INTERNATIONAL COMPARISON STUDY ON ROAD TRAFFIC FLOW

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1. INTRODUCTION

The main objective of this research is to determine the local factors which affect the traffic flow capacity especially in developing countries and compare these with those in the developed countries in order to :

(a) help in the solution of various traffic problems,
(b) contribute to the development of highway capacity manuals for developing countries, and
(c) determine the relationship of intersection capacity and the current level of economic development of the country.

The developing countries have yet to complete establishing their own highway capacity manuals which are very important in road transport planning, traffic engineering and assessment of level of service. These countries' use of foreign capacity manuals for road traffic planning and analysis may not be suitable to the local conditions and therefore, the necessity of developing their own manuals is urgent. There is a necessity for research on the characteristics of traffic flow of these countries. It is therefore needed to determine the values of the characteristics of traffic flow through the use of various methods. The capital cities of the countries of Japan, South Korea and the Philippines are chosen for this comparison study.

The major part of this paper is the comparison analysis of saturation flow rate through intersections on arterial roads sampled in Tokyo, Seoul and Manila. The following characteristics of traffic flow which affect the saturation flow rate and intersection capacity in the three capital cities are compared in the study:

(a) frequency of lane-changing of vehicles,
(b) start-up lost time, and
(c) effect of certain vehicle types such as jeepneys on traffic flow.

The saturation flow rate in Manila is lower than both Tokyo and Seoul because of frequent lane-changing and large start-up lost time attributed mostly to the operating performance of jeepneys and behaviour of drivers. An interesting finding was that that the saturation flow rate for Seoul was a little over than Tokyo and its start-up lost time is lower, contrary to the expected trend where capacity is proportional to economic development.

The bus traffic flow in the three capital cities and Fukuoka City in Japan was also compared in this study. The bus flow for Metro Manila was the highest among the three cities and following it was Seoul and Tokyo. It was shown that the less developed the rail network, the greater is the bus flow.

2. DATA COLLECTION

2.1. Intersection Flow Data

All the roads containing the intersections chosen for this purpose are classified as arterial roads originating from the capital city center or heart of the metropolis and traversing outward to the outlying suburban areas of each country of study. The method of video survey is preferred because it would need lesser number of surveyors and lesser time and money at the same time preserving the important events on tape. The research relied mainly on video data. Video footage was taken on selected intersections in Tokyo, Seoul and Manila.

The specifications for the taking of the video footage at intersections were such that the stop line and the traffic signal are clearly seen in the screen during viewing. As in Tokyo and Manila, the video camera was set in an elevated position where the direction of the shooting was against the traffic flow. The elevated position that was usually accessible for survey purposes was the pedestrian overpass overlooking the intersection.

2.1.1. Tokyo

In Tokyo, Route 20, in the area of Sasazuka in Shibuya Ward, was surveyed by the author. This road has four lanes and the video footage was shot against the traffic flow going to the suburban area of Tokyo opposite of the direction of Chiyoda Ward which is the central district of Tokyo. The two inner lanes were considered and named as "Sasazuka L" and "Sasazuka R" samples with "Sasazuka R" as the innermost lane keeping in mind the right-hand side driving system in Japan. See Figure 1 below for a better picture.

2.1.2. Manila

In the city of Manila, Espana Avenue, which is one of the busiest arterial roads in Metropolitan Manila, was surveyed by the author and graduate students of the National Center for Transportation Studies (NCTS). This road has four lanes where the outer lanes are designated for jeepneys which are Manila's major paratransit mode. The inner lanes are designated for private vehicles. The study focused on the intersection of Espana Avenue and Governor Forbes Street in the Sampaloc District. The direction of traffic flow on which the footage was taken is away from central Manila towards Quezon City and the outlying suburban areas of the metropolis. As in the Tokyo survey, the two inner lanes were considered and named as "Espana R" and "Espana L" samples with "Espana L" as the innermost lane. The left-hand side road driving system is the one used in Manila and for more details, see Figure 1.

2.1.3. Seoul

In Seoul, the Daebang Road in the Yongdungpo District was surveyed by a researcher of the Korea Transport Institute. Yongdungpo is the broadcast district of Seoul since major broadcast networks are located here. The video camera was positioned at an angle with respect to the center line of the road consisting of three lanes in one direction overlooking the intersection. The traffic flow observed was towards the direction of the central Seoul the intersection. The traffic flow observed was towards the direction of the central Seoul which is the Chun District. South Korea also uses the left-hand side road driving system as in Manila. The second innermost lane is considered as the sample for the analysis and is labeled as "Seoul" as shown in Figure 1.

2.2. Vehicle Classification

The vehicle classification varies for different countries and this depend on the number of vehicles in that category, if it is significant.

Manila : passenger cars, medium and large-size vehicles, jeepneys
Manila' : passenger cars, medium and large-size vehicles, jeepneys
Tokyo : passenger cars, medium-size vehicles, large vehicles, motorcycles
Seoul : passenger cars

Passenger cars include the usual private cars and taxis while the medium-size vehicles include small and light trucks, pick-up trucks and vans. Large-size vehicles consist of big trucks, trailer trucks and buses.

2.3. Video Data Analysis

The analysis of intersection capacity started at translating video data to numerical data through the viewing of the footage taken from the intersections. A computer program, in which the time of passing of the vehicle and the type of vehicle could be registered by just pressing the different keys, was made to aid in the computations of the headway and the percentage composition of different vehicle types. This idea of using the computer as an aid in the analysis came from Dr. Ricardo Sigua (Sigua, 1993), who analyzed video data by making computer programs which computes automatically the spot speeds in video surveys for the Philippine Highway Capacity Manual (PHCM) Project. In the actual study, the front bumper of the vehicle of interest was used as the reference point in the discharge. Samples of signal cycle were chosen from every country's video data. In each sample cycle, the start of green for each cycle, time of passing of the front bumper of each vehicle on the stop line, the vehicle type and end of green interval were inputted to the program.

2.4. Lane-Changing Survey

The study was limited on the two innermost lanes of the arterial roads of the three capital cities. The distance interval was decided to be about over a 50-meter section of road. This interval was based on the study of lane-changing in Manila, conducted by the NCTS for the PHCM Project (3). However, due to the limitations of the range of video shooting, the section observed was from the stop line to the upstream direction only. There was no distinction in the direction of vehicles changing lanes. All cases were counted.

