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Development of parking estimation on rest service area in Malaysia

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Abstract. Roadside rest area also known as rest service area (RSA) is one of the important facilities for expressway users. However, designing an efficient RSA is a challenge to most transport planners since it needs the information on potential and existing traffic volumes to estimate the parking demand and design of rest area facilities are also critical. Planning for these facilities is crucial in order to avoid over- design or under design which will affect the cost in the future for capacity issues. Therefore, this study is to determine the parking occupancy and develop parking estimation on RSA. The study was conducted on 10 sites of RSA along E1 and E2 expressway (Southern-Northern Expressway). The data collection for this study was conducted during the mid-week. Simple count observation and indirect method were used to determine the parking occupancy and traffic characteristics on RSA. The results show the peaking characteristics of space occupied, whereas the highest demand exhibited was during the midday period. The estimation model was found that traffic and site characteristics can be explained to estimate parking occupancy on RSA. The estimation result seems to be applicable.

1. Introduction

Roadside rest area also known as rest service area (RSA) is one of the important components to facilitate highway users. The facilities services may be vital even if there is a fairly low demand for it. On the other hand, RSAs may attract highway users every day because of its convenient place to stop by. Planning for this facilities is crucial; over- design of a facility will result in wasteful use of limited financial resources, whereas underdesign of a facility will likely result in the need to expend greater financial resources in the future to address capacity issues. As a result, highway planners are faced with the challenge of balancing their designs to meet present needs while also accommodating future growth in an adequate manner, thus demanding accurate estimates of vehicle counts to avoid improper rest area design. In summary, information on potential and existing traffic volumes are critical to the estimation of parking needs and design of rest area facilities.

Many research had been conducted on parking needs for the facilities. Evaluation study of significant parameters related to parking occupancy was conducted [1]. Authors found that the parking occupancy varies with the time of the day and day of the week. The analysis showed that there were significant correlations between the vehicular volume on major road and facilities gross floor area to parking occupancy on RSA. One of the factors influencing the parking occupancy is the prevailing vehicular volume on the major roads. A few studies were able to draw on a conclusion based on the results which showed a positive relationship between RSA spacing and fatigue-related crashes [2]. The frequency of crashes due to fatigue significantly increased at distances of more than 30miles (50km) from the RSA

[3-5]. A few researchers then identified that assumption on time-of-day dimension influenced by parking activities [6-9]. Authors emphasized the importance of time-dependent analysis on parking and travel choice model. In fact, the entering volumes of roadside rest areas and turn-in rates for travellers tended to be higher during the day of week and time of day [10]. Furthermore, most of the research studies represent site characteristic as an explanatory variable to determine parking occupancy rates on land use types [1, 11-21]. As such, it is important to understand and quantify the factors affecting RSA demand in order to most efficiently design these facilities. As described, several parameters can be related to previous works to give an idea to establish parking occupancy estimation on RSA. In local studies, only a single factor was studied related to parking occupancy on RSA [1-2] which is the volume on the main-line traffic attribute to the parking demand on RSA. It is believed that other factors could contribute to parking occupancy for RSA.

The values of RSA certainly should be considered to have higher potential to attract highway users and therefore to keep its potential, one of the criteria to look forward to is site capacity. The site capacity consists of utilities and parking areas. These criteria may be influenced by two major components which are traffic characteristics and site characteristics. Therefore, this work focuses only on the parking occupancy which is generated by the highway users. Furthermore, the development of parking estimation will be carried out to discover the applicability of the estimation model from the inferences criteria.

2. Methodology
Firstly, this work was conducted on 10 sites of RSA along E1 and E2 expressway (Southern-Northern Expressway). .The expressway was indicated as the oldest and well-established expressway located in Peninsular Malaysia. The expressway was designed by Malaysia Highway Authority (Lembaga Lebuhraya Malaysia, LLM) and it is handled by PLUS Malaysia Berhad concession. The surveys were done during mid-week (Tuesday or Wednesday) without any disturbance from seasonal effects (public holidays, festive season and school holidays) which included a week before and after.

