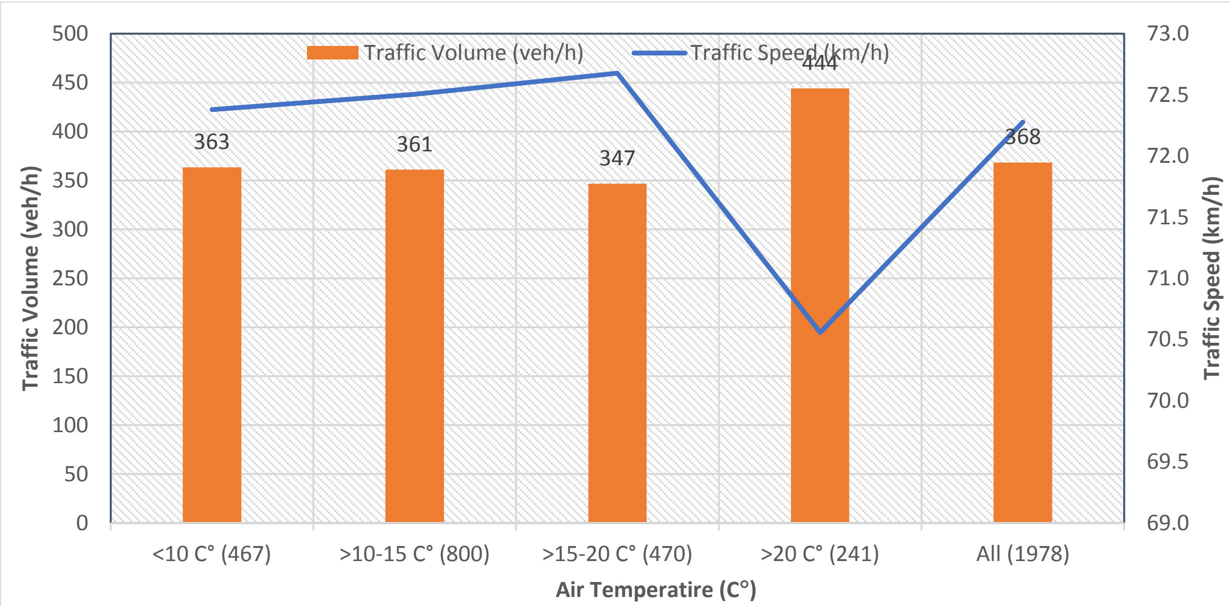
Air temperature seems to have some influence on traffic parameters. Negative relationship between traffic speed and volume is illustrated in Figure 4. As temperature increases, traffic volume slightly decreases while speed increases. When the traffic volumes start to increase due at high temperature, speed dcreases. The correlation magnitude and significance differ according to temperature category. Poor significant relationships were found for cold (<10 C°) and mild temperature (>10-15 C°) in this time of the year. The correlation coefficients were -0.104 (p=0.025) and -0.108 (p=0.002) for cold and mild weather conditions respectively. Similar correlation coefficients, but not significant, were reported for warm (>15-20 C°) and relatively hot weather conditions in this time of the year (>20 C°). The correlation coefficients were -0.082 (p=0.076) and -0.093 (p=0.15) for warm and hot weather conditions respectively. ANOVA test result showed that the speed differs according to the temperature category (F=5.444, p=0.001). The same applies to traffic volume (F=9.758, p=0.000). The impact of temperature seems more pronounced on traffic volumes, particularly at high temperature.

Wind Speed influences on traffic parameters. A negative relationship between traffic speed and volume is illustrated. The correlation magnitude and significance differ according to wind speed category (Figure 5). Traffic speed is the lowest when the wind is calm while traffic volume is the highest. As wind speed increases the traffic speed decreases while traffic volume fluctuates. Significant relationships between traffic volume and speed were found for calm wind (<2 km/h) and light air (2-3.99 km/h). The correlation coefficients were -0.266 (p=0.00) and -0.093 (p=0.021) for calm and light breeze conditions respectively. Poor correlation coefficients and not significant are related to light air/ breeze (>4-6 km/h) and light breeze (>6 km/h). The correlation coefficients were -0.045 (p=0.277) and -0.072 (p=0.111) light air/breeze and light breeze respectively. ANOVA test result showed that the speed differs according to wind speed category (F=2.305, p=0.056). The level of significance is rather poor and exceeds the two-side test limit (0.025). On the other hand, traffic volume differs significantly due to the wind speed (F=43.49, p=0.000).



Number in parenthesis refers to number of observations

Figure 4 Relationship between Traffic Flow Indicators and Air Temperature

The influence of other factors that are related to time of day (day versus night) and the period of the day (morning "am" and afternoon "pm") on speed and its variation was further investigated as shown in Figure 6. The speed in the morning period is lower than the afternoon but the variation in the afternoon is less. The difference in speed variation due to the period is significant (F=11.607, p=0.00) but the difference in the average speed between the two periods is marginally insignificant (t=-2.001, p=0.046). Surprisingly, the speed at night (74.31 km/h) is higher than the average speed at day time (71.87) and the difference in the speed due to this factor is significant (t=-6.782, p=0.000). Traffic at night is more uniform as indicated by the standard deviation, which is 5.675 at night compared to 7.296 in day time. F-test results showed the difference in speed variation due to day of time is significant (F=15.286, p=0.00). The variation in speed when the road surface is wet (s=7.522 km/h) is higher than when the surface is dry (6.986 km/h) and the difference is significant (F=7.47, p=0.006).

