Accident Analysis and Prevention 95 (2016) 33–41

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Using Quasi-Horizontal Alignment in the absence of the actual alignment

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ARTICLE INFO

Article history:
Received 8 January 2016
Received in revised form 25 April 2016
Accepted 21 June 2016

Keywords:
Horizontal alignment
SHRP 2 RID
Crash prediction
Alignment extraction

ABSTRACT

Horizontal alignment is a major roadway characteristic used in safety and operational evaluations of many facility types. The Highway Safety Manual (HSM) uses this characteristic in crash prediction models for rural two-lane highways, freeway segments, and freeway ramps/C-D roads. Traffic simulation models use this characteristic in their processes on almost all types of facilities. However, a good portion of roadway databases do not include horizontal alignment data; instead, many contain point coordinate data along the roadways. SHRP 2 Roadway Information Database (RID) is a good example of this type of data. Only about 5% of this geodatabase contains alignment information and for the rest, point data can easily be produced. Even though the point data can be used to extract actual horizontal alignment data but, extracting horizontal alignment is a cumbersome and costly process, especially for a database of miles and miles of highways. This research introduces a so called "Quasi-Horizontal Alignment" that can be produced easily and automatically from point coordinate data and can be used in the safety and operational evaluations of highways.

SHRP 2 RID for rural two-lane highways in Washington State is used in this study. This paper presents a process through which Quasi-Horizontal Alignments are produced from point coordinates along highways by using spreadsheet software such as MS EXCEL. It is shown that the safety and operational evaluations of the highways with Quasi-Horizontal Alignments are almost identical to the ones with the actual alignments. In the absence of actual alignment the Quasi-Horizontal Alignment can easily be produced from any type of databases that contain highway coordinates such geodatabases and digital maps.

1. Introduction

A majority of highway safety and operational evaluation models require horizontal alignment data to conduct such evaluations efficiently and properly. However, many agencies lack such data for the major portion of their highways in their databases and have only point coordinates, in the form of Latitude/Longitude or Cartesian coordinates (e.g., a series of (X,Y) coordinates) that when linked together, give an approximation of the horizontal alignment. Agencies are increasingly using mobile data collection systems or electronic maps to obtain highway data. One of the immediate results of such data collection methods are roadway points coordinate data. The coordinate data can later be used to derive the alignment data of the road. This type of data collection is becoming quite fast and low-cost compared to the more precise geometry data collection such as on-site surveying.

Much of point data collected through mobile data collection systems or electronic maps can be processed in an efficient and automated manner to produce data for the entire length of highway projects such as lane width, shoulder width, grade, roadside, etc. An exception is the horizontal alignment data. Except for the mobile data collection systems that now a days produce horizontal alignment from their collected point data, it is relatively time consuming and costly for the other point data collection systems to produce horizontal alignment from point coordinate data and the process usually requires human intervention in different stages.

This research presents a relatively simple algorithm generating a "Quasi-Horizontal Alignment" from point coordinate data that can be used in the safety and operational evaluation of highways. The algorithm produces Quasi-Horizontal Alignment automatically from point data with some straight forward equations. It can be coded in regular spreadsheet programs (i.e., EXCEL) and can be used for large databases containing point coordinate data. As part of the process, a maximum radius, R_{max}, is estimated in advance, as the threshold value for producing Quasi-Horizontal Alignment. In the

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http://dx.doi.org/10.1016/j.aap.2016.06.019
0001-4575/

Quasi-Horizontal Alignment, tangents and curves with radii flatter than R_{max} are approximated by tangents, and curves with radii equal or sharper than R_{max} are approximated by compound curves with radii close to the actual radii of the curves.

Horizontal alignment is a major factor in safety and operational evaluations of rural two-lane highways. These facilities lack horizontal alignment data in many databases. In this study the Quasi-Horizontal Alignment is produced for a sample of 30 sections of rural two-lane highways, each between 2 and 3 miles of length, and the safety and operational evaluations of these alignments are compared to those of the same highways with the actual horizontal alignment. The comparison shows that the results are almost identical. IHSDM software, 2015 is used to conduct the evaluations. The IHSDM Crash Prediction Module (CPM) – a faithful implementation of the Highway Safety Manual (HSM), 2010 Part C Predictive Method – is used for the safety evaluation, and the Traffic Analysis Module (TAM) is used for operational evaluation.

Part C of the HSM contains crash prediction models for different types of highways. The general structure of these mathematical models includes a Safety Performance Function (SPF) and a series of Crash Modification Factors (CMFs).

