ESTABLISHING THE VEHICULAR SPEED-DENSITY-FLOW RELATIONSHIPS ALONG SELECTED PRIMARY ROADS IN ILOILO CITY

Paper Identification Number: SCS12_007

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ABSTRACT

There is a high mix of vehicle types that ply the roads of Iloilo City ranging from the smallest possible means of motor transportation such as the motorcycle to the largest commercial truck. Almost every type of vehicle can be found travelling along the roads of the city. From the entry points and exit ways of Iloilo city the researchers hypothesized that because of the high mix of vehicles the capacity of the roads is reduced. The objective of this study is to establish the relationship between speed, density, and flow of the primary roads of Iloilo City. Different traffic flow models were used to establish the relationships of speed-density, speed-flow and flow-density. The roads were then classified into two different types, primarily, roads with a divider and roads without a divider. In this study, the effect of a divider on a road was seen when the two types were compared in terms of the flow of vehicles and the speed at which the vehicles travel along both road types. With these three models, the capacity of the roads studied was also established and the results showed that there was a greater chance of traffic congestion along roads without a divider. Using the Greenshield, Greenburg, and Bureau of Public Roads model, together with a travel time study and the use of the JICASTRADA 3software the relationship of speed, density and flow were established for the major roads in Iloilo City.

Keywords: Capacity, Speed-density-flow, relationship, Density, Flow

Background of the study

Iloilo City is the economic center of the Western-Visayas Region in the Philippines and is

also the capital of Iloilo Province. It has a busy international airport that connects the city to major destinations in the country and the. The city's fish port complex is just as busy with millions of kilograms of fish shipped in and out yearly. Based on the NSO, 2007 Census, Iloilo City has a population of 418,710 with a 1.8% population annual growth rate. Iloilo city also has a land area of approximately 56 square kilometers. This is a small land area for the City. This means the density of the City is 7,476 persons per square kilometer. It is a very dense City, and the population is still increasing annually. Given these circumstances, the travel of vehicles to and from Iloilo City further increases with the demand to transport goods and services to the population, the need to travel arises because of the increasing urban growth. Transportation is the main key to help the growing populace, with proper transportation planning we can limit the congestion of national roads in Iloilo City and in turn help the moving masses continue their growing businesses. The study covers a wide-ranging and full observation of five major roads in the City of Iloilo. The analysis aims to understand the different traffic flow characteristics. Briefly, traffic flow aims to understand and take on a most favorable or best possible road network with efficient movement of traffic and nominal traffic congestion problems by studying the interactions between vehicles, drivers, and infrastructure. A few examples of the traffic flow characteristics that this study aims to understand include time headway, distance headway, flow, time-space trajectory, speed and density. This study proposed to establish the relationship between speed – density – flow in the primary roads throughout the given area of study. Iloilo City is a fast growing community budding with small businesses that help jumpstart its growth, agriculture being the main source of livelihood by the greater population is increasing in the annual use of farm land, "*from April 2010 a farm land use of 106,414 hectares of land was set aside for farm land and in March 2011 it was increased to 151,004 hectares of farm land use (www.NSO.gov.ph)*". Because of the rising farm land use and population the movement of people and goods becomes a necessity for Iloilo to adapt to the changes in its transportation sector and to the adaptation to rapid urbanization. But amidst the rising number in population and the need to transport goods and people to their destinations, Iloilo City lacks the planning in transportation.

Main Objective of the Study and Specific Objectives of the Study

The main objective of this study is to establish the speed, density, and flow relationships of vehicles along the major roads of Iloilo City.

Specifically the study aims to

1. Establish traffic models like the Greenshield, Greenberg and the Bureau of Public Roads (BPR) model.
2. Test the accuracy of the developed models using actual traffic flow data.
3. Recommend further studies for other similar small cities experiencing the same problems as Iloilo city.

Hypothesis of the Study

The hypotheses of this study are:

1. The high vehicle mix along the roads of Iloilo city reduces the capacity of the road.
2. Roads with a divider have higher capacity compared to roads without a divider.

Literature Review

Traffic congestion is a world-wide problem that has haunted traffic engineers and

researchers for decades. From the economic point of view, traffic congestion happens when there is unbalanced in supply and demand, i.e. the traffic demand is much greater than the road capacity. This problem can be tackled by building more roads or additional road lanes to disperse the traffic. Nonetheless, most of the cities in the world face land scarcity problem that makes this option difficult. Khoo, Hooi Ling (2007). As a common and important problem in many urban areas around the world, traffic congestion causes tremendous public concern, Intelligent Transportation Systems (ITS) focus on increasing the efficiency of existing surface transportation systems through the use of advanced computers, electronics, and communication technologies. Although several field experiments have been conducted to demonstrate possible benefits of ITS in Taiwan, a dynamic network model needs to be developed to estimate and forecast possible traffic flow patterns in order to efficiently utilize possible traffic control measures as well as advanced traffic information (Hu et al., 2005). Several dynamic models, including DYNASMART and DYNAMIT, have been developed to utilize ITS technologies (FHWA, 2001).

