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Impact of Multilane Median Openings Zone on Travel Speed

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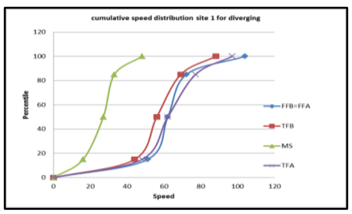


Abstract

Thispaperaims to assess the impact of median openings zone of travel speed. Median openings or Midblock U-turn facilities are often constructed to provide motorists with detour option in circumstances where traffic conflict manoeuvres are eminent and prevalent. In previous studies, it has been shown that median openings will reduce the number of conflicts at relevant intersection.Hence median openings were built on multilane highways in Malaysia.Theirconstruction provoked debate on safety and traffic flow impediment issues. Based on the hypothesis that multilane median openings would cause travel speed reduction; an impact study was carried out at selected sites in Johor, Malaysia during daylight and dry weather conditions. Traffic volume, speed, and vehicle types were collected per road section for two directions continuously for eight weeks. The survey data were supplemented with highway design information culled from the Malaysian Public Works Departments manual. Travel speeds at median opening zone were estimated for both directional traffic flows. Results show significant decrease in travel speed of up to54.2% at the diverging section of the median openings zone. A slight drop of about 5% resulted from median openings zone at the merging section. The paper concluded that median openings zone facilities irrespective of their traffic conflicts minimisation merits will trigger significant travel speed reduction.

Keywords: U-turn facility, median openings, highway, travel speed, flow

1.0 INTRODUCTION

Often found on multilane highways in Malaysia, median openings are often constructed to allow motorists detour in circumstances where conflicting manoeuvres are proven to be prevalent. Median openings permits vehicles to make U-turn movements and provides separate channelized roadways,thus, opposing U-turn vehicles will not overlap. They are appropriate where U-turn volumes are relatively high, such that U-turn vehicles in opposing directions of travel would otherwise interfere with one another. Although median openings have been effective in traffic conflicts reduction, however they have raised traffic safety and speed reduction concerns.These concerns have provoked debate among motorists about the merits and demerits of median openings.

Speed and traffic flow are two parameters that often used in traffic engineering as traffic effectiveness. The study is aimed at ascertaining traffic flow effectiveness in the presence of multilane highway median openings. US Highway Capacity Manual (HCM2010) [9] used speed / flow to describe six level of service experienced by road users. As the level decreased so will the average speed and service quality: at level A the highest quality service occurred and motorists were able to drive at desired speed while at level F the lowest quality occurred with forced flow, stop-start and uncomfortable conditions. Level B was a transition from level A to C because at level C even though the traffic might appear stable, it was more susceptible to congestion from turning movements and slow moving vehicles. At level D unstable traffic flow was approached with high overtaking demand that was virtually impossible to achieve at level E where perturbations in the traffic stream often caused a quick transition to level F.

In this empirical study the percentile distribution approach is preferred because the HCM method is based on service volume theory. The 85th50thand 15th percentile distributions were examined. In the Manual on Uniform Traffic Control Devices (MUTCD) [8] for streets and highway when a speed limit is to be posted, the 85th percentile speed of free-flowing traffic, rounded up to the nearest 10 km/h increment is used. In the light of the discussion so far travel speed and percentile distribution literature are reviewed in context.

2.0 LITERATURE REVIEW

A U-turn refers to vehicles performing a 180 degree rotation to reverse the direction of travel. Midblock right U-turn facilities are built to assist with these deft manoeuvres. While some are built as complimentary facilities to existing road geometric design, others are built as a complete replacement to existing facilities on the premises that they will reduce conflicts and ease congestion at adjoining intersections. That may be so, but there are road safety consequences that are often ignored. When a direct conventional multilane divided roadway is installed the directional median opening or U-turn bay: drivers desiring to make U-turn at the fast lane that may reduce speed instantly and it will reflect the traffic flow of that road segment. There have been considerable numbers of studies [3, 5, 15] conducted concerning the safety effects of U-turns. However, relatively no studies are available concerning the influence of midblock U-turn facilities by the drastic changing travel speed on the road link highway sections.

