1 0 2 年 道 路 交 通
安 全 與 執 法 研 討 會
中華民國 102 年 9 月 26 日

固定自動測速照相執法對高速公路行車速率與事故之影響分析

The Effects of Fixed Automatic Speed Photo Enforcement on Speeds and Traffic Crashes on Freeways

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摘 要

國道高速公路採用自動測速照相取締違規超速行之有年，但對於其設置的位置並無明確的設置準則或標準，在國內亦無相關的研究，針對其執行成效和行車安全與車流所造成的影響，進行相關的評量，特別是長時間的觀察與分析。因此，本研究乃以國道公路警察局第六警察隊的轄區為研究範圍(國道 3 號福爾摩沙公路)，蒐集近兩年內(2011 和 2012)轄線內所有交通事故資料，以及由交通偵測器所得之流量和速率資料，針對轄區內現有南向 4 組測速照相固定桿的前後路段進行比較分析，以了解車輛在行經測速照相桿前後的速率之變化情形，以及前後鄰近路段的交通事故次數差異；同時針對新設置的兩組(2011 年 8 月)測速桿，於設置時間前後，該路段的行車事故和速率變化情形，用以評估自動測速照相執法是否能有效降低交通事故的發生。研究結果發現，在車流量高及低速限之城郊路段，車輛在行經自動測速照相固定桿後，自由流之平均速率明顯降低；在測速桿後路段(1 公里內)之交通事故件數亦較測速桿上游路段交通事故次數低；在新設置固定測速桿後，該路段的交通事故亦較設置前明顯減少；然而在低車流量和高速限之郊區路段，測速桿前後交通事故的次數並無明顯的差異。

關鍵字：固定自動測速照相、自由車流速率、交通事故分佈

Abstract

Automatic speed photo enforcement (SPE) devices have been used to enhance speed limit compliance on freeway systems for more than a decade in Taiwan. This study investigated the effects of SPE devices on speed and crash distributions on a major freeway section. Four fixed SPE zones were selected for the comparison study. The differences of speeds and traffic crash distributions at upstream and downstream sections of the SPE fixed locations were compared. The results indicate that the fixed

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SPE devices significantly decreased the mean speed at the fixed SPE point and consecutively for the next 2 kilometers at both suburban and rural freeway sections. Even though the SPE devices were not operated properly, mean speeds at the rural freeway sections decreased, and speed variations at the suburban freeway sections were reduced. The fixed SPE devices also reduced the number of traffic crashes at the location immediately downstream of the SPE point. However, on the rural freeway sections, the installation of a non-functionalized SPE device does not seem to prevent the occurrence of traffic crashes. There was not enough evidence in this case study to determine whether the fixed SPE devices would increase the risk of crashes when vehicles are approaching the fixed SPE points. More SPE sites and a combination of the speed zones with moveable SPE devices are needed to further confirm the effectiveness of the SPEs.

Key Words：*Automatic Speed Photo Enforcement, Free Flow Speeds, Traffic Crash Distribution*

1. INTRODUCTION

Speeding is a significant issue on major freeways. Excessive speeding will increase the frequency and severity of traffic crashes. The speed differentials between vehicles is another contributor to traffic crashes (Pisarski,, 1981; Garber and Gadiraju, 1989). To increase the speed limit compliance and reduce the speed variance, numerous countries have implemented speed photo enforcement (SPE) programs (Wilson et al., 2011; Thomas et al., 2008). At least 90 studies from 16 countries that were initially identified as potential evaluation studies of safety effects of the SPE programs (Thomas et al., 2008). The research consistently shows that speed cameras are an effective intervention in improving road safety (Pilkington and Kinra, 2005).

Automatic speed photo enforcement devices have been used to enforce the speed limit on freeway systems in Taiwan for more than a decade. To enhance the effectiveness of enforcement and improve traffic safety, the National Highway Police Bureau (HPB) in Taiwan deployed several SPE devices at fixed spots along the freeways. A sign alerting drivers is presented a half kilometer prior to the SPE spot. These devices work well a majority of the time as most drivers tend to reduce speeds when approaching the SPE enforcement segments. However, when sudden braking is applied by some aggressive drivers after noticing the SPE devices, there is the potential for rear-end collisions. This study investigated the effects of SPE on speed and crash distributions on a major freeway section in northern Taiwan. Four fixed SPE zones were selected for the examination. The differences of free flow speeds and traffic crash distributions at upstream and downstream sections of the fixed SPE locations were investigated and compared.