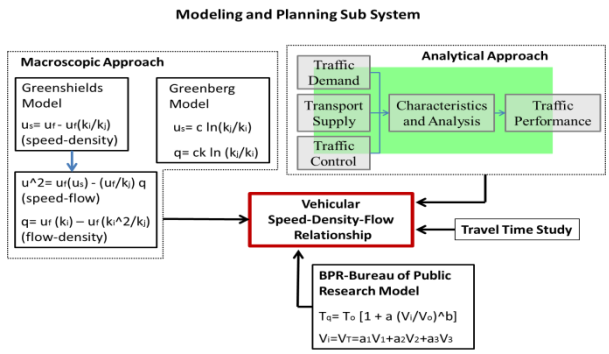

Figure 1 Modeling and Planning Sub System

Figure 1 emphasizes the solution part in the theoretical framework. It showed the three models that were used to establish the equations for Iloilo City. It also showed the travel time study that was used for the comparison of the JICASTRADA modeling. Basically, it summarizes the different approaches that were used.

Average Model of all Major Roads

For this segment, the average results of all major roads are shown as well as the capacity that was derived based on the Greenshield model.

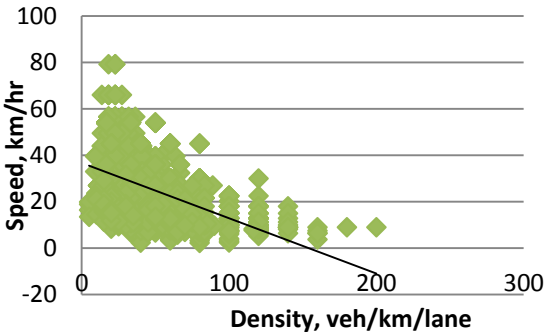

Figure 2 Average Greenshield Speed-Density of All Major Roads

Figure 2 represents the average of all data when establishing the relationship between speed and density, we can see the equation of Us = 37.10 - 0.246k with an R^2 value 0.327. This model results in a jam density value of 150.81veh/km.

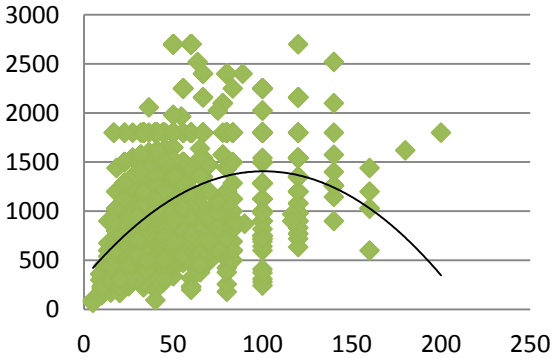

Figure 3 Average Flow Density of All Major Roads

Figure 3 represents the average flow density curve for all the major roads in Iloilo City has an equation of $q = 37.10k – 0.246k^2$ with an R^2 of 0.2617. We can see the low suitability index of the curve and the point where the max flow is obtained at a value of 1398.79veh/hr.

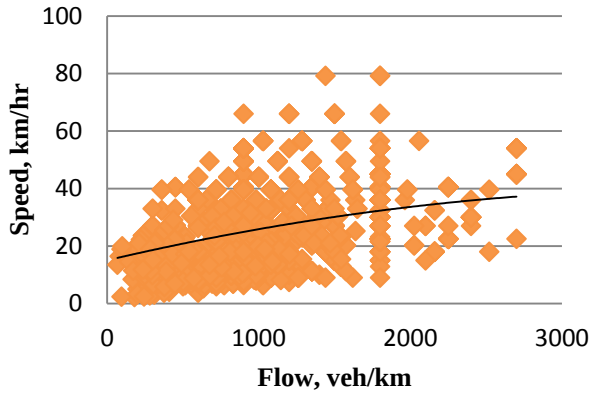

Figure 4 Average Speed Flow of All Major Roads

Figure 4 represents the average speed-flow relationship of all major roads in actual data with an equation of $\mathbf{q = 150.81(U_s) – (U_s)^2 / 0.246}$ with an R^2 value of 0.1279.

