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# Studying the Role of Traffic Flow Control Methods in Freeways and its Effect on Drivers' Behavior

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## ABSTRACT

High and improper speed is one of the most important factors in traffic accidents in many countries; as long as vehicle and road conditions remain constant, the severity of the accident increases by speeding the vehicle up. Therefore, injuries and damages caused by traffic violations and, consequently, road accidents are important and significant matters challenging the public health of society. Therefore, speed management is necessary to control the severity of accidents; thus, it is important to reduce casualties due to accidents. Speed cameras could be considered as one of the most important tools for managing the traffic flow on freeways. The methodology of the present study is quantitative and cross-sectional, and its main purpose is to investigate and analyze the role of traffic flow control methods on freeways and its effect on driver's behavior on the Karaj-Qazvin freeway based on comparative and field studies. In this study, after reviewing the traffic flow control methods, a standard questionnaire was prepared to analyze the studied traffic flow control and their feasibility on the Karaj-Qazvin freeway and was distributed among the members of traffic police and drivers. Data were inputted into SPSS software, and research hypotheses were tested using linear regression. The results indicated that the number and type of video surveillance cameras, along with the simultaneous presence of police in the route, is effective to reduce speed and driving violations.

**Keywords: Traffic, Speed, Crash Reduction, Camera, Regression.**



## 1. INTRODUCTION

High and improper speed is one of the most important factors in traffic accidents in many countries[1-4]. The higher the speed, the greater the distance required to stop the car, resulting in an increased risk of injury from the accident. Many drivers are unaware of the involved risks and often consider the benefits of speed violation higher than its potentially critical consequences [5, 6]. Drivers' speed can be controlled by factors such as accelerators, traffic police, signs and equipment, and speed cameras. Speed cameras are considered one of the most important tools for managing the traffic flow on freeways. Speed cameras are used as an important element for managing vehicle speed in the field of intelligent systems. These cameras were first used in the United Kingdom in 1991 to encourage drivers to comply with speed limits. [7] The use of automatic speed control tools such as speed cameras will facilitate following up and warning the violators. In the traditional procedure, with the presence of police forces, when the offending vehicle is stopped for submitting the fine sheet, it occurs an interruption in the control process, which may lead to the failure to identify and stop other vehicles moving at an unauthorized speed at the same time. However, by using automatic speed control tools, there is no need to stop the car in place, and as a result, speed control will be done continuously. This will increase the performance of the police together with increasing the identification and arresting the offending drivers, which will by itself increase the level of deterrence [8]. Injuries resulting from traffic violations and, consequently, road accidents are important and significant issues that can challenge the public health of the community. Therefore, in order to reduce these damages, there is a need for coordinated and integrated

efforts and measures for applying effective and continuous prevention. According to the World Health Organization, globally 25 million people are killed in road accidents each year, and about 20 to 50 million people are seriously injured in these accidents [9].Every day, more than 3,000 people in the world die as a result of car accidents and injuries from it. In low-income and developing countries, road accidents are the cause of about 85% of deaths and 90% of disabilities of people involved [10]. Speed is the cause of most vehicle accidents, especially in those leading to serious injuries [11]. Studies indicated that the higher the speed of vehicles, the greater the chance of overturning and deviating the car, and the greater the likelihood of accidents, injuries, and deaths is. According to the traffic regulations of Iran, speed is divided into two categories: plan speed and allowable speed. Experts of the Association for Safe International Travel also predict that road accidents in 2030 will be the fifth leading cause of death if serious and practical efforts are not made to improve the laws and use of new technologies in the field of car safety. Today, developed countries are trying to improve the current situation and make optimal use of ITS equipment and facilities in order to increase safety and save energy, and delay travel time instead of building new roads at a high cost. Speed cameras are one of these efficient equipment that reduce traffic violations and consequently reduce road accidents. Methods for controlling the traffic flow and reducing the speed violations in the present study include two variables: speed cameras and police manpower [12].The high number of road violations and accidents indicates that traffic control and monitoring has not yet been fully achieved. The traditional management and surveillance system, due to the limited capabilities of the police force and control equipment, is not able to detect all violations by drivers, and therefore it is very important to use a system called ***Video Surveillance***.

