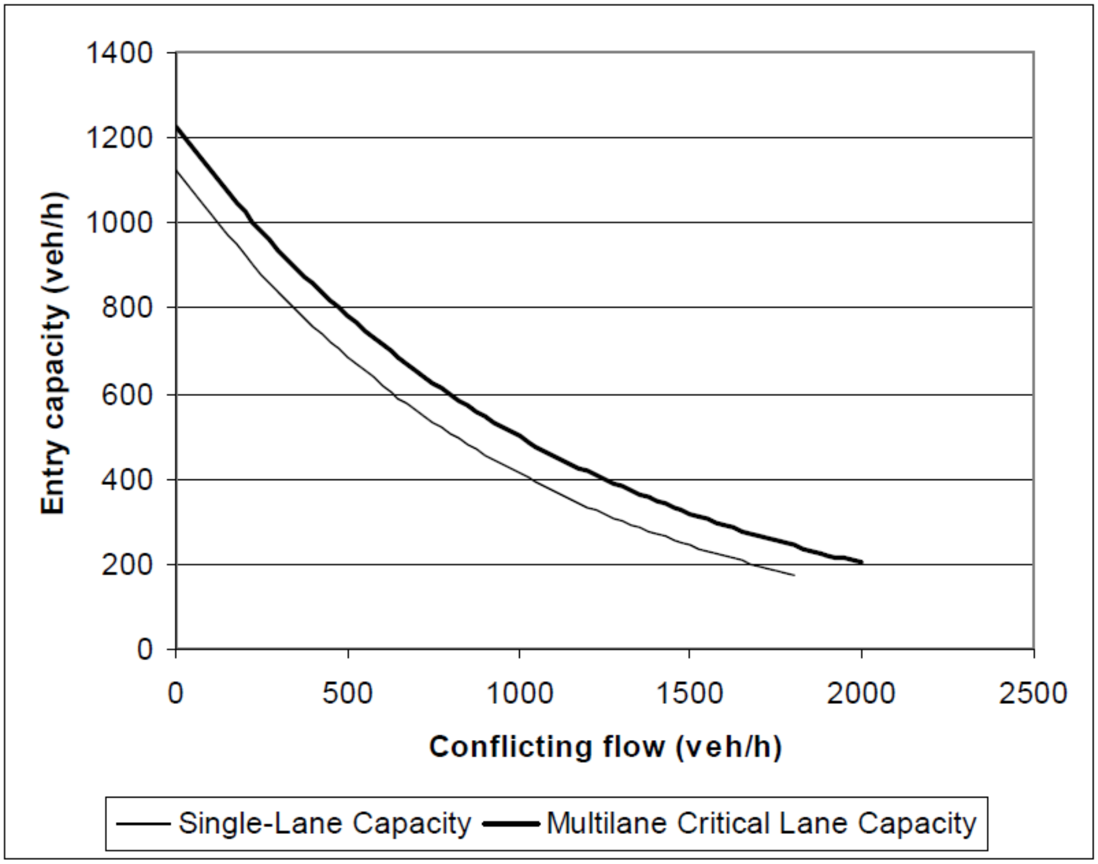

Figure 1. Typical Capacity Curve*(Source: HCM 2010)*

As shown above, the concavity of the curve suggests the possibility of underestimating the capacity at low flows while in the higher flow region, the graph shows that it "floats" thus failing to intersect the horizontal axis which is kind of unrealistic resulting to overestimation of capacity at higher flows. One cause that this might be attributed to is probably the lack of inclusion of some important parameters in the simple gap acceptance model. To a proponent of gap forcing idea, one would concur with the suggestions of possible scenarios mentioned above due to the following reasons: at low flows, a larger number of vehicles from the minor stream, as compared with the estimated values from the figure, would be able to cross the intersection due to gap forcing while at higher flows only a moderate amount of vehicles from the minor stream would be able to cross as the vehicles from the majority stream would now impose absolute priority.

The seeming defects of the simple gap acceptance theory have led other researchers to resort to other methods of estimating capacity. In the case of roundabout studies, England came up with an empirical data. They can simply afford to have these data as they have numerous roundabouts constructed all over their country. The Philippines has not been there yet in terms of construction of this type of facilities and therefore cannot obtain a sufficient database. Simulation is one solution to this type of problem as some other countries have done. It is therefore imperative that we develop a simulation program that incorporates the gap forcing behavior to be able to estimate the capacity of intersections.

