Evaluation of Reopening of Signalized Intersections at Katipunan Avenue

MARYAM JAZZMINE D. AZUCENA
Undergraduate Student, B.S. Civil Engineering Program
Institute of Civil Engineering, University of the Philippines Diliman
E-mail: mj.azucena@ymail.com

Adviser:
Dr. Hilario Sean O. Palmiano
Assistant Professor, Institute of Civil Engineering, University of the Philippines Diliman

Abstract: Katipunan Avenue is an arterial road that is surrounded by commercial establishments and three universities. Because of this, large volume of vehicles has led to heavy traffic congestion especially during peak hours. The traffic scheme has shifted from signalized intersection to U-turn scheme in 2003 and then from U-turn scheme to signalized intersection this 2014. There has been a debate of whether the recent change of traffic scheme has improved or worsened the traffic flow along Katipunan Avenue. Therefore this study aimed to compare the traffic conditions before and after the implementation of signalized intersections. The parameters that will be considered will be the travel time along the study area, the level of service, the degree of congestion at an intersection and the number of accidents. An actual field measurement was conducted to obtain the travel time. The average travel speed was used to get the level of service. The number of accidents were obtained from the MMDA Road Safety Unit and were summarized in order to determine the rate of accidents. The type and location of accidents were also observed. The results showed that for 2015, there is no significant change in the travel time and level of service during the morning peak hour. However, the level of service for the afternoon peak hour reached LOS F. The current degrees of congestion at the intersection are both greater than 1. However, there is a relative decrease in the rate of accidents at the road section and a significant decrease at the intersection. Based on the results, the change in traffic scheme may have worsened the traffic condition but improved the road safety.

1. INTRODUCTION

Katipunan Avenue is an arterial road that is part of Circumferential Road 5 (C-5). It starts from the end of Tandang Sora Avenue at the north and ends at the intersection of White Plains Avenue at the south. It is a busy thoroughfare that caters to three universities namely the University of the Philippines Diliman, Ateneo de Manila and Miriam College as well as to various residential and commercial establishments. Because of this, large volume of vehicle has lead to heavy traffic congestion especially during peak hours. In 2003, the intersections along the road were closed and were replaced by U-turn slots in an attempt to ease the traffic. A decade later, the U-turn slots were closed and signalized intersection scheme was again implemented last September 13, 2014. According to Noemie Recio, Metro Manila Development Authority (MMDA) Traffic Engineering Center Head, that the reopening of signalized intersections along other parts of Quezon City such as at Banawe Street, Roosevelt and Timog-West Avenue has eased the traffic flow along Quezon Avenue. However, the implementation on Katipunan resulted in heavier traffic especially during rush hours that led the MMDA to turn off traffic lights and manually direct vehicular flow during those periods (Brizuela, 2014).

A U-turn scheme is said to ease traffic conditions on the premise of providing a continuous flow of traffic along the major road by eliminating intersection stop delays. This has been shown from previous studies such as by Madrigal (2004) wherein there has been improvement in terms of travel time after switching to U-turns from signalized intersections. However, statistical measurement and anecdotal evidence do not always coincide in Metro Manila due to varying traffic conditions and driving behavior. According to Combinido and Lim (2010), the effectiveness of U-turns is only present for roads with low car flow and minimal lane changing maneuvers. Once the traffic changes to congested flow, the U-turns worsen traffic conditions. As the volume of vehicles increased at Katipunan Avenue, the U-turn slots became sources of congestion as they created bottlenecks and increased conflicts caused by turning and weaving vehicles. This prompted the MMDA to change the traffic scheme back to signalized intersections.

In determining the effectivity of a traffic scheme, road safety is also an important factor that must be included. In 2005, 76% of the total number of U-turn slots in Metro Manila had accidents, and one of the critical sections is located at Katipunan Avenue (Dela Vega and Magno, 2006). This may be due to the fact that when signalized control are converted to U-turn slots, the number of vehicle conflict points increases.

To identify the real effect of changing the traffic scheme along Katipunan Avenue, this study aims to compare the traffic conditions before and after the reimplementation of the signalized intersection.

