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SPATIAL EVALUATION OF SPEED-FLOW-GEOMETRY RELATIONSHIP ON TWO-LANE RURAL HIGHWAYS

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ABSTRACT
The mean travel speed of drivers on uninterrupted flow facilities such as two-lane rural highways is deemed as good performance indicator for the subject road class; as the variable relates well with user perception. However, the operating conditions on two-lane roads relating to travel speed is different from those on other types of facilities, as fast moving vehicles in either direction are usually impeded by slower moving ones in the same travel direction and also facing oncoming traffic in the opposing lane. Thus, impeded vehicles may be compelled to travel at lower speeds than desired; particularly, in the absence of sufficient sight distance and permissible gap in the opposing traffic stream, being the appropriate lane used for passing maneuvers. This implies that the operating speed on two-lane highways substantially depends on the level of traffic flow and perhaps, its composition as well as the roadway geometric features. This paper examines the effects of traffic level, composition and road geometric features on the operating speed on two-lane highways based on a spatial approach. An empirical model relating mean travel speed to traffic flow parameters and highway geometric features was derived for prediction of mean travel speed on two-lane rural highways based on easily observable variables.

Keywords: speed-flow-geometry relationship, two-lane highways, operating condition, spatial approach.

INTRODUCTION
Two-lane rural highways constitute a significant proportion of roads in many countries. This type of facility is well known for high vehicular interactions in both traffic directions as only two opposing lanes are used for vehicular movements. The effect of the interactions among the vehicles, traffic level and composition as well as the road geometric features made the operating conditions on this class of road relating to mean travel speed different from that on other roads classes. On two-lane roads, fast moving vehicles are usually impeded by slower moving ones in the same travel direction and equally facing oncoming vehicles in the opposing lane. Consequently, impeded vehicles may be forced to travel at lower speeds than their desired.

The decline in the travel speed tends to be more with increase in traffic volume; particularly, for streams with high proportion of heavy vehicles. Because, presence of heavy vehicles within a traffic stream reduces speed and in turn cause a reduction in capacity due to their size and lower desired speed [1]. More so, restricted passing opportunities along the segment result in higher effect of the slow moving vehicles [2] as passing maneuver is performed using the opposing traffic lane subject to availability of sufficient sight distance and acceptable gap in the opposing stream. This implies that the mean travel speed on two-lane highways considerably depends on the amount of traffic flow and perhaps, its composition as well as the characteristics of the highway geometry.

The mean or average travel speed (ATS) of traffic stream is used and deemed as good performance indicator for two-lane highways, as the variable relates well with user perception. Further, ATS is one of the service measures used in evaluating the operational performance of two-lane highways upon which the operating condition can be described and an appropriate level-of-service (LOS) be assigned. Despite the significance of ATS in the LOS analysis of two-lane highways and its variability with changes in traffic flow level and roadway geometric features over extended segment, previous studies regarding the effect of traffic flow and road geometric features [3-9] were conducted based on spot observations. This approach may not accurately reflect the effects of variations in traffic level and geometric features along the segment. Hence, the impacts of traffic level, composition and variations of roadway geometric features over extended segment were not given the desired attention.

This paper examines the impacts of variations in traffic level, composition and roadway geometric variables on mean travel speed on two-lane highways based on spatial observation.

METHODOLOGY
In the course of this investigation, the required data for the work were fully gathered from field observation. Data relating to traffic flow and roadway geometric parameters on various segments of two-lane highways with varying characteristics were sampled. A total number of twenty directional segments drawn from Johor and Pahang States, Malaysia, were utilized for the data sampling. Table 1 presents the list of the study sites and number of segments used at each of the locations.

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Table-1. Study sites and number of segments.

