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Impact of highway geometry and posted speed on operating speed at multi-lane highways in Egypt

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KEYWORDS

Operating speed;
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Abstract The paper presents an analysis of roadway factors and posted speed limits that affect the operating speed at multi-lane highways in Egypt. Field data on multi-lane highways in Egypt are used in this investigation. The analysis considers two categories of highways. The first consists of two desert roads (Cairo–Alexandria and Cairo–Ismailia desert roads) and the second consists of two agricultural roads (Cairo–Alexandria and Tanta–Damietta agricultural roads). The paper includes three separate relevant analyses. The first analysis uses the regression models to investigate the relationships between operating speed (V_{85}) as dependent variable, and roadway factors and posted speed as independent variables. The road factors are lane width, shoulder width, pavement width, median width, number of lanes in each direction, and existence of side access along each section. The second analysis uses the Artificial Neural Network (ANN) to explore the previous relationships while the third one examines the suitability of the posted speed limits on the roads under study. It is found that the ANN modeling gives the best model for predicting the operating speed and the most influential variables on V_{85} are the pavement width, followed by the median width and the existence of side access along section. It is also found that the posted speed limit has a very small effect on the operating speed due to the bad behavior of drivers in Egypt. These results are so important for controlling V_{85} on multi-lane rural highways in Egypt.

Introduction

Highway geometry and traffic speed consider the most important factors affecting the efficiency and safety of highway systems. Improving the geometry of multi-lane rural highways should be a high priority for highway authorities, as this represents an important component of the rural network. Traffic speed is an important parameter because it relates to safety, time, comfort, convenience, and economics. The ability to predict accurate vehicular operating speeds is useful for evaluating the planning, design, traffic operations, and safety of roadways.

In the present paper a driver's speed under free flow conditions avoid the effect of traffic flow on vehicle speed, as only the effect of highway geometry and posted speed on operating speed is considered as stated by Hashim [1]. Geometric

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features that are considered important in affecting traffic speed are lane width, right shoulder width, number of lanes, median width, existence of side access, and pavement width. These features will be considered beyond the scope here.

Therefore, the first part in the analysis presented in this paper involves an investigation of speed–roadway relationship using linear regression models in order to predict operating speed under free flow condition on rural multi-lane highways in Egypt.

As the Artificial Neural Networks (ANNs) is a new technique which used all over the world for predicting purposes, it is necessary to assign this methodology to predict the operating speed. However, the modeling of operating speed–roadway relationship by ANN models is another aspect of this paper.

Speed limits are used in most countries to regulate the speed of road vehicles. Speed limits are important to reduce the differences in vehicle speeds by drivers using the same road at the same time which increases safety. Studying the impact of the posted speed limit on V_{85} for the roads under study is another objective of this paper. This is performed by entering the posted speed limits in the regression and ANN models.

According to the objectives of this paper, which are stated earlier, a detailed statistical analysis are carried out to examine the speed characteristics on the selected field sites.

More specifically, the analysis is carried out for the following objectives:

- To investigate speed–roadway relationship corresponding using conventional regression models and ANN models.
- To achieve the best relationship for safely road geometric design in future.
- To examine the suitability of the posted speed limit and the compliance of the driver with it.

Background studies

A free moving vehicle is a vehicle that is free from interaction with other vehicles in the traffic stream; as only the effect of highway geometry on vehicle speed is considered. Several authors had various definitions of the case of free flow conditions. Homburger et al. [2], in the Fundamentals of Traffic Engineering, recommended 4 s as a minimum headway between the following vehicle and the vehicle traveling ahead to define free flow, although larger values are preferred if traffic conditions permit. Poe and Mason [3] concluded that vehicles with headway equal to or greater than 5 s are considered to be under free flow conditions. A free-flowing vehicle was defined by Fitzpatrick et al. [4] as having 5 s headway. Lamm et al. [5] reported that the speed data is considered under flow conditions when the isolated vehicles have a time gap of at least 6 s or heading a platoon of vehicles.

Ali et al. [6] studied the interrelationship between the free-flow speed, posted speed limit, and geometric design variables along 35 four-lane urban streets in Fairfax County, Virginia. The models had $R^2 = 0.87$ and 0.86, respectively. Correlation analysis showed that posted speed, median width, and segment length had a significant effect on free-flow speed on urban streets. The coefficients of the previous variables were +2.1, +3.6, and +13, respectively. This indicated that a positive correlation between these variables and V_{85} was achieved.