In the Malaysian Highway Capacity Manual (MHCM 2011) treats U-turns as left turns for estimating saturation flow rate [11]. However, the operational effects of U-turns and right turn are different. U-turning vehicles have slower turning speeds than right-turning vehicles. In previous studies [1, 15] on the midblock U-turn facilities discussions on therein were mainly conflict minimization and collusion risk reduction at the opening or at the signalized intersection. Some of the researchers [5, 16] agree that U-turn could only be located at signalized intersections and greater care taken when considering roadway segment design. In some studies, it has been shown that conflict and crashes do not relate at all. As a result, researchers [4, 5] are divided on the issues of where to locate median opening U-turn facilities. It is understandable given the scanty availability literatures on road safety at median openings.

Florida State Department of Transportation (FDOT) [6] has shown that higher traveling speeds are not necessarily associated with an increased risk of being involved in a crash. When drivers travel at the same speed in the same direction, even at high speeds, as on interstates, they are not passing one another and cannot collide as long as they maintain the same travelling speed. Conversely, when drivers travel at different rates of speed, the frequency of crashes increases especially crashes involving more than one vehicle. The key factor is speed variance. The greater the speed variance or distribution of speeds the greater the number of interactions among vehicles. Thus, drivers attempting passing manoeuvres due to speed variance increase the risk of having collisions.

In HCM 1998 [7] special report, the 85th percentile speed is an important descriptive statistic in evaluating road safety.The comparison of two or more sample populations is very common in analytical works for engineers and scientists. T-tests and analysis of variance (ANOVA) are simple convenient statistical tools that widely used to compare the means of different populations. Although these statistical tools are useful for providing evidence of a statistically significant change in mean between different populations, they are much less common used for inference of other population parameters, such as percentiles according to Spiegelman and Gates [13].

Several methods have been used for comparing percentiles such as nonparametric double bootstrapping, quantile regression, binomial test and averaging percentiles. A nonparametric double bootstrapping and the quantile regression are typical methods used for comparing percentiles. Double nonparametric bootstrap procedure is a simulation method based on resampling of existing data. There are two procedures involved: the first bootstrapping is used to produce estimates the standard errors for the desired percentiles and the second bootstrapping is used to get the threshold cutoff values for the test of hypothesis or confidence interval. This statistical test is beneficial in that it does not require populations to follow specific distributions and to have balanced sample sizes or equal variances [12].

Brewer et al [14] used a nonparametric double bootstrapping method on the 85th percentile speed in a work zone speed limit study, while Voigt et al. [4]performed this test on the 85th percentile speed to investigate the impact of dual-advisory warning signs on speed reduction on freeway-to-freeway connectors in Texas. Quantile regression method is a type of regression analysis commonly used in econometrics. It is considered a natural extension of ordinary least squares that estimate the conditional means to the conditional quantile. This method builds a linear model relating desired quantile to intervention factors then estimates the standard error of desired quantile through the standard error of model parameters.

Binomial test is yet another plausible method used to assess the statistical significance of differences in the 85th percentile speeds [3]. Pesti and McCoy [2] used binomial test method for evaluating long-term effectiveness of speed monitoring displays in work zones on rural interstate highways, Averaging percentiles method can also be used for comparing percentiles. By averaging percentiles, t-test can be applied. using this method to analyze 85th percentile speeds from many work zone sites.

Even though these statistical methods were applied in many studies, the most recent study found that there are some problems associated with existing methods. A nonparametric double bootstrapping and the quantile regression are fairly complex methods and not easy to apply. The use of binomial test and averaging percentiles for analyzing percentile values is questionable and could be argued because it is perhaps not the most appropriate fit. Since there is a lack of a statistical test for comparing percentiles that can be easily applied and is theoretically sound, some studies have not pursued statistical analysis.

Therefore, Sun, C and Edara [12] proposed statistical test for the 85th and 15th percentiles based on Crammer's theory of asymptotic distribution of sample quantile. This theory has been in existence for many years as derived by Crammer [10]. Normality of data is required for accuracy of the quantile test. The estimated value of the standard error was somewhat different. The statistical test is fully developed for 85th percentiles speed with the assumption that 15th percentile speed has the same form because of the symmetry of the normal distribution. The difference can be compared using the test statistic below when the sample size reached approximately 200.