2.1. Data Collection
This work is consist of two main phases. The first phase is the parked vehicles observations. Simple counts parked vehicles had been conducted throughout the day (9:00 a.m. to 17:00 p.m.) to perceived variations of the data. The count was made continuously during the study period with the time interval 15 or 20-minutes (depends on the compound activities). Non-designated parked vehicles were included for the parking observations. At the same time, "indirect method" was chosen by using a digital video camera to capture the vehicular volume on a major road (expressway) and vehicles entering the compound. So that the parked vehicles observations while capturing the traffic volumes can be done simultaneously. Figure 1 shows the example for the placement of the digital video camera and its viewing angle. The parameters indicator will be carried out on continuous traffic counts including vehicular volume on major road, trips-in volume (entering vehicular) and composition traffic volume (light and heavy vehicles ratios) throughout the study period. Site characteristics were determined while conducting the survey works.

Figure 1. Placement and viewing angle for the digital video camera.

Then, the data aggregation for counted data which had been made by choosing the highest parked vehicle within the observed hour as representative as peak parking occupancy as stated in ITE analysis procedure [22]. Parking occupancy is defined as the percentage of occupied spaces and is typically examined on hour-by-hour basis. The second phase, parking occupancy will be plotted for each site to determine the pattern of parking behaviour across a period of time. Once the parking trends are presented, statistical estimation can be drawn between measured parameters and parking occupancy.

2.2. Data analysis
As described, the development of parking occupancy estimation by using the traditional method of estimation which is ordinary least squared (OLS) method also known as multiple linear regression. This method perhaps is the most common statistical method used to obtained parameter estimates. The most commonly used methods in selecting the explanatory variables to be included in the regression model are the forward selection approach and the backward elimination approach. For this study, backward elimination process was chosen for estimation analysis. Assumptions have been made that a linear relationship exists between the dependent variable which is parking occupancy and the independent variables (parameters). Let y_i be the ith observation of the response variable (i = 1, 2, …, n), the linear relationship is commonly expressed as shown in equation (1):

$$Y_i = \beta_{n \times p} \, X_{p \times 1} + \varepsilon_{n \times 1} \tag{1}$$

where:
Y = the column vector for dependent variable (parking occupancy);
X = referred to as the design matrix, containing the set of independent variables (traffic characteristics and sites characteristics);
β = column vector of regression parameters to be estimated; and
ε = column vector that contains the random errors.

The purpose of OLS is to minimize the total sum of squares, defined as the difference between the predicted values and the observed data. There are five assumptions associated with the OLS estimator. The assumptions are:

i. The dependent variable is linearly associated with the independent variable(s) plus an error term.
ii. The error term has a zero expected value and is normally distributed and uncorrelated with the independent variables
iii. The error terms have equal variances and are not correlated with one another.
iv. The observations on the independent variables are fixed in repeated samples.
v. The number of observations is greater than the number of independent variables and the independent variables are not correlated.

Through this review from previous research, it can relate that there are several factors which can influence parking occupancy in RSA as shown in Table 1.

Table 1. Traffic and site characteristics criteria and related parameters.

Traffic characteristics	Site characteristics	Time of day
• Total vehicular volume on major roads • Turn-in rate • Vehicles composition ratio	• Gross floor area • Next distance interchange • Number of a petrol station • People capacity(number of sits of dining table) • Distance travelled from previous RSA	• Morning period (9:00 am – 9:59 am) • Midday period (10:00 am – 14:59 pm) • Evening Period (15:00 pm – 17:59 pm)

3. Results and discussion

3.1. Parking occupancy across time of day for each site

The data of parking occupancy was plotted for each study site to seek variations of trends for parking occupancy on each site. Figure 2 illustrates parking occupancy across time of day for each site. Most of the sites demonstrate the highest parking occupied during midday (12:00-14:00) and some of them in the evening (15:00-17:00) time period. In certain ways, the patterns were examined to ascertain peaking characteristics. This peaking phenomenon illustrated the demand on RSA tended to peak from morning to midday period and literally remain constant from 12:00 p.m to 14:00 p.m and then declined gradually through the evening period. To summarize, in general, on weekdays, peaked hourly parked vehicles are reached by midday and continue, more or less level, until evening period.

