The Impact of Abrupt Lane Reduction Due to Work Zones along Epifanio Delos Santos Avenue (EDSA) - Magallanes Road Segment

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Abstract
This study aims to describe and analyze the effects of sudden lane reduction along Epifanio De los Santos Avenue (EDSA) brought by work zones during road construction. These work zones are temporary and have implemented lane closures without giving prior notice to the public and applying proper traffic management system on the location. Primarily, researchers have shown two cases of lane reduction that differs in the number and location of lane reduced. It focuses on determining for both cases the changes in volume, speed, level of service, and travel time experienced by each vehicle categorized into five transportation classifications. The study used traffic studies involving volume studies, speed studies, travel- time studies, delay studies and level of service studies as the primary data to validate the significant effect of lane reduction caused by road construction. Furthermore, ocular evaluation is also utilized as the secondary instrument to confirm the travel time delay caused by this condition evident in the long queue length formed in the affected area. In view of the mentioned impact of lane reduction along EDSA, there is a need for a more concrete and well-planned traffic management system to be implemented during such situations to reduced the total travel time delay experienced by motorists. Most importantly, this system will decrease the occurrence of accidents promoting not only the safety of the motorists but also the construction workers.

Keywords: EDSA, travel time delay, lane reduction, queuing, work zones

1. INTRODUCTION

Traffic congestion has been a constant problem for most major cities in Asia. The Asian Development Bank already urges these cities to find new approaches to ease traffic congestion in their respective areas. This is because the existing problem about traffic congestion is said to be one of the factors that paralyzes major cities in Asia economically, including Metro Manila.

The traffic congestion along EDSA is an example. Epifanio Delos Santos Avenue (EDSA) is said to be one of the most frequently used roads in Manila. It contains a number of commercial and industrial centres that makes it a very important route for most motorists. It is also an important arterial road that serves as a mojor transportation corridor for motorists coming from the northern part of Luzon to the southern part of Luzon and vice versa. In addition to that, it is where the Metro Rail Transit is located, making EDSA also vital for commuters. Since the said road is often used, maintenance is also frequently done to ensure the quality and safety of the road for its users.

Based on the above information, it is therefore necessary to be able to gather data that would allow the analysis of the effects of lane reduction due to work zones on the traffic flow along EDSA. This would allow the formulation of possible traffic management strategies that could help address the lane reduction problem.

The main objective of this study is to analyze the effect of abrupt lane reduction due to work zones on the traffic flow characteristics along EDSA and formulate a possible new traffic management strategy that would reduce the total delay experienced by the motorists. By identifying the variables and factors that cause heavy traffic on vehicles traversing EDSA, recommendations may be made for lessening the delay. Lessening the travel time delay would mean a faster transportation of goods to and from commercial and industrial centres in the country, contributing to the economical development of it. there would also be economic conservation of fossil fuel and a decrease in car emission. It would also improve road courtesy and behaviour of drivers during traffic congestion. Moreover, the study could also pioneer other studies regarding other road schemes and strategies that would lessen traffic congestion on roads with reduced lanes due to work zones.

2. REVIEW OF RELATED LITERATURE

2.1 Work Zones

Road construction operating daily in our major road artilleries result to the reduction of available lanes that can be utilized by the motorists. Work zones are usually attributed to road maintenance work causing the closure of one or more lane from the time of construction. The time period of construction depends on the type of work to be done. The study of Zhou et al (2010) states that bottlenecks are the source of the traffic congestions, which decreases the efficiency, and effectiveness of the traffic network. Thus identifying the traffic bottleneck is the first step to improve the traffic system's performance and to relieve traffic congestion, which is also essential for transport planning. According to Jiang (2001), the traffic flow is delayed at a work zone because the traffic capacity and vehicle speed are lower at the work zone than the other portions of the road. Traffic delays include delays caused by deceleration of vehicles approaching the work zone, reduced vehicle speed through the work zone, the time needed for vehicles to resume freeway speed after exiting the work zone and the queues formed at the work zone. According to McShane and Roess (1990), the decrease in the available lanes cannot attend the volume of the arriving vehicle volume exceeding the designed working volume capacity of the road with all lanes open. Thus, queues develop and force flow is insisted. These merging lanes further increase the hazards and the travel time as explained by Idewu (2009). In his dissertation, he reiterated that there should be an increasing need to uphold the safety and efficient travel of motorists with an increasing active work construction among roads. According to the study of Utah et al (2009), traffic delays brought by road congestion has resulted to a lot of fatal problems. Drivers' senses such as rapid reaction time, consistent speed, appropriate following distance and anticipatory visual scanning are more likely to decrease when experiencing traffic congestion. Driver's attention is diverted to other tasks, which may lead to fatal road accidents.