In order to fulfill the comparison, the following will be the objectives of the study:

1.) Determine the travel time and level of service (LOS) of Katipunan Avenue before and after the traffic signalization
2.) Determine the degree of congestion at one of the intersections along Katipunan Avenue
3.) Determine the number of accidents that happened within the study area before and after the traffic signalization
4.) Compare if there were any significant difference between the said parameters

The data obtained can be used to determine the effectiveness of changing the traffic scheme of different intersections in Metro Manila. From the data, additional traffic solutions may be suggested to further improve the road section. This will also be valuable to aid further study and model the effectiveness of U-turns versus signal lights in the Philippine setting.

The area of the study will be the section of Katipunan Avenue starting from the intersection at Magsaysay Avenue at the north and the intersection at Aurora Boulevard at the south. The study will focus on the before and after changes in delay, level of service and number of accidents. Only the peak hour condition was observed and the off peak conditions was not included in the study.

Conceptual Framework

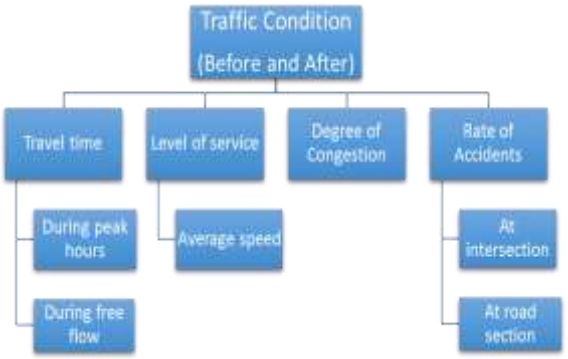

Figure 1. Conceptual Framework of the Research.

2. REVIEW OF RELATED LITERATURE

2.1 Previous Relates Studies

Madrigal (2004) investigated the effect of implementing the U-turn scheme last 2003 at Katipunan Ave. Travel time, accident frequency and pedestrian safety were the parameters determined for the analysis for the before and after effects of the implementation. A perception survey was done in order to determine the travel time. The results showed that travel time of vehicles has improved after the implementation of U-turns, however, frequency of road accidents had increased.

Luzano and Tolentino (2012) determined the delay in traffic flow by vehicles after the transition of signalized intersection to a U-turn scheme. The study was conducted at a U-turn facilitated intersection at Quezon Avenue. The delay for the U-turn is determined by the difference between the normal travel time and travel time for free flow condition. The delay for the signalized intersection was computed using the Webster's formula. The comparison of delay was only done on one intersection. The results showed that signalized intersection was a better traffic control than U-turns.

The U-turn slots have been a widely used traffic scheme in Metro Manila since it was said to have improved the traffic congestion at major thoroughfares. However, several issues with regards to road safety had risen since the implementation and brought to question the effectivity of the U-turn scheme. The study of Dela Vega and Magno (2011) aimed to determine the effectivity of the change from signalized intersections to U-turn slots through the analysis of accident records obtained from the MMDA for the year 2005. For the analysis, the study determined the distribution and frequency of accidents U-turn slots in Metro Manila. The rate of accidents occurring at the road sections were also calculated. The results showed that the U-turn slots at Katipunan Avenue was one of the critical sections based on the frequency of accidents that occurred in that location. It was also found out that out of all the U-turn slots in Metro Manila, 76% of them had accidents.

2.2 Level of Service for Urban Streets

Based on the Highway Capacity Manual (HCM) 2000, the level of service can be obtained using various methods depending on the type of roadway being evaluated. Katipunan Avenue is classified as an urban street such that it is relatively a high density street located in an urban area with traffic signals not more than 3.0 km apart. The methodology of obtaining the level of service for urban streets involves the measurement of the average through vehicle speed. The term through vehicles is defined as vehicles passing straight through the whole street segment and not turning. The factors that may influence the level of service in an urban street are number of signals per kilometer and intersection control delay. Inappropriate signal timing and increasing traffic flow contribute to the substantial degradation of LOS. The level of service criteria depending on the average travel speed and urban street class is shown in the table below.

