Determining Level of Service for Multilane Median Opening Zone

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Abstract. The road system is a capital-intensive investment, requiring thorough schematic framework and funding. Roads are built to provide an intrinsic quality of service which satisfies the road users. Roads that provide good services are expected to deliver operational performance that is consistent with their design specifications. Level of service and cumulative percentile speed distribution methods have been used in previous studies to estimate the quality of multilane highway service. Whilst the level of service approach relies on speed/flow curve, the cumulative percentile speed distribution is based solely speed. These estimation methods were used in studies carried out in Johor Malaysia. The aim of the studies is to ascertain the extent of speed reduction caused by midblock U-turn facilities as well as verify which estimation method is more reliable. At selected sites, road segments for both directional flows were divided into free-flow and midblock zones. Traffic volume, speed and vehicle type data for each zone were collected continuously for six weeks. Both estimation methods confirmed that speed reduction would be caused by midblock u-turn facilities. However level of service methods suggested that the quality of service would improve from level F to E or D at midblock zone in spite of speed reduction. Level of service was responding to traffic volume reduction at midblock u-turn facility not travel speed reduction. The studies concluded that since level of service was more responsive to traffic volume reduction than travel speed, it cannot be solely relied upon when assessing the quality of multilane highway service.

1. Introduction

A qualitative assessment of roadway service aims to gather an in-depth understanding of road providers and users perception of quality[2]. Often a central issue in qualitative research is validity of study outcomes. In other to overcome this, quantitative assessment are used to seek empirical support for postulated assertions. It would be different in this study. It is obvious that qualitative assessment would require that the perceptions of both the road providers and users be taken into account whereas, effectiveness would be restricted to differential ratios between competing samples. Therefore it would be correct to postulate that effectiveness not quality of service of road segment with midblock facility is the central theme of the paper. However, since effectiveness and quality of service are often used interchangeably the paper will also use quality of service instead of effectiveness of service.

In the Malaysian Highway Capacity Manual (MHCM 2011) [8], LOS is defined as a qualitative description of operating conditions within a traffic stream based on service measure including travel flow, travel speed, freedom to maneuver safely, driver comfort and convenience. MHCM 2011 definition of LOS was culled from US HCM 2000. In Highway Capacity Manual (HCM 2010), Level
of service (LOS) is a measure used to determine the effectiveness of elements of transportation infrastructure and to analyze highways by categorizing traffic flow with corresponding safe driving conditions. Clearly HCM 2000 definition of LOS has been superseded by HCM 2011 definitions and by default MHCM 2011 that is hinged on HCM 2000. HCM 2000 LOS used familiar letter-grade system, which is denoted by the letters A (free flow traffic) through F (forced or breakdown flow) for characterizing the quality of operations on a variety of traffic facilities. LOS A intended to describe free flow operations, where individual users virtually unaffected by the presence of others in the traffic stream. It implies less travel time, lower operating costs, and greater driving comfort and convenience. At LOS B, the traffic operations are still at the free flow speed but with some influence from other users. At LOS C, the presence of other vehicles in traffic stream begins to restrict maneuverability, but the flow is still remains stable. At this level, the general level of comfort and convenience declines noticeably. LOS D represents speed and maneuvering within the traffic stream are severely restricted and driving comfort and convenience have declined even though flow remains stable. At this LOS, small increases in flow can quickly cause breakdowns. LOS E describes unstable flow at or near capacity levels with poor levels of comfort and convenience. LOS F is the forced traffic flow, where the amount of traffic exceeds the amount that can be served by facility. It is the lowest level of traffic service characterized by stop-and-go waves, poor travel times, low comfort and convenience, and increased accident exposure [3, 4].