2.2 Traffic Analysis

Papacostas et al. (1993) provided major areas or topics concerning the broad scope of transportation engineering and planning. This also described the different concepts such as vehicular stream models, stream measurements and stream variables. The vehicular stream model is the basic data needed for the analysis of vehicle flow. This includes the speed of vehicles, length of vehicles, deceleration and acceleration, and their safety margins. According to Mathew et.al. (2006), speed is one of the basic parameters of traffic flow. This parameter can be represented into two namely time mean speed and space mean speed. Time mean speed is known to be the average of all vehicles passing through the marked point over a period of time. It is also known as the spot speed.

$$\text{time mean speed (x)} = \frac{\sum \mathrm{f_i} u_i}{n} \tag{1}$$

where:

f_i = number of occurrences of observation
μ_i = speed, m/s
N = total number of observations

The study by Underwood (1961) discussed the variables of speed, density and volume in relation to traffic flow. It was shown through models and graphs how the said variables affect the traffic flow system together with its governing mathematical equations used to interpret the said parameters to conclusive characterization of traffic flow. In the characterization of traffic flow, determining the volume is important. Volume count can be obtained manually per quarter an hour, per half an hour or per hour. Based on the highest total number of vehicle obtained per chosen duration, the Estimated Hourly Volume of vehicles (EHV) can be obtained from this equation,

$$\text{EHV} = \frac{\text{(total no. of vehicles)}}{\frac{1}{60} \times \text{total duration of blockage}} \tag{2}$$

Another parameter determined using the obtained volume count is the peak hour factor (PHF). It is used to know the most critical time period where the volume is at its highest. The peak hour factor (PHF) is defined by this equation as

$$PHF = \frac{\text{Hourly Volume}}{\text{Peak Rate of Volume within the duration}} \quad (3)$$

Typically, the values for the peak hour factor ranges from 0.80 to 0.95 given freeway condition. It is expected to have higher values for PH during peak hours. The study of Immers and Logghe (2002) states that the operation of bottlenecks is an important mechanism in functioning of our road network. The location and timing of bottlenecks determine the location and length of tailbacks. Orso-Delagado (2004) defines bottleneck as a condition that restricts the free movement of traffic, creating a point of congestion during specific periods of time. Roess (1990) states that congestion occurs due to bottleneck which can be determined by flow density relationship where factors such as the flow rate and density are to be considered.

Flowrate can be obtained from this equation,

$$\text{Flowrate (Q)} = \frac{N}{T} \quad (4)$$

where: N = total number of vehicles
T = unit time

Meanwhile, Density can be obtained from this equation,

$$\text{Density (k)} = \frac{N}{L} \quad (5)$$

where: N = total number of vehicles
T = unit length

3. Research Methodology

3.1. Study Area

The study area is located along Epifanio de los Santos Avenue (EDSA)- Magallanes particularly the road section in between Taft Avenue Station and Magallanes Station of Manila Metro Rail Transit System Line 3 (MRT-3). It is a ten lane arterial road where only five lanes going northbound was studied and analyzed. The minor road repair happened for about 55 minutes without prior public notice and proper traffic management strategy applied. The sudden lane reduction was observed to occur due to the work zone in two different cases. All data for lane reduction both in case 1 and case 2 were gathered last January 21, 2013 from 10:30 to11:30 in the morning. On the other hand, data for the free flow condition of the study area were obtained from the video footages taken last January 25 and March 22, 2013 from 10:30 to 11:30 in the morning, the same time where the lane reduction occurred.

