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Using stationary image based data collection method for evaluation of traffic sign condition

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A R T I C L E I N F O

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A B S T R A C T

Transportation asset management helps monitor the transportation systems and optimize the construction, operation, and maintenance of assets. Many state Department of Transportations (DOTs) have already established asset management systems for high cost and low quantity assets, e.g., bridge and tunnel assets. However, due to the sheer number of traffic signs deployed by DOTs, statewide sign inventory and condition information are not well developed. Currently, using handheld devices is the most selected method by agencies to measure signs. To address safety challenge and high cost of data collection, an innovative stationary image based method has recently been proposed. This paper discusses the advantages and disadvantages of such image based method over using handheld devices in terms of the accuracy, possibility and consistency of data, speed, safety, maintenance, and cost. At its completion, this study provides suggestions to tackle the issues associated with image based method.

1. Introduction

The fast pace of deterioration in existing infrastructure systems and limited budget available have motivated U.S. Departments of Transportation (DOTs) to prioritize rehabilitation or replacement of roadway assets based on their conditions. These assets require preventive, restorative, or replacement work activities to preserve their functionality in an accepted level of service (Khalilikhah and Heaslip, 2016). Transportation asset management provides support for infrastructure management to facilitate the construction, operation, and maintenance of infrastructure with special attention given to budget constraints. The (Federal Highway Administration, 2007), Office of Asset Management, defines transportation asset management as a "foundation from which to monitor the transportation system and optimize the preservation, upgrading, and timely replacement of highway assets". Many state DOTs have already established asset management systems for high cost and low quantity assets, e.g., bridge and tunnel assets.

Providing important travel information for road users, traffic signs are one of the most important roadway assets to ensure roadway safety (Khalilikhah et al., 2016). Road users need to detect signs and comprehend the message content in a timely manner in both daytime and nighttime conditions (Carlson and Urbanik, 2005). Improvement of nighttime visibility is one of the effective low-cost safety improvements for roadways. (Carlson and Picha, 2009) discussed that the rate of fatal

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crash in nighttime is approximately three times that of the daytime crash rate. To establish a cost-effective traffic sign management system, traffic sign inventory and condition assessment are two significant components (Ai et al., 2013). However, most of state DOTs do not have well developed statewide inventory and condition information since tracking sign inventory and condition is a significant issue. To assess the condition of traffic signs, agencies should evaluate traffic sign placement, message clarity, line-of-sight, redundancy, daytime color, and measure a material property called retroreflectivity during the nighttime. Every transportation agency responsible for maintaining public highways and streets is required to use retroreflective materials on traffic control devices to facilitate driver safety (Balali and Golparvar-Fard, 2015). Currently, using handheld devices is the most selected method to measure traffic sign retroreflectivity by transportation agencies (Brimley et al., 2013; Hummer et al., 2013). However, due to the sheer size of data, this method is labor-intensive, expensive, and potentially unsafe for the inspectors (Preston et al., 2014). In other words, this method for collecting traffic sign retroreflectivity data is cost prohibitive and offset the benefit of having such information (Balali et al., 2013).

To address these issues, one may take into account adoption of technological innovations. In previous studies, there have been a few attempts to develop mobile based methods for traffic sign retroreflectivity condition assessment. Although some prototype systems have been developed, their accuracy is seriously questioned yet. That said, issues with mobile based methods hinder their implementation in DOTs' practices. To address these issues, (Balali et al., 2015) proposed a novel stationary image based technique which performs remote sign retroreflectivity measurements and can be used during daytime. More precisely, computer vision techniques were used to reconstruct nighttime images using photos taken during the day. Then, the reconstructed nighttime images were used to measure sign retroreflectivity. The objective of this paper is to discuss the advantages and disadvantages of such computer vision based method, named stationary image based method (IBM) over using handheld devices for sign retroreflectivity measurement. To do so, the paper reviews the recent research efforts and current retroreflectivity management practices, examines the various methodologies used to collect traffic sign data, presents the results of the comparison between two methodologies, identifies key research findings and conclusions, and makes recommendations for further research.

2. Traffic sign retroreflectivity overview

Traffic signs should be clearly visible to drivers at night, as well as they are comprehended in daytime. Thus, background sheeting made of retroreflective materials need to be incorporated for redirection of light from the sign face back to the source (Khalilikhah et al., 2015). The amount of light reflects off a surface from a source to an observer known as Retroreflectivity. Retroreflectivity is measured by the units of candelas per lux per square meter ($cd/lx/m^2$). In 1992, the minimum levels for traffic sign retroreflectivity were legislated by the U.S. Congress (United States Department of Transportation, 1992). The goal of the standard retroreflectivity requirements was to improve safety on the streets and highways (Re and Carlson, 2012). In order to fulfill that mandate, the Manual on Uniform Traffic Control Devices (MUTCD) established minimum retroreflectivity levels for traffic signs in 2009. The coefficient of retroreflection, R_A, so-called retroreflectivity, is the ratio of a sign's luminance to its illuminance. The 2009 MUTCD included an obligation for agencies to replace traffic signs that were not in compliance with the minimum MUTCD levels. Final revisions were added to the MUTCD in 2012, altered the three original target compliance dates to achieve minimum retroreflectivity levels (Manual on Uniform Traffic Control Devices, 2012). The MUTCD also outlined five methods to guide agencies in achieving standards levels, including assessment and management methods, as following discusses:

2.1. Assessment methods

Retroreflectivity assessment methods can be performed through visual inspection during nighttime (Nighttime Visual Inspection Method) or using retroreflectometer devices during daytime (Retroreflectivity Measurement Method). Considering assessment methods, agencies can more frequently measure sign retroreflectivity and provide recommendations on the best timing for sign inspections and replacements based on the degradation levels. Although levels of subjectivity exist in nighttime visual inspections, previous studies showed that well-trained observers can reasonably identify inefficient signs (Carlson and Lupes, 2007). Measuring sign retroreflectivity through a systematic process removes subjectivity and provides the most direct means of monitoring the maintained retroreflectivity levels. A specialized instrument called retroreflectometer is used to directly assess sign compliance.

2.2. Management methods

Outlined management methods in MUTCD include expected sign life, blanket replacement, and control signs. In expected sign life method, signs are replaced when they reach a certain age, usually through the use of stickers placed on the back of the signs. This method requires that agencies track the installation date of their signs using a date sticker, bar code, or computerized sign management system. However, it may be time-consuming to inspect date stickers if the stickers are not easily viewable or identifiable on the sign. Blanket replacement is similar to expected sign life, except that each individual sign is not tracked. In this method, an area is divided into corridors and/or zones based on the location or type of signs. The number of areas can be determined with respect to the replacement cycle. At the time of replacement, replacement cycle, all of the