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Automated Speed Enforcement in Thailand: Evaluations and Recommendations

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CHAPTER I INTRODUCTION

1.1 Statement of Problem and Objective

Speeding is a major factor in road crashes in Thailand. In 2011, more than 1,600 crashes occurred on the expressways resulting in 712 injuries and 22 fatalities. Seventy percent of them were identified as speed-related crashes (see Figure 1.1). Government agencies do not have sufficient personnel to enforce the speed limit laws. With a rapid advancement in intelligent transportation systems, automatic speed enforcement system appears to be the direct answer to the problem.

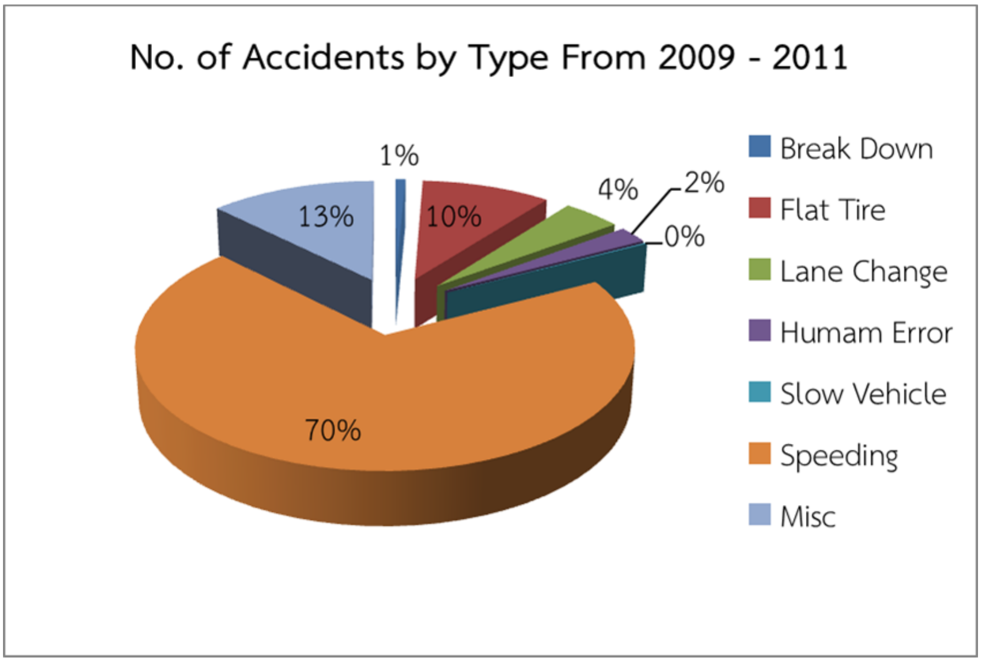


Figure 1.1 Three-year historical crash data (2009-2011) on EXAT's expressway network by crash type

The Expressway Authority of Thailand (EXAT) has planned to install automatic speed enforcement system in 2012. Other agencies such as Royal Police, Department of Land Transport, and Department of Highways also have planned to install the system in the near future.

Regardless of the gradual adoption in the automatic technology, these agencies are facing the operational, legal, and financial challenges. For example, there are no technical guidelines or standards of the equipment placement, warning signs, and choice of technologies. The study on the effectiveness of such automatic system has been limited in Thailand and not sufficiently comprehensive for implementing the system in board area.

Since EXAT is going to implement the first automatic speed enforcement system in Thailand in early 2013, it is possible for researchers to design the experiments such that the results can be to address several issues that have not yet answered by previous research. The findings from this proposed research would yield important information for law enforcement agencies and related organizations to install the system in a cost-effective manner.

This study aims to evaluate the speed enforcement programs in Thailand in operational, legal, and financial aspects. The objectives of this research are as follows:

1. Review current practices and identify challenges in implementing speed enforcement program in operational, legal, and financial aspects.
2. Based on the issues/challenges identify in Objective #1, conduct a field test to determine the effectiveness of the automatic speed enforcement system in different scenarios. Note that EXAT's expressways will be used as our testbed.
3. Based on the findings from Objective #2, Develop a set of recommendations that law enforcement agencies can use as a guideline to effectively deploy the speed enforcement scheme

1.2 Research Method/Technique

The research will be performed in three main phases with seven tasks (see Figure 1.2) corresponding to each of the research objectives:

- Phase 1 - Review of current practices
- Phase 2 - System Evaluation
- Phase 3 - Guideline Development

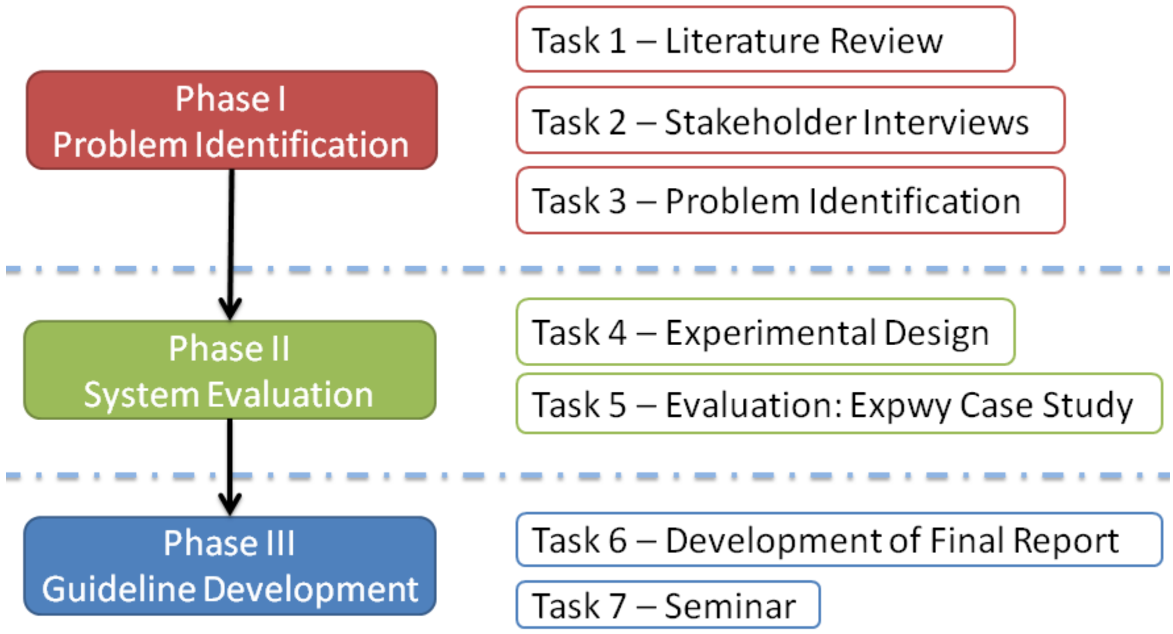


Figure 1.2 Research Tasks.

Details of each phase are as follows:

Phase I: Problem Identification

In the first phase, information pertaining to speed enforcement programs in Thailand and other countries will be gathered. Information such as available technologies, system benefits, legal and institutional issues will be focused. The effectiveness of the newly-deployed automatic speed enforcement system will also be investigated. The review phase consists of two key tasks: literature review and stakeholder interviews.

Task 1: Literature Review

Previous studies, reports, and other media related to the speed enforcement programs in Thailand and other countries will be reviewed. This will help the researchers to understand the benefits and challenges of the system in Thailand and elsewhere.

Task 2: Stakeholder Interviews

Stakeholder interviews will be conducted. Inputs on current practices and challenges in operational, legal, and financial aspects will be obtained from the public agencies such as Traffic Police, Highway Police, Expressway Authority of Thailand, Department of Land Transport, and Department of Highways.

Task 3: Problem Identification

Problems and challenges in implementing the automatic speed enforcement system in Thailand could be identified using the information gathered in Tasks 1 and 2.

Phase II: System Evaluation

Since EXAT is going to install 6 units of the speed enforcement system on three routes (see Figure 1.3) including 1) Kanchanapisek Expressway, 2) Burapha Withi Expressway, and 3) Chalong Rat Expressway, it is possible for the research team to test the hypothesis that we establish from Phase I, i.e., Problem Identification. Phase II includes two tasks: the experimental design and the evaluation of system effectiveness.

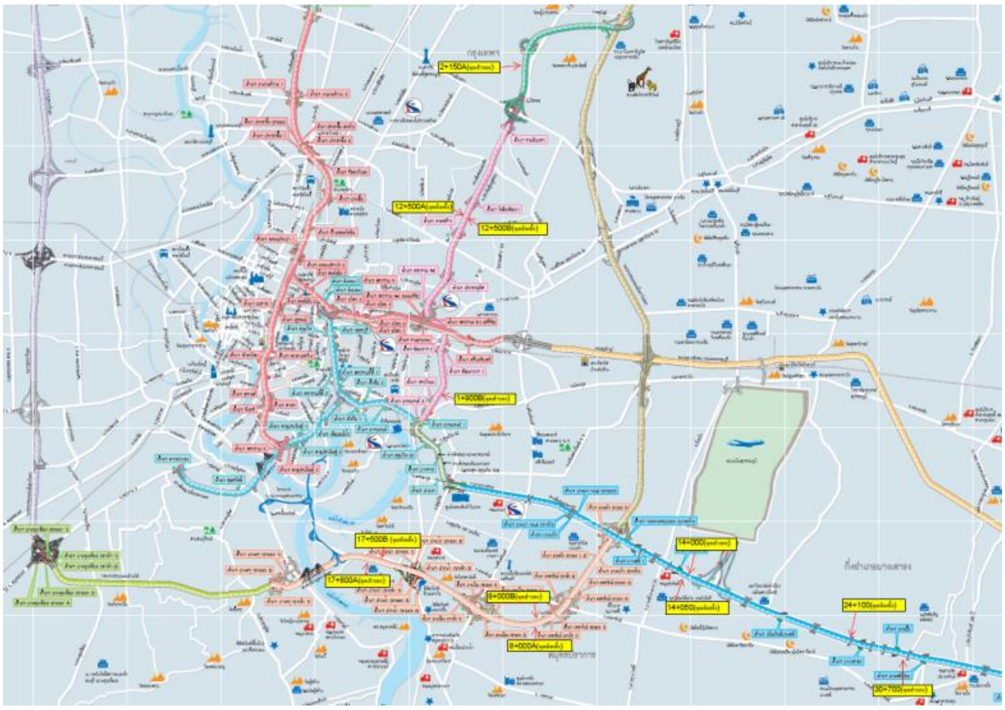


Figure 1.1.3 Three Study Expressway Routes and Potential Automatic Speed Enforcement Installation Locations (denoted by yellow boxes).

<u>Task 4: Experimental Design</u>

The Expressway Authority of Thailand has installed six automatic speed enforcement systems in January 2013. The research team selected three routes as our study case, namely, Chalongrat expressway, Kanchanapisek expressway, and Burapa Withi expressway. Two automatic speed enforcement units will be installed on each route. Additional two empty housings will also be installed at other locations so that the camera units can be rotated into.

Different scenarios can be tested on the three expressways. A few of tests that will run on the real-world expressways are:

- Effect of the dummy cameras,
- Effect of the ASE system on spot speeds, and
- Effect of the ASE system on link speeds

<u>Task 5: Evaluation of system effectiveness: expressway case study</u>

The most straightforward way to evaluate the effectiveness of an automatic speed enforcement system is to conduct a before vs. after study comparing crash frequency and/or severity before and after the system implementation. When time is limited, surrogate safety measures such as speed magnitude and speed distribution are commonly investigated.

In this study, speed reduction and speed variance will be used as surrogate safety measures. Speed data before and after the installation of automatic speed enforcement system on the expressways will be collected. Two types of speed data used in this study are: spot speeds and link speeds. Spot speeds will be collected from the EXAT's image processing cameras. Automatic traffic sensors will be installed where image processing cameras are not available. Since the selected expressway stretch is a closed expressway system (Figure 1.1), it is possible to collect link speed data from the EXAT's transit card transactions. This study will be one of the first attempts to investigate changes in link speeds.

Speed and speed distribution of the before and after traffic operations were be compared to determine the effectiveness of the EXAT's enforcement program.

Phase III - Guideline Development

<u>Task 4: Development of final report</u>

The research team developed guidelines based on findings from Tasks 1 to 3. The report considers three aspects of implementation: operations, laws, and program finance.

<u>Task 5: Seminar</u>

One seminar was held at the end of the study on Feb 28, 2014. Stakeholders in the automatic speed enforcement program were invited to discuss findings from this research effort.

1.3 Schedule/timeframe of the project

	2013									2014		
Task	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**
1. Literature review												
2. Stakeholder interviews												
3. Design of Experiments												
4. Evaluation												
4.1) Speed Data collection												
4.2) Crash Data collection												
4.3) Data Analysis												
5. Develop Guideline												
5.1) Develop Guideline												
5.2) Seminar on 28 Feb 14												

CHAPTER 2 LITERATURE REVIEW

2.1 Speed Enforcement Measures

This section presents existing speed enforcement measures implemented in many countries around the world and in Thailand as follows.

2.1.1 Speed Enforcement Measures in General

Three types of speed measurements using for law enforcements in Europe, Asia, and North America were described in the first section including manual speed enforcement, automatic speed enforcement, and section speed enforcement. In the second part, speed limits from different countries are reviewed.

1) Speed Measurements

In the 1950s-1970s, speed measurements for enforcement had been done manually by police and took a lot of labor and time resources. Until 1976, U.S. firstly brought automatic speed measurement system by photo radar for better accuracy and less staff. From then, the photo radar have gain more popularity and have been widespread to European countries such as U.K., Sweden, German since 1987, 1990, and 1996 respectively. Although automatic speed measurements have gain market shares for police enforcement, the manual speed enforcements are still presented nowadays.

<u>Manual speed enforcement</u>

Manual speed enforcement requires police officers to be present at the site, record speeds, curb or follow speeding vehicles, and write a speed ticket. This form of enforcement takes a large amount of resources and cannot be done during the off-time by police officers. Therefore, a very few percentages of speeding drivers got caught.

The manual speed enforcement can be divided into two subcategories, i.e., fixed location enforcement and moving enforcement. First, a policeman could be at a fixed location, generally called a speed trap near a section with high-speed driving, and control a radar gun for speed measurement. Second, a policeman could be moving along an expressway or be in a helicopter and detect speeds of vehicles on particular routes. He might coordinate with another police officer at the downstream location for curbing or ticketing speeding vehicles.

This kind of speed enforcement can only detect and fine a very few speeding drivers comparing with the whole speeding ones. Elvik et al (2009) reported that police in Sweden and Norway can caught only 0.03% and 0.1% of all speeding drivers by this method.

Automatic speed enforcement

Automatic speed enforcement was implemented to detect speeding vehicles more efficiently and accurately. This method does not require a police officer to be on site. It requires automatic equipments ranging from automatic speeding radar, automatic camera with flash, automatic matching of vehicles' license plates and drivers' name and address, up to an automatic printing of speeding tickets. A policeman might work only in the verification process. However, current speed enforcement system in some countries might still be partially automatic. Figure 2.1 shows the automatic speed enforcement in general.

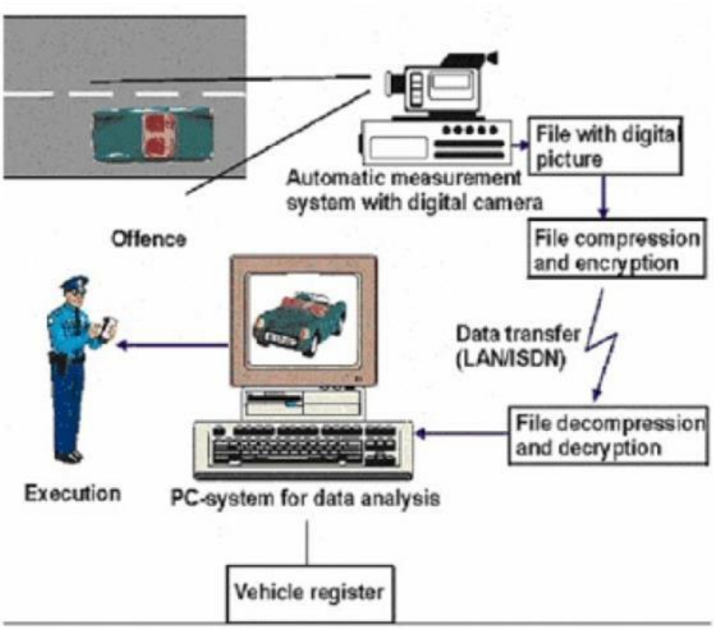


Figure 2.1 Automatic Speed Enforcement Systems (Thailand Accident Research Center, 2007)

Section speed enforcement

According to Austroad (2012), Section speed enforcement, or Point-to-point enforcement, consists of the installation of a series of cameras at multiple locations along a road section. this system captures an image and record the vehicle registration data of each vehicle as it enters the system at the initial camera site. The average speed of a vehicle is calculated using data collected from at least two points within the system. Specifically, average speed is calculated by dividing the distance between two camera sites by the time taken for the vehicle to travel between those two sites. If the corresponding average speed of a vehicle exceeds the legal posted speed limit for that road section, image and offence data are transmitted to a central processing unit from the local processor via a communication network

Now, the section speed enforcement has been used in several countries. Austroad (2012) reported that Victoria was the first Australian jurisdiction to implement point-to-point speed enforcement April in 2007 and the system was in the trial process in other states such as Queensland, South Australia. In New South Wales, section speed enforcement is applied only to heavy vehicles.

Besides Australia, Stefan (2006) reported the trail period of section speed enforcement in the Kaisermühlen Tunnel section of A22 Expressway in Vienna, Austria and presented the popularity of this system in many European countries including U.K., Belgium, Italy, and Netherlands.

This method is considered to be a relatively new technology approach to traffic enforcement and involved many technical requirements for successful implementation.

2) Speed Limits

Normally, Speed limits on each highway are varied depending on design speed, neighboring areas, type of road. In the U.S., speed limits on city streets are varied between 25-40 mph (40-65 km/hr) and limits on expressways are between 65-80 mph (105-130 km/hr) according to the Insurance Institute for Highway Loss Data Institute (2011). In Europe, speed limits are 45-60 km/hr and 110-130 km/hr on city streets and expressways, respectively (European Tourist Office, 2011). In Japan, speed limits are between 40-60 km/hr on city streets; however, on the expressway, the limit is 100 km/hr. It was noted that in Japan, all vehicles are required to driver faster than 50 km/hr on the expressway except in the case of traffic congestion or incidents (Central Nippon Expressway Company Limited, 2010).

2.1.2 Types of Speed Enforcement Measures in Thailand

According to Kocharasri (2011), Thailand began speed enforcement measures on intercity highways since around 1992 but the speed detector is a mobile type and cannot take a photograph. It requires a police officer to check vehicle types and license plates and call another officer at the downstream location to stop the speeding vehicle and issue a ticket.

Currently, highway police in Thailand implemented manual speed enforcement with laser technology that can automatically take a photo of speeding vehicles given any enforcement threshold. However, the camera's memory is limited and can store up to 300 data of speeding vehicles, or approximately 3 hours. These data must be manually copied to an office's desktop before running the registration data for sending a ticket. Similarly, most expressway police has the same machine. Figure 2.2 shows manual speed enforcement regularly used by both highway and expressway police in Thailand.

It is note that expressway police along with the Expressway Authority of Thailand have together implemented an automatic speed enforcement system on Bangpli-Suksawat Expressway in 2012 to gain better enforcement efficiency (Expressway Police 1, 2005) and reduce officer time. In addition, it can deal with night-time speeding vehicles and increase safety for police officers.

Figure 2.2 Manual Speed Enforcement on an expressway (Expressway Police 1, 2005).

2.1.3 Speed Limits in Thailand

For highways in Thailand, speed limits are strictly followed the Land Traffic Act of 1979 (in Thai: พระราชบัญญัติจราจรทางบก พ.ศ. 2522) and the Highway Act of 1992 (in Thai: พระราชบัญญัติทางหลวง ฉบับที่ 2 และ 3 พ.ศ. 2542). In fact, there is no clear limit on the Expressway Act of 2007 (in Thai: พระราชบัญญัติการทางพิเศษแห่งประเทศไทย พ.ศ. 2550). However, the Expressway Authority of Thailand assumes that the Land Traffic Act is valid for expressways as well and can issue a specific regulation on expressways for public safety. Table 2.1 shows the speed limits on highway roadways. Note that existing speed enforcement thresholds are well above the law limits. Current enforcement speeds for a regular car and a heavy vehicle are 120 km/hr and 80 km/hr, respectively. The maximum fine is up to 1,000 THB.

Table 2.1 Speed Limits for Vehicles in Thailand according to the laws

Vehicle Type	**Speed Limits(km/hr)**
Expressway (Land Traffic Act of 1979)[1]	
1. passenger car	80 (urban)/ 90 (suburb)
2. heavy vehicle over 1.2 tons and bus	60 (urban)/ 80 (suburb)
3. trailer and three-wheel vehicle	45 (urban)/ 60 (suburb)
Rural road (Highway Act of 1992)[2]	
1. car and motorcycle	90
2. heavy vehicle over 1.2 tons and bus	60
3. trailer and three-wheel vehicle	80
Express Highway No. 7 (Motorway) and No. 9 (Outer Ring Road) (Highway Act of 1992)[2]	
1. heavy vehicle carried less than 1.2 tons and bus	100
2. heavy vehicle over 1.2 tons and trailer	80
3. passenger car	120
Note Speed limits could be reduced in some specific zones such as black spots, urban area. Drivers must follow a slower speed limit if traffic signs state otherwise.	

Source: [1]Expressway Authority of Thailand (2011);[2]Thailand Accident Research Center (2007)

2.2 Attitudes of Drivers toward Speed Enforcement

There are many measures for speed reduction on roadways. Examples are speed warning signs, speed limit signs, circles, speed humps, rumble strips. For enforcement, speed cameras, speed guns, police speed traps, increasing speeding fines, etc (Kanitpong et al, 2011). The implementation of each measure requires public acceptance. Some past studies therefore focused on how public react with these measures. In addition, detailed study such as the relationship between driver characteristics and speeding is important for managing these measures effectively.

2.2.1 Attitudes toward speed enforcement measures

1) Perception toward speed enforcement in foreign countries

Blincoe et al (2006) studied attitudes and public perception toward speed enforcement on suburb roads in England. Drivers were divided into four groups, i.e., 1) conformers – who never violate speed laws, 2) deterred drivers – who usually go speeding but reduce their speeds only when they saw speed cameras, 3) manipulators – who usually go speeding but reduce their speeds in the speed control zone, and 4) defiers – who always go speeding. After that each group of drivers was analyzed to find their attitudes and perception toward speed enforcement. The study shows that most drivers dislike automatic speed enforcement. Some thought that they have better driving skills and can go speeding without an accident. The conformer is the least percentage among all. The deterred drivers usually evade speed detection and might cause an accident. The manipulators are difficult for police to detect and their speeds depends whether a speed camera is obvious or hidden. Lastly, defiers are the ones who disapproved speed enforcement and believed that speed limits should not be fixed and would depend on road condition. They rarely though that their driving behavior is risky. The study also pinpoints that different policies among each driver type are needed. The change of their attitudes is very important so that these last three groups are willing to accept the speed control policy. The stricter enforcement such as higher ticket fine or more severe penalty might be used together as well.

2) Perception toward speed enforcement in Thailand

There have been several research works in Thailand on the attitudes of drivers toward speed enforcement and speed control as follows:

Kanitpong et al (2011) surveyed driver attitudes toward different speed controls such as automatic speed camera, increase speeding fine, use in-vehicle speed control equipment, etc. 2,180 drivers from 7 provinces i.e., Bangkok, Lopburi, Chonburi, Nakhon Ratchasima, Chacheongsao, Samut Sakorn, and Saraburi were surveyed at gas stations, rest areas, bus terminals. They were asked for their general profile, vehicle type, driving characteristics, and attitudes toward different measures. The data were analyzed by using an ordered probit regression model. Major findings are that 1) without any speed sign, most drivers selected their driving speeds higher than 90 km/hr; 2) most drivers, especially for elderly male drivers, dislike all kinds of speed enforcement. They agree with only speed control sign.

Sontikul et al (2011) focused on the driver attitudes when driving past manual speed enforcement on Highways No. 1 and No. 32 in Ayudhya and categorized drivers into four groups according to the Corbett's driver typology (see Blincoe et al (2006)). Then, it studied characteristics of each group by on-road questionnaires. They found that all 617 drivers can be divided into conformers, deterred drivers, manipulators, and defiers by 38.4%, 14.3%, 22.0%, and 25.3%, respectively. Additionally, from multinomial logistic regression with the dependent variable is group of drivers and independent variables are gender, age, income, education, marital status, insurance availability, driving experiences, past ticketed and accident history, etc. They also found that manipulators and defiers who usually got speeding tickets are drivers with higher income, higher education and longer years of driving experience but has negative attitudes toward speed enforcement schemes.

2.2.2 Relationship between driver characteristics and their attitudes toward speed enforcement measures

Some researches focused on the relationship between driver characteristics and their attitudes toward speed enforcement measures. Driver characteristics include socio-economic profile data such as gender, age, marital status, education level, household location, income, and driving behavior and attitudes such as years of driving experience, vehicle type, driving frequency, driving distance, selected maximum speed, past ticketed or accident history. These variables are analyzed to find their correlation with attitudes towards speed enforcement schemes. Research examples in this field are:

Jorgensen and Pedersen (2005) studies drivers' knowledge on traffic laws and speed control zone and correlate them with driver characteristics. 204 drivers were sampled from several gas stations in Bodo, Norway. The results are that 1) older drivers usually ignore speed limits but know speed control zone better than younger ones; 2) experienced drivers usually drive faster; and 3) drivers with past ticketed or accident history would know more about speed limits and speed control zone. However, this study did not ask whether the drivers who know speed limit will follow the law well.

Kanitpong et al (2011) reported that drivers who disagree with speed enforcement are male, older, and have higher income, more years of driving experience. Williams et al (2006) also reported similar results.

2.3 Effectiveness of Speed Enforcement

This section discuseed the effectiveness of speed enforcement in other countries and in Thailand.