3.1.1. Case 1

For the first case, one lane, the inner most lane, was closed for about thirty minutes. Figure 1 shows the actual footage taken in the study area.

Fig. 1 Actual Footage of Case 1 Study Area

It describes the actual condition of the road where one lane is reduced due to the work zone. The lane reduction has a length of 60 meters and a width of four meters. Other three lanes were free of obstruction that catered the whole volume of motorists. The outermost lane is neglected since it accomodates all vehicles coming from Evangelista Street which is perpendicular to EDSA- Magallanes Road and those who loads and unloads.

3.1.2. Case 2

After thirty minutes, the road construction shifted from the inner most lane to the adjacent lanes. Almost two lanes were reduced for about twenty five minutes. The workzone occupied the two center lanes as seen in figure 2.

Fig. 2 Actual Footage of Case 2 Study Area

The measured length of the lane reduction is about sixty meters and six meters in width. The previous lane reduced in the first case is now passable together with the other outmost three lanes. Similarly in case 1, the outermost lane is neglected since it accomodates all vehicles coming from Evangelista Street which is perpendicular to EDSA- Magallanes Road including those vehicles that loads and unloads.

3.1.2. Free Flow Condition

Figure 3 shows the actual footage taken in the study area during free flow condition without the lane reduction.

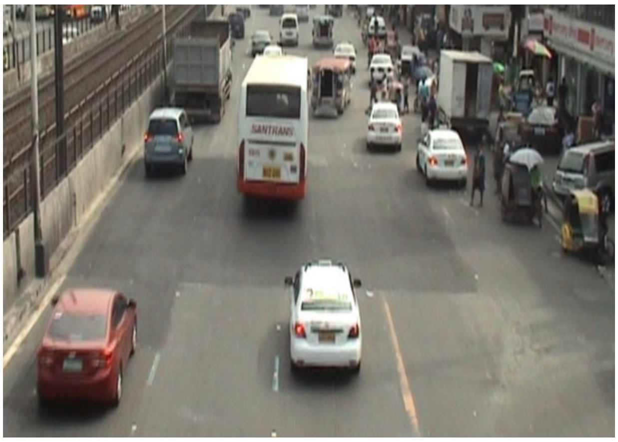

Fig. 3 Free Flow Condition Study Area

To analyze the impact of sudden lane reduction due to work zones, the gathered data from case 1 and case 2 road condition were compared to the data obtained from the free flow condition of the same location where all five lanes were passable to all motorists as seen in figure 4.6. All vehicles that loads and unloads were not considered in this study. In addition to that, the outermost lane is neglected since it accomodates all vehicles coming from Evangelista Street which is perpendicular to EDSA- Magallanes Road and those vehicles that loads and unloads.

3.2 Classification of Transportation Vehicles

The vehicles passing through the study area were classified into four categories in reference with their vehicular size and use namely, private cars, jeepneys, vans, bus and truck. For the private car, this classification includes all vehicles that are conventional four- wheel types manufactured primarily for carrying four to six passengers. The second classification is solely comprised by jeepneys used as a public utility vehicle with a maximum capacity of sixteen seated passengers. On the other hand, the third classification named as van includes all service utility two- axle and four- tire vehicles aside from what is included in the first classification such as pick ups, passenger vans, ambulances, mini buses and the like. The bus, as the fourth classification, is entirely comprised of traditional type of buses that serve as a passenger- carrying vehicles. The last classification includes all truck units with or without a trailer.

3.3 On- Site Data Collection

Video recorders are placed at an elevated area to have an over-all overview of the study area. Each video recorder is placed before the start of the queue and before the start of the

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lane reduction. These devices are positioned facing opposite the direction of the traffic flow to document the behaviour in the start and end of the merging zone for quantitative analysis. Parameters such as vehicular type, speed, volume, and merging manoeuvres of vehicles will be recorded as well from the video images. Most importantly, it will also be utilized to document the before and after situation of the study area that would further give a more detailed impact of lane reduction due to road construction. A part from the setting up of video recorders, land surveying was also done to obtain the road measurements of the location. This would give a more detailed layout to the affected area.