Figueroa and Tarko [7] studied the relationship between various roadway and roadside design features and operating speeds on four-lane roadways in Indiana. A regression model was used to estimate operating speed. The model for four-lane highways had $R^2 = 0.86$. The model showed that increasing the posted speed limit resulted in higher operating speeds. It also showed that speeds are higher in rural areas. The coefficients of the effective variables were +4.75, and +2.04, respectively. Therefore, there was a positive relationship between these variables and V_{85}.

Fitzpatrick et al. [8] explored speed relationships and agency practices related to speed. The research team modeled operating speeds at 78 suburban/urban sites in Arkansas, Missouri, Tennessee, Oregon, Massachusetts, and Texas. Only the posted speed limit was found to be a statistically significant predictor of 85th percentile operating speed on urban–suburban arterials. The estimated models had $R^2 = 0.90$. The coefficient of posted speed limit was +0.98 which indicating a positive relation with V_{85}.

Wang et al. [9] studied the effects of cross section characteristics and adjacent land use on operating speeds in Atlanta, Georgia. Speed data were collected using 200 vehicles equipped with GPS devices. A mixed model approach was used to predict 85th and 95th percentile speeds for urban streets. The models had $R^2 = 0.88$ and 0.85, respectively. It was found that the number of lanes, presence of curb, and commercial and residential land uses were positively associated with operating speed. For the V_{85} model, the coefficients of variables were +6.49, +3.01, +3.31, and +3.27, respectively.

Himes and Donnell [10] investigated the effects of roadway geometric design features and traffic flow on operating speed characteristics along rural and urban four-lane highways in Pennsylvania and North Carolina. A simultaneous equations framework was used to model the speed distribution. This simultaneous equation modeling framework was first introduced by Shankar and Mannering [11] to model speeds on a freeway segment in Washington State. It was later explored in depth and compared to limited information (e.g. OLS regression) and full-information (e.g. seemingly unrelated regression) modeling methods by Porter [12]. They found that different geometric design features were associated with mean speed and speed deviation in the left- and right-lanes such as pavement, median width, and right shoulder width. The coefficients of the previous variables were +1.81, +2.23, and +7.44, respectively. Thus, there were strong positive relationships between these variables and operating speed.

Singh et al. [13] developed ANN models to predict V_{85} of two-lane rural highways in Oklahoma. Several input parameters, namely, roadway characteristics, traffic conditions, and accident experience were considered in developing the ANN models. Data from a total of 241 two-lane rural highway sites were collected and used in developing the ANN models. Four models were developed. Model 1 includes Posted Speed but does not include Accident Data; Model 2 includes neither Posted Speed nor Accident Data; Model 3 includes both Posted Speed and Accident Data; and Model 4 does not include Posted Speed but includes Accident Data. The models had $R^2 = 0.93$, 0.55, 0.95 and 0.74, respectively. It was conclude that the developed ANN models were expected to be useful for prediction of V_{85} when roadway characteristics with posted speed limits change.

Issa et al. [14] developed ANN model for predicting V_{85} for two-lane rural highways in Oklahoma. Data from 121 sites, distributed throughout Oklahoma, were used in this study. The input parameters were average daily traffic (ADT), international roughness index (IRI), present serviceability index (PSI), and surface width. Results from that project indicated that the developed ANN model might have suffered from over fitting. Nonetheless, the previous model developed by the University of Oklahoma was an important first step towards realizing the objective of developing ANN-based models for the setting of V_{85} for two-lane rural highways in Oklahoma.

McFadden et al. [15] used models. Data from 100 sites in five states including New York, Pennsylvania, Oregon, Washington, and Texas (approximately two thirds of the data) were used for network training. The remaining 38 sites were used for model testing.

The models were also compared to regression models estimated by Krammes et al. [16] using the same data. It was concluded that ANNs offer predictive powers comparable with those of regression and ANNs are able to overcome many of the assumptions and limitations inherent to linear regression.

In Egypt, there are few studies on operating speed and road factors due to lack of road geometric and speed data. The most important research in this direction is published by Hashim [1]. The analysis in this paper uses 20 sites from two-lane rural roads that connect Shebin El-Kom, the capital city of Minoufiya Governorate, with the adjacent cities. Three separate analyses are carried out. The first analysis investigates the relationship between 85th percentile speed and headway to define a headway value corresponding to free moving vehicles. The second analysis examines the suitability of the posted speed limits on the roads under study. The third and last analysis inspects the conformity of the study sites' speed data with normal distributions. It was found that the 85th percentile speed took a constant value at headway equal to 5 s or more. Also, a significant proportion of drivers exceed the posted speed limit as well as the current speed limit may not be appropriate. Finally spot speed data follow a normal distribution.