3. METHODOLOGY

The current travel time along the study area was determined during peak hours using the test car method. Six trials per direction, northbound and southbound, were measured during the morning and afternoon peak hours. The morning peak travel time was measured from 06:00 AM to 07:00 AM while the afternoon peak travel time was measured from 14:00 PM to 15:00 PM. In order to compare with previous conditions, travel time data was obtained from a study of Macababbad (2011). Only the morning peak travel times for both northbound and southbound were available and were used to compare with the present conditions. It was made sure that the distance traveled are relatively the same since no other obstruction was observed that may cause a change in the travel course. The average travel speed for each direction and was obtained from the travel times and length of the course.

The average travel speeds computed from the travel times were used to determine the level of service of the road section. The level of service table used was from the Highway Capacity Manual 2000.

The current traffic volume was determined during a field survey when a one-hour traffic volume count was conducted for both the morning peak hour (06:00-07:00) and afternoon peak hour (14:00-15:00). This was done by taking a video footage during the said hours and counting each type of vehicles for different types of movement. The volume count was done at the Katipunan-Gonzales intersection which was located at the front of the gate of Miriam College. This intersection was chosen in order to compare it with the obtained 2012 volume count data from MMDA.

From the vehicle movement count, the degree of congestion at the intersection for each year was computed using the equation:

$$X = \frac{CY}{C - L} \qquad (1)$$

where: X = degree of congestion at the intersection
C = cycle time (s)
Y = y value
L = loss time (s)

The degree of congestion of each movement (x_i) was also computed using the following equation.

$$x_i = \frac{q_i}{s_i \times \frac{g_i}{C}} \qquad (2)$$

where: x_i = degree of congestion of a movement i
q_i = volume of the movement
s_i = saturation flow rate
g_i =green time (s)
C = cycle time (s)

The number of accidents that occurred along Katipunan Avenue was obtained from the Metro Manila Accident Reporting and Analysis System (MMRAS) data of Road Safety Unit of MMDA. The data obtained was from 2005 to the first quarter of 2015. From the data, only the accidents that have happened within the range of the study area were considered. The specific location and nature of accident were also taken into consideration. Since the implementation of the signalized intersection have just started last September and only seven months have passed since the implementation, only the accidents from September to March were used for comparison. One type of classification that was accounted was the fatal accidents that occurred within that time range. Also, the number of accidents that occurred at the Katipunan-Gonzales intersection for each year range was obtained.

The rate of accidents that occurred within the road segment of the study area for both 2012 and 2015 were computed using the following equation:

$$R_s = \frac{100{,}000{,}000 \times N}{365 \times T \times V \times L} \qquad (3)$$

where: R_s = rate of occurrence of accident (per 100 million vehicle-kilometers)
N = total number of accidents that occurred in time T
T = time frame of analysis (year)
V = volume of vehicles (vehicles/day)
L = length of section (km)

The rate of accidents that occurred within the Gonzales-Katipunan intersection for both 2012 and 2015 were computed using the following equation:

$$R_i = \frac{1{,}000{,}000 \times N}{365 \times T \times V} \qquad (4)$$

where: A_i = rate of occurrence of accident (per 1 million entering vehicles)
N = total number of accidents that occurred in time T
T = time frame of analysis (year)
V = volume of vehicles (vehicles/day)

The t-statistic (t-test) was used in order to determine the significance of the difference between the travel time, and rate of accidents to compare the before and after.

4. RESULTS AND DISCUSSION

4.1 Travel Time and Level of Service Analysis

The average travel times for the years 2011 and 2015 are shown in the figure below. For the northbound direction, there is a relative increase in the travel time from the year 2011 to 2015 during the morning peak hour. However, it is shown that there is a relative decrease during the morning peak hour in the

southbound direction. It is also observed that the travel time for the afternoon peak hour is relatively high for both northbound and southbound direction.

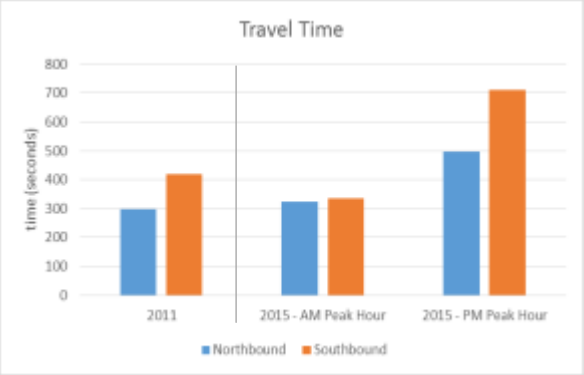

Figure 2. Travel time of 2011 and 2015 at peak hours.