2.3.1 Effectiveness of speed enforcement in general

Elvik et al (2009) compiled 28 articles on speed enforcement effectiveness from various countries, including Finland, Netherlands, Norway, Belgium, Sweden, U.S., U.K., Ireland, and Australia in the handbook of road safety measures. This study summarizes the effectiveness of manual and automatic speed enforcement in terms of effect on accident reductions, effect on speed reduction, and benefit-cost analysis of the system. For section speed enforcement, due to limited usage and literature, only one study (Stefan (2006)) is presented here.

1) Manual speed enforcement

Table 2.2 summarizes the percentages of accident reduction due to manual speed enforcement. It shows that fixed speed detectors can reduce accidents significantly. For mobile speed detectors, it rarely reduced the accidents since the drivers would not know its location and might not decelerate well. For mixed type, the results lie between these two cases.

Table 2.2 Effect of Manual Speed Enforcement on Accident Reductions (Elvik et al, 2009)

Speed detection type	Percentages of accident reduction		
	Accident Severity	Best estimates	Within 95% Confidence Interval
fixed-point speed detection			
All studies	Not specified	-17	(-31; -2)
Mobile speed detection			
All studies	Not specified	-1	(-5; +4)
Mixed speed detection			
All studies	Not weighed by the number of data from each study	-7	(-15; +1)
	Weighed by the number of data from each study	-1	(-11; +9)

For speed reduction, Elvik et al (2009) reported that in Norway, more speed police patrols were increased, the average speed of all vehicles was reduced by 2 km/hr within 2 days to 10 weeks after stricter enforcement.

For economic analysis, Elvik et al (2009) reported that benefit-cost ratios of manual speed enforcement system in the U.K. ranged between 0.3-1.8, while ranged between 3.3-5.7 in the U.S. For the Australia, where most manual speed enforcement is done by helicopter, this ratio ranged up to 12.1.

2) Automatic speed enforcement

Difference in automatic speed enforcement type, level of public campaigns, roadway hierarchy, affects percentage of accident reduction significantly. Table 2.3 from Elvik et al (2009) presents the percentages of accident reduction due to manual speed enforcement. The table is divided into two situations: observable or hidden speed detectors. We found that with observable speed detectors, the number of accidents will be reduced by 16-24%. Note that the number of fatal accidents was reduced precipitously (39%). For hidden speed detectors, the number of fatal accidents was reduced by 16% only. We also found that more public campaigns on automatic speed enforcement would reduce accidents much more.

For speed reduction, Elvik et al (2009) reports that the values and percentages of speed reduction are varied greatly based on enforcement location and cannot be summarized together.

For economic analysis, automatic speed enforcement requires higher initial installation costs as well as maintenance costs. Elvik et al (2009) reports that the benefit-cost ratios of systems in the European countries ranges between 2.1 to 5.9. This number is not much different from manual speed enforcement.

Other individual studies on effectiveness of manual and automatic speed enforcement are follows:

Table 2.3 Effect of Automatic Speed Enforcement on Accident Reductions (Elvik et al, 2009)

Speed detection type	Percentages of accident reduction		
	Accident Severity	Best estimates	Within 95% Confidence Interval
Observable Speed Detector			
All studies	Not weighed by the number of data from each study	-24	(-29; -19)
	Weighed by the number of data from each study	-16	(-23; -8)
	Only with fatality	-39	(-60; -7)
First Year of Campaign	Not specified	-24	(-29; -19)
Hidden Speed Detector			
All studies	Only with casualty	-10	(-22; +4)
	Only with fatality	-16	(-33; +5)

Chen et al (2000) studied the effects of speed radars with hidden camera in British Columbia and compare speed and accident data before and after the speed radars were implemented. The findings show that after one year of speed enforcement, the average speed throughout the region had been reduced by 2.4 km/hr and the numbers of accidents were reduced by 25% for daytime accidents, 11% for injury accidents, and 17% for fatal accident. However, this study results were obtained within one year (a very short term) after implementation.

Keall et al (2001) studied the comparison between the effects of hidden mobile speed enforcement camera with warning campaign on an arterial road with 100 km/hr speed limit in New Zealand. They found that hidden camera and warning campaigns can help reduce driving speeds in general. Notably, they also found that warning campaigns without real camera could affect driving speeds in an earlier period of campaigns.

Chen et al (2002) studies the effect of Photo Radar Program (PRP) on accident and speed reduction between two arterials streets in Vancouver with and without the radar for two years. They found that radar can reduce the average speed and the standard deviation of speeds by 2.8 km/hr and 0.5 km/hr, respectively. The effect can happen up to 2-km away from the enforcement area. In addition, they found that the numbers of accident reduction inside and outside the enforcement zone were reduced by 19% and 14%, respectively.

Hirst et al (2005) studies the effect of speed control by using a model calibrated from 149 locations, i.e., 17 fixed speed camera locations, 62 mobile speed camera locations, 70 other engineering speed control. The model shows that 56% of accident reductions were due to speed reduction. The model also shows that speed cameras can reduce 1 mph of speed on a 30-mph local street speed limit and reduce the accidents by 7-8%. However, these effects will be greater if speed cameras are used on a higher speed roadway.

Shin et al (2009) studies the effect of automatic speed camera on Highway 101 in Scottsdale, Arizona, U.S. The cameras were installed at fixed locations along 6.5-mile corridor for 9-month evaluation period. The study shows that automatic camera can capture speeding vehicles (> 76 mph) up to 9 times as much as manual camera. The average speed on this corridor was reduced by 9 mph and all accident types except rear-end collision were reduced. This project is considered to have a net benefit of 17 million U.S. Dollar per year. However, the amount of benefit could be changed years later.

In summary, manual speed enforcement can reduce average speed by 2 km/hr, reduce accidents by 1-17%, and has benefit-cost ratio of 0.3-5.7, while automatic one can reduce average speed by 15 km/hr, reduce accidents by 10-39%, and has benefit-cost ratio of 2.1-5.9. These effects could depend on area, types of installation, road condition, and existing speed limit.

3) Section speed enforcement

Since section speed enforcement is still rare nowadays, the sampling of its effectiveness and the literature is also limited. Stefan (2006) reported the effect of a trail period in the Kaisermühlen Tunnel section of A22 Expressway in Vienna. The results show that after two years of implementation, the numbers of accidents in the tunnel were reduced by 40%. It reported that the numbers of fatal accidents were reduced by 49%. Average speeds were also reduced significantly and varied among different period of campaign and ranged from 1-14 km/hr as shown in Figure 2.3.

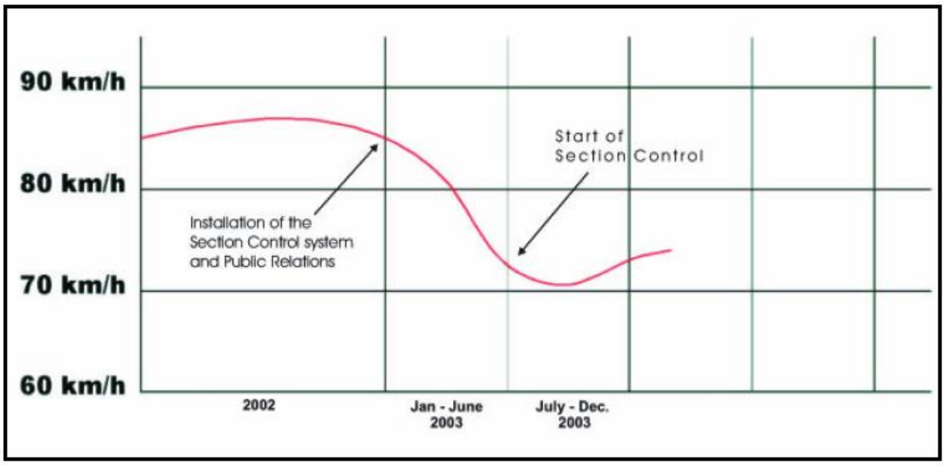


Figure 2.3 Effect of Section Speed Enforcement on Average Speeds (Stefan, 2006)

For benefit-cost calculation, Stefan (2006) showed that benefit-cost ratio of section speed at this tunnel was 5.3. This number is considerably high and at the upper end of automatic speed enforcement’s one.

2.3.2 Effectiveness of speed enforcement in Thailand

In Thailand, the Highway police and Expressway police are the main authorities for enforcing speed laws. For expressways, police usually use mobile radar to detect speeding vehicles and capture them at toll gates. The normal period of enforcement is between 9-12 and 13-16 due to limitation of radar memory and daylight. It is similar to highway police except that they will send a speeding ticket to vehicle owner addresses.

Nowadays, both highway and expressway polices are targeting only passenger cars and vans since mobile radar can only be set with a single speed threshold values. The main problem of existing enforcement is bad weather or night time due to camera limitation in poor lighting.

Speed enforcement in Thailand has no concrete plan and was set in some random locations. The effects of speed enforcement on speed and accident reduction in Thailand are not well evaluated. Satienpong (2011) believed that the speed of vehicles in Thailand is nearly the same with or without speed cameras.

2.4 Data Analysis Techniques

2.4.1 Methods to analyze drivers' attitudes toward automatic speed enforcement

Two methods are generally used to analyze drivers' attitudes toward automatic speed enforcement. The first one is the basic statistics such as percentage, average, deviation calculations to show data in comprehensive format. The second one is regression analysis by using a multivariable logistic model (Sontikul et al, 2011) or an ordered probit model (Kanitpong et al, 2011). The descriptions of each regression model are as follows:

Sontikul et al (2011) collected data from driver questionnaires and divided drivers into four groups. After that, the multivariable logistic model was used by letting the group of drivers to be dependent variable (Y) and other variables, e.g., gender, age, income, marital status, insurance availability, driving experience, driving distance, driving frequency, trip purpose, knowledge of speed limits and enforcement, ticketed and accident history as independent variables (X).

Kanitpong et al (2011) collected data regarding driver attitudes on different types of speed enforcement schemes by using ordered probit model. The first model, they assigned views toward scheme (from 4 = strongly agree to 1 = strongly agree) as the dependent variable (Y) and driver characteristics such as age, gender, marital status, occupation, education level, vehicle type, vehicle age, driving distance, driving experience, accident history, etc as independent variables. The second model is similar to the first one except that the selected maximum speeds in 6 levels were assigned to be a dependent variable.

After running these models, variables with significant correlation were obtained. Also, the notation signs (+/-) of each coefficient would show the direction of correlation (negative or positive correlation). In addition, relationships between each pair of independent variables are obtained.

2.4.2 Methods to analyze effectiveness of automatic speed enforcement

Generally, two values that show the effectiveness of speed enforcement are the reduction in accidents and the reduction in speeds. The methods in the past studies to determine these values are:

1) Average Speed Reduction

Chen et al (2000) evaluates the effect of Photo Radar Program (PRP) on average speed reduction by using time-series of speed as shown in Figure 2.4. The solid vertical line in the figure shows the starting point of photo radar program implementation. We can obviously see that percentages of speeding vehicle (driving 16 km/hr over the speed limit) were reduced significantly

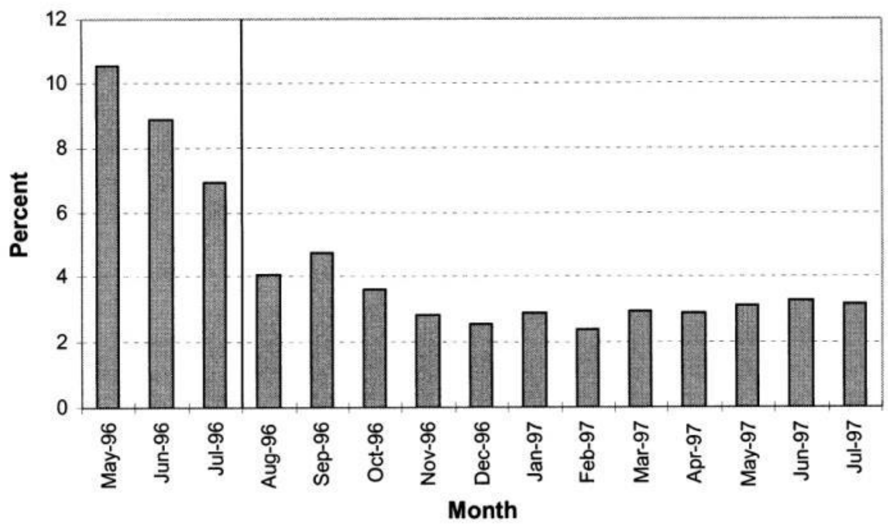


Figure 2.4 Percentage of vehicles speeding over 16 km/hr from the speed limit (Chen et al, 2000)

Keall et al (2001) and Chen et al (2002) evaluate the change in average speeds after speed enforcement campaigns by using speed distribution function as shown in Figure 2.5. From the figure, we can observe the change in speeds after the campaign by comparing two curves. First, if the “after curve” is similar to the “before curve” but shifted to the left, it means that speeds in general are reduced. Secondly, the height of these curves somewhat show the deviation of speeds.

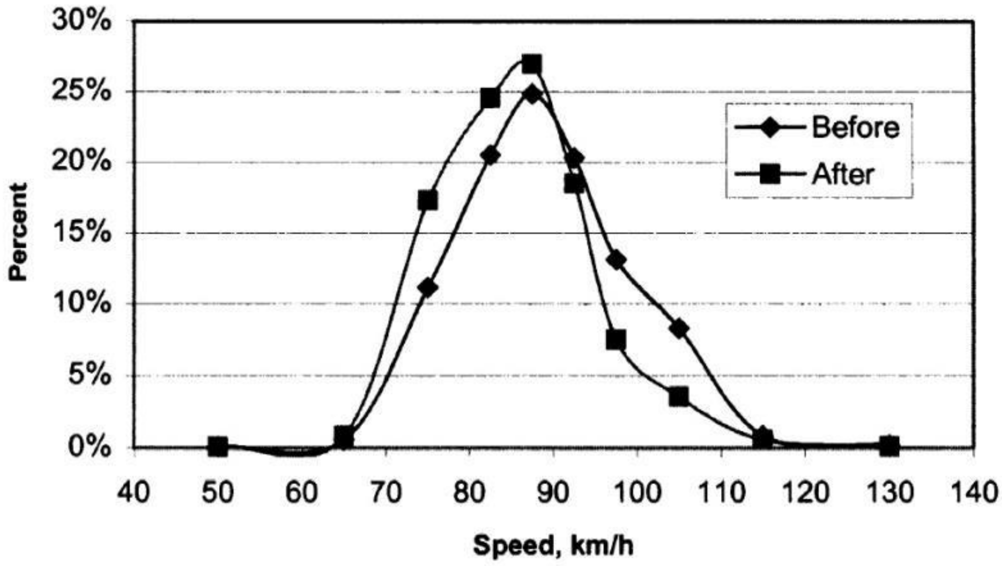


Figure 2.5 Speed distribution at a highway with 80 km/hr limit (Chen et al ,2002)

Shin et al (2009) use an analysis of variance (ANOVA) to determine the significance of changes in average speed before and after enforcement campaigns. In addition, they use a least square estimation (LSE) to determine the difference of variance in different period. The plot between average speed and average flow in each time period as in Figure 2.6 was shown also to determine the situation when average speeds dropped.

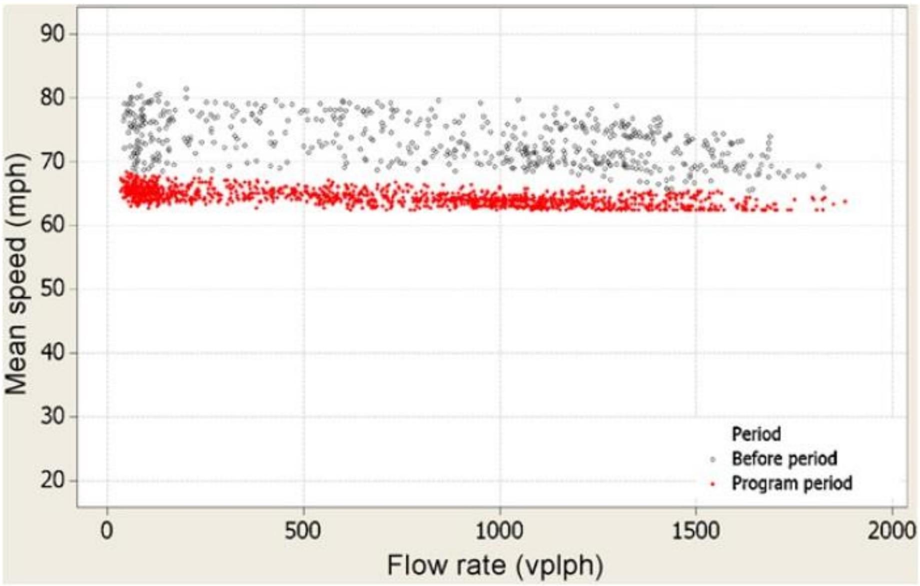


Figure 2.6 Relationship between traffic volumes and speeds at an automatic enforcement highway (Shin et al, 2009)

2) Accident Reduction

The most usual method to compare the accident reduction on a roadway is to define the "accident rate" as the ratio of the number of accidents to the number of vehicles entering the road. After that, accident rates before and after enforcement schemes are compared.

Chen et al (2002) uses linear regression equation to forecast traffic accident and compare 2 years of data before implementation with 2 years after implementation. Chen et al (2000) uses time-series data from 1992-1995 to forecast the accident rate of do-nothing situation with the actual data with an enforcement scheme. The results are shown in Figure 2.7.

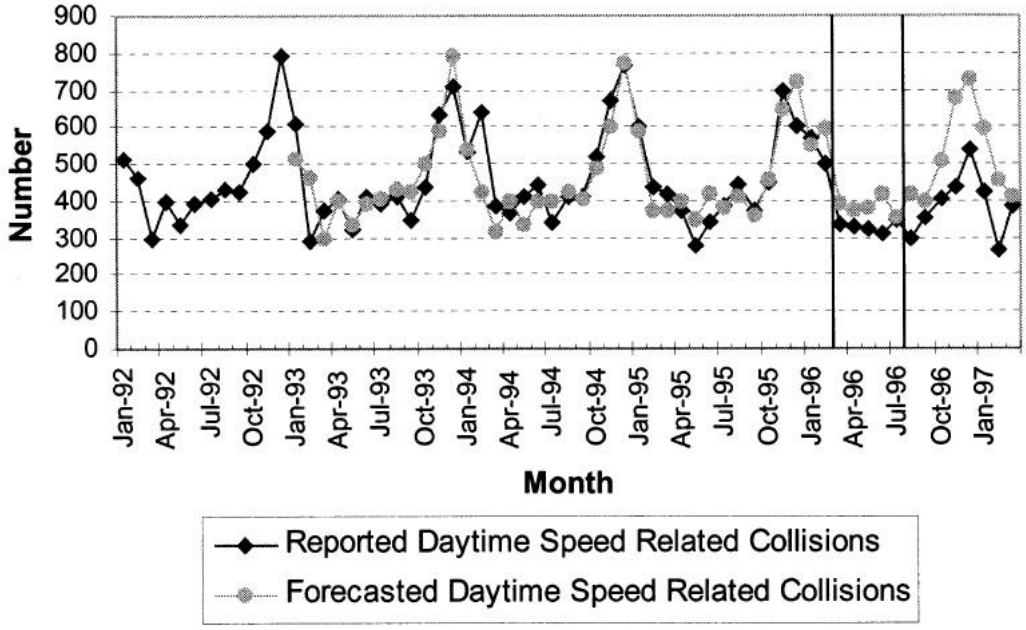


Figure 2.7 Comparison of forecasted and actual no of accidents (Chen et al, 2000)

Keall et al (2001) and Shin et al (2009) also use similar methods but the period of analysis is different, i.e., Keall et al (2001) compares monthly data while Shin et al (2009) uses annual data.

2.5 Summary of Past Studies

The summary of past studies is as follows.

1) Types of speed enforcement in each country are varied. Although automatic speed enforcement has gain more popularity around the world, manual speed enforcement in some specific locations and situations does exist. In Thailand, manual speed enforcement with mobile radar camera has been implemented in most highways and expressways but automatic speed enforcement has just

deployed in 2013. In addition, section speed is now in trial period in most countries especially in Europe and Australia although no implementation of this scheme in Thailand yet.

2) The implementation of each measure requires public acceptance. Some past studies therefore focused on how public react with these measures. The findings show that most drivers, especially for elderly male drivers, dislike all kinds of speed enforcement. They agree with only speed control sign or less strict schemes. Therefore, implementation of speed enforcement schemes would be done together with education campaigns so the ignorant drivers would understand the negative impact to the society due to speeding.

3) There have been several studies regarding the effectiveness of speed enforcement. Past studies show that manual speed enforcement can reduce average speed by 2 km/hr, reduce accidents by 1-17%, and has benefit-cost ratio of 0.3-5.7, while automatic one can reduce average speed by 15 km/hr, reduce accidents by 10-39%, and has benefit-cost ratio of 2.1-5.9. These effects could depend on area, types of installation, road condition, and existing speed limit. For section speed enforcement, it reported that the numbers of fatal accidents at one site were reduced by 49%. Average speeds were also reduced significantly, varied among different period of campaign and ranged from 1-14 km/hr. In Thailand, there is no comprehensive study regarding this issue.

4) Analysis of driver attitudes toward speed enforcement policy could be done by descriptive statistics, or use regression equation by either a multivariable logistic model or an ordered probit model. The latter method can be used to determine correlation significance of driver characteristics and their comments. To analyze effectiveness of speed enforcement schemes, before and after study must be done. The main variables in the study are accident rates and average speeds before and after speed enforcement system implementation.

CHAPTER 3 DATA

One of the key tasks in this study is the data collection for a “before” and “after” analysis. Two types of data will be collected to perform such analysis, namely, speed and accident data. Study sites where automatic speed enforcement cameras have been installed are described in Section 3.1. Based on the findings in the literature and stakeholder interviews, the experimental design has been established in Section 3.3.

The Expressway Authority of Thailand (EXAT) has installed six automatic speed enforcement cameras onto three expressway routes, namely, Chalongrat expressway, Kanchanapisek expressway, and Burapha Withi expressway since January 2013. Figure 3.1 depicts the locations of the three expressway routes. Note that due to a lengthy work process, speeding tickets were sent out to the violators a couple months after the installation.

Chalongrat expressway is 38.6 km in length, bounded by the Outer Ring Road (Motorway Route 9) and the Chalerm Mahanakorn expressway. Second, Kanchanapisek expressway is 22.5 km long connecting the east and south portions of the Outer Ring Road (Motorway Route 9). Finally, Burapha Withi is 54 km long serving as an intercity corridor connecting Bangkok and the eastern region of the country.

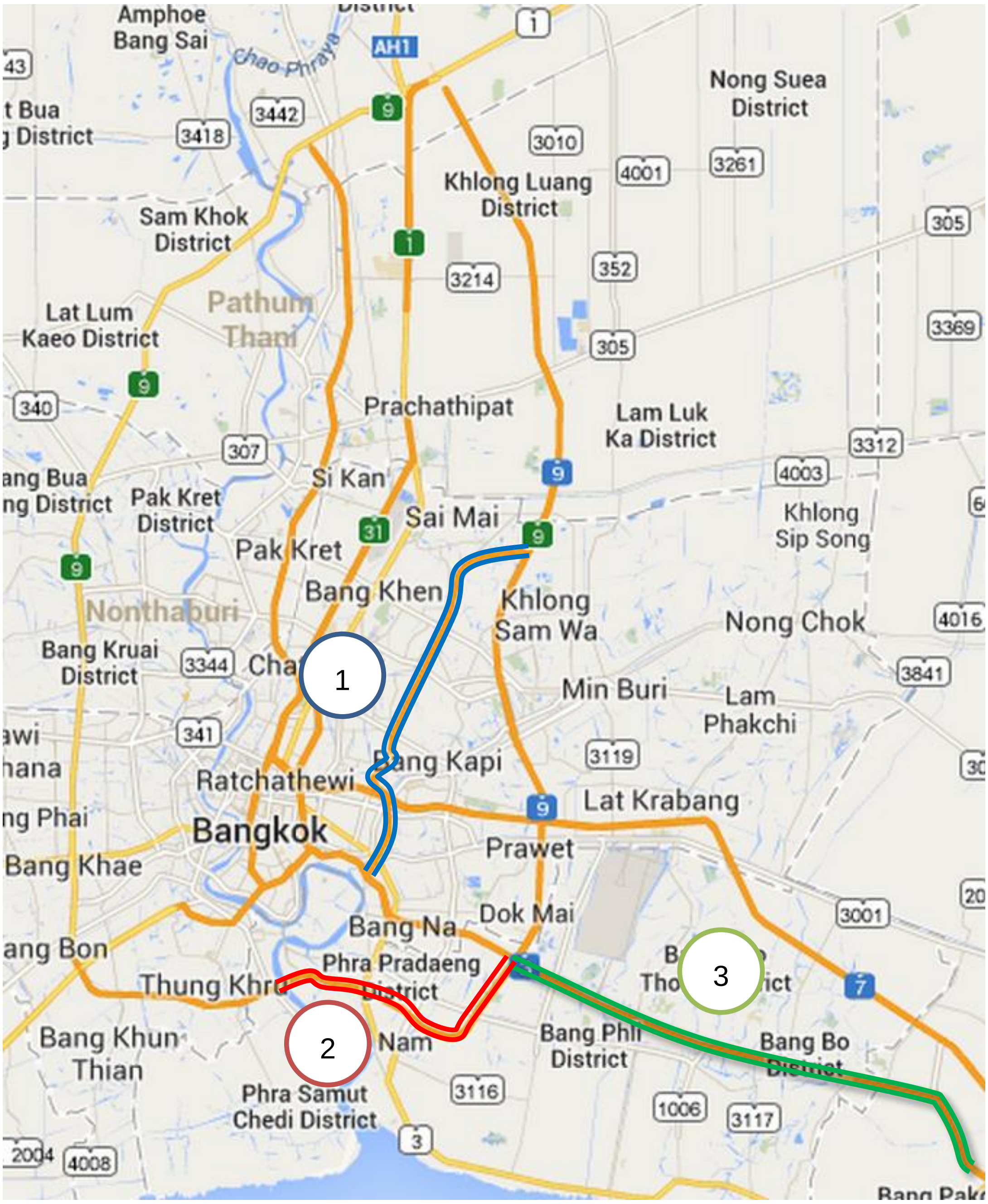


Figure 3.1 Study Corrridors: 1) Chalong Rat Expressway (Blue Line), 2) Kanchanapisek Expressway Red Line), and 3) Burapha Withi Expressway (Green Line).

