A STUDY ON THE EFFECT OF LANE CHANGING BEHAVIOR ON THE APPROACH RAMP OF A ROAD OVERPASS

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Abstract: Approaching the Buendia flyover along Roxas Boulevard, various types of abrupt lane changing is performed by public vehicles who alight passengers right before the overpass, vehicles who came from the service lane, and others who want to avoid traffic. The lane changing causes congestion and bottlenecking along the approach of the flyover, leading to delays of the succeeding vehicles. This study focuses on the lane changing behavior of the vehicles as well as analysing the delay caused by the lane changing on other vehicles. The Metropolitan Manila Development Authority (MMDA) (2012) stated that irresponsible and abrupt lane changing is called swerving which may cause unnecessary queuing ultimately leading to traffic delays. It was observed that the increase of the delay of vehicles is polynomial, at most 78% of lane changing incidents caused delay and that the total delay incurred by the vehicles in an hour is 5238.9 veh-min.

Keywords: Discretionary lane changing, mandatory lane changing, queuing, delay, swerving

1. PROBLEM SETTING

1.1 Background of the Study

Along Roxas Boulevard, there is a four lane highway directed northward where the two leftmost lanes lead to the Buendia flyover and the remaining two lanes lead to Buendia-Makati-Ayala. It has been observed that there is a tendency for vehicles to abruptly change lanes near the entrance of the flyover. The abrupt lane changing done by the vehicle can be considered as swerving. The vehicles on the lanes of the path of the lane changing vehicle will be forced to stop and wait until the lane changing vehicle has passed their lane. The time it takes for this vehicle to reach its desired lane is long enough causing traffic congestion and bottlenecking. Figure 1 shows that the vehicles in the area do swerve or change lanes as previously described and that the other vehicles in the area are affected by the swerving. It is because of the congestion and bottle necking found in the area that this study was conducted.

Only the queues within the congestion and bottle necking that is mainly caused by the abrupt lane changing of the vehicles in the area were observed. A vehicle was considered to be swerving illegally when the vehicle abruptly changes lanes within the area between the initial "NO SWERVING" sign and entrance of the flyover.

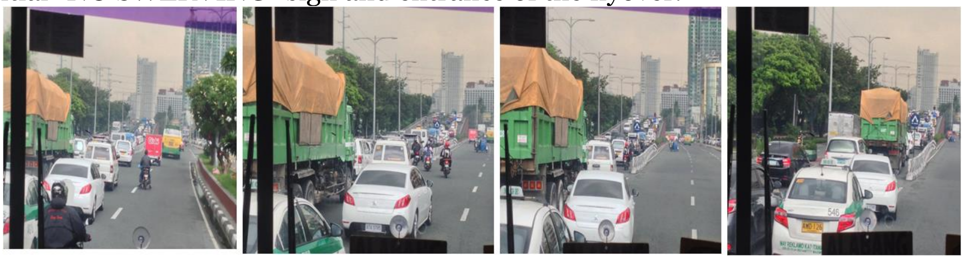


Figure 1. Example of Swerving Vehicle

1.2 Statement of the Problem

Traffic congestion occurs and worsens before and after flyovers. At the entrance of the flyover vehicles tend to swerve; the swerving then contributes to congestion in the area. In a study done by Cua (2015), the average time for the drivers in the Philippines to change lanes is 5.5 secs which was compared to a similar study that showed that at an average driver takes 4.2 seconds. The observed deviation points that on average, drivers in the Philippines take a longer time to change lanes which causes congestion or bottlenecking. It was observed that the greater the congestion in the area, the more the drivers will choose to swerve compounding to the already prevalent congestion in the area. The congestion caused by swerving vehicles leads to a decrease in work productivity due to increased commute times, as well as an increase in vehicle emissions. As stated from a research by Li and Sun (2015), congestion causes an increase in fuel consumption leading to higher demands for fuel, an increase in emissions raises the amount of air pollutants and decreases productivity due to the time the drivers were held in the congested areas. It is seen that traffic congestion is a problem that should be addressed.

1.3 Objectives

The study aims to analyze the impact on traffic flow of the lane changing behaviour of vehicles when entering the flyover along Roxas Boulevard. Specifically, the researchers aim to assess the effect of swerving or abrupt lane changing on traffic flow in the study area, to determine the number of vehicles that changed lanes and to recommend plausible traffic management schemes to minimize swerving.

2. REVIEW OF RELATED LITERATURE

Specific ideas that were found significant for the paper from various studies focusing on the different aspects of lane changing have been identified and used as a basis for the methods and theories in the research. One of which is the idea of the different types of swerving based on the number of lanes changed, (direct and staggered) and reason for lane changing (discretionary and mandatory). Staggered lane changing is where the vehicle's desired lane is two or more lanes away from the vehicle's current lane while direct is where the desired lane is the lane adjacent to the vehicle's current lane as mentioned by Aghabayk, K. *et al.* (2013). On the other hand, discretionary is where the vehicle changes lanes to gain a speed advantage while mandatory is where the vehicle changes lane to reach its destination as discussed by Kusuma, A. *et al.* (2014). All lane of the said types was observed for the research. However, there are conditions where this lane changing can be considered as improper. It was stated by the MMDA (2016) that abrupt lane changing is a type of swerving which can be considered as a violation. It was then based from a research by Hohm and Winner (2010) that proper lane changing length was used as a basis for the study. It stated that the minimum value for proper lane changing length for small vehicles are 9m and 27m depending on the type of vehicle. Next is the setup of cameras to help optimize the view for the data gathering. Cua (2015) and Gurupackiam, S. *et al.* (2010) used views that were at a high elevation showing a top view of the study area. The view of the camera in the research was at a high elevation but angled due to the lack of possible areas to gather the data from a top view. The next set of ideas were on the parameters considered by other researches that were also observed in the study which are the time to finish a lane changing incident, average speed, volume, number and type of lane changing incidents, and type of lane changing vehicle. Lv, W. *et al.* (2013) stated that lane changing can even help improve the traffic conditions when controlled and implemented correctly but in the current situation vehicles abruptly changes lanes or swerves causing delay to the succeeding vehicles. It was even said by Oh, S. *et al.* (2013) that typically only 34% of the vehicles that lane changes cause congestion this value was also taken to compare the situation in the study area to the conditions from the other areas. These are the reasons why a research was done to help provide a better traffic scheme. It was also said by Buisson, C. *et al.* (2013) that congestion is evident on merging locations which helps substantiate that bottlenecking does occur in the area. It was also said by Cua (2015) that drivers in the Philippines were observed to finish a lane changing incident slower than the average range thus further increasing the congestion in the area. When it comes to determining the effect of lane changing, the 95th percentile, buffer index and total delay have been used by Transport Research Board of the National Academes (2008) and the Transportation Research Board (1997). The 95th percentile was used to identify the travel time of 95% of the vehicles in the area. The buffer index on the other hand, uses the 95th percentile and average travel time to determine the additional travel time needed by the vehicles. Lastly, total delay is the values used to measure how much time was lost from all the vehicle in the segment for that instance. To categorize these values according to vehicular flow conditions, the use of flow rate or volume can be considered to find patterns within the data. (Gurupackiam and Jones, 2011). Possible solutions for these delay were identified by Guler and Cassidy's (2012) paper that stated that using barriers and allotting a specific lane for certain type of types of vehicles.