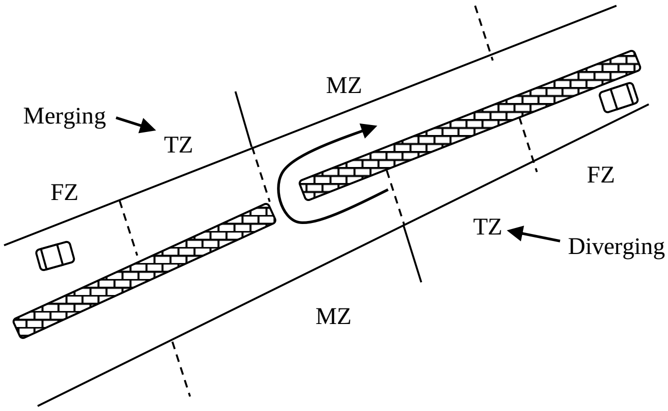
$$\frac{X_{([n0.85]+1)} - Y_{([n0.85]+1)} - 0}{1.53\sqrt{S_x^2/n_x + S_y^2/n_y}} \quad (1)$$

Where

$X_{([n0.85]+1)}$ and $Y_{([n0.85]+1)}$ are the 85th sample quantile from independent normal distributions, X_n and Y_n are sample sizes, and S_x and S_y are the sample variances.

3.0 DATA COLLECTION, RESULTS AND DISCUSSION

The setup of median opening U-turn facilities impact study is illustrated below in Figure 1. The dual carriageway Federal Highway FT001 Senai, Kulai in the Johor State of Malaysia has been selected for the study after careful considerations. The roadway was divided into three sections (upstream, median openings and downstream) in both directions. The upstream sections are divided into two sections (transition flow after and free flow after) and in this upstream section were set at a distance greater than stopping sight distance (SSD). Motorists at free flow after upstream section are assumed to be driving at free flow speed. The downstream sections are divided into two sections (transition flow before and free flow before) and in this downstream section were set at a distance greater than stopping sight distance (SSD). Motorists at free flow before downstream section are assumed to be driving at free flow speed. While in the median opening zone the motorist are driving at the slower speed caused by the deceleration and acceleration when diverging and converging. 24 hours traffic volume, speeds, vehicle types, headways and gaps were recorded continuously for 8 weeks (January – March 2012) for both directions. Over 500,000 vehicles per roadway direction were captured on the data logger. Study was carried out under dry weather and daylight conditions.



Note:
Automatic traffic counters (ATC)
FZ denotes f-flow zone
MZ denotes median opening zone

Figure 1 Typical survey site layout

Note also that a typical site as both diverging and merging approaches as shown above in figure 1.

Site 1: As illustrated in Figure 1, site 1 has been divided into 3sections: FZ (Free flow section), TZ (Transition flow section), MZ(Midblock section). Considering that traffic stream operation was at off peak period, the influence of peak traffic flow was minimises. Speed distributions on both lanes are the same. At the transition section of the carriageway, there is a dilemma zone where drivers must decide whether to stay in the lane or move to the right. The drivers moving to the right include those detouring as well as those making U-turns. There are evidences from the studies showing that about 4.2% of speed will drop from the free-flow to the transition section. While the drastic drop of speed about 52.2% occur from transition section to the midblock median opening zone. For the transition section, it shows speed will increase to 52% after the median openings zone. Since, the median openings U-turn have a decelerating lane at this section of the roadway; it is obvious that the deceleration effect would most be pronounced here.

Site 2: As also illustrated in Figure 1, site 2 has also been divided into 3road sections as; FZ (Free flow merging section), TZ (Transition flow section), MZ (Midblock section). Considering that traffic stream operation was at off peak period, the influence of peak traffic flow was minimised. Speed distributions on both lanes are the same. At the transition section of the carriageway, there is a dilemma zone where drivers must decide whether to stay in the lane or move to the right. The drivers moving to the right include those detouring as well as those making U-turns. There are evidences from the studies showing that about 1.3% of speed will drop from the FZ to the TZ section. While the drastic speed of speed about 58.2% occur from TZ section to the MS section. For the TZ section, it shows significant 54.2% speed increase after the median openings section. Since, the median openings section has accelerating lane at this section of the roadway; it is obvious that lower speed will occur at the TZ section. The median openings section would experience weaving, and critical gap acceptance impediments. Drivers emerging from the facilities must wait for gap to appear along lane 2a before accelerating into that lane. It is often a dangerous manoeuvre that can trigger road accident. This is so because drivers along the overtaking lane 2a are forced to abandon the overtaking move in other to avoid collusion.

