Development of Speed Prediction Models for Day-time Versus Night-time Conditions on Rural Multilane Egyptian Highways

A Thesis

Submitted to the Faculty of Engineering
Ain Shams University for the Fulfillment
of the Requirement of M. Sc. Degree in Civil Engineering
(Highways & Traffic Engineering)

Prepared by

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Statement

This dissertation is submitted to Ain Shams University, Faculty of Engineering for the degree of M. Sc. in Civil Engineering.

The work included in this thesis was carried out by the author in the department of Public Works, Faculty of Engineering, Ain Shams University, from 2014 to 2018.

No part of the thesis has been submitted for a degree or a qualification at any other University or Institution.

The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

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ABSTRACT

One of the shortcomings of the design speed concept is that it uses the design speed of the most restrictive geometric element as the design speed of the entire road. This may lead to potential inconsistencies among successive sections of a road. So, the operating speed-based method is popularly used for examining design consistency. Numerous studies have been completed on rural two-lane highways for predicting operating speeds. However, little is known for rural four-lane non-freeway highways.

This thesis presents the development of operating speed models for day-time and night-time conditions for highways in Egypt based on a study of ٥٨ horizontal curves at different sites on rural multilane roads. In each horizontal curve, Spot speeds were collected during the day and night at five points. Spot speeds were collected at the middle of first tangent, point of curve, middle of curve, point of tangent and the middle of second tangent.

Statistical tests were used to compare day-time and night-time speeds at the midpoint of each horizontal curve. T-test reveals that there is no statistical difference between daytime and nighttime speeds at the midpoint of the horizontal curves. ANOVA test reveals that there is significant difference in speed variance at the midpoint of the horizontal curves between day-time and night-time conditions.

Another comparison was done to investigate the design consistency of the horizontal curves. Comparison between speeds at the main points of the horizontal curve was made using ANOVA. The results of ANOVA test for horizontal curves showed that there is no significant difference in speeds between each two successive points within the horizontal curve.

In the operating speed models, the radius of the horizontal curve was used to estimate the operating speed. The speed models determined that the operating speed is highly correlated with the radius of the horizontal curve.

Key Words: Operating speed, design consistency, daytime and nighttime speeds, model development and validation, rural multilane highways, horizontal curve, speed comparison.

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CHAPTER ONE: INTRODUCTION

Although the number of vehicle miles driven at night generally represents less than 20 percent of the total vehicle miles driven on US highways, between 40 and 50 percent of traffic fatalities occur at night (Richard J. Porter, 2014). The National Highway Traffic Safety Administration (NHTSA) reported that 49 percent of passenger vehicle occupant fatalities occur at night, while only 25 percent of travel occur during the night (Varghese and Shankar, 2007).

The severity of the night-time crash problem is further evidenced by nighttime traffic fatality rates, which are more than four times higher than in the day (Richard J. Porter, 2014). Night-time traffic fatality rates have traditionally been the highest in rural driving environments. Despite these numbers, current geometric design criteria and knowledge on the operational and safety effects of geometrics seems limited with respect to night-time speeds (Richard J. Porter, 2014).

Accidents on horizontal curves have presented a safety challenge for many years. A study conducted near Nashville, Tennessee revealed that crashes occur on rural areas due to inconsistency between the geometric elements of the road and the driver expectations, speeding and the driver inattention. At horizontal curves, about 76 percent of the fatal crashes involve single vehicles leaving the roadway and driving into trees or other fixed objects and overturning. Another 11 percent are head on crashes (Ridwan B.A Quaiam, 2010).

Studying the night-time speeds was an important issue to be investigated. First, it is important to define the different types of speeds. Design speed is the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern (AASHTO, 2001). Operating speed is maximum safe speed at which a vehicle can be conducted in a given traffic stream, without exceeding the design speed of the highway segment. In other words, operating speed is the speed at which drivers are observed operating their vehicles during free-flow conditions (AASHTO, 2001). According to AASHTO, the 85^{th} percentile of the distribution of observed speeds is the most frequently used measure of the operating speed associated with a particular location or geometric feature. Posted speed is the maximum allowed speed for vehicle movement posted on a section of highway using regulatory sign. Transportation Research Circular: Number E-C151 (2011) recommends that future operating speed

modeling work be designed to develop operating speed models at night-time conditions. However, most of the current studies have been carried out in Europe and North America. The study provided in this thesis presented one of only few studies that attempt to develop reliable speed models in a developing country.

1.1.PROBLEM STATEMENT

The rate of accidents that happen during night-time is higher than day-time rate especially at horizontal curve locations. The presence of sunlight enhances the vision of the driver during day-time. At night, especially on rural roads where there is usually no street lighting, a driver would depend solely on their vehicle headlights, thus reducing their visibility (Ridwan B.A Quaiam, 2010).

