

# The Beneficial Effects of Section Control Speed Cameras on Variation of Freeway Crash Variables

Hamid Mirzahosseini<sup>1,\*</sup>, Armin Amini<sup>2</sup>, Abolfazl Khishdari<sup>3</sup>

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## Abstract

Speeding is one of the most leading causes of almost any road traffic crash; that can increase either crash frequency or intensity. As a well-known intelligent transportation system (ITS), automated section control average speed cameras can enhance the traffic safety through spot control and section control. Previous studies looked at how much crashes might be related to speed, but they didn't look into how cameras could change crash patterns. In this regard, the present paper aims to investigate section control speed cameras' safety effects on Qazvin-Karaj freeway crash variables., eight years of police-reported crash data (2011–2018) were analyzed using the Chi-square ( $\chi^2$ ) test of independence. The results indicated that regardless of crash variable type, there is a statistically significant relationship between the crash frequency variations and speed camera installation. However, Cramér's V measure degree of association showed an ignorable correlation between section control speed camera installation and crash intensity and crash time variations. However, this index depicted more significant but still marginal impacts of their installation on crash category and crash type, with Cramér's V values of 0.208 and 0.188, respectively. Applied research has cleared the effects of speed cameras on crash-related variables that can assist stakeholders in the decision-making process that help them toward prioritizing budget assignment to make road safer in view of speed management.

**Keywords:** Speed Cameras, Section Control, Safety Effects

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\* Corresponding author. E-mail: mirzahosseini@eng.ikiu.ac.ir

<sup>1</sup> Department of Civil– Transportation Planning, Imam Khomeini International University, Qazvin, 34149, Iran

<sup>2</sup> Department of Civil– Transportation Planning, Imam Khomeini International University, Qazvin, 34149, Iran

<sup>3</sup> Department of Civil– Transportation Planning, Imam Khomeini International University, Qazvin, 34149, Iran

## 1. Introduction

Road traffic injuries draw world's attention toward finding potential remedies for safety improvement. In this regard, years between 2011 and 2020 were named decade of action. Five pillars were defined to reduce road fatalities, namely; 1) road safety management, 2) safer roads and mobility, 3) safer vehicles, 4) safer road users, and 5) post-crash response. Speed management highly and directly affects

pillars (1), (2), and (4) (WHO 2011). It has been claimed that speeding contributes to roughly one-third of total road traffic fatalities (NHTSA 2013). To date, there are many types of researches regarding speed importance from different points of view, as depicted in Table 1. However, speed cameras safety impacts on crash-related variables have rarely been discussed in developing countries. Thus, this has been investigated in the present study.

**Table 1. Review of researches related to speed management and characteristics**

Authors and years published	Subject	Analytical Method	Country	Research Findings
(X. Wang, Zhou, Quddus, Fan, & Fang, 2018) (Wang, Zhou et al. 2018)	Employing random effect Poisson lognormal model to investigate speed variations effects on the total number of crashes	Crash modeling using random effect Poisson lognormal model	China	Using random effect Poisson lognormal model, results indicated 1% mean speed increase results in 0.7% total crashes, and longer speed fluctuations dealt with crash increases
(Vadeby & Forsman, 2018)(Vadeby and Forsman 2018)	Long term drivers' speeding changes due to new posted speed limits	Measuring safety effectiveness using $\theta$ index (that investigate before and after crashes)	Sweden	Lowering speed limits promises a reduction in fatalities but no significant changes in seriously injured ones
(Ravani & Wang, 2018) (Ravani and Wang 2018)	Methods to control speed in highway work zone areas	Four measures were used to investigate effectiveness (average speed, speed variance, 85 <sup>th</sup> percentile speed and proportion of high speed vehicles)	USA	Results insisted that the use of radar speed display and passive police vehicle existence was the best scenario in work zone safety speed control
(LaVoie, Lee, Allison, & Parker, 2018) (LaVoie, Lee et al. 2018)	New technology adoption in driving speeding training	Using online statements by the selected participants	USA	Speed pattern of novice drivers differs from experienced ones
(Vadeby & Forsman, 2017) (Vadeby and Forsman 2017)	Employing aggregate models to investigate speed changes of different vehicles	Measuring safety effectiveness of speed cameras using the Power model and Exponential model at in individual vehicle speed level	Sweden	Employed aggregated modeling was near individual modeling results. however, Power and Exponential individual speed models outperformed
(Sadat & Celikoglu, 2017) (Sadat and Celikoglu 2017)	Modeling speed limit variations in the driving simulator	Microscopic traffic simulation to implement variable speed limit (VSL) algorithm based on	Turkey	Rational compliance level of driver (i.e. 50% to 75%) based on posted speed limit showed improved