Descriptive cumulative percentile speed distributions are presented in Table 1. The percentile distribution was performed on the speed data to determine the 15th percentile, 50th percentile, 85th percentile and 100th percentile were significantly different for five different road sections. The quantile test developed in this paper was applied at 85th percentile speeds. Results of the test are shown in Table 2. The null hypothesis was rejected, which suggested that the difference of 85th percentile speed was statistically significant.

As shown in figures 2 and 3, there is a normal- like curve for five different road sections. Sharp shift in curve from right (free-flow) to left (median openings zone) indicates that majority of the drivers experienced speed drop from 70km/h to 30km/h. The driver behaviour pattern can be attributed to weaving intensity whilst jockeying for advantage positioning of vehicle. This avoidable manoeuvre can trigger the road accident.

In sum, median openings are designed to allow motorists perform u-turning on the roadways. A U-turn refers to vehicles performing a 180 degree rotation to reverse the direction of travel. Direct median opening facilities allow u-turning movement to be carried out by crossing over from the main stream onto the dedicated entry and exit lanes. On entry, u-turning motorists often interfere with through traffics by encroaching on part or all of the through traffics lane and slowing down follow up vehicles. At the exit lane, motorists are faced with gap acceptance problem where misjudgments are fatal. The potential for conflicts at the facilities has called to question the operating performance of traffic flow at affected zones. Based on the synthesis of evidences obtained from the relationship between travel speed and median opening zone it is correct to conclude that no lasting solution to the challenges of traffic conflicts at intersection will be found unless that solution addresses the issue of persistent travel speed reduction attributable to median openings.

Table 1 Cumulative percentile speed distribution

Site	Percentile (%)	Speed (km/h)				
		Downstream		U-turn	Upstream	
		FZ	TZ	MZ	TZ	FZ
1	100	104	88	48	97	104
	85	72	69	33	77	72
	50	62	56	27	62	62
	15	51	44	16	48	51
	0	0	0	0	0	0
2	100	120	104	48	114	120
	85	80	72	33	79	80
	50	66	61	27	67	66
	15	54	50	16	55	54
	0	0	0	0	0	0

Note: FFB denote free flow before midblock U-turn for downstream, TFB denote transition flow before midblock U-turn for downstream, MS denote midblock U-turn segment, FFA denote free flow after midblock U-turn for upstream, TFA denote transition flow after midblock U-turn for upstream.

Table 2 Result of statistical test on 85th percentile speed

Hypothesis		85th Percentile Speed Distribution (km/h)					Change (km/h)	P-Value	Reject Ho
		FZ	TZ	MZ	TZ	FZ			
Site 1	Case 1: Ho:(ξ0.85)FZ=(ξ0.85)TZ H1(ξ0.85)FZ>(ξ0.85)TZ	72	69	33	77	72	3	0	Yes
	Case 2: Hoξ0.85)FZ≤(ξ0.85)TZ H1(ξ0.85)FZ>(ξ0.85)TZ						-5	0	Yes
Site 2	Case 1: Ho:(ξ0.85)FZ=(ξ0.85)TZ H1(ξ0.85)FZ>(ξ0.85)TZ	80	72	33	79	80	8	0	Yes
	Case 2: Hoξ0.85)FZ≤(ξ0.85)TZ H1(ξ0.85)FZ>(ξ0.85)TZ						1	0	Yes

Note: (Figures 2 and 3 below) MS is same as MZ (Midblock zone); TFA denotes transition after; TFB denotes transition before; FFA denotes free-flow after; FFB denotes free-flow before
- (ξ0.85)FZ is the 85th percentile of speed at Downstream section for Free Flow Before
- (ξ0.85)TZ is the 85th percentile of speed at Downstream section for Transition Flow Before
- (ξ0.85)FZ is the 85th percentile of speed at Upstream section for Free Flow After
- (ξ0.85)TZ is the 85th percentile of speed at Upstream section for Transition Flow After