In general, the roots of traffic violations can be categorized as follows [13]:

a- Violations with human causes and roots

- ✓ Violations caused by mental illness and disease;
- ✓ Violations due to haste (time factor) and individual indiscipline;
- ✓ Violations due to lack of personal and social responsibility;
- ✓ Violations due to insufficient knowledge about laws and regulations and philosophy of the existence of violations due to lack of familiarity with the outcome of the implementation of regulations.

b- Violations with environmental causes and roots

- ✓ Violations due to lack of urban network and proper roads;
- ✓ Violations due to deficiencies related to signs on the streets and roads;
- ✓ Violations due to weather and light factors

c- Violations due to control and executive weaknesses

- ✓ Violations due to improper training and inadequate training of driver;
- ✓ Violations due to the lack of seriousness of officials and agents for enforcing the regulations;
- ✓ Violations caused by not using new control equipment and road safety;
- ✓ Violations due to the long interval between the occurrence of the violation and the punishment of the violators;

In general, when examining the methods for controlling the flow of traffic on freeways, we find that the flow of traffic has had effects on the behavior of drivers that have not been able to properly address the problems of drivers. For this reason, in order to solve these problems, extensive studies have been carried out at the international, regional, and national levels by various organizations, and it is inevitable in this study to consider their importance, as well as reviewing and mentioning the titles of researches for the necessary guidelines. In 2019, Tabadkani Aval et al. prepared an article entitled "Cooperative Control Strategy and Integrated Tracking Based on Eligible Tracking to Control Traffic Flow on Freeways," indicating the congestion and road traffic as major problems in urban highway network design. To this end, traffic flow control strategies have been proposed in recent decades to address this problem. This paper has proposed an **Eligibility Tracking-based traffic control strategy** (ETRL). This strategy is based on Ramp Metering (RM) and Variable Speed Limit (VSL). To test the proposed method, the macroscopic traffic model was first calibrated through optimization of genetic algorithm (GA) to simulate traffic behavior; In addition, a traffic control strategy has been implemented along the M62 route, one of the smartest highways in the UK [14]. XinGu et al. (2019) prepared a paper called Using UAV Video Data for In-Depth Analysis of Driver Accident Risk in Merger Exchange Zones. In the merger exchange area, it suffers a lot of risks in the freeway system, which is highly related to strict enforcement merger maneuvers. Ignoring such a correlation may lead to limited and biased conclusions and ineffective countermeasures. Recently, the availability of drones has provided an opportunity to collect personal vehicle data for microscopic traffic analysis. These results could help traffic engineers taking different steps to increase the security of the merger area. The results also indicate the design of integrated areas and the emergence of connected vehicle technology [15]. In India, Narayana Raju et al. (2019) studied the issue of setting a risk-based safety threshold through naturalistic driving patterns using route data on highways. The study reported here has developed a micro-level parameter, i.e. immediate perception time (IPT), as a safety measure, which is a function of vehicle interactions [16]. Rongjian Daia et al. (2019) conducted a study as a simulation-based method to investigate the driver path selection behavior in a connected vehicle environment. This study assists in investigating the relationship between traffic system performance and driver path selection behavior in a connected vehicle environment. In particular, drivers' heterogeneity in terms of fuel consumption and travel time is taken into account. Using the multi-factor simulation method, microscopic and macroscopic behaviors of vehicle driver factors were investigated, and a series of simulation experiments were performed under different percentages of drivers who pay sufficient attention to fuel consumption, and then the simulation results were compared [17]. Rongjie Yu (2020) conducted a study on the patterns of road use in vehicles in the Shanghai Urban Highway System and their impact on traffic safety, in which the highway system plays a key role in the road transport system. However, the safety status of urban highways is becoming an important issue because many traffic accidents have had a major impact