Methodology

The methodology of operating speed prediction in the present research is divided into three main steps: (1) data collection, (2) linear regression models, and (3) ANN models.

Data collection

The present research focuses on the rural multi-lane highways in Egypt. The analysis uses 41 sites (sections) from two categories of multi-lane highways. These categories are as follows:

1. Agricultural highways category
   - Cairo–Alexandria Agricultural highway (CAA)
   - Tanta–Damietta Agricultural highway (TDA)
2. Desert highways category
   - Cairo–Alexandria Desert highway (CAD)
   - Cairo–Ismailia Desert highway (CID)

Each section length is 100 m. These roads have a posted speed limit ranging from 100 to 40 km/h. The chosen sites are located on straight sections with level terrain to avoid the effect of the longitudinal gradient, and to be far from the influence of horizontal curves.

Free-flow speeds are collected for passenger cars only. Spot speed data are collected using radar gun (version LASER 500 with ± 1 km/h accuracy) that is placed at midpoint of each section so as to be invisible to drivers [17]. Vehicles traveling in free-flow conditions are considered to have time headways of at least 5 s. The number of speeds collected at each site range from 100 to 160, which led to a total of 5330 spot speeds. Speeds are carried out in working days, during daylight hours.

During all data collection periods, the weather is clear and the pavement is dry and in a good condition.

The road geometric data are collected directly from site investigation which included lane width, right shoulder width, number of lanes in one direction, median width, pavement width, and existing of side access along section. All the previous variables, their symbols, and statistical analysis are provided in Table 1.

The research uses a total number of eight variables which are divided into dependent and independent variables.

- Dependent variable
  - V_{85} = 1 variable (see Table 1).
- Independent variables (7 variables)
  - Road geometric = 6 variables (see Table 1).
  - Posted speed limit = 1 variable (see Table 1).

Linear regression models

The collected data are used to investigate the relationships between operating speed (V_{85}) as dependent variable and roadway factors and posted speed limit as independent variables. Simple linear regression was used to check the correlation coefficient between dependent variable and the independent variables. The independent variables that have relatively high R^2 values were introduced into the multiple linear regression models. The form of multiple linear regression models is shown in the following equation:

$$Y = \beta o + \sum i\beta iXi \tag{1}$$

where $Y = V_{85}$; Xi = explanatory variables; βo = regression constant; and βi = regression coefficient.

Then, stepwise regression analysis was used to select the most statistically significant independent variables with V_{85} in one model. Stepwise regression starts with no model terms. At each step, it adds the most statistically significant term (the one with highest F statistic or lowest P-value) until the addition of the next variable makes no significant difference. An important assumption behind the method is that some input variables in a multiple regression do not have an important explanatory effect on the response. Stepwise regression keeps only the statistically significant terms in the model. Finally, the R^2 and (Root Mean Square Error) RMSE values are calculated for each model.

Several precautions are taken into consideration to ensure integrity of the model as follows [18]:

(1) The signs of the multiple linear regression coefficients should agree with the signs of the simplelinear regression of the individual independent variables and agree with intuitive engineering judgment.

Table 1 Statistical analysis and symbols of all variables.

Variable	Variable symbol	Max.	Min.	Avg.	S.D.
1 – Lane width in meters	LW	6	3.25	3.74	0.484
2 – Pavement width in one direction in meters	PW	14	3.5	8.94	2.7
3 – Right shoulder width in meters	SW	3	1	1.87	0.61
4 – No. of lanes in each direction in lanes	NL	4	1	2	–
5 – Median width in meters	MW	16	1	5.93	3.78
6 – Existence of side access (1 if exiting; 0 otherwise)	SA	1	0	–	–
7 – Posted speed limit in km/h	PSL	100	40	90.5	14.65
8 – The 85th percentile speed in km/h	V_{85}	116.14	38.13	82.95	21.37

(2) There should be no multicollinearity among the final selected independent variables; and
(3) The model with the smallest number of independent variables, minimum RMSE, and highest R^2 value is selected.

ANN models

In general, ANNs consist of three layers, namely, the input, the hidden and the output layers. In the input layer, the input variables of the problems are situated. The output layer contains the output variables of what is being modeled. In statistical terms, the input layer contains the independent variables and the output layer contains the dependent variables. The nodes between successive layers are connected by links each carrying a weight that quantitatively describes the strength of those connections, thus denoting the strength of one node to affect the other node [13].

ANNs typically start out with randomized weights for all their neurons. This means that they do not know anything and must be trained to solve the particular problem for which they are intended. When a satisfactory level of performance is reached the training is ended and the network uses these weights to make a decision [19].