3. CONCEPTUAL AND THEORETICAL FRAMEWORK

In this study, lane changing behavior was considered to be affected by the following factors: volume of vehicles, speed of vehicles and the behavior of other vehicles. These factors would affect The decision making of the driver towards lane changing that then altered the traffic flow resulting to either congested or free flowing traffic.

The relationship between the different cases that were observed in the study and the total delay of queuing vehicles were determined. The cases were dependent on the gathered data: number and type of swerving vehicles, length of queue, average speed of the vehicles and the time of queuing of vehicles. The data were then classified depending on the affected swerving time of the vehicles, beginning of queuing, and traffic condition (light, moderate, or heavy).

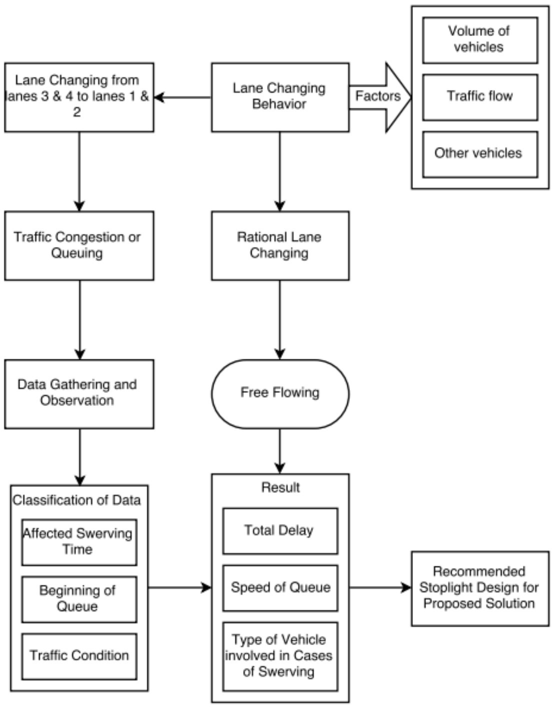


Figure 2. Conceptual Framework

4. METHODOLOGY

The Buendia flyover along Roxas Boulevard is the study area of this research, specifically from the entrance of the ramp of the flyover until the “no swerving” sign located approximately 150 meters from the ramp entrance. Observing the flow of traffic allowed the researchers to study and analyze the data to discern the effects of swerving into the flyover entrance and whether it causes local queuing to occur.

The researchers utilized graphical analysis to process the data obtained such as the number of swerving vehicles, type of swerving vehicle, time it takes for a vehicle to change lanes, time it takes to traverse fixed points of the road for both swerving and affected vehicles, etc., as well as use various transportation analysis approaches such as analyzing the distance, time, speed, and queuing for the affected vehicles, as well as the overall delay caused by swerving vehicles.

Observing and recording the vehicular traffic along the flyover was done on the rooftop of a condominium along Roxas Boulevard which is located approximately 160 meters from the entrance of the flyover (Figure 3). The rooftop provided the researchers an adequate view of the traffic below, as well as a view of the entrance to the flyover. The researchers observed the traffic on Fridays of January 8, 22, and 29 from 6:15 am until 1 pm; it is worth noting that the study recorded the traffic during the morning rush hours (7 am – 9 am). Figure 4 shows the traffic viewed from the rooftop with the primary camera whereas Figure 5 shows the view of the secondary camera which documents the queue if it exceeds the view of the primary camera, the major hindrance to the researchers would be the trees which mar the complete view of the road. A brief overview of how the researchers set their equipment up can be seen in Figure 6.

Figure 3. Location of Observational Rooftop from Entrance of Flyover

Figure 4. View of the Primary Camera

Figure 5. View of the Secondary Camera

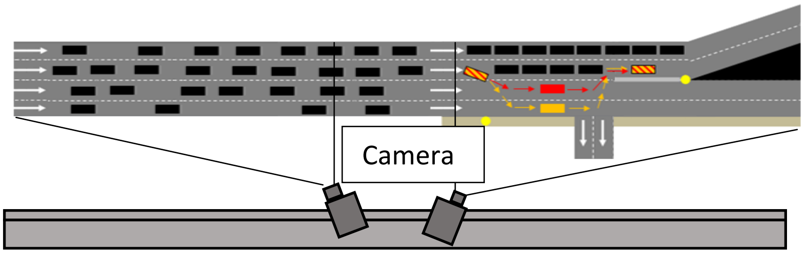


Figure 6. Equipment Setup

Using a steel measuring tape, the researchers measured and marked, starting from the 'no swerving' sign up to the entrance of the flyover, 10 meter intervals while the primary camera was recording in order to set fixed distances for future data processing. The acquired video footage was used to determine traffic characteristics such as volume, speed, and queuing of the arriving affected vehicles, as well as the number and type of swerving vehicles.

Data interpretation was done in which the researchers' hypothesis was tested by compiling and comparing the processed data and computing for the hourly/overall volume, swerving time, and overall delay caused by the different vehicle types. With the analyzed data, the researchers proposed a new stoplight design for the intersection located under the flyover in order to alleviate and better control the flow of traffic along the said route. Figure 7 shows a brief overview of the process done by the researchers.

Queuing time is used to establish an appropriate delay diagram in order to portray the capacity and demand over time of the study area as well as provide a guide when computing for the various queuing parameters (average queue length, maximum queue length, and queuing duration). Through and right turning vehicular volumes, speed limits, as well as road and lane widths were established or measured in order to properly design the proposed stoplight located in the intersection beneath the flyover.