## The Beneficial Effects of Section Control Speed Cameras on Variation of Freeway Crash Variables

Authors and years published	Subject	Analytical Method	Country	Research Findings
	environment	volume, occupancy and average speed		network traffic safety and performance
(Q. He, Zhang, & Nip, 2017) (He, Zhang et al. 2017)	Speed optimization over a road based on arc cost estimations	Development of optimized algorithm to find a set of speeds for each arc of road to minimize total cost	USA	Results indicated that the use of heterogeneous modeling of road path generally enhances 20 to 100 times other than the traditional method
(Čičić, Liang, & Henrik Johansson, 2017) (Čičić, Liang et al. 2017)	Employed neural network as a tool for accurately forecast platoon merging distance	Speed control based on platoon merging distance prediction	Sweden	Using experimental data, results showed that error in distance estimation to merge in platoon situation decreased by 8%
(Kocatepe, Ozguven, Vanli, & Moses, 2017) (Kocatepe, Ozguven et al. 2017)	Exploring speed of intra-urban highways of south Florida	Analysis speed pattern in a case study highway using statistical modes <u>including: Gaussian mixture model with classical EM algorithm (GMM), Gaussian Mixture Model with Greedy EM Algorithm (GMM) and K-means Algorithm</u>	USA	Using K-means clustering approach and Gaussian mixture approach, results indicated the great performance of employed algorithm in speed variability evaluation
(Shrestha & Shrestha, 2016) (Shrestha and Shrestha 2016)	Try to regulate proper zone-based speed limit based on literature review	Review of existing studies	USA	The results showed that we might need to define speed based on 6 successive steps
(Li & Graham, 2016) (Li and Graham 2016)	Investigating speed characteristics variation on different sites to deal with heterogeneity speed variability issue of speed cameras	Using local linear and quadratic regression to estimate heterogeneous treatment effects of speed cameras	England	Results insisted that speed cameras dealt with a 25.9% reduction of total crashes on average.
(Deng & Ma, 2014) (Deng and Ma 2014)	Establishment of a method called "A Fast Algorithm" to optimally plan truck energy saving	Development of optimal trajectory modeling of platoon leader speed using fuel consumption theory	Sweden	Using the intelligent approach, results insisted that the applied method is far better than conditional dynamic programming of truck optimal energy saving
(De Pauw, Daniels, Brijs, Hermans, & Wets, 2014) (De Pauw, Daniels et al. 2014)	The use of section control approach on driver-selected speeds	Estimating Odds ratios based on Logistic regression model with binomial distribution and logit link function	Belgium	Results showed 5.84 km/h traffic speed reduction, 74% of the drivers exceeding the normal speed limit, and 86% reduction on drivers who

Authors and years published	Subject	Analytical Method	Country	Research Findings
				traveled with 10% greater than the posted speed limit
(Huang & Bai, 2014) (Huang and Bai 2014)	The application of "graphic-aided" signs in controlling speed in work-zone areas	Linear regression of mean speed before and after implementation of signs	USA	Comparing influential factors including; text, text-graphic and graphic PCMSs, results suggested the use of signs graphic-aided PCMSs
(Bachmann, Abdulhai, Roorda, & Moshiri, 2013) (Bachmann, Abdulhai et al. 2013)	Employing simulation techniques to assess the capability of sensor-fusion data on traffic speed calculation	Microsimulation modeling of various multi-sensor fusion techniques	Canada	Equipped vehicles with GPS, results showed that data-fusion technique method outperformed compared to one-single sensor use in traffic speed estimation
(S. Wang, 2013) (Wang 2013)	"Efficiency and equity of speed limits in transportation networks"	Development of bi-level programming model to optimize speed limit in order to enhance network efficiency and equity	Australia	Using bi-level programming model, results showed promising effects of applied approach in speed limit design
(Grabowski & Morrisey, 2007) (Grabowski and Morrisey 2007)	The effects of repealing the speed limit on road safety	Using state-year panel data and fixed effects modeling to investigate negative impacts of repealing systemwide national maximum speed limit	USA	It was found that the national speed limit was important as it repealing the associate speed limit increased fatalities by 36-37 %
(Abdel-Aty, Dilmore, & Dhindsa, 2006) (Abdel-Aty, Dilmore et al. 2006)	Evaluation of different methods regarding variable speed limit the influence on road safety improvements	Using simple linear regression of logarithm of variables	USA	Results showed that using variable speed limit scenarios on high travel speed zones could significantly improve road safety, but it would be rather useless on low travel speed zones
(Sheikholeslami et al. 2020)	Evaluating 90 number of licensed drivers in simulation study	Using Liner Probability Model (LPM)	Iran	23% more likely to experience accident when encountering a dark small stationary hazard at nighttime
(Sheikholeslami et al. 2023)	An online questionnaire comprising 20 number of questions from 232 participants	Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA)	Iran	Sociodemographic explanatory variables might only serve as a foundation for forming a driver's contingent emotions, which are later specified by other factors, such as the driving context.