2.5. Bus Volume Counts

Regarding the comparison analysis on the traffic flow of buses, the behavior of these buses around bus stops in the capital cities of the three countries and one of Japan' s major cities, Fukuoka City, are studied.

2.5.1. Tokyo Metropolitan Area

In the Tokyo Metropolitan Area, the city of Kawasaki was surveyed. There are three lanes in one direction and no bus lane is existing. The point surveyed was at the vicinity of Kawasaki Station of the East Japan Railway Company at Arai Avenue towards the direction of the waterfront industrial area in the morning peak period at 7:30 - 9:00.

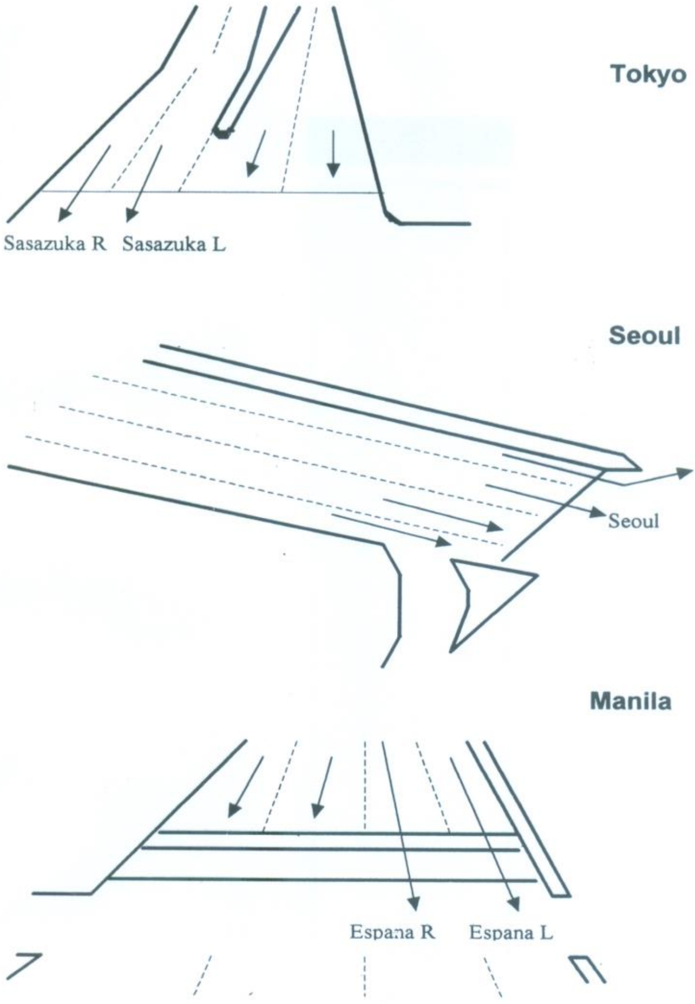


FIGURE 1. Intersection flow survey areas for the different countries

2.5.2. Fukuoka City

In Fukuoka City, Route 202, a national road, was surveyed at the position of the Arae pedestrian overpass at the Jonan District. The direction was towards the city center and the period was from 7:30 to 9:00 in the morning peak. This is a four-lane undivided road with the innermost lane reversible at peak hours. At the period of the survey, three lanes were in use in the direction of the city center and the outermost lane was designated as the bus lane.

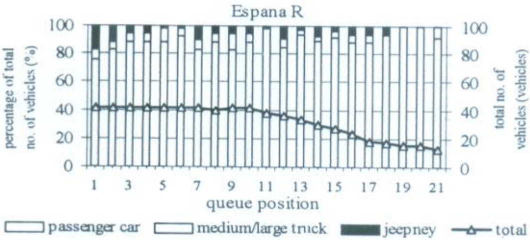
2.5.3. Seoul City
In Seoul, the same Daebang Road was surveyed in the direction of the city center in which there were no designated bus lanes. The survey period was from 7:40-8:40 in the morning peak.

2.5.4. Metropolitan Manila
In Metropolitan Manila, Epifanio de los Santos Avenue (EDSA), a major circumferential and national road, was surveyed from the pedestrian overpass near the ABC Building in Guadalupe in the municipality of Makati. The traffic flow was towards the southern direction to Makati, the country's business and financial center. This road consisted of 6 lanes in one direction with the two outer lanes designated as bus lanes. Survey period started from 7:30 to about 8:00 in the morning peak.

3. METHODS OF COMPUTATION AND INITIAL RESULTS

3.1. Average Variation of Composition of Traffic Flow

The following graphs show the percentage composition of the different categories of



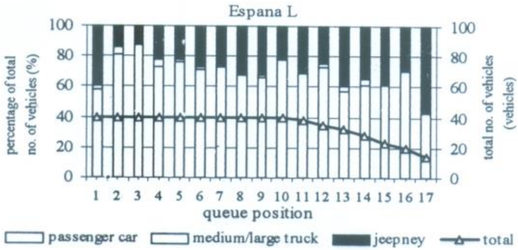


FIGURE 2A. Variation of composition of traffic flow in queue(Espana sample)

vehicles for each position in queue as a result of the survey of the three capital cities. The bar graph corresponds the percentage composition. The line graph represents the total number of vehicles surveyed in each queue position. In Manila, a truck ban was in effect during the time of the survey so that a smaller percentage of the medium or large vehicle category resulted as compared to Tokyo. The video survey for the saturation flow computation was done during the start of traffic build-up until the peak hour of flow from 4:00-6:00 P.M. There is no graph for Seoul because traffic consisted of only passenger cars in the lane that was surveyed.