The HSM crash prediction model for Rural Two-lane highways and its CMF for horizontal alignment are the focus of this research. This CMF has the following form:

$$CMF_{3r} = \frac{(1.55 \times L_c) + \left(\frac{80.2}{R}\right) - (0.012 \times S)}{(1.55 \times L_c)} \tag{1}$$

Where:CMF_{3r} = crash modification factor for the effect of horizontal alignment on total crashes;L_c = length of horizontal curve (miles) which includes spiral transitions, if present;R = radius of curvature (feet); and$S$ = 1 if spiral transition curve is present; 0 if spiral transition curve is not present; 0.5 if a spiral transition curve is present at one but not both ends of the horizontal curve.

The value of this CMF is 1 for tangents and larger than 1 for horizontal curves. As the radius or the length of the curve decreases, the value of this CMF increases. If the radius or the length of the curve is less than 100 ft, then 100 ft should be used in Eq. (1). Also if there is a compound curve (adjacent curves with the same direction curvature) the horizontal curve length used in Eq. (1) is the total length of the compound curve for all curves CMFs of the compound curve.

TWOPAS – the microscopic traffic simulation model used in the IHSDM Software (2015) Traffic Analysis Module (TAM) – had been developed for rural two-lane highways and had been used for the development of the two-lane models of the Highway Capacity Manual for years. This microscopic simulation model uses the horizontal alignment information along with the posted speed and traffic flow. The model simulates the traffic and produces traffic operational measures such as average speed and percent time following that can be used to determine the Level of Service (LOS).

The main purpose for this research is to develop an easy-to-obtain surrogate horizontal alignment that can be used in the absence of the actual alignment in the crash prediction and traffic simulation processes. The IHSDM modules, CPM and TAM, were used for the safety and operational evaluation of the 30 test highway sections. For highway sections that are used in these experiments, the probability that the estimated value for number of crashes predicted by the CPM for Quasi-Horizontal Alignment falls within 5% of the number of crashes predicted for the actual alignment is about 95% and the probability that the operational measures produced by the TAM for Quasi-Horizontal Alignment falls within 5% of the number of operational measures for the actual alignment is about 99%.

2. Related research

The related research reviewed here is focused on the techniques used for extracting horizontal alignment data from point data.

Karimi and Liu (2004) used image processing techniques to extract coordinates from satellite images. The proposed process extracts road data from satellite images and vectorizes the extracted data for GIS databases. Coordinates obtained through this process can later be used for the extraction of horizontal alignment.

Carlson et al. (2005) identified 10 techniques for obtaining horizontal curves and conducted a controlled experiment on 8 of these techniques to measure 18 horizontal curves on rural two lanes to evaluate their accuracy, precision, and cost. The tested methods were:

- Ball Bank Indicator
- Chord Length
- Compass
- Field Survey
- GPS Unit
- Lateral Acceleration
- Plan Sheet
- Advisory Speed Plate

Compared to the Field Survey method, all other methods had a relative error less than 7.5%, with the Plan Sheet and the GPS methods being the most accurate with relative errors of −0.9% and 1.2%, respectively. However, all methods needed human interaction for identifying curve locations.

Imran et al. (2006) employed non-linear regression to deduct the horizontal alignment of a road based on the path of a control vehicle (coordinate data). As an extension for *ArcView*, this application could identify horizontal tangents, spirals, and simple curves from coordinate data. The application of the model on a 25-km section of a two-lane highway test case was successful. However, this procedure cannot be used for a consistent and comprehensive application of the algorithm on a large-scale database because the tangents need to be identified by the user.

Easa et al. (2007) presented a method for establishing road horizontal alignment using IKONOS 1-m spatial resolution, a type of new generation commercial satellite imagery. This process identified the characteristics of simple curves as well as reverse curves. The process started with image processing that identified edges in the image by using some thresholds. The outcomes of this step were coordinates that were used in the second step. The standard Hough Transform algorithm was used to identify tangents vs. curves. The process started with identifying tangents on both sides of the curve, and then continued with identifying the curve characteristics. Curves could be simple or reverse. This was an interactive procedure and the entire process for a road that contains many tangents and curves could not be automated.

Dong et al. (2007) continued the work of Easa et al. (2007) using IKONOS 1-m spatial resolution imagery. They added a process to the algorithm that could extract the spiral curves as well. Similar to the previous work, this one also needs human interaction and cannot be fully automated.

Pratt et al. (2009) developed the “Texas Roadway Analysis Measurement Software” (TRAMS) program to measure curve geometry while driving through the curve. TRAMS uses data from a GPS receiver and an electronic ball-bank indicator and calculated curve radius, deflection angle, and superelevation rate. The process was (a) filtering the heading data for the noise with Kalman filtering as an option; (b) dividing the curve into 25-ft segments and for each segment the deflection angle was calculated; (c) deriving a sixth-order polynomial that predicted the deflection angle along the curve; (d) joining the segments if necessary to have deflection