The experience in this field is extracted from Semeida [20]. In his research, the multi-layer perceptron (MLP) neural network models give the best performance of all models. In addition, this network is usually preferred in engineering applications because many learning algorithm might be used in MLP. One of the commonly used learning algorithms in ANN applications is back propagation algorithm (BP), which was also used in this research (NeuroSolutions 7) [21].

The overall data set of 41 sites is divided into a training data set and a testing data set.

This partition was done randomly with roughly 85% of the data used for training and 15% of the total data used for testing. Model performances are RMSE and R^2 for testing and training data set in one hand and for all data set in the other hand [22].

Results and discussion

Linear regression models

There are four models that are statistically significant with V_{85} after stepwise regression using SSPS Package. All of the variables are significant at the 5% significance level (95% confidence level) for these four models. In other words, (P-value) is <0.05 for all independent variables. Finally, many models are excluded due to poor significance with V_{85}. Therefore, the best models are as follows (shown in Fig. 1).

$$\text{Model (1)}\ V_{85} = 68.01 + 2.515(\text{MW})(R^2 = 0.2,\ \text{and RMSE} = 18.9) \tag{2}$$

$$\text{Model (2)}\ V_{85} = 36.51 + 24.889(\text{SW})(R^2 = 0.501,\ \text{and RMSE} = 14.8) \tag{3}$$

$$\text{Model (3)}\ V_{85} = 63.03 - 23.893(\text{SA}) + 15.36(\text{SW})(R^2 = 0.732,\ \text{and RMSE} = 10.93) \tag{4}$$

$$\text{Model (4)}\ V_{85} = 44.6 - 25.3(\text{SA}) + 12.3(\text{SW}) + 0.273(\text{PSL}) \tag{5}$$

$(R^2 = 0.761,\ \text{and RMSE} = 10.32)$

Investigation of the previous results shows that:

- Model 4 is the best for all models and contains the maximum number of variables. In addition, it has the best R^2, and the lowest RMSE for all models.
- The negative sign of the coefficient for SA means that the V_{85} decreases with the existence of side access. The drivers are to be careful when they see side access signs ahead; consequently, they decrease their speeds. This is consistent with logic. In addition, the coefficient of this variable is -25.3 which indicating the strong effect of SA on decreasing V_{85} in the Egyptian highways. It should be noted that this variable was not effective in the previous studies out of Egypt.
- The positive sign of the coefficient for SW means that the V_{85} increases with the increase of SW. In other word, the wider right shoulder width encourages the driver to increase his speeds if he is not restricted by other vehicles. The coefficient of this variable is $+12.3$ which indicating its strong effect on increasing V_{85} comparable with Himes and Donnell [10] as equals to $+7.44$.
- The smallness of PSL coefficient which equals to $+0.27$ indicates a so limited increase in V_{85} comparable with $+2.1$ in Ali et al. [6], $+4.75$ in Figueroa and Tarko [7], and $+0.98$ in Fitzpatrick et al. [8]. Then, the effect of PSL on V_{85} is very low due to the bad driving behavior in Egypt.
- Although LW, NL, PW and MW have considerable effect on operating speed, but they are excluded from the statistical model, because they are insignificant(P-value > 0.05) in all models. Therefore, the modeling with other technique is necessary to assure these results.