on traffic operations. Among the factors influencing safety, various factors of operational traffic parameters (such as speed and volume of traffic), and geometric features have been extensively studied [18]. Ying Jiang et al. (2020) conducted a study entitled "Drivers' Behavioral Responses to Detecting the Driving Danger and Providing Real-Time Warning Information on the Highway: A Smartphone App-based Driving Experiment in Japan," indicates that using Smartphone Apps are an important topic in traffic safety research to detect driving hazards or provide the drivers with warning information. [19]. Lanfang Zhang et al. (2020) conducted a study in China on the safety effects of freeway electronic billboards on drivers' visual characteristics: Insights from field tests that the popularity and rapid growth of roadside electronic billboards in recent decades have led to extreme safety problems in China, especially at night time [20]. Xu Wang et al. (2020) studied the effect of open and medium management safety on wide one-way freeways: Assessing the driving simulations that it is mostly necessary to develop and upgrade highways to increase the capacity of the road network. This study proposes a method examining the safety of open management strategies for one-way highways [21].

## 2. METHODOLOGY

In this study, we intend to examine the psychological analysis of speed cameras on drivers' behavior and its analysis in comparison with the presence of police manpower, while examining the speed camera systems installed in recording the violations in Iran. We will also look at the combined role of speed cameras and police manpower, and ultimately select the best approach to reduce speeding violations. For this purpose, this research considers the analysis of the following variables:

- ✓ Presence of police manpower;
- ✓ The influencing role of all types of violation control cameras;
- ✓ The role of speed cameras in reducing violations
- ✓ Location of speed cameras
- ✓ Number of control cameras
- ✓ Speed installed in the vehicle speed lane
- ✓ Route information boards about speed cameras
- ✓ Familiarity of the driver with the route
- ✓ The combined role of speed cameras and police force for reducing the violations.

### *2.1. DATA COLLECTION TOOLS*

Due to the nature of the subject and the studied components, the approach for this research is of applied-developmental type and is of descriptive-analytical and survey in terms of methodology and is quantitative in term of its nature. Theoretical framework and data collection are conducted based on library and survey methods as well as field study and literature review related to the effective parameters in reviewing and analyzing the role of traffic flow control methods in freeways. Considering that various parameters affect the selection of these factors and the extent of the effects of these parameters are different from each other, thus, in this study using the method of linear regression analysis, the weight of different parameters is calculated, and in the next step a linear equation is presented in this regard.

### *2.2. POPULATION AND RESEARCH SAMPLE*

The statistical sample of the present study consists of two general groups, including the traffic police and road drivers, and since the expert must have sufficient knowledge about the study topic to be involved in the discussion and influence the process, The standard data for 384 people, who should have two characteristics, should, firstly be familiar with the subject and, secondly, have a work experience of five years or more, which were selected by purposive non-probabilistic sampling. Different methods are used to determine the sample size. In this study, the number of the statistical sample using Cochran's formula in equation (1) is 384 people.

$$n = \frac{(z)^2 \times \frac{pq}{d^2}}{1 + \frac{1}{N} \times \left(\frac{(z)^2 \times pq}{(d)^2} - 1\right)} = 384 \qquad (1)$$

According to the status of the statistical population, the form, as indicated in figures 1 to 3 according to gender, demographic situation of this research is presented in the degree, and work experience.