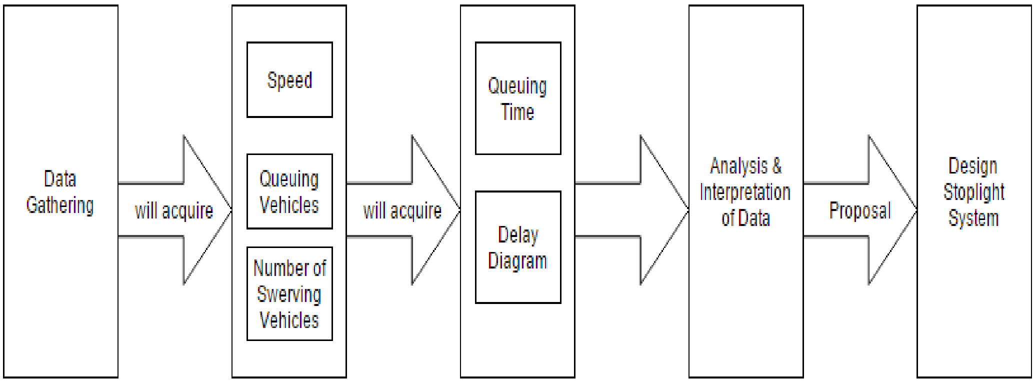


Figure 7. Methodology Schematic Map

5. DATA ANALYSIS AND PRESENTATION

5.1 Volume Count and Distribution

In the data observed, the peak hour volume occurs at 6:00am – 7:00am, and the graph referring to all the volume counts is presented below. The computed peak hour factor ranged from 0.96 – 0.98 which is the typical peak hour factor for the arterial roads.

The least present vehicle type in the study area are jeeps while the most is SUV. It was also observed that there was an approximately equal distribution between private and public vehicles, and that the distribution of vehicle types does not drastically change along the time and dates observed. From table 1, jeeps were observed to have drastically increased in volume while trucks experience a decrease from off peak to peak hour. The distribution of vehicles is not the same for all dates where a vehicle type can decrease from peak hour to off peak in one day but increase in another, but as a whole the increase in volume is almost the same with values ranging from 22% to 29%.

The hourly factor computed volume was initially used as the basis for categorizing the data. The ranges for the categorization shown in table 2 were based on various researches but due to the lack of pattern for the values, it led to discarding of the previous categorization. The direct use of the volume count was used instead. The ranges for the different vehicular flow conditions are shown at table 3.

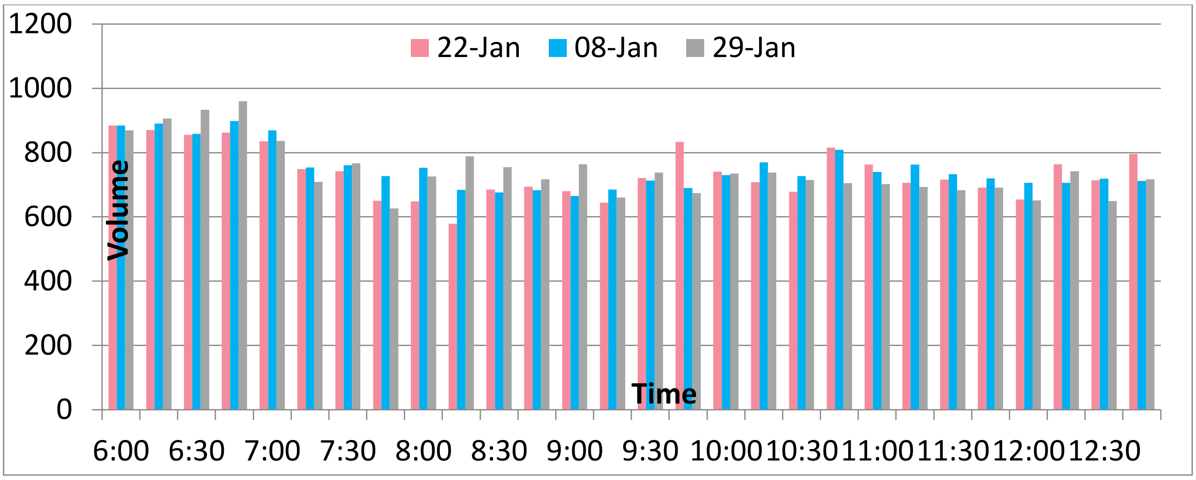


Figure 8. January Volume Count

Table 1. Volume Count for Peak and Off Peak Volumes

	Jan. 8					Jan. 22					Jan. 29				
Time	6:30 - 7:30 Peak		8:15 - 9:15 Off-peak		Percent Diff.	6:30 - 7:30 Peak		7:45 - 8:45 Off-peak		Percent Diff.	6:15 - 7:15 Peak		11:15 - 12:15 Off-peak		Percent Diff.
	Volume	Percent	Volume	Percent		Volume	Percent	Volume	Percent		Volume	Percent	Volume	Percent	
Bus	190	6	205	8	-8	148	4	121	5	20	143	4	158	6	-10
Car	787	23	543	20	37	824	25	495	19	50	822	23	467	17	55
SUV	1232	36	887	33	33	1236	37	935	36	28	1325	36	953	35	33
Fx	206	6	196	7	5	157	5	166	6	-6	280	8	161	6	54
Taxi	377	11	353	13	7	406	12	414	16	-2	472	13	353	13	29
Van	430	13	390	14	10	417	13	337	13	21	442	12	427	16	3
Jeep	53	2	28	1	62	48	1	22	1	74	79	2	21	1	116
Truck	104	3	106	4	-2	66	2	72	3	-9	73	2	178	7	-84
Total	3379		2708		22.047	3302		2562		25.239	3636		2718		28.895184

Table 2. Hourly factor ranges

Volume Consistency	
Condition	Range
Poor	0.25 - 0.69
Below Average	0.7 - 0.9
Average	0.91 - 0.94
Above Average	0.95~

Table 3. Vehicular flow ranges

Vehicular Flow	
Condition	Range (veh / 15 min)
Low	550 - 699
Medium	700 - 849
High	850 - 99

5.2 Swerving Vehicle Classifications

Based on figure 9, 50% of the vehicles that swerve and private and the other 50% are public vehicles. It also shows that majority of the vehicles that swerved are medium sized vehicles. These observations were used in the formulation of traffic management schemes.

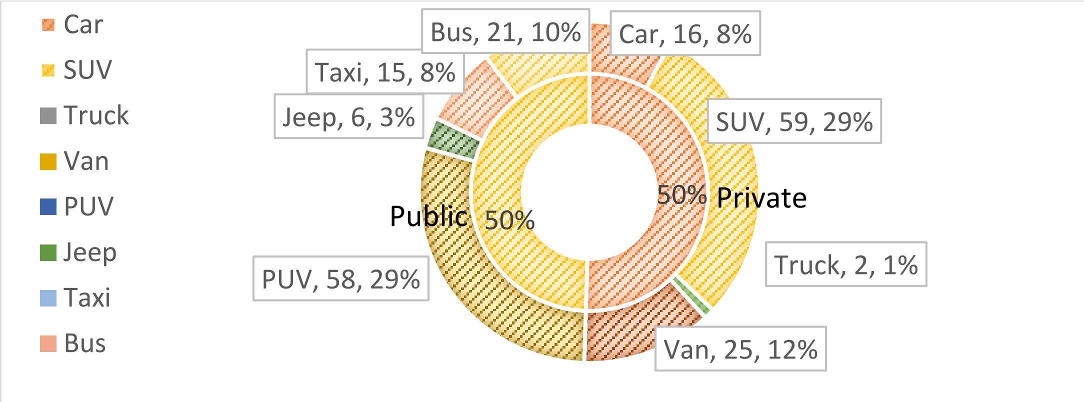


Figure 9. Swerving vehicles according to type

5.3 Lane Changing Incidents based on number of Lanes Swerved

The number of lanes changed of the shifting vehicle was initially believed to determine whether the lane changing incident will occur. Direct lane changing is where the destination lane is adjacent to the current one and staggered lane changing is where the destination is 2 or more lanes away. Observations have shown that the number of lanes changed does not determine whether the lane changing caused delay (Figure 10 & 11).