3.1 Camera Sites

Currently, six automatic speed enforcement cameras have been installed on the three expressway routes, namely, Chalongrat expressway, Kanchanapisek expressway, and Burapha Withi expressway. Locations of the six cameras are as follows:

- KM 12+500A on Chalongrat Expressway, northbound
- KM 12+500B on Chalongrat Expressway, southbound

- KM 8+000A on Kanchanapisek Expressway, westbound
- KM 17+500B on Kanchanapisek Expressway, eastbound
- KM 14+050 (Inbound) on Burapha Withi Expressway, westbound
- KM 24+100 (Outbound) on Burapha Withi Expressway, eastbound

All six cameras have been used for enforcement since January 2013. The Kanchanapisek and the Burapha Withi Expressways are closed-system expressways and can be considered as suburban routes while the Chalongrat Expressway can be considered as an urban expressway.

Details of equipment on each expressway route are as follows:

3.1.1 Chalongrat Expressway

Chalongrat Expressway, a six-lane expressway, is located on the east side of Bangkok, connecting traffic between the eastern section of the Outer Ring Road (Motorway Route 9) and the Chalerm Mahanakorn expressway (see Figure 3.2). It spans 38.6 km in length serving a daily traffic of 40,800 vehicles per day. Two automatic speed enforcement cameras were installed at the 12+500 Kilometer Post, one being pointed to the northbound traffic (12+500A) and the other to the southbound traffic (12+500B). Both cameras were installed on the left-hand side of the road, facing the back of vehicles, i.e., receding traffic configuration. Additionally, two backup housings were installed for future equipment relocations (see Figure 3.3). One backup site is at the Kilometer Post 20+800A Northbound. The other backup site is at 1+900 Southbound. The appearance of the two cameras are depicted in Figure 3.4 and Figure 3.5.

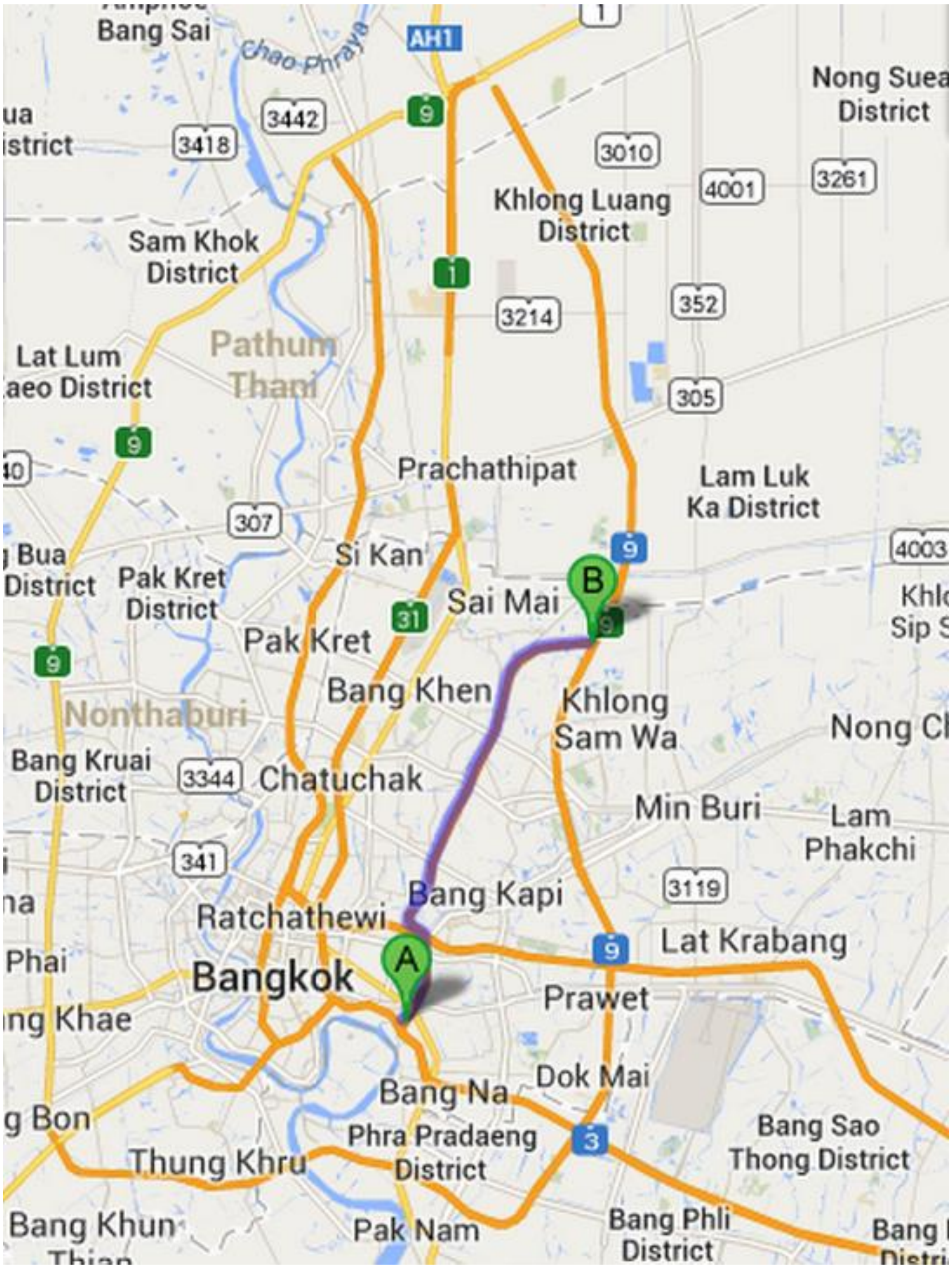


Figure 3.2 Chalongrat Expressway Route.

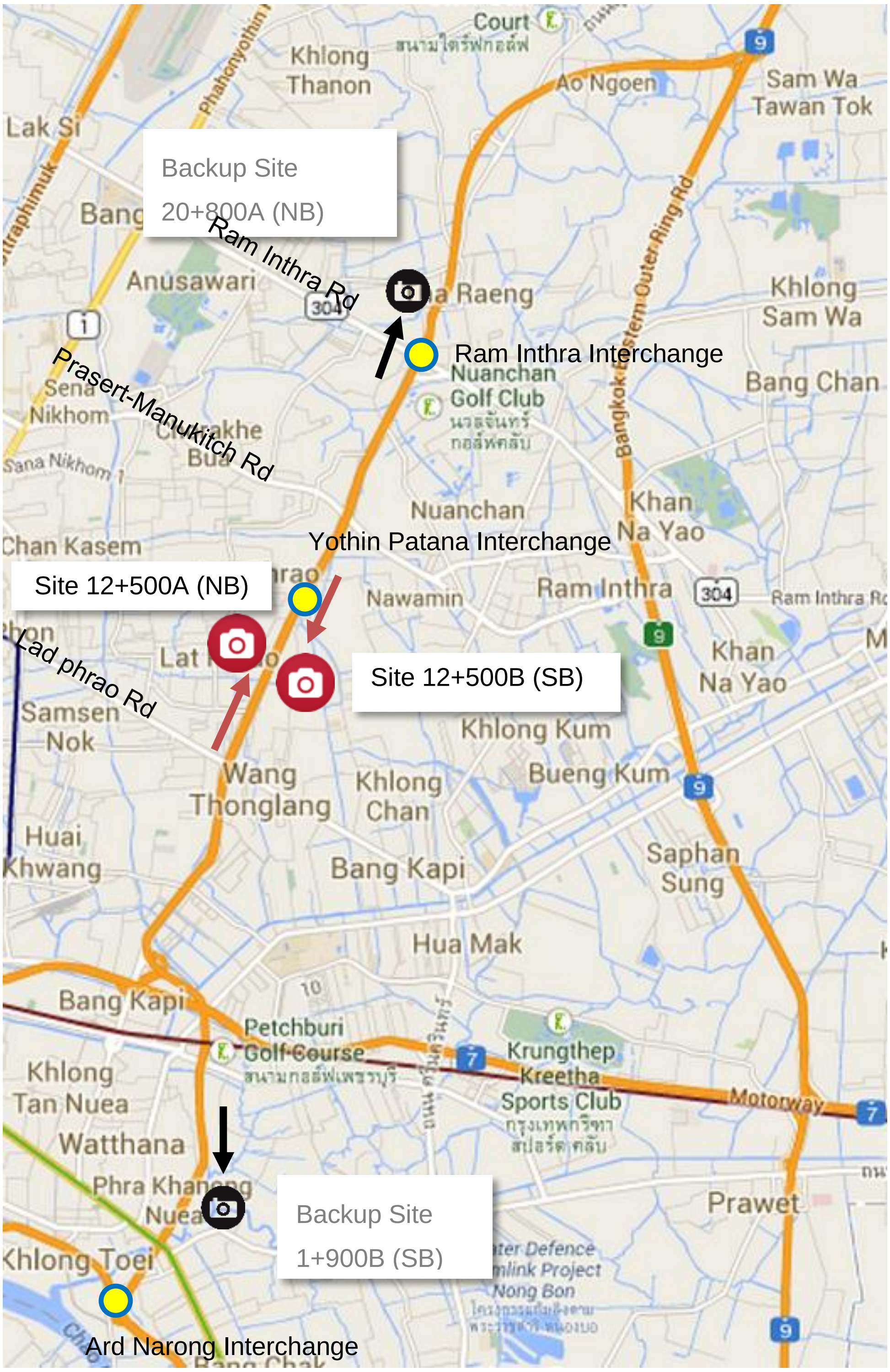


Figure 3.3 Locations of camera sites and backup sites on Chalongrat expressway. Red camera icon denotes active camera site and black camera icon denotes backup site.

Figure 3.4 Speed Enforcement Camera at KM 12+500A on Chalongrat Expressway, Northbound

Figure 3.5 Speed Enforcement Camera at KM 12+500B on Chalongrat Expressway, Southbound

3.1.2 Kanchanapisek Expressway

Kanchanapisek Expressway, a six-lane expressway, is part of the southern section of the Outer Ring Road, located south of Bangkok (see Figure 3.6). It spans 22.5 km in length serving a daily traffic of 122,700 vehicles per day. Two automatic speed enforcement cameras were installed at the Kilometer Post 17+500 Eastbound and 8+000 Westbound. Additionally, two backup housings were installed for future equipment relocations (see Figure 3.7). One backup site is at the Kilometer Post 8+000 Eastbound. The other backup site is at Kilometer Post 17+800 Westbound.

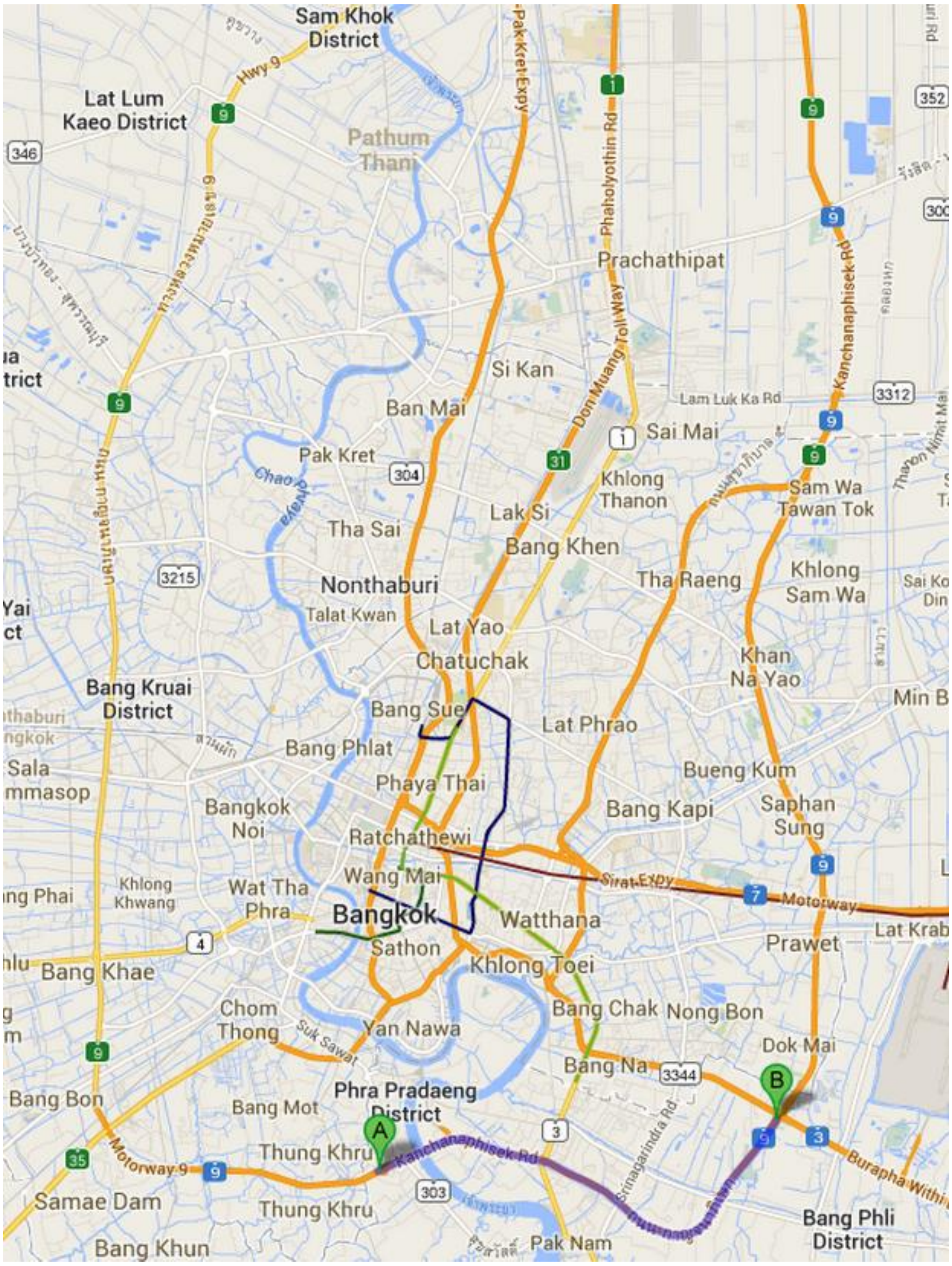


Figure 3.6 Kanchanapisek Expressway between Bang Kru Toll Plaza and Bang Kaew Toll Plaza.

Two automatic speed enforcement cameras were installed on this route. One is at KM 8+000A (WB) and the other one is at KM 17+500B (EB) as shown in Figure 3.7. Both cameras were installed on the left-hand side of the road, facing the back of vehicles, i.e., receding traffic configuration. The appearance of the two cameras are depicted in Figure 3.8 and Figure 3.9.

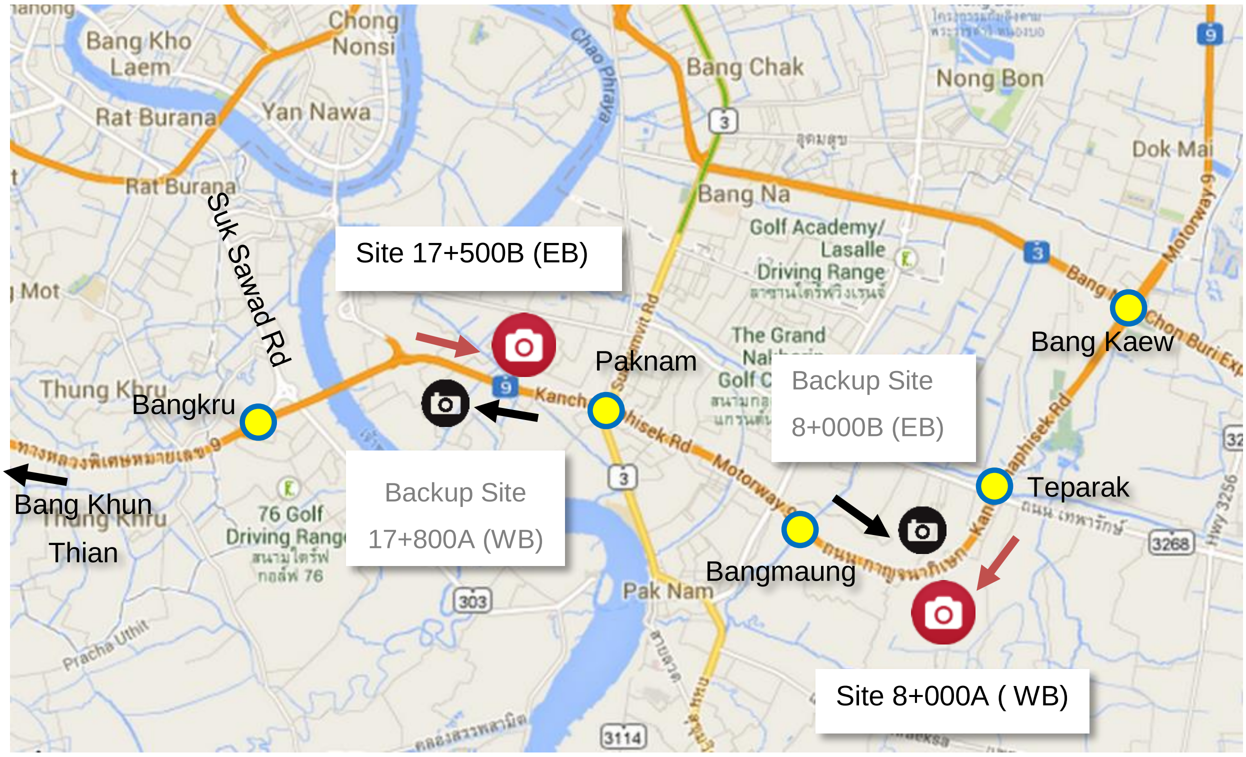


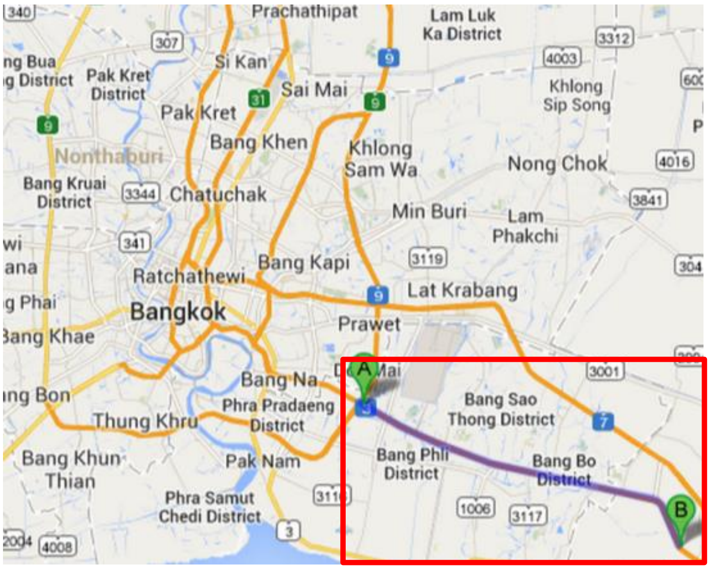
Figure 3.7 Locations of camera sites and backup sites on Kanchanapisek expressway. Red camera icon denotes active camera site and black camera icon denotes backup site.

Figure 3.8 Speed enforcement camera at KM 8+000A on Kanchanapisek expressway, westbound

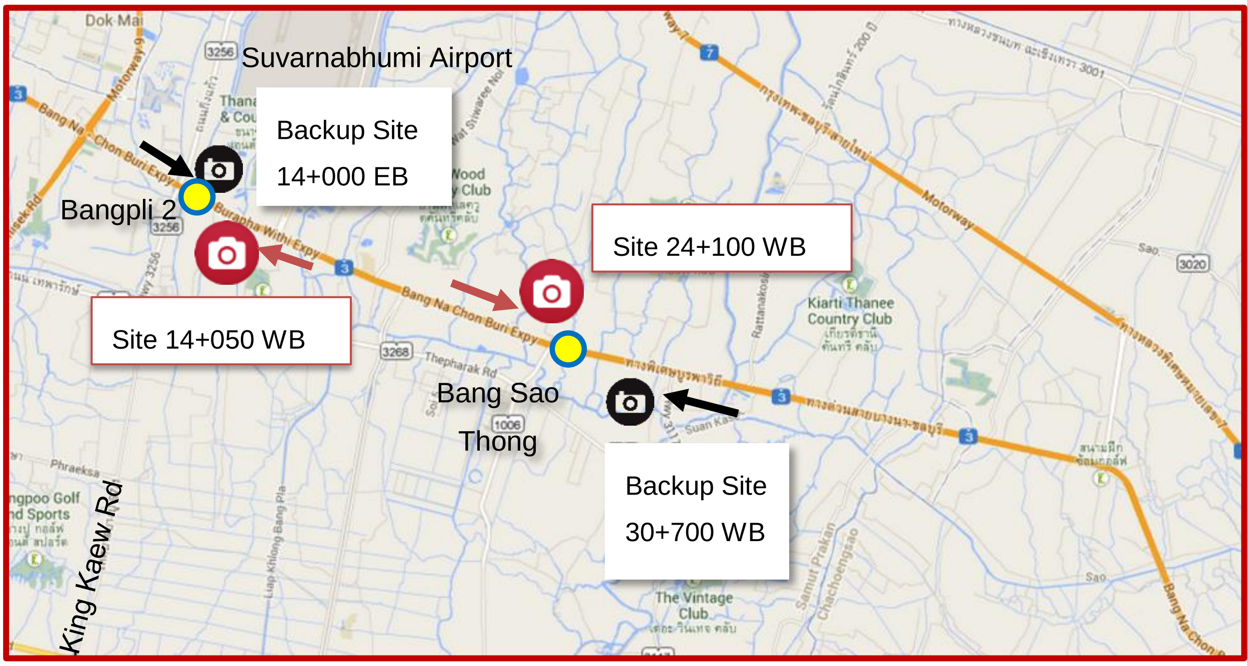
Figure 3.9 Speed enforcement camera at KM 17+500B on Kanchanapisek expressway, eastbound

3.1.3 Burapha Withi Expressway

Two automatic speed enforcement cameras were installed on this route. One is at 14+050 Inbound (WB) and the other one is at KM 24+100 Outbound (EB) as shown in Figure 3.10. Both cameras were installed on the left-hand side of the road, facing the back of vehicles, i.e., receding traffic configuration. The appearance of the two cameras are depicted in Figure 3.11 and Figure 3.12.



(a) Study Section on Burapha Withi Expressway Route



(b) Camera and Backup Installation Locations

Figure 3.10 Locations of camera sites and backup sites on Burapha Withi expressway. Red camera icon denotes active camera site and black camera icon denotes backup site.

Figure 3.11 Speed Enforcement Camera at KM 14+050 (Inbound) on Burapha Withi Expressway, Westbound

Figure 3.12 Speed Enforcement Camera at KM 24+100 (Outbound) on Burapha Withi Expressway, Eastbound

3.2 Backup Sites

Beside the automatic speed enforcement cameras, the Expressway Authority of Thailand (EXAT) has also installed six backup sites for future equipment rotation. The exterior, e.g., housing and wiring system, of the backup sites look identical to the actual speed enforcement camera sites. The six backup sites are:

- KM 20+800A on Chalongrat Expressway, northbound (a.k.a. KM 2+150A on ROE expressway)
- KM 1+900B on Chalongrat Expressway, southbound
- KM 8+000B on Kanchanapisek Expressway, eastbound
- KM 17+800A on Kanchanapisek Expressway, westbound
- KM 14+000 (Outbound) on Burapha Withi Expressway, eastbound
- KM 30+700 (Inbound) on Burapha Withi Expressway, westbound

Similar to the actual enforcement cameras, the backup housings are facing vehicle rears, i.e., receding configuration. The appearance of the six housings are shown in Figure 3.13 - Figure 3.18. The locations of backup housings installed on Chalongrat expressway, Kanchanapisek expressway, and Burapha Withi expressway are shown previously in Figure 3.3, Figure 3.7, and Figure 3.10, respectively.

Figure 3.13 Backup Site at KM 20+800A on Chalongrat Expressway, Northbound

Figure 3.14 Backup Site at KM 1+900B on Chalongrat Expressway, Southbound

Figure 3.15 Backup Site at KM 8+000B on Kanchanapisek Expressway, Eastbound

Figure 3.16 Backup Site at KM 17+800A on Kanchanapisek Expressway, Westbound

Figure 3.17 Backup Site at KM 14+000 (Outbound) on Burapha Withi Expressway, Eastbound

Figure 3.18 Backup Site at KM 30+700 (Inbound) on Burapha Withi Expressway, Westbound

The locations of the cameras and backup sites are summarized in Table 3.1.

Table 3.1 Locations of Speed Enforcement Cameras and Backup Sites on the Expressways

Route	Direction	Camera Location	Backup Site Location
Chalongrat	NB	KM 12+500A	KM 20+800A
	SB	KM 12+500B	KM 1+900B
Kanchanapisek	WB	KM 8+000A	KM 17+800A
	EB	KM 17+500B	KM 8+000B
Burapha Withi	WB	KM 14+050 (Inbound)	KM 30+700 (Inbound)
	EB	KM 24+100 (Outbound)	KM 14+000 (Outbound)

3.3 Experimental Design

It is known that road safety improvement is the key objective of deploying an automatic speed enforcement system. Measuring number of speed-related crashes on the study expressways seems to be the most straight forward means to measure the effectiveness of the automatic speed enforcement system. Speed reduction is also commonly used to as a surrogate safety measure when "after data" is insufficient, i.e., less than one year. Therefore, in this study, we will collect both speed and crash data before and after the deployment of the automatic speed enforcement system to determine whether the speed reduction and crash reduction are statistically significant.

To compare speed data, two types of data will be used, namely, spot speed and link speed data. Spot speed can be obtained from existing traffic sensors and the automatic speed enforcement cameras themselves.

On closed-system expressways such as Kanchanapisek and Burapha Withi Expressways, link speed can be determined indirectly from timestamp data on transit cards as well as Electronic Toll Collection (ETC) database. On the open-system expressway such as Chalongrat Expressway, link speed can be obtained from ETC transaction data between Ram-Indra and Arj-Narong Toll Plaza.