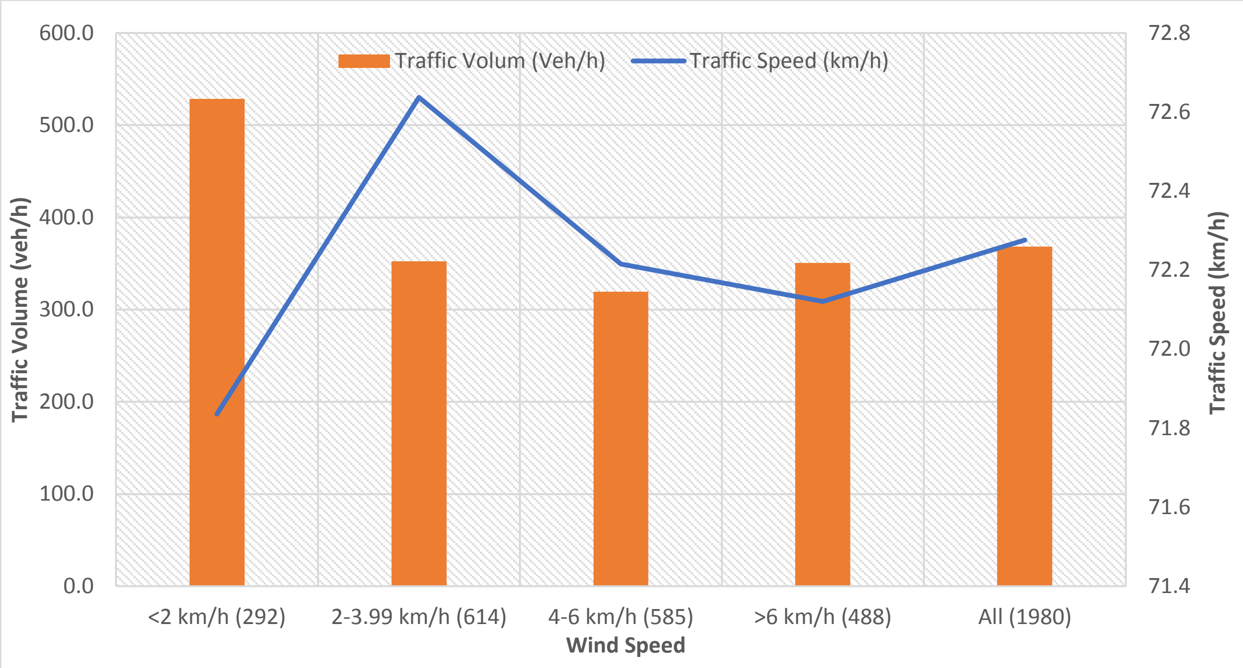


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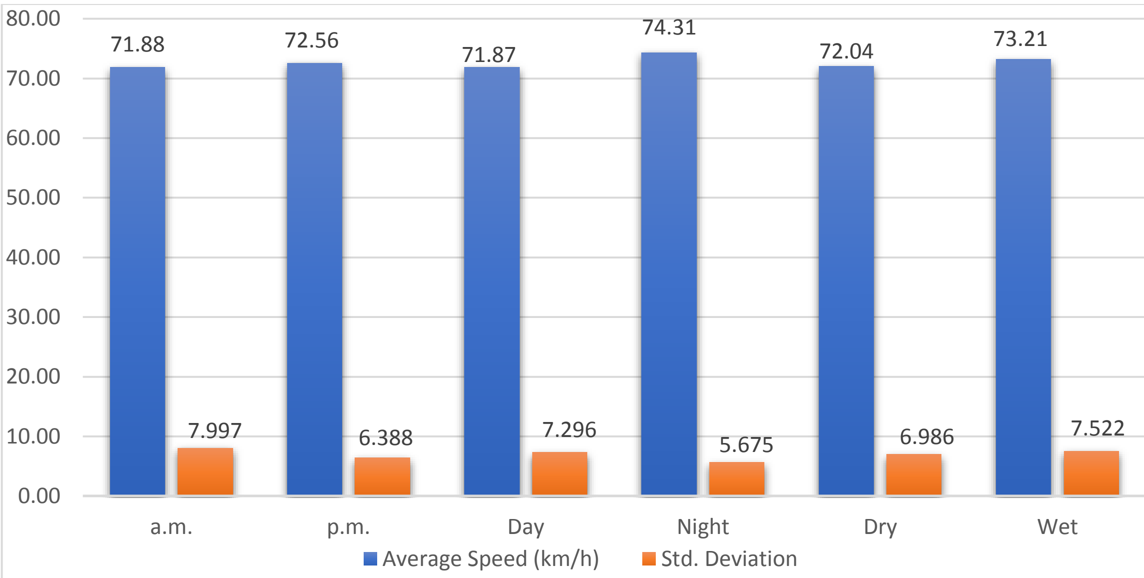
Figure 5 Relationship between Traffic Flow Indicators and Wind Speed