At worst, the number of lane changing incidents can reach 102 incidents where 76.5% of which caused delay. The values for lane changing from 10:00 – 10:30 am and 12:30 – 1:00 pm were skipped due to the presence of a vehicle breakdown and car accident. The correct lane changing length is dependent on the shifting vehicle's size where small vehicles need to change lane for a minimum length of 9m and trucks need 27m to be considered as proper lane changing (Hohm & Winner, 2010). Majority of the delay causing swerving incidents were lane changing of vehicles towards the 2nd lane. Where vehicles that lane change towards the 1st lane does not always cause delay, but when delay does occur the value is small enough to be considered insignificant.

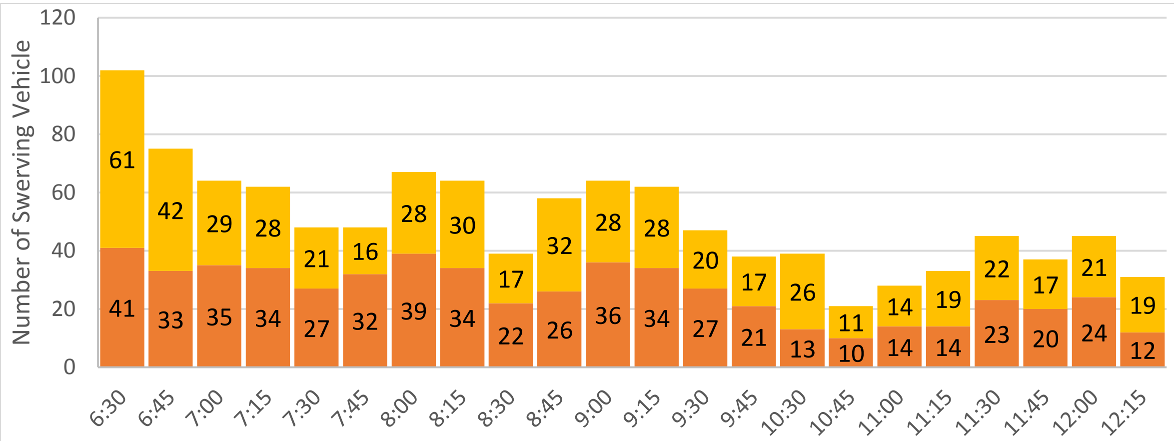


Figure 10. Distribution of lane changing Vehicles according to the number of lane/s swerved by the vehicle

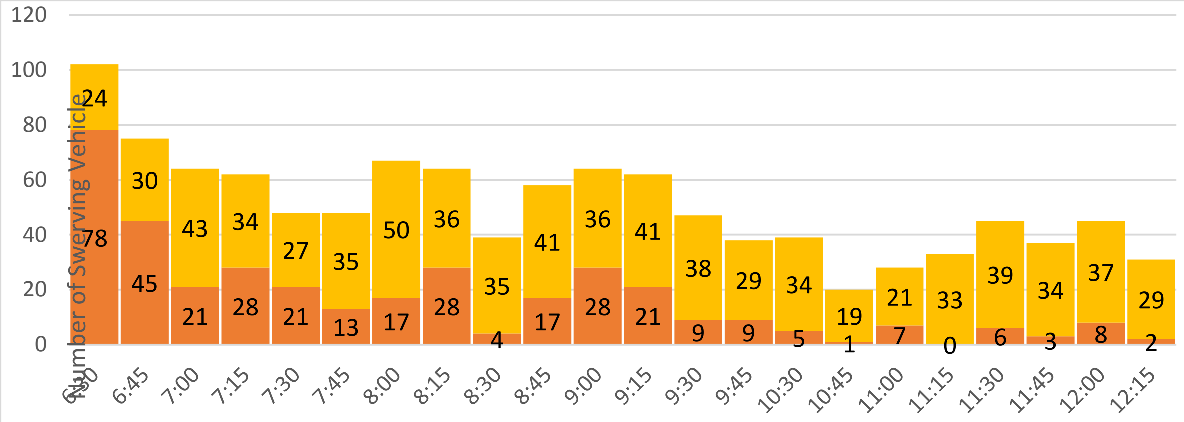


Figure 11. Distribution of Lane changing vehicles according to whether the vehicle caused a delay or not to other vehicles

5.4 Lane Changing Incidents based on Type of Swerving Executed

The observed swerving incidents were categorized into two types according to the driver's purpose for changing lanes. The first category is discretionary lane changing wherein the vehicle changes lanes to avoid congestion. The second one is mandatory lane changing in which it is necessary for the vehicle to change lanes to reach its destination. In the study area, the unloading of passengers is not prohibited and vehicles can freely use the service lane to bypass the traffic before the flyover. In figure 12, vehicles that came from the service lane and unloaded passengers are considered as mandatory lane changing. The graph signifies that majority of the vehicles perform discretionary lane changing except for jeeps where a large percentage of which swerved to the 2nd lane after unloading passengers on the 4th lane. This information can help in formulating an efficient management scheme.