Road	No. of segments
Pekan Nanas – Pontian	2
Pontian – Kukup	2
Kota Tinggi Junction – Desaru Junction	2
Tangkak – Jementah	2
Yong Peng – Segamat	4
Kota Tinggi – Jemaluang	2
Segamat – Muadzam Shah	4
Bentong – Raub	2

Data collection

Basically, two categories of data sets influencing mean travel speed on two-lane highways were collected for the purpose of the current study. Firstly, traffic flow related parameters were collected using a moving car observer (MCO) method being the sole (a part from vehicle plate matching with disadvantage of using stationary observers at both the entry and exit of the study section) and most appropriate technique for measuring traffic flow parameters over extended segments of roads [10]. The MCO method allows an analyst to measure travel time, flow rate, and speed over a segment of roadway by conducting series of test runs; and the approach has been established as quite efficient and practical in estimating these variables [11]. All data relating to traffic flow parameters were collected during daylight period and good weather condition in order to avoid the effects of factors influencing the measured variables; especially, those affecting speed [12-16]. Secondly, information on roadway geometric variables were observed separately. These variables include lane width (Lw), shoulder width (SHw), proportion of no-passing zones (NPZ), and access point density (APD). The lane and shoulder widths were measured manually using measuring tape. The proportion of no-passing zones along the segment was measured using a vehicle's odometer, whereas, the access points were counted based on visual observation from which the access points density (APD) was estimated accordingly.

As stated earlier, the MCO method was employed for the data collection. A segment length of 3.5 km was demarcated on each directional course for performing the moving observation test runs. This length is deemed sufficient enough for space-based measurement of mean travel speed [10, 17]. The method was applied for estimating the traffic flow parameters in accordance with the guidelines provided in the Manual of Transportation Engineering Studies (MTES) [17] on the basis of floating car technique. In this technique, the driver of the test car drives within the traffic stream under study and passes as many vehicles as pass the test car over the road section as passing opportunities permit. In this way, the test vehicle estimates the performance of an average vehicle within the traffic stream and is usually applied only on two-lane highways [18]. Six (6) test runs were made in each traffic direction to observe and record the required information; a number established to be sufficient for reliable and unbiased estimates of the measured traffic flow variables [19]. Two data sets were observed from each site in order to acquire the sampled variables under different operating conditions.

A passenger car equipped with video recording system known as Video Velocity Box (VBox) was used as the test vehicle. VBox is an on-board data acquisition system used for real time traffic events recording. It basically comprises of a VBox video recorder, 10Hz GPS data logger with an external antenna, forward facing camera, secure digital memory card (SD card), and a microphone. To collect the required information, the VBox is connected to the test car and powered by cigar plug. The camera attached to the system and fixed on the test car's front windscreen records the traffic events of the road under study. The system automatically stores the recorded traffic events onto the memory card inserted into the VBox. The recorded traffic events is later uploaded and played back in a computer to extract the required variables. Figure-1 (a and b) shows the VBox, its accessories, and installation on the test car.

(a)

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VBox system connected to the test car

Camera mounting GPS antenna mounting

(b)

Figure-1. VBox, accessories, and installation.

In the course of the data extraction, the directional hourly flow rates were derived from traffic flow variables that are easily obtainable from the video records. These are; travel time taken to traverse the study section (*T*), number of vehicles opposing test car's travel direction while traveling with traffic stream (*M*), number of vehicles overtaking the test car in the same travel direction (*O*), and numbers of vehicles passed by the test vehicle in the same travel direction (*P*). The numbers of vehicles (M, O, and P) were extracted based on classified count with the aid of *Traffic Analysis System* (TAS) software, version 1.0.0.11. TAS is a video-based traffic data processing system used for extraction of classified traffic volume and time headways from field video recorded data by simply uploading the video unto the software environment and playback.

During the traffic volume extraction, vehicles were classified as light, medium, heavy, bus, and motorcycles. These classes were coded in the TAS with five (5) distinct icons. Each class of vehicle is counted by clicking on the appropriate icon from TAS dialogue box or use of shortcut key from the computer keyboard. The five icons are provided for each of the three categories of vehicles considered during the extraction; *M*, *O*, and *P* corresponding to opposing, overtaking test car, and passed by test car, respectively. As the video plays and counting progresses, the software continuously displays the total number of vehicles counted and speed of the test car at any moment as shown in Figure-2.

Figure-2. Extraction of traffic volume using TAS

Immediately the video playback is completed, the TAS software automatically displayed the summary of the total number of vehicles for each of the variables *M*, *O*, and *P* denoted by opposing, overtaking, and passed, respectively, as shown in Figure-3.