Individual crash data can be obtained from the EXAT's crash database.

Table 3.2 Sources of Speed and Crash Data

Route	Spot Speed	Link Speed	Crash Data
Kanchanapisek	Autoscope at 12 sites	ETC, MTC	EXAT Database
Burapha Withi	NA	ETC, MTC	EXAT Database
Chalongrat	Autoscope at 4 sites	ETC (Ram-Indra, Arj-Narong)	EXAT Database

3.4 Spot Speed Measurements

Spot Speed can be measured where automatic traffic sensors are available. The image processing cameras were installed on two expressways including Chalongrat and Kanchanapisek expressways. Note that Burapha Withi expressway does not have automatic traffic sensors installed, therefore, spot speed analysis will not be available on this route.

3.4.1 Spot Speed: Chalongrat Expressway

Spot speed can be directly obtained using image processing camera installed along the corridor between Ram Inthra Rd and the eastern Outer Ring Road. Three image processing cameras (IDS No. 01, 05, and 03) were installed to collect the northbound traffic speeds and the other three cameras (IDS No. 06, 02, and 04) were installed to collect the southbound traffic speeds. Locations of the six image processing cameras as well as speed enfocement cameras and their backups on the Chalongrat expressway are summarized in Table 3.3. Figure 3.19 represents the geographical locations of the equipment.

Table 3.3 Locations of image processing cameras on Chalongrat expressway (Backup housing is at 2+150A, Northbound).

Northbound Image Processing Camera ID	Camera Location	Southbound Image Processing Camera ID
	KM 25+000	IDS04
IDS03	KM 24+500	
IDS05	KM 22+500	
IDS01	KM 21+000	IDS02
	KM 19+000	IDS06

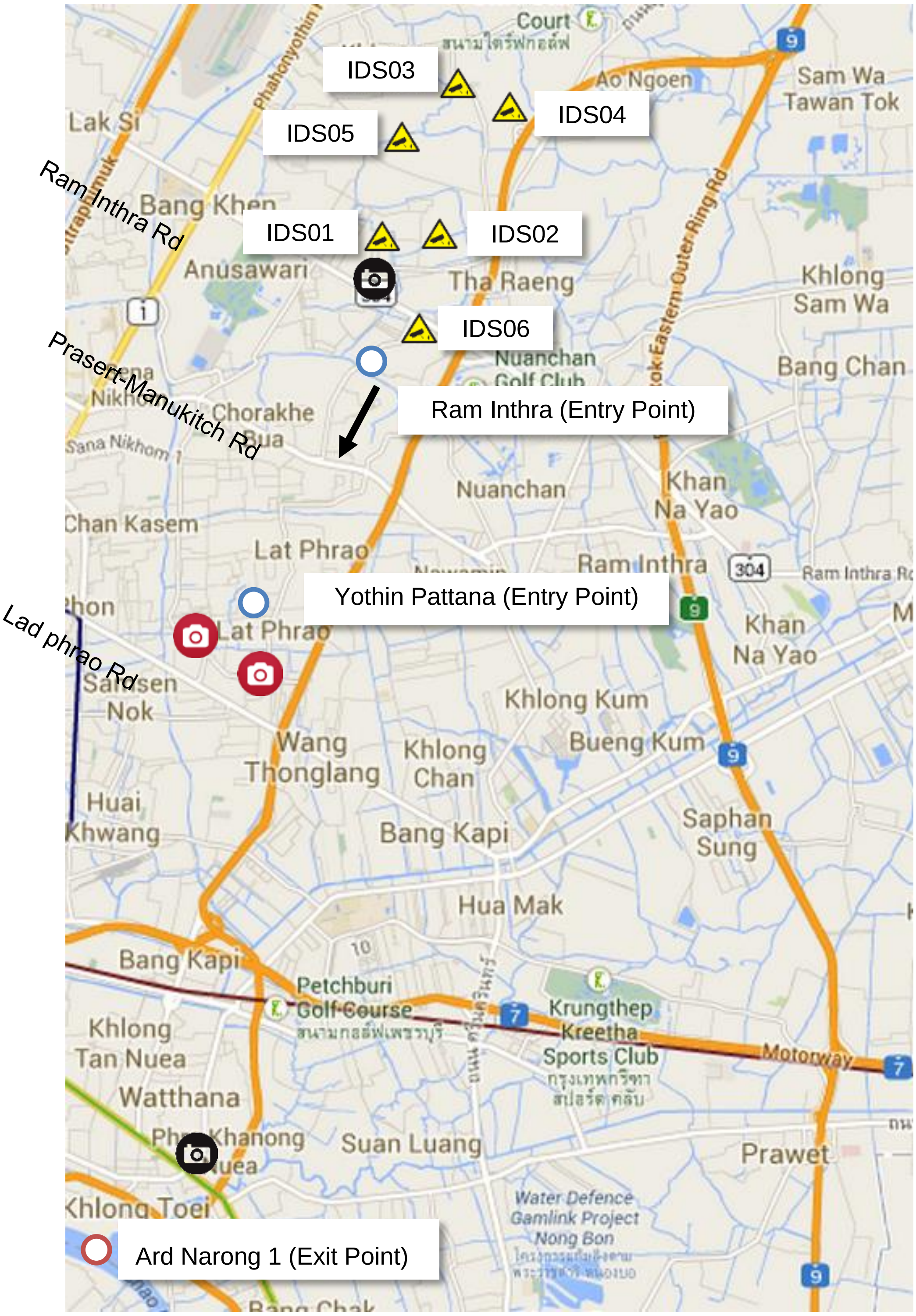


Figure 3.19 Locations of Image Processing Camaras and ETC Toll Plazas on Chalongrat Expressway.

3.4.2 Spot Speed: Kanchanapisek Expressway

On Kanchanapisek expressway, there are twelve image processing detection stations, six stations for each direction as shown in Figure 3.20. Each detection station has two image processing cameras. The left-hand side camera covers shoulder lane and lane 1 while the right-hand side camera covers lane 2 and lane 3, i.e., middle lane and right lane, as illustrated in Figure 3.21. Note that the cameras were installed since the opening of the expressway and their installation and locations are different from the speed enforcement cameras. Therefore, it is reasonable to assume that drivers on this expressway does not confuse the image processing camera with speed enforcement camera.

Locations of the six image processing cameras on the Kanchanapisek expressway are summarized in Table 3.4.

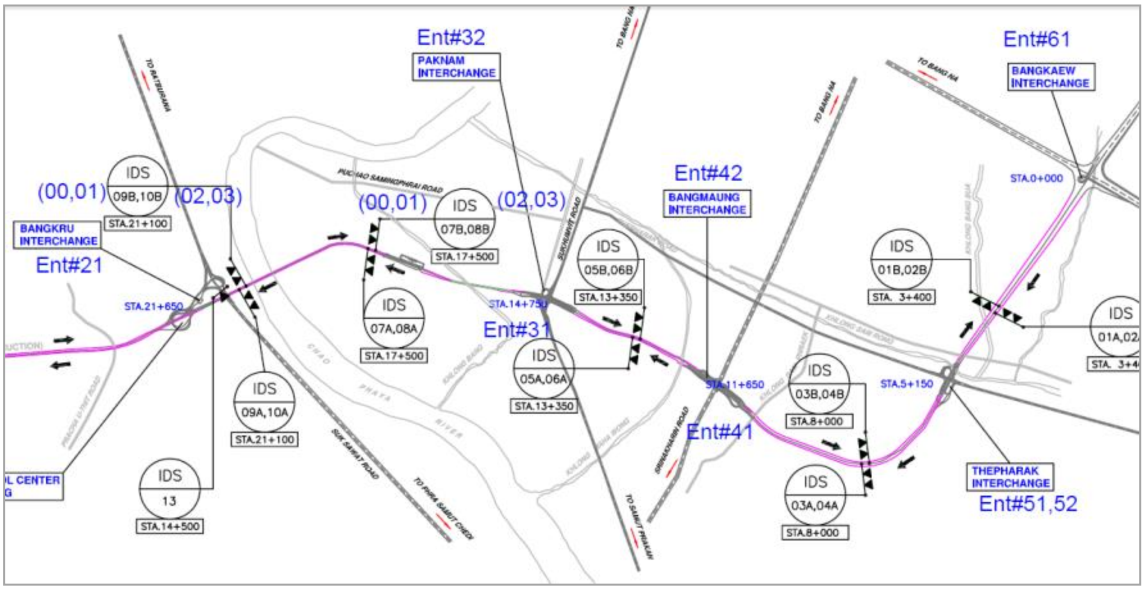


Figure 3.20 Location of the image processing sensors along the Kanchanapisek Expressway. Note that the image processing cameras are denoted by solid triangles.

Figure 3.21 Appearance of image processing cameras and lane configuration on the Kanchanapisek expressway (station KM 8+000A)

Table 3.4 Locations of image processing cameras on Kanchanapisek expressway

Westbound Image Processing Camera ID	**Camera Location (From East to West)**	**Eastbound Image Processing Camera ID**
IDS01A, IDS02A	KM 3+400	IDS01B, IDS02B
IDS03A, IDS04A	KM 8+000	IDS03B, IDS04B
IDS05A, IDS06A	KM 13+350	IDS05B, IDS06B
IDS07A, IDS08A	KM 17+500	IDS07B, IDS08B
IDS09A, IDS10A	KM 21+100	IDS09B, IDS10B
IDS11A, IDS12A	KM 8+000 (Motorway Route 9)	IDS11B, IDS12B

3.5 Link Speed Measurements

Link speed can be obtained from timestamps recorded when a vehicle entering and exiting the expressway system. In this study, there are two sources of database that entering/existing timestamps are available for the link speed calculation including manual toll collection (MTC) transit ticket database in the closed system expressways and the electronic toll collection (ETC) database.

3.5.1 Link Speed: Chalongrat Expressway

On Chalongrat expressway, ETC timestamps were collected at three interchanges including Ram Inthra (entry point), Yothin Pattana (entry point), and Ard Narong (exit point). The interchange locations are depicted in Figure 3.3. Average speed on two sections can be obtained, one is from Ram Inthra to Ard Narong, and the other one is from Yothin Pattana to Ard Narong.

3.5.2 Link Speed: Kanchanapisek Expressway

On Kanchanapisek expressway, MTC timestamps were collected at six interchanges including Bang Kaew, Teparak, Bangmaung, Bangkru, and Bang Khun Thian. The interchange locations are depicted in Figure 3.7. For westbound traffic, average speed on four sections can be obtained including:

- Link speed from Thepharak to Paknam
- Link speed from Thepharak to Bangkru

- Link speed from Bangkaew to Paknam
- Link speed from Bangkaew to Bangkru

For eastbound traffic, average speed on four sections can be obtained including:

- Link speed from Bangkru to Paknam
- Link speed from Bangkru to Bangmaung
- Link speed from Bang Khun Thian to Paknam
- Link speed from Bang Khun Thian to Bangmaung

3.5.3 Link Speed: Burapha Withi Expressway

On Burapha Withi expressway, MTC timestamps were collected at three interchanges including Ram Inthra (entry point), Yothin Pattana (entry point), and Ard Narong (exit point). The interchange locations are depicted in Figure 3.10. Average speed on two sections can be obtained, one is from Ram Inthra to Ard Narong, and the other one is from Yothin Pattana to Ard Narong.

CHAPTER 4 INTERVIEWS OF POLICE OFFICERS

This chapter presents the summary of comments and opinions from four police officers who have experiences in speed enforcement in Thailand. These officers are based in both Bangkok and neighboring areas. The interview contents consist of past and existing operations, problems and obstacles as well as recommendations to improve speed enforcement operations in Thailand. Six officers who were interviewed are:

- Police Lieutenant Colonel Pichai Kojarayasri, Deputy Director, Highway Police District 8 (Figure 4.1A);
- Police Lieutenant Pairoj Supprasert, Highway Police District 8;
- Police Lieutenant Colonel Sanei Satienpong, Deputy Director, Bangpli-Suksawat Expressway Police (Figure 4.1B);
- Police Lieutenant Colonel Nattawachra Pungpothi, Head of Buraphawithi Expressway Traffic Control Center (Figure 4.1C); and
- Police Senior Sergeant Major Sa-ard Klumkonthong, Head of Traffic Control Center, Expressway No. 1, Thai Traffic Police (Figure 4.1D).

(A)

(B)

(C)

(D)

Figure 4.1 Interviews of police officers regarding speed enforcement operations

The summary of these interviews are the followings:

4.1 Current Speed Enforcement Operations

In the past, all speed enforcement on expressways or express highways are done manually by mobile speed radar, or usually called tripod speed enforcement radar since the radar camera is installed on a tripod. This kind of camera was acquired by both the Thai Police and the Expressway Authority.

4.1.1 Enforcement Procedure

Figure 4.2 illustrated the process of issuing a mail-in speeding citation to violators. First of all, the police at the site would collect photos of each violating vehicle along with speed and measurement location. Each photo shows the overall appearance of the vehicle such as make, model, color, vehicle type, and most importantly a clear look of its license plate number. Second, the police would come back to the police station and transfer photos and other information to a designated workstation computer with associated speed radar software. A police would check whether the license plate number, vehicle model, classification, and speed could be clearly identified. If not, the case would be disregarded to avoid dispute from the violator. If all required information are complete, the police would use the license plate number to acquire vehicle owner's information from the POLIS database. Note that the POLIS database requires the police to log-in with the officer's account and password. The police would check whether the vehicle description such as vehicle type, make, model, and color matches with the appearance in the photo. If there is a descripancy of information from the two sources, i.e., POLIS database and photo, the license plate in the photo taken at the site might be counterfeit and will be disregarded. If the vehicle description matches up between the photo and the database, then the police will retrive additional information such as owner's name and address from the POLIS database. The police would mail out a "Notice to Appear" to the vehicle owner at the person's registered mailing address. If the owner does not pay or argue within seven days, the police would flie the legal documents to the court. The court would then send the documents to the Department of Land Transport (DLT) to revoke the vehicle registration until the vehicle owner pays the fine.

Figure 4.3 illustrates the document "Notice To Appear". Section 1 includes messages notiying the vehicle owner to report to the investigator. Section 2 and 3 shows the image of the vehicle during operation. Section 4 shows a close-up photo of the vehicle license plate number. Lastly, Section 5 summarizes related information such as license plate number, location, date, time, and speed.

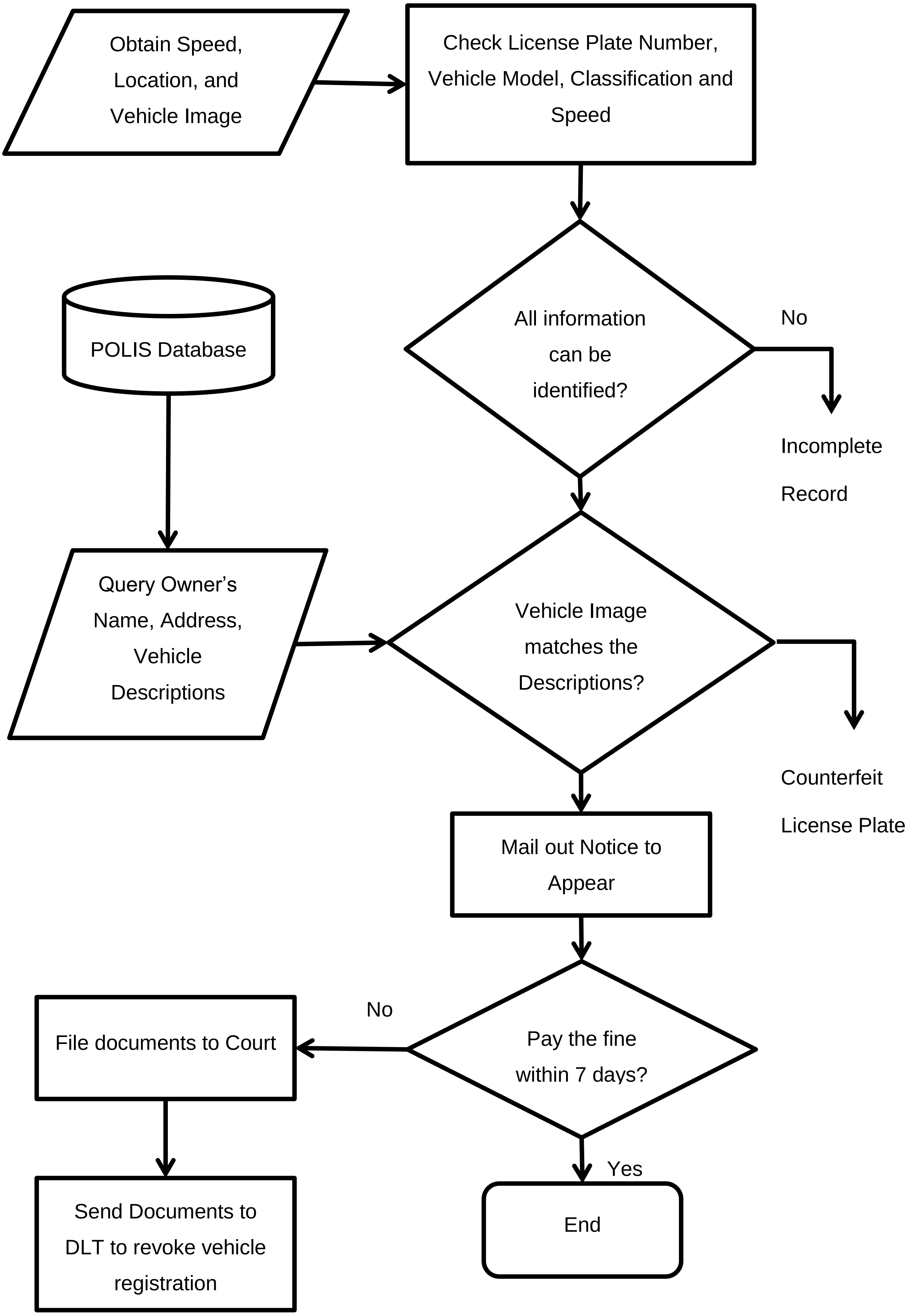


Figure 4.2 – Flow Chart of Current Speed Enforcement Operations

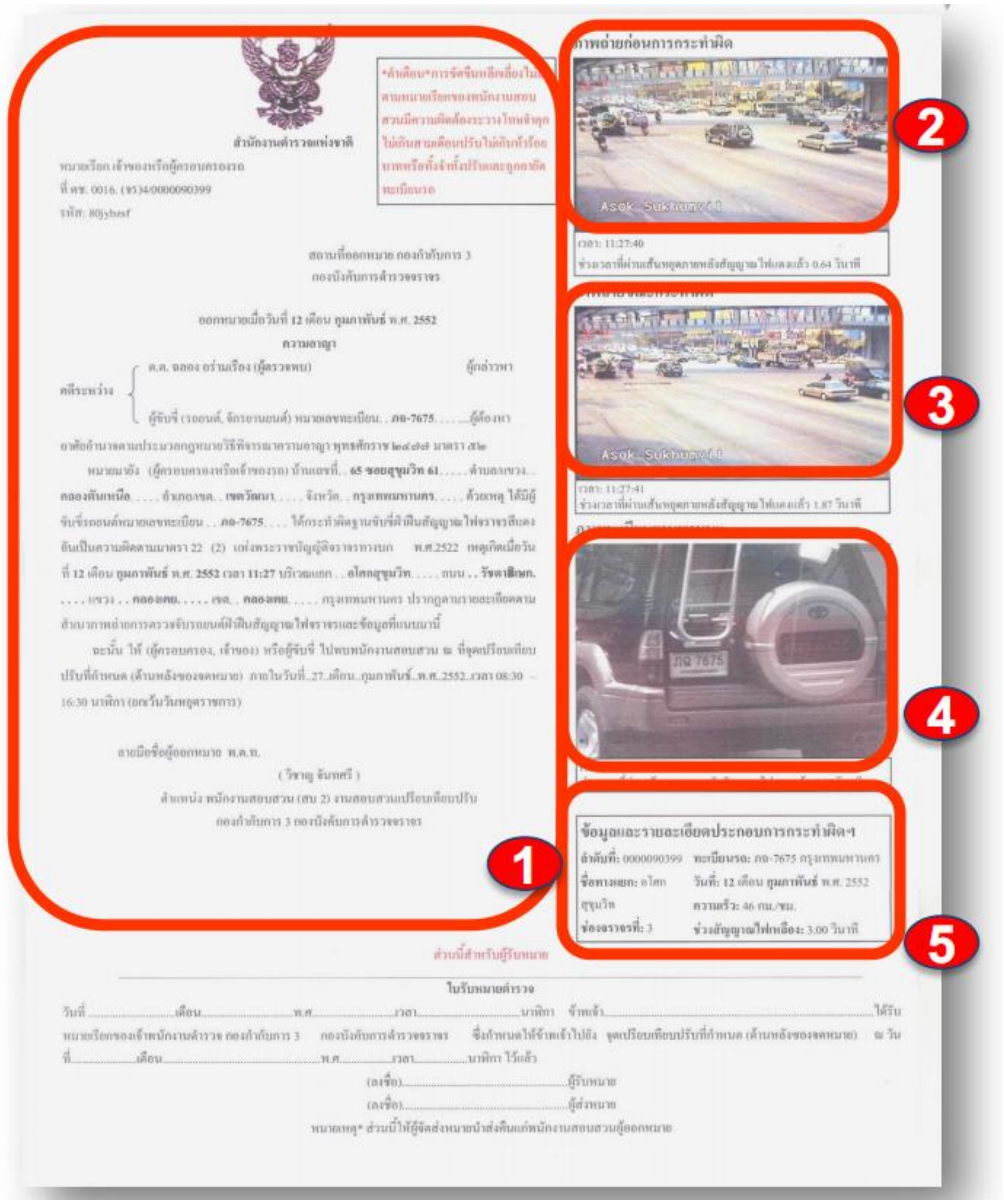


Figure 4.3 – Notice To Appear. Section 1 includes messages notiying the vehicle owner to report to the investigator. Section 2 and 3 shows the image of the vehicle during operation. Section 4 shows a close-up photo of the vehicle license plate number. Lastly, Section 5 summarizes related information such as license plate number, location, date, time, and speed.

4.1.2 Enforcement period and location

The use of this radar to detect speeders is usually in late morning (9-11AM) or in the afternoon (2-4PM). Once it starts detecting, it can be operated up to 2-3 hours depending on traffic volumes and weather. The police officer and the radar are hidden in a safe spot and often on a straight stretch of highways. The camera will take photos from both back and front of speeding vehicles to make sure the pictures are clear and can be used to issue a speeding ticket to vehicle owner.

The data from the camera will be evaluated carefully in house to eliminate the case with obscure pictures or misleading data. After that, the license plates of remaining cases will be checked from the Department of Land Transport's data for vehicle owners and their addresses to issue tickets by registered mail later.

The major problem of not-paying the fines are return mail due to wrong addresses, wrong owners since the vehicle registration data might not be updated and the tickets are issued too late (2-3 months after speeding was detected). Also, since the speeding case must be settled within one year before it is nullified, some vehicle owners might just neglect the fine. In addition, some drivers might argue that they receive more than one ticket on a day and negotiate with police officers.

Although the speed limits according to Thai laws (see Chapter 2) are only 80 km/hr and 90 km/hr for urban and suburb areas, respectively, the maximum allowable speed for Thai polices is up to 120 km/hr with the fixed maximum fine of 1,000 Bahts, no matter how excessive speeds are. Also, since the radar can be detected only one speed threshold at a time; therefore, it cannot detect speeding heavy vehicles, with much less allowable speeds below 120 km/hr at the same time. So, there is no speeding ticket issued to truck owners or drivers at this time.

For the specific case on Express Highway, the law allows the fine up to 5,000 Baths. However, the ticket is mostly issued with 200-400 Baths fine. It also tests the variable fine up to 900 Baths in case of higher speeds than 180 km/hr on Express Highway.

4.2 Issues with Manual Speed Enforcement

4.2.1 Resources

There are limited number of equipment. In Bangkok, Traffic Police has only 10-12 working laser guns, which are being used throughout the metropolitan area. On the expressways, there are 4-6 working units which rotate to different expressway routes periodically.

In addition to equipment constraints, It can be seen that the current speed enforcement operation requires a number of staff to be outside in the field as well as processing the tickets at the police station. At each check point, the manual speed enforcement require 5 to 6 officers to perform the enforcement. In the office, one to two officers are required to select photos, pull drivers' information from the POLIS database, and issue tickets.

4.2.2 Public Contest

There are sometimes questions from the speeders regarding the accuracy of the speed measurement equipment as well as skills of the police offices who operated the equipment. Therefore, it is recommended that the equipment should have a fixed calibration schedule such as performing calibration every six months to maintain the accuracy of the equipment. In addition, there should be a training course for the officers involving in the speed enforcement efforts.

4.2.3 Failure to Pay

Normally, 150-200 speeding tickets will be issued daily from one period of radar enforcement. However, it was found that only 30 percent or less of vehicle owners actually paid the fine and most of them paid by mail. This compliance rate is in line with the 27.5 percent compliance rate found in the Bangkok's red light camera study (Kanluan 2012).