The Fisher's Least Significant Difference (LSD) test was used to compare the differences in mean speeds at upstream and downstream sections of the SPE device. The numbers of traffic crashes from one kilometer upstream and downstream of the SPE were counted in a 0.5 kilometer interval. The crash distribution was used to identify the effects of the SPE on the location and quantity of traffic crashes. Traffic crash distributions before and after the installation of the SPE devices were also investigated to determine the effects of SPE on traffic crashes.

2. LITERATURE REVIEWS

Automated speed enforcement programs have been implemented worldwide in a number of countries to enhance the compliance of the speed limits and improve the traffic safety. At least 90 studies from 16 countries that were initially identified as potential evaluation studies of safety effects of the SPE programs (Thomas et al., 2008). Several studies were conducted to review the evaluations of the SPE in various quality levels. Pilkington and Kinra (2005) reviewed 14 studies of safety effects of the SPEs on the reduction of road traffic collision and injures.

They concluded that although the evidence is weak, the research consistently shows that speed cameras are an effective intervention in improving road safety. Wilson et al. (2006) reviewed 26 papers that evaluated speed enforcement using any type of speed detection device including speed cameras, radar, and laser detection. They similarly concluded that because of the consistency of reported speed and crash reductions, speed enforcement detection devices are effective at reducing traffic crashes and injuries.

Thomas et al. (2008) also reviewed 13 studied which included the crash effects and rational detail methodologies. They summarized that the SPE programs can generate the reductions of injury crashes in the range of 20% to 25% appear to be a reasonable estimate of site-specific safety benefit from conspicuous, fixed-camera, automated speed enforcement programs. However, no conclusions were reached regarding site-specific effects of mobile enforcement programs. Estimates of system wide crash reductions likely attributable to covert, mobile speed enforcement programs were based on different subsets of crashes (daytime casualty crashes and daytime speed-related crashes) and were limited to two studies, but also were in the range of 20% to 25%.

In their systematic review, Pilkington and Kinra (2005) report that: (1) all but one study found evidence that speed cameras were effective in reducing average speeds and (2) all studies reported decreases in fatal as well as non-fatal traffic crashes. Some studies have also investigated specific issues related to automated speed enforcement programs (ASEP) (see Cameron and Delaney (2006) for a synthesis about specific effects according to specific speed camera programs). It is well documented that compared to the localized effect of visible cameras on speeds and crashes, hidden cameras produce general effects on all the roads of a traffic network (Keall et al., 2001, 2002). Evidence from the British–Columbia program in Canada, also suggests that the impact of an enforcement program on speeds is greater when a fine is imposed as compared to just sending a warning letter (Chen et al., 2000).

Goldenbeld, C. and I. Van Schagen (2005) studied the effects of speed enforcement with mobile radar on speeds and accidents on rural roads in the Dutch province Friesland. The evaluation covered a 5 year period of enforcement. The study showed a significant reduction in mean speed and percentage exceeding the posted speed limit. They estimated a 21% decrease in the number of injury accidents and serious casualties. Chen et al. (2002) evaluated the influence of the photo radar program on speeds of vehicles and collisions at the location of the photo radars and also at interleaving locations. They found that using photo radar reduced the average speed and speed standard deviation by 2.8 km/hr and 0.5 km/hr respectively in their monitoring area(s). In addition, they observed 14% ± 11% reduction in expected collisions at photo radar locations and 16% ± 7% reduction along the study area.

Bloch (1998) studied the speed reduction effects of Photo-radar and speed display board on three streets in Riverside, California. The results showed that both devices significantly reduced vehicles speeds by 7 to 8 km/hr, and reduced the number of vehicles exceeding the speed limit by 16%. Benekohal et al. (2009) evaluated SPE in one work zone and presented the results for the effects of SPE. They showed that the SPE system significantly reduced the mean speed and increased speed limit compliance at work zones.