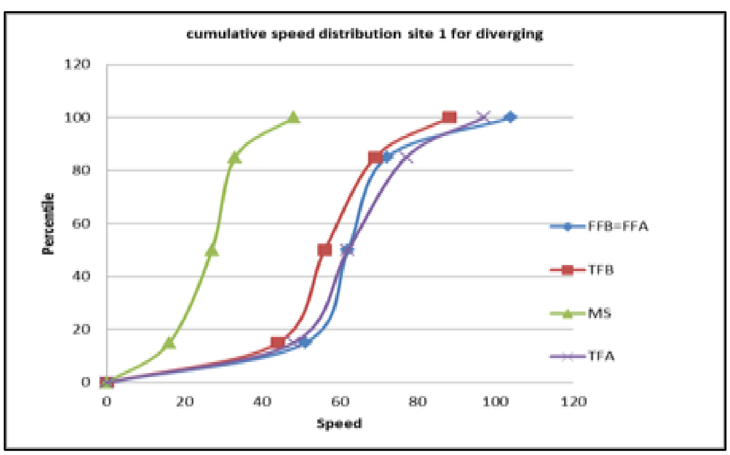


Figure 2 Cumulative percentile speed distribution site 1

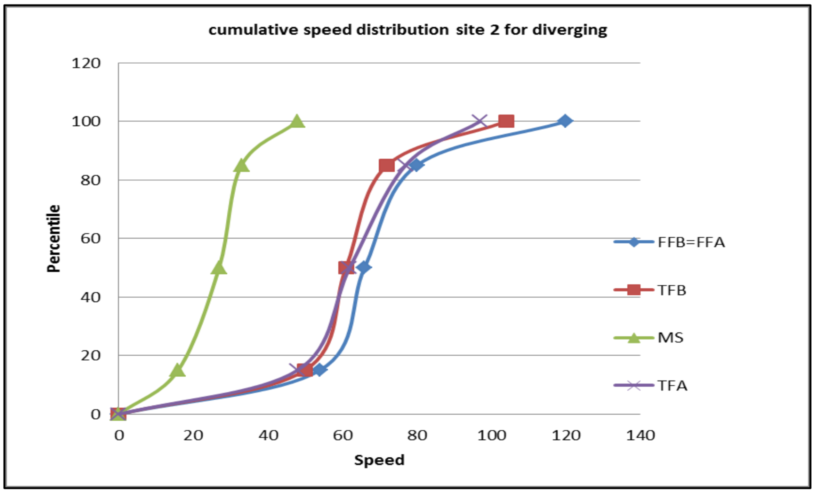


Figure 3 Cumulative percentile speed distribution site 2

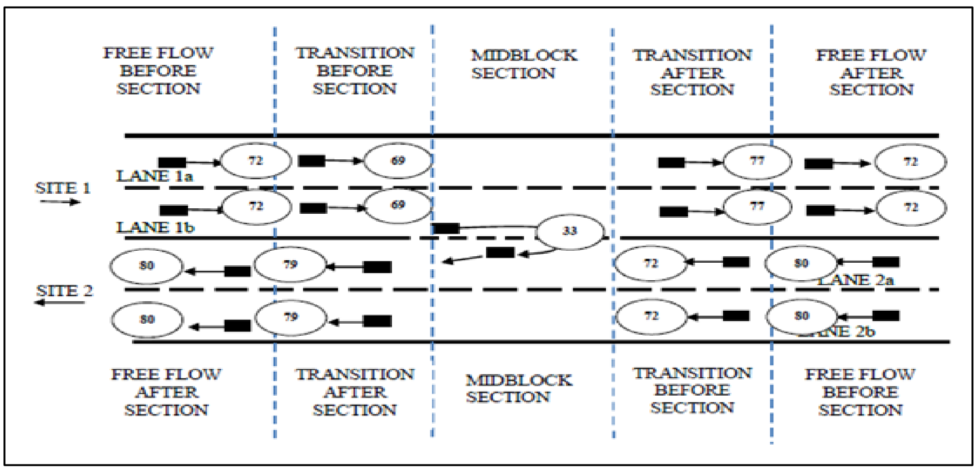


Figure 4 Travel Speed for 85th Percentile Speed Distribution per lane

■4.0 CONCLUSION

The paper is aimed to focus the impact of median openings zone on variable travel speed in Malaysia. The impact study gave an insight into some of the problems associated with U-turn movements at median openings or midblock facilities (often used interchangeably) in Malaysia. The paper has shown that travel speed at free-flow section decreased significantly at the median opening zoneat all sites.Speed reductions are greater at the diverging sections than the merging sections. At the merging section vehicles exiting from the U-turn facilities must give way to all approaching vehicle, hence the slight drop of about 5 per cent at the merging sections. Nonetheless the assertion that median openings would cause travel speed reduction remain valid. The paper concluded that median openings zone facilities irrespective of their traffic conflicts minimisation merits will trigger significant travel speed reduction.

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References

[1] Ben-Edigbe, J. 2010. Assessment of Speed-Flow-Density Functions under Adverse Pavement Condition, *International. Journal of. Sustainable. Development and. Planning*. 5(3): 238–252

[2] G. Pesti and P. T. McCoy. 2001. Long-term effectiveness of speed monitoring displays in work zones on rural interstate highways, Paper No. 01-2789. *Transportation Research Board*. 80th Annual Meeting Washington, D.C, January 7-11.

[3] P. J. Hewson. 2008. Quantile regression provides a fuller analysis of speed data. *Accident Analysis and Prevention*. 40(2): 502–510.

[4] A. P. Voigt, C. R. Stevens, and D.W. Borchardt. 2008. Dual-advisory speed signing on freeway-to-freeway connectors in Texas. In Transportation Research Record: *Journal of the Transportation Research Board*. No. 2056, Transportation Research Board of the National Academies, Washington, D.C. 87–94,