Despite the mentioned studies on speed patterns and different scenarios of speed management and optimization, they lacked proper investigation to answer the question of to what extent crash-related variables might change after section control cameras' installation. The present paper aims to address this lack of evaluation.

## 2. Research Method

This section discusses employed methodology in greater detail including, data collection as well as analytical approach that is depicted in Figure 1.

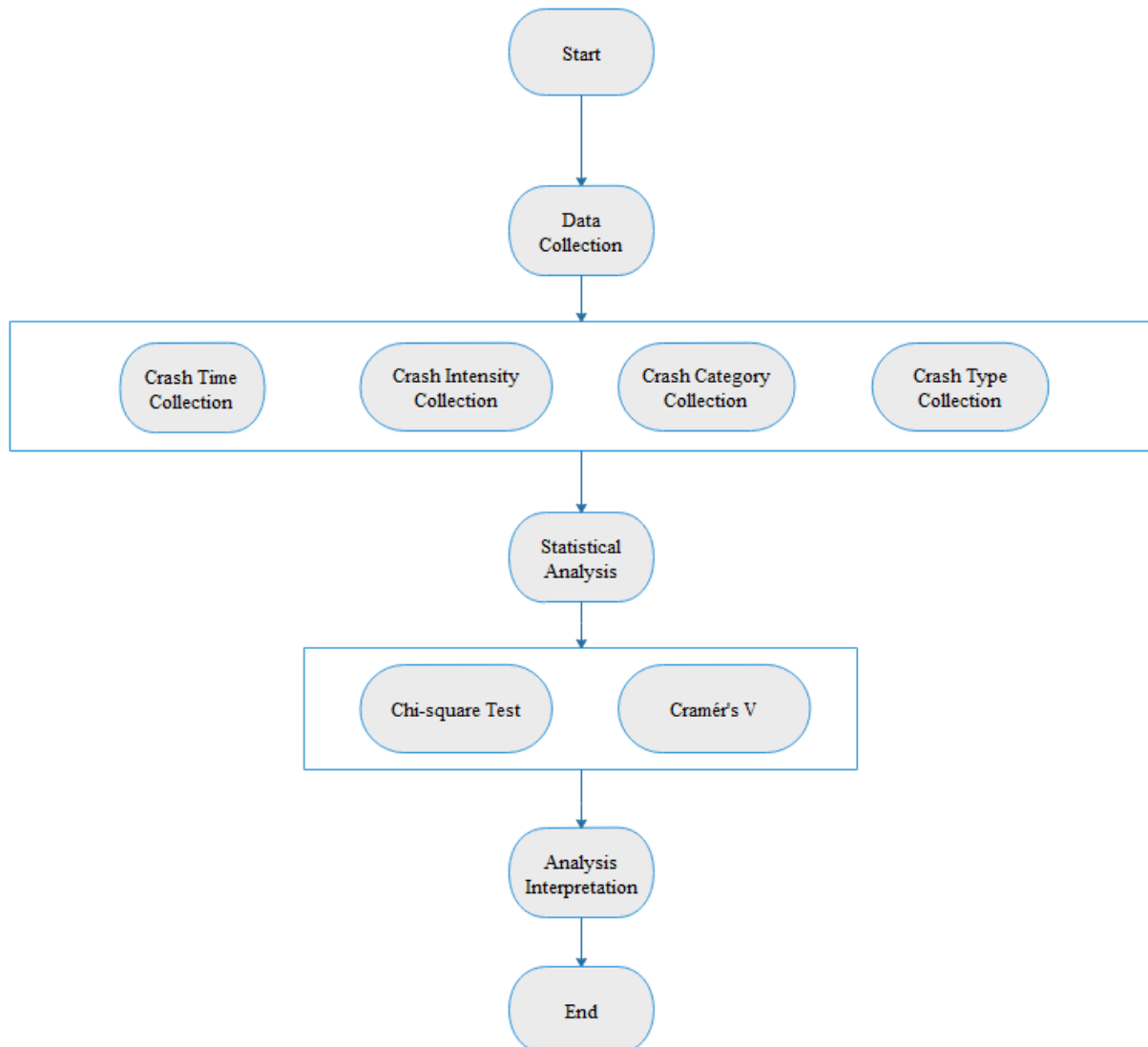


Figure 1. Research Flowchart

### 2.1. Data Collection

In this study eight years of crash data between 2011 and 2018 are collected based on police reports. The dataset comprises four variables as it depicted in Table 2 with descriptive statistics of each individual. The variables

crash category and crash type were classified according to police-reported crash form.

Figure 2 shows the Qazvin-Karaj freeway located in the north-west of Iran, where data is gathered. Construction of this 95-kilometer section dates back to the 1960s. The freeway is

great to be noticed as it discussed in previous studies (Hosseinlou et al, 2018).

Section control speed cameras were installed in 2015. From the table, it can be inferred that some crash variables have increased and some have decreased since speed cameras were installed. Thus, crash related variables are invaluable to investigate and gain knowledge to assist traffic accident practitioners in making an appropriate decision. A reduction in

crash-related variables could be attributed to greater control over driver speed selection behavior. In contrast, the increase in crash related variables is not due to speed camera installation. The leading cause of this change is an increase in traffic volume. It's worth mentioning that traffic volumes were not available since traffic counters were not established for the study period.