The results were tested for significance using the t-test with a confidence interval of 95%. The mean values, t-values, and p-values are shown at the tables below.

Table 1. T-test for the comparison of delay at the morning peak hour.

2011 vs 2015 Morning		
	Northbound	**Southbound**
2011 Mean Travel Time (s)	296.7	420.0
2015 Mean Travel Time (s)	322.8	336.2
t-value	-0.78	1.88
p-value	0.490	0.205

Based on the obtained p-values, there is no significant difference between the morning travel time for both northbound and southbound direction. The change in the afternoon travel time cannot be compared since there was no available travel time data for 2011.

The relatively high travel time in the 2011 may be due to the congestion incurred by the combined weaving flows of vehicles and the conflict of incoming vehicles at the U-turn slots which limits the speed of the vehicles along the road. The relative increase in travel time during the morning and afternoon peak hour for the northbound direction as well as the afternoon peak hour for the southbound direction may be due to the stopping of vehicles at the signalized intersections. The factors that contribute to the delay on signalized intersections are the red or the stop time and the starting loss. The relatively high travel time in the afternoon for the southbound direction may be also due to the queuing at the subsequent signalized intersection in front of Ateneo gate which is approximately 230m away from the Miriam gate intersection.

During the field measurement, the stoplights were not operational and were set to flashing while the traffic was manually operated by traffic enforcers. This operation was done ever since the first month of the implementation of the signalized intersection in effort to ease the traffic congestion especially during peak hours. Even though this was the condition during the study period, it was assumed that the operational red and green time are relatively similar to the stop and go time enforced by the traffic enforcers.

The change in travel time may be attributed to the change in the traffic scheme. However, the effect of vehicle volume may also contribute to the increase or decrease of travel time. In this study, the effect of the delay caused by the signal lights to the travel time cannot be fully isolated from the effect of volume. The increase in travel time may be attributed to the increase in the vehicle volume. There is also a relative increase of heavy vehicles which may have added to the congestion and affected the travel time of the test car.

In addition to travel time, the level of service was also obtained for both northbound and southbound. This was done using the average travel speed (S_A) derived from the travel time data of 2011 and 2015. To get the LOS, the average speed was compared with the LOS table from the Highway Capacity Manual. The travel speed, LOS and AADT are tabulated below with travel speed in terms of kilometers per hour and AADT in terms of vehicles per day. It can be observed that the level of service of morning peak hour at the southbound direction changed from LOS E to LOS D, while the level of service for the northbound direction remained LOS D. This may be due to the decrease in congestion of vehicles since vehicle conflict due to the U-turn slots is eliminated. Even though, the level of service did not change during the morning peak hour in the northbound direction, it can be seen that the average speed has relatively decreased. For the afternoon peak hour of 2015, the levels of service for the northbound and southbound direction during are both LOS F. It can be observed from the AADT values that the vehicle volume from the year 2011 has increased in the year 2015. This may add as a factor to the decline in LOS aside from the congestion due to queuing at the signalized intersections.

Table 2. Level of service of Katipunan Avenue.

	2011		**2015**			
	AM		AM		PM	
	NB	SB	NB	SB	NB	SB
S_A (km/hr)	34.63	24.45	31.63	30.33	20.88	15.15
LOS	D	E	D	D	F	F
AADT	98937		126184		122862	

4.2 Degree of Congestion at the Katipunan-Gonzales Intersection

In 2012, when the U-turn scheme is still being implemented, the movements for the Katipunan-

Gonzales intersection are as shown at the figure below with each movement represented by a number. The intersection was closed and left turn movement was prohibited.

Figure 3. Movement distribution of U-turn scheme

From the field survey conducted, the current movements as well as the traffic signal timing and phasings along the Katipunan-Gonzales intersection was determined. The following figure shows the movements occurring at the intersection for the year 2015.