3. RESEARCH SCOPES

3.1 Research Goals

The objective of this study is to:

(1) Exam the effects of the fixed SPE devices on speed distributions

(2) Analyse the traffic crash frequencies near the fixed SPE devices

(3)Compare the traffic crashes before and after the installation of the fixed devices

Travel speeds and traffic crashes data at upstream and downstream sections of the fixed SPE locations were compared to determine the effects of the fixed SPE devices.

3.2 Research area

The research area is limited to District 6 of Highway No. 3 (Formosa Highway) from 31 kilometer pole to 110 kilometer pole. There are 14 interchanges (including an interchange to the rest area), 2 toll facilities and 4 tunnel sections in the research area. The northern part of this freeway is located at the suburbs of the Taipei metropolitan area, an area with a high population and traffic volume. Traffic volume decreases heading south and away from the metropolitan area. The speed limits vary by freeway sections and maximum vehicles load. The speed limit for regular vehicles (passenger cars or trucks with a maximum load under 20 tons) traveling between sections located at 31 Km and 35 Km is 90 Km/hr; the speed limit for vehicles traveling between sections 35 Km and 43 Km is 100 Km/hr. The designated speed limit for the rest of the research sections is 110 Km/hr. For heavy vehicles with a maximum load of more than 20 tons, the speed limit is 90 Km/hr for the entire research sections.

3.3 SPE Scenario

In addition to manual speed enforcement by uniformed officers, the automatic SPE devices have also been used to enhance the speed limit compliance on Taiwanese highway systems. The SPE devices are primarily used in two methods based on how their installed: one method is to install the SPE devices at a fixed location (as shown in Figure 1) on a mounted and visible pole; the other method is to set up a moveable SPE device on an unmarked police car or van, or temporarily mount it on a tripod and place it on the roadside of the SPE zones. The fixed SPEs at fixed locations are visible and noticeable, but the movable SPEs are normally less visible. Drivers may not know exactly where and when the movable SPE devices are placed and operated. However, according to traffic regulations in Taiwan, both types of SPE zones should have a "SPE ahead" warning sign (as shown in Figure 2) located approximately 300 to 500 meters in advance of the SPE point. The SPE sites are also published on the HPB website for public viewing.

According to the HPB website, there are 4 and 2 sites designated as fixed SPE zones on southbound and northbound lanes of the studied freeway sections, respectively. HPB also published 49 sites that have moveable SPE devices along the research sections. It should be noted that some of the two types of SPE zones overlap or are located very close to each other. Because the movable SPE devices are less visible and therefore less expected than the fixed devices, the effects may vary depending on the location and area. Thus, only the fixed SPE sites were examined in this study. In addition, due to the data availability, only four fixed SPE devices on the southbound of the freeway were included for the analysis.

Among those four fixed SPE devices on the southbound of freeway, two of them have been operating regularly for the past decade and worked properly during the study period. These two SPE devices are both equipped with a digital camera and a flash light and operate twenty four hours a day, seven days a week. The other two devices were installed in August of 2011. Due to camera quantity limitations, these two more recently installed SPE devices did not operate normally during the study period; however, they could still be used to examine the effects of the fixed SPE devices whether they are regularly operated or not. Thus the SPE scenarios include:

(1) Fixed SPE devices without functional operation on the suburban freeway section (Site A)

(2) Fixed SPE devices operated normally on suburban freeway section (Site B)

(3) Fixed SPE devices operated normally on the rural freeway section (Site C)

(4) Fixed SPE devices without functional operation on rural freeway section (Site D)

It should be noted that the fixed SPE devices were installed at the road side in the middle sections which normally are away from upstream and downstream interchanges.

Figure 1 SPE device installed a the roadside of freeway

Figure 2 SPE ahead warning sign

4. DATA COLLECTIONS

4.1 Sampled Free Flow Speed Data

Two types of data were collected in this study including: (1) volume and speed data; and (2) traffic crash data. Volume and speed data were obtained from vehicle detectors located along the freeways in 2011. The detectors were installed in each lane of the segment to measure the traffic data on a 5-minute interval. Data from the detectors include average speeds, accumulative volume every 5 minutes, types and average lengths of vehicles, as well as the average headways.