4. Data Presentation and Analysis

The data gathered from the video footages of the lane reduction along EDSA-Magallanes are tabulated and analyzed through the presentation of graphs and figures. Generally, there are three cases that are analyzed and compared in this study. The first case of blocking is termed as “Case 1” where the blocking occurs at the leftmost part of the road. This blocking lasted for about 30 minutes. The second case of blocking is termed as “Case 2” where the blocking occurs at the centre part of the road. The second occurrence of blocking lasted for about 25 minutes. The two cases are compared to the data gathered during the considered free flow condition taken at the same area and at the same time.

4.1. Volume Count

To determine the estimated hourly volume of vehicles, the actual total number of vehicles with respect to the duration is taken and converted to its one-hour equivalent as seen in Table 5.1. It could be observed from Table 5.1 that the free flow volume is 37% more than that of the Case 1 volume. Meanwhile, it is also 12% more than the volume of Case 2 blocking. On the other hand, a 23% difference can be seen between the volumes of Case 1 and Case 2 blocking with Case 2 being the one with the higher volume.

Table 1 Estimated Total Hourly Volume of Vehicles

	Actual Volume (veh)	Estimated Hourly Volume Equivalent (veh)
Case 1	1097	2194
Case 2	1120	2688
Free Flow	1508	3016

From the volume count differences, the drop of the volume of vehicles in the traffic flow of Case 1 and Case 2 blocking may signify the decrease in capacity of EDSA-Magallanes section because of the lane reduction due to the work zone. It restricts the flow of traffic that results into lesser vehicles that can be accommodated by the road. The difference of the volume of Case 2 blocking from the volume count of Case 1 blocking is also very notable.

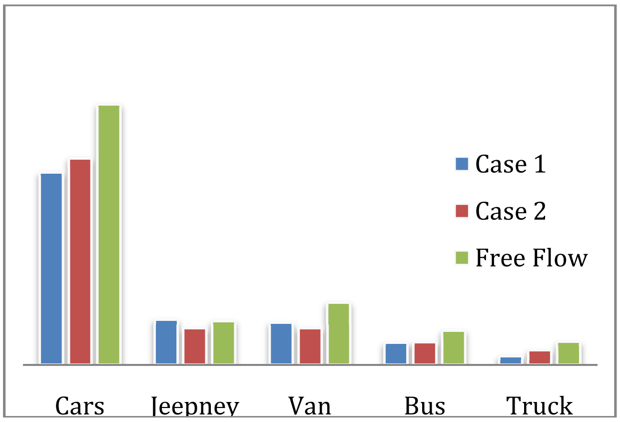

Fig. 4 Volume Count per Transportation Mode

Figure 4 shows the volume of vehicles per mode during the Case 1 and Case 2 blocking and as well as during the free flow condition. From the graph, it can be seen that among all the modes, cars occupy the highest percentage of volume with an average of about 64% for both Case 1 and Case 2 blocking while it is about 61% of the free flow condition. Trucks, on the other hand, occupy the least percentage of the overall volume for all the conditions. The volume of cars counted in the study includes taxis and all private vehicles with an estimated same size as that of a typical car. The vans considered are the delivery vans whose sizes are considered as medium, ranging between the size of a bus and a private car. The trucks counted are the very large ones, which are longer than buses. Recreational vehicles such as motorcycles are neglected in the study.

4.2. Capacity and Level of Service

From the volume studies, other parameters such as peak hour factor, flow rate, average speed and density are also computed and presented. The level of service (LOS) of the section of the highway is also determined.