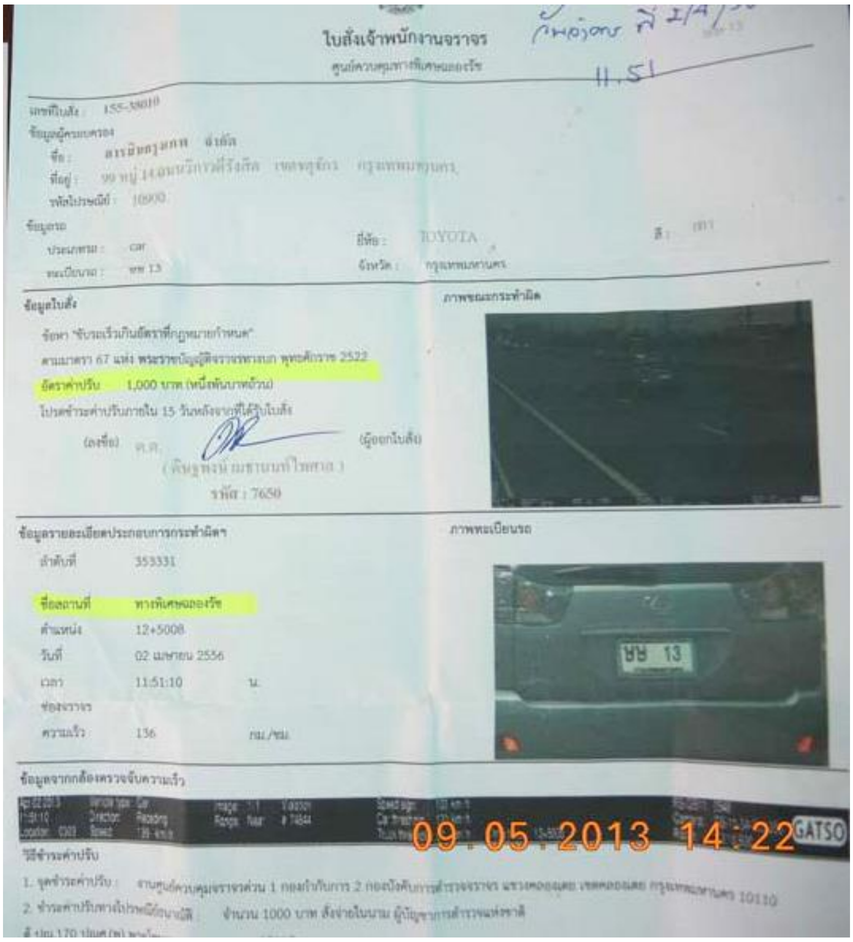
4.2.4 Legal Challenges

Currently, the law does not directly support the use of mail citation. If the violator does not report of pay the fine within seven days of the Notice to Appear, the police officer needs to file a case to the court so that the court can order the Department of Land Transport (DLT) to revoke the violator's vehicle registration. This process takes extensive efforts of the police officer to follow up the case. As a result, the police officers rarely file a case to the court.

In the future, it is recommended that a new law should be proposed to endorse police officers to report the violator's license plate number directly to the DLT by themselves.

4.3 Automatic Speed Enforcement

After the test run of automatic speed enforcement, all police officers agreed that the new system reduces field work and enhance safety for officers. The remaining tasks for the officers are to coordinate with Expressway Authority officers to acquire photo files and process them into a speeding ticket as shown in Fig. 4-2. The processing includes the verification of clear and valid photos and signing on the ticket.



ใบสั่งเจ้าพนักงานจราจร

เลขที่ใบสั่ง 155-38010

TOYOTA

car

ข้อหา "ขับรถเร็วเกินอัตราที่กฎหมายกำหนด"

ตามมาตรา 67 แห่ง พระราชบัญญัติจราจรทางบก พุทธศักราช 2522

อัตราค่าปรับ 1,000 บาท (หนึ่งพันบาทถ้วน)

โปรดชำระค่าปรับภายใน 15 วันหลังจากที่ได้รับใบสั่ง

(ผู้ออกใบสั่ง)

รหัส : 7650

ลำดับที่ 353331

ตำแหน่ง 12+5008

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GATSO

Figure 4.2 Speeding ticket issued by automatic speed enforcement system

Now, if automatic speed enforcement system is installed on any highway section, police officers will not operate mobile speed radar anymore. They will move the radar to other section instead. For example, the radar was moved from Expressway No. 2, the location with automatic speed enforcement, to Expressway No. 1 since Expressway No. 1 currently has no automatic speed enforcement system and requires the mobile radar as well as speeding checkpoint stations, alternately.

Although the automatic system can reduce police workload on site, it requires much higher load on the office. The vehicles captured by the automatic system are about tenfold of the manual one so it requires more officers in the office. At least 3-4 officers are required to verify the photos and issue the tickets at the office. However, due to lack of officers comparing with the workload, most tickets reach vehicle owners 3-4 months after the speeding date. This delay causes ineffectiveness of the system to reduce speeding or change driver behavior.

4.4 Legal Issues

In Thailand, vehicle owners are accountable for the violation. In some areas, such as Sweden and in the West Coast Cities in the U.S., drivers are responsible for the violation. Therfore, in these countries, a clear image of driver's face is required.

4.5 Recommendations on Automatic Speed Enforcement Policy

Most police officers agree with the automatic speed enforcement policy since it could be a way to effectively change driver behavior, reduce vehicle speeds and traffic accidents. However, some issues would be solved for better efficiency.

- The legal speed limits are not corresponding with current vehicle specifications and driver perceptions. They accept that the legal speed limits should be higher based on engineering study to reflect better vehicle specifications and road conditions. For example, the threshold of 120 km/hr should be the appropriate speed limit for regular vehicles.
- The fine penalty on speeding is too low. The fine should not be fixed but variable depending on the excess speed.
- On the highway with several detectors, there should be a program to eliminate the repetitive speeding tickets from the same vehicle on the same day.
- The Expressway Authority would coordinate with police officers to detect vehicle speeding from Expressway CCTV and IDS cameras for real-time enforcement.
- Due to fixed locations of automatic enforcement, police officers are afraid that the drivers might recognize the locations and speed up on other locations without a camera. Therefore, ads are needed to inform drivers to reduce speeds on the whole section of highways not just at camera locations.
- Camera flash would be lighter since some nighttime photos from automatic cameras are obscure comparing with mobile type and hard to identify license plate numbers causing driver dispute and wrong ticket issuance.
- More police officers and printing/processing equipment are needed in the office to manage much more speeding cases.

4.6 Summary of Interviews

In summary, the officer believe that more automatic system would be installed since the system can work 24 hours a day, both daytime and nighttime. They believe that after a long and sustain period of automatic enforcement, reducing in speeds and accidents would be realized. However, the number of police officers in the office would be increased to issue the tickets faster.

Furthermore, the campaign to drivers is needed to present that speeding on expressway is controlled throughout the whole section not just the camera locations. Lastly, the speed laws should be modified to represent the current situation, reduce driver complaints and excuses.

CHAPTER 5 SYSTEM EVALUATION

Since January 2013, the Expressway Authority of Thailand has installed 6 speed enforcement cameras onto three expressway routes, namely, Chalongrat expressway, Kanchanapisek expressway, and Burapha Withi expressway. In this section, various forms of speeds, i.e., spot speed and link speed, collected during the "before" and "after" the implementation of the cameras are compared to determine the effectiveness of the automatic speed enforcement device. Spot speed can be obtained using the existing image processing cameras installed on Chalongrat and Kanchanapisek expressways. Link speed of each entry-exit toll plaza pair can be obtained from transaction data in the closed expressway systems including Kanchanapisek and Burapha Withi expressways. Note that Chalongrat expressway is an open expressway system. Therefore, only a few pairs of link speed can be calculated only when a vehicle passes two mainline toll plazas which require all vehicles to stop and pay the toll.

5.1 Chalongrat Expressway Route

On Chalongrat expressway, two types of data were analyzed, namely, spot speed and link speed. Spot speed analyses are described in sections 5.1.1 and 5.1.2. Additionally, link speed analyses are described in 5.1.3.

Spot speed were collected using image processing cameras. Link speed on Chalongrat expressway can be derived from the Electronic Toll Collection (ETC) database. Since Chalongrat expressway is an open system, i.e., drivers pay a fixed toll fee at the entry toll plaza, therefore timestamp at the exit toll plaza cannot be directly obtained. However, drivers on this expressway will need to pay the toll again when entering the S1 expressway at the Ard Narong 1 toll plaza, which is also the end of Chalongrat expressway (see Figure 3.19). Consequently, two pairs of southbound link speeds can be determined using Ram Inthra and Yothin Pattana toll plazas as the entry points and Ard Narong 1 toll plaza as the exit point.

There are six image processing cameras on Chalong Rat route between the Eastern Outer Ring Road and Ram Inthra Rd. Even though the cameras are rather far from the automatic speed enforcement camera (KM 12+500), i.e., at least 4.5 km, the EXAT notifies drivers on this route through the VMS signboard that "Speed limit is enforced throughout the expressway route" (see Figure 5.1). Therefore, speed change may be expected at the image processing camera stations. The analysis is divided into the northbound and southbound analyses. Data during peak period were excluded from the analysis since the scope of study focuses on the speed reduction during light traffic condition. Vehicles during peak-hour traffic tend be operated at "forced" speed where the automatic speed enforcement camera has minimal impacts.

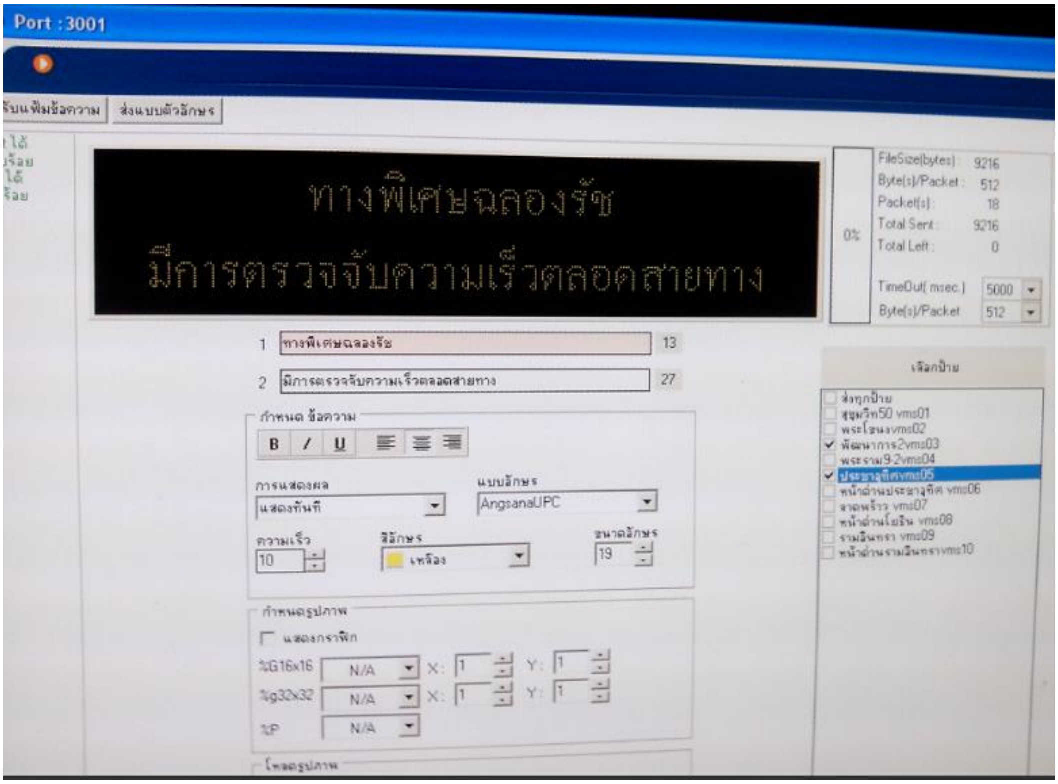


Figure 5.1 Warning Message Posted on the Variable Message Sign on the Chalongrat Expressway. The Literal Translation is “Speed limit is enforced throughout the expressway route”.

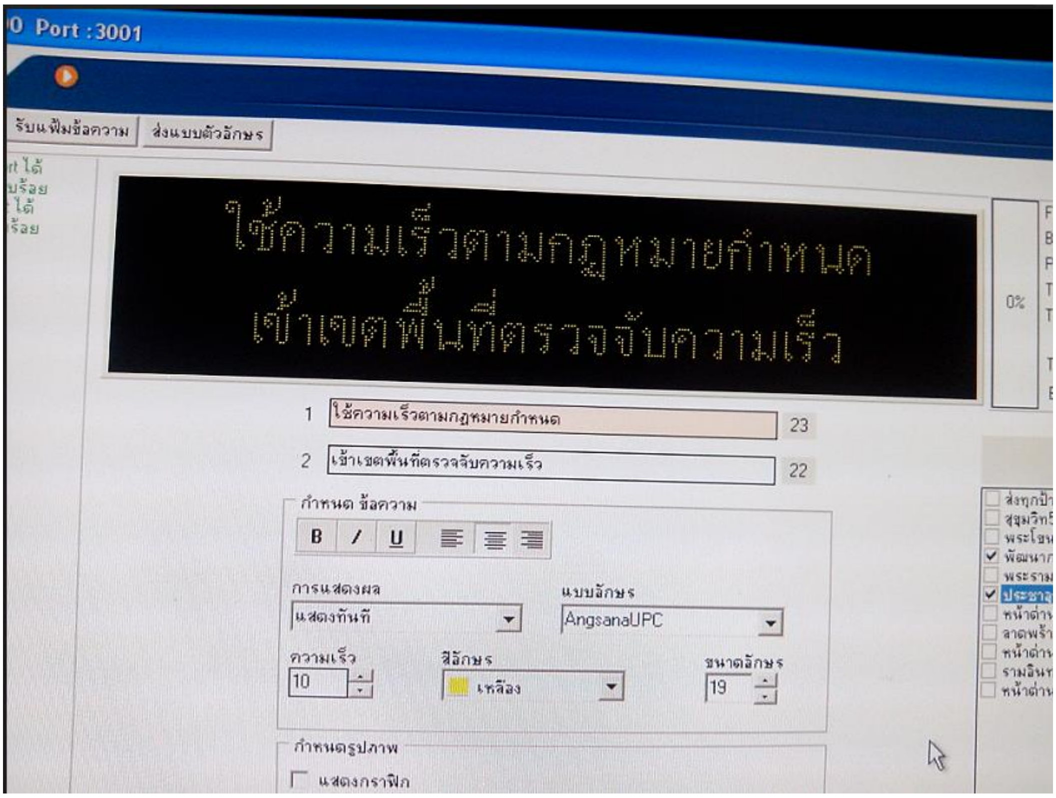
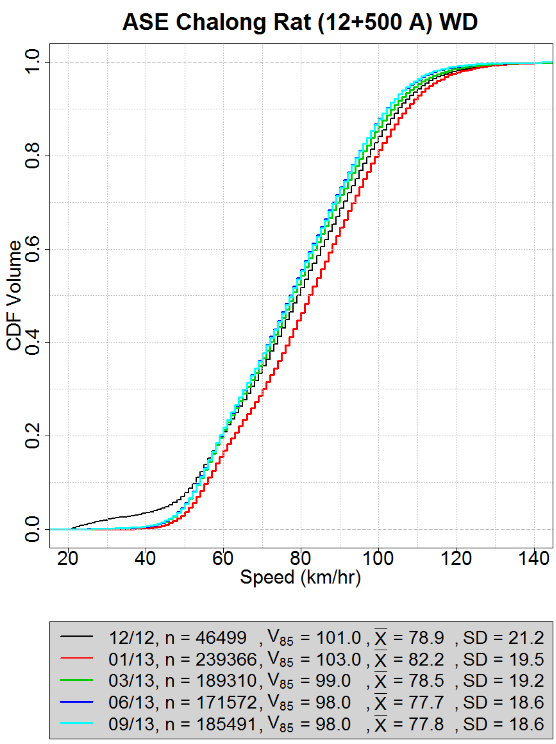


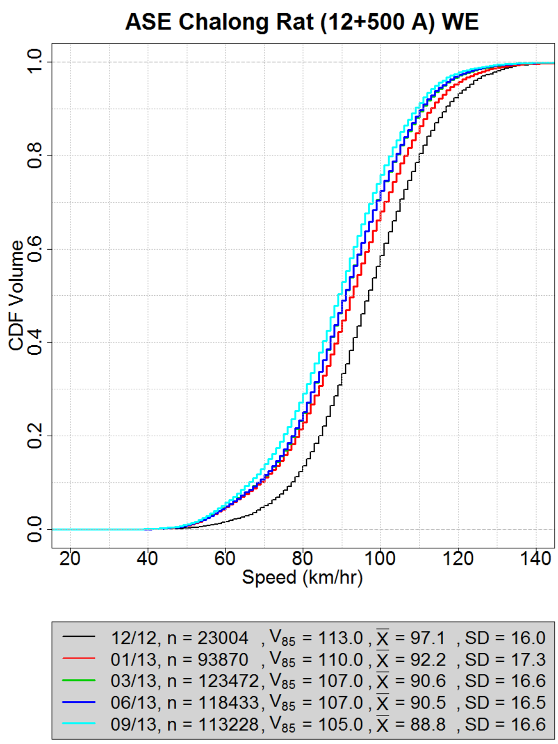
Figure 5.2 Warning Message Posted on the Variable Message Sign on the Chalongrat Expressway. The Literal Translation is “Speed limit is enforced throughout the expressway route”.

5.1.1 Spot Speed Comparisons for Camera Site KM 12+500A (Northbound)

Speed data collected from the speed enforcement camera KM 12+500A northbound direction are shown in Figure 5.3. The mean speed reduction over the nine-month period is rather small, i.e., 1.1 km/hr. The 85th percentile speed also reduced but at a greater magnitude, i.e., 3 km/hr. the standard deviation also reduced from 21.2 km/hr to 18.6 km/hr.



(a) Weekday

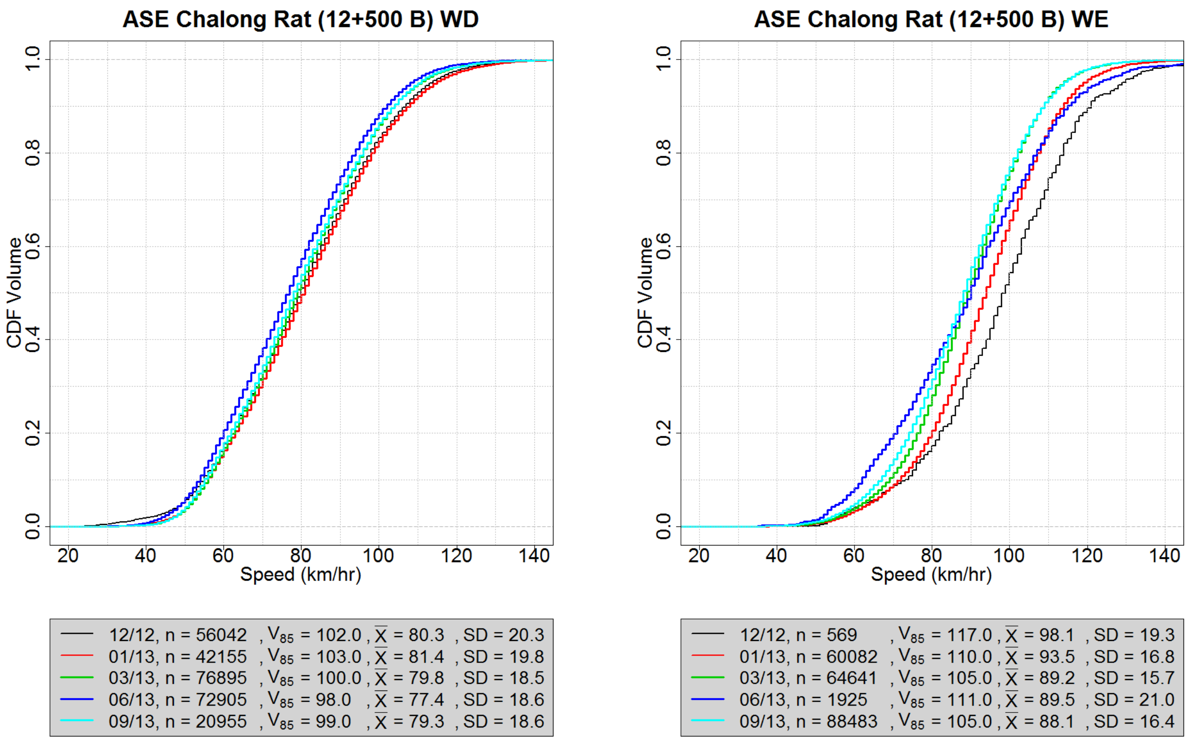


(b) Weekend

Figure 5.3 Cumulative Distribution Function (CDF) Plots of Speeds on Chalongrat, Northbound, at the speed enforcement camera location KM12+500A.

5.1.2 Spot Speed Comparisons for Camera Site KM 12+500B (Southbound)

Speed data collected from the speed enforcement camera KM 12+500B southbound direction are shown in Figure 5.4. The mean speed reduction over the nine-month period is rather small, i.e., 1 km/hr. The 85th percentile speed also reduced but at a greater magnitude, i.e., 3 km/hr. the standard deviation also reduced from 20.3 km/hr to 18.6 km/hr.



(a) Weekday (b) Weekend

Figure 5.4 Cumulative Distribution Function (CDF) Plots of Speeds on Chalongrat, Northbound, at the speed enforcement camera location KM12+500A.

5.1.3 Link Speed Comparisons for Camera Site KM 12+500B (Southbound)

Insignificant changes in spot speeds in the previous section might be due to long distance from the actual speed enforcement cameras. In this section, average link speed of two routes that pass through the southbound automatic speed enforcement camera were analyzed. As aforementioned, only southbound link speed can be determined due to limitation in data collection method. Two pairs of origin-destination routes were used in the analysis. The first southbound route is from Yothin Pattana toll plaza to Ard Narong toll plaza, approximately 15 km in length. The second route is from Ram Inthra toll plaza to Ard Narong toll plaza, approximately 20 km in length. Figure 5.5 illustrates the location of entry and exit points as well as the automatic speed enforcement camera.

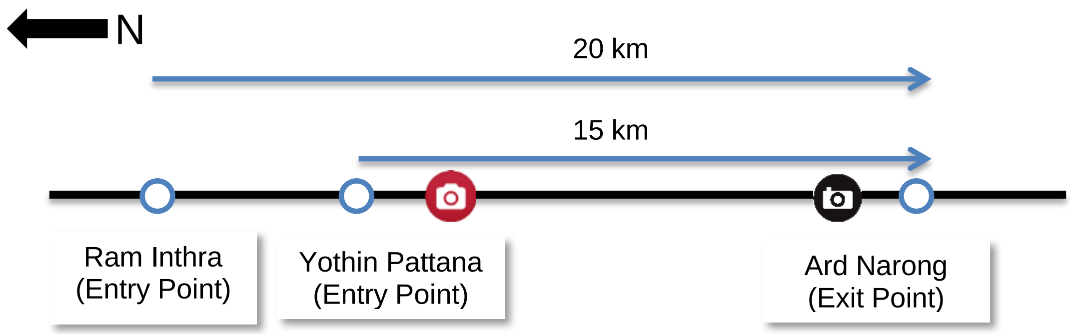
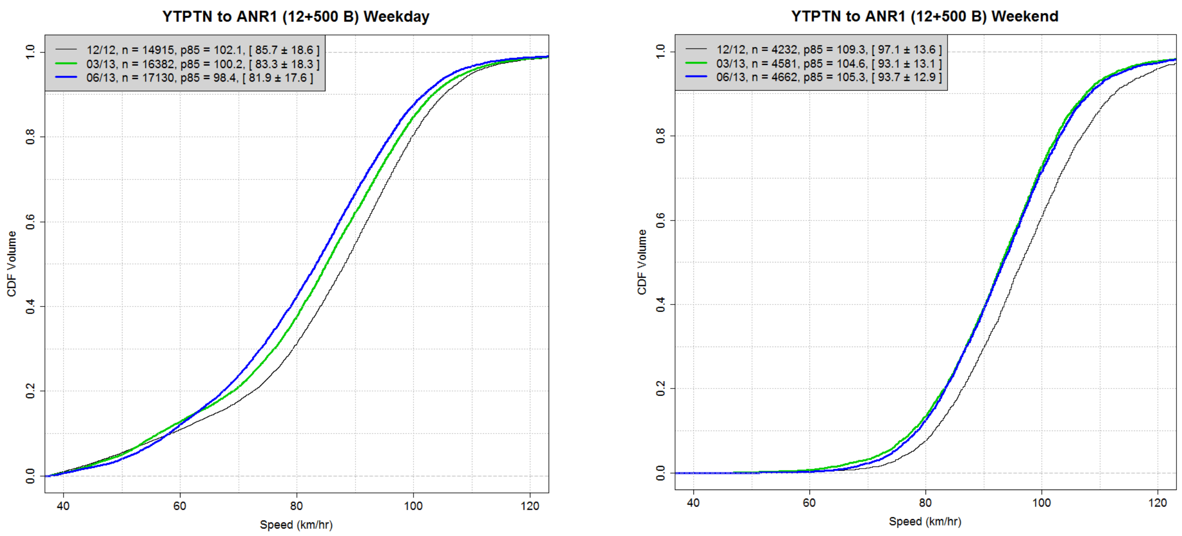


Figure 5.5 Schematic Map of Link Speed Data Collection and Location of the Automatic Speed Enforcement Camera on Chalongrat Expressway, Southbound Direction.

1) Link Speed From Yothin Pattana to Ard Narong 1 (15-km Section)

Speed distributions during three time periods were shown in Figure 5.6. The speed data collected in December 2012, March 2013, and June 2013 were plotted in grey, green, and blue lines respectively. In March 2013, during the weekdays, the 85th percentile speed decreased from 102.1 km/hr to 100.2 km/hr (1.9 km/hr reduction) and the mean speed decreased from 85.7 km/hr to 83.3 km/hr (2.4 km/hr reduction). In June 2013, speed still decreased but at a slower rate of change. Speeds during weekend also decreased. In March 2013, the 85th percentile speed decreased from 109.3 km/hr to 104.6 km/hr (4.7 km/hr reduction) and the mean speed decreased from 97.1 km/hr to 93.1 km/hr (4 km/hr reduction).