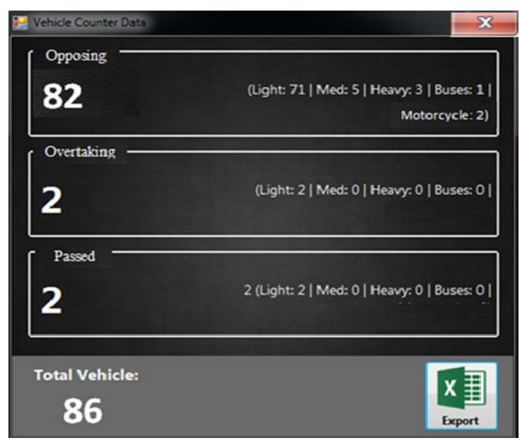

Figure-3. Retrieved traffic volume from TAS

From the classified count for each directional segment, the proportions of heavy vehicles and motorcycles were respectively determined relative to the total number of observed vehicles for each of the directions and expressed as percentage.

Equations. (1) and (2) were applied to determine the equivalent hourly flow rates for the two streams, respectively.

$$q_n = \frac{60(M_s + O_n - P_n)}{(T_s + T_n)} \quad (1)$$

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$$q_s = \frac{60(M_n + O_s - P_s)}{(T_n + T_s)} \quad (2)$$

Where, q is the directional hourly flow rate, M is number of opposing vehicles to the test car's direction of travel, O is the number of vehicles overtaking the test car, P is the number of vehicles passed by the test car, T is the travel time taken to traverse study segment. Travel time was measured in minutes, and the subscripts n and s refer to northbound and southbound traffic directions, respectively.

The average travel times for the north and south-bounds directions were determined using Equations. (3) and (4), respectively.

$$T_{nave} = T_n - \left\{ \frac{60(O_n - P_n)}{q_n} \right\} \quad (3)$$

$$T_{save} = T_s - \left\{ \frac{60(O_s - P_s)}{q_s} \right\} \quad (4)$$

Similarly, the average travel speeds for the north and south-bounds were estimated from Equations. (5) and (6), respectively.

$$ATS_n = \frac{60(l)}{T_{nave}} \quad (5)$$

$$ATS_s = \frac{60(l)}{T_{save}} \quad (6)$$

Where l is the length of the test segment (km)

Speed-flow-geometry relationship

To explicitly evaluate the effects of variations in traffic level, composition and road geometric features on ATS on two-lane rural highways, a mathematical relationship was developed between speed as response variable and four (4) variables for each of traffic flow and road geometric features as influencing factors. The traffic flow variables used are; flow rate in the analysis direction *(q)*, proportion of heavy vehicles *(Hv)*, proportion of motorcycles *(Mc)*, opposing flow rate (q_o) while the geometric features are lane width *(Lw)*, shoulder width *(SHw)*, percent of no-passing zones *(NPZ)* and access points density *(APD)*. The variables considered as independent in this study were established as speed influencing factors on two-lane highways [7, 20, 21].

The field observed values of both the response and influencing variables were analyzed using SPSS version 20.0. A multiple linear regression approach was used in the analysis through which a relationship was developed between the variables.

RESULTS AND DISCUSSIONS

Segments geometric variables

Table 2 presents the mean estimates of the segments geometric features used in this study. Entries in Table 2 shows that the segments used for the data collection vary in terms of geometric characteristics. Their selection was meant to investigate the effects of the variations of roads geometry on the mean travel speed.

Table 2. Mean values of segments geometric features.

Segments No.	L_w [m]	SH_w [m]	NPZ [%]	APD [No. of access points / km]
1	3.73	1.39	25.71	0.57
2	3.58	1.83	32.86	0.57
3	3.06	0.24	33.71	0.57
4	3.11	0.30	33.71	0.57
5	3.50	0.20	87.14	0.00
6	3.47	0.20	80.00	0.00
7	2.75	0.00	87.71	0.00
8	2.70	0.00	92.86	0.00
9	3.42	2.00	54.29	0.00
10	3.42	2.00	54.29	0.00
11	3.45	2.01	0.00	0.26
12	3.45	2.03	0.00	0.26
13	3.18	0.10	47.86	0.00
14	3.24	0.10	50.00	0.00
15	3.20	0.10	28.86	0.26
16	3.16	0.10	28.86	0.26
17	3.45	1.95	22.86	0.00
18	3.65	2.08	22.86	0.00
19	3.74	2.10	64.00	0.26
20	3.90	1.83	68.29	0.26

Traffic flow variables

Traffic flow variables comprising of hourly flow rate in the analysis direction *(q)* derived from Equations 1 and 2, proportions of heavy vehicles *(Hv)* and motorcycles *(Mc)* in the analysis direction deduced from classified vehicles count, and opposing flow rate (q_o) were the only parameters considered as having influence on speed. The selection of the variables was based on factors influencing speed on roadway section [1, 20, 21].