Table 2 Capacity and Level of Service Data

	PHF	Flow Rate (vphpl)	Average Speed (kph)	Density (veh/km)	LOS
Case 1	0.90	541	14.01	193	F
Case 2	0.98	562	16.46	171	F
Free Flow	0.86	809	35.05	115	E

As shown in Table 2, the peak hour factors obtained for Case 1, Case 2 and the free flow condition all indicate a high volume of vehicles using the section of the highway. The values are typical for urban peak-hour conditions. Comparing the flow rate of the free flow condition from Case 1 blocking, a difference of 268 vphpl could be observed. In one hour, this is equivalent to 1340 vehicles that are unable to utilize the section of the road. On the other hand, comparing free flow condition from Case 2, a difference of 247 vphpl could be seen. This is equivalent to about 1235 vehicles that are unable to pass the road in an hour.

Meanwhile, comparing Case 1 and Case 2 conditions, it could be observed that the capacity for Case 2 blocking is slightly higher than that of Case 1 by 21 vphpl. This difference may be attributed to the observed lane-changing choice of the motorists. For Case 1, only one option for lane changing can be seen for the vehicles located at the leftmost part of the road because the blocking is also located at the same part. On the other hand, for Case 2, two options can be made for the vehicles located at the blocked lane. This incidence may have resulted to a higher capacity accommodated by the road with Case 2 blocking condition for vehicles than that of the Case 1 blocking condition.

Still in Table 2, the average speed and the density computed from the different cases could be seen. The speed and density of vehicles in Case 1 blocking agrees with the low flow that is observed with the leftmost blocking condition. Same values could be observed in the Case 2 blocking with a slight positive difference. Generally, the densities in Case 1 and Case 2 blocking conditions are very high. Both cases are about 67 vehicle/km higher than free flow condition.

From the density computed from each of the case of blocking and the free flow condition, the level of service of the section of the road could be identified based on the standard capacity and LOS criteria of the Highway Capacity Manualpublished by the Transportation Research Board.

From Table 2, it could be seen that the Case 1 and Case 2 condition of blocking falls under LOS F criterion which is regarded as the worst operating condition within a traffic system. This criterion is also considered as an unacceptable condition of a highway and it could mean that the capacity for the road design is already being exceeded by the traffic demand. On the other hand, the considered free flow condition of the section of the road along EDSA falls under LOS E criterion, which is also an unacceptable condition but is one level higher than the two cases of blocking. The movement of vehicles within this type of traffic stream is already considered to be very limited.

4.3. Speed

The speed of vehicles as they travel the length of the service area is analyzed per case of blocking as well as the free flow condition along the section of the road of EDSA-Magallanes. The length of the blocking is measured to be about 60 metres. The speed analysis is conducted per mode of transportation that passes the said section of the road.

From Table 3, car speed analysis results show that the average speed without blocking which is 38.07 kph greater than of the two cases, as expected.

Table 3 Mean Speed

	Mean Speed (km/hr)		
Classification	Case 1	Case 2	Free flow Condition
Car	15.54	19.23	38.07
Jeepney	12.98	12.81	29.62
Van	13.52	18.28	40.22
Bus	15.81	14.83	32.15
Truck	12.18	17.17	35.19

To compare the two sets of data gathered for the Case 1 blocking and Case 2 blocking, a student t-test assuming unequal variances is performed. The null hypothesis made is that the mean difference of the two sets of data is equal to zero. The alternative hypothesis on the other hand states that it is less than or greater than zero, making the test a two-tail t-test. Assuming a value 0.05 for the level of significance, a p-value of almost zero is obtained. Therefore, the null hypothesis is rejected. The mean difference between the two sets of data is significant. From Table 3, it could be observed that the speed of the cars in Case 2 blocking is generally higher than that of the Case 1 blocking. This behavior is observed to be the same with the most of the other modes of transportation except for Jeepneys and Buses where there is almost no significant change in mean speed for case 1 and 2.
Comparing all modes of transportation, jeepneys registered the lowest mean speed consistent to in all cases namely case 1, 2 and free flow condition. On the other hand, cars have the highest mean speed for all cases.