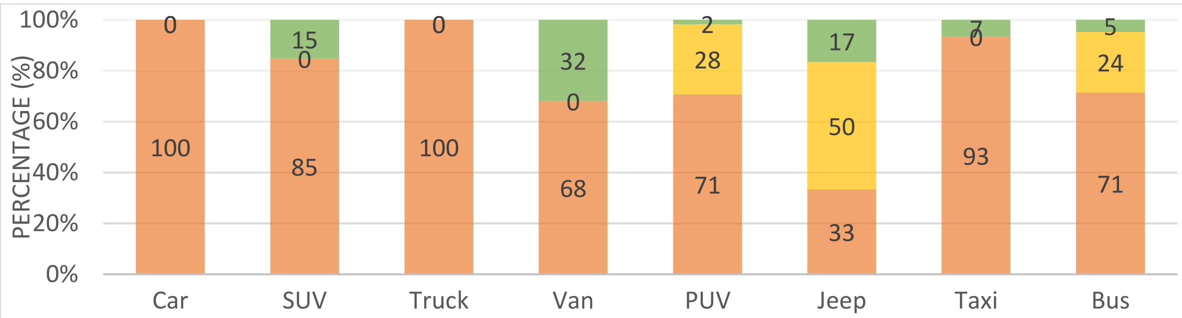


Figure 12. Swerving vehicle cases according to vehicle type

5.5 Different Aspects of Lane Changing Behavior of Vehicle and its Effect on Succeeding Vehicles

There were various aspects of the lane changing behavior of the vehicle that affected the succeeding vehicles. Among these observed aspects were the location of affected vehicle during swerving incident and the sum of swerving time of the vehicle experienced by the affected vehicle. Its effect on the vehicles was measured through the amount of delay experienced by the vehicles in vehicle-minutes, the difference between the vehicle's initial and final speed, and finally with the travel time of the vehicle. The delayed incidents were also categorized according to its vehicular flow conditions to determine how they differ under various flow conditions.

5.5.1. Effect of Location of Affected Vehicle During Swerving Incident Occurrence

Based from the calculation of total delay, the further the vehicle is to the flyover the larger the area between the accepted time and the actual time therefore resulting to a large delay. In the study, 10 meter intervals were numbered with the starting point being the "No Swerving" sign and ending at the concrete barrier at the entrance of the flyover, ergo the nearer the vehicle is to the "No Swerving" sign, the further it is from the flyover. In theory, the nearer the vehicle is to the "No Swerving" sign when the swerving incident occurred the larger the experienced delay is as drivers have less time to adjust to the abrupt lane changing and will have to slow down or even stop their vehicles. This can be better illustrated through figure 13 where the shaded area is the total delay experienced by the vehicle. Other than the distance, the vehicular flow under which the incident occurred also affects the amount of experienced delay.

Figure 14 shows that majority of the data follows this trend. The exceptions are due to the other factors being more dominant for these incidents. It also shows that the affected vehicles under medium vehicular flow will experience greater delay when nearer to the signage compared to the rest of the vehicular flow. It signifies that the vehicles are more sensitive under medium vehicular flow due to the combination of conditions under this vehicular flow like the distances between the vehicles, and average speed of vehicles in the area. Also, that the location of the affected vehicle when the swerving incident occurred roughly determined the magnitude of delay experienced by the vehicle.

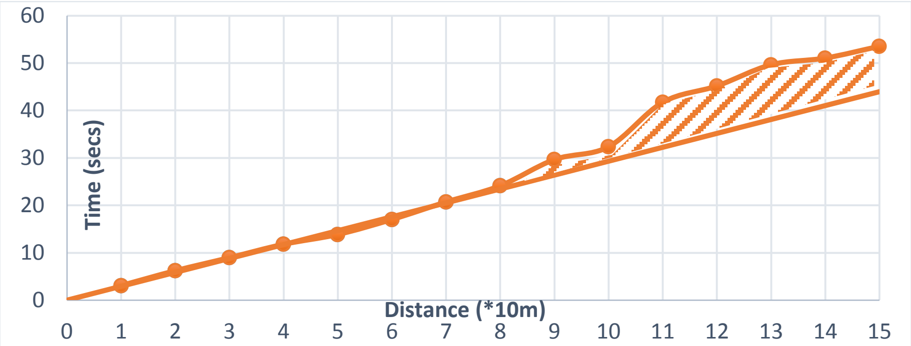


Figure 13. Sample Delay of Vehicle

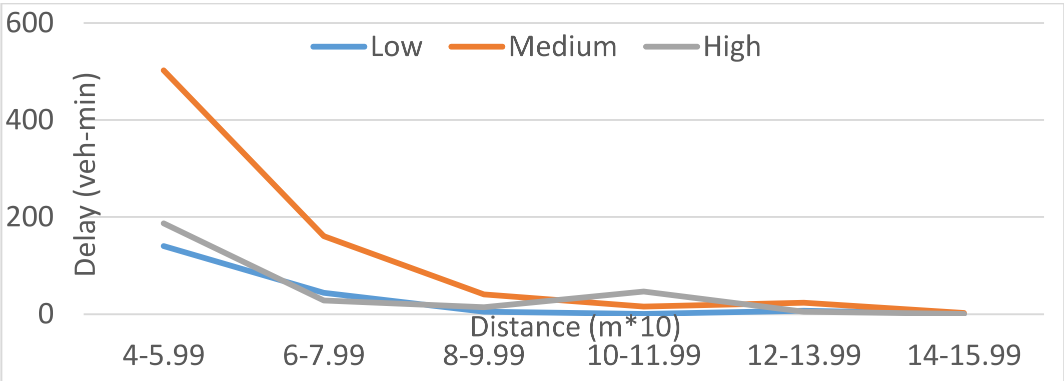


Figure 14. Delay of vehicle vs its distance from the "No Swerving" sign

5.4.2. Effect of the Sum of Swerving Time Experienced by the vehicle

Initially, the type of swerving vehicle was associated with the delay it will cause due to its correlation with the vehicle's swerving time. Taking the swerving time of each observed vehicle and categorizing it according to the type of vehicle resulted to figure 15. This graph shows that the distribution of swerving time of per vehicle type is scattered. This signifies that there is no one set swerving time for specific vehicle types.

In figure 16 the swerving time and delay experienced by the affected vehicle were graphed. It shows that for smaller values of delay, the increase in sum of swerving time will result to an increase in the delay experience by the vehicle. The larger delays are more dominantly affected by other factors like the distance as to where the vehicle was affected. In the next figure, the effect of the sum of swerving time is further analyzed by taking into account the vehicular flow condition as to when the incident occurred. The delay of the vehicles was categorized under the same range for sum of swerving time to easily compare the change in delay. It shows that under medium vehicular flow conditions the increase in delay is more drastic under the same range with the other vehicular flow conditions. This proves that vehicles under medium vehicular flow conditions are more sensitive to the swerving time of the shifting vehicle in front, that vehicular flow conditions influence the maximum swerving time of the vehicles, and that under high vehicular flow a large increase in the sum of swerving does not signify a large increase in the delay that it will cause. All these observations result to the idea that an increase in sum of swerving time will also increase the delay of the vehicle only up to a certain extent. Also, that the degree of the increase is influenced by the vehicular flow condition.