As for cumulative percentile speed distributions, they are used when effectiveness of highway service or safety is a main concern. The most important speed percentiles are 85th and 15th percentiles. The 85th percentile is defined as the speed at or below which 85 percent of vehicles moving and it is the primary guide in determining what speeds the majority of safe and reasonable drivers are travelling. In other words, this percentile is normally used in evaluating or recommending posted speed limits as it is assumed to be the highest safe speed for a roadway section. The 15th percentile is the speed at or below which 15 percent of vehicles are travelling. This value is useful in determining the allowable speed limit because the vehicles travelling below this speed tend to obstruct the flow of traffic, thus would increase the potential of accident. However, most of the statistical tests for percentile are not practical to use.

There are several ideal statistical tests for percentiles; however some of researchers choose to neglect statistical analysis because of complex procedure for conducting statistical test. In some studies, the method applied was focuses on averaging percentile instead of ideal methods while some have applied the binomial test for percentiles. Yet others have described their methodology in detail while avoiding the toxic concept of statistical testing. They argue that existing literatures show scanty evidence of sound theory on statistical test for percentiles. Hou et al. [10] proposed statistical test for the 85th and 15th percentiles based on Crammer’s theory of asymptotic distribution of sample quantiles. This theory has been in existence for many years as derived by Crammer [5, 7, 9]. Normality of data is required for accuracy of the quantile test. The proposed statistical test is almost similar with the statistical test used by Knoblauch et al. [1] on 15th percentile pedestrian crossing speeds. However, 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. It was used in this paper. According to Hou et al.[10], t-test for mean differential and asymptotic crammer’s theory test for speed quantile are computed as follows:

$$t = \frac{\bar{x}_A - \bar{x}_B}{\sqrt{\frac{s_A^2}{n_A} + \frac{s_B^2}{n_B}}}$$ (1)

Where:

- $\bar{x}_A$ and $\bar{x}_B$ = means for sample A and B; $n_A$ and $n_B$= sample sizes; $S_A$ and $S_B$ = sample variances
\[ C = \frac{X_{n_x,0.85} - Y_{n_y,0.85}}{1.530 \sqrt{\frac{s_x^2}{n_x} + \frac{s_y^2}{n_y}}} \] (2)

\( X_{n_x,0.85} \) and \( Y_{n_y,0.85} \) = 85th sample quintiles from independent normal distributions
\( n_x \) and \( n_y \) = sample sizes; \( S_x \) and \( S_y \) = sample variances

2. Site Layout and Data Collection

Study site at Skudai, Johor Federal Route 5 has two lanes at each directional traffic flow. Each directional traffic flow has either a diverging or merging section. At the diverging section vehicles enter the midblock facility and exit at the merging section. Each section was divided into free-flow zone (FFZ) and midblock zone (MOZ) as shown below in fig. 1. Note that there is a transition zone (TZ) between the free-flow and midblock zone. The paper is not concerned about traffic flow along this zone. Note also that ATC denotes automatic traffic counters.

Fig. 1 Typical Site Layout

In order to determine where to install the automatic traffic counter, the study assumed that the influence of midblock facility on drivers would be minimal at a distance outside the drivers’ line of sight. Hence Eqn. 1 below was used to determine sight distance from the midblock zone. The sight distance was computed to be 155m which is higher than the 140m prescribed in Malaysian Design Guideline ATJ 8/86 [6, 11]. Traffic data were monitored for six weeks from end of July to mid of October 2013. A total of 1798534 vehicles were recorded; passenger cars accounted for 81.2%, motorcycles 6.8%, Light Good Vehicles 7.4% and heavy vehicles 4.8%. Passenger car equivalent values prescribed in MHCM were used to convert traffic volumes into traffic flows.

\[ SSD = 0.039 \frac{v^2}{f} + 0.278vt \] (3)

Where: \( v \) = design Speed, (km/hr); \( f \) = deceleration rate, (m/s²); \( t \) = brake reaction time, in seconds

3. Findings

The two main criteria considered in MHCM approach are free-flow speed and the flow rate with adjustments made as shown below in Table 1. Fig. 2 illustrates the cumulative speed distribution for free-flow and midblock zones. Note that of peak data were used so as to remove the effect of peak
hour travel in the ensuing outcomes. The cumulative speed distribution has been used to test the effectiveness of highway segments.

