Available online at www.sciencedirect.com
ScienceDirect
Procedia
Social and Behavioral Sciences
Procedia - Social and Behavioral Sciences 160 (2014) 449 – 458

XI Congreso de Ingeniería del Transporte (CIT 2014)

Sight distance studies on roads: influence of digital elevation models and roadside elements

C. de Santos-Berbel[a,]*, M. Castro[a] , S. López-Cuervo Medina[b], M. Paréns-González[a]

[a]Dept. Trasportes, E.T.S.I.C.C.P., Universidad Politécnica de Madrid (U.P.M.), C/ Prof. Aranguren s/n, 28040 Madrid, Spain
[b]Dept. Ingeniería Topográfica y Cartografía, E.T.S.I.G. y C. Campus Sur, Autovía de Valencia, km 7.5, 28031 Madrid, Spain

Abstract

Sight distance plays an important role in road traffic safety. Two types of Digital Elevation Models (DEMs) are utilized for the estimation of available sight distance in roads: Digital Terrain Models (DTMs) and Digital Surface Models (DSMs). DTMs, which represent the bare ground surface, are commonly used to determine available sight distance at the design stage. Additionally, the use of DSMs provides further information about elements by the roadsides such as trees, buildings, walls or even traffic signals which may reduce available sight distance.

This document analyses the influence of three classes of DEMs in available sight distance estimation. For this purpose, diverse roads within the Region of Madrid (Spain) have been studied using software based on geographic information systems. The study evidences the influence of using each DEM in the outcome as well as the pros and cons of using each model.

Peer-review under responsibility of CIT 2014.

Keywords: Geometric design; Alignment; Digital elevation model; Geographic information system; Sight distance; Traffic safety.

1. Introduction

Drivers ought to have a sufficient available sight distance, among other factors, if succeeding at any possible manoeuver involved in driving is targeted. Different manoeuvers inherent in driving such as emergency stops,

* Corresponding author. Tel.: +34 913366654; fax: +34 913366654.
E-mail address: cesar.desantos@upm.es

Peer-review under responsibility of CIT 2014.
doi:10.1016/j.sbspro.2014.12.157

evasive manoeuvers, passing or merging, require certain room to be carried out effectively and safely. In response to this, guidelines for geometric design of roads in different countries set minimum sight distance threshold values for each of these manoeuvers, depending on design speed (Ministerio de Fomento, 2000; AASHTO, 2004; FGSV, 2012).

Due to its close relationship with traffic safety, available sight distance studies should not take place exclusively at the design stage, but also during exploitation since conditions either of the road itself or by the roadsides might have varied. On certain occasions, in fact, available information about the geometry of the road either does not exist or it is not reliable because such roads have not been executed exactly according to project specifications or due to alterations in the geometry of the road. Moreover, elements by the roadsides might have arisen, such as trees or buildings, after the road was completed, which may obstruct the driver's vision. In addition, roadside equipment (i.e. signals and barriers) could also influence visibility.

In order to calculate available sight distance, which is measured along the theoretical path travelled by a vehicle, two data sets are needed: the vehicle path itself and a model which represents the pavement surface as well as the roadsides. In addition, the height of the driver's eye and the target object height are two fundamental parameters that must be defined.

The aim of this document is to analyze the influence of each type of DEMs for sight distance studies, comparing the output data produced by each.

2. Background

In order to facilitate the geometric design of roads, the Spanish guidelines for geometric design of roads (Ministerio de Fomento, 2000), among others, proposes a two-dimensional analytical methodology for available sight distance estimation. Nevertheless, these procedures are not practical since they consider separately horizontal and vertical alignment, which may lead to over- or underestimate actual available sight distance (Hassan, Easa & Abd El Halim, 1997). It is more common instead, to use DEMs and algorithms based on line-of-sight loops to perform this task, using though a 3-D approach. Such procedures retrieve the cross-sectional terrain profile below the line of sight, between observer and target location, identifying any possible obstruction. Besides algorithms based on line-of-sight loops, procedures based on viewsheds have been considered to study available sight distance of roads (Castro, Iglesias, Sánchez & Ambrosio, 2011; Jha, Karri & Kühn, 2011). Concerning the relationship between the presence of elements by the roadsides and visibility, Ismail and Sayed (2007) studied the influence of median barriers on available sight distance.

Computer-aided applications for road design estimate available sight distances and compare them against distances required to carry out specific manoeuvers. They also have visualization tools that simulate the driver's perspective while travelling along the section involved (Kühn, Volker & Kubik, 2011; Castro, 2012). Such visualization tools are utilized to supervise proper 3-D alignment coordination, yet it requires this checking procedure is performed by experienced engineers (Larocca, da Cruz, Quintanilha & Kabbach, 2011).

Moreover, methods based on line-of-sight loops permit to create sight distance diagrams. These charts represent the stations where the driver is sequentially placed on the horizontal axis, and visibility characterization of stations ahead from each position on the vertical axis (Kühn & Jha, 2011; Castro, Anta, Iglesias & Sánchez, 2014). Sight distance studies along vehicle path using such charts have been used not only to compare available and required sight distances but also to evaluate 3-D alignment coordination (Roos & Zimmermann 2004; Jha, Karri & Kühn, 2011; Castro et al., 2014) and to assess geometric design consistency (Altamira, Marcet, Graffigna & Gómez, 2010). The German Road and Transportation Research Association has drawn up guidelines in order to provide recommendations both for virtual image generation and sight-distance diagrams (FGSV, 2008).

Several authors have researched about the effects of insufficient available sight distance on traffic safety (Olson, Cleveland, Fancher & Kostyniuk, 1984; Fink & Krammes, 1995; Fambro, Fitzpatrick & Koppa, 1997; Andueza 2000; Caliendo, Guida & Parisi, 2007). Crash frequency has been observed to be negatively correlated to available sight distance (Sparks, 1968; Sylianov, 1973; Urbanik II, Hinshaw & Fambro, 1989).

DEMs, which are 3-D depictions of the earth surface, are increasingly derived using Light Detection And Ranging (LIDAR) techniques to capture points from such surface. Two classes of DEMs can be distinguished: digital terrain models (DTMs) and digital surface models (DSMs). DTMs, which represent the bare ground surface,