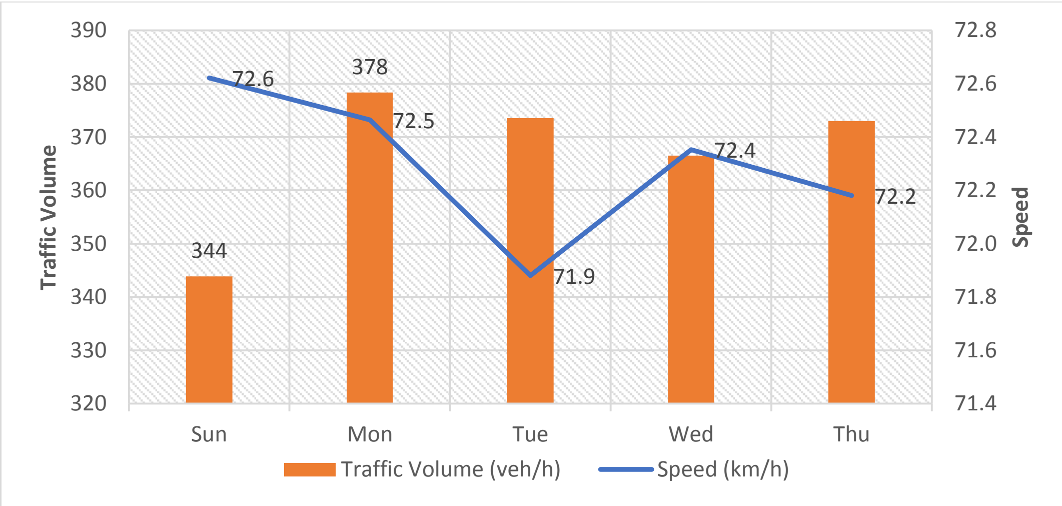
Statistical Parameter	Period of the Day	Time of the Day	Surface Condition
F-test	11.607	15.286	7.470
Sig.	.001	.000	.006
t-test	-2.001	-6.782	-2.792
Sig. (2-tailed)	.046	.000	.005

F-Test used for testing difference in variation while t-test is used to test difference in means

Figure 6 Variation in Traffic Speeds due to Time of the Day and Period of the Day

Variation in traffic parameters by day of the week shown in Figure 7 illustrates that the highest average peak traffic volumes on the selected sites occurs on Monday (378 veh/h) while the lowest happened to be on Sunday (344 veh/h), which indicates a narrow margin of variation in traffic (34.5 veh/h, the difference between the highest and lowest peak). The average speed also does not vary by the day of the week.

The highest average speed (72.6 km/h) is reported on Sunday, which has relatively the lowest traffic peak volume while the lowest speed is on Tuesday (71.9 km/h). Average speed fluctuates in narrow margin that does not exceed 0.74 km/h. ANOVA analysis showed that there is no significant difference in traffic speed nor traffic volumes that can be explained by day of the week (F=0.618, p=0,649 for speed) and (F= 1.079, p=0.365).



Traffic Parameter	F	Sig.
Speed	0.618	0.649
Volume	1.079	0.365

Figure 7 Traffic Flow Parameters Variation by Day of the week

The average speed fluctuates in narrow range (71.1 to 73.7 km/h) that composed 73.2%, 81.9 and 88.9% of posted speed limits of 100, 90 and 80 km/h respectively (Figure 8).

The average speed on the selected locations differ due to speed limit (F=28.27, p=0.000). The association between speed limit and operating speed proven to be significant (r=0.137, p=0.000).