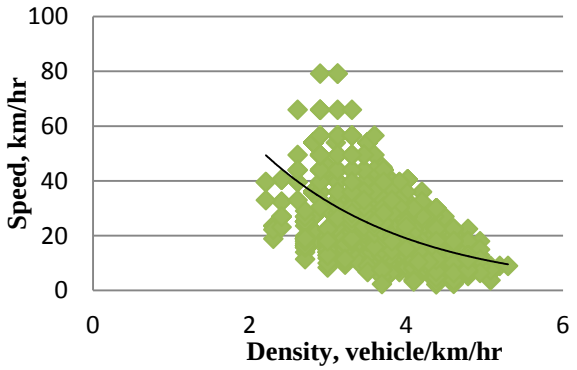

Figure 5 Greenberg Average Speed Density of Major Roads

In Figure 5, it seen see from the average Greengberg speed-density model for all major roads in Iloilo City, the values for the jam density is quite low as compared to individual roads shown above. And calibrating the model we can get an equation of $0.494 = U_o \ln(140.04/k)$ where at an assumed free flow speed we can get the density of the road. The value of maximum flow is 1090veh/hr, when comparing this to the Greenshield model, we can see that it is lower. With respect to the definition of the Greenburg study, the trend for this model does not fit a linear trend and that is one assumption why the value of the maximum flow is lower when compared to the Greenshield model.

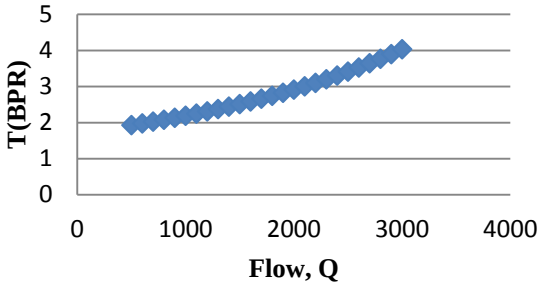

Figure 6 Average BPR of All Major Roads

Figure 6 represents the average BPR Model of all five major roads that we have studied, From what we can see it takes about fifty minutes before the maximum assumed flow is reached. There is still a reduction in road capacity with the pretense that it takes less than one hour for the mix of vehicles to travel all across the city of Iloilo. The equation $T_q = 0.86 (1 + 2.18(V_i / 1398.79)^{1.00}$

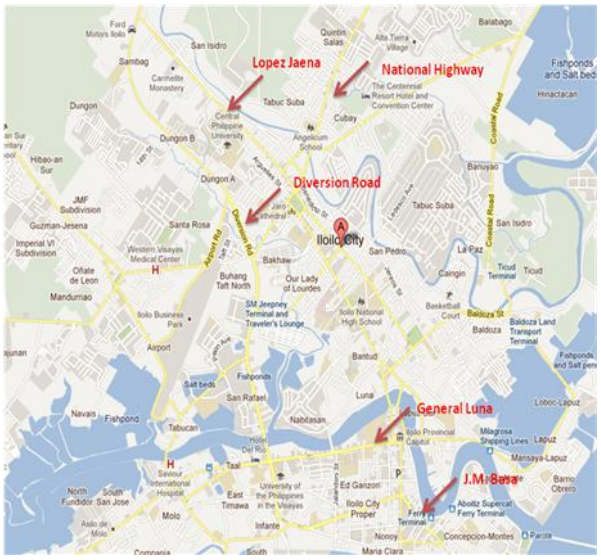

Figure 6 Site Map of Iloilo City
Source: Google Maps

For the primary roads studied in Iloilo City, Fig. 6 shows their locations. These primary roads were selected because they are the entry and exit points to and from the city proper. Specifically, one road travels through the main entertainment sector of the city, another road leads to and from the provincial capital of Iloilo city, the other road is mainly used for the distribution of exported and imported goods from the harbor. These roads are namely, the National Highway and Lopez Jaena St., Diversion Road, General Luna St., and J.M. Basa St. respectively.

TRAVEL TIME STUDIES AND JICASTRADA MODELING

The travel time study conducted took about three hours of traversing the whole of Iloilo City, the route used passed through major roads and places of Iloilo city. The result of the travel time study together with the result of the JICASTRADA simulation was compared and analyzed. The researchers used the equation that were developed using the BPR method and was input in the JICA STRADA program. The equation for the average BPR method for all major roads that was used was $T_q = 0.86 (1 + 2.19(V_i / 1398.79) ^{1.00}$ with an alpha = 2.19 and a beta = 1.00. A simulation of the Iloilo network was created in the JICA STRADA program. The results of the simulation were compared to the actual data that was gathered. Other data that was used in the simulation using the program JICA STRADA was obtained from the study of Alarcon. etal(2012).