Speed data from a set of traffic detectors at upstream and two sets at downstream sections of the fixed SPE locations were used for the comparison. It should be noted that the distances of the detectors to the nearby SPE device are not equal. Thus, the detectors with a distance to the SPE of more than 2 kilometers were not considered for the analysis. To examine the distribution of speeds, this study used seven days (coving each day of a week) of speed data selected arbitrarily from one day of the third week of the month from March to September in 2012. For example, the sampled data included March 12 (Monday), April 17 (Tuesday) and May 16 (Wednesday) etc. If traffic crashes were found nearby the detectors on the date or the data from the traffic detector were not usable, such as negative volume or speed, the data from the same day on the next or previous week or the other week were used. To ensure the sampled speed data are collected from the free flow traffic, only vehicles travelling on the inside lanes when the average volume per 5-minutes is less than 60 (average car following headway larger than 5 seconds) were used for the study. Thus, this analysis only examines the speed data at the first and second lanes (Lane 1 and Lane 2) from the median of freeway on the four lane sections, and the first lane (Lane 1) on the three lane sections. The heavy vehicles are restricted for those inside lanes on the research freeway. The inside lanes can only be used by passenger cars. No specific facilities, such as interchanges or toll stations, are located between the upstream and downstream detectors.

4.2 Traffic Crashes Data

Traffic crashes data consist of all crashes along the research freeway sections in 2011 and 2012. A total of 3,890 crashes, which lead to 17 fatalities and 294 injuries, occurred during these two years. Among the total crashes, 1,757 were at the southbound sections. It was found that the highest portion of crashes (about 32 Percent and 25 percent in southbound and northbound, respectively) occurred inside and near the tunnel freeway sections. At the southbound research section, 50 and 39 crashes occurred in 2011 and 2012, respectively, within one kilometer upstream and one kilometer downstream of the SPE devices. In order to identify the actual reaction of the drivers on the SPE zone, traffic crashes which were caused from non-human, road condition factors or impaired drivers, such as mechanical issues or hitting a broken tire, or alcohol related crashes, were not considered for the analysis. Thus, a total of 68 crashes were found near the fixed SPE devices during these two years.

5. EFFECTS OF SPE DEVICES

5.1 Speed Distributions

The difference of mean speeds at upstream and downstream detectors for each SPE set were compared and grouped by using Fisher's Least Significant Difference (LSD) test under a 95 percent level of significance. Table 1 shows the speed statistics and comparisons by travel lanes. The cells with a darker background show that the mean speeds are significantly higher than the cells with a lighter background. The cells with the same background at each SPE site represent the differences of the mean speeds that were not statistically significant. It is obvious that the mean speeds at the inside lane (Lane 1) have a higher travel speed in every SPE sites. The speeds distribution at Lane1 and Lane 2 are shown in Figure 2 and Figure 3, respectively.

At Site A, the mean speeds at the upstream and the immediate downstream sections of the fixed SPE devices were not significantly different for vehicles traveling on Lane 1. The mean speed at the immediate downstream location was even higher than the mean speed at the upstream section for vehicles traveling on Lane 2. This could be because most drivers traveling on the suburban freeway are commuters that realized the SPE devices were not operating properly based on their daily driving experience. However, the standard deviations of speeds at the immediate downstream section on Lane 1 and Lane 2 were both higher than the standard deviations of speeds at the upstream and farthest downstream locations. This indicates that some unfamiliar drivers traveling on this section may still apply the brakes when they notice the SPE devices.