The findings of the present work were found that the peak period of parking demand is exhibited in the midday time period [1-2]. Likewise, this study also consistently supported and found that percentage vehicles entering RSA remained high level in the early afternoon and gradually decreased later which can be concluded that the demand is higher during midday time period [23]. Further analysis in Figure 2 showed that there is a higher value for the standard deviation for light vehicles compare to heavy vehicles. Comparing the two results, it can be seen that heavy vehicles contributed less demand or vary. Generally, parked vehicles for light vehicles can be suggested that there is a relatively high degree of variation of demand in RSA. This is mainly because the parking demand in RSA varies throughout the day for each site and also different sites demonstrate a varying trend.
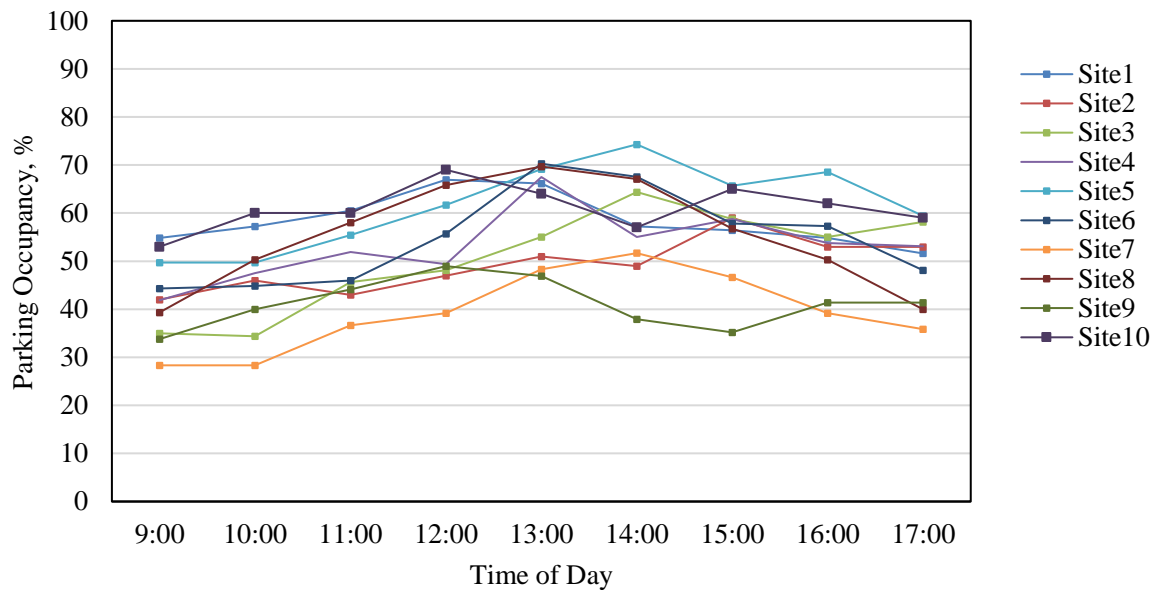
Figure 2. Parking occupancy across time of day for each site.

Further analysis of parking occupancy estimation was made to clarify the factors that influence the demand for RSA. In-depth analysis was conducted using statistical software which is SPSS. An initial OLS regression model was estimated using a backward elimination procedure. A correlation matrix was computed to verify that any two independent variables were not significantly correlated. Table 2 shows the descriptions of the significant variables, including parking occupancy. In addition, variance inflation factors (VIF) were calculated to detect multicollinearity. The correlation matrix indicated low correlation levels among the independent variables included in the OLS regression model (less than an absolute value of 0.4) and the VIF values were all less than 10. Both methods indicated that no collinear variables were present in the model specification. The results of the OLS regression model are summarized in Table 3. The result of R^2 value is 0.764 respectively. The results of the regression indicated the 7 predictors explained 76.4% of variance (F $(7, 82)$ = 37.976, $p < 0.05$). All regresses estimated parking occupancy was found significant with the confidence level of 95%.

In summary, the R^2 value produced by the model indicated that the variables were strongly related to parking demand in RSA. Although the *p*-values of many coefficients were significant, it is found that only one variable did display a noticeable association with parking demand in RSA. In this case, the "people capacity" variable in the model indicated that the opposite was true, as a decrease in parking occupancy is indicated. It may cause by the variation of parking demand on each different location of RSA. In light of the confounding result of the regression analysis, other variables such as the different location of RSA(low and high-volume interstate expressway), traffic mix by expressway users type (local and nonlocal users), trip purpose, and trip length may be important in explaining the variability parking demand in RSA.