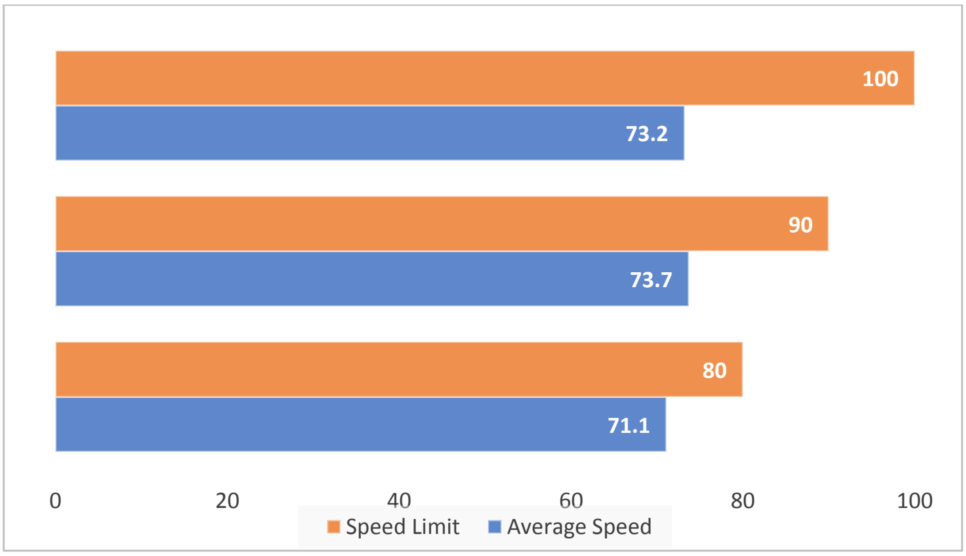
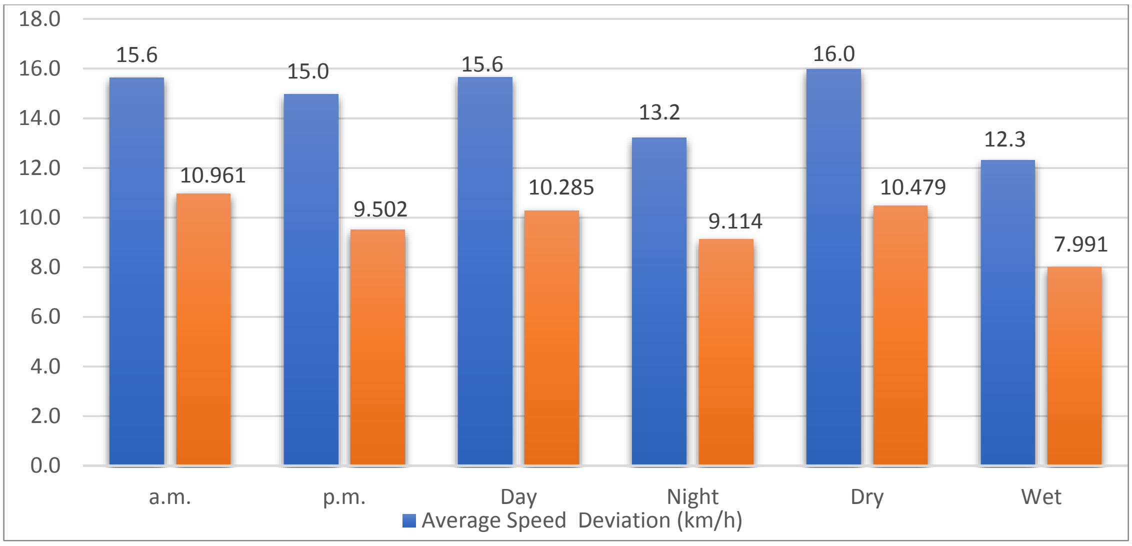


Figure 8 Relation between Speed Limit and Average Operating Speed on the Selected Sites.

Further, the analysis covered the speed deviation from the posted speed limit as shown in Figure 9. The speed deviation in the morning period is higher than the afternoon peak (15.6 and 15.0 km/h respectively), which is not found statistically significant (t=1.421, p=0.156). This is not the case for the variation as the speed variation in the morning (s=9.502 km/h) is less than the afternoon (s=10.961 km/h), which is significantly different (F=14.211, p=0.000). Further, the average deviation of speed at night is 13.2 km/h is lower than the daytime deviation (15.6 km/h), which is a reflection of the fact that the speed at night were higher the daytime. The average speed deviation is significantly different due to time of the day (t=4.012, p=0.000) while the variation where insignificantly different (F=1.609, p=0.205).



Statistical Parameter	**Period of the Day**	**Time of the Day**	**Surface Condition**
F-test	14.211	1.609	45.542
Sig.	.000	.205	.000
t-test	1.421	4.012	7.592
Sig. (2-tailed)	0.156	0.000	0.000

F-Test used for testing difference in variation while t-test is used to test difference in means

Figure 9 Speed Deviation from Speed Limit due to Time of the Day and Peak period Time

Further, the variation of speed deviation as expressed in standard deviation is lower if the surface is wet (7.99 km/h) compared to 10.479, if the surface is dry. The difference in speed variation due to surface conditions was statistically significant (F=45.542, p=0.000). The average speed deviation when the surface is dry is 16 km/h while it is only 12.3 km/h on wet surface. The difference in speed is also statistically significant (t=7.592, p=0.000).

Average hourly volume in the morning (398 veh/h) is higher than the afternoon (347 veh/h) and there is significant difference in average hourly traffi volume due to period of the day (t=4.739, p=0.000) while the variation is not statistically significant (F=1.59, p=0.208). The coefficient of variations were 0.57 and 0.71 for morning and afternoon respectively. Similar results were reported for difference in traffic volume due to time of the day. There is significance difference in average speed (t=3.047, p=0.002) but not the variation (F=0.656, p=0.418). Traffic on wet surface does not vary to the extent that of the dry surface (Figure 10). The coefficient variations are 0.56 and 0.66 for wet and dry surface respectively. There is a significant difference in the average traffic volumes due to surface type (t=3.025, p=0.003) and this also applies for difference in variation, which was proven to be significant (F=13.195, p=0.000).