Development of speed-flow-geometry relationship

An empirical model relating speed as response variable to eight traffic flow and geometric variables was derived for possible prediction of average travel speed on two-lane rural highways. Multiple linear regression analysis was employed in developing the relationship. Equation (7) shows the general form of the model.

$$SPD = \beta_o + \beta_1 q + \beta_2 Hv + \beta_3 Mc + \beta_4 q_o + \beta_5 Lw + \beta_6 SHw + \beta_7 NPZ + \beta_8 APD \quad (7)$$

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Where, *SPD, q, Hv, Mc,* q_o*, Lw, SHw, NPZ* and *APD* are as defined in the preceding sections, β_o is constant of regression, and $\beta_1, \beta_2, \beta_3, \ldots\ldots\ldots, \beta_8$ are coefficients of regression.

In the course of developing the model, a total of forty data points were used for each of the variables involved. The resulting model relating the response variable (SPD) to the influencing traffic flow and roadway geometric variables is given by Equation (8).

$$SPD = 80.359 - 0.014q - 0.584Hv - 0.230Mc - 0.007q_o \\ +5.319Lw + 0.922SHw - 0.111NPZ - 0.885APD. \quad (8)$$

The details of the regression modeling output are presented in Tables-3, 4 and 5.

Table-3. Model summary.

Model	R	R Square	Adj. R Square	Std. Error of the Estimate
1	.676[a]	.456	.316	5.415

a. Predictors: (Constant), q, Hv, Mc, q_o, Lw, SHw, NPZ, APD

Table-4. ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	763.038	8	95.380	3.253	.008[b]
	Residual	909.032	31	29.324		
	Total	1672.069	39			

a. Dependent Variable: SPD
b. Predictors: (Constant), q, Hv, Mc, q_o, Lw, SHw, NPZ, APD

Table-5. Coefficients[a]

Model		Unstandardized Coefficients		Std. Coeffs.	t	Sig.
		B	Std. Error	Beta		
1	Constant	80.359	22.224		3.616	.001
	q	-.014	.008	-.463	-1.787	.084
	Hv	-.584	.273	-.517	-2.143	.040
	Mc	-.230	.329	-.140	-.699	.490
	q_o	-.007	.008	-.230	-.884	.383
	Lw	5.319	6.708	.250	.793	.434
	SHw	.922	1.647	-.129	-.560	.579
	NPZ	-.111	.046	-.462	-2.412	.022
	APD	-.885	6.768	-.030	-.131	.897

Dependent Variable: SPD

The summary presented in Table 3 shows the multiple correlation in which the coefficient of multiple correlation (R = 0.676) between the response and the influencing variables for the model appears reasonable. However, the value of the coefficient of determination (R^2) suggests that the influencing variables account for only an approximate of 46% in the variability of the mean travel speed on two-lane highways. Even though, the coefficient of determination (R^2) does not reveal a strong enough relationship between the response variable and the predictors; however, the value of the test of significant (P = 0.008) for the model from analysis of variance (ANOVA) shown in Table 4 suggests that the influencing variables are significantly related to the response variable. This is evidently confirmed by the significance test result, in which the P – value was found to be 0.008 (P << 0.05).

The resulting model coefficients presented in Table 5 indicate the effect of each of the predictors on the response variable. The output demonstrates that an increase in each of lane and shoulder widths cause corresponding increase in mean travel speed; with lane width having more impact than shoulder width. The implication of sufficient lane and shoulder widths is that they both provide for sufficient sight distance, ease of movements within the stream, which in turn results in higher travel speed. While an increase in each of all the other variables causes a decrease in the mean travel speed within the traffic stream.