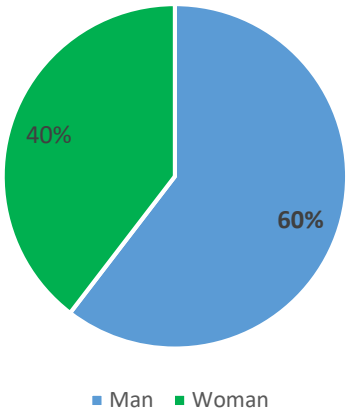


**Figure 1.** Frequency chart of the statistical population of this research by gender.

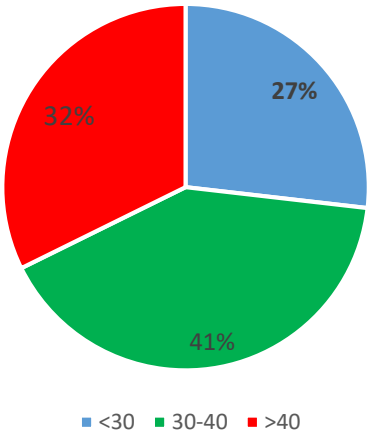


**Figure 2.** Frequency chart of the statistical population of this research By age.

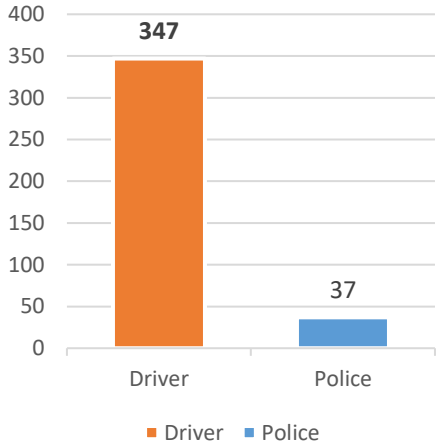


**Figure 3.** Frequency chart of the statistical population of this research based on the type of activity.

## 3. RESULTS AND DISCUSSION

### *3.1. INFERENTIAL ANALYSIS*

In order to determine the justifiability character in this research, first by reviewing the theoretical and experimental texts of domestic and foreign sources and research conducted in valid papers related to the subject, a list of questions was determined and selected through a survey of experts using the Delphi approach and was used in the form of a questionnaire as the main tool in collecting the information required for this research. Considering that in the first stage, the literature review was used and methods such as brainstorming and gathering ideas were not used; therefore, the questionnaire in the first stage is structured and analyzed using a 5-point Likert scale. Delphi panel members consisting of 12 people, were identified and selected using non-probabilistic sampling methods. After identifying the members of the panel and making the initial meeting, they were asked to determine the importance of each of the criteria, and in addition to the indicators presented in the form of a questionnaire, they also enter their desired indicators, and this trend was performed by Delphi method in three stages, and questionnaires of each stage were distributed and collected in person. Finally, the initial questionnaire consisted of 21 items, 10 items of which were removed in the first stage, and in the second stage, the question was removed, and the number of questions was reduced to 11 items. Table 1 indicates the reliability statistics of experts opinions on research components using Cronbach's alpha test:

**Table 1.** Cronbach's alpha coefficient for the reliability of the questionnaire.

| Number of items | Cronbach's alpha |
|---|---|
| 11 | 0.829 |

The results of reliable statistics of research components using Cronbach's alpha test indicate high reliability of the data collection tools of this research; because the average Cronbach's alpha coefficients are calculated above 0.7, indicating that there is a good reliability between opinions and expertise view. In this part of the research, the main questions of the questionnaire have been statistically analyzed.

### *3.2. DESCRIPTIVE STATISTICS OF RESEARCH VARIABLES*

In this section, using the data collected from the questionnaire, for each of the research variables, we provide statistics on the minimum and maximum values, mean and variance, skewness and elongation.

**Table 2.** Descriptive statistics of research variables.

| Variables | Minimum value | Maximum value | Mean | Var. | Skewness | Elongation |
|---|---|---|---|---|---|---|
| **Number of cameras** | 1 | 5 | 3.76 | 0.512 | -0.720 | -0.988 |
| **Type of cameras** | 1 | 5 | 3.79 | 0.809 | -0.399 | -0.617 |
| **Existence of police along the way** | 1 | 5 | 3.42 | 0.855 | -0.192 | -0.763 |
| **Existence of police and camera together** | 1 | 5 | 3.73 | 0.655 | -0.382 | -0.416 |
| **Existence of signboards** | 1 | 5 | 3.58 | 0.768 | -0.186 | -0.343 |