Figure 2. Illustration of the studied road (Qazvin-Karaj freeway in NW of Iran)

Table 2. Summary of variables' descriptive statistics involved in the study

Variable	Category	2011	2012	2013	2014	2015	2016	2017	2018
crash time	Morning	1356	1452	1056	1210	1300	1313	2030	1563
	Afternoon	2189	1826	1578	2051	2255	1901	3716	3241
crash intensity	property-damage only	432	640	412	463	529	468	453	324
	injury	3033	2564	2139	2732	2943	2686	5248	4436
	fatality	80	74	83	66	83	60	45	44

## The Beneficial Effects of Section Control Speed Cameras on Variation of Freeway Crash Variables

Variable	Category	2011	2012	2013	2014	2015	2016	2017	2018
crash category	motorcycle-pedestrian	0	1	1	1	1	0	1	1
	parked vehicle	0	0	3	8	12	0	1	0
	vehicle-bicycle	0	0	0	0	0	0	2	0
	motorcycle-motorcycle	1	4	0	0	0	0	0	1
	multiple vehicles	300	269	447	260	310	405	842	564
	vehicle-barrier	444	394	327	522	605	351	437	326
	vehicle-pedestrian	86	75	65	66	65	40	58	40
	vehicle-motorcycle	29	51	28	22	20	25	20	22
	single vehicle to single vehicle	2364	1743	1429	1729	2117	1942	3868	3374
	vehicle-animal	10	6	6	5	7	3	2	8
	vehicle-bicycle	0	6	3	0	0	4	5	1
	occupant-dropout	0	0	1	0	0	0	1	0
	multiple types	10	2	16	401	197	6	3	1
	single-vehicle runoff	110	164	120	75	73	255	201	200
	indeterminate	58	362	69	18	11	18	21	35
	single-vehicle rollover	132	201	119	154	136	165	284	230
crash type	fired vehicle	1	0	0	0	1	0	0	1
	rear-end	1983	1542	1880	1853	1893	1898	3139	2431
	single-vehicle	40	41	84	374	383	276	134	56
	T-bone	184	172	100	159	167	110	1468	341
	sideswipe	285	205	41	286	329	140	39	54
	head-on	74	125	127	97	56	51	33	12
	indeterminate	979	1193	402	492	727	739	933	1910

