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Enforcement avoidance behavior near automated speed enforcement areas in Korean expressways

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ABSTRACT

Automated speed enforcement system (ASES) has been deployed as a safety countermeasure on Korean roadways to reduce speeding-related traffic crashes; information on ASES locations is mandated to be open to the public. However, because drivers are alerted about enforcement via on-board navigation systems and roadside signs, they can avoid enforcement by momentarily reducing their speeds near ASES locations. This enforcement avoidance behavior (EAB) can induce sudden changes in speed near the enforcement locations and thereby increase risk of crash occurrence.

In light of this situation, the present study evaluates the effects of ASES on traffic behavior and safety. An analysis of traffic data shows that drivers indeed diminish their speeds near enforcement locations, and accelerate shortly after passing the locations. To investigate how this behavior affects safety performance, this study, by using Empirical Bayes analysis with comparison groups, compares crash occurrences along a certain section before and after the installation of ASES. The comparative analysis shows that overall crash occurrence dropped by 7.6% on average near the enforcement locations, although the reduction was not significant. However, an average 11% non-significant increase in crash occurrence is also observed in the upstream segment, where enforcement is announced to drivers and traffic starts to diminish speed.

The findings suggest that the sudden changes in traffic speed induced by EAB substantially negate the benefits of ASES. Therefore, modification of the design of current ASES is required to mitigate EAB and further improve the effectiveness of ASES.

1. Introduction

Speeding is a behavior of driving at excessive speed and a major contributing factor to crash occurrence and its consequences, as speeding shortens time for drivers to react to events and increases the force of any impact. Crash data collected from different locations have shown that speeding increases the risk of crash occurrence (Maycock et al., 1998; Gambard et al., 1997) and that it has a direct influence on the severity of injuries (Nilsson, 1982; Elvik et al., 2004; Evans, 2004; Aarts and Schagen, 2006; Park et al., 2012). Since expressways are designed to facilitate faster travel, drivers on expressways are exposed to an environment in which speed is generally higher than that on other roadways. Statistics on traffic crashes on Korean expressways also indicate that speeding is one of the leading causes of traffic injuries and fatalities. In Korean expressways, a total of 8513 crashes occurred between 2007 and 2010, resulting in 197 fatalities and 1097 injuries. Among these crashes, 21% were caused by speeding, which accounts for 17.1% and 17.4% of fatalities and of injuries, respectively.

To reduce injuries and fatalities caused by speeding, a simple but effective countermeasure has been enforcement of speed limits by police officers. Despite the effectiveness of police enforcement, broader deployment of manual enforcement measures has been impeded by limited resources and safety concerns for police officers. Thus, the automated speed enforcement system

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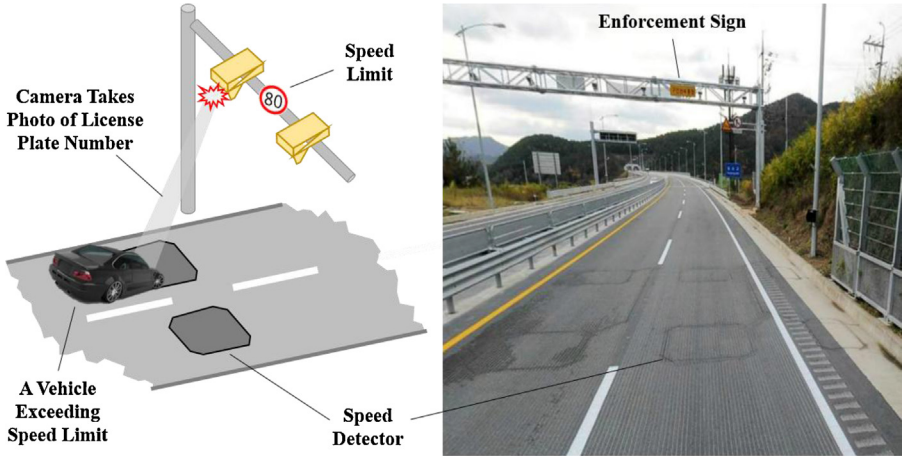

Fig. 1. Illustration of an ASES in Korea.

