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MODELLING THE RELATIONSHIP BETWEEN VEHICLE OPERATING SPEED AND THE GEOMETRY OF THE ROADS USING GEOGRAPHIC INFORMATION SYSTEMS (GIS)

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Thesis submitted in partial fulfilment of the requirements for the degree

Master of Science

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Dedication

To my dear,

Father, Mother, Sister and husband

Acknowledgement

I am heartily thankful to my research supervisor and present research coordinator of Department of Civil Engineering, University of Moratuwa, Prof. J. M. S. J. Bandara, whose encouragement, guidance and support from the initial to the final level enabled me to carry out my research works and understand the subjects related to my Master of Science Degree.

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R P G K S Rajapaksha

Abstract

It is known that road geometric features significantly contributes to the variation in vehicle speed. According to conventional Highway Geometric design procedure there is no accurate method to predict actual vehicle speed with different combinations of geometric elements such as horizontal alignment and vertical alignment etc. This study explores a methodology to evaluate actual vehicle speed variation mainly considering geometry.

In this paper after classification of all the design elements, a new predictor called "curvature Index" (the degree of angle variation per unit length) is introduced to represent actual horizontal alignment variation of a road segment including number of bends and nature of bends. The curvature index measures analyzed were: bend density (number of bends per km); cumulative angle (degrees per km); mean angle (degrees); and standard deviation of angles. The research confirmed that driver's speed choices are more strongly related to curvature Index than curve design speed, and to the approach speed environment. Similar measures were carried out for vertical alignment variation and new predictor called "Elevation Index" is introduced to represent different combination of vertical alignments. International Roughness Index (IRI) and Road width selected as other predictors to obtain the correlation between Geometry and speed.

The curvature index, elevation index and actual vehicle speed are estimated using the database of GPS (Global Positioning System) receivers. Data was collected at selected road segments in Sri Lanka under less traffic condition. A methodology developed to increase the reliability and accuracy of GPS data. Simple linear regression analysis is carried out using SPSS and MINI Tab software to develop actual vehicle speed model together with ArcGIS. ArcGIS (Geographical Information System) provides a good platform to graphical analysis of data and integrate with GPS data.

This study conforms positive correlation between actual speed and combination of Geometric elements. This model could be combined with other social environmental factors (e.g.: land use) and effectively use as speed prediction model or as a design tool.

Terminology and Notation

The following terms and abbreviations are commonly used in speed literature and discussions. Other references may use or define these terms somewhat differently than as defined below and used in this publication.

GIS = Geographical information systems

GPS= Global position system.

IRI = International Roughness Index

FHWA - abbreviation for the Federal Highway Administration, an operating agency of the U. S. Department of Transportation.

Green Book – A Policy on Geometric Design of Highways and Streets (1) as published by AASHTO.

AASHTO – abbreviation for the American Association of State Highway and Transportation Officials.

15th percentile speed – the speed at or below which 15 percent of vehicles travel. Also, see Speed distribution.

85th percentile speed – the speed at or below which 85 percent of vehicles travel. Also, see Speed distribution.

Advisory speed – a speed below the speed limit that is recommended for a section of highway. The advisory speed is normally determined through an engineering study that considers highway design, operating characteristics and conditions. Advisory speeds are displayed on warning signs in speed values that are multiples of 5 mph. Advisory speeds cannot be enforced.

Designated design speed – the speed established as part of the geometric design process for a specific segment of roadway.

Inferred design speed – the maximum speed for which all critical design-speed-related criteria are met at a particular location.

Mean speed - the summation of the instantaneous or spot-measured speeds at a specific location of vehicles divided by the number of vehicles observed. It is a common measure of central tendency.

Operating speed - the speeds at which vehicles are observed operating during free flow conditions. Free flow speeds are those observed from vehicles whose operations are unimpeded by traffic control devices (e.g., traffic signals) or by other vehicles in the traffic stream. The 85th percentile of the distribution of observed speeds is the most frequently used measure of the operating speed.

Posted speed – one of two speed limit types (statutory speed is other type); the maximum lawful vehicle speed for a particular location as displayed on a regulatory sign. Posted speeds are displayed on regulatory signs in speed values that are multiples of 5 mph.

Side friction – the lateral force developed between the tires and the roadway as a vehicle traverses a horizontal curve, expressed as a dimensionless coefficient of vertical force imposed by the vehicle's weight.

Sight distance – the length along a roadway over which a driver has uninterrupted visibility – this is known as available sight distance. Different minimum sight distance design criteria exist for various operations and maneuvers, including stopping sight distance, passing sight distance and intersection sight distance.

Speed deviation – sometimes used to indicate Standard deviation of speed (see definition). Also, see Speed distribution.

Speed distribution – an arrangement of speed values showing their observed or theoretical frequency of occurrence.

Speed limit – the maximum lawful vehicle speed for a specific location. There are two types of speed limits, posted speed and statutory speed, definitions of each are provided.

Speed zone – a speed limit established on the basis of an engineering study for a particular section of road, for which the statutory speed limit is not appropriate.

Standard deviation of speed – a statistical measure (standard deviation) of the spread in values, applied to speeds. Also, see Speed distribution.

A = algebraic difference of vertical grades (%)

ADT = average daily traffic (vehicles/day)

CCR = curvature change rate (degree/km)

Curve–dir = curve direction (right-turn: curve-dir=1, else, curve-dir=0)

DC = degree of curvature (degrees)

DF = deflection angle (degrees)

DF 1 = deflection angle for curves 1 of compound curve, (degrees)

DF 2 = deflection angle for curves 2 of compound curve, (degrees)

DFC = deflection angle of circular curve (degrees)

DL = design speed –posted speed limit (mph)

Drv-flag = driveway flag (intersection on curve: drv-flag=1; otherwise: drv-flag=0

DS = design speed (mph)

E = super elevation rate (%)

G = vertical grade (%)

G_1 = first grade in direction of travel (%)

G_2 = second grade in direction of travel (%)

K = length of vertical curve for 1% change in grade (m)

L_C = length of horizontal circular curve (m or ft)

L_T = length of tangent (m)

L_{T1} = length of preceding tangent (m)

L_{T2} = length of succeeding tangent (m)

L_v = length of vertical curve (m)

L_0 = distance between horizontal and vertical points of intersection (m)

LW = lane width (m)

R = radius of the curve (m or ft)

R a = radius of previous curve (m)

RES = equal to 1 if segment has 10 or more residential driveways per mile; 0 otherwise

R_1 = radius of curve 1 of the compound curve (m)

R_2 = radius of curve 2 of the compound curve (m)

RSW = right shoulder width (ft)

SD = sight distance

SE = maximum super elevation rate, percent

SL = speed limit

SW = shoulder width (m)

V a = curve approach speed (km/h)

V d = desired speed (km/h)

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