Available online at www.sciencedirect.com

ScienceDirect

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

Original Research Paper

Traffic sign vandalism and demographics of local population: A case study in Utah

Majid Khalilikhah [a,*], *Kevin Heaslip* [b], *Kathleen Hancock* [c]

[a] *Smart Urban Mobility Lab, Virginia Polytechnic Institute and State University, Falls Church, VA 22043, USA*
[b] *Department of Civil & Environmental Engineering, Virginia Polytechnic Institute and State University, Arlington, VA 22203, USA*
[c] *Department of Civil & Environmental Engineering, Virginia Polytechnic Institute and State University, Falls Church, VA 22043, USA*

ARTICLE INFO

Article history:
Received 21 July 2015
Received in revised form
20 October 2015
Accepted 2 November 2015
Available online 22 April 2016

Keywords:
Traffic sign vandalism
Mobile-based data collection
Demographics
Statistical methods

ABSTRACT

Among the different types of traffic sign damage, vandalism is exclusively caused by humans. Traffic sign vandalism is a serious concern, since it can lead to an increase in unsafe driving behaviors. In addition, it results in increased costs to transportation agencies to replace, repair, or maintain the vandalized signs. This paper examines the association between the local population demographics and traffic sign vandalism rates in the State of Utah. To accomplish this goal, sign data of over 97,000 traffic signs across Utah were digitally collected by an equipped vehicle. Sign damage data were obtained from the inspection of daytime digital images taken of each individual sign. Demographic data of Utah's counties, including population density, ethnicity, age, income, education, and gender, were obtained from the U.S. Census. The association between demographic groups and vandalism rates was tested using chi-square and trend tests. The results reveal that the most statistically significant variables comprise median household income, completion of at least an associate degree, and population density. According to the fitted linear regression model, a relationship exists between sign vandalism rate and local population demographic. The findings of this investigation can assist transportation agencies in identifying areas with a higher likelihood of sign vandalism, based on demographic characteristics. Such information can then be used to encourage scheduled sign inspections and to implement various countermeasures to prevent sign vandalism.

1. Introduction

To reduce the number of vehicular crashes, transportation agencies across the country continually make efforts for safety improvement. Since the important task of traffic signs is to convey critical information to drivers, the replacement of ineffective signs promotes safe driving and road navigation (Hugh and McGee, 2010). To better see and understand traffic

* *Corresponding author*. Tel.: +1 435 554 8499.
E-mail addresses: majidk@vt.edu (M. Khalilikhah), kheaslip@vt.edu (K. Heaslip), hancockk@vt.edu (K. Hancock).
Peer review under responsibility of Periodical Offices of Chang'an University.
http://dx.doi.org/10.1016/j.jtte.2015.11.001

signs, both high legibility and visibility are key characteristics. A study concluded that sign damage causes a decline in the overall legibility of the sign (Boggs et al., 2013). The effects of damage on the legibility of traffic signs vary considerably with respect to the form of damage (Khalilikhah and Heaslip, 2016a). Of all forms of sign damage, vandalism is the only one that is exclusively caused by humans. Types of human vandalism on signs include shooting paintballs and bullets, throwing beer bottles, putting stickers, and painting graffiti (Evans et al., 2012a). The overall legibility of the sign is affected by vandalism during both daytime and nighttime conditions. In addition, up to hundreds of thousands of dollars are spent to repair or replace vandalized signs (Evans et al., 2012b; Harris, 1992). Previously, a study showed that the vandalism rate for rural signs was greater than that of urban signs (Boggs et al., 2013).

After focusing on the sign data collected throughout the State of Utah, the authors observed that a significant number of measured signs (97,314) were damaged, intentionally caused by humans. Due to a lack of detailed information about traffic sign vandalism, this paper aims to answer the following question. How does the vandalism rate change with respect to the local population demographics where the sign is placed? To answer this goal, creating contingency tables is necessary to yield the desired results. The authors used U.S. Census Bureau data to obtain the - demographic data, such as population, ethnicity, age, income, education, and gender. To identify more significant demographics associated with sign vandalism, the authors applied the chi-square and trend statistic tests with respect to the categorical variables. Research results serve as a basis for agencies to schedule more frequent inspections or conduct countermeasures in areas that are more capable to vandalism. The paper reviews recent research efforts regarding sign vandalism and examines the collected data. Then, the results of the data analysis are presented, and key research findings and conclusions are identified.