Among the traffic parameters with a reduction effect on ATS, the proportion of heavy vehicles in the traffic stream tends to be the most significant one. This could be due to the lower travel speed associated with heavy vehicles as a result of their low performance capacity compared with that of passenger cars. This finding is consistent with the effect of heavy vehicles reported in other sources [1, 7, 20-22]. The significance of this variable is clearly indicated by its low p-value (0.040) which falls on the lower side of 0.05 as shown in Table 5. However, the proportion of motorcycles in the stream seems to be not a significant variable in the model as its p-value (0.490) is much greater than 0.05. This could be attributed to the traffic characteristics on rural highways; particularly, relating to composition in which motorcycles contribute a little portion of the traffic unlike in urban roads where the motorcycles constitute a considerable proportion of the traffic.

Likewise, among the road geometric variables having a reduction effect on mean travel speed, the percent of no-passing zone appears as the most significant variable among all, as demonstrated by its p-value of 0.022 which is smaller than 0.05. The implication of no-passing zones as the most significant variable is that an increase in its proportion would result in considerable reduction of passing opportunities. Generally, a reduction in overtaking opportunities on two-lane highways causes formation of platoons in the traffic stream with attendant decrease in operational performance [23] of which speed is one of the most affected variables. The effect demonstrated by the proportion of no-passing zones on mean travel speed is well consistent with the assertions in many existing literatures [24-29] regarding its significance in operational performance and capacity analyses of two-lane highways.

CONCLUSIONS

This paper examined the effects of variations in traffic flow and compositions, and roadway geometric features on the mean travel speed on two-lane rural highways based on spatial observation. In the course of the investigation, traffic flow and roadway geometric variables influencing mean travel speed on two-lane highways were sampled on various segments under varying operating conditions. These variables were subsequently used to derive an empirical speed-flow-geometry relationship.

From the relationship developed, it was discovered that the influencing traffic flow and highway geometric variables account for only an approximate of 46% in the variability of mean travel speed on two-lane highways. This suggests that the combined impact of the influencing variables on the mean travel speed seems not strong enough. In spite of the weak combined effect of the influencing variables on the mean travel speed, it was however, discovered that the formers are significantly related to the latter as indicated by the result of test of significance at $\alpha = 0.05$. It was also discovered that among the traffic flow variables influencing mean travel speed, the proportion of heavy vehicles in traffic stream is the most significant parameter whose increase results in reduction of the response variable. Whereas the proportion of motorcycles in traffic stream seems not be a significant variable. Similarly, the proportion of no-passing zones along a roadway segment was found to be the most significant highway geometric variable with a significant reduction effect on the response variable.

The trend indicated by the results from the current investigation could be attributed to the limited data used in the analysis, as the findings presented are based on the preliminary evaluation. Hence, more data samples would be required to improve the reliability on the relationship derived and validate the findings.

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REFERENCES

[1] Parker, M. 1996. The effect of heavy goods vehicles and following behaviour on capacity at motorway roadwork sites. Traffic engineering & control. 37(9): 524-531.

[2] Al-Kaisy, A. and Durbin, C. 2008. Evaluating new methodologies for estimating performance on two-lane highways. Canadian Journal of Civil Engineering, NRC Research Press. 35(8): 777-785.

[3] Andueza, P. J. 2000. Mathematical models of vehicular speed on mountain roads. Transportation Research Record: Journal of the Transportation Research Board. 1701(1): 104-110.

[4] Glennon, J. C., Neuman, T. R. and Leisch, J. E. 1983. Safety and Operational Considerations for Design of Rural Highway Curves - Final Report, Federal Highway Administration, Washington, D.C.

[5] Gonet, H. M. 2007. Design Consistency of Horizontal Alignments on Two-Lane Trunk Roads. Unpublished Doctoral Thesis, Addis Ababa University.

[6] Khairi, S., Abbas, S., Akram, M. and Rohani, I. 2012. An investigation of the 85th percentile operating speed models on horizontal and vertical alignments for two-lane rural highways: A case study. The Institution of Engineers, Malaysia. 73(1): 31-40.

[7] Lamm, R. and Choueiri, E. M. 1987. Recommendations for evaluating horizontal design consistency based on investigations in the state of New York: Transportation Research Record, Washington, D.C.