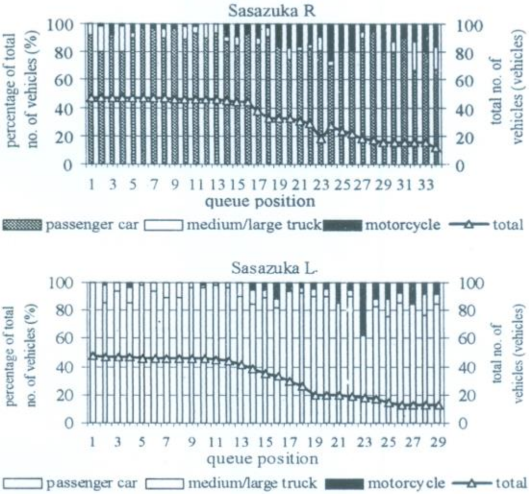


FIGURE 2B. Variation of composition of traffic flow in queue (Sasazuka sample)

Viewing the graphs in Figure 2A, the results indicated that there was a higher percentage of jeepney in the Espana L or the innermost lane than Espana R which was contrary to what was expected. Normally, there should be more jeepneys in the outer lane because they are public vehicles which need to be as close as possible to the roadside for passenger service. This should be the situation provided that there is no lane restriction in effect. In Manila, there was but it was not being followed so it can be said that there is no lane restriction and any type of vehicle can move freely in any desired lane. This is due to the frequent lane-changing behaviour observed committed mostly by jeepneys which would be discussed extensively in the section on lane-changing. In Tokyo, a varied composition of trucks, buses, cars and motorcycles were observed. The traffic of motorcycles was quite significant as the traffic of jeepneys. There were buses observed for public transport in Tokyo but the volume is fewer compared to the volume of jeepneys in Manila. In the arterial street observed in Manila, there were very few buses and mostly consisted of provincial buses going to their terminals in the city. Jeepneys now generally have the major share of public transport especially in the arterial roads as a result of the pullout of buses due to stiff competition in the early 1980's. This shows that Manila is highly dependent on road-based public transport such as the jeepneys due to the lack of railway compared to the highly-developed railway network in Tokyo.

3.2. Headway Adjustment to Account for Traffic Flow Composition

Regarding the adjustments to traffic flow due to the different vehicle categories, the researcher used a simple method differing from the procedures employed by the HCM, CCG and ARRB. This method was recommended by Dr. Kuwahara of Tokyo University. The main assumption used was that under equal conditions and for homogeneous traffic flow, the number of passenger-car units crossing the stop line of a single lane of an intersection approach should be constant during green intervals of equal duration (Teply and Jones, 1991). Variations are therefore attributed to differences in behavior of individual vehicle categories.

3.2.1. Determination of Passenger Car Equivalent Factors

The research employed the method of weighted average determined by proportions of various vehicle types and the main difference from the usual methods is that these traffic composition factors were instead applied to the average headway values corresponding to each position in queue. The average headway of each vehicle category for each position in queue was first calculated. Thereafter, the average headway of each vehicle category was divided by the average headway of the passenger car category in each queue position. This is the normalization procedure with respect to the passenger cars. The adjustment factor for passenger cars is therefore equal to 1.0 and the adjustment factors for other vehicles are the passenger car equivalents (PCE). Table 1 below shows the comparison of PCE's.

TABLE 1. Comparison of passenger car equivalent factors

city	vehicle type	average PCE
Tokyo	medium/large vehicles	1.35
Manila	jeepneys	1.7

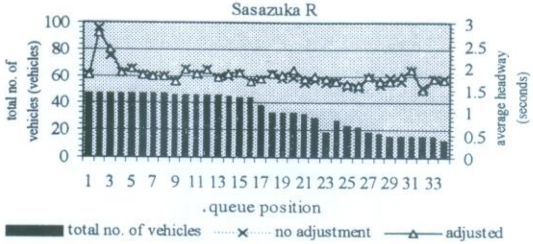
The maximum value of PCE computed for Tokyo was lower than that of Manila. This was the outcome despite the composition in Tokyo for medium/large vehicles were mostly trucks and vehicles larger than the jeepneys in Manila. The adverse effects of trucks on traffic stream performance can be attributed to the following factors (Krammes and Crowley, 1986) :

(a) trucks are larger than passenger cars,
(b) trucks have operating capabilities that are inferior to those of passenger cars, and
(c) trucks have a physical impact on nearby vehicles and a psychological impact on the drivers of those vehicles.

In comparison to passenger cars, jeepneys are a little bit larger in size. In the section on start-up lost time comparison, the operating capabilities of jeepneys were observed to be lower than passenger cars. Also, the behaviour of drivers of jeepneys which resulted to the excessive lane-changing as, analyzed in detail later in this paper, corresponds to factor (c). Therefore it could be concluded based on the results of PCE computations that the behaviour of jeepneys is similar to that of trucks.

3.2.2: Adjustment of Average Headway

The preceding PCE factors are then used to adjust the average headway corresponding to each position in queue. The revised computation is similar to the weighted average



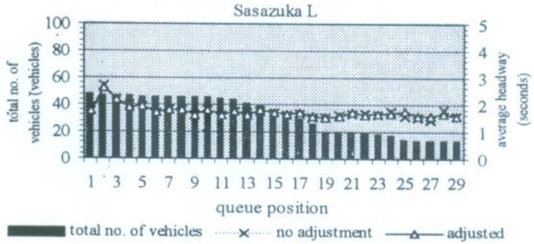
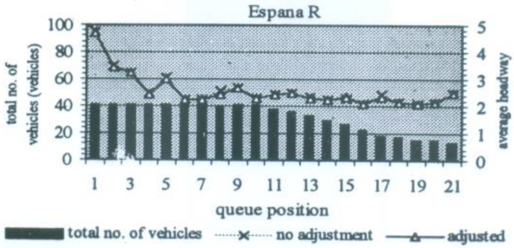


FIGURE 3C. Variation of average headway with and without adjustments with respect to vehicle composition in the Sasazuka sample

In Manila, the headway of the first vehicle is the highest in contrast to the headway graphs in Tokyo and Seoul wherein the second vehicle had the maximum headway. For the cases of Tokyo and Seoul, the shape of the graph follows the theoretical headway curve wherein the criterion for discharge used is stop line and front bumper. However, viewing the Espana graphs, they seem not to deviate from the established relationship. Presented here are some reasons for this difference:
(a) large start-up lost time, and
(b) cautious entry by the first driver of the queue into the intersection.
The start-up lost time in Manila was observed to be higher than in Tokyo and Seoul. This is due to the factors such as poor operating capability of vehicles in general and violations of traffic regulations which are related to driver and people behaviour. This would be discussed in detail in Section 4.1.2 of the paper. Factor (b) is another main reason observed in places with high degrees of red signal violations (Teply and Jones, 1991). This was confirmed in the video wherein drivers in the first position in queue were not able to accelerate immediately compared to their counterparts in Tokyo and Seoul due partially to the spill-over of vehicles of the crossing street and obstructing pedestrians.