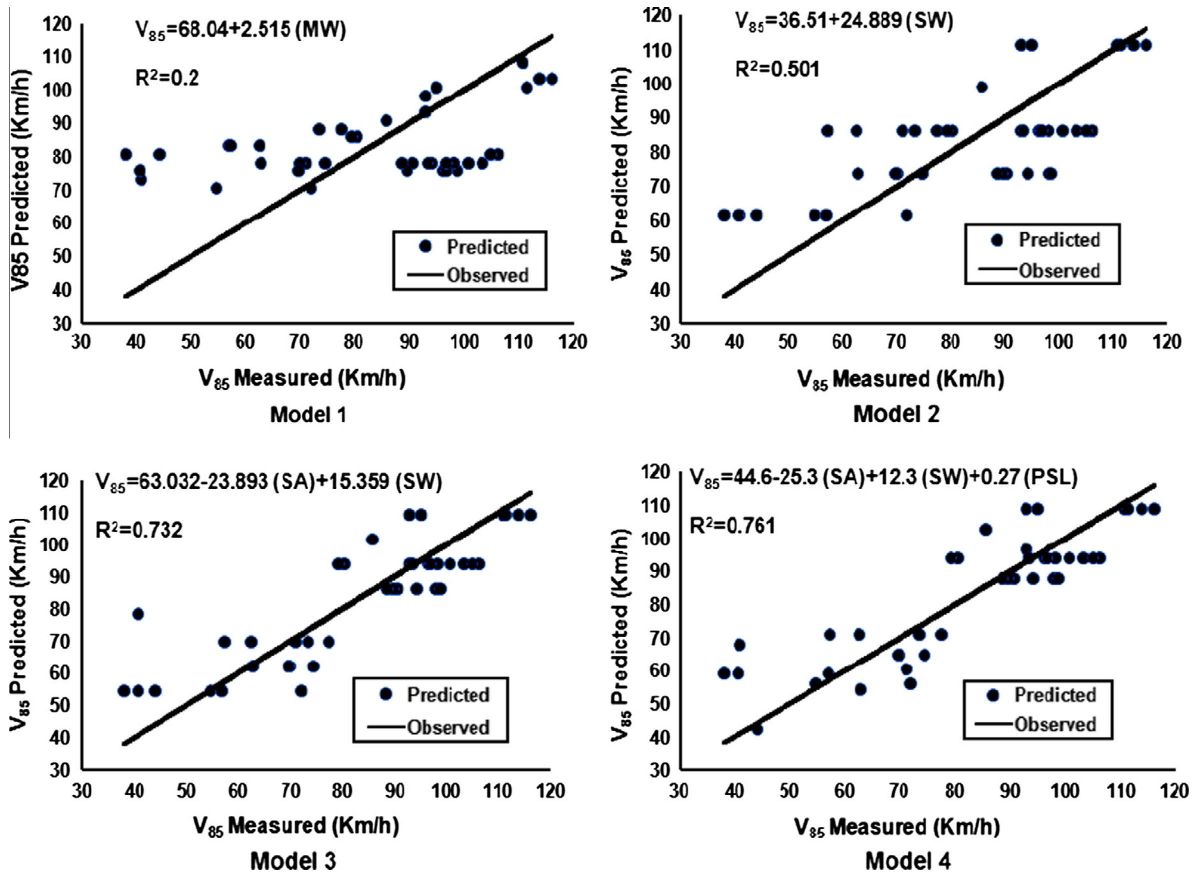

Fig. 1 Measured and predicted V_{85} for Models 1–4.

ANN models

For ANN models (MLP); the input variables (seven variables) are in input layer. One hidden layer, and one desired variable (V_{85}) is in output layer with 41 observations are used. The architecture of the ANN model is shown in Fig. 2. Sites are divided into training data set that has 35 sites (85% of all observations), and testing data set that has six sites (15% of all sites). So many trials are done to reach this percentage between training and testing data. As in the literature, the training data set varies from 70% to 90%. Therefore, 85% and 15% of training and testing data set respectively gives the best model performance in the present case of research. In addition, over fitting can be avoided by randomize the 41 sites before training the network to reach the best performance for both training and testing data. The performance of testing data must be good as training data (R^2 must not be smaller than 0.5) [23].

The number of neurons in hidden layer is about half of the total number of neurons at the input and output layers (three neurons), which is set based on generally accepted knowledge in this field. Using of learning rule of (momentum) and the suitable number of epochs (iterations) is 5000. The previous conditions are suitable for quick convergence of the problem [24].

So many trials were done to reach the best model performance. As a result of training and testing processing, the performances of the best model for training (35 samples) and testing (six samples) data set are presented in Table 2.

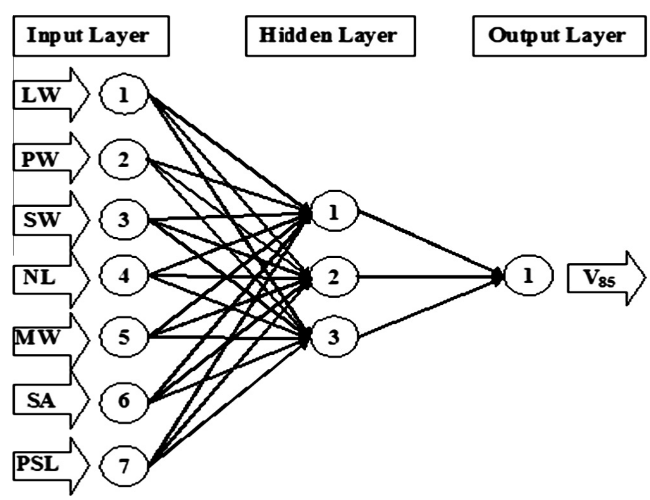

Fig. 2 MLP network architecture of the present model.

Table 2 Performances for ANN model.