Figure 4. Movement distribution of signal lights scheme

In order to compare the degree of intersection of 2012 and 2015, the vehicle movement distribution of 2012 was converted into a signalized intersection. In order to do this, it was assumed that the upstream incoming vehicles from each direction of the original traffic scheme is equal to that of the converted traffic scheme. The number of U-turning vehicles from the north is same for both the original and converted. This is because there is no change in the traffic conditions of the upstream roadways that may significantly affect the volume of incoming vehicles. It is also assumed that the number of vehicles going to Miriam, and going to Gonzales St. are both the same for the original and converted traffic scheme. Each movement is then calculated by its percentage of distribution derived from the 2015 movement distribution.

The green time (g) and movement for each phase is shown in the table below. For the current signalized intersection at Katipun-Gonzales, there are four phases that are operational at the intersection as shown in the succeeding figure.

Table 3. Summary of phasings, movement and green time at the Katipunan-Gonzales intersection

Phase	Movement	g (s)
A	4	24
	5	24
	6	24
B	9	43
	10	43
C	1	15
	2	107
	3	107
	11	15
D	2	107
	3	107
	7	90
	8	90

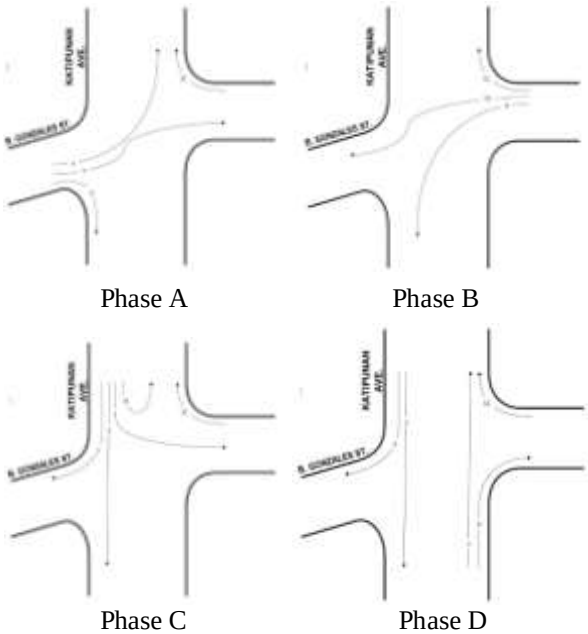

Figure 5. Phases at Katipunan-Gonzales Intersection

For the 2015 degree of congestion, the current vehicle volume data is used. Both degrees of congestion at the Gonzales – Katipunan intersection for 2012 and 2015 are computed using the current cycle time being used which is 170 seconds. The computed values for the degrees of congestion are shown at Figure 6.

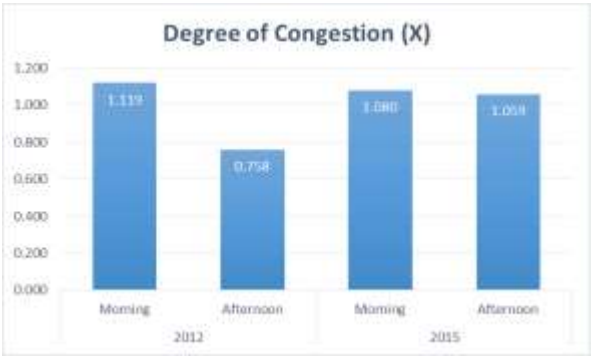

Figure 6. Degree of congestion at intersection.

The results showed that for the 2012, the morning peak hour degree of congestion is greater than one which shows that it is congested. However, the afternoon degree of congestion is relatively low. The 2015 degree of congestion is 1.08 for the morning peak hour and 1.06 for the afternoon peak hour. Both values are greater than one and show that the intersection is congested. It can be observed that the degree of congestion has improved in the morning however it has worsened in the afternoon. The relatively high degrees of congestion may be due to the relatively high upstream volume of vehicles.