3.3. Determination of Saturation Headway

The saturation headway is computed as the mean of the average headway starting from a specific queue position, determined from the graph of the time difference between consecutive vehicles against the queue position. This specific position is chosen as starting computation with the adjustment factor acting as the weight of a vehicle category multiplied to the number of vehicles of this category. They are then totaled and divided by the total number of vehicles surveyed for every position. These result to the adjusted average headway values shown in the following graphs.



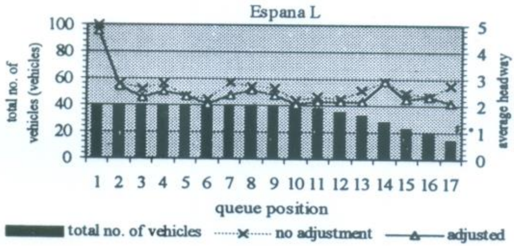


FIGURE 3A. Variation of average headway with and without adjustments with respect to vehicle composition in the Espana sample

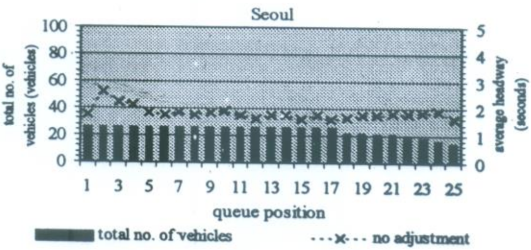


FIGURE 3B. Variation of average headway with and without adjustments with respect to vehicle composition in the Seoul sample

position for stabilization of headway, that is the start of saturation period, when the time difference of headways (see Figure 5) between two positions become very small, say about 0.055 second. From the graphs of adjusted average headway due to traffic composition, the saturation headway graph is derived. In the following graph of Figure 4, the saturation headway value for each particular queue position is computed by getting the mean of the average headway values from this particular position.

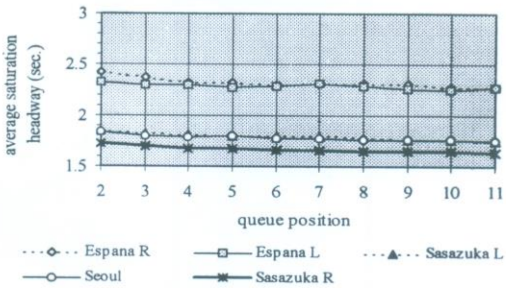


FIGURE 4. Graph of saturation headway of each position in queue

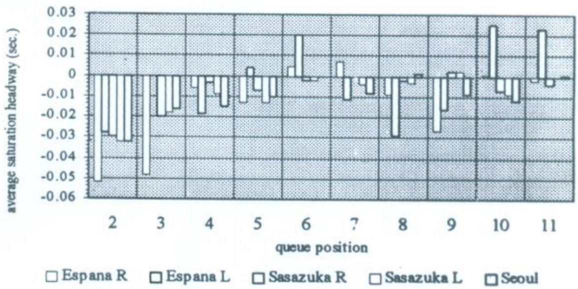


FIGURE 5. Graph of saturation headway time difference

It is clear from the graph of saturation headway in Figure 4 that there is a large difference between the saturation headways of Manila and the other two cities. It is higher for Manila and this result indicates a lower capacity for the intersection flow. This large difference is very significant in terms of design of roads and the design of the intersection and lanes since this shows us the importance of establishing highway capacity manuals specific to the country where the local parameters are used.

4. RESULTS OF THE STUDY

4.1. Comparison of Saturation Flow Rates

The saturation flow rates of the five sample sets from the cities are computed in this section based on the determination of the saturation headway. Equation 1-6 of the US HCM was used for this purpose. The equation is explained in detail on the Appendix of this paper. In the assessment of signalized intersections, the capacity of an intersection is derived from saturation flow rate and the relationship is a direct proportion.

TABLE 2. Ranges of saturation flow rates for the three capital cities

Tokyo	1950 - 2150 vehicles/hour green/lane
Seoul	1900 - 2200 vehicles/hour green/lane
Manila	1450 - 1700 vehicles/hour green/lane

Table 2 above shows that the analysis yielded significantly higher saturation flow rates for Tokyo and Seoul compared to the rate of Manila. The reasons for this outcome are mainly due to the following factors:

(a) high frequency of lane-changing of vehicles in Manila,
(b) large start-up lost time in Manila, and
(c) effect of public vehicles such as the jeepneys.

4.1.1. Lane-Changing

First, let us investigate the phenomenon of lane-changing and how it affects the saturation flow. In this study, the rate of lane-changing behaviour of vehicles is quantified in terms of the number of times or frequency per hour of green time per lane over a specific road section which is the intersection approach. Table 3 compares the rate of lane-changing for the different object cities :

TABLE 3. Comparison of frequency of lane-changing in the three capital cities

Manila (Espana Avenue)	jeepneys	35 times
	other vehicles	8 times
Tokyo (Route 20)	2 times	
Seoul (Daebang Road)	1.5 times	

It is clearly indicated from the above table that Manila has the highest rate of vehicles shifting lanes, following it is Tokyo and then Seoul. Notice the partitioning of the table in the rate for Manila. It was divided into two categories which are other vehicles and the jeepneys. More than 80% of the frequency accounted for the jeepneys which is another point of study in this paper to be discussed in the later section on the effect of certain vehicle types such as jeepneys on the road traffic flow. After analyzing the data from video footage of the different intersections, the following instances when a vehicle changes its lane were noted :

(a) the vehicles move to the appropriate lane for their intended movement approaching an intersection which is either a turn or through movement,
(b) drivers positioning their vehicles as they line up in queue,
(c) the driver overtakes a leading vehicle of lower speed,
(d) overtaking a stopped vehicle, and