Performance	Training (35 samples)	Testing (6 samples)	Overall model
R^2	0.982	0.84	0.978
RMSE	2.9	4.12	3.11

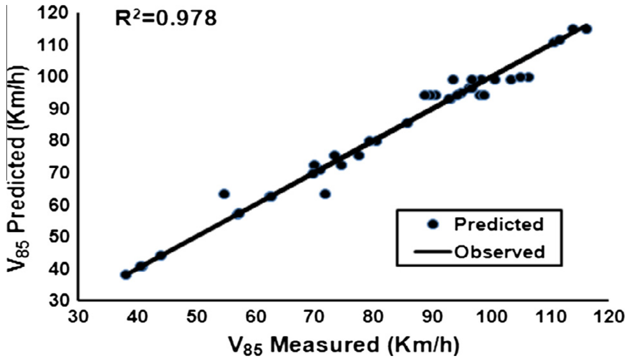

Fig. 3 Measured and predicted V_{85} for the best ANN model.

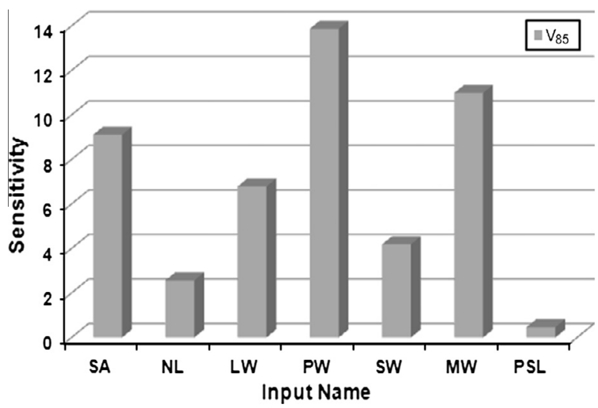

Fig. 4 Sensitivity for explanatory variable.

The observed values are plotted versus predicted values as shown in Fig. 3. It is clearly that the ANN models give so better and most confidence results than regression models.

In order to measure the importance of each explanatory variable, general influence (sensitivity about the mean or standard deviation) is computed based on the trained weights of ANN. For specified independent variable, if this value (sensitivity about the mean) is higher than other variables. This indicates that the effect of this variable on dependent variable (V_{85}) is higher than other variables. Fig. 4 shows the sensitivity of each explanatory variable in the selected model. It is found that the most influential variable on V_{85} is PW, followed by MW and SA while PSL has the lowest effect on V_{85}.

The relationships between each input variable and V_{85} are shown in Fig. 5. For PW MW, LW, and SW; V_{85} increases with the increase of these four variables. In addition, the existence of SA leads to a considerable decrease of V_{85}. Although the average V_{85} at sites without SA is 95 km/h, the average V_{85} at sites with SA is 66 km/h. Also, it is that the increase in NL leads to more V_{85} values. The average V_{85} for 2, 3, and 4 lanes site are equal to 69, 89, and 108 km/h, respectively. Finally, the effect of PSL on V_{85} is very low and can be neglected due to the bad driving behavior in Egypt. All the previous results are consistent with logic.

Impact of post-speed limits on V_{85}

The previous models (especially ANN) show that, the PSL has a very small effect on V_{85} and can be neglected. This may be due to the bad behavior of drivers are not to care with PSL signs generally in Egypt. Table 3 shows the 85th percentile speed (operating speed), the PSL, and the absolute difference between speed limit and the operating speed.

Investigation of Table 3 shows that,

- The V_{85} is higher than PSL at 21 sites.
- The V_{85} speeds vary widely from site to site as follows:
- At PSL 100 km/h, the maximum of 116.14 km/h and a minimum of 56.88 km/h.
- At PSL 90 km/h, the maximum of 106.27 km/h and a minimum of 54.7 km/h.
- At PSL 40 km/h, the maximum of 44.09 km/h and a minimum of 38.13 km/h.
- The V_{85} exceeding the speed limit at the study sites varies broadly from about 16.27 km/h, as in site No. 36, to about 0.51 km/h, as in site No. 28. The V_{85} exceeding the speed limit by less than 10 km/h at 12 sites, and more than 10 km/h at nine sites.

Based on the above points and Table 3, the results show considerable changes in 85th percentile speed among the study sites despite that they are in the same class (i.e. rural multi-lane two-way). The road characteristics of straight section used in the present paper such as pavement width and shoulder width surly have significant impact on the drivers' choice of speed at straight sections. This may explain also the variance in the observed speed data between the survey sites and assures the results of the operating speed modeling in the present research.