[5] Fitzpatrick, K., Carlson, P., Brewer, A. M., Wooldridge, M. D. & Miaou, S.P. S. 2003. Design Speed, operating speed and Posted speed practice. *NCHRP Report 504*. TRB, National Research Council

[6] FDOT Traffic Engineering and Operations Office Tallahassee, Florida March. 2010. Topic No 750-010-002. *Speed Zoning For Highways, Roads and Streets in Florida*.

[7] Highway Capacity Manual .1998. Special Report 209 *Transportation Research Board*. Washington, D.C.
[8] U.S. Department of Transportation .2012. Manual on uniform traffic control devices for streets and highway (MUTCD). U.S. Department of Transportation, Washington, DC.
[9] Highway Capacity Manual. HCM. 2010. *Transportation Research Board*. United States of America.
[10] H. Crammer .1946. *Mathematical Methods Of Statistics*. Princeton University Press.
[11] Malaysian Highway Capacity Manual .2011. *Highway Planning Unit*, Ministry of Work Malaysia.
[12] Sun, C, Hou, P. Edara. 2012. A statistical test for 85th And 15th percentile speeds using the asymptotic distribution of sample quantile in: *The 91st Annual Meeting Of The Transportation Research Board Of The National Academies.* Washington D.C.
[13] C. Spiegelman, and T. J. Gates. 2012. Post hoc quantile test for one-way ANOVA using a double bootstrap method. In Transportation Research Record: *Journal of the 14 Transportation Research Board*, No. 1908, Transportation Research Board of the National Academies, Washington, D.C. 19–25.
[14] Brewer et al. 2006. Prevention of age-related dysregulation of calcium dynamics by estrogen in neurons. *Neurobiology of Aging.* 27: 306–317
[15] Ben-Edigbe, J. and Ferguson, N. 2005. Extent of Capacity Loss Resulting from Pavement Distress. *Proceedings of the Institution of Civil Engineers*. Transport 158. 27–332.
[16] Ceulemans, W., Magd, A. W., Kurt De, P., and Geert, W. 2009. Modeling Traffic Flow with Constant Speed using the Galerk in Finite Element Method. *Proceedings of the World Congress on Engineering.* London, U.K., vol II