[8] Misaghi, P. and Hassan, Y. 2005. Modeling operating speed and speed differential on two-lane rural roads. Journal of Transportation Engineering. 131(6): 408-418.

[9] Trentin, L. C., Kabbach Jr, F. I. and Suzuki, C. Y. 2010. Analysis of Speed Prediction for Design Consistency of Two-Lane Rural Highways. Proceedings of the 4th International Symposium on Highway Geometric Design.

[10] Lee, B. H. and Brocklebank, P. J. 1993. Speed/Flow/Geometry Relationships for Rural Single carriageway Roads. TRRL Contractor Report No.319, Crowthorne.

[11] Wardrop, J. G. and Charlesworth, G. 1954. A Method of Estimating Speed and Flow of Traffic from a Moving Vehicle. ICE Proceedings: Engineering Divisions. 3(1): 158-171.

[12] Brilon, W. and Ponzlet, M. 1996. Variability of speed-flow relationships on German autobahns. Transportation Research Record: Journal of the Transportation Research Board. 1555(1): 91-98.

[13] Ibrahim, A. T. and Hall, F. L. 1994. Effect of adverse weather conditions on speed-flow-occupancy relationships.

[14] Kyte, M., Khatib, Z., Shannon, P. and Kitchener, F. 2000. Effect of environmental factors on free-flow speed. U. S. National Academy of Sciences Transportation Research Board.

[15] Medina, A. M. F. and Tarko, A. P. 2005. Speed factors on two-lane rural highways in free-flow conditions. Transportation Research Record: Journal of the Transportation Research Board. 1912(1): 39-46.

[16] Yagar, S. and Van Aerde, M. 1983. Geometric and environmental effects on speeds of 2-lane highways. Transportation Research Part A: General. 17(4): 315-325.

VOL. 11, NO. 20, OCTOBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

[17] Robbertson, H. D. and Findley, D. J. 2010. Manual of Transportation Engineering Studies, 2nd ed.: Institute of Transportation Engineers.

[18] Roger, P. R., Elena, S. P. and William, R. S. 2004. Traffic Engineering, 3rd Ed., New Jersey: Pearson Prentice Hall.

[19] Mortimer, W. 1957. Moving Vehicle Method for Estimating Traffic Volumes and Speeds. Highway Research Board Bulletin 156, Highway Research Board, Washington DC.

[20] HPU. 2011. Malaysian Highway Capacity Manual: Highway Planning Unit, Ministry of Works, Malaysia.

[21] TRB. 2010. Highway Capacity Manual, 5th Ed.: National Research Council, Washington, D.C.

[22] Al-Kaisy, A. and Karjala, S. 2008. Indicators of Performance on Two-Lane Rural Highways: Empirical Investigation. Transportation Research Record: Journal of the Transportation Research Board. 2071(1): 87-97.

[23] Farah, H. and Toledo, T. 2010. Passing behavior on Two-lane Highways.Transportation Research Part F: Traffic Psychology and Behaviour, 13(6), 355-364.

[24] Moreno, A. T., Llorca, C., García, A. and Pérez-Zuriaga, A.-M. 2013. Operational Effectiveness of Passing Zones Depending on Length and Traffic Volume. Transportation Research Record: Journal of the Transportation Research Board. 2395(1): 57-65.

[25] Llorca, C. and Garcia, A. 2011. Evaluation of passing process on two-lane rural highways in Spain with new methodology based on video data. Transportation Research Record: Journal of the Transportation Research Board. (2262): 42-51.

[26] Aashto. 2001. A Policy on Geometric Design of Highways and Streets, 4th ed.: American Association of State Highway and Transportation Officials, Washington D. C.

[27] Harwood, D. W. and Sun, C. 2008. Passing sight distance criteria, Vol. 605: Transportation Research Board, Washington, D. C.

[28] Mwesige, G., Farah, H., Bagampadde, U. and Koutsopoulos, H. N. 2014. Capacity and Safety of Passing Zones on Two-Lane Rural Highways: A Review of Theory and Practice. Journal of Traffic and Logistics Engineering. 2(2): 156-163.

[29] Hassan, Y., Easa, S. M. and El Halim, A. O. A. 1996. Passing sight distance on two-lane highways: Review and revision. Transportation Research Part A: Policy and Practice. 30(6): 453-467.