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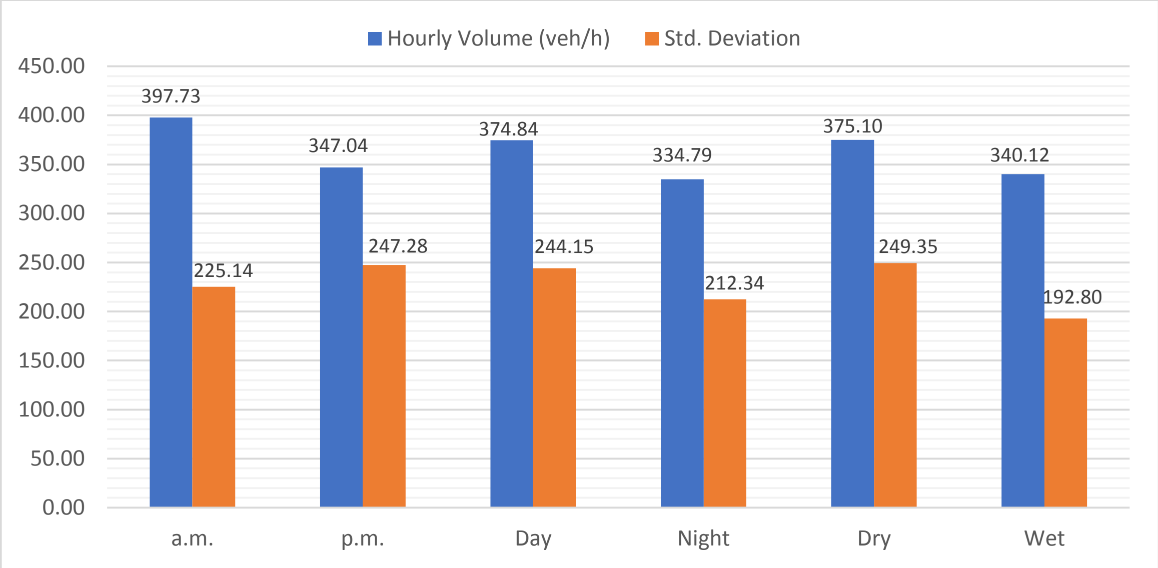


Statistical Parameter	Period of the day	Time of the Day	Surface Condition
F-test	1.590	.656	13.195
Sig.	.208	0.418	.000
t-test	4.739	3.047	3.025
Sig. (2-tailed)	.000	0.002	.003

F-Test used for testing difference in variation while t-test is used to test difference in means

Figure 10 Contributing Factors of Traffic Volume Variations

Generalized linear models were used to develop the relation between speed and the contributing factors. The likelihood chi-square ratio was used to test the goodness of fit of the model. Different models were developed. The response variables were traffic speed or traffic volumes. The predictors differ according the response variables. The results presented below are the models that were significant including their coefficients.

Two models were developed to predict the speed; the first one does not include interaction term (interaction of traffic volume as covariate with the time of the day) while the second model includes interaction term. The likelihood chi-square ratios were 61.218 and 69.214 for the models with no interaction and with interaction respectively. Both were proven to be significant (p=0.000). The models involved two factors that were treated as dummy variables. The time of the day factor has two values 1 for day and 0 for night, surface condition which is reflecting the raining status is assumed to be zero while it is 1 if it was dry.

The noninteraction model suggests that as traffic volume increases (model 1), the speed decreases. It also shows that traffic at night is 2.38 km/h higher than the day traffic. The speed tends to be slightly higher (1.162 km/h) when it rains and the surface becomes wet.

Traffic Speed= 76.195 – 0.003 x Traffic Volume -2.338 x Time of Day -1.162 x Surface Condition……..(1)

(χ^2 =18.37, p=0.000) χ^2 =30.56, p=0.000) (χ^2 =8.672, p=0.003)

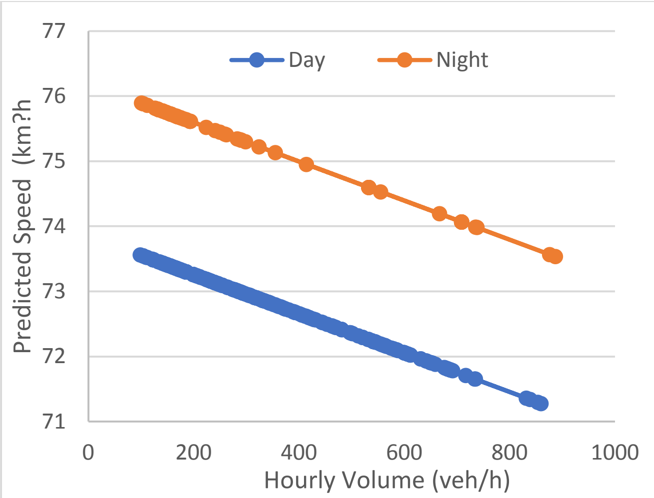
The interaction model suggests that as traffic volume increases (model 2), the speed decreases. However, impact of volume size is lessened when the period of day is considered, particularly at day time (Figure 11). It also shows that traffic at night is 4.235 km/h higher than the day traffic. The speed tends to be slightly higher (1.158 km/h) when it rains and the surface becomes wet.