(ASES) was introduced on Korean expressways in 1997 as a more efficient speed enforcement measure. The ASES automatically measures vehicle speeds and photographs the plate numbers of vehicles that exceed the speed limit (See Fig. 1). Since this system is fully automated and cost-effective, ASESs are considered as a primary countermeasure for locations where speeding-related crashes frequently occur. As of 2013, ASESs have been deployed at more than 5200 locations. To further discourage drivers from speeding, information on enforcement locations is mandated by law to be open to the public so that drivers can be informed of the locations via navigation services, which are widely used in Korea.

In response to this information, however, drivers tend to reduce their speeds momentarily only near enforcement locations, as they seek to avoid a penalty. Safety concerns with regard to this type of Enforcement Avoidance Behavior (EAB, often called the *kangaroo effect*) arise because sudden changes in speed may increase the risk of crash occurrence, especially upstream of the enforcement locations. In this study, using both cross-sectional and longitudinal approaches, we analyze a detailed set of traffic data to understand the attributes of this type of EAB and evaluate its impact on the safety performance of ASESs.

2. Literature review

Extensive research has shown that ASESs have a positive effect on traffic safety because they reduce vehicle speeds near enforcement areas (ETSC, 1999; ARRB Group, 2005). Some studies have found that ASESs enhance traffic safety not only in the immediate vicinity of enforcement locations but also along the extended section associated with the system (Chen et al., 2000; Goldenbeld and van Schagen, 2005). However, these studies were conducted based on crash data collected from sites for which the location of the ASES was undisclosed. Therefore, as drivers did not know precisely where the enforcement locations were they tended to maintain their speeds below the speed limit throughout the section to avoid a penalty. This implies that the positive effect of the ASES is attenuated if drivers are aware of the enforcement locations, as in such cases they can avoid speeding tickets by reducing their speeds only at the ASES and not throughout the section.

Evidence from a comparative study by Keall et al. (2001) confirms this implication. Keall et al. (2001) used hidden and visible cameras for ASESs to evaluate the effects of revealed location information of these systems. In the experiment, drivers were informed that speeding was enforced by ASESs somewhere along the roadways, but cameras were hidden for one group (i.e., drivers were without information on enforcement locations), whereas cameras were fully exposed for the other group (i.e., drivers had information on enforcement locations). The comparative analysis showed that drivers maintained their speeds below the speed limit on a longer section when the information on the enforcement location was not given.

Other studies on ASES have postulated that, to avoid a penalty, drivers may momentarily reduce their speeds only at the enforcement locations and that this EAB can increase the risk of crash occurrences, specifically as drivers suddenly change their speeds (Decina et al., 2007; Elvik, 1997; ARRB Group, 2005; Christie et al., 2003; Thomas et al., 2008; Newstead and Cameron, 2003). De Pauw et al. (2014a) analyzed traffic speed data collected near speed enforcement cameras and showed that EAB occurred in the vicinity of speed cameras. Although identified as a potential risk factor, the impact of this behavior on traffic safety was not evaluated. In this study, we use vehicle trajectories and loop detector data to understand the attributes of EAB; we also examine crash data collected near ASESs to evaluate the safety performance of the ASES.

3. Enforcement avoidance behavior

3.1. Descriptions of the study sites and data

This section analyzes detailed traffic data collected from GPS-equipped taxis and inductive loop detectors to observe how ASESs affect the trend of vehicle movements. The study sites were selected based on data availability. Trajectory data were obtained from the driving records of 259 taxis in Daegu, South Korea during all days in May of 2013. These data include the vehicles' speeds and locations in terms of longitude and latitude collected every second. For site selection, we used a geographic information system (GIS) to spatially match the trajectory data with the ASES locations; we selected ASES sites at which the largest number of vehicles passed. Four sites were selected and are marked by white circles in Fig. 2.

Although trajectory data provide detailed information on vehicle movements, those trajectories were from a small subset of all passing vehicles, and were collected from limited locations and at various times. To supplement this, we analyzed two years (from 2010 to 2011) of five-minute aggregated traffic data including traffic volume, occupancy (detector occupancy is a dimensionless measure of density, which is the percentage of time that vehicles are above the detector), and average speed, as measured by inductive loop detectors along the Gyeongbu Expressway. To conduct a before-and-after study, we selected