2. Data description

To decrease crash numbers, specifically fatality crashes, transportation agencies have no choice but to take into consideration all of the contributing factors, including drivers, vehicles, and roadway infrastructure (Baratian-Ghorghi et al., 2015; Preston et al., 2015). Stop signs, yield signs, and speed limits are a few examples of traffic signs that increase safety by conveying essential information to drivers (Prieto and Allen, 2009). Previous studies showed that driver behavior can be dramatically influenced by the placement of yield to pedestrian at crosswalks signs (Ellis et al., 2007), work-zone warning signs (Strawderman et al., 2013), and school zone signs (Strawderman et al., 2015). In addition, a study concluded that installing chevrons (W1-10 traffic signs) in curves and using supplemental signs when implementing the flashing yellow arrow signals significantly reduce crashes (Schattler et al., 2015; Zhao et al., 2015).

2.1. *Traffic sign vandalism background*

Previously, multiple studies have focused on traffic sign conditions (Brimley and Carlson, 2013; Carlson and Lupes, 2007; Harris et al., 2009; Jalayer et al., 2014; Khalilikhah et al., 2015a; Khalilikhah and Heaslip, 2016b; Kipp and Fitch, 2009; Mace et al., 1982; Rasdorf et al., 2006; Worsey et al., 1986). Also, researchers have studied traffic signs based on road user characteristics. For example, the understandability and comprehensibility of traffic signs, as well as driver recognition of signs, have repeatedly been investigated (Drory and Shinar, 1982; Kirmizioglu and Tuydes-Yaman, 2012; Liu et al., 2014; Viganò and Rovida, 2015). However, few studies have focused on traffic sign vandalism. Over the past decades, traffic sign vandalism has become a serious problem for traffic agencies (Chadda and Carter, 1983; Harris, 1992). With special attention given to its various forms of sign vandalism, some researchers have discussed countermeasures against vandalism (Picha, 1997; Perkins and Barton, 1997). Many have proposed the utilization of various countermeasures to reduce sign vandalism, such as using more resistant materials to construct signs, mounting signs higher, applying penalty notices to signs, and using public information campaigns. Other studies have estimated the costs of sign vandalism (Smith and Simodynes, 2000), developed methods for sign vandalism detection (Mueller, 1995), and examined the effects of releasing information via the media to reduce sign vandalism (Ellison, 1996). Although the association between demographics and transportation infrastructure and facilities, such as road improvements (Majumdar and Mitra, 2014), public transit (Mulley et al., 2014), pedestrian overpass (Wu et al., 2014), and car ownership (McGoldrick and Caulfield, 2015) have been studied by many researchers, the research regarding the effects of demographics on traffic sign vandalism rate is far from complete. This study aims to fill this gap.

2.2. *Traffic sign data collection methodology*

In an effort to obtain comprehensive information about its road assets, the Utah Department of Transportation (UDOT) sponsored a mobile-based data collection effort to digitally capture transportation assets in 2012 (Ellsworth, 2013). This included data collection on many types of roadway assets, including traffic signs, pavements, guardrails, barrier walls, and markers across over 6000 center lane miles of state routes and interstates. This comprehensive approach was deployed by an instrumented vehicle driving at freeway speeds and collecting asset data on the roadway. The vehicle sensors included a light detection and ranging (LiDAR) sensor, laser road imaging system, laser rut measurement system, laser crack measurement system, road surface profiler, and position orientation system. In addition, imaging technologies were integrated to automatically collect high-resolution detailed images from the assets. Fig. 1 shows a snapshot of the data collection process.

The first phase of the project, data gathering, was completed by driving one vehicle along state roads. The second phase of the project, post-processing, was conducted by survey to derive the desired data. At project conclusion, data on more than 97,000 traffic signs under the jurisdiction of