(e) frequent stopping of public utility vehicles.
The first three instances are natural reasons for vehicles to change lanes in order to maintain the smooth and maximum flow of traffic on the streets but this depends on the frequency and the manner of shifting to a different lane. In the video, there were observations wherein the drivers of these vehicles change lanes over a short period of time for these three cases and this behaviour disrupted the smooth flow of traffic as seen in the traffic flow in Manila. The smooth flow of traffic observed in the discharge of vehicles in the intersection of Tokyo and Seoul giving them higher saturation flow rates was due to the minimal rate of lane-changing and in cases where vehicles changed lanes, they were done in a gradual manner making the least negative effect to traffic flow. In the case of (c), this is usual where vehicles find the path with least resistance or the fastest way which has a positive effect on traffic flow but only to some extent. But if the rate of lane-changing is high due to (c) especially during peak-hour periods of flow, this disrupts the flow and decreases the saturation flow rate and therefore, a problem of general performance of vehicles running on the streets and driver behaviour as observed in Metropolitan Manila. Subsequently, the last two reasons pertaining to the stopping of vehicles had a more negative effect on the traffic flow since the stopping of a vehicle on the street virtually blocked one lane and the vehicles following it were forced to abruptly change lanes, and thus, lessening the total capacity of the lane group. Queuing occurs from the point of stopping and propagates like a shock wave as time progresses due the constriction of the road where one lane is blocked. There are two cases of stopped vehicles. It can either be a stalled vehicle or a public utility vehicle temporarily stopping for passenger service. The stalled vehicle has a more serious effect on intersection capacity since this vehicle blocks one lane for a certain period of time. This was observed in the video footage taken in Manila wherein a truck stalled at an intersection approach and reduced the saturation flow rate by as much as 20%. The effect of stopping public vehicles such as jeepneys had lesser negative effect since they move again with traffic after a shorter period of stopping time thereby preventing longer queuing of following vehicles. This problem, however, is compounded by the frequent stopping of public vehicles as observed in Manila where jeepneys running at the inner lanes shift as much as 1-3 lanes in order to get as near as the sidewalk in order to load or unload passengers and what these drivers did was to cut abruptly into other lanes causing the vehicles in the other lanes to stop abruptly. This also causes chain reaction of stopping of vehicles following since the headway between vehicles is small, thereby disrupting the smooth flow of traffic and lowering the average speed of the lane and the saturation flow rate.

Now, let us analyze in more depth the behaviour of lane-changing, that is, at the level of the driver of the vehicles who basically makes the decision to change lanes. All of the above observations and their analyses could be classified into factors that affect the decision of drivers to change lanes :

(a) gap between the average speeds of the vehicles of the two adjacent lanes,
(b) magnitudes of the leading headway of the adjacent lanes,
(c) length of vehicle queue of each lane at the intersection approach,
(d) patience and attitude of drivers,
(e) proportion of public utility vehicles in traffic flow,
(f) existence of a designated lane for public vehicles, and
(g) type of the leading vehicle.

The initial three factors generally has a positive effect on traffic flow since drivers seek the fastest lane and these increase the saturation flow rate but with limitations as stated earlier. In a peak-hour flow observed in Tokyo, a vehicle changed lane gradually without disrupting the smooth flow when the driver perceived that the leading headway in the adjacent lane is larger than his own lane. Although this is not advisable especially during congested flow since headways are very little, the number of lane-changing observed in Tokyo is too low to have a significant effect on the traffic flow. Also, when the drivers of the following vehicles in a certain lane see a vehicle from adjacent lane shifts to their lane, they generally give way by maintaining ample headway giving space for the vehicle changing lanes, thus maintaining the smooth flow of vehicles. This is in sharp contrast with the behaviour in Manila wherein the drivers mostly of jeepneys change lanes suddenly by cutting into the adjacent lane even though the leading headway in the latter lane is not enough for the vehicle to have a gradual shifting and, for the following vehicles in the latter lane, drivers tend to put pressure on the vehicle changing lanes by not giving way through maintaining a very little headway. Additionally, jeepneys were observed to change lanes often to overtake other rival jeepneys in order to get ahead at the stop to get more passengers or if already full, the drivers get to the destination the fastest way by cutting and swerving disregarding other vehicles. This behaviour leads to the disturbance in the smooth flow of traffic characterized by sudden stops and accelerations and not being able to maintain a constant speed and constant headway. Therefore, the discussion leads to factor (d) which pertains to the general attitude of drivers in a specific city that is governed by the culture of the country. This is considered as the dominant factor in the behaviour of lane-changing observed in Manila. While the first three factors are generally beneficial to the traffic flow, factor (c) is a critical factor since it has a long-term negative effect on the smoothness of traffic flow and thus, the saturation flow rate and capacity of the intersection. Long-term means that it would last as long as the attitude of the drivers remain poor especially in road traffic courtesy and discipline. Generally, patience of drivers are quite short in Manila attributable mainly to the lack of road courtesy and partly due to the pollution, heat and stress due to the congestion and traffic jams.

With respect to (d), the effect of the proportion of public vehicles on traffic flow is later discussed in the section on effect of certain vehicles on traffic flow. In Espana Avenue in Manila, the two outer lanes were designated as jeepney lanes but the video showed that it was not being followed by the drivers. Private vehicles go into the jeepney lane as well as the jeepneys going out of their designated lanes although majority composition of the traffic flow in the outer two lanes accounted for the jeepneys which was just natural for public transport vehicles. If these designated lanes were enforced effectively, there would have been lesser rate of lane-changing since the jeepneys would be confined to the outer lanes and traffic would flow smoother increasing the capacity of the two inner lanes for private vehicles. Furthermore, if the leading vehicle is a jeepney, other vehicles following it tend to lower their running speeds because of the unpredictability and they try to be cautious to prevent bumping due to very close spaces between vehicles.

4.1.2. Large Start-up Lost Time

Another important reason for the low intersection capacity of the streets in Manila is the large start-up lost time in the green signal period. In the following graph in Figure 6, a consistent trend could be seen where the start-up lost times for the initial vehicles discharging through the intersection in the outer and inner lanes of Espana Avenue are greater than those of Tokyo and Seoul. In between Tokyo and Seoul, it was surprising to note that after a same initial value, the plots deviate that resulted to a little higher start-up lost times for the two lanes Route 20 in Tokyo than the lane of Daebang Road observed in Seoul.

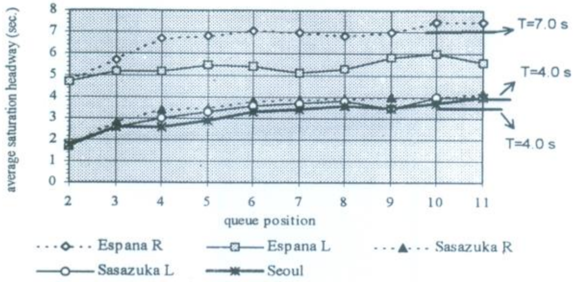


FIGURE 6. Plot of cumulative start-up lost time of vehicles

Therefore, from the above results, let us examine what are the reasons for this significantly larger start-up lost time for Manila. A more detailed discussion of the mechanics of start-up lost time as described by the US HCM can be seen on the Appendix section. Ideally, the headway for the initial vehicles discharging through the intersection are comparatively long and this headway is supposed to decrease and stabilize to a constant headway which is the saturation headway as vehicles discharge. But in reality, as analyzed from the video, there were little variations in headway where a straight line could not be fitted as seen in Figure 3 for the variation of headway against the queue position. The following are the reasons for large value of start-up lost time in Manila based on the analysis of video data:

(a) vehicles in general have road performance inferior to that of the vehicles in Tokyo and Seoul,
(b) vehicles not in the proper lane,
(c) crossing pedestrians and vehicles of the intersecting street,
(d) public vehicles stopping at the intersection approach, and
(e) passengers waiting at the outer lane of the road.