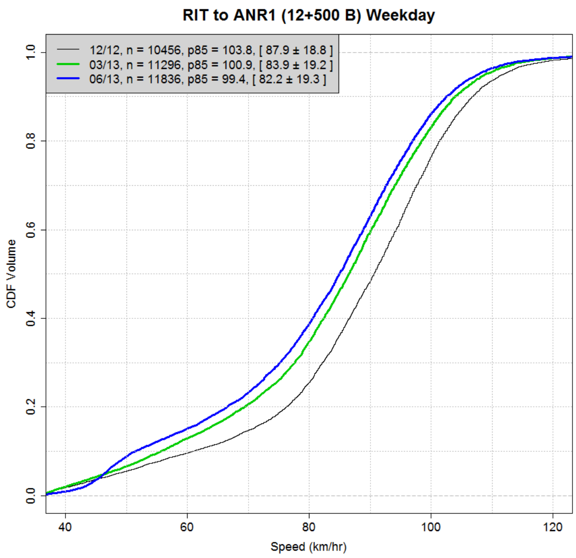
(a) Weekday Data

(b) Weekend Data

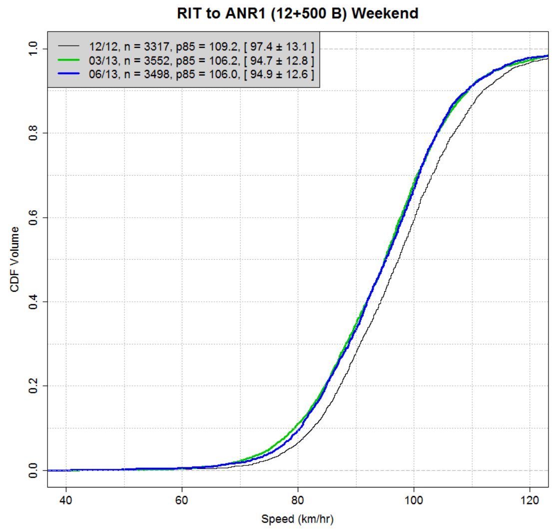
Figure 5.6 Cumulative Distribution Functions (CDF) of Link Speeds from Yothin Pattana Toll Plaza to Ard Narong Toll Plaza during Weekdays (Left) and Weekends (Right). The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively. The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.

2) Link Speed from From Ram Inthra to Ard Narong 1 (20-km Section)

Link speed data of a longer route, namely, from Ram Inthra to Ard Narong were also investigated in this section. The speed data collected in December 2012, March 2013, and June 2013 were plotted in grey, green, and blue lines respectively (see Figure 5.7). It is noticed that speed reduce accordingly since the installation of the automatic speed enforcement camera in January 2013. More specifically, for weekday data in March 2013, the 85th percentile speed reduced from 103.8 km/hr to 100.9 km/hr (2.9 km/hr reduction) and the mean speed reduced from 87.9 km/hr to 83.9 km/hr (4 km/hr reduction). Three months later, speed still decreased but in a slower rate. That is, in June 2013, the 85th percentile speed reduced from 100.9 km/hr to 99.4 km/hr (1.5 km/hr) and the mean speed decreased from 83.9 km/hr to 82.2 km/hr (1.7 km/hr reduction). The weekend data followed a similar trend but the changes were smaller.



(a) Weekday Data



(b) Weekend Data

Figure 5.7 Cumulative Distribution Functions (CDF) of Link Speeds from Ram Inthra Toll Plaza to Ard Narong Toll Plaza during Weekdays (Left) and Weekends (Right). The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.

5.2 Kanchanapisek Expressway Route

Two speed cameras and two backup housings were installed on Kanchanapisek expressway in January 2013. Two types of speed data including spot speed and link speed can be obtained on this route to evaluate the effects of the equipment.

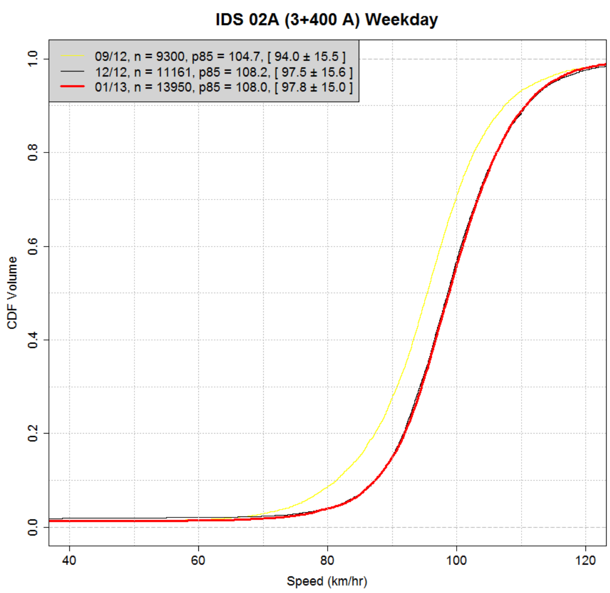
For spot speed comparisons, spot speeds were measured at the upstream, downstream, and camera installation locations for each of the six camera/backup sites. Link speeds were measured between two pairs of the entries and exits.

5.2.1 Spot Speed Comparisons for Camera Site 8+000 (Westbound)

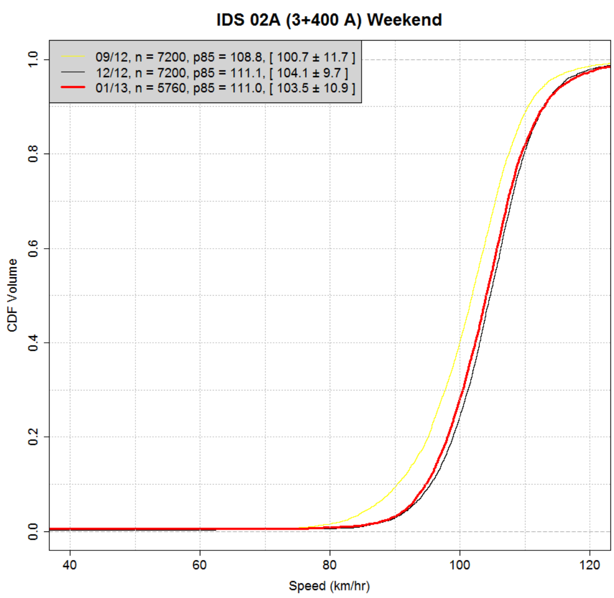
At the camera site 8+000A (Westbound), spot speed data can be obtained from three traffic detection stations including upstream location (KM 3+400A), camera location (8+000A), and downstream location (KM 13+350A) of the camera.

Speeds during three periods were collected including September and December 2012, and January 2013. Note that speed after installation, i.e., after January 2013, are being collected and will be represented in the next report.

Speed distributions at the upstream location are depicted in Figure 5.8. Additionally, Figure 5.9 demostrates speed distributions at the camera installation location and Figure 5.10 demonstrates speed distributions at the downstream location.



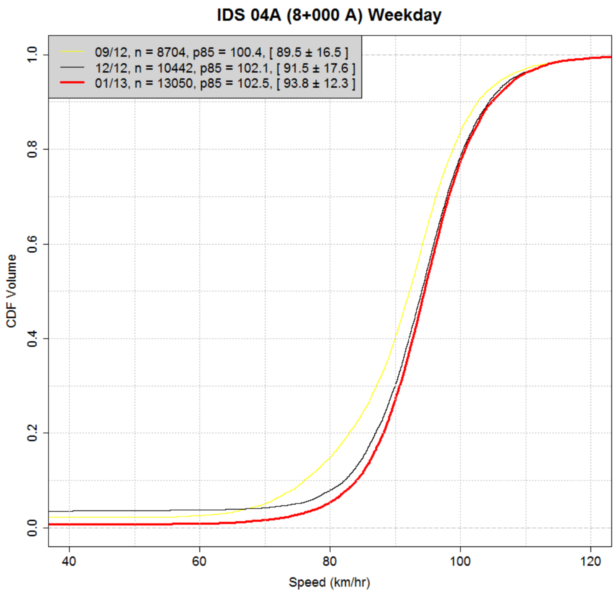
(a) Weekday



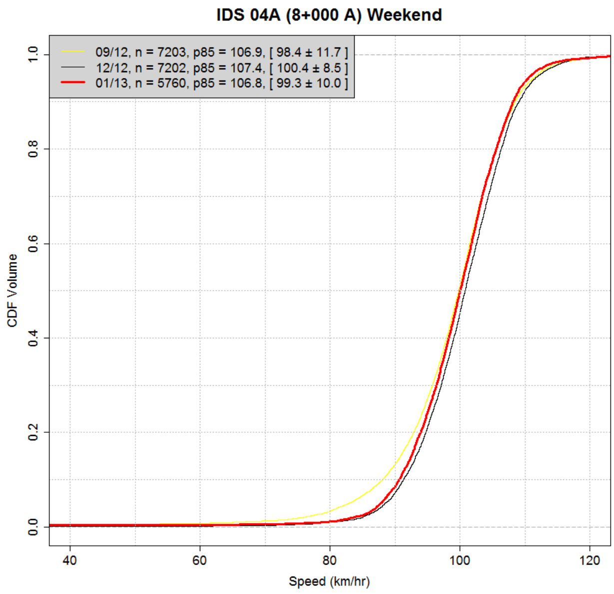
(b) Weekend

Figure 5.8 Cumulative Distribution Function (CDF) plots of speed data at upstream location KM 3+400A (Westbound) on Kanchanapisek Expressway during weekday (left) and weekend (right).

The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.

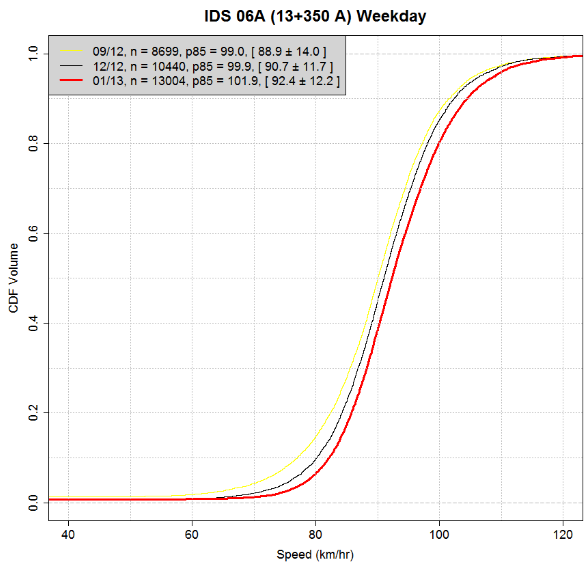


(a) Weekday

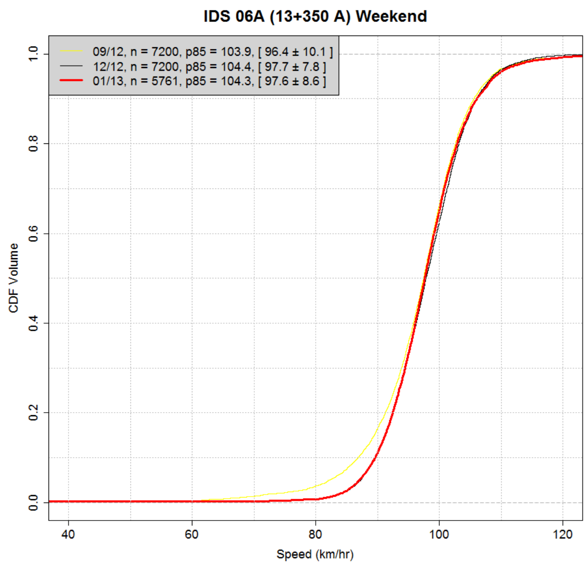


(b) Weekend

Figure 5.9 Cumulative Distribution Function (CDF) plots of speed data at camera location KM 8+000A (Westbound) on Kanchanapisek Expressway during weekday (left) and weekend (right). The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.



(a) Weekday



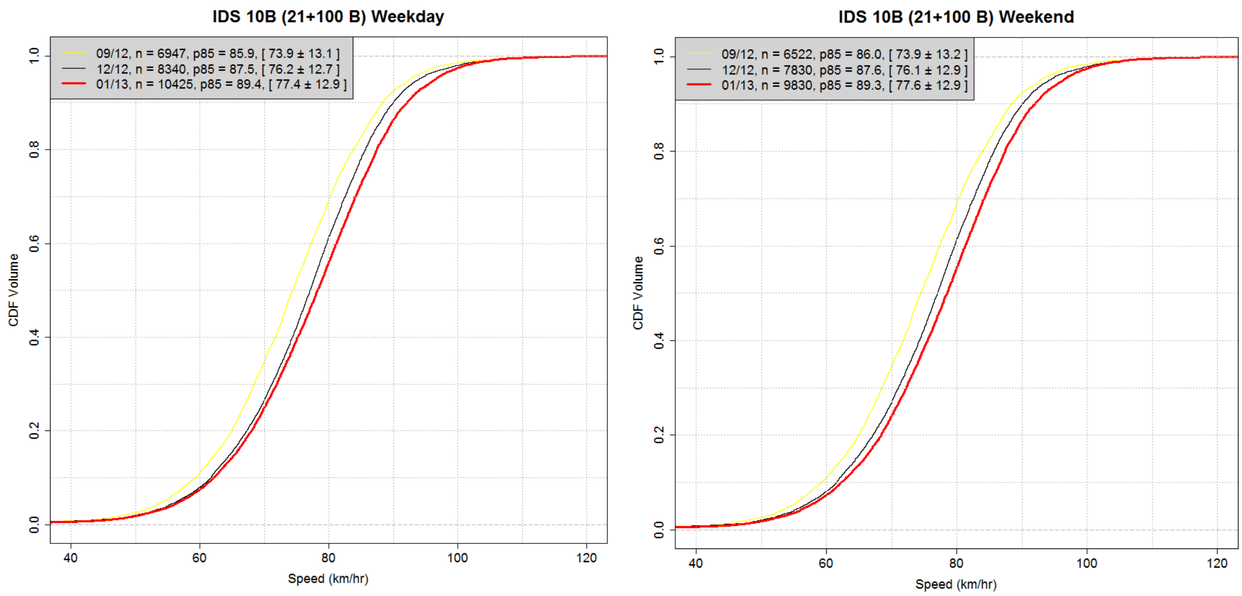
(b) Weekend

Figure 5.10 Cumulative Distribution Function (CDF) plots of speed data at downstream location KM 13+350A (Westbound) on Kanchanapisek Expressway during weekday (left) and weekend (right). The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.

5.2.2 Spot Speed Comparisons for Camera Site 17+500 B (Eastbound)

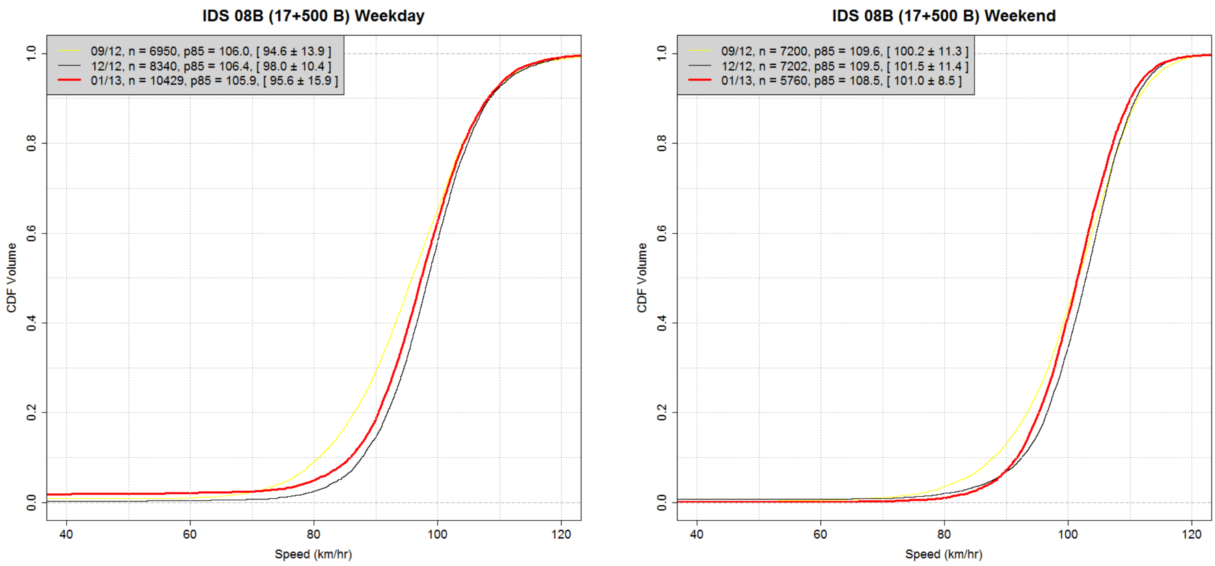
At the camera site 17+500 B (Eastbound), spot speed data can be obtained from three traffic detection stations including upstream location (KM 21+100B), camera location (17+500B), and downstream location (KM 13+350B) of the camera.

Speed distribution during three periods, including September, December 2012, and January 2013, were used in this analysis. The speed distributions at upstream, camera location, and downstream location are shown in Figure 5.11, Figure 5.12, and Figure 5.13, respectively.



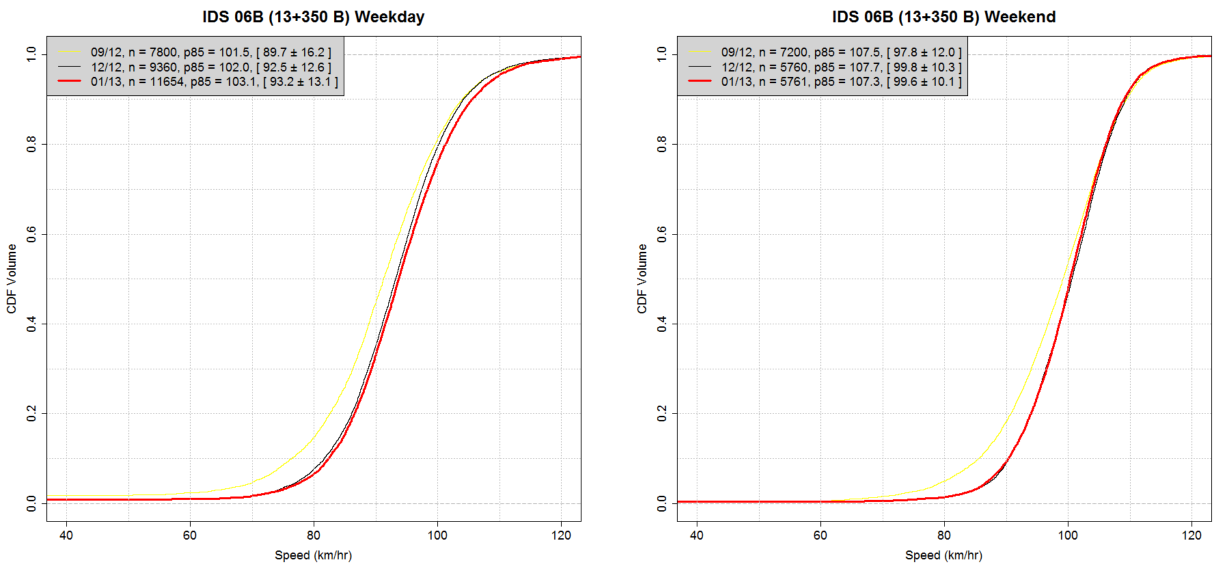
(a) Weekday (b) Weekend

Figure 5.11 Cumulative Distribution Function (CDF) plots of speed data at upstream location KM 21+100B (eastbound) on Kanchanapisek Expressway during weekday (left) and weekend (right). The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.



(a) Weekday (b) Weekend

Figure 5.12 Cumulative Distribution Function (CDF) plots of speed data at camera location KM 17+500B (eastbound) on Kanchanapisek Expressway during weekday (left) and weekend (right). The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.



(a) Weekday (b) Weekend

Figure 5.13 Cumulative Distribution Function (CDF) plots of speed data at downstream location KM 13+350B (eastbound) on Kanchanapisek Expressway during weekday (left) and weekend (right). The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.

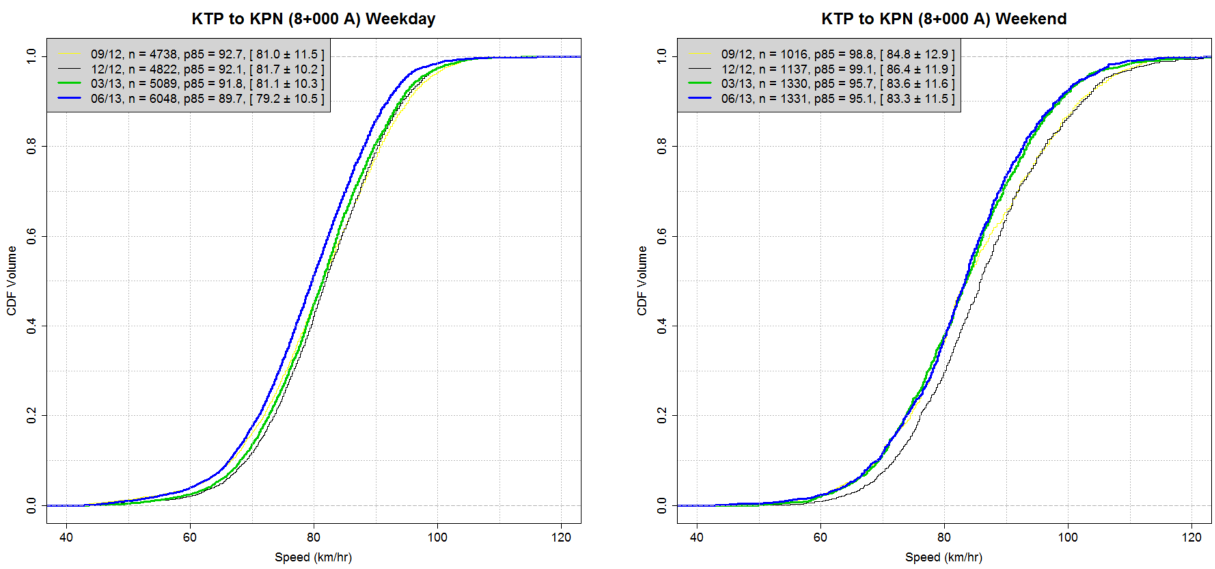
5.2.3 Link Speed Comparisons for Camera Site 8+000 (Westbound)

Average speeds on two routes were collected to determine the effect of the speed camera at location KM 8+000A westbound including 1) link speed from Thepharak entry toll plaza to Phaknam exit toll plaza and 2) link speed from Thepharak entry toll plaza to Bangkru exit toll plaza.

1) Link Speed From Thepharak (KTP) To Paknam (KPN)

Link speed data during four time periods were compared in Figure 5.14. The September (yellow) and December 2012 (grey) data represented the speed distributions before the speed cameras were installed. The March (green) and June 2013 (blue) data illustrated the speed distributions after the camera was installed. For the weekday dataset, the 85th percentile speed continuously reduced from 92.1 km/hr in December 2012 to 89.7 km/hr in June 2013, a 2.4-km/hr reduction in 6 months. The mean speed also reduced at approximately the same magnitude during the six-month period, that is, from 81.7 km/hr to 79.2 km/hr, a 2.5-km/hr reduction.

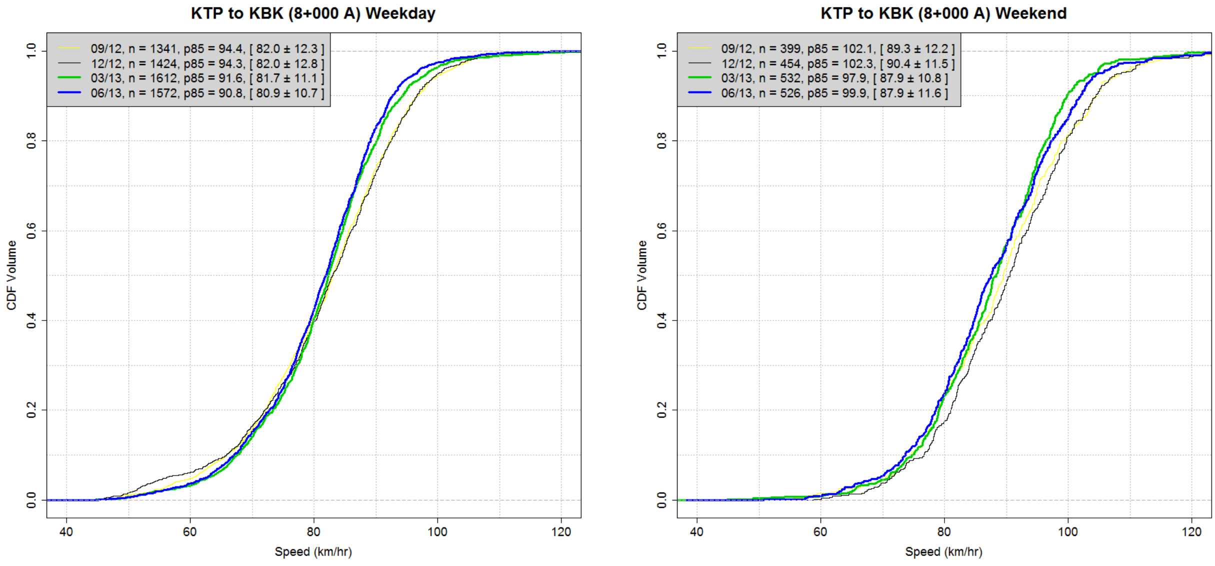
Furthermore, the weekend dataset experienced a greater speed reduction. The 85th percentile speed reduced from 99.1 km/hr in December 2012 to 95.1 km/hr, a 4-km/hr reduction. The mean speed reduced from 86.4 km/hr to 83.3 km/hr, a 3.1 km/hr reduction.



(a) Weekday (b) Weekend

Figure 5.14 Cumulative Distribution Functions (CDF) of westbound link speeds from Thepharak Toll Plaza (KTP) to Ard Narong Toll Plaza (KPN) during weekdays (Left) and weekends (Right). The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.