Traffic Speed= 77.818 – 0.008 x Traffic Volume-4.235 x Time of Day -1.158 x Surface Condition

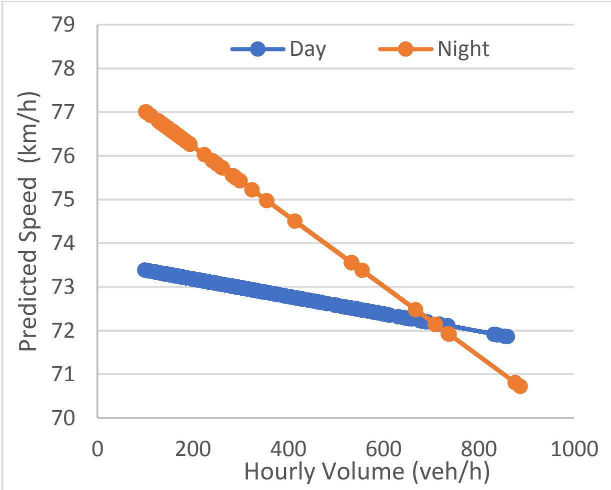
(χ^2 =17.94, p=0.000) (χ^2 =29.09, p=0.000) (χ^2 =8.618, p=0.003)

+ 0,006 x Traffic Volume x Time of Day …………………………………………..(2)

(χ^2 =8.237, p=0.004)



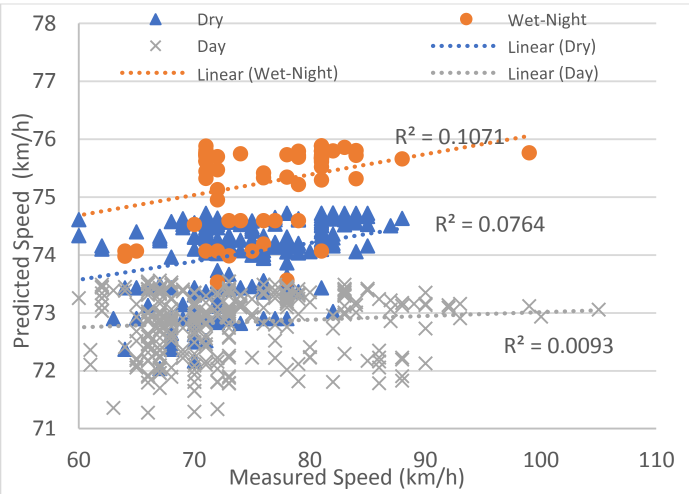
Noninteraction Model



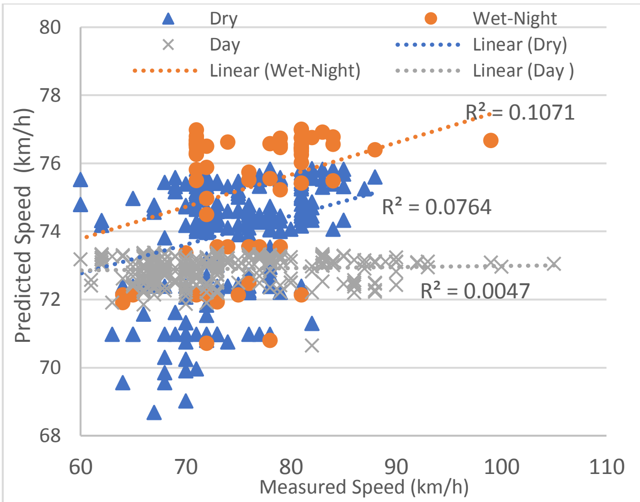
Interaction Model

Figure 11 The Impact of Introducing Interaction Term (Volume with Time of the Day) to Speed Prediction Model

The predicted speed values are related to the measured values as shown in Figure 12. The relationships although significant but do not show high correlation coefficients. The highest person correlation coefficient was reported for wet surface conditions during night (r=0.33). The lowest value reported for wet surface during day time (r=0.069), which refers to the interaction model. Figure 12 shows correlation coefficient of the interaction model (0.069) is lower than the non-interaction model coefficient (0.096) by 28%.