For a closer observation, the degree of congestion for each movement for the intersection was obtained. The values for the morning and afternoon peak hour for the year 2012 and 2015 are shown at Figure 7 and 8. The degrees of congestion that have decreased in value are inferred to have improvement in their corresponding movement while those that increased are inferred to have worsened. In the morning, the through vehicle movement going to the southbound direction (Movement 2), and the U-turning vehicles (Movement 11) are congested as can be observed with their degrees of congestion greater than one. The relatively high values may be due to the short green time of a highly saturated traffic flow of that movement. It can be observed that the increase in congestion is common to the through movements along Katipunan Avenue (Movement 2 and 7) and the movements coming from B. Gonzales Street (Movement 4, 5, and 6). The decrease in congestion is common to the right-turning movements coming from Katipunan Avenue (Movement 3 and 8), and the movements coming from Thorton Drive (Movement 9 and 10).

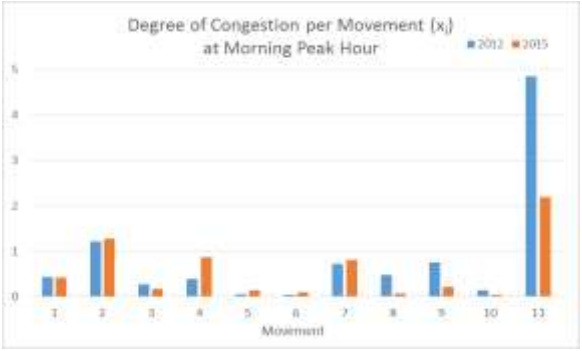

Figure 7. Degree of congestion per movement during the morning peak hour

The same observations are deducted for the afternoon peak hour, with the computed degrees of congestion are as shown below. The movements that have congestion greater than one for the year 2015 are the through U-turning vehicles coming from north, and left turning vehicles coming from Gonzales Street.

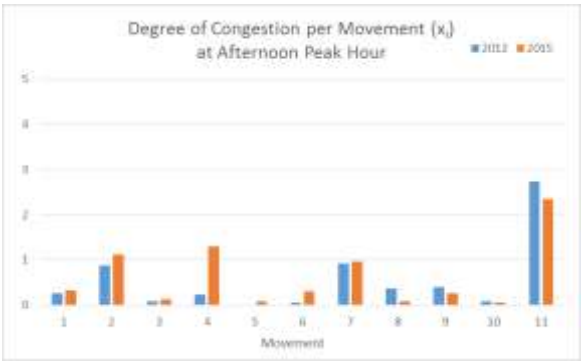

Figure 8. Degree of congestion per movement during the afternoon peak hour

4.3 Accident Frequency Analysis

The accidents from the MMARAS database are filtered such that only the accidents that happened within the study area are included. Only the accidents starting from September 13 to March 13 are included in order to compare it properly with the recent signalized intersection which started operation last September 13.

The rate of accidents is used to correlate the number of accidents that have occurred at the area to the corresponding vehicle volume. The rate of accidents at the road section (R_s) is computed to determine the number of occurring accidents per 100 million vehicle-kilometers (mvk) at the entire road section of the study area. The rate of accidents occurring at the intersection was also computed at the Katipunan-Gonzales intersection. It is expressed in accidents per one million entering vehicles

Table 4. Rate of Total Accidents for 2012 and 2015

Year	At road section, Rs (accidents per 100 mvk)	At intersection, Ri (accidents per 1 mev)
2012	432.6934	1.452925
2015	293.0754	0.526659

Both rates were computed for the year 2012 and 2015. There is a relative decrease in the rate of accidents for the entire Katipunan section from 2012 to 2015. This observation is similar with the rate of accidents occurring at the Katipunan-Gonzales intersection. The monthly rates of accidents are also computed. From the rates, the t-test was done order to determine if there is a significant difference at the 95% confidence interval. The t-value and p-value for R_s are 1.10 and 0.323 respectively. This shows that there is no significant difference between the rates of accidents at the road section. For the Katipunan-Gonzales intersection, the t-value and p-value of R_i are 2.39 and 0.041 respectively. This means that the

rate of accidents at 2015 for the intersection is significantly higher than that of 2012.

The rate of fatal accidents that occurred within the study area along Katipunan Avenue for the years, 2012 and 2015, are 0.00 and 1.59 respectively.