Pertaining to factor (a), it was generally observed from the video that many vehicles in Manila spent longer time in starting up to move through the intersection as the signal shifted to green, as compared to the vehicles in Tokyo and Seoul. Most vehicles are inferior in acceleration especially the jeepneys. Although new models of vehicles are seen running in the streets of Manila, there are still many people using the old models of vehicles. These observations indicate that the general performance of vehicles in Manila is lower than the other two cities. In addition, many of the jeepneys were made using surplus or second-hand truck engines imported mainly from Japan.

Moving now to factor (b), many vehicles in Espana, as they line up in queue at the intersection, were not in the appropriate lane. In some cycle signal phases, the original four lanes intended for four vehicles were occupied by five vehicles. This affects the starting up since the lateral space between vehicles are small which makes the drivers cautious and therefore, lowering the level of start-up acceleration. On the matter of pedestrians, they were observed to continue crossing the street even after the start of the green signal. This behavior was very common in Manila as seen in the video. As a result, vehicles in the first position could not start up immediately thus compounding the start-up lost time and lessening the capacity of the intersection. Not only the pedestrians were the problem but also the spill-over of vehicles in the crossing street which blocks the main arterial or Espana Avenue in Manila during the start of green signal. The spill-over was due to the narrowness of the crossing street wherein volume exceeded the capacity and also the stopping of the jeepneys at the far side curb of the intersection. This had a more negative effect on traffic flow and capacity since about 1-3 lanes of the main arterial were blocked in at some signal cycles. Furthermore, it was noted that many drivers of the crossing street, upon seeing the queue due to the spill-over, instead of stopping at the stop line, they continued to cross the main arterial thereby lengthening the queue and blocking more lanes of the arterial contributing to larger start-up lost time. It seems that they want to hurry always and take advantage disregarding that they would be causing more congestion and inconvenience to the other street. The behaviour observed in Tokyo was quite the contrary. The driver would stop before the stop line even though the signal is green if he sees a queue at the far side curb at the downstream portion of the intersection mindful of the other vehicles of the crossing street. Another factor contributing to the large start-up lost time is the stopping of the jeepney just before the stop line to load or unload passengers which take up portion of the green signal time. Due to the limited carrying capacity of the jeepneys plying along the arterial, the waiting time for commuters during rush hours is long and the result observed was too many people waiting spilling over at jeepney stops. What affects the saturation flow rate was lots of commuters waiting at the outermost lane constricting the road space which was already congested. This behaviour was not seen in the video of Tokyo nor Seoul. From these, it could be said that the first factor is more of an economic problem which really depends on the level of economy of the country and these would be solved in the process of economic development. The remaining factors are generally a human behaviour problem specifically on the traffic courtesy of drivers and the discipline of pedestrians which could be remedied through traffic education of drivers, pedestrians and policemen, and through strict traffic law enforcement.

It is interesting to find out from the preceding results that the saturation flow rate for Seoul was a little more than Tokyo and its start-up lost time was observed to be lower. There seems that there is no significant proportional relationship of capacity or saturation flow rate and the level of economic development of the country as expected.

4.1.3. Effect of Jeepneys on Traffic Flow

Many of the factors which reduce the saturation flow rate including frequent lane-changing and larger start-up lost time were already discussed in the preceding sections. Here, the plotting of relationship among different factors is done to reaffirm the observations and analyses presented earlier.

From the graph in Figure 7, the high percentage of jeepney traffic and its grouping at the first position in queue contributed to the large headway and consequently to the large start-up lost time in Manila. This result reaffirms the low acceleration capability of vehicles which are composed of mostly jeepneys in the arterial roads of Manila. The relatively high percentage of jeepney traffic compared to the public vehicle traffic in the lanes observed in Tokyo and Seoul contributed to the lowering of the saturation flow rate as a result of frequent lane-changing mostly done by jeepney drivers as explained earlier. Another thing is that the average headway of other vehicles fluctuates and is not stabilized relative to the curve for the jeepneys. This is due to the leading vehicle factor where other vehicles keep distance from jeepneys because of its unpredictable movements caused mainly by the drivers' behaviour. It can be said based in the preceding analyses that the relatively high proportion of jeepneys in the traffic flow has a reductive effect on the saturation flow rate and the capacity of an intersection.

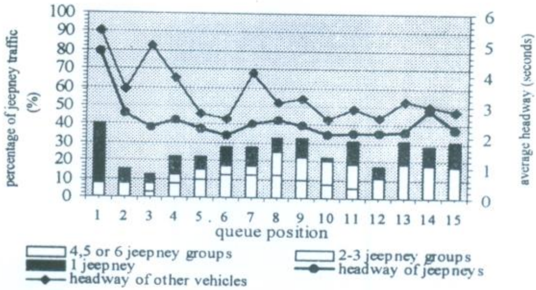


FIGURE 7. Variation of jeepney traffic, headway and platooning behavior

4.2. Comparison of Bus Flow

The number of buses passing a reference point at 5-minute intervals for Kawasaki (Figure 8) is higher than Fukuoka (Figure 9). The values for Kawasaki are higher than in Fukuoka. In Kawasaki's industrial area, few railway lines were constructed. The major role of buses in Kawasaki City is transport people from the railway stations to the work places which is

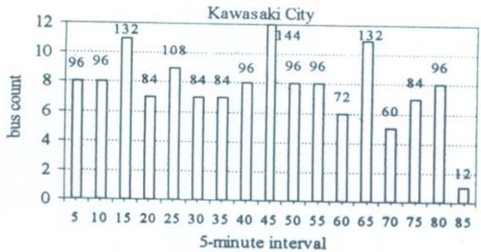


FIGURE 8. Observed 5-minute bus flow rates in Kawasaki City

mainly in industrial areas. The waterfront area of Kawasaki City is mainly an industrial area where many plants and industries are located. Another reason for this difference in results as seen in Figure 8 and 9, is that at the time of the survey, there was traffic congestion in the road leading to the city center of Fukuoka, thereby, resulting to the lower bus flows. During the same time period of survey, the road surveyed in Kawasaki was not congested and buses can utilize two lanes, in contrast to Fukuoka, where there was only one lane for buses.