### 2.2. Analytical Method

In this paper, the correlation analysis between section control speed camera installation status and other crash related variables has examined. Two statistical analyses were conducted. Initially, it was tested whether speed camera installation had significant correlation with the desired studied crash variable or not. Chi-square ( $\chi^2$ ) test of independence index selected for this examination that calculated using Eq. (1) (McHugh 2013).

$$\sum \chi_{i-j}^2 = \sum \frac{(O - E)^2}{E} \quad (1)$$

where O is the observed and E is the expected number of crashes for studied variable.  $\chi_{i-j}^2$  is also the calculated Chi-square value of  $i^{\text{th}}$  row and  $j^{\text{th}}$  column of the crosstab table. The degree of freedom results from multiplying (number of rows-1) by (number of columns-1).

In order to calculate Chi-square ( $\chi^2$ ) test index, let consider a crosstab of speed camera installation and desired crash related variable hear in the column divided in to camera

installed or not and rows are the number of crashes for different speed camera states. O in the Eq. (1) is the value of crosstab's  $i^{\text{th}}$  row and  $j^{\text{th}}$  and E can also be calculated using Eq. (2) (McHugh 2013).

$$E = \frac{(\text{row total})(\text{column total})}{\text{total sample size}} \quad (2)$$

While useful, earlier Chi-square ( $\chi^2$ ) estimation can only determine whether there is strong relationship among variables or not in studied confidence interval (which is mostly 95%). To better investigate, the strength of association among studied variables calculated using Cramér's V index, as it represented by Eq. (3).

$$\text{Cramér's } V = \sqrt{\frac{\chi^2}{n(k-1)}} \quad (3)$$

where n is the minimum number of rows/columns, k is the degree of freedom, and Cramér's V is the coefficient that varies between 0 and 1 herein; 0 means zero correlation, and 1 represents the strong

correlation between studied variables (McHugh 2013).

In this paper, 4 different hypotheses are as depicted in Table 3.

**Table 3. Studied hypothesis in the research**

Number	Hypothesis
1	H <sub>0</sub> : There is no strong relationship between section control speed camera installation and crash intensity. H <sub>1</sub> : There is a strong relationship between section control speed camera installation and crash intensity.
2	H <sub>0</sub> : There is no strong relationship between section control speed camera installation and crash time. H <sub>1</sub> : There is a strong relationship between section control speed camera installation and crash time.
3	H <sub>0</sub> : There is no strong relationship between section control speed camera installation and crash category. H <sub>1</sub> : There is a strong relationship between section control speed camera installation and crash category.
4	H <sub>0</sub> : There is no strong relationship between section control speed camera installation and crash type. H <sub>1</sub> : There is a strong relationship between section control speed camera installation and crash type.

### 3. Results and Discussion

As discussed earlier, four different hypotheses were thoroughly examined in terms of a significant relationship and the degree of association. **Error! Reference source not**

**found.** through Table 7 demonstrates crosstabs employed for statistical analysis of the hypothesis as depicted in **Error! Reference source not found.** for 95% confidence interval.

**Table 4. Crosstab of speed camera installation and crash severities**

		Section Control Speed Camera		Total
		Not Installed	Installed	
Crash Intensity	property damage only	2195	1526	3721
	injury	11716	14065	25781
	fatality	340	195	535
Total		14251	15786	30037

**Table 5. Crosstab of speed camera installation and times of crash**

		Section Control Speed Camera		Total
		Not Installed	Installed	
Crash Time	Morning	5635	5645	11280
	Afternoon	8616	10141	18757
Total		14251	15786	30037

**Table 6. Crosstab of speed camera installation and crash categories**

		Section Control Speed Camera		Total
		Not Installed	Installed	
Crash category	motorcycle-pedestrian	3	3	6
	parked vehicle	16	8	24
	vehicle-bicycle	0	2	2
	motorcycle-motorcycle	5	1	6
	multiple vehicles	1353	2044	3397
	vehicle-barrier	1985	1421	3406
	vehicle-pedestrian	320	175	495
	vehicle-motorcycle	140	77	217
	single vehicle-single vehicle	8114	10452	18566

The Beneficial Effects of Section Control Speed Cameras on Variation of Freeway Crash Variables