According to the above table, we conclude that all research variables have an average value of more than 3, and based on questionnaire options, it should be stated that in the viewpoint of participants in this study, factors such as the number and type of speed camera, the familiarity of drivers with the route and awareness from speed cameras, the presence of police along the route, the difference between the cameras, the simultaneous presence of police and speed cameras, the presence of traffic signs and recording the speed of vehicles and controlling the entrance to the freeway have reduced traffic violations on the Tehran-Karaj freeway. However, in the inferential part of this chapter, we will examine and test these cases through statistical methods. Among the variables of this study, the variable for the number of cameras with a variance of 0.512 had the lowest dispersion, and the variable of difference in cameras with a variance of 0.983 had the highest dispersion among the variables of this study. Also, the skewness and elongation of all variables in this study are in the numerical range of -2 to 2, and it can be stated that all variables and components of this study follow the normal distribution.

### 3.3. *CHECKING THE NORMALITY OF DATA DISTRIBUTION*

In this section, we use the Kolmogorov-Smirnov (KS) test to examine whether the data are normal or not; if the significance value is less than the significance level (0.05), the assumption of abnormality is confirmed. Table 3 indicates the results for examining this hypothesis.

**Table 3.** Data normality test

| Variables | KS statistics | Significance value |
|---|---|---|
| Number of cameras | 0.189 | <0.001 |
| Type of cameras | 0.143 | <0.001 |
| Existence of police along the way | 0.149 | <0.001 |
| Existence of police and camera together | 0.167 | <0.001 |
| Existence of signboards | 0.158 | <0.001 |

- According to this table, we conclude that the distribution of variables is not normal, but given that the number of samples is large (more than 30 people), then according to a theorem in statistics called the ***Central Limit Theorem***, the distribution of this data can be considered normal; In fact, since the number of samples is high, the distribution of data can be considered normal. To prove this, it can be cited to the data elongation and skewness. According to the test results as in Table 4-6, the skewness and elongation statistics of the variables are in the range (2 and 2-), so the condition of not violating the normal distribution of data is maintained.
- According to the above table, the regression coefficient for the variable of speed video surveillance camera and the presence of police manpower together is equal to 0.498, which is a positive value, i.e. speed video surveillance camera and the presence of police manpower together can have a positive effect on reducing the driving violations. Therefore, the simultaneous presence of speed cameras and police manpower will reduce traffic violations. Also, the significance of this coefficient has been less than 0.05, and the effectiveness of the video surveillance camera confirms together the speed and the presence of the police manpower in reducing traffic violations.

Hypothesis 5: Track information boards for speed cameras are effective in the level of drivers' performance and reduce the rate of traffic violations.

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**Table 4.** Regression results for testing the fifth hypothesis

| Variable | Regression coefficient | Significant value of regression coefficient | F statistics |
|---|---|---|---|
| Track information boards for speed cameras | 0.037 | 0.481 | 0.498 |

More, we will present the results of multiple regression and regression equation between the variable for reducing the violations and independent variables including a number of speed video surveillance camera, type of speed video surveillance camera, the existence of police manpower and simultaneous existence of police manpower and speed video surveillance camera:

**Table 5.** Results of multiple regression model

| Variable | Regression coefficient | Standard error | T statistics | Significance value | VIF |
|---|---|---|---|---|---|
| Intercept | 0.048 | 0.237 | 2.01 | 0.840 | --- |
| Number of cameras | 0.360 | 0.049 | 7.345 | 0 | 1.183 |
| Type of cameras | 0.516 | 0.044 | 11.667 | 0 | 1.521 |
| Existence of police along the route | 0.354 | 0.042 | 1.282 | 0.001 | 1.434 |
| Existence of both police and camera | 0.355 | 0.040 | 1.377 | 0.009 | 1.004 |
| The coefficient of determination | 0.510 | F significance level | 0 | Watson Camera Statistics | 1.543 |

According to the table above, the regression equation of this research is as follows:

$Y= 0.360x_1+ 0.516x_2+ 0.354x_3+0.355x_4$

Where the variables y, x1 to x4 include the reduction of violations, the number of speed video surveillance cameras, the type of speed video surveillance camera, the presence of police, and the simultaneous existence of camera and police along the route, respectively.