Table 5. Rate of Fatal Accidents for 2012 and 2015

Year	At road section, Rs (accidents per 100 mvk)	At intersection, Ri (accidents per 1 mev)
2012	0.00	0.00
2015	1.59	0.00

The zero value for the 2012 R_s is because there was no reported fatal accident within that time range. For 2015, one fatal accident was reported that occurred near the intersection of C.P. Garcia Ave. Both rates of accidents at the intersection are zero since there were no reported accidents that occurred within the Katipunan-Gonzales intersection.

The total number of fatal accidents that have happened from September to March for each year range is also taken into account and is tabulated as shown below. It is observed that there is a relatively low number of fatal accidents every year and none have occurred at U-turn slots. It is also observed that most of the accidents that happened at U-turn slots have caused damage to property.

Table 6. Number of fatal accidents per year range

Sept to March Year Range	Fatal Accidents	Rate of accidents, Rs
2005-2006	1	
2006-2007	0	
2007-2008	0	
2008-2009	2	
2009-2010	1	
2010-2011	3	
2011-2012	0	0.00
2012-2013	1	
2013-2014	1	
2014-2015	1	1.59

It is observed that the two most common collision type are rear end and side swipe. At the year range 2011-2012, about 32% of the total U-turn related accidents are classified as rear end collision and 47% as side swipe collision. For the year range 2014-2015, the only U-turn related accident is due to a rear end collision. It can be inferred that the decrease in these types of accidents may be due to the removal of the U-turn slots. Based on the results, the improvement in safety, as shown by the decrease in the frequency and rate of accidents, may be due to the elimination of the conflicts created by the weaving and turning movements in U-turn slots.

5. CONCLUSION

This study aimed to evaluate the change of traffic scheme, in Katipunan Avenue, from the before condition, which is the U-turn slot scheme, to the after which is the signalized intersections.

Based on the travel time results of 2011 and 2015, there is a relative increase in the northbound travel time during the morning peak hour. The travel time for the 2015 afternoon peak hour is also relatively high. When comparing 2011 and 2015, the level of service in the northbound direction during the morning peak hour has remained LOS D while the southbound has changed from LOS E to D. However, the LOS at 2015 afternoon peak hour reached LOS F. The signalized intersections may have caused the worsening in the traffic conditions of the road section, however, the factor of the increase in vehicle volume from 2011 to 2015 may have contributed to change in travel time and level of service.

For the intersection, the degrees of congestion were computed using the actual intersection count of 2015 and converted intersection count of 2012. Results of the 2012 and 2015 values showed that even if the congestion in the morning has relatively decreased, the values computed for both morning and after degrees of congestion of 2015 are both greater than one which means that that specific intersection is congested based on the current cycle time being operated. This is why the signal lights were closed during peak hours and the traffic is being manually directed by traffic enforcers.

Based on the results, it can be concluded that there is no improvement done on the traffic condition after the change to signalized intersections. The change may have worsened some of the movements along the road section especially the through vehicular movement. This shows that the signalized intersection alone is not enough to improve the worsening traffic at Katipunan Avenue.

For the road safety, the 2012 and 2015 rates of accidents were compared. Both the rate of accidents of the road section and at the Katipunan-Gonzales intersection have relatively decreased in the year 2015. Statistical analysis showed that there is a significant change in rate of accidents at the intersection. It is also observed that there is a decrease in the total number of accidents from the year 2005 to 2015. From this, it can be concluded there is an improvement in the safety aspect of the signalized intersection scheme. Overall the findings imply that even if there is a decline in the traffic condition after the change of traffic scheme, there is an improvement in road safety.

6. RECOMMENDATIONS

In order to further study the effect of signalized intersection, additional studies should isolate the effect of volume in order to determine if there really is a direct effect of the signalized intersections to the travel time. Historical data was also a constraint such that the current study's 'before' data was limited to

the year 2011 for the travel time and 2012 for the volume count. Perception of people traversing through Katipunan Avenue can also be added as a parameter to determine their opinion on which traffic scheme they feel more safe and comfortable.

This study only evaluated the effect during peak hours. Off-peak hour conditions should also be tested in order to determine the effectiveness of the signalized intersections. The other intersections should also be included for study in order to wholly cover Katipunan Avenue. On a wider scale, other road sections that has been converted to signalized intersections from U-turn traffic scheme may be studied in order to get a more general conclusion.

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