Table 2. Descriptions of model estimation for parking occupancy.

Abbreviations	Parameters	Descriptions
*PU	Parking Occupancy	Percentage, %
TVV	Total Vehicular Volume	Vehicles/hour, $\frac{TVV}{hour}$
Hv/Lv$_{ratio}$	Heavy and Light Vehicles Ratio	$\frac{HvV_n}{LvV_n}$
PvRSA	Distance between previous RSA	Distance, kilometer, Km
**NxtItrcg	Distance to the next interchange from the RSA**	Distance < 10km = "0"; Distance > 10km = "1"
**D$_{pstn}$	Number of Petrol Station provided in RSA	P. Station < 2 = "0" P.Station > 2 = "1"
P.C.	People capacity (no. of sits on dining table provided)	Scale Value
**D$_{midday}$	Midday between 10:00 am to 14:59pm	10:00am to 14:59 pm= "1" or Else = "0"

Notes –
*PU – Parking Occupancy (Dependent Variable)
**Binary variables (Dummy variables); HvV – Total Heavy Vehicles entering RSA on "n"
observation; LvV - Total Light Vehicles entering RSA on "n" observation

Table 3. OLS regression model result.

Parameter	B	SE	t	p-value	VIF
Constant	51.617		8.194	0.000	
TVV	0.019	0.248	3.531	0.001	1.712
Hv/Lv$_{ratio}$	-1.429	-0.466	-6.965	0.000	1.554
PvRSA	0.166	0.310	4.218	0.000	1.879
NxtItrcg	7.637	0.357	5.139	0.000	1.676
D$_{pstn}$	7.213	0.270	3.633	0.000	1.914
P.C.	-0.037	-0.329	-5.729	0.000	1.147
D$_{midday}$	6.984	0.324	5.881	0.000	1.057
Analysis of Variance					
Source	df	SS	MS	F	Sig.
Regression	7	7882.574	1126.082	37.976	<0.05
Residual	82	2431.478	29.652		
Total	89	10314.053			

The assumptions should be tested for the estimation model. Graphical assumptions assessment were made to assess the normality and homoscedasticity. The P-P plot of studentized residuals in Figure 3(a) compares the distribution of the residuals to a normal distribution. The diagonal line represents the normal distribution. The closer observed cumulative probabilities of the residuals are to this line, the closer the distribution of the residuals is to the normal distribution. Figure 3(b) shows that there is equality of constant variance across the observations. The assumption that there are no outliers in the data also can be assessed from this plot.
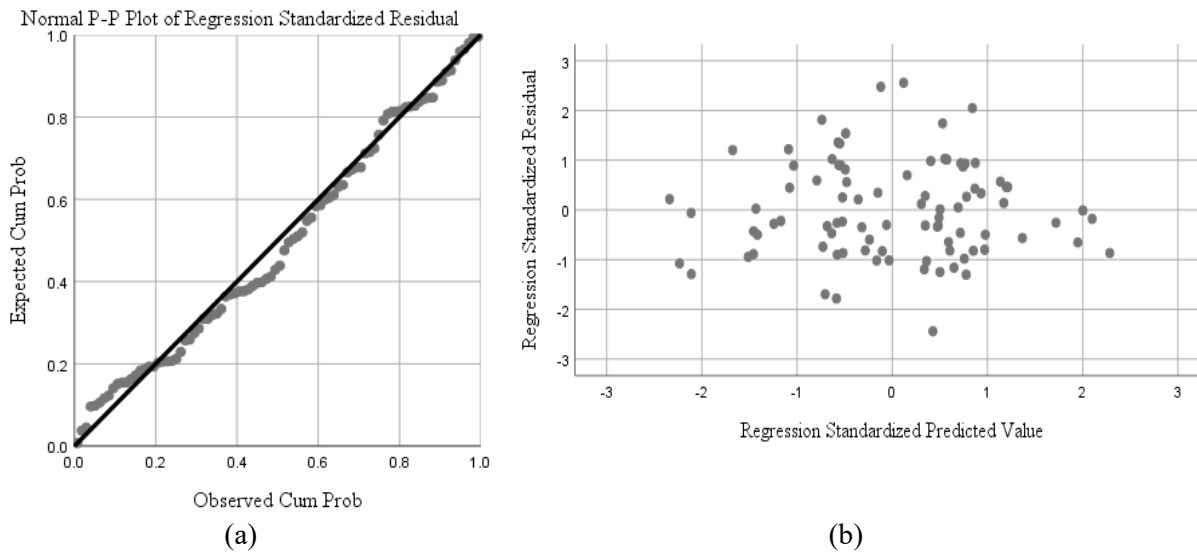
Figure 3. (a) Normal probability plot and (b) Residual plots of fitted for estimation model.