Comparing the flow of buses in the two Japanese cities and that of Seoul (see Figure 10), results show that the values in Seoul are greater. The major reason is that bus is still the

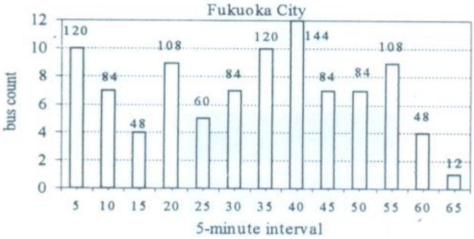


FIGURE 9. Observed 5-minute bus flow rates in Fukuoka City

major mode of urban transportation in Seoul and its railway network is still in the process of developing. In Japan, the network for rail is already in place so commuters have alternatives. The main functions of buses in Japanese cities is to carry people from the railway station to the residential area and to provide commuter service between stations.

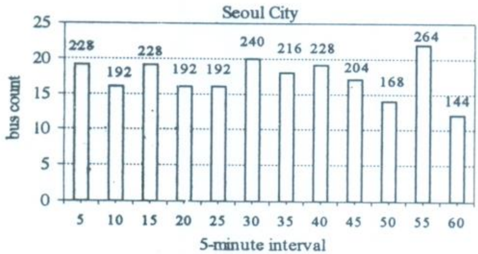


FIGURE 10. Observed 5-minute bus flow rates in Seoul City

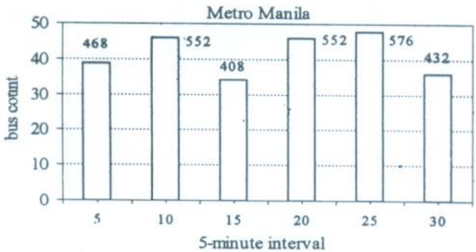


FIGURE 11. Observed 5-minute bus flow rates in Metropolitan Manila

Figure 11 indicates the results of bus flow which show the highest flow rates in EDSA arterial road in Metropolitan Manila in comparison to the cities in Japan and in Seoul. Most of the buses are plying this road. The rail-based mass transportation system network is still at the initial stage. There is only one LRT line operating inside Metropolitan Manila and the old commuter line of the Philippine National Railways (PNR). Basically, Manila is still road-based in terms of mode of transport. In EDSA, not only city operation buses are using this road but also provincial or inter-city buses with terminals inside Manila. The large volume of buses is due to the mentioned reason of the lack of a rail-based mass transportation system and lack of alternative roads. EDSA is the only completed circumferential road and the other roads in the planned network are encountering problems in right-of-way acquisitions due to the increase in built-up areas. Furthermore, EDSA is the major through link between the north and south expressways. The high volume of buses in Metro Manila resulted to the following :

(a) reduction in the capacity of bus stops, and

(b) reduction of the road capacity.

The exclusive bus lane in EDSA, Metro Manila was in effect at the time of the survey. From the video data, the headway was observed to be short in comparison to Tokyo and Seoul. The high bus flow resulted to instances wherein buses spill over at bus stops and other buses not being able to easily unload and load passengers. Buses, therefore, at some times occupied the portion of the inner lanes allotted for private vehicles at the vicinity of bus stops and constricted traffic flow at these areas of the road although at rush hours, traffic enforcers were there to limit buses in to their exclusive lanes. This was compounded by the problem of behaviour of some bus drivers who tend to stop a long time at bus stops in order to get more passengers. All of these resulted to the reduction of capacity of the bus stops in Metro Manila. Result (b) above is due to mainly to the behaviour of bus drivers. To the credit of buses, they were observed to stop only at bus stops which has a positive effect to traffic flow and thereby preventing frequent bus blockages. However, the behaviour of lane-changing were observed to be similar to jeepneys especially when bus lanes were not being enforced by the police. The effect of abruptly changing lanes or cutting into other lanes by buses was the reduction of speed of the other lanes since the size of the buses has a physical and psychological effect on other vehicles specially the smaller vehicles such as private cars. The drivers of private cars tend to keep a larger headway when following buses because of the frequent lane-changing behaviour of buses and in order to prevent accidents. These observed behaviour reduces the capacity of the road in Metro Manila.

5. SUMMARY AND CONCLUSIONS

Based on the results of this study from video data analysis summarized in Table 4 in the next page, there was little difference in the values of the characteristics of traffic flow between Tokyo and Seoul. However, comparing these two cities with Manila, there was significant difference. The lower saturation flow rates and the higher values of start-up lost time and time for flow stabilization in Manila reflect the congested traffic conditions which are mainly due to the observed high frequency of lane-changing in Manila. It was found out that most of the instances of lane-changing are done by jeepney drivers. These problems are due to the observed lower performance of vehicles, specially the jeepneys, and the observed poor road traffic behavior of motorists. The most significant factor derived from the analysis was the behaviour problem of drivers, pedestrians and passengers in Metro Manila. The human behavior problem seems to affect every aspect affecting traffic flow and capacity, such as lane-changing and start-up lost time. Results also have shown that the capacity and saturation flow are not related to the level of economic development of the country. The realization that there are significant differences in traffic flow characteristics indicates the need for the establishment of a local highway capacity manual which takes into account the characteristics of traffic flow specific to that country. The results of this study could contribute in the current development of the capacity manual especially to developing countries such as the Philippines. These local manuals would make the planning and design of roads and road networks more effective and responsive to the traffic demand since the capacity of roads specific to the country is determined more accurately.