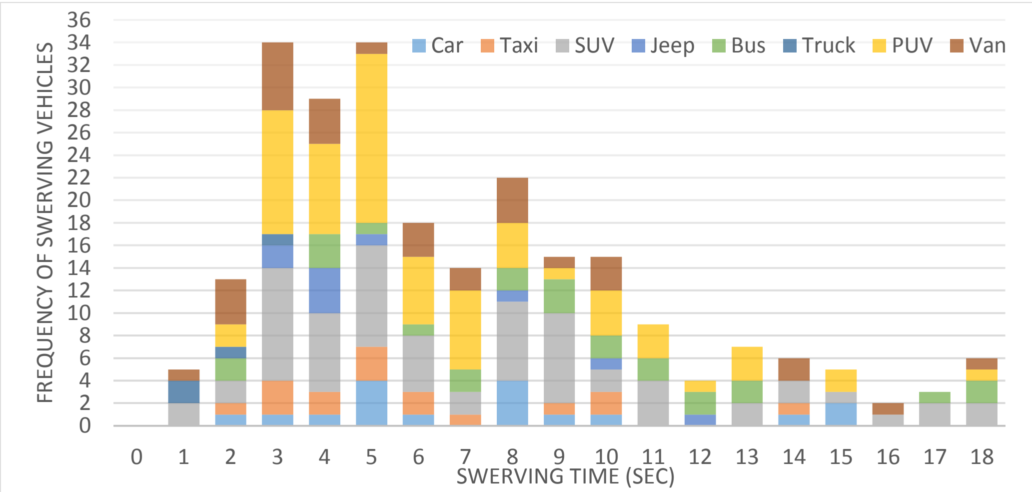


Figure 15. Swerving time of vehicle arranged according to the type of vehicle

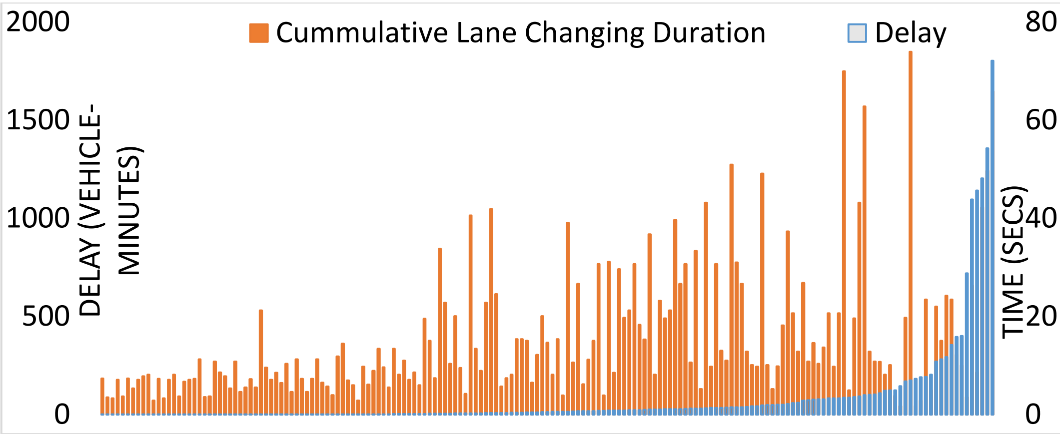


Figure 16. Delay and Sum of affected Swerving time vs Vehicular flow

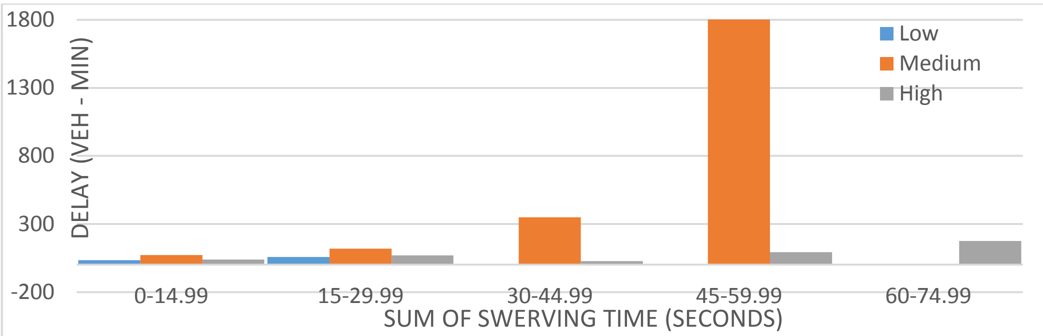


Figure 17. Delay of vehicle according to sum of swerving time and vehicular flow

5.4.3. Correlation of the vehicle's speed and experienced delay

The figure below was used to identify the correlation between the speed and delay of the affected vehicles. It was observed that there was no distinct correlation between the difference in speed of the vehicle, but the vehicle is slower with higher incurred delay. Based from observations on site that is also reflected in the graph is that fast vehicles need to slowdown to react to the swerving vehicle while slow vehicle needs not to slowdown any further. On the graph below the difference start to drastically change at values of speed greater than 19 kph. In figure 19, these values were categorized according to vehicular flow conditions. It shows that initial and difference in speed increases as vehicular flow increases. And the previous observations are magnified by the next figure.