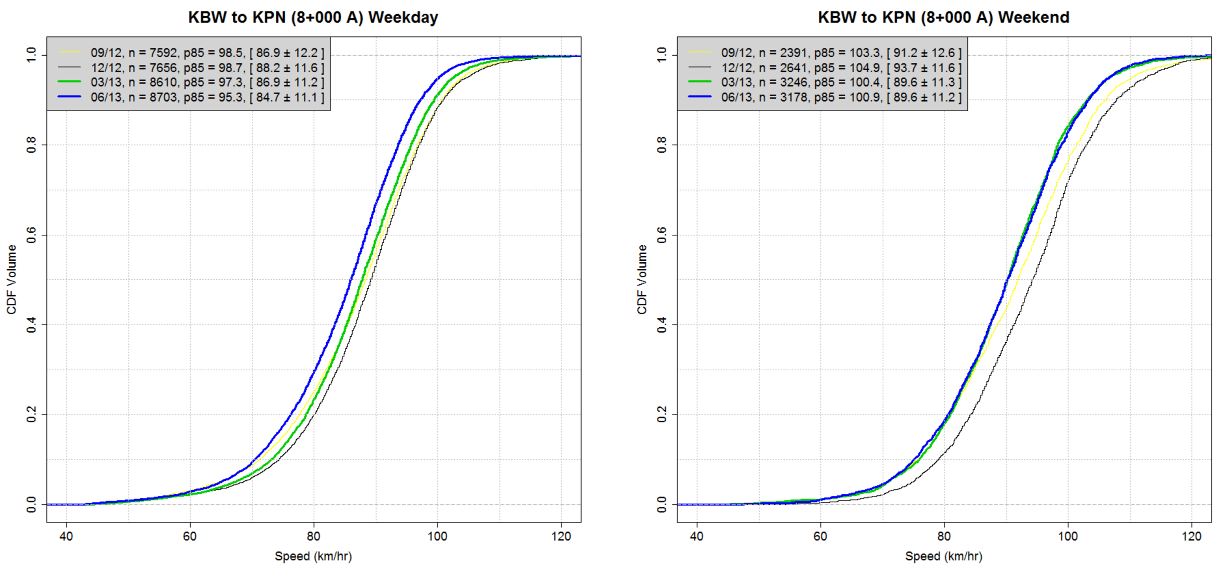
2) Link Speed from Thepharak (KTP) To Bangkru (KBK)



(a) Weekday (b) Weekend

Figure 5.15 Cumulative Distribution Functions (CDF) of westbound link speeds from Thepharak Toll Plaza (KTP) to Bangkru Toll Plaza (KBK) during weekdays (Left) and weekends (Right). The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.

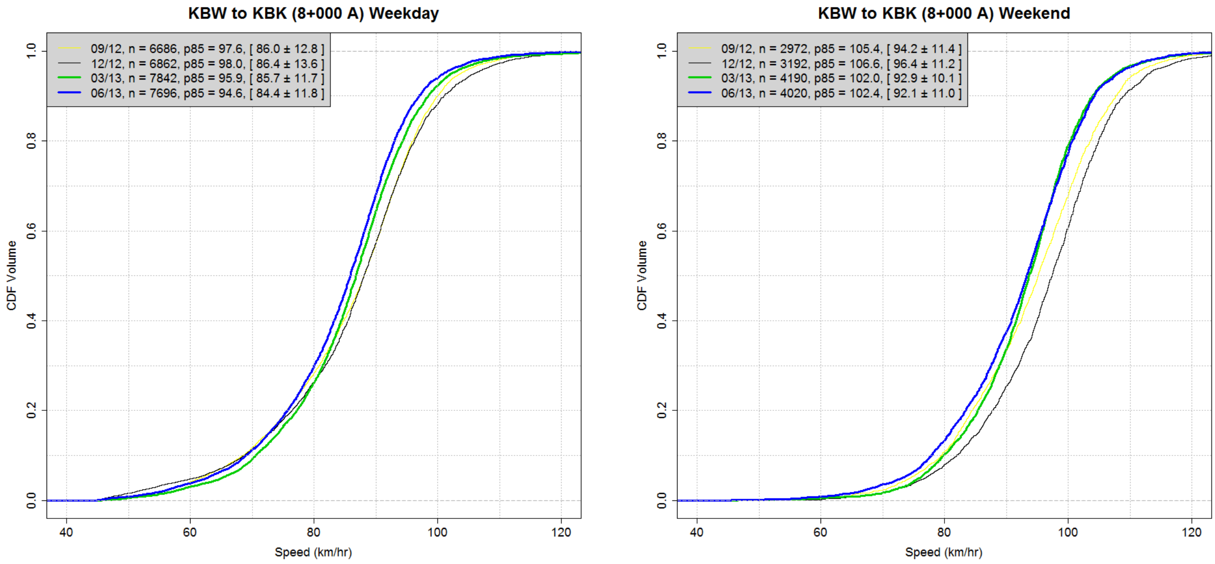
3) Link Speed From Bangkaew (KBW) To Paknam (KPN)



(a) Weekday (b) Weekend

Figure 5.16 Cumulative Distribution Functions (CDF) of westbound link speeds from Bangkaew Toll Plaza (KBW) to Paknam Toll Plaza (KPN) during weekdays (Left) and weekends (Right). The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.

4) Link Speed From Bangkaew (KBW) To Bangkru (KBK)

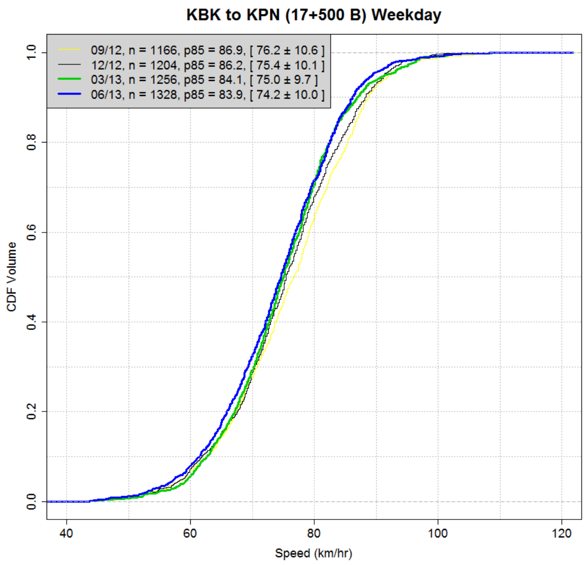


(a) Weekday (b) Weekend

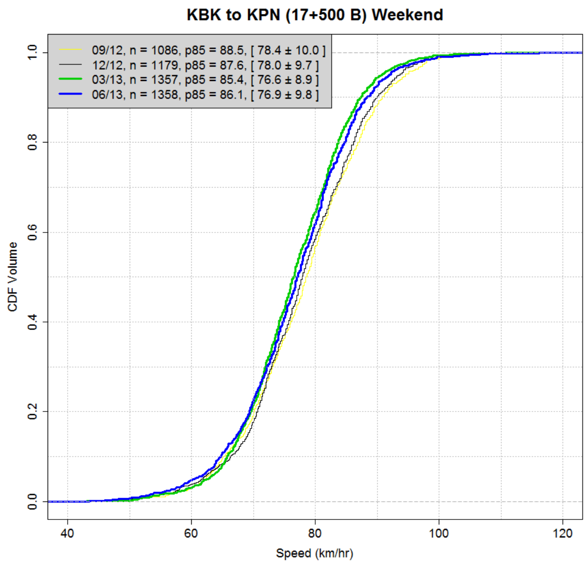
Figure 5.17 Cumulative Distribution Functions (CDF) of westbound link speeds from Bangkaew Toll Plaza (KBW) to Bangkru Toll Plaza (KBK) during weekdays (Left) and weekends (Right). The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.

5.2.4 Link Speed Comparisons for Camera Site 17+500B (Eastbound)

1) Link Speed From Bangkru (KBK) To Paknam (KPN)



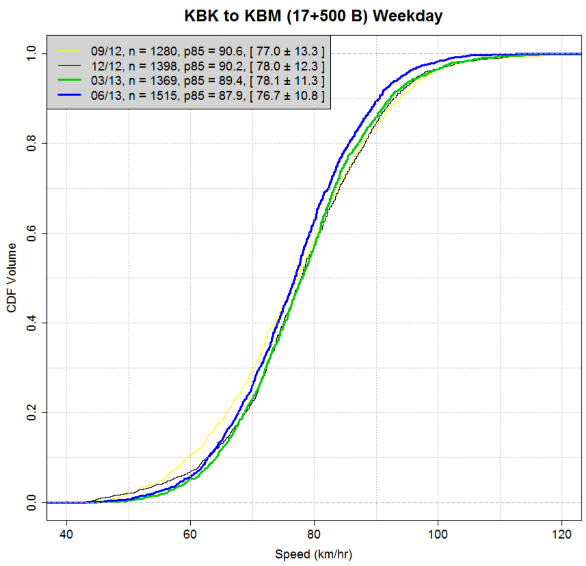
(a) Weekday

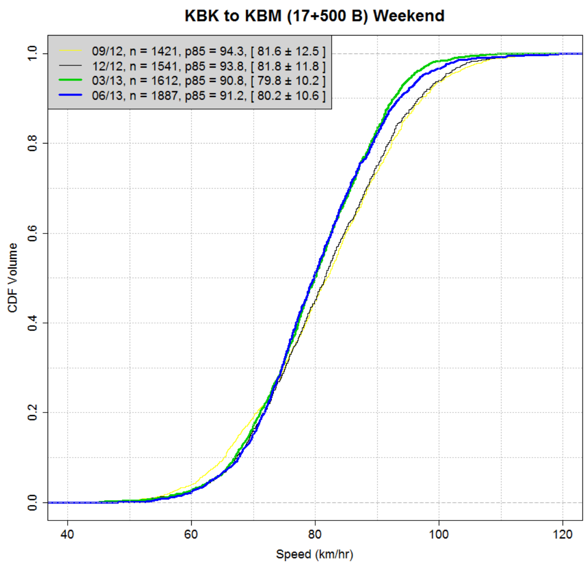


(b) Weekend

Figure 5.18 Cumulative Distribution Functions (CDF) of eastbound link speeds from Bangkru Toll Plaza (KBK) to Paknam Toll Plaza (KPN) during weekdays (Left) and weekends (Right). The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.

2) Link Speed From Bangkru (KBK) To Bangmaung (KBM)

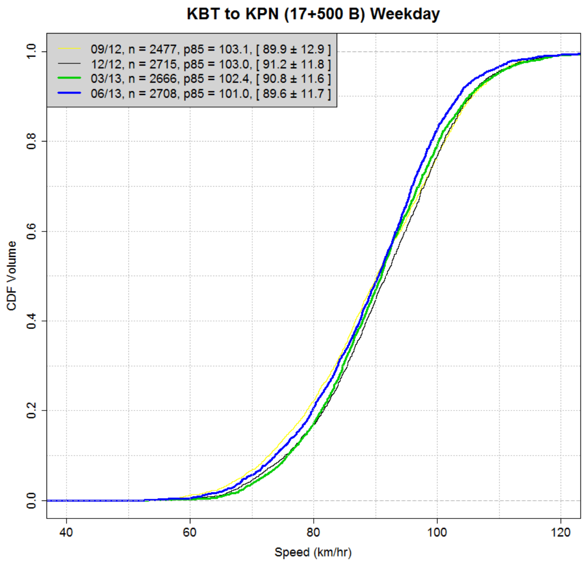


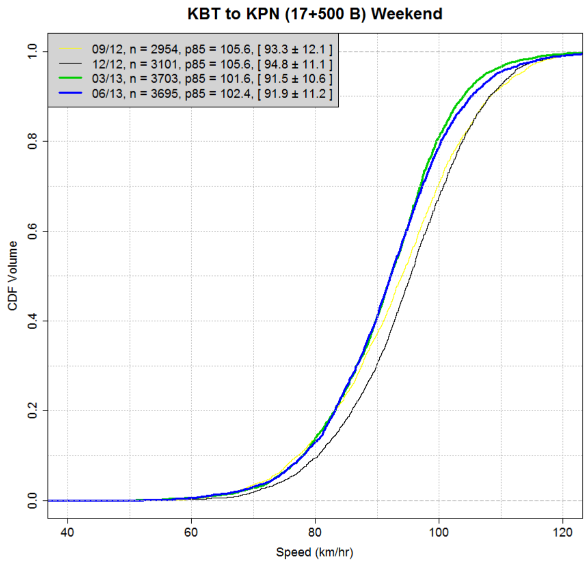


(a) Weekday (b) Weekend

Figure 5.19 Cumulative Distribution Functions (CDF) of eastbound link speeds from Bangkru Toll Plaza (KBK) to Bangmaung Toll Plaza (KBM) during weekdays (Left) and weekends (Right). The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.

3) Link Speed From Bang Khun Thian (KBT) To Paknam (KPN)

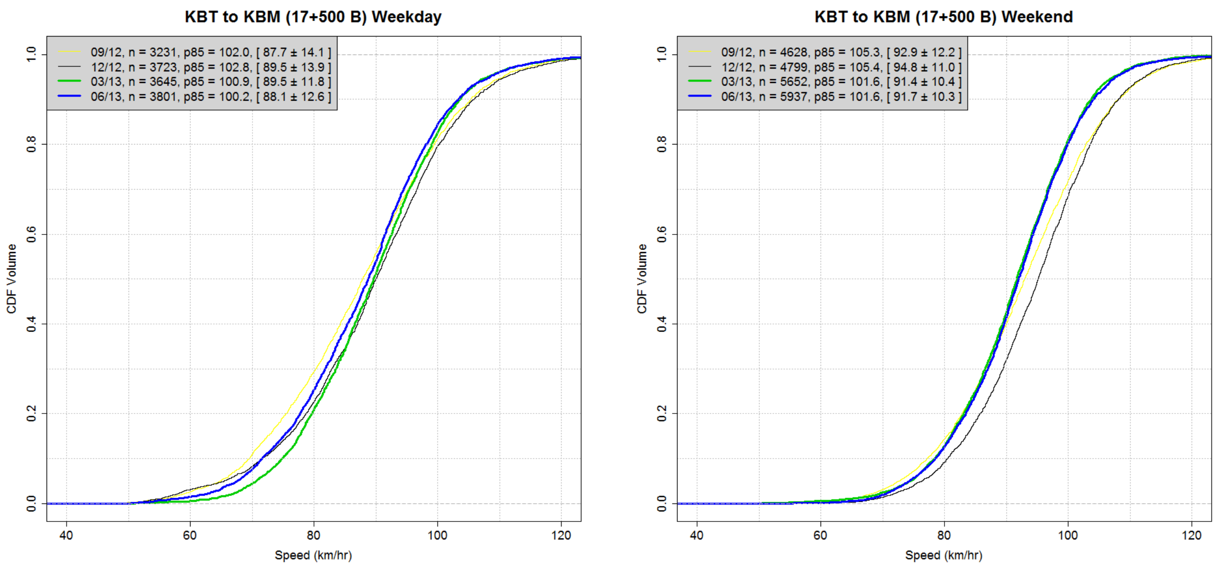




(a) Weekday (b) Weekend

Figure 5.20 Cumulative Distribution Functions (CDF) of eastbound link speeds from Bang Khun Thian Toll Plaza (KBT) to Paknam Toll Plaza (KPN) during weekdays (Left) and weekends (Right). The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.

4) Link Speed From Bang Khun Thian (KBT) To Bangmaung (KBM)



(a) Weekday

(b) Weekend

Figure 5.21 Cumulative Distribution Functions (CDF) of eastbound link speeds from Bang Khun Thian Toll Plaza (KBT) to Bangmaung Toll Plaza (KBM) during weekdays (Left) and weekends (Right). The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.

5.3 Burapha Withi Expressway Route

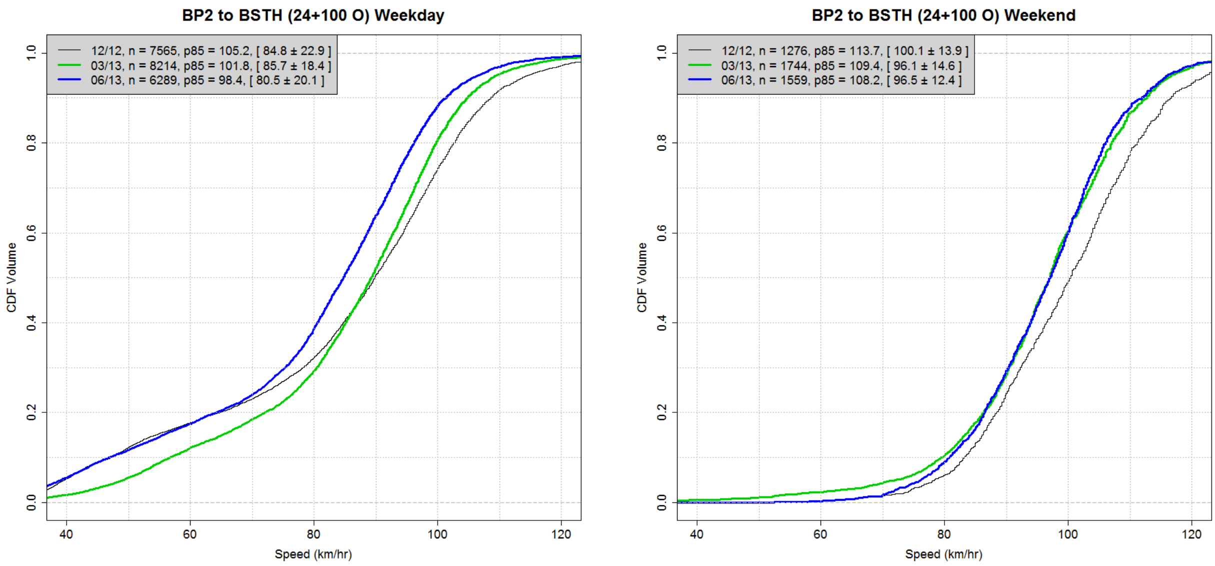
On Burapha Withi expressway, automatic traffic detectors are not available. Therefore, only link speed can be obtained from the Manual Toll Collection (MTC) data. The following sub-sections analyzed the changes in link speeds on two origin-destination (OD) pairs. Eastbound link speeds from Bangplee 2 toll plaza entry to Bang Sao Thong toll plaza exit were analyzed to determine the effects of the speed enforcement camera installed at KM 24+100 O, eastbound traffic direction. Additionally, westbound link speeds from Bang Sao Thong toll plaza entry to Bangplee 2 toll plaza exit were analyzed to determine the effects of the speed enforcement camera installed at KM 14+050 I, westbound traffic direction.

5.3.1 Link Speed Comparisons for Camera Site KM 24+100 O (Eastbound)

Three periods of speed data were collected including December 2012, March, and June 2013. The "before" data include December 2012 period. The "after" data include March and June 2013 periods.

1) Link Speed From Bangplee 2 (BP2) To Bang Sao Thong (BSTH)

From Figure 5.22, it can be seen that speeds during weekday and weekend significanty reduced. For weekday dataset, the 85th percentile link speed reduced from 105.2 km/hr in December 2012 to 98.4 km/hr in June 2013, a 6.8 km/hr reduction within 6 months. The mean speed reduced from 84.8 km/hr to 80.5 km/hr, a 4.3 km/hr reduction. For the weekend dataset, the 85th percentile link speed reduced from 113.7 km/hr to 108.2 km/hr, a 5.5 km/hr reduction. The mean speed reduced from 100.1 km/hr to 96.5 km/hr, a 3.6 km/hr reduction.



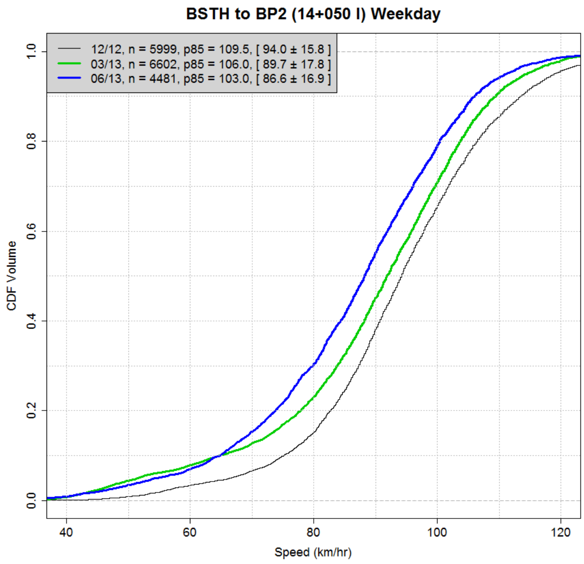
(a) Weekday (b) Weekend

Figure 5.22 Cumulative Distribution Functions (CDF) of eastbound link speeds from Bangplee 2 (BP2) To Bang Sao Thong (BSTH) during weekdays (Left) and weekends (Right). The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.

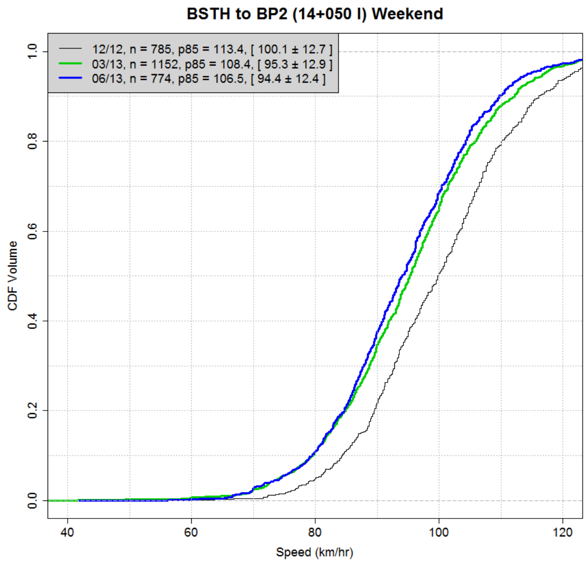
5.3.2 Link Speed Comparisons for Camera Site KM 14+050 I (Westbound)

1) Link Speed from Bang Sao Thong (BSTH) to Bangplee 2 (BP2)

From Figure 5.23, the westbound link speed showed a greater magnitude of speed reduction compared with that of the eastbound traffic. For weekday dataset, the 85th percentile link speed reduced from 109.5 km/hr in December 2012 to 103.0 km/hr in June 2013, a 6.5 km/hr reduction within 6 months. The mean speed reduced from 94.0 km/hr to 86.6 km/hr, a 7.4 km/hr reduction. For the weekend dataset, the 85th percentile link speed reduced from 113.4 km/hr to 106.5 km/hr, a 6.9 km/hr reduction. The mean speed reduced from 100.1 km/hr to 94.4 km/hr, a 5.7 km/hr reduction.



(a) Weekday



(b) Weekend

Figure 5.23 Cumulative Distribution Functions (CDF) of westbound link speeds from Bang Sao Thong (BSTH) to Bangplee 2 (BP2) during weekdays (Left) and weekends (Right). The associated labels denote data collection period, number of vehicles, 85th percentile speed, [mean speed +/- speed], respectively.

5.4 Statistical Inferences

In this section, a formal statistical test was used to determine whether the speed difference are statically different. Speed data in December 2012 were considered as “Before” period data and speed data in September 2013 were considered as “After” data. Since the two dataset are two different populations, Monte Carlo analysis – a repeated random sampling method – was used to determine the mean difference between the two datasets with diffrerent population parameters (Hunter, Boonsiripant et al. 2010).

Six Monte Carlo analyses were performed for six speed camera locations. Each analysis composed of three iterations of random sampling with replacement. For each iteration, a sample of 4,000 data points were drawn (with replacement) from the Before dataset and another 4,000 data points were drawn from the After dataset. Both Before and After speed data points were then randomly paired and the 4,000 individual speed difference data points were calculated. A pair of parameters, that is, sample mean and standard deviation could be estimated from the 4,000 data points at the end of each iteration. The three sample means were averaged to obtain an unbiased speed difference between before and 9-month after periods. The pooled variance (s_p^2) was calculated using the following formula (Hines, Montgomery et al. 2008):

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2 + (n_3 - 1)s_3^2}{n_1 + n_2 + n_3 - 3}$$

where n_i and s_i^2 are the number of sampling data points and variance for the i^{th} iteration, respectively.

The results from the Monte Carlo analyses were shown in Table 5.1. The second column depicted the mean difference between the Before and After speed datasets. The 95 percent confidence interval (lowerbound and upperbound) were also provided in the table. The statistical t-test was performed with the null hypothesis that the mean difference of the Before and After speed data is zero. The results in Table 5.1 rejected the null hypothesis at all six location and it can be concluded that the mean difference does not equal zero at 0.95 confidence level.

Table 5.1 Speed differences between the ninth month after and before the speed enforcement camera installation with t-test results at 95% confidence level.

Speed Camera Location	Mean Diff. Ninth Month-Before (kph)	95% Confidence Lowerbound	95% Confidence Upperbound	Mean Diff. Significant at 95% Confidence Level?
Kanchanapisek (8+000 A)	-2.028	-2.487	-1.570	yes
Kanchanapisek (17+500 B)	-2.791	-3.274	-2.307	yes
Burapha (14+050 I)	-3.612	-4.073	-3.152	yes
Burapha (24+100 O)	-1.242	-1.736	-0.749	yes
Chalong Rat (12+500 A)	-3.747	-4.240	-3.255	yes
Chalong Rat (12+500 B)	-4.912	-4.431	-5.393	yes

5.5 Overspeed Analysis

This section evaluated the overspeed trend after installing the automatic speed enforcement system from January 2013 to September 2013. Note that during the nine-month period the citable speed limits for passenger cars and trucks was set to 130 km/hr and 90 km/hr, respectively. The overspeed percentages were then calculated from the proportion of overspeed vehicles to the total number of vehicles of the same classification. The speed data during the peak period was removed from the analysis.

5.5.1 Chalongrat Expressway Route

The percent overspeed has been reduced since the deployment of the speed enforcemeny system in January 2013. Figure 5.24 represents the overspeed trend for the eastbound (red lines) and the westbound (blue lines) traffic. Since the car and truck speeds are different, they were analyzed separately. The solid lines illustrates the car's overspeed trends while the dash lines illustrates the truck's overspeed trends.

It can be seen that the automatic speed enforcement system has more impact on the truck speeding than the car speeding as the truck trend lines decline at a higher rate than do the car trend line. This is likely due to the fact that the previous manual enforcement applied only to the passenger cars constrained by the equipment setting capability. Therefore, truck speed had never been suppressed by the enforcement activity before and consequently yielded a higher reduction when the enforcement has been applied to the truck traffic.