To test for the assumption of no autocorrelation among the residuals, the Durbin-Watson test was performed resulting in a value, d, of 1.431. This was indicative that positive autocorrelation was present in the model. In order to correct for this problem, the Prais-Winsten approach was performed. In the Prais-Winsten procedure, the error term for a particular period is assumed to be linearly associated with the error term at a previous period. However, the lag variable cannot be calculated for the first observation, resulting in a loss of observations. Prais-Winsten regression generates values for the lost observations and recalculates the Durbin-Watson statistic. The model developed using Prais-Winsten regression is shown in Table 4.

Table 4. Model Estimation comparison for total parking occupancy on RSA.

Independent Variable	No Correlation for Autocorrelation	MLE[1]	MLE[7]
Constant	52.254 ($p<0.01$)	50.449 ($p<0.01$)	50.479 ($p<0.01$)
TVV	0.019 ($p<0.01$)	0.020 ($p<0.01$)	0.020 ($p<0.01$)
Hv/Lv_{ratio}	-1.429 ($p<0.01$)	-1.273 ($p<0.01$)	-1.253 ($p<0.01$)
$PvRSA$	0.166 ($p<0.01$)	0.174 ($p<0.01$)	0.175 ($p<0.01$)
$Nxtltrcg$	7.637 ($p<0.01$)	7.690 ($p<0.01$)	7.710 ($p<0.01$)
D_{pstn}	7.213 ($p<0.01$)	6.551 ($p<0.05$)	6.480 ($p<0.05$)
$P.C.$	-0370 ($p<0.01$)	-0.037 ($p<0.01$)	-0.037 ($p<0.01$)
D_{midday}	6.984 ($p<0.01$)	5.067 ($p<0.01$)	4.824 ($p<0.01$)
First-order ρ^+	0	1 iteration	7 iterations
DW,d	1.431	1.879	1.921
R^2	0.764	0.639	0.620

DW – Durbin Watson Statistic
MLE[1] estimation of ρ for first-order serial correlation.
MLE[7] estimation of ρ for first-to 7th order serial correlation.

The model developed using the Prais-Winsten procedure had a coefficient of determination, R^2, of 0.620 indicating that almost 62% of the variation in explanatory variables is explained by the model

(Table 4). The Durbin-Watson statistic, d, for the corrected model was 1.921 with 7 iterations were performed, a value close to 2.0 which is indicative of no autocorrelation. The values for the parameter estimates were very similar to those obtained using the OLS estimator as indicated by the consistency in signs and by the small differences in magnitudes. Table 5 shows the estimates of autoregressive parameters on 7 iterations.

Table 5. Descriptions on autoregressive parameters on 7 iterations.

	Rho (AR1)		Durbin-Watson	Mean Squared Errors
	Value	Std. Error		
0	.278	.107	1.794	27.092
1	.352	.104	1.879	26.853
2	.377	.103	1.906	26.822
3	.386	.102	1.916	26.817
4	.389	.102	1.919	26.816
5	.390	.102	1.920	26.815
6	.391	.102	1.920	26.815
7[*]	.391	.102	1.921	26.815

The Prais-Winsten estimation method is used.

*The estimation terminated at this iteration because all the parameter estimates changed by less than .001.

4. Conclusions

The present study has examined the trend of parking occupancy for RSA alongside the expressway. Based on the findings, it can be concluded that the parking occupancy trend demonstrates peaking characteristics. This peaking phenomenon illustrated the demand on RSA tended to peak from morning to midday period and literally remain constant during midday and then decline gradually through the evening period. The study also found that the highest space occupied fall on the midday period. The trend or pattern is slightly similar on each site with a different percentage of parking occupied. Further statistical analysis was done to estimate parking occupancy. The key findings of the estimation model include the following:

i.   As the mainline traffic volume increased, the percentage of space occupied in RSA increased. The percentage of the ratio between heavy vehicles and light vehicles was anticipated to have an indirect related with demand, as it assumed that the presence of more heavy vehicles is believed to be to reduce the demand. This is based on the well-accepted notion of the safety and comfort issues from the expressway users.

ii. The distance between RSA from the previous one and the distance on next interchange from the RSA also had a significant effect on space occupied in RSA. This finding indicates that the spacing of rest areas played a larger role in the decision-making process. The demand significantly increased with an increase in distance travelled by expressway users.

iii. Site characteristics indicate that the presence of amenities influenced the demand needs.