Table 1 Speed statistics at upstream and downstream of SPE sties

SPE Device Location		Detector Location	No. of 5-min. interval	Lane 1						Lane 2					
				Average Cars per Interval	Mean Speed (km/hr)	Median Speed (km/hr)	Std. of Speed	85th of Speed	Max. Speed	Average Cars per Interval	Mean Speed (km/hr)	Median Speed (km/hr)	Std. of Speed	85th of Speed	Max. Speed
Site A	39.5	39.13	774	17.6	104.9	104	4.94	109	148	28.8	99.2	99	2.71	102	109
		41.01	772	18.0	105	104	5.26	110	140	26.6	100.2	100	3.18	103	113
		41.8	807	18.2	105.8	105	4.84	110	144	26.8	100.3	100	3.06	103	113
Site B	64.2	62.52	1058	20.9	111.5	112	4.70	116	135	25.7	104.7	105	3.57	108	116
		64.5	1413	25.2	95.82	95	7.08	103	120	41.9	93.9	94	6.10	100	117
		66.02	1187	22.2	106.8	107	5.41	112	129	32.0	100.7	101	4.79	105	119
Site C	81.5	80.4	1334	24.0	112.5	112	4.11	116	138	31.9	105.2	105	3.35	109	126
		81.85	1285	23.3	110.7	111	4.13	114	131	30.5	105.7	106	2.94	109	119
Site D	107.5	106.55	1310	23.9	114.1	114	3.82	117	136	32.6	107.6	107	3.28	111	120
		108.32	1457	25.2	113.5	113	4.01	117	142	30.0	106.4	106	3.42	110	121

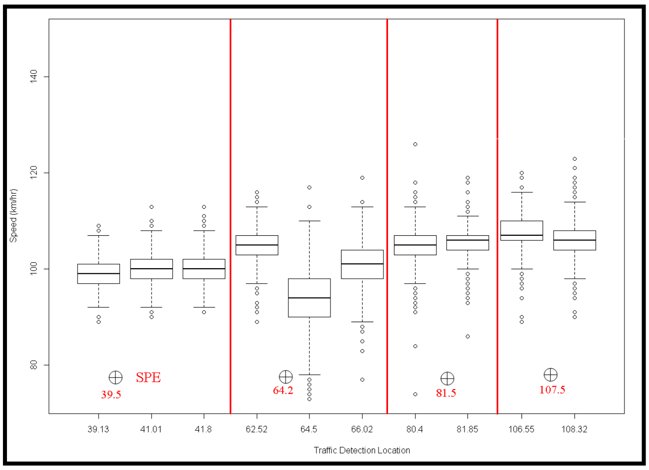

Figure 2 Speed Distribution at Lane 1 at upstream and downstream detectors

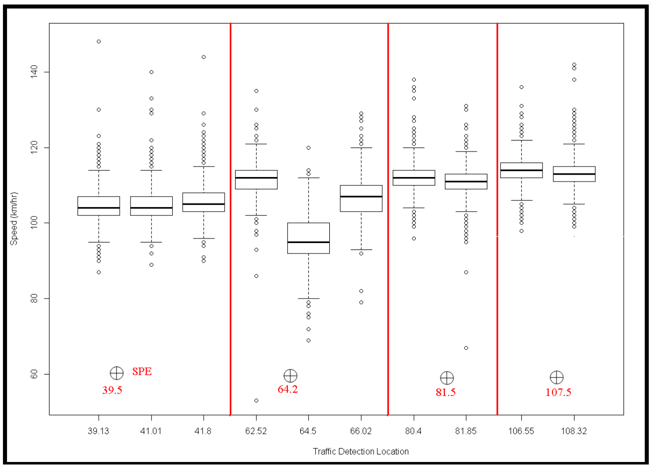

Figure 3 Speed Distribution at Lane 2 at upstream and downstream detectors

At Site B, where the SPE device operated regularly, the mean speeds significantly decreased from 111.5 km/hr to 95.8 km/hr, and from 104.7 km/hr to 93.9 km/hr on Lane 1 and Lane 2, respectively, when vehicles passed the SPE devices. The speed picked up significantly when vehicles went farther downstream (1.8 km from the SPES). However, the mean speed farther downstream from the fixed SPE device was still lower than the mean speed at the upstream section and locations within the posted speed limits (110 km/hr). This indicates that the fixed SPE devices can effectively decrease the mean speeds when vehicles travel pass the SPE devices and consecutively for about the next 2 kilometers.

At Site C, where the SPE device also operated regularly, the mean speed significantly decreased from 112.5 km/hr to 110.7 km/hr on Lane 1 when vehicles passed the SPE device. However, the mean speed reduction was not evident on vehicles travelling on Lane 2.