Majority of gap forcing maneuvers done by the driver is executed when a vehicle from the minor stream is following closely with the lead vehicle while negotiating through the intersection. Drivers from both streams both recognize that once the lead vehicle from the minor stream enters the conflict area, the trailing vehicle from the minor stream evaluates the sufficiency of the available gap from the major stream and then if insufficient, he will then make use of the spacing he had with his lead vehicle to follow suit. The probability that this second step works in the minor stream driver's favor would depend on the type of facility involved and the geometric configuration of the facility. For example, this manuever may not work in entry ramps at multilane highways due to relatively high velocities involved in such facilities but may be frequent in occurrence in unsignalized intersections or in roundabouts.

The specific purpose of this study is to study the effects of taking into account gap forcing in the estimation of capacity of a simple intersection. This can be done by comparing the simulation results of the simple gap acceptance theory and gap forcing. As yet, the study is limited for this purpose but will serve as a staging point for further development of a new capacity estimation method.

2. CONCEPTUAL AND THEORETICAL FRAMEWORK

Capacity of a given stream is affected by certain driver characteristics which are most often controlled by factors such as geometric characteristics of a given facility and more. Such characteristics are manifested in the arrival patterns of vehicles, the distribution of the accepted gaps and rejected gaps and follow on times. The study suggests taking into consideration other important parameters which could potentially increase the capacity of streams. These include the gap forcing parameter as well as the follow-on-time of vehicles not only in the major streams but in the minor streams as well.

3. RESEARCH DESIGN AND METHODS

In order to achieve the purpose of this study, two simulation models will be developed and simulation runs will be made. For the two models, the shifted exponential distribution is fed for the arrival times and a common fitted polynomial function is inputted for the accepted gaps. An actual distribution of gaps may be used for this purpose. The different manner of interactions of vehicles for each model will be discussed below. The results from the two simulation runs will then be compared.

The two models will be implemented in a pascal program. The logical structure of the two programs is presented in the figures that follow.