In conclusion, this current study discovered the application of the influencing criteria that may affect the parking demand of the RSA. In-depth investigations should be conducted for better information on the parking characteristics on RSA land use type and related parameters. This work also recommend investigation of other potential variables that are thought to affect the parking demand such as different location of RSA(low and high-volume interstate expressway), traffic mix by expressway users type

(local and nonlocal users), trip purpose, and trip length may be important in explaining the variability parking demand in RSA.

5. References

[1]   Ramli I, Hassan S A and Hainin M R 2017 *Malaysian J. of Civil Engineering (MJCE)* 1 108118
[2]   Abd. Wahab M S 2015 *Trend of Parking Demand at Machap Northbound Rest Area* (Universiti Teknologi Malaysia)
[3]   Banerjee I, Ho Lee J, Jang K, Pande S and Ragland D R 2010. *Rest Areas: Reducing Accidents Involving Driver Fatigue* Vol. CA 09/1092
[4]   SRF Consulting Group. INC. 2007. *Interstate Highway Safety Study: Analysis of Vehicle Crashes Related to Safety Rest Area Spacing* 9 (Saint Paul)
[5]   Taylor W C, Sung N, Kolody K and Jawad A 1999 *A Study of Highway Rest Area Characteristics and Fatigue Related Truck Crashes* (Lansing)
[6]   Hensher D A and King J 2001*Transportation Research Part A: Policy and Practice* *35(5)* 177196
[7]   Hess D B 2001 *Transportation Research Record: J. of the Transportation Research Board* **1753(1)** 3542
[8]   Lam W H, Li Z C, Huang H J and Wong S C 2006 *Transportation Research Part D: Transport and Environment* **40(5)** 368395
[9]   Shiftan Y and Burd-Eden R 2001 *Transportation Research Record: J. of the Transportation Research Board* 1765(1) 2734
[10] Kay J, Gates T J, Savolainen P T, McArthur A and Russo B J 2014 *Transportation Research Record: Journal of the Transportation Research Board* 2430(1) 200206
[11] County M 2000 *Statistical Analyses Of Parking By Land Use* 585
[12]   Shoup D and Moynihan D P 2003 *J. of Transportation and Statistics* 6(1) 116
[13] Al-Zahrani A H M and Hasan T 2008 *Institute of Transportation Engineers (ITE) Journal* **78(2)** 2429
[14] Cutter W B and Franco S F 2012 *Transportation Research Part A: Policy and Practice* **46(6)** 901925
[15] Ahmed I, Abdulrahman S, Hainin M R and Hassan S A 2014 *Traffic and Transportation* **26(6)** 0111
[16] Ahmed I, Ramli I and Hainin M R 2014 *J. Teknologi (Sciences and Engineering) 69*(2) 2326
[17]   Abd Wahab M S, Ramli I, Hassan S A, Hainin M R and Minhans A 2015 *J. Teknologi (Sciences and Engineering)* **14(76)** 0921
[18] Lee Y W 2015 *Study on the Variables for On-street Parking Demand Estimation through Parking Survey* **100** 4346
[19] Al-Sahili K and Hamadneh J 2016 *Transportation Research Part A: Policy and Practice*, **91**(January) 213222
[20] Neamah Z K 2017 *Developing a Relationship Between Land Use and Parking Demand for The Center of The Holy City of Karbala Abstract* **5** 16521659
[21] Suthanaya P A 2017 *Journal of Sustainable Development* **10(5)** 52
[22] Institute of Transportation Engineers 2010 *Parking Generation Handbook, 4th Edition* (Washington, DC)
[23] Al-Kaisy A, Kirkemo Z, Veneziano D and Dorrington C 2011*Transportation Research Record: J. of the Transportation Research Board* **2255(1)** 156164