Table 1 LOS for Impact site study using MHCM (2011) approach

| MOID | Diverging section | Merging Section |
|------|-------------------|-----------------|
|      | FFZD   | MOZD  | FFZM  | MOZM  |
| Lane width, m | 3.8 | 3.7 | 3.65 | 3.65 |
| shoulder width, m | 0.6 | 0.6 | 0.8 | 0.8 |
| median clearance, m | 0.4 | 0.4 | 0.4 | 0.4 |
| access points density (per km) | 2 | 2 | 2 | 2 |

**Free-Flow Speed**

- Base free-flow Speed, BFFS (km/hr): 100
- Adjustment for lane width, flw: 0
- Adjustment for lateral clearance, Flc: 5.8
- Adjustment for access point density, Fapd: 6.9
- adjustment for lane position, Flp: 0

**Free-Flow Speed,(km/h)**

- Diverging section: 87.3
- Merging Section: 87.3

**Traffic Composition**

- Total Cars, qc(veh/hr): 1892
- Total lorries, ql(veh/hr): 79
- Total trailers, qt(veh/h): 47
- Total Buses, qb: 14
- Total Motorcycles, qm: 144

**Demand volume for the full peak hour, Vi(veh/h)**

- Diverging section: 2176
- Merging Section: 2046

**fc=(qc+1.58ql+1.76qt+1.65qb+0.84qm)/vi**

- Diverging section: 1.031
- Merging Section: 1.0308

**Peak Hour Factor**

- Diverging section: 0.999156
- Merging Section: 0.9958

**Level of Service**

- Flow Rate, vi(pc/h/ln): 2245
- Average Travel Speed, S(km/hr): 70
- Density, D(pc/km/ln): 32.07

| LOS | Diverging section | Merging Section |
|-----|-------------------|-----------------|
|     | FFZD   | MOZD  | FFZM  | MOZM  |
| F   | D      | F     | E     |
The t-test was performed on the percentile speed distribution in order to assess the statistical significance of the difference mean speeds between free-flow and midblock zones for both diverging and merging sections. And C-test was performed to assess the 85th speeds difference for FFZ and MOZ and their results shown below in table 2.

Table 2 Statistical speed Test impact site locations

| Items                        | Hypothesis : H0 : \( \mu_F = \mu_M \) and H1: \( \mu_F > \mu_M \) | Hypothesis : H0 : \( P_{0.85F} = P_{0.85M} \) and H1: \( P_{0.85F} > P_{0.85M} \) |
|------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|
| Zones                        | \( MO_D \)          | \( MO_M \)          | \( MO_D \)          | \( MO_M \)          |
| Mean speed for Free-flow Zone| 60.9                | 32.9                | 71.2                | 46                  |
| Mean Speed for Midblock Opening| 59.7                | 32                  | 70.1                | 45.1                |
| 85%Speed percentile for Free-flow Zone |                |                    | 1.2                  | 0.9                  |
| 85%Speed percentile for Midblock Opening |                |                    | 0.0001              | 0.0053               |
| Change                       | 1.2                | 0.9                 | 1.1                 | 0.9                 |
| p-value                      | 0.0001             | 0.0053              | 0.016               | 0.047               |
| Reject null hypothesis       | Yes                | Yes                 | Yes                 | Yes                 |

4. Discussion
Highway that provides good services is expected to deliver high operational performance which is consistent with its design specification. Direct Midblock U-turn facilities are often constructed as a
cost-effective way of alleviating congestion and traffic conflicts at adjoining intersections. It is accepted that traffic conflicts and congestions are reduced at adjoining multilane highway intersection nevertheless the issue of speed reduction at the midblock zone cannot be overlooked. Based on findings from MHCM LOS estimation methods, at the diverging section travel speed would increase from 70km/h at the free-flow zone to 77km/h at the midblock zone. Traffic volume would decrease from 2245veh/hr to 1650 veh/hr. Traffic density would decrease from 32veh/km at the free-flow zone to 21veh/km at the midblock zone. Level of service would improve from level F at the free-flow zone to level D at the midblock zone. 26.5% decrease in traffic volume at the midblock zone is only an indication of the number of vehicles using the midblock facility. It is clear from outcomes at the diverging section that LOS was responding to decrease in traffic volume not travel speed reduction on which the speed/flow curve is based.