Significantly, it can also be observed from Table 3 that the jeepneys and buses have the lowest mean speed reduction. This maybe because these two vehicles are public utility vehicles. They have been consistent to have the lowest mean speed for case 1, case 2 and free flow condition as compared to trucks which has high mean speed for free flow condition.

4.4 Travel Time Delay

The estimated travel time delay of vehicles is determined by using the mean speed computed per transportation mode. In each case, it is computed as the difference of the travel time between the blocking condition and the free flow condition. The results are shown in Table 4.

Table 4 Travel Time Delay Computations

Case	Total Delay per Mode (veh-hr)					Total
	Car	Jeepney	Van	Bus	Truck	
1	3.11	0.83	0.88	0.30	0.19	5.31
2	2.71	0.82	0.55	0.42	0.22	4.72

The computed total delay for all the modes indicate the number of hours that is spent beyond the normal duration of travel time if the ideal speed or the free flow speed is followed. From Table 4, it could be observed that the total delay is very high. It could also be noted that the travel time delay in Case 1 blocking is generally higher than that of the Case 2 condition.

5. Conclusion

The impact of the lane reduction on the traffic flow along EDSA-Magallanes segment with blocking at the leftmost lane and centre lane respectively is very significant although the work zone duration is short.

The sudden lane reduction causes significant drop in the volume of vehicles for both cases of blocking. Comparing Case 1 condition to the considered free flow condition of the road, a capacity reduction of about 33% is computed. Meanwhile, comparing Case 2 condition to the considered free flow condition, a capacity reduction of about 31% is computed. The capacity reduction from both of the cases is very high especially for a road like EDSA. The reduction is already about one third of the considered free flow condition and it is very important to note that the free flow condition in the study is just a considered free flow condition of the area. Therefore, it could be concluded that the exact capacity reduction due to the road blocking would be higher when compared to the real free flow condition of the area. Meanwhile, from the overall data analysis, the capacity of the road in a centre-lane blocking is observed to be generally slightly higher than that of leftmost-lane blocking. Private cars passing along the area occupy the largest percentage of the total volume of vehicles traversing the analyzed section while trucks occupy the least.

For the speed of the vehicles, it could generally be concluded that the effect of the lane reduction on the speed reduction on all the transportation modes is more than half of the computed speed of the considered free flow condition. Comparing all the speeds of the transportation modes, cars have the highest speed while the jeepneys have the lowest. Smaller vehicles do not necessarily travel faster than the larger ones. Generally, private vehicles travel faster than public utility vehicles.

The lane reduction causes a significant travel time delay with an average of about five vehicle-hours for a period of around 25 to 30 minutes as computed for both cases. The delay could be caused by the queue that developed in the area, the deceleration of vehicles before the service area, the speed reduction while traversing the section of blocking and the time in resuming the ideal speed of vehicles for the highway which all in turn contribute to the development of heavy traffic congestion.

Meanwhile, it is important to note that the location of blocking in the study matters. Comparing Case 1 and Case 2, the vehicles can generally travel at a higher speed with the centre lane blocking condition.

Overall, it can be concluded that the impact of work zones to the traffic flow along EDSA-Magallanes segment must not be neglected although it is short-termed. A proper and standardized traffic flow management should be applied every time an abrupt lane reduction of lanes on a road occurs.

6. Recommendation

For the improvement of the study, acquiring of more locations of abrupt lane reduction situation would be of much help for the analysis of the sudden lane reduction along road segments. The comparison between the different cases of abrupt lane reduction could validate the similarities and differences between the acquired data in the study. One of the main difficulties encountered in this study is the number of locations which could be found in Manila. It is recommended that for the purpose of an efficient data gathering, coordination with the authorities like the DPWH and MMDA must be done as early as possible.

For the tools for data gathering and analysis, the acquirement of high-technological devices could greatly contribute to the improvement of accuracy and precision of the gathered data in this kind of study. Only video cameras are used in the study and most of the counts are done manually. Gadgets like vehicle sensors could be acquired for a more effective and efficient way of gathering data in different locations.

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