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Advanced Evaluation Methods for Variable Speed Limit Systems

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Abstract

The variable speed limit (VSL) system has been implemented on many freeways and urban arterials as a link control strategy. Objectives for deploying VSL systems may include giving advance warning, stabilize and smooth traffic (i.e. harmonization). Accuracy and reliability of the messages displayed by VSL systems can "make or break" its successful implementation. The aim of this paper was to present methods for evaluating VSL systems. As VSL systems may be implemented with different control strategies, an approach for assessing different features of the system independently was adopted. In this way, systems with different control strategies can be evaluated. Methods for assessing incident detection, warning and harmonization abilities were presented. A case study on the VSL system on the Autobahn A99 near Munich, Germany was also discussed.

Keywords: Variable speed limit system, Incident detection, Warning, Harmonization, Consistency

1 Introduction

Active traffic management (ATM), including the variable speed limit (VSL) system, is seen as a more dynamic approach in managing congestions. In Germany and other advanced countries, VSL systems have been deployed on high traffic freeways, arterial roads, and in work zones. Basically, VSL systems use dynamic speed limits to manage traffic. This control system aim to systematically dampen speeds to stabilize and smooth traffic, usually based on the prevailing measured traffic flow, speed, density, or weather condition. Some systems, in addition to the displayed variable speed limits, provide extra information (e.g. congestion, slippery road, roadworks, etc.) justifying the speed limit. It has been established that compliance levels are higher if the displayed speed limit is accompanied by an explanation of the reason behind the displayed speed (Steinhoff, Kates, Keller, & Faerber, 2001). Earlier research works have documented the ability of VSL systems to improve traffic safety, environmental pollution and noise (Lee, Hellinga, & Saccomanno, 2004; Bel & Rosell, 2013; Mott MacDonald, 2008). While VSL systems have not been established to increase traffic flow (Weikl,

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Bogenberger, & Bertini, 2013; Papageorgiou, Kosmatopoulos, & Papamichail, 2008), researchers have argued that its safety improvement ability will result in decreasing congestion due to traffic crashes.

Installation of VSL system on a road corridor is capital intensive. Accuracy and reliability of the variable speeds and messages displayed by the system, can "make or break" its successful implementation. Incorrect information will lead to drivers disregarding warning messages. This paper aims to present methods for assessing VSL systems. This can be helpful for service providers in evaluating the system's effectiveness, thereby enhancing the credibility of the system.

2 Review of Literature

Previous works on assessing VSL systems include the study of the system in Antwerp, Belgium (Corthout, Tampère , & Deknudt, 2010) which used vehicle trajectories, integrated from speed data, to evaluate the system's warning effectiveness based on detection rate (DR) and false alarm rate (FAR). The study, considered the speed displayed by the first upstream gantry of a bottleneck in its evaluation. If the difference between the displayed speed at the upstream gantry, and the lower bound of the detected speed in the segment is within an allowable deviation (taken as a one-step speed difference between two successive gantries, e.g. 10 km/h or 20 km/h depending on how speed is decremented at the site), warning is assessed to have been detected. Vukanovic (2007), without access to standard deviation of speed data, evaluated harmonization (the ability of VSL system to smooth traffic) by comparing driven speed to control speed. If the traffic flow is in the synchronized state, and if the driven speed does not deviate significantly (defined by a measure of range of the VSL and 'bias' or 'offset') from the control speed, the system is assumed to have harmonized traffic. Later studies (e.g. Downey, 2015; Nissan, 2010), have employed the standard deviation of speeds to evaluate harmonization potential of VSL systems. Traffic flow variables such as headway and lane distribution have also been used in "before-and-after" studies, or compared the test site with a control site to assess VSL systems' ability to harmonize and improve safety (Lucky, 2014; Weikl, Bogenberger, & Bertini, 2013; Downey, 2015). Nissan (2010); Piao & McDonald (2008), through simulation studies, also assessed VSL systems' ability to improve traffic flow and safety.

3 Features of VSL Systems

Garcia-Castro & Monzon (2014) classified VSL control systems into two: scheduled variable speed limit and dynamic speed limit. Scheduled VSL depend on a pre-established timetable based mostly on historical data whereas dynamic VSL uses real-time traffic data and weather information. The problem with the scheduled system is that it is unable to deal with non-recurrent congestions. This study focuses on dynamic VSL systems. A dynamic VSL system is expected to firstly detect and alert the control of any changes in the traffic environment. This component of VSL systems is very important in dealing with the volatile nature of traffic on freeways. After an incident is detected, a corresponding warning message and/or speed must be displayed. The algorithm for warnings depends on input from incident detection. Consequently, correctly detected incidents may result in efficient warning. A feature of VSL systems is also to smooth traffic. Speed harmonization is defined as the reduction of speed differences among vehicles and of mean speed differences among lanes (Papageorgiou, Kosmatopoulos, & Papamichail, 2008). Reduced speed differences ensures that vehicles travel with a more consistent speed, decrease lane changing maneuvers which lead to fewer traffic conflicts, decreases noise and reduces environmental pollution. It is our view that if a VSL system is implemented with a set of control strategies, an assessment on the system should encompass all the strategies.