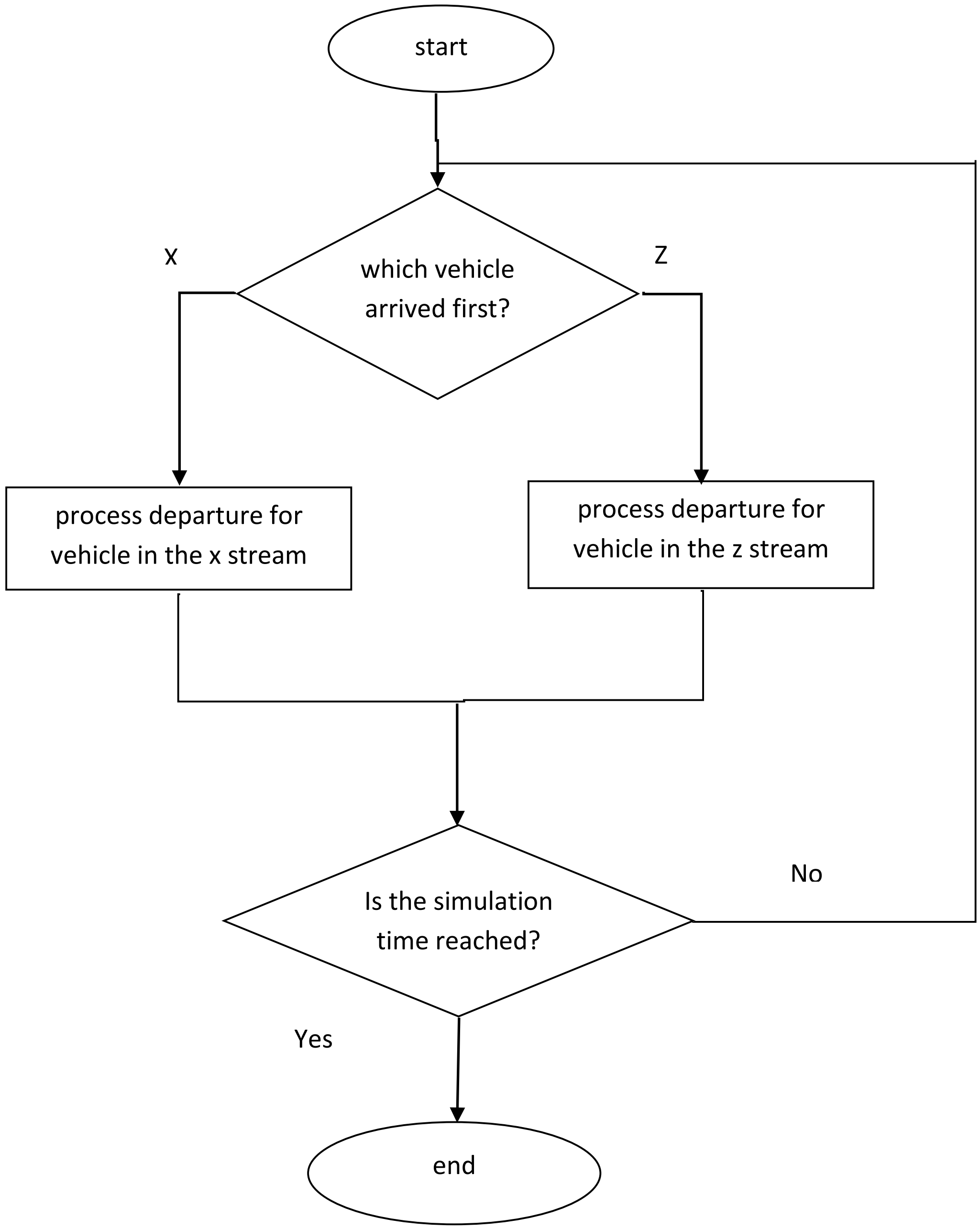

Figure 2. Simple Gap Acceptance

The manner by which the vehicles interact with each other for each model is presented in Figure 3. During the queue dissipation process in the minor stream in a gap forcing model, the vehicle in the minor stream evaluates first the gaps available in the major stream, and if it is sufficiently large, he then proceeds to cross the intersection. The difference between the two models comes up after the first evaluation leads to no success. In the simple gap acceptance model, the vehicle stops, waits for the vehicle in the major stream to pass and then evaluate another gap from the next vehicle skipping the process illustrated in the shaded diamonds in the figure below. In the gap forcing model, the decision to wait for another suitable gap is waived by checking his position relative to the lead vehicle which has already departed. If he finds himself closely following that vehicle then he can take advantage of it by maintaining that close spacing so that it would not be cut off by a major vehicle. This close spacing is achieved if he can attain a headway equal to the follow-on-time. Per observation the probability that this happens could sometimes reach as high as 70 percent and will be used to run the program for the 2nd model while a 0 percent probability will be used in the first model.

