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ORIGINAL ARTICLE

New models to evaluate the level of service and capacity for rural multi-lane highways in Egypt

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Abstract Multi-lane highways represent the majority of the total length of highway network in Egypt. The road geometry and the percentage of heavy vehicles (HVs) are considered the most important factors affecting the level of service (LOS) and capacity for any roadway. Therefore, this paper aims to explore the relationship between the road geometric characteristics and HV, and the LOS and capacity by two ways. First is the statistical modeling and second is the modeling by artificial neural networks (ANNs). In this research, the traffic and road geometric data are collected from mid-tangent points at 45 different sites that are located in desert and agricultural highways. The results showed that the ANN modeling gives the best models for estimating LOS and capacity. Also, it is better for analysis to separate the desert and agricultural sites. In addition, the most influential variables on LOS and capacity in desert sites are HV and lane width (LW), respectively, while in agricultural sites are LW and existence of side access (SA), respectively. These results are so important for road authorities in Egypt as they can determine LOS and capacity for different tangent sections and improve the traffic performance of them in the future.

1. Introduction

The transportation system in Egypt is suffered from limited roadway infrastructure and the lack of operation and management experience. Among the most critical issues in highway planning and management is to explore the effectiveness of road geometric characteristics and the percentage of HV in traffic composition on LOS and capacity at multi-lane rural highways. Rural multi-lane highways are an important type of uninterrupted flow facilities in which there is no obstruction to the movement of vehicles along the road. Such facilities represent the majority of the highway system in Egypt. Highway Capacity Manual (HCM) [1] uses density in terms of passenger cars per kilometer per lane as the primary level of service (LOS) measure for multi-lane highways and also [1] uses free flow speed (FFS) as the primary capacity measure for the same type of highways. Therefore, this paper aims to evaluate LOS and capacity on multi-lane highways by two modeling techniques. First is the traditional statistical technique and the second is ANN technique.

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Field data on multi-lane highways in Egypt are used in this investigation. The analysis considers 45 tangent sections from 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). Then, the paper includes two separate relevant analyses. The first analysis uses the regression models to investigate the relationships between LOS and capacity as dependent variables, and roadway factors and HV percentage as independent variables. The road factors are lane, pavement, median width, lateral clearance, number of lanes in each direction, and existence of side access along each section. The second analysis uses the ANN to explore the previous relationships and comparing the results. According to the objectives in this research, road authorities in Egypt can determine LOS and capacity for different multi-lane highway tangent sections and improve the traffic performance of them in the future.

Several researches have been carried out to analyze the effect of road geometry and traffic composition on LOS and Capacity for multi-lane highways. Kerner [2] confirmed that the determination of capacity and LOS for any highway is one of the most important applications of any traffic theory. Some previous theories and empirical researches focused on the interrelationships among the influence of capacity, traffic features, and geometric elements on uninterrupted multi-lane highways [3–6]. Bang [7] in their study for establishing Indonesia HCM mentioned travel speed as the main measure of performance of road segments. Yang and Zhang [8] have established based on their extensive field survey of traffic flow on multi-lane highways in Beijing and subsequent empirical model development that the average roadway capacity per hour per lane on four-lane, six-lane and eight-lane divided carriageways is 2104, 1973 and 1848 passenger car unit, respectively. Velmurugan et al. [9] studied the speed-flow characteristics on varying types of multi-lane highways in India and subsequent capacity of Indian multi-lane highways had been estimated based on traditional and microscopic simulation models. Arasan and Arkatkar [10] studied the effect of variation of traffic composition, road width, magnitude of upgrade and its length on Indian highways capacity, and subsequently, it was concluded that highway capacity significantly changes with change in traffic volume composition, width of roadway, magnitude of upgrade, and its length. Sakai et al. [11] used an empirical approach to produce LOS measure for basic expressway segments in Japan incorporating Customer Satisfaction (CS). It was concluded that LOS and CS were confirmed to have a nonlinear relation. García et al. [12] studied the effect of traffic calming devices on the cross-town roads capacity in Spain based on different type and spacing of devices. The results showed that capacity varied between 810 and 1300 vehicles per hour per lane with traffic calming devices spacing from 25 to 400 m.

2. Data collection and methods of LOS and capacity estimation

This section is divided into two main parts as (1) study sites and field data, and (2) equations of LOS and capacity determination.

2.1. Study sites and field data

This research focuses on the rural multi-lane highways in Egypt. Therefore, the analysis of this paper uses 45 sites (sections) from four main multi-lane highways in Egypt. These roads include Cairo–Alexandria Agricultural Highway (CAA), Tanta–Damietta Agricultural Highway (TDA), Cairo–Alexandria Desert Highway (CAD), and Cairo–Ismailia Desert Highway (CID). These sites are divided into 21 sections in desert roads and 24 sections in agricultural roads. Each section length is 100 m. 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. The collected data are divided into three types as road geometric characteristics, vehicles speed, and traffic volume data.

2.1.1. Road geometric data

These data are collected directly from site investigation that included lane width, lateral clearance, number of lanes in each direction, median width, and pavement width. All the previous variables, their symbols, and statistical analysis are provided in Table 1.

2.1.2. Vehicles speed data

There are two main types of the collected speed. First is FFS data and the second is average travel speed of passenger cars (ATS_{pc}) data. Each of them is measured in field as follows.

2.1.2.1. FFS data. FFS are collected for passenger cars only for 45 sections (the passenger cars include taxis, vans/jeeps, and microbuses). 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 [13]. Vehicles traveling in free-flow conditions are considered to have time headways of at least 8 s [14]. The number of speeds collected at each site range from 100 to 160, which led to a total of 6300 spot speeds. Speeds are carried out in

Table 1 Statistical analysis and symbols of independent variables.

Variable	Symbol	Max.	Min.	Avg.	SD
1 – Lane width in meters	LW	3.65	3.00	3.5	0.2
2 – Pavement width in one direction in meters	PW	14.6	7	8.9	2.3
3 – Lateral clearance in meters	LC	3.6	1.5	2.4	0.7
4 – No of lanes in each direction in lanes	NL	4	2	3	–
5 – Median width in meters	MW	16	1	7.2	3.2
6 – Existing of side access (1 if exiting; 0 otherwise)	SA	1	0	–	–
7 – Percentage of heavy vehicles %	HV	28	2.1	8.1	5.9