Fig. 6 shows the cumulative frequency distribution curves for sites 2 and 18. From this figure, it is obvious that the two cumulative distributions are completely different; i.e. the difference between operating speeds (V_{85}) is very large. Therefore, the use of the same speed limit (100 km/h) for both sites may not be completely correct.

The correct way to solve this situation is the establishment of speed zoning of reasonable and safe speed limits on roadways based on an engineering study. A speed zone is a section of highway where a speed limits different from the statutory speed limit has been established [1].

Conclusion

The most important conclusions of the current paper are as follows: first, the ANN models give so better and most confidence results than regression models in terms of predicting V_{85}. The evident of this is as follows, the best ANN model gives R^2 and RMSE equal to 0.978 and 3.11 for overall data set compared with the best regression model gives R^2 and RMSE equal to 0.761, and 10.32 for all data set. The second conclusion concludes that the most influential variable on V_{85} is PW, followed by MW and SA. The increase of PW from 6.8 m to 7.1 leads to an increase of V_{85} by nearly 40 km/h. Also the increase in MW from 2.2 m to 2.8 m leads to an increase in V_{85} by 27 km/h, and the increase from 2.8 m to 7 m leads to an increase in V_{85} by 21 km/h. In addition, the existing of SA leads to a considerable decrease of V_{85}. Although the average V_{85} at sites without SA is 95 km/h, the average V_{85} at sites with SA is 66 km/h. The last conclusion shows that as a result of the best ANN model, the PSL has a very small effect on V_{85} and can be neglected. This may be due to the bad behavior of