At Site D, the mean speeds significantly decreased from 114.1 km/hr to 113.5 km/hr on Lane 1 and from 107.6 km/hr to 106.4 km/hr on Lane 2, respectively, when vehicles passed the SPE device, even though this SPE device was not operating properly. On the rural freeway sections, most drivers are likely travellers that are not familiar with road side condition of the freeway. Thus, these drivers may not realize that the SPE device at that point was not actually operating.

5.2 Crash Distributions

The distribution of the traffic crashes during the years of 2011 and 2012 is shown in Figure 4. It should be noted that the SPE devices at Sites A and D were installed in August of 2011. As expected, the total number of crashes at upstream sections was higher than the total number of crashes at the downstream sections for each of the studied SPE site.

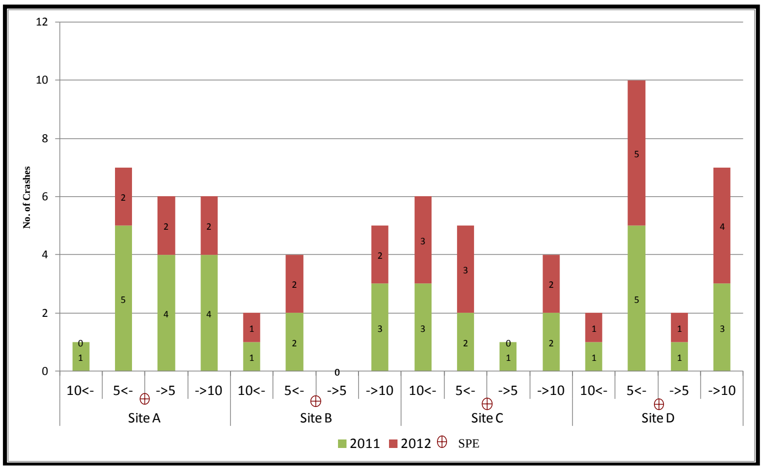

Figure 4 distributions of crashes upstream and downstream of the SPE sites

At Sites B and C, where the SPE devices operated regularly for a decade, the numbers of crashes within 500 meters downstream of the fixed SPE site remained the lowest of all traffic crashes. However the number of crashes increased when the distance to the SPE devices was more than 500 meters. This indicates that the fixed SPE devices could reduce the number of traffic crashes located near the downstream. However, the number of crashes decreased at Site C but increased at Site B when vehicles approached to the SPE point. There was not enough evidence in this case study to determine the fixed SPE device would increase the traffic crashes when vehicles approached the SPE devices.

At Site A, located on the suburban freeway, the number of traffic crashes dropped in 2012 compared to the number of traffic crashes in 2011. By checking the date of the crashes, it was found that only one of the total 14 crashes occurred near the SPE site in 2011 after the installation of the SPE device. The fixed SPE device in the suburban freeway section effectively decreased the number of traffic crashes in this site, even though the SPE device was not functionally operated. At the rural freeway section (Site D), the installation of the SPE device does not seem to prevent the occurrence of traffic crashes. The SPE device at Site D may need to be moved to a location 500 meters backwards to examine the actual effectiveness of the SPE devices.

6. CONCLUSIONS AND RECOMMENDATIONS

This study examined four fixed SPE devices with different functions at suburban and rural freeway sections. The results found that the fixed SPE devices significantly decreased the mean speed at the fixed SPE points and consecutively for about the next 2 kilometers at both suburban and rural freeway sections. Even though the SPE device was not operated properly, it also decreased the mean speeds at rural freeway sections, and reduced the speed variation at suburban freeway sections. The fixed SPE devices also decreased the number of traffic crashes located immediately downstream of the SPE points. Even though the SPE device was not functionally operated, the fixed SPE device in the suburban freeway section still effectively decreased the number of traffic crashes. However, at the rural freeway section, the installation of a non-functionalized SPE device does not seem to prevent the occurrence of traffic crashes. There was not enough evidence in this case to determine whether the fixed SPE device would increase the risk of crashes when vehicles approached the SPE devices. More SPE sites and a combination of the speed zones with moveable SPE devices are recommended to further confirm the effectiveness of SPE devices on speed and crashes reductions.

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