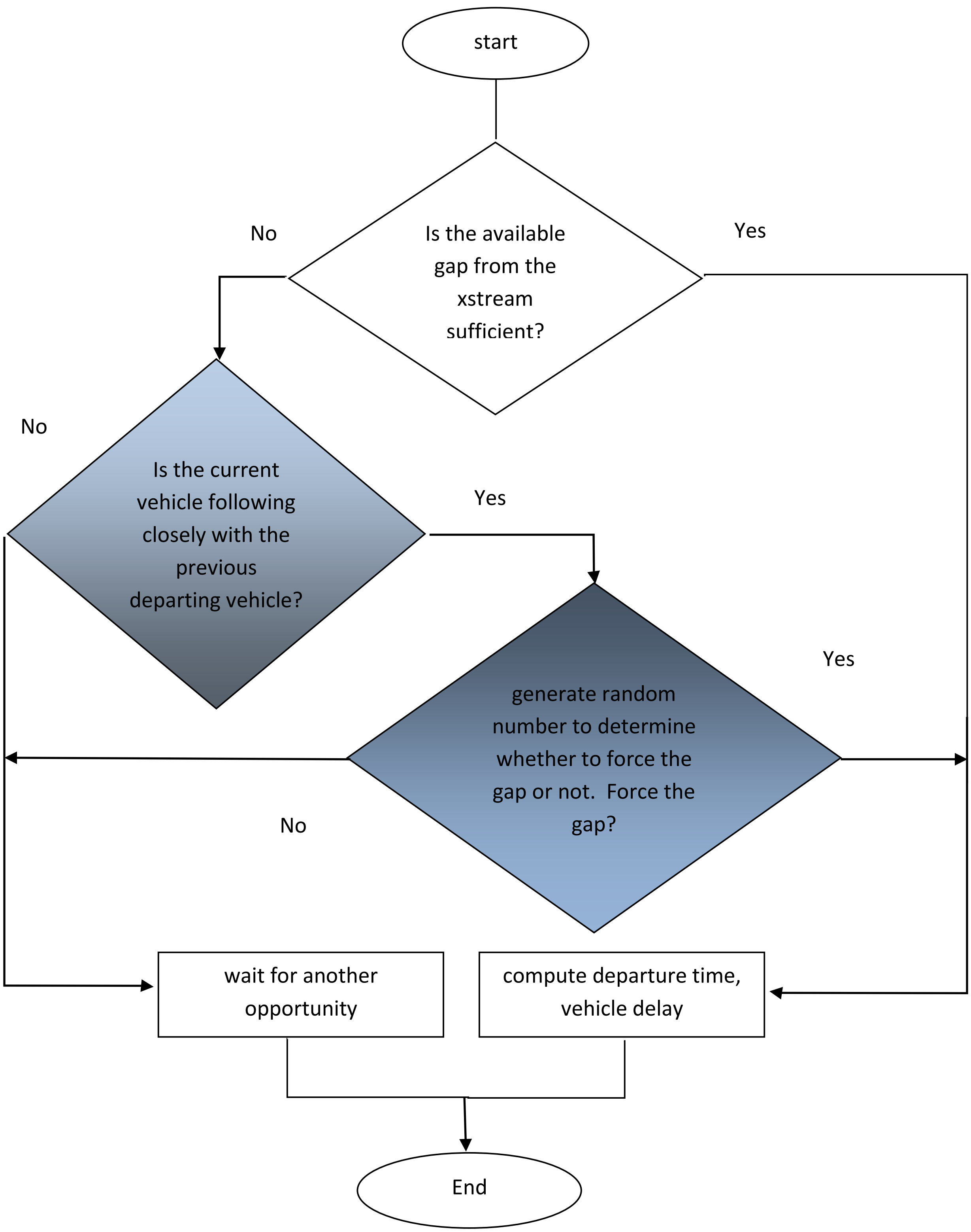

Figure 3. Gap Forcing

4. RESULTS AND DISCUSSIONS

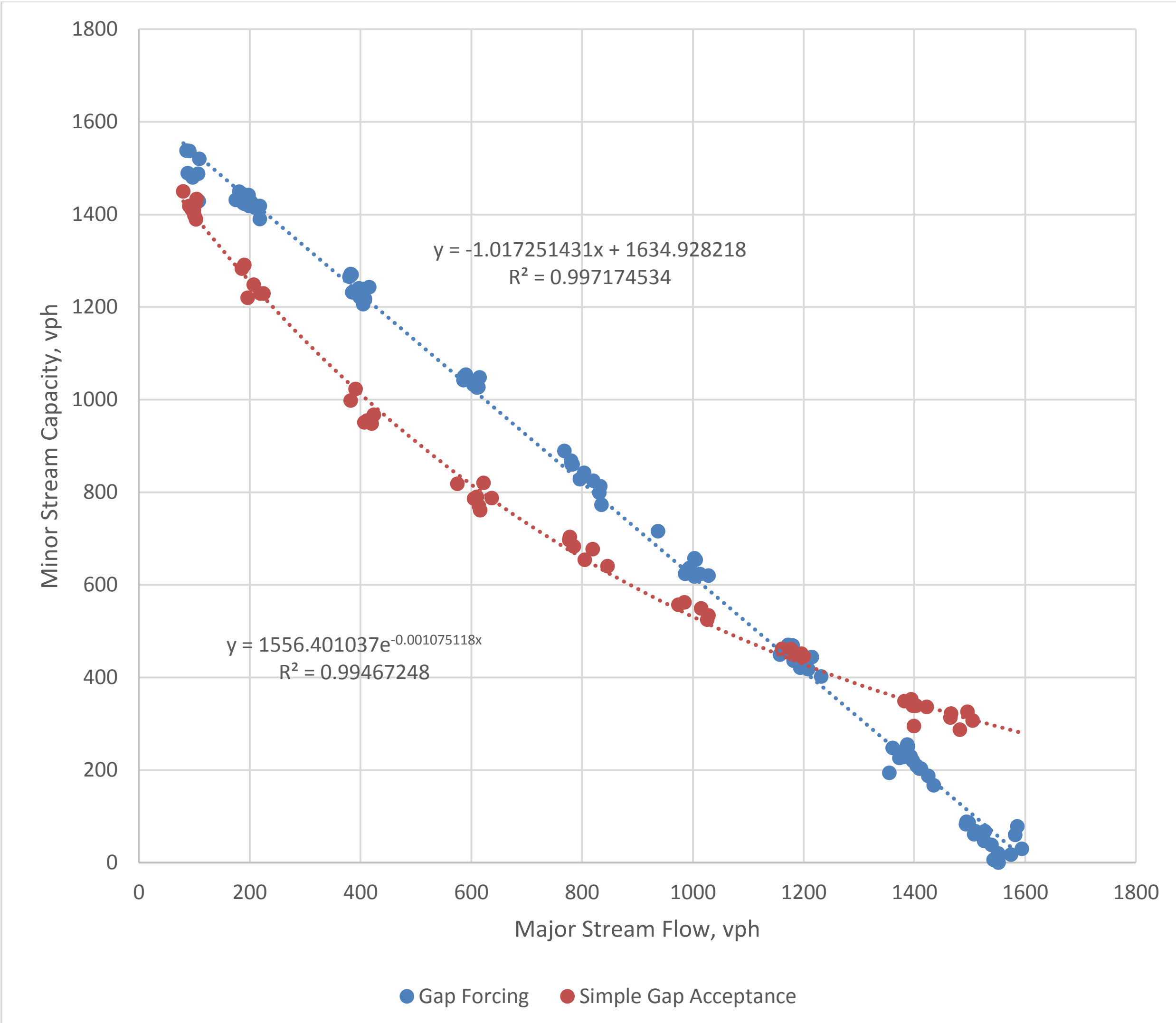

Figure 4. Comparison of Capacity Curves for Simple Gap Acceptance and Gap Forcing

The estimated capacity using two different models are presented in the figure above. Test shows that significant differences of results would be obtained for the two different assumptions. The graphs show that in the lower flows, the simple gap acceptance model produces a lower estimate of the volume capacity compared with the gap forcing model. The reverse is true at higher flows.

For the gap forcing case, the results are such because for lower flows, the minor stream vehicles outnumber the vehicles from the major stream. With this, a situation called priority reversal occurs making the minority stream look more like the priority stream. A larger number than that predicted in the first model therefore, results because the gap forcing maneuver works favorably with higher volume. As the flows in the major streams increase, however, the priority status of vehicles in the major stream is reestablished. Slight delays caused by occasional gap forcing results in queues in the major streams. The result is, in the queue-dissipation process in the major stream, which happens even more often this time, lesser number of minor stream vehicles than that predicted in the simple gap acceptance model can enter the conflict area. It would be interesting to note that the model dives early to intersect the horizontal axis. This is because the follow on time of the vehicles in the major stream now plays a role in the queue dissipation process in much the same way it plays in the dissipation process in the minor stream. It has the effect of tying the right lower end of the graph to a specific point in the x-axis-an observation not present for the first model. It is therefore suggested that in any model, the follow-on-time of the major stream be taken into account.

The development of the gap forcing model was spurred by the fact that Filipino drivers are a little different from the drivers from other countries particularly in the US. Again, the US Highway Capacity Manual Model which is a simple gap model requires only two parameters which are the critical gap and the follow-on-time on the minor stream. When applied in the Philippine setting, complications could particularly in the computation of the critical gap since the gap forcing parameters would not be accounted for. The gap forcing model could accommodate such parameter in addition to the parameters used by the HCM model.

5. CONCLUSION

The study shows that there is a significant difference between the results obtained from the simple gap acceptance model and the gap forcing model. The question now that one would ask is which of the two models fits the Filipino driving behavior best. It would be interesting to recall that the English model is of linear form and the result above displays a linear behavior for the gap forcing model. The use of gap forcing model therefore is promising. However, validations from the actual data is needed.

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