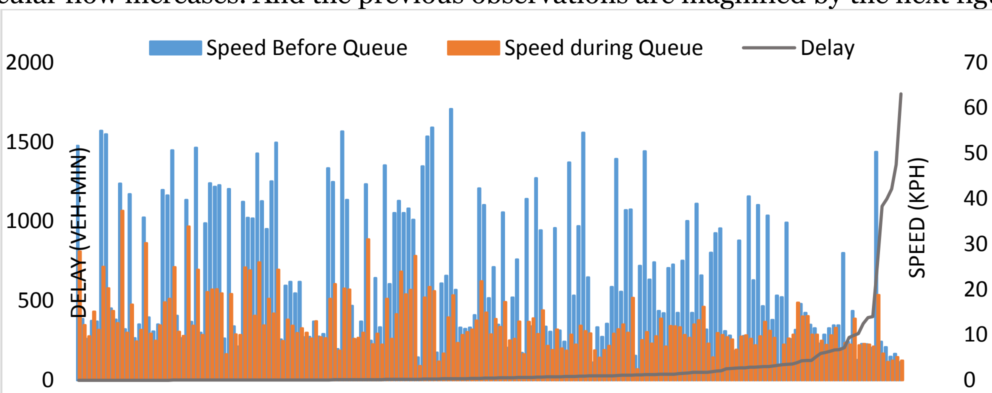


Figure 18. Speed and delay of affected vehicle

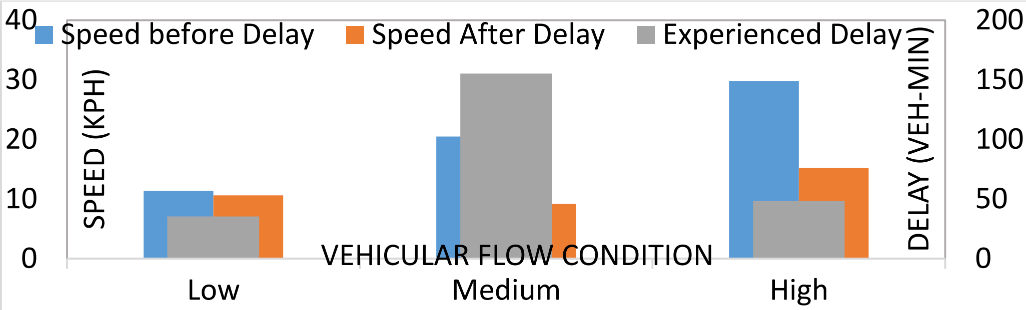


Figure 19. Speed and delay of affected vehicle according to vehicular flow

5.5. Effect of lane changing behavior on vehicles for the entire day

5.5.1. Sum of total delay for each considered hour

It was stated that only congestion mainly caused by swerving vehicles are those observed in the area. Out of the 6.5 hours observed not all of these were considered due to the presence of accidents and stoplight congestion. The percentage is seen through figure 20. Jan 8 observes a different case compared to the other two days of observation because this was a time when majority has not yet gone back to work or school due the previous holidays.

The total delay of the vehicles was then summated per 15 minutes to determine the most delayed time of the day. 10:15 – 10:30am has the most delay incurred for at this time the greatest sum of swerving was observed and that the vehicles were under medium vehicular flow. It was discussed that vehicles under medium vehicular flow are more sensitive to the increase in swerving time. The low values were caused by the combinations of the factors and the vehicular flow condition of the vehicles when the incident occurred. Vehicles tend to swerve less when conditions are good and when swerving does occur the delay it produces is minimal.

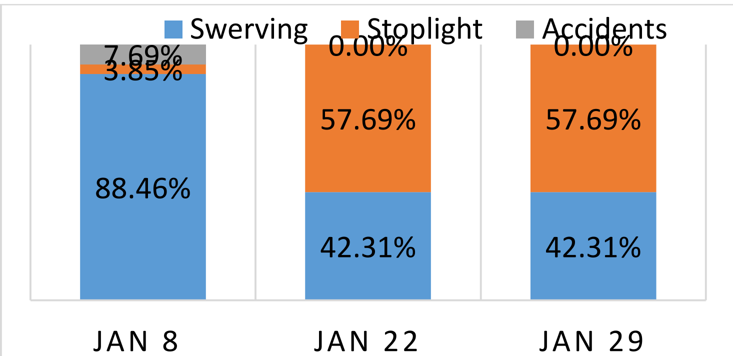


Figure 20. Time period

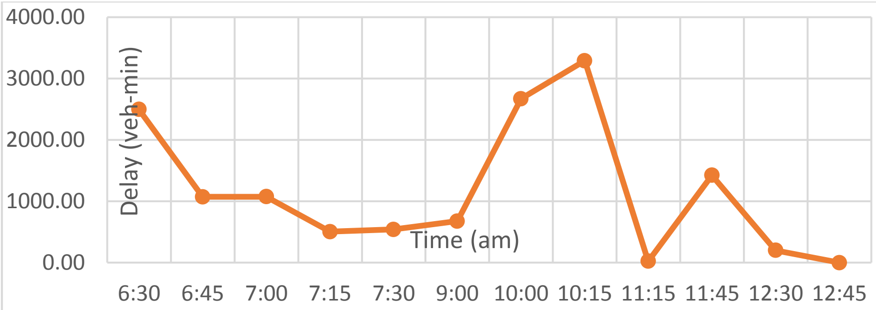


Figure 21. Total Delay

5.5.2. Effect of swerving on the vehicle's travel time

The travel time of 95% of the vehicles traversing the area was compared to the average travel time resulting to the various buffer index presented below. The travel time under free flow conditions were also considered to help illustrate the delay experienced by the vehicles. It shows that the shortest time is 16.95 secs and the longest is 169.7 secs when the delay due to swerving was considered. The highest buffer index computed was 0.393 which is the value multiplied to the average travel time to identify the additional time needed by the individuals to arrive in their destination. These values signify a large loss in the community due to the additional time spent on the road due to swerving.

Table 4. Travel Time Reliability

Start Time	6:30	6:45	7:00	7:15	7:30	9:00	10:00	10:15	11:15	11:45	12:30	12:45
End Time	6:45	7:00	7:15	7:30	7:45	9:15	10:15	10:30	11:30	12:00	12:45	1:00
95th	86.24	84.58	79.65	61.45	66.52	90.35	169.70	166.93	73.31	66.34	59.88	53.97
Delay	2497.36	1073.49	1076.19	505.54	541.19	675.77	2672.70	3292.21	21.82	1425.10	201.06	0.46
Ave	61.93	62.13	58.56	58.26	51.12	69.12	131.52	139.93	73.31	58.79	49.93	52.64
Free Flow	44.20	42.60	42.64	16.95	20.79	42.14	111.32	115.78	3.29	54.77	48.38	51.65
Buffer	0.393	0.361	0.360	0.055	0.301	0.307	0.290	0.193	0.000	0.128	0.199	0.025

5.6. Trend of delay of affected vehicles

The delayed was initially identified to increase exponentially. The value of r-squared computed ranged was a consistent 0.92. Though it was quite high the value can still potentially increase. Therefore, a better fitting line was identified. It was realized that a polynomial line under the 2nd degree is better fitted to the trend of delay. A greater degree increases the value of r-squared insignificantly therefore the 2nd degree was enough. Signifying that the increase in delay is not as drastic as an exponential line, and fluctuates with one hill or valley. The arrangement of the vehicular flow's average delay is due to the combination of the various factors and their effects on the vehicles under the different vehicular flows.

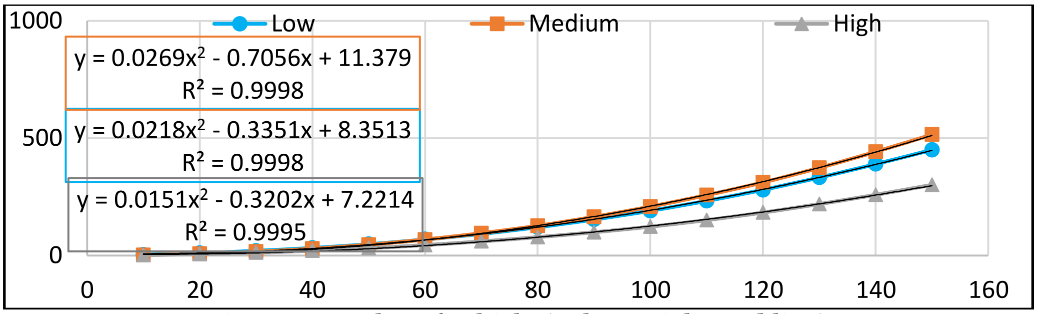


Figure 22. Delay of vehicle (polynomial trend line)

5.7. Stoplight Design

It was observed that the road adjacent to the flyover is barricaded. It is because of this that there are numerous vehicles that swerve after unloading and coming from the service lane for there is no other way for these vehicles to reach their destination. Along with that is that there is a large percentage of public vehicles swerving in the area. All these combined led to the proposal of opening the adjacent road. When the road is opened, public vehicles and vehicles from the service lane will be prohibited from using the overpass. This is based on the idea that it will lessen the delay by preventing mandatory lane changing. Also this will reduce the amount of swerving vehicles by 50% at the least.