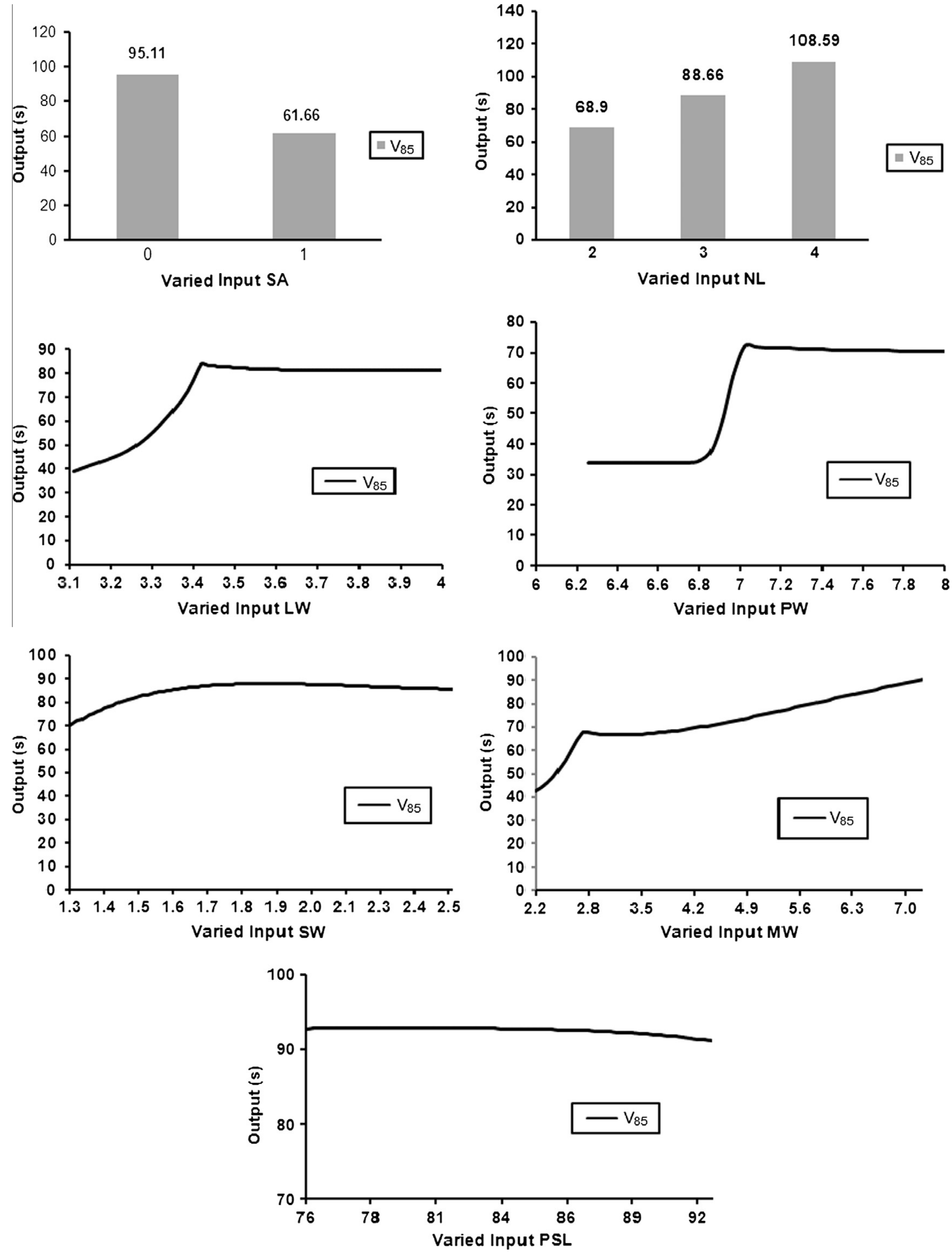

Fig. 5 The relationships between each explanatory variable and V_{85}.

drivers not to care with PSL signs generally in Egypt. Based on the analysis of measured V_{85} at all sites, the results show considerable changes in 85th percentile speed among the study sites despite that they are in the same class (i.e. rural multi-lane two-way). The road characteristics of straight section used in the present paper such as pavement width existing of side access, and median width surly have significant impact on drivers' choice of speed at straight sections. The previous results are so important for controlling V_{85} on multi-lane rural highways in Egypt. V_{85} can be controlled by targeting road geometric factors to improve the safety performance of the highways. Finally, future research should be conducted to extend all aspects of this research using comprehensive field data from various rural roads to increase number of sites to more

Table 3 The V_{85}–PSL relationships.

Site	V_{85} (km/h)	PSL (km/h)	$\|V_{85}$–PSL$\|$	V_{85} > PSL	V_{85}–PSL < 10 km/h	V_{85}–PSL > 10 km/h
1	73.4	100	26.6			
2	56.88 (min.)	100	43.12			
3	93	100	7			
4	77.5	100	22.5			
5	95	100	5			
6	62.5	100	37.5			
7	57.25	100	42.75			
8	44.09	40	4.09	4.09	√	
9	38.13	40	61.87			
10	40.81	40	0.81	0.81	√	
11	110.76	100	10.76	10.76		√
12	80.4	90	9.6			
13	71.03	60	11.03	11.03		
14	79.35	90	10.65			√
15	62.75	60	2.75	2.75	√	
16	85.67	100	14.33			
17	69.92	100	30.08			
18	116.14 (max.)	100	16.14	16.14		√
19	69.68	100	30.32			
20	111.49	100	11.49	11.49		√
21	74.56	100	25.44			
22	113.82	100	13.82	13.82		√
23	92.91	100	7.09			
24	40.65	40	59.35			
25	54.7	90	35.3			
26	71.95	90	18.05			
27	94.26	90	4.26	4.26	√	
28	90.51	90	0.51	0.51	√	
29	98.03	90	8.03	8.03	√	
30	89.6	90	0.4			
31	98.72	90	8.72	8.72	√	
32	93.49	90	3.49	3.49	√	
33	103.36	90	13.36	13.36		√
34	100.7	90	10.7	10.7		√
35	98.22	90	8.22	8.22	√	
36	106.27	90	16.27	16.27		√
37	96.29	90	6.29	6.29	√	
38	96.67	90	6.67	6.67	√	
39	96.81	90	6.81	6.81	√	
40	105	90	15	15		√
41	88.62	90	1.38			

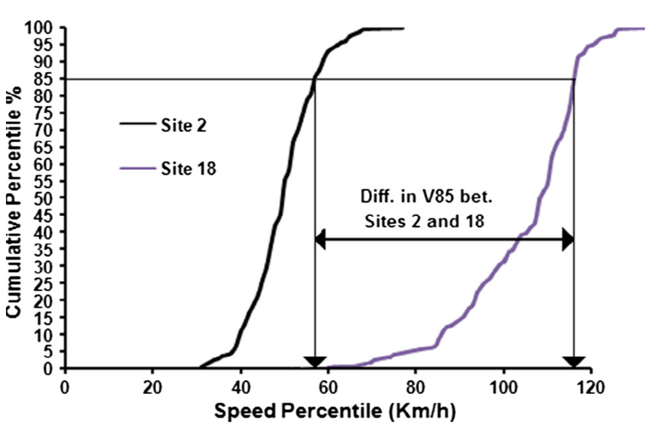

Fig. 6 Speed cumulative frequency distribution curves for sites 2 and 18.

than 100 sites in order to reach more accurate modeling and analysis of V_{85}. In addition, the use of curved and sloping sections in order to explore the impact of them on operating speeds for rural multi-lane highways in Egypt.

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