	Section Control Speed Camera		Total
	Not Installed	Installed	
vehicle-bicycle	31	16	47
vehicle-bicycle	9	10	19
occupant-dropout	1	1	2
multiple types	579	57	636
single-vehicle run off	504	694	1198
indeterminate	511	81	592
single-vehicle rollover	679	742	1421
fired vehicle	1	2	3
Total	14251	15786	30037

Table 7. Crosstab of speed camera installation and crash types

Crash Type	Section Control Speed Camera		Total
	Not Installed	Installed	
rear-end	8031	8588	16619
single-vehicle	736	652	1388
T-bone	694	2007	2701
sideswipe	967	412	1379
head-on	456	119	575
indeterminate	3367	4008	7375
Total	14251	15786	30037

Table 8. Results of investigated hypothesis

Hypothesis number	$\chi^2$		Cramér's V	
	value	.Sig	value	.Sig
1	295.933	0.000 <sup>a</sup>	0.099	0.000 <sup>a</sup>
2	45.671	0.000 <sup>a</sup>	0.039	x0.000 <sup>a</sup>
3	1300.290	0.000 <sup>a</sup>	0.208	0.000 <sup>a</sup>
4	1062.947	0.000 <sup>a</sup>	0.188	0.000 <sup>a</sup>

<sup>a</sup> Figure is not absolute zero and is less than 0.001

The last column of **Error! Reference source not found.** indicates that there is statistically significant difference between section control speed camera installation status and each individual studied variable, implying that section control speed cameras significantly changed crash-related variables for the studied period.

It is worth mentioning that each crash related variables has their own levels and there might be contrasting changes in crash frequencies before and after the camera installation. But totally, there are significantly change in the number of crashes. Contrasting results are better depicted in **Error! Reference source not found.** through Table 7. For instance, aggregated number of property damage only and fatal crashes reduced after speed camera

implementation; however, the number of injury crashes increased after installation. This might be due to increase in traffic volumes as discussed earlier.

Table 5 tabulates descriptive analysis of the variation of total number of crashes regarding morning and afternoon implying worsened situation of afternoon crashes might rooted from lighting conditions rather than speed cameras. As Table 2 previously showed temporal section control speed camera installation status during eight years of study, it can be understood that speed cameras were installed from 2015 onwards. Accompanying the results of both Table 5 and Table 2, we may associate the increased number of crashes in the afternoon to the undeniable increases in the traffic flow (from 2015 onwards), which

exacerbate crash frequencies as an exposure variable.

In addition, results showed that section control speed cameras installation has minor effects on crash categories and crash types. Table 6 shows that single vehicle, vehicle-barrier, and multiple vehicle crashes are the most frequent crash categories, respectively. Table 7 also indicates that rear-end crashes are the most frequent crash type.

#### 4. Conclusion

Controlling driver speeding behaviour draws many safety researchers' attention. One way to mitigate speeding behaviour is by installing section control speed cameras. Despite the safety benefits, speed cameras may influence crash-related variables in different ways or perhaps at contrasting values. This study aimed to investigate these effects. In this regard, section control speed camera installation effects were investigated based on the aggregate number of crashes before and after the installation process. The Qazvin-Karaj freeway was chosen for research purposes. The effects on crash intensities, crash time, crash category, and crash type were studied. Using non-parametric Chi-square ( $\chi^2$ ) tests, results indicated that section control speed camera installation significantly varies between each variable level as all p-values were less than 0.001. Meanwhile, Cramér's V results showed that crash intensities and crash time are correlated with installation of section control speed cameras. However, crash category and crash type have a greater but marginal correlation with section control speed camera installation. It should be mentioned that all variables at hand were included. Thus, research is limited to viable variables. The traffic volumes of the studied freeway were not organized well and biased over time for the period of study, hence not included in the research and recommended to be undertaken in future studies to normalized crash data. The increased number of crashes after the section

control speed cameras was due to a daily increase in the number of travelling vehicles. However, this research showed fewer fatalities after cameras were established. Application of this research is that it can assist decision makers toward selecting proper budget assignment strategy to take control of speeding and resulted crash. For instance, they can extract crash patterns since crash related variables were significantly important.

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## The Beneficial Effects of Section Control Speed Cameras on Variation of Freeway Crash Variables

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