Figure 7 Estimated Vehicular Velocity along the Roads in Iloilo City from JICA STRADA Incremental Assignment Results

In figure 7, using the Incremental Assignment results an analysis of the vehicular velocity for each segment of the Iloilo network was shown. The color code of each segment means red = low velocity, green = moderate velocity and blue = high velocity. The shaded part is the route that was used in the analysis. It can be seen that the route passed throught the major roads were there is high density representing a low vehicular velocity. The small boxes in the figure shows a magnified version of the simulation were the values of the average velocity per link is shown.

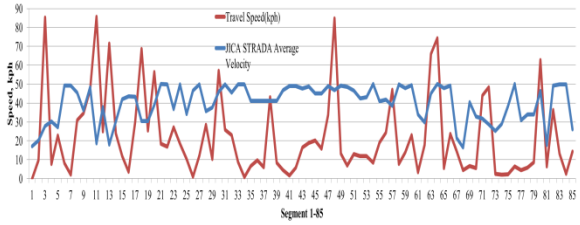

Figure 8 Comparison of the Average Vehicular Velocity per Segment Between the Actual andSimulated Results

Figure 8 represents the comparison of results between the travel time study and the simulation using the JICA STRADA program. The data that was compared is specifically the average vehicular velocity per segment. It can be seen the the JICA STRADA program was not able to compute the sudden increase and decrease of the vehicular velocity per segment. The result of the simulation can be seen that the velocity fluctuates between 20-30 kph. It can be observed that program averaged the vehicular velocity as compared to the actual result of the travel time study.

The difference between the actual data and the simulated data can be affected by many factors since in the actual data there are uncontrolled factors like obstructions on the road. The program meanwhile do not consider those factors. It is also observed that the simulation has increased the capacity of the road showing higher values of vehicular velocity than the results of the travel time study

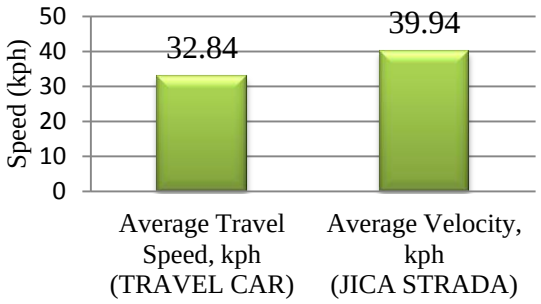

Figure 9 Comparison of the Total Average Vehicular Velocity Between the Actual and Simulated Results.

Figure 9 represents the total average vehicular velocity of the travel time study and the simulation using the JICA STRADA program. It can be seen that the total average vehicular velocity from the JICA STRADA simulation is higher than the total average vehicular velocity of the travel time study. The reason the simulation has higher vehicular velocity results are because it does not consider other factors that can be encountered on the actual road. It can be seen that the simulation has better results than the travel time study. The higher the average vehicular velocity shows a better road capacity. The total average vehicular velocity in the JICA STRADA simulation is 39.94kph and the total average vehicular velocity from the travel time study is 32.84 kph.

Table 1 Average Results of Greenshield's and Greenburg's Model

	q(veh/hr)	Us(km/hr)	k(veh/km)
Greenshield's model	1398.79	18.56	75.41
Greenburg's model	1090	18.56	58.75

Table 1 represents a comparison of the Greenshield model and Greenberg model. For the results of the Greenshield's and Greenburg's

model the max flow of vehicles for both models differ with values of 1398.79veh/hr and 1090veh/hr respectively. Comparing this to the Highway Capacity Manual (HCM) standards, we can see that these models show an approach to congestion of roads. With reference to the HCM the 1,700 veh/hr is the optimum capacity for two lane highways travelling in each direction, this suggests that for the road segments in Iloilo City, the average flow of vehicles could be assumed to increase further as the time of the day progresses and in turn exceed the limit of 1,700veh/hr. The capacity of these roads are therefore assumed to be congested as the day goes for Iloilo City, comparing these data to the actual results there is very little difference from what the researchers could observe. The congestion in the main part of the city is very terrible from the researchers own experience and with feasible data as expressed by the travel time study and the JICASTRADA 3 network model. These data are proof of the prevailing traffic conditions in Iloilo City and how they affect the movement of vehicles towards and out of the city; these established equations have given us an insight on how we could properly plan a transportation model to help lessen the congestion of traffic in Iloilo City.

CONCLUSION

The established equations show that the high mixes of vehicles present on the roads of Iloilo City reduce the capacity of the road. And that, roads with a divider have a higher capacity compared to that of roads without a divider.

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