TABLE 4. Summary of comparison of traffic flow characteristics in the some East Asian capital cities

characteristics	Tokyo	Seoul	Manila
saturation flow rate (pcu/hr green/lane)	1950 - 2150	1900 - 2200	1450 - 1700
start-up lost time (sec.)	4.0	3.5	7.0
time from start of green when flow stabilizes(sec.)	12.0	11.0	16.0 - 19.0
P.C.E. for certain types of vehicles	large/medium-sized vehicles = 1.2 - 1.5	———	jeepneys = 1.2 - 2.2
frequency of lane - changing (times/lane/hr.)	2.0	1.5	jeepneys = 35.0
			other vehicles = 8.0
peak bus flow (buses/hr.)	Kawasaki = 144	264	576
	Fukuoka = 144		

Bus flows were observed to be highest in Metropolitan Manila in which there is lack of a railway mass transportation system such that commuters depend on bus as their major mode of transport to work places and homes. Next to Manila is Seoul where the mode of transport is generally by bus since its urban railway network is still in the process of developing. Lower values of bus flow were observed in Japanese cities due to developed railway network inside and outside urban areas. The buses function as links between railway stations and as transport mode from stations to residential areas. Furthermore, the reduction of capacity of bus stops and the road in the vicinity of stops are attributed to behavior of drivers of buses and the high flows observed in the EDSA arterial road in Metropolitan Manila. The high volume of buses and the future modal split should be considered also in the development of the capacity manual since buses reduce the road capacity especially in the vicinity of bus stops. The consideration of these factors would be very important in the planning and design of roads and bus stops especially along corridors where bus flow is high.

This study introduced many characteristics of traffic flow which are known but usually taken for granted. It is recommended by this study that the phenomenon of lane-changing which is very high in Metropolitan Manila must be studied in more detail. The observation conducted in this study was limited which did not include traffic flow on other days of the week such as wet and off-peak conditions. More intersections should be surveyed to identify more special characteristics and behavior of traffic in the different cities. Most important matter to consider is the change in traffic flow in the future and this should be studied in terms of future modal split, general vehicle performance characteristics and many others considering the economic growth of the country. These are very important elements which are needed to be incorporated in the development of the local highway capacity manual.

6. APPENDIX

6.1. Headway

There are many definitions of headway as defined by different capacity manuals of different countries. Therefore, there are also different criteria of vehicle discharge which are combinations of roadway reference point and reference point on the vehicle that is discharging through the intersection. Since it is convenient, specially in the analysis of video footage, the study used in its analysis the current definition of headway by the British Transport and Road Research Laboratory (TRRL) and also the discharge criterion specified in the Canadian Capacity Guide (CCG) and the Australian Road Research Board(ARRB). The TRRL defines headway as "the time elapsed between the front of a vehicle crossing the stop line and the front of the following vehicle crossing the stop line."

6.2. Saturation Flow

In this paper, the saturation flow rate is determined using Formula 1-6 of the United States' Highway Capacity Manual (US HCM, 1985). The HCM defines the saturation flow rate as the flow rate per lane at which vehicles pass through a signalized intersection in such a stable moving queue. By definition, it is computed as:

$$s = 3{,}600 \text{ seconds per hour} / h$$

where:

s = saturation flow rate, in vehicles/hour green/lane, and
h = saturation headway, in seconds.

The method used in this paper for computing the saturation headway differs from the HCM. Different manuals have different definitions for saturation headway. The saturation headway, as defined by the HCM, is estimated as the constant average headway between vehicles which occurs after the 6th vehicle in queue and continues until the last vehicle in initial queue clears the intersection. The ARRB Report 123 calculates saturation flow, on the basis of average headway of vehicles discharging after the initial 10 second of green until the end of green. The CCG method, in contrast to the preceding methods, utilizes the whole of the green interval.

6.3. Start-up Lost Time

Start-up lost time is due to the start-up reaction of the initial vehicles as a result of the change of signal phase from red to green. At signalized intersections, traffic flow is periodically stopped. When signal turns green, the standing queue of vehicles begins to move and headways can be observed as they discharge through the stop line. The first headway measured would be the elapsed time between the start of green and the crossing of the front bumper over the stop line and thereafter, succeeding headways would also be measured. As described in the HCM, the driver of the first vehicle in the queue must observe the signal change to green and react to the change by taking his foot off the brake, and accelerating through the intersection. Therefore, the first headway would be comparatively long as a result of this process. The second vehicle in queue follows the same process, except that the reaction and acceleration period can partially occur while the first vehicle is beginning to move. The second vehicle would be moving faster than the first as it crosses the curb line, because it has an additional vehicle length in which to accelerate. Its headway would still be comparatively long but is generally less than that of the first vehicle. The third and fourth vehicles follow a similar procedure, each achieving a slightly lower headway than the preceding vehicle. After a certain number of vehicles, the effect of start-up reaction and acceleration has dissipated and the headway will be relatively constant. The constant average headway after a certain number of vehicles is actually the saturation headway and the incremental headways for the initial vehicles represent the start-up lost times.

6.4. Lane-changing

Another factor affecting traffic flow is studied in this paper. Leutzbach (1972) tried to relate lane-changing with traffic volume in terms of the frequency per hour per kilometer through observations made on a section of the German autobahn but he said that to date, it has not proved possible to obtain analytically the number of lane changes as a function of traffic volume. This relationship can only be observed or simulated.

6.5. Bus Flow

In the HCM (1985), bus flows are measured in terms of the number of buses per lane per hour. The reductive effect of buses on vehicular capacity depends on the method of operation. In the case of roads where buses stop at the normal traffic lane, the effect on the road vehicular capacity depends on the time loss due to the dwelling at the stop and the time loss due to stopping and starting. For roads with bus lanes, the main effect is on the capacity of the bus lanes.

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REFERENCES

1. **Japan Highway Traffic Databook** (1988) Transportation Engineering Research, Tokyo
2. Krammes, R. and Crowley, K. (1986) Passenger car equivalents for trucks on level freeway segments. **Transportation Research Record 1091**, 10-17
3. Leutzbach (1972) **Introduction to the Theory of Traffic Flow,** Springer-Verlag, Berlin
4. **Special Report 209 : Highway Capacity Manual** (1985) Transportation Research Board, National Research Council, Washington, D. C.
5. Sigua (1993) A study on the traffic characteristics of some arterial roads in Metro Manila. **Proceedings of the First Annual Conference of the Transportation Science Society of the Philippines.** Manila, Philippines, 30-31, July, 1993
6. Teply, S. and Jones, A. M. (1991) Saturation flow : do we speak the same language?. **Transportation Research Record 1320,** 144--153
7. Tonaki, S. (1994) International comparison study on road traffic flow, Undergraduate Thesis, Department of Civil Engineering, Tokyo Institute of Technology, Tokyo