The signal timing diagram is shown below where the public vehicles from the study area are the ones considered as through for east bound. The desirable stoplight cycle for peak and off peak volume were calculated having values of 234.67 and 320.9 seconds respectively. The stoplight designed will result to a delay of 7532.31 and 5579.64 veh-min for peak and off peak volumes respectively while the amount of delay caused by swerving for 1 hour reaches a value of 5238.9 veh-min. The amount of delay for stoplight is greater therefore based on the initial analysis, the stoplight will only increase the delay experienced by the vehicles.

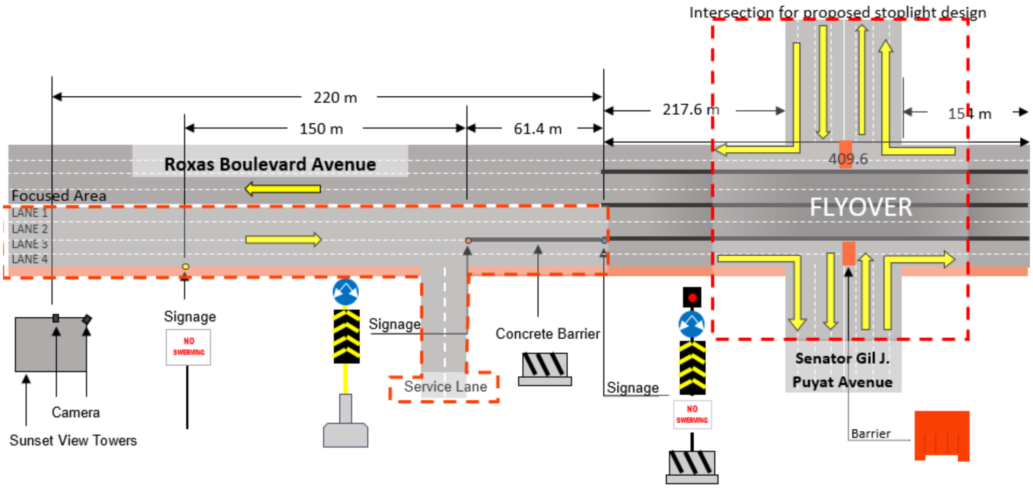
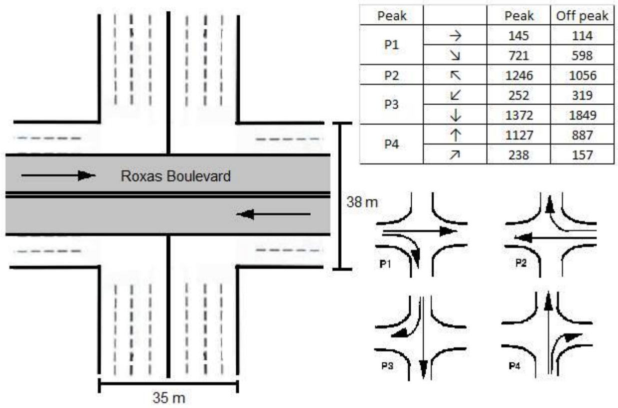


Figure 24. Study area including the intersection for the proposed stoplight design



Peak		Peak	Off peak
P1	→	145	114
	↘	721	598
P2	↖	1246	1056
P3	↙	252	319
	↓	1372	1849
P4	↑	1127	887
	↗	238	157

Figure 25. Signal Timing Diagram

6. CONCLUSION

The result of all the observations shows that lane changing behavior does have an effect on the traffic flow, and that all vehicular flow conditions identified can be considered as critical flow for delay due to swerving can occur at any of the three vehicular flow conditions. Majority of the delay observed causing lane changing were found to be abrupt lane changing or swerving. The swerving time of the vehicle and the location where it swerved caused various degrees of delay for the succeeding vehicles depending on the vehicular flow condition when the incident occurred. It was also found that vehicles are slower under high delay and tends to slow down only when the initial speed of the affected vehicle is not enough for them to react to the swerving incident. It was also seen that swerving causes the vehicles to exponentially increase the delay of the vehicle but better fits a polynomial curve in the 2nd degree due to the fluctuations of the values. Finally, it was realized that the opening of the adjacent road will not help alleviate the conditions in the area when based from the study's initial analysis. Other traffic management scheme, can be recommended to help improve the situation in the area and possibly other areas which are also affected by the congestion caused by swerving vehicles.

7. RECOMMENDATION

There are numerous possible traffic management schemes that can be implemented to help reduce the effect of lane changing behavior to other vehicles. Concrete barriers were suggested by studies that can reduce the effect of lane changing behavior; however, these were already present in the area and did nothing to alleviate traffic. The concrete barrier is adjacent to the service lane and the area where public vehicles unload passengers. One plausible solution is to reduce the concrete barriers to allot enough space for the vehicles to maneuver into the overpass. Another is to provide an unloading zone for public vehicles far from the flyover to allow them to be in the proper lanes once necessary. Turning the service lane into a one-way entrance in order to prevent vehicles bypassing the traffic is also possible. Properly educating drivers is paramount to reducing traffic problems everywhere. Proper implementation and supervision is necessary to guarantee success in alleviating traffic within the vicinity.

In terms of data gathering, a vantage point is practical as it provides a bird's eye view of the traffic, preferably, the vantage point should be clear of obstructions. A camera with clear video recording capabilities is also convenient.

For data processing, increasing the days of observation will also provide better results as some trends may only be perceived through more days of observing traffic. The possibility of using a program for the processing and simulation of the data to determine the delay of the vehicles must also be considered to reduce the chance of human error as well as the data processing period.

For future studies, it is recommended to observe the conditions in the area when the vehicles are affected by the delay caused by the stoplight at the end of the flyover. It is under these conditions that the swerving incidents are more drastic and the delay experienced by the vehicles are greater. Also, a more in depth analysis and simulation of the possibility of reducing delay in the area by opening the adjacent road is suggested because only a preliminary analysis was done to determine the possible effect of opening the adjacent road. Finally, a study can be done on observing on what distance between lane changing vehicle and succeeding vehicle does the delay start to occur.

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