Also, according to results given in Table 6, the following results were obtained:

- According to the value of the obtained coefficient of determination, more than 50% of the changes in the variable for reducing the violations can be expressed by the variables for the number of speed video surveillance camera, type of speed video surveillance camera, presence of police and simultaneous presence of camera and police along the route.
- The significance level F is equal to zero, based on which it should be said that the fitted model is significant.
- The value of Watson's camera statistics ranges from 1.5 to 2.5; therefore, it is assumed that the regression model errors are independent.
- The VIF values used to check for alignment between the independent variables are close to 1 for every 4 independent variables in the study; therefore, there is no alignment problem between the variables of speed video surveillance camera, type of speed video surveillance camera, presence of police and the simultaneous presence of camera and police along the route. If the VIF values are close to 10, it indicates that there is an alignment between the independent variables. The following figure also indicates the normal probability plot of regression standardized residuals.

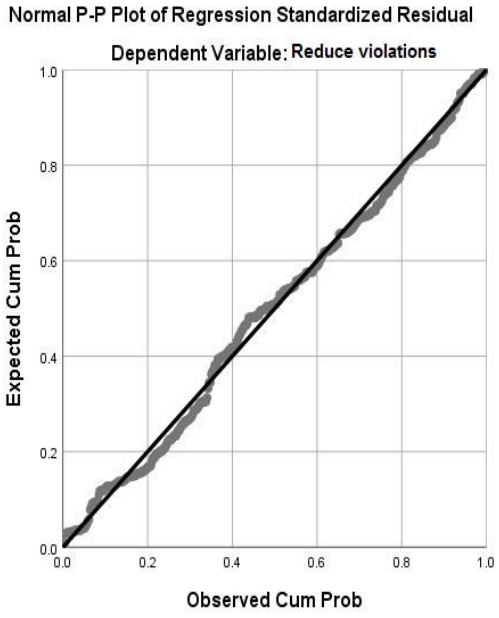


**Figure 4.** Normal probability plot of residuals.

**Table 6.** Summarizes the results of these hypotheses:

| Hypothesis | Result of hypothesis |
|---|---|
| The number of speed video surveillance cameras is effective in reducing traffic violations | Accepted |
| The type of speed video surveillance camera is effective for reducing driving violations. | Accepted |
| The presence of police manpower along the route is effective for reducing the traffic violations | Accepted |
| The presence of speed video surveillance cameras and the presence of police manpower together is effective for reducing the traffic violations | Accepted |
| Route information boards for speed cameras | Rejected |

## 4. CONCLUSION

As indicated in the previous hypotheses, both the type of camera and number of speed video surveillance and the presence of police personnel along the route had an effect on reducing the traffic violations, and it was expected that the simultaneous presence of both factors together would also reduce the number of violations followed by reduced driving crashes. Therefore, the regression equation between the variable for reduction of violations and the variables for the number of speed video surveillance camera, type of speed video surveillance camera, presence of police, and simultaneous existence of camera and police along the route are as follows:

$$Y= 0.360x_1+ 0.516x_2+ 0.354x_3+0.355x_4$$

Where the variables y, $x_1$ to $x_4$ include the reduction of violations, the number of speed video surveillance cameras, the type of speed video surveillance camera, the presence of police and the simultaneous existence of camera, and police along the route, respectively. This regression model expresses more than 50% of the changes in the variables for violation reduction variable by the variables for speed video surveillance camera, type of speed video surveillance camera, presence of police, and the simultaneous presence of camera and police along the route. As can be seen from this equation, the coefficients of the variables for the number of speed video surveillance camera, type of speed video surveillance camera, presence of police and the simultaneous presence of the camera, and police along the route are positive, indicating the positive, and direct impact of these variables on reducing traffic violations.

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AUTHORS CONTRIBUTION

This work was carried out in collaboration among all authors.

CONFLICT OF INTEREST

The author (s) declared no potential conflicts of interests with respect to the authorship and/or publication of this paper.

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