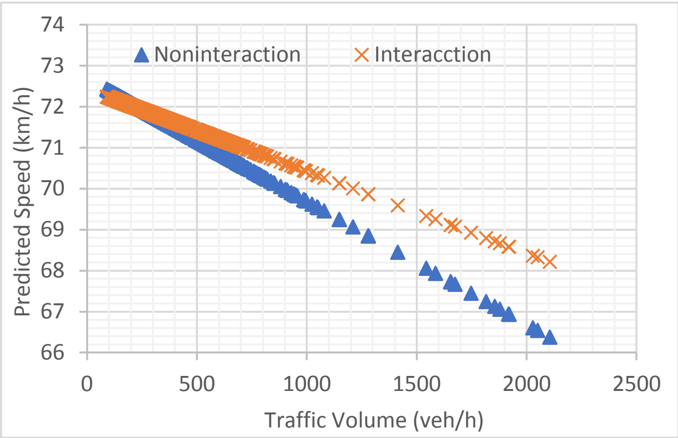
Noninteraction Model



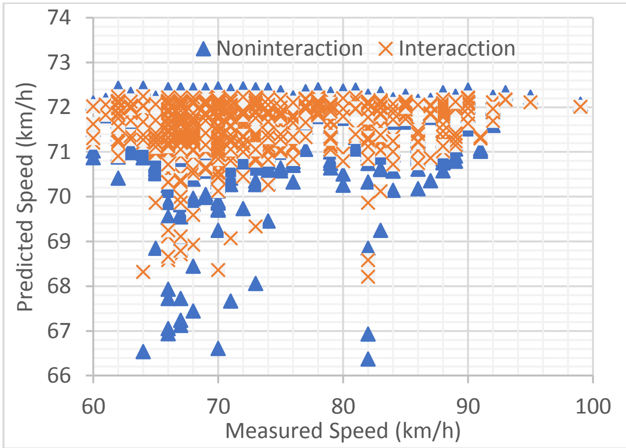
Interaction Model

Figure 12 Correlation between the Predicted Speed and the Measured Speed for both Models (Interaction and Noninteraction)

The application of the developed models for predicted speeds during daytime on dry surface conditions as shown in Figure 13 suggest that the two the models provide the same prediction of speed for low traffic volume (<500 veh/h). The prediction begins to deviate after this level and the interaction model gives higher estimate compared to the non-interaction. Both models failed to indicate high correlation coefficient between the predicted speed and the actual speed (r=0.072).



Predicted Speed Function of Traffic Volume



Correlation between Predicted & Measured Speed

Figure 13 Speed Prediction during Day time on Dry Surface Conditions

A model was developed to predict traffic volume as function of environment conditions as shown below,

Traffic Volume= 276.975 + 2.718 x Air Temperature + 36.271 x Time of Day +28.396 x Surface Condition

(χ^2 =6.39, p=0.011) (χ^2 =6.28, p=0.012) (χ^2 =4.29, p=0.038)

The model indicates that traffic on daytime is higher than daytime by 32.7 vehicle per hour and it is also higher if the surface condition is dry by 31.323 compared to wet surface conditions. The correlation coefficient between the predicted volumes and actual count sis 0.105. The relationship is slightly stronger if the prediction is used to determine traffic on dry surface conditions (r=0.154). The correlation between the predicted and the counted traffic volume is low if the prediction is related to wet surface conditions (r=0.0557). Although a model that includes speed to predict traffic volume was developed and found to be valid for the estimation as indicated by the high likelihood chi-square ($\chi 2$ =33.124, p=0.000). However, it will not be discussed hereby because it might be illogical to predict the traffic as function of speed because traffic volume has impact on the speed but the opposite might not be justified.

CONCLUSION

The results of analysis showed that both average speed and the 85th percentile traffic speeds are below the posted speed limit. The average speed fluctuates in narrow range (71.1 to 73.7 km/h) that composed 73.2%, 81.9 and 88.9% of posted speed limits of 100, 90 and 80 km/h respectively. The average speed on the selected locations differ due to speed limit (F=28.27, p=0.000). The association between speed limit and operating speed proven to be significant (r=0.137, p=0.000). Table 5 indicate that traffic speed on wet conditions is higher than when it is dry. The difference in speeds increase as speed limit increases. Raining seems to influence the speed more than it influences traffic volume. Table 5 does not show clear relationship between change in traffic volumes due to surface and speed limit. As surface became wet, traffic volume decreases for roads with speed limits less than or equal 90 km/h while it increases for 100 km/h speed limit. For all sites and irrespective of the speed limit, the statistical analysis showed that there is a difference in average speed (t=-2.96, p=0.003) and its variation (F=9.486, p =0.002) due to road surface conditions.

Table 5 Traffic Parameters Function of Speed Limit and Surface Condition

Speed Limit	Surface Condition	Average Speed (km/h)	85th Speed (km/h)	Average Hourly Volume (veh/h)
80.00	Dry	71.1	76.0	543
	Wet	71.3	77.8	495
	All	71.1	76.0	534
90.00	Dry	73.0	81.0	200
	Wet	74.7	83.0	197
	All	73.7	83.0	199
100.00	Dry	73.0	82.0	209
	Wet	81.5	92.2	255
	All	73.2	82.0	210
All	Dry	72.0	79.0	375
	Wet	73.3	82.0	340
	All	72.3	81.0	368

The same applies for the traffic volumes, the data showed that there is a difference in average traffic volume (t=3.06, p=0.002) and the variation (F=13.446, p=0.000). The situation is different when the data is classified by speed limit, the difference in speed due to surface conditions was only significant for road with speed limits 90 km/h (t=-2.329, p=0.02) and 100 km/h (t=-3.306, p=0.001). Traffic volumes, on the other hand, was significant for road with speed limit 80 km/h (t=2.53, p=0.012). The analysis suggests that there is specificity for each site and both speed (F= 21.09, p = 0.000) and traffic volumes (F=1127, p=0.000) are significantly different from one site to another.