Based on findings from MHCM LOS estimation methods, at the merging section, travel speed remain the same at free-flow and midblock zones. Traffic volume would decrease from 2164 vech/hr to 2005 veh/hr. Traffic density would decrease from 30veh/km at the free-flow zone to 27veh/km at the midblock zone. Level of service would improve from level F at the free-flow zone to level E at the midblock zone. It is clear from outcomes at the merging section that LOS was also responding to decrease in traffic volume not travel speed reduction on which the speed/flow curve is based. Incorrect selection of free-flow speed, incorrect estimation of capacity and/or incorrect estimation of passenger car equivalent values may also be responsible for LOS poor speed responses. It must be mentioned in passing that the criteria used for determining different levels in LOS are yet to explained. With regard to the cumulative percentile speed distribution method, the results in table 2 suggest that there is difference in mean speeds and 85th speed between free-flow zone and midblock zone. At the diverging section, the mean speed at free-flow zone dropped from 61km/h to 60km/h; the 85th percentile speed reduction at the diverging section. However, at the merging section both the mean speed and 85 percentile speeds are reduced.

5. Conclusions

The paper examined two methods often used to assess the quality of multilane highway in Malaysia. In both the MHCM and cumulative speed percentile distribution methods travel speed was relied upon when determining level of service. Whilst the cumulative percentile speed distribution measures effectiveness of service by comparing ratios, MHCM uses speed/flow curve without explanation on how criteria table can be drawn. Cumulative percentile speed distribution method affirmed that midblock facility would cause travel speed reduction without indicating the extent; whereas MHCM indicated the extent of level of service based on traffic volume reduction at the midblock facility. The paper concluded that cumulative percentile speed distribution could be used as a verification check on MHCM LOS estimation instead of depending solely on either estimation method.

References

[1] R.L. Knoblauch, M.T. Pietrucha, and M. Nitzberg, “Field studies of pedestrian walking speed and start-up time,” Transportation Research Board of the National Academies, Washington, D.C., pp. 27–38, 2006.
[2] Quality/Level of Service Handbook. State of FLORIDA Department of Transportation. 2013
[3] Adolf, D., May. Traffic flow fundamentals. UCLA, Berkeley, Prentice Hall.; p. 338, 1990
[4] Maerivoet, S. and B. De Moor, Traffic flow theory. arXiv preprint physics/0507126, 2008..
[5] H. Crammer, Mathematical methods of statistics. Princeton University Press, 1946.
[6] Arahan Teknik A Guide on Geometric Design of Roads, PWD,. Ministry of Works, Malaysia 1987
[7] Landis, B.W., et al., Modeling the roadside walking environment: pedestrian level of service. Transportation Research Record: Journal of the Transportation Research Board,. 1773(1): p. 82-88. 2001
[8] Malaysian Highway Capacity Manual. Ministry of Works, Malaysia, 2011.
[9] Ben-Edigbe, J., Assessment of speed-flow-density functions under adverse pavement condition. International Journal of Sustainable Development and Planning 1743-7601.2010
[10] Hou, Y., C. Sun, and P. Edara, Statistical test for 85th and 15th percentile speeds with asymptotic distribution of sample quantiles. Journal of the Transportation Research Board, 2279(1): p. 47-53.2012
[11] IRDA Road layout Design Blueprint for Iskandar Malaysia, Iskandar Development Regional Authority Johor Bahru, Malaysia. p. 15.2011