At horizontal curves on multilane rural highways, this maybe an added safety concern. To find out whether horizontal curves coupled with night-time driving is a safety issue, vehicle speed during the day and night should be compared at horizontal curves with different curve geometry.

1.2.RESEARCH OBJECTIVE

The main objective of the current research is to develop and assess operating speed models as a function of the specific road geometric design parameters for day-time and night-time conditions for selected sample of rural multilane highways in Egypt.

1.3.RESEARCH METHODOLOGY

This research develops operating speed models on horizontal curves on different geometric conditions for day-time and night-time conditions and evaluates these models to get the best model for predicting operating speed. The following stages summarize the general approach followed in this research:

1. Review of literature related to the research topic
2. Data needs assessment.
3. Design of a data collection plan including the following:
   - Selection of several rural multilane road(s) that can be used for data collection.
   - Specification of locations on selected highways for speed data collection.
   - Determination of the speed sample size at each location for day-time & night-time conditions.
   - Geometric data collection at the horizontal curves.

4. Assessment and comparison of day-time and night-time speeds and speeds at different locations in the horizontal curves.
5. Choice one of the modeling techniques that will be used in the analysis.
6. Studying suitable computer program for development of operating speed models.
7. Development and validation of the models.
8. Choice of the best model.
9. Provision of research conclusions, in addition to recommendations for future research work.

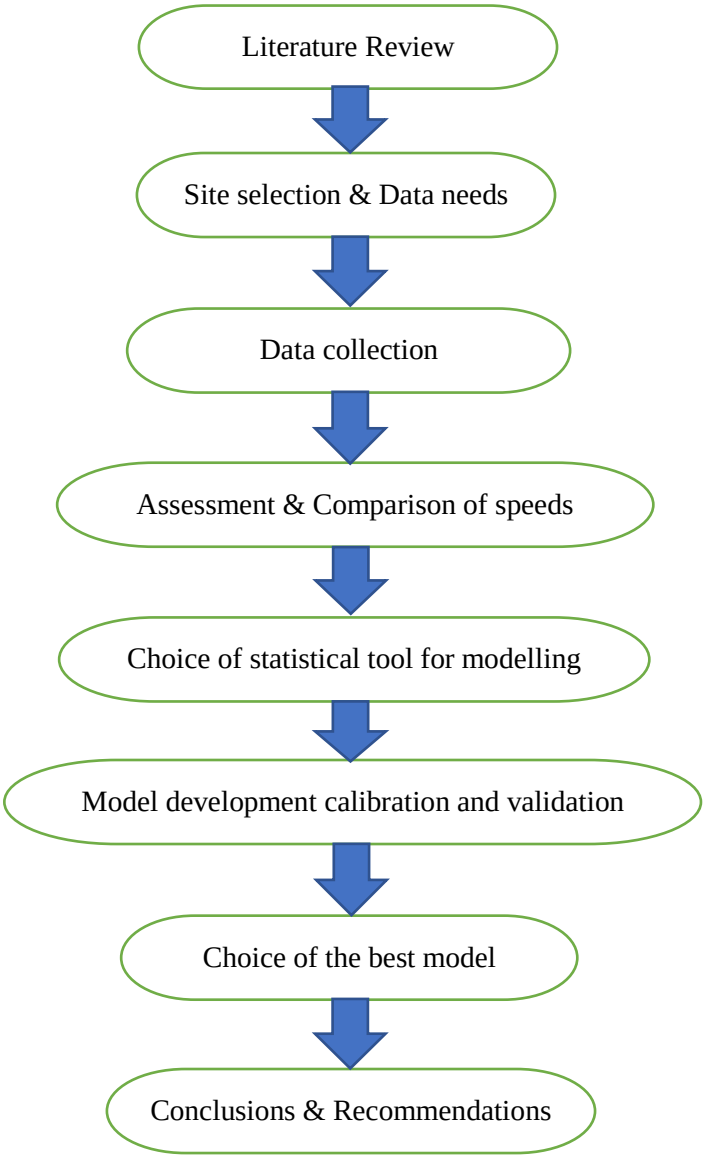

Figure 1- 1 Proposed Research Methodology

1.4.THESIS STRUCTURE

This thesis consists of five chapters. The first chapter is an introduction that includes a brief description of night-time driving and its fatalities, research objective and research methodology. The second chapter is a literature review about safety impacts of horizontal curves, night-time driving as well as operating speed models for day-time and night-time conditions are reviewed. The third chapter discusses site selection and data collection. The fourth chapter discusses assessment of speeds and compares day-time and night-time speeds. Also, in this chapter, comparisons of speeds of the different points on the horizontal curve - point of curve, middle of curve and point of tangent – are provided. Comparison between design speed, operating speed and speed limit at midpoint of horizontal curves were provided. Also, this chapter discusses the development of operating speed models based on the collected data. Finally, this chapter presents the validation of the selected model. The fifth and final chapter summarizes the conclusions from this research and recommendations for future research.