The impact of weather conditions on traffic parameters appears to be significant for depth of rain precipitation. Average speed differs according to the rain depth category (F=5.927, p=0.000) as well as the traffic volume (F=14.843, p=0.000). As rain precipitation depth (RPD) increases the speed decreases. The strength of association between traffic flow indicators (speed and volume) differ by the depth of rain precipitation. The highest, significant, correlations are reported (r=-0.236, p=0.01) for moderate rain fall (2.5-10.0 mm). Air temperature influences the relationship between speed and volumes with a negative trend. Traffic volume decreases as temperature increase but not when the temperature increased beyond 20 C°. The highest correlation between traffic indicators was related - mild temperature (>10-15 C°) (r=-0.108, p=0.002) while the lowest was reported for warm weather condition (>15-20 C°) (r=-0.082, p=0.076). In general, speed (F=5.444, p=0.001) and traffic volume (F=9.758, p=0.000) differ significantly due to the temperature category. The impact of temperature has more influence on traffic volumes, particularly at high temperature. Further, as wind speed increases the traffic speed decreases while traffic volume fluctuates. Significant negative relationships between traffic volume and speed were found for calm wind (<2 km/h) (r=-0.266, p=0.00) and light air (2-3.99 km/h) (r=-0.093, p=0.021). Poor correlation coefficients and not significant are related to light air/ breeze (>4-6 km/h) (r=-0.045, p=0.277) and light breeze (>6 km/h) (r=-0.072, p=0.111). Poor association between traffic speed and wind speed categories (F=2.305, p=0.056) while the association is significant for traffic volume (F=43.49, p=0.000).

The study also showed that the average speed fluctuates over the day of the week in narrow margin that does not exceed 0.74 km/h, but the difference is not significant (F=0.618, p=0,649). Traffic volumes differ slightly over the day of the week with the significant evidence (F= 1.079, p=0.365). Speed at night (74.31 km/h) is higher than the average speed day time (71.87), the difference is statistically significant (t=-6.782, p=0.000). for the period of the day, speed in the morning is lower than the afternoon but the variation in the afternoon is less with significant variation (F=11.607, p=0.00). However, average speed between the two periods is marginally insignificant (t=-2.001, p=0.046). further, the speed deviation from the posted speed limit in the morning peak is higher than the afternoon peak (15.6 and 15.0 km/h respectively), the difference was not found statistically significant (t=1.421, p=0.156) whereas, the variation as the speed variation in the morning (s=9.502 km/h) is less the afternoon period (s=10.961 km/h), which is significantly different (F=14.211, p=0.000). Average hourly volume in the morning (398 veh/h) is higher than the afternoon (347 veh/h) and there is significant difference in average traffic volume due to peak hour time (t=4.739, p=0.000) while the variation is not statistically significant (F=1.59, p=0.208).

Generalized linear models were used to develop the relation between speed and the contributing factors. Two models were developed, non-interaction and interaction (Interaction of traffic volume with the time of the day. The non-interaction model suggests that as traffic volume increases, the speed decreases. It also shows that traffic speed at night is 2.38 km/h higher than the day traffic. The speed tends to be slightly higher (1.162 km/h) when it rains and the surface becomes wet. The interaction model also suggests that as traffic volume increases, the speed decreases. However, impact of volume size is lessened when the time of the day is considered, particularly at day time. It also shows that traffic speed at night is 4.235 km/h higher than the day traffic. The speed tends to be slightly higher (1.158 km/h) when it rains and the surface becomes wet. The predicted speed values were correlated to the measured values and it was found significant but do not show high correlation coefficients. The highest person correlation coefficient was reported for wet surface conditions during night (r=0.33). The lowest value reported for wet surface during day time (r=0.069), which refers to the interaction model. The developed models were used for predicted speeds during daytime on dry surface conditions. The two the models provide the same prediction of speed for low traffic volume (<500 veh/h). The prediction begins to deviate after this level of volume. The interaction model gives higher estimate compared to the non-interaction. Both models failed to indicate high correlation coefficient between the predicted speed and the actual speed (r=0.072). It is true that the correlation coefficient is significant but that is maybe due to the large size of the sample. In addition, a model was developed to predict traffic volume as function of environment conditions. The model indicates that traffic on daytime is higher than daytime by 32.7 vehicle per hour and it is also higher if the surface condition is dry by 31.323 compared to wet surface conditions. The correlation coefficient between the predicted volumes and actual count sis 0.105. The relationship seems slightly stronger if the prediction is used to determine traffic on dry surface conditions (r=0.154). The authors, although developed model that includes speed to predict traffic volume and found to be valid for the estimation, would not consider for prediction, because it may not be logical to predict the traffic as function of speed. As traffic volume has impact on the speed but the opposite might not be debatable. Some believes, if the speed is high on one road segment, then it will invite more traffic, while others would not consider this is a valid assumption.

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