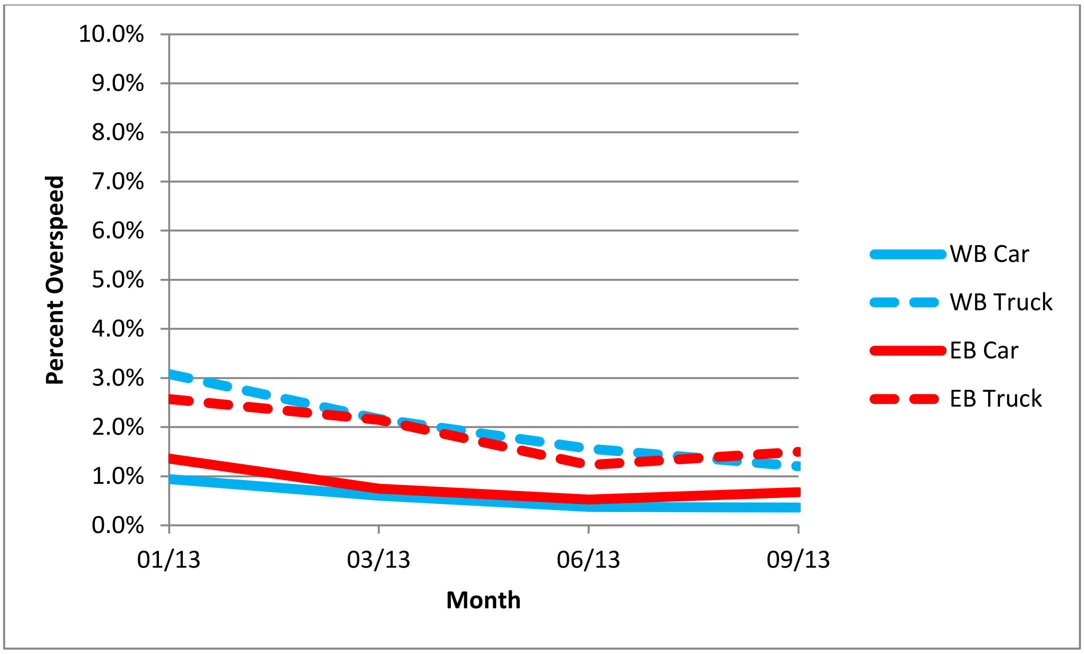


Figure 5.24 Overspeed Trend After Installing Automatic Speed Enforcement System between January 2013 and September 2013, Chalongrat Expressway

5.5.2 Kanchanapisek Expressway Route

Percent overspeed of trucks on Kanchanapisek Expressway is significantly higher than that of Chalongrat Expressway as seen in Figure 5.25, i.e., 20 to 25 percent. Percent overspeed of passenger cars on this route is also higher than that of the Chalongrat Expressway since traffic on this suburban route is generally lighter than Chalongrat Expressway.

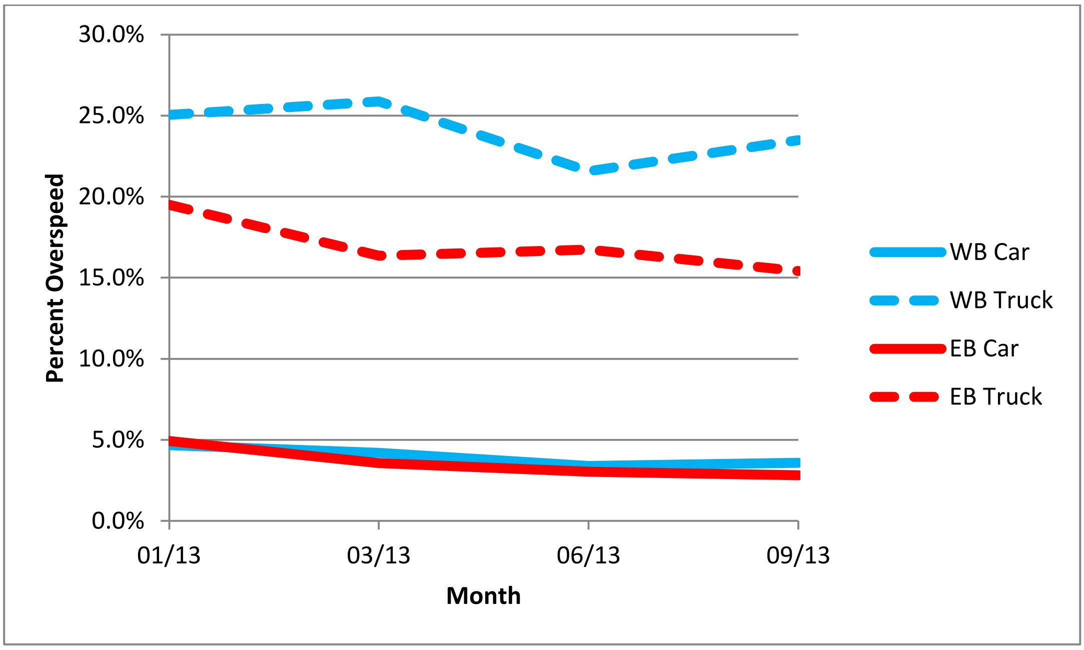


Figure 5.25 Overspeed Trend After Installing Automatic Speed Enforcement System between January 2013 and September 2013, Kanchanapisek Expressway

5.5.3 Burapha Withi Expressway Route

The automatic speed enforcement on Burapha Withi Expressway is highly effective for reducing overspeed vehicles on this intercity expressway as depicted in Figure 5.26. The percent overspeed for trucks decreased sharply from approximately 20 percent to 10 percent during the first six months of deployment. The percent overspeed for car decreased from 5-7 percent to 3 percent during the same period.

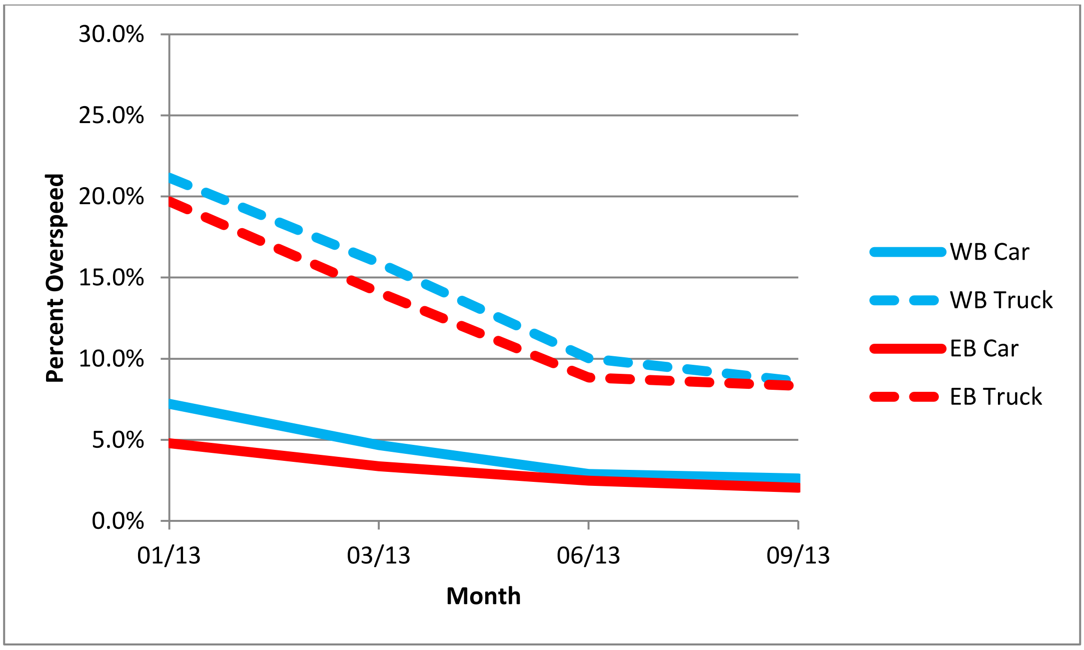


Figure 5.26 Overspeed Trend After Installing Automatic Speed Enforcement System between January 2013 and September 2013, Burapha Withi Expressway

5.6 Findings and Summary

- In general, weekend traffic experienced a greater speed reduction than the weekday traffic since the traffic is lighter on weekend and therefore the drivers could drive faster before the installation of the automatic speed enforcement camera.
- Both Mean speed and the 85th percentile speed reduced after the deployment of the automatic speed enforcement cameras. However, the standard deviation of speeds does not necessarily reduce at all sites.
- Surprisingly, link speeds were also affected by the automatic "spot" speed enforcement camera at the same magnitude as the spot speeds. This means that when we installed a couple automatic speed enforcement systems on an expressway route along with warning signs notifying that "the speed limit is enforced throughout the route", it would result in speed reduction throughout the route since drivers are not certain where the speed enforcement system is. Therefore, the person would try to keep the cruising speed lower than the speed limit throughout the route.
- The Monte Carlo analysis was used to estimate the mean difference between "Before" and "9-month after" speed datasets. The December 2012 data were compared with January 2013 data. The speed reduction ranges from 1.2 to 4.9 km/hr depending on the camera sites. Chalongrat Expressway seemed to have the greatest speed reduction even though it has a higher traffic volume than the other two suburban routes. This might cause by the fact that previously Kanchanapisek and Burapha Withi Expressways has a stricter manual speed enforcement than Chalongrat expressway since drives could not use very high speed on the urban expressway. The police therefore focused more on the suburban expressways before installing the automatic speed enforcement cameras.
- The statistical t-test showed that the speed reductions after installing the speed enforcement cameras are statistically significant at all six sites at 95 percent confidence level.
- Before the speed camera deploymenet, the percent overspeed on Chalongrat expressway, urban expressway, (1 percent for passenger cars and 3 percent for trucks) is much lower than Kanchanapisek and Burapha Withi Expressways (5 percent for passenger cars and 20 percent for trucks).
- The automatic speed enforcement system has a greater impact on the overspeed truck than the operspeed passenger cars. At all three sites, it can be seen that the percent overspeed truck decreased at a higher rate than the passenger cars during the nine months of system deployment.
- In summary, the automatic speed enforcement system effectively reduces speeds of both passenger cars and trucks on the three expressway routes. The speed reduction effect seems

to be route-wide rather than just at the camera spots since the cameras are disguised and the speed enforcement warning signs do not provide a specific information of the camera locations.

- It is also worthwhile to examine the safety benefits of the automatic speed enforcement system which is the ultimate goal of the system deployment. The safety analysis was elaborated in the next chapter.

CHAPTER 6 SAFETY ANALYSIS

In this chapter, the crash data during the “before” and “after” data were analyzed. The automatic speed enforcement system has been deployed since January 2013. Therefore, the “Before” data would include three-year crash data from 2010-2012 and the “After” data include a one-year crash data from January 2013 to December 2013. The crash data were obtained from EXAT’s TFC Crash database. Note that the accident records in year 2013 has not been verified by the EXAT staff. Each accident records include the following attributes:

- Date and time of occurance
- Expressway route
- Traffic direction
- Facility type such as mainline, on/off ramp, toll plaza
- Method of reporting incident
- Crash type such as rear-end, sideswipe, hitting with roadside objects, turnover, vehicle on fire, spillage
- Cause of accidents such as speeding, drunk driving, fallen a sleep while driving, sudden braking, and sudden lane changing.

The initial filters has been applied to the crash data to remove accident records that are not relevant to speeding. Accidents that are deemed not related to the scope of stuy are such as:

- Accidents that did not occur on the mainline, e.g., ramp and toll booth
- Vehicles on fire and breakdown vehicles

6.1 Crash Frequency

The before and after study was used to evaluate the impact of the automatic speed enforcement camera to the three expressway routes. Direct comparisons of crash frequencies between the before and after periods were conducted. The 9-km effective zone used by Shin (Shin, Washington et al. 2009) were also used in this analysis. Table 6.1 compares crash frequencies between the before and after treatment periods. The crash frequencies during the before period were averaged from 2010 to 2012 (three-year period). It can be seen that not all treatment sites have reduction in crashes caused by speeding. Chalongrat Northbound site seems to have the greatest crash reduction from 25 to 17 crashes within the 9-km zone (32 percent reduction). Burapha Withi Northbound and Chalongrat Southbound treatment sites also have crash reduction of 9% and 2%, respectively.

On the other hand, crash frequency increased at the other three treatment sites including Kanchanapisek Eastbound (+29%), Kanchanapisek Westbound (+18%), and Burapha Withi Eastbound (+3%).

Table 6.1 Crash frequency per year in the 9-km treatment section before (2010 - 2012) and after the speed enforcement treatment (2013).

Treatment Site	Before Period (3-yr Avg)	After Period	Percent Difference
Chalongrat NB	25	17	-32%
Chalongrat SB	18.3	18	-2%
Kanchanapisek EB	17	22	+29%
Kanchanapisek WB	17	20	+18%
Burapha Withi EB	24.3	25	+3%
Burapha Withi WB	29.7	27	-9%

6.2 Crash Rate

It is known that crash frequency does not take into account of traffic exposure. That is, crash frequency increases as traffic volume increases over time. Therefore, the research team incorporated traffic volume into comparison by using crash rate. The Crash Rate (CR) is expressed as crashes per million vehicle kilometers travelled (MVKT) and can be calculated as follows:

$$CR = \frac{C * 1{,}000{,}000}{L * ADT * 365}$$

where *C* is number of crashes per year, *L* is the segment length (km) which we used 9 km in this study, and ADT is the average daily traffic (vehicles/day) of the section.

The latest sectional traffic volume data were collected in 2009 shown in the Traffic Survey Report (Part 2), Figure 3.3-37, page 3-121, which collected 24-hour traffic data on November 18, 2009. Sectional traffic volume data for the treatment sections are shown in Table 6.2. Since sectional traffic volume after 2009 were unavailable, the research team decided to calculate growth rates for each expressway route from the traffic volume entering the expressways publicly available on the EXAT's website. The compound growth rates were calculated from the traffic volume entering the expressways beween year 2010 and 2013. Note that Kanchanapisek and Burapha Withi expressways are closed expressway system. Therefore, the traffic volume reported on EXAT's website were traffic volume exiting the system instead. The compound growth rate (GR) can be calculated using the equation below:

$$GR = \left(\frac{ADT_n}{ADT_1}\right)^{(1/n)} - 1$$

where ADT_n is the average daily traffic of year n.

The sectional volumes from year 2010 to 2013 were then projected using growth rates determined from the entering traffic volumes. Crash rates in Table 6.3 were calculated from the projected traffic volume and historical crash data on the 9-km treatment section. It can be seen that when taking into account the traffic growth, road safety were improved at all treatment sites, except on the Kanchanapisek expressway routes. The crash rate on Kanchanapisek eastbound segment was slightly increased from 0.13 to 0.14 crashes per MVKT whereas the westbound segment stayed the same at 0.20 crashes per MVKT. During the police interview, we were informed that the before the full-scale implementation in January 2013, the police and traffic control officers already used portable speed guns regularly on Kanchanapisek expressway. This might be the reason why crash rate on Kanchanapisek expressway did not decrease after introducing the automatic speed enforcement cameras.

Table 6.2 Sectional traffic volume and growth rates on the 9-km treatment sections before (2010-2012) and after the treatment (2013)

Treatment Site	2009	Growth Rate	2010	2011	2012	3-Yr Average	2013
Chalongrat NB	43,065	10.6%	47,646	52,714	58,322	52,894	64,526
Chalongrat SB	41,937	10.3%	46,242	50,988	56,222	51,151	61,993
Kanchanapisek EB	34,379	8.3%	37,221	40,298	43,630	40,383	47,236
Kanchanapisek WB	21,839	8.2%	23,622	25,551	27,637	25,603	29,894
Burapha Withi EB	23,965	15.0%	27,567	31,709	36,475	31,917	41,956
Burapha Withi WB	27,550	21.8%	33,546	40,847	49,738	41,377	60,563

Table 6.3 Crash rates (Crashes per MVKT) in the 9-km treatment section before (2010 - 2012) and after the speed enforcement treatment (2013).

Treatment Site	Before Period	After Period
Chalongrat NB	0.14	0.08
Chalongrat SB	0.11	0.09
Kanchanapisek EB	0.13	0.14
Kanchanapisek WB	0.20	0.20
Burapha Withi EB	0.23	0.18
Burapha Withi WB	0.22	0.14

CHAPTER 7 CONCLUSIONS

This research project evaluated the speed enforcement programs in Thailand. Current practices on the manual and automatic speed enforcement in Thailand and other countries have been reviewed.

7.1 Current Practices

The findings can be summarized as follows:

- Most of the speed enforcement efforts are conducted using manual laser gun or semi-automatic laser gun. This type of equipment require personels attending the equipment and therefore cannot be used all day long. The police usually selected off-peak period for two to three hours during the day to monitor vehicle's speeds.
- Citable speed limit is different from the legal speed limit. For example, the expressway police would give a citation to the driver who drives faster than 120 km/hr while the legal speed limit is 90 km/hr. Citable speed limit on arterials is more controversial as different arterials have different contexts. Police is reluctant to use the speed limit of 60 km/hr where higher speed can be used comfortably on some major arterials.
- Camera location is usually determined by the police officers. The officers usually select the site where drivers use high speed and it is safe for the officer to setup the equipment. This consequently does not guarantee the reduction in speed-related crashes since the location is not selected based on speed-related black spots.
- Manual speed enforcement is much less effective than the automatic speed enforcement because the manual speed enforcement cannot be performed 24/7 due to personnel and safety constraints. The speed reduction is reported to be between 1-17 km/hr whereas the automatic speed enforcement yield a result of up to 39 km/hr speed reduction.

7.2 System Evaluation

The reseach team also determined the effectiveness of the automatic speed enforcement cameras installed on three expressway routes, namely, Chalongrat expressway, Kanchanapisek expressway, and Burapha Withi expressway in January 2013. The analyses were divided into two types, that is, speed analysis and safety analysis.

7.2.1 Results from Speed Analysis

- In general, weekend traffic experienced a greater speed reduction than the weekday traffic since the traffic is lighter on weekend and therefore the drivers could drive faster before the installation of the automatic speed enforcement camera.

- Link speeds were also affected by the automatic “spot” speed enforcement camera at the same magnitude as the spot speeds. This means that when we installed a couple automatic speed enforcement systems on an expressway route along with warning signs notifying that “the speed limit is enforced throughout the route”, it would result in speed reduction throughout the route since drivers are not certain where the speed enforcement system is. Therefore, the person would try to keep the cruising speed lower than the speed limit throughout the route.
- The Monte Carlo analysis was used to estimate the mean difference between “Before” and “9-month after” speed datasets. The December 2012 data were compared with January 2013 data. The speed reduction ranges from 1.2 to 4.9 km/hr depending on the camera sites. Chalongrat Expressway seemed to have the greatest speed reduction even though it has a higher traffic volume than the other two suburban routes. This might cause by the fact that previously Kanchanapisek and Burapha Withi Expressways has a stricter manual speed enforcement than Chalongrat expressway since drives could not use very high speed on the urban expressway. The police therefore focused more on the suburban expressways before installing the automatic speed enforcement cameras.
- Before the speed camera deploymenet, the percent overspeed on Chalongrat expressway, urban expressway, (1 percent for passenger cars and 3 percent for trucks) is much lower than Kanchanapisek and Burapha Withi Expressways (5 percent for passenger cars and 20 percent for trucks).
- The automatic speed enforcement system has a greater impact on the overspeed truck than the operspeed passenger cars. At all three sites, it can be seen that the percent overspeed truck decreased at a higher rate than the passenger cars during the nine months of system deployment.
- In summary, the automatic speed enforcement system effectively reduces speeds of both passenger cars and trucks on the three expressway routes. The speed reduction effect seems to be route-wide rather than just at the camera spots since the cameras are disguised and the speed enforcement warning signs do not provide a specific information of the camera locations.

7.2.2 Results from Safety Analysis

- Comparison of crash frequency before and after the treatment showed that the crash reduction range from 3 to 29 percent, except on Kanchanapisek eastbound, westbound, and Burapha Withi eastbound where the crash frequency increased. This might be due to increase in traffic exposure over time. Therfore, crash rate which takes into account of traffic volume were calculated.

From 2010 to 2013, crash rates decreased at all sites except the Kanchanapisek treatment sites, both directions. This might be due to the fact that police and traffic control officers already used portable speed guns regularly on Kanchanapisek expressway. This might be the reason why crash rate on Kanchanapisek expressway did not decrease after introducing the automatic speed enforcement cameras.

7.3 Recommendations

Finally, based on the findings from the interview and EXAT's enforcement program evaluation, several recommendations can be drawn from.

- Speed Limit - Guideline and standard for setting up speed limit on different road facilities are needed. Currrently, police is hesititating to directly use the legal speed limit which sometimes can be impractically low on major arteirials. Appropriate speed limit setting will reduce resistance from the public.
- Financing – Automatic speed enforcement camera has a high capital cost. It also requires fair amount of operating cost and maintenanace cost. Current law distribute the speeding fines to the police and local government. The revenue distribution will need to be changed at the institutional level to fund the automatic speed enforcement program and promote speeding preventioin campaign so that the program can be self-sustained and reduce resistance from the public.
- Engineering – location of speed enfocement camera is often determined law enforcement officers with no engineering background. The normally selected site is the site with high speed vehicles but does not necessarily possesses high-speed crashes. Therefore, implementation of automatic speed enforcement camera might not be effective in reducing crashes caused by speeding. It is recommended that black spot analysis should be performed by traffic engineers to determine an appropriate camera location.
- Fixed rate revenue vs. varied rate revenue – Fixed rate revenue will be easiler to understand by the public. However, varied rate revenue is found to be more effective on reducing speeds.
- Implementation – The transparency of the revenue generated from the speeding fine will reduce public resistant. It is recommended that surplus revenue should be allocated to other highway safety programs.
- At the beginning of the camera operation, e.g., 30 days, the law enforcement agency should start with warnings sent to the violators instead of citations.

7.4 Seminars

Presentations on the automatic speed enforcement has been given at several occasions to inform the public and stakeholders regarding the use of the automatic speed enforcement system and its benefits. Those occasions are as follows:

- September 16, 2014, presentation was given to the Accident Prevention and Traffic Congestion Mitigation committee meeting at Kosa Hotel, Khonkaen.
- February 28, 2014, presentation and guidelines was given to the local authorities during the ATRANS and Community Road Safety Forum Awards at the Grande Centre Point Hotel, Terminal 21.
- March 27, 2014, presentation was given to the Road Safety Directing Center board meeting 2/2014 at the Department of Disaster Prevention and Mitigation (DDPM). Recommendation on the usage and benefits of the automatic speed enforcement cameras were given to the board members.
- June 25, 2014, presentation was given during the meeting on “Decade of Action for Road Safety” at the Department of Disaster Prevention and Mitigation (DDPM). The meeting concluded that speed limit setting guideline is needed. Law change is also needed to

References

Austroad. (2012) Point-to-Point Speed Enforcement. Austroads Publication No. AP-R415-12.

Blincoe, K. M., Jones, A.P.J, Sauerzapf, V., and Haynes R. (2006) Speeding driver' attitudes and perception of speed camera in rural England. Accident Analysis and Prevention 38 : 371-378.

Central Nippon Expressway Company Limited (2010) Driving on the expressway and traffic rules. [online]. Available from : http://global.c-nexco.co.jp/en/faq/1.html [2011, May 21]

Chen, G., Wilson, J., Meckle, W. and Cooper, P. (2000) Evaluation of photo radar program in British Columbia. Accident Analysis and Prevention 32 : 517-526.

Chen, G., Meckle, W. and Wilson, J. (2002) Speed and safety effect of photo radar enforcement on a highway corridor in British Columbia. Accident Analysis and Prevention 34 : 129-138.

Elvik, R., Hoye, A., Vaa, T. and Sorensen, M. (2009) The Handbook of Road Safety Measures (2nd edition). Howard House, UK: Emerald Group Publishing Limited.

European Tourist Office, European Communities (2011) Driving in Europe: Speed limits. [online]. Available from : http://www.europe.org/speedlimits.html [2011, May 21]

Expressway Authority of Thailand (2011). Driving according to law reduces accidents. Pamphlet 9 February 2011. Office of Research and Development, Expressway Authority of Thailand.

Expressway Police 1 (2005). Speed Enforcement [Online]

http://www.expresswaypolice.com/Album/Overspeed/ [May 23, 2011]

Hines, W. W., et al. (2008). Probability and Statistics in Engineering, John Wiley & Sons.

Hirst, W.M., Mountain, L.J. and Maher, M.J. (2005) Are speed enforcement cameras more effective than other speed management measures? An evaluation of the relationship between speed and accident reductions. Accident Analysis and Prevention 37 : 731-741.

Hunter, M., et al. (2010). "Evaluation of Effectiveness of Converging Chevron Pavement Markings in Reducing Speed on Freeway Ramps." Transportation Research Record: Journal of the Transportation Research Board 2149: 50-58.

Insurance Institute for Highway Safety, Highway Loss Data Institute (2011) Maximum posted speed limits. [online]. Available from : http://www.iihs.org/laws/speed limits.aspx [2011, May 21]

Jorgensen, F. and Pedersen, H. (2005) Enforcement of speed limits-actual policy and drivers' knowledge. Accident Analysis and Prevention 37 : 53-62.

Kanitpong, K., Jiwattanakulpaisarn, P. and Yaktawong, W. (2011) Speed Management Strategies and Drivers' Attitude in Thailand. In Transportation Research Board 90th Annual Meeting. Washington, D.C.

Kanluan, P. (2012). The Feasibility Study of Intelligent Traffic Police Project. Faculty of Commerce and Accountancy, Chulalongkorn University. Master of Business Administration.

Keall, M.D., Povey, L.J. and Frith, W.J. (2001) The relative effectiveness of a hidden versus a visible speed camera programme. Accident Analysis and Prevention 33 : 277-284.

Kocharayasri, P. Interview of Highway Police Director (Interview on April 12, 2011).

Satienpong, S. Head of Bangpli-Suksawat Expressway Police Station (Interview on April 5, 2012)

Shin, K., Washington, S.P. and Schalkwyk, I.V. (2009) Evaluation of the Scottsdale Loop 101 automated speed enforcement demonstration program. Accident Analysis and Prevention 41 : 393-403.

Sontikul, S., Kanitpong, K. and Jiwattanakulpaisarn, P. (2011) Driver Typology and Speeding Behavior in Speed Enforcement Zone. In Transportation Research Board 90th Annual Meeting. Washington, D.C.

Stefan, C. (2006) Section Control – Automatic Speed Enforcement in the KaiserMuhlen Tunnel (Vienna, A22 Motorway). Project Report. Kuratorium fur Verkehrssicherheit.

Thailand Accident Research Center (2007) Speed Law. [Online]

http://www.tarc.ait.ac.th/th/speed4.php [April 2, 2012]

Williams, A.F., Kyrychenko, S.Y. and Retting, R.A., 2006. Charateristics of speeders. Journal of Safety Research 37 : 227-232.

Final Report

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