

Research Article

Analysis of the Impact of Traffic Violation Monitoring on the Vehicle Speeds of Urban Main Road: Taking China as an Example

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In recent years, there are more and more applications of traffic violation monitoring in some countries. The present work aims to analyze the vehicle speeds nearby road traffic violation monitoring area on urban main roads and find out the impact of road traffic violation monitoring on the vehicle speeds. A representative urban main road section was selected and the traffic flow was recorded by camera method. The vehicle speeds before, within, and after the road traffic violation monitoring area were obtained by the calculation method. The speed data was classified and processed by SPSS software and mathematical method to establish the vehicle speed probability density models before, within, and after the road traffic violation monitoring area. The results show that the average speed and maximum speed within the traffic violation monitoring area are significantly slower than those before and after the traffic violation monitoring area. 70.1% of the vehicles before the road traffic violation monitoring area were speeding, and 80.2% of the vehicles after the road traffic violation monitoring area were speeding, while within the road traffic violation monitoring area, the speeding vehicles were reduced to 15.9%. When vehicles pass through the road traffic violation monitoring area, the vehicle speeds tend to first decrease and subsequently increase. In its active area, road traffic violation monitoring can effectively regulate driving behaviors and reduce speeding, but this effect is limited to the vicinity of the traffic violation monitoring. The distribution of vehicle speeds can be calculated from vehicle speed probability density models.

1. Introduction

In many countries, with the development of the social economy, the number of automobiles has increased yearly, and a series of problems such as road congestion mess in traffic order and traffic accidents becomes frequent [1–7]. Traffic accidents can cause huge casualties and economic losses [8]. To maintain traffic order and reduce the occurrence of traffic accidents, traffic violation monitoring systems have been installed in some risk road sections (such as school sections and main road sections). A traffic violation monitoring system can capture and process various traffic violations such as speeding, illegal lane changes, and traffic sign violations in the active area. It primarily uses computer image processing technology and communication technology and obtains illegal vehicle information through an

automatic detection device. It can regulate driving behaviors and ensure road traffic safety [9–13]. Some scholars have studied the effect of traffic violation monitoring on driving behaviors and vehicle speed. Zhu et al. [14] believed that traffic violation monitoring significantly affects driving behaviors. Traffic violation monitoring can effectively reduce the probability of traffic accidents. Traffic violation monitoring has a positive effect on road traffic safety. Pan et al. [15, 16] found that intersection traffic violation monitoring can effectively regulate the behavior of drivers and reduce the occurrence of speeding, which helps to reduce the occurrence of traffic accidents. Luo et al. [17] obtained drivers' opinions on traffic violation monitoring through a questionnaire survey, and they noted that traffic violation monitoring can alert the driver and reduce the occurrence of speeding, illegal lane changes, and other behaviors. Zhang

et al. [18] analyzed the effect of traffic violation monitoring on driving behaviors from the psychological point of view. They believe that traffic violation monitoring may negatively affect driving behaviors and that rear-end accidents significantly increase under traffic violation monitoring. Qian [19] studied driving behaviors under traffic violation monitoring at intersections and proposed that traffic violation monitoring helps to ensure traffic safety. Jiang et al. [20] studied the impact of traffic violation monitoring on traffic accidents at intersections in response to China's specific national conditions. They believe that traffic violation monitoring can reduce the occurrence but increase the severity of traffic accidents. Ahmed and Abdel-Aty [21] analyzed traffic accidents at intersections and found that traffic violation monitoring would reduce left-turn traffic accidents but increase traffic accidents in other directions. Chai et al. [22] believed that traffic violation monitoring has different effects on different types of traffic accidents. Traffic violation monitoring reduces the occurrence of collision accidents, but the probability of rear-end accidents increases. Pulugurtha and Otturu [23] analyzed traffic accidents with or without traffic violation monitoring at intersections and found that traffic violation monitoring at intersections increased rear-end accidents by 50% but reduced total traffic accidents by 16%. Higgins et al. [24] believed that traffic violation monitoring significantly affects driving behaviors and that most drivers and nondrivers support the installation of traffic violation monitoring.

At present, research on the impact of traffic violation monitoring on drivers is mostly concentrated at the intersection and focuses on the impact of traffic violation monitoring on traffic accidents. There are few studies on road traffic violation monitoring. In recent years, some countries such as China have implemented the large-scale installation of traffic violation monitoring facilities on urban roads to regulate driving behaviors, but the mechanism of the impact of traffic violation monitoring on drivers is not clear. To clarify the rationale and necessity of road traffic violation monitoring, we explore the impact of road traffic violation monitoring on driving behaviors and traffic safety. This work conducts field measurements through cameras, obtains vehicle speed data from different sections (before, within, and after the road traffic violation monitoring area), and studies the impact of road traffic violation monitoring on vehicle speeds.

2. Methodology

2.1. Data Collection Site. The road section selected in this study is a typical urban main road, Jialingjiang East Road, located in Huangdao District, Qingdao, Shandong Province, China. This traffic violation monitoring site is located on Jialingjiang East Road, specifically at 2000 m west of the intersection of Jialingjiang East Road and Hengshan Road in Huangdao District, Qingdao, and 500 m west of the south gate of Jialingjiang Road Campus of the Qingdao University of Technology. Its geographical location is shown in Figure 1.



FIGURE 1: Geographic location of the data collection area.

Jialingjiang East Road is a one-way three-lane road with an isolation barrier in the middle of the road to isolate the two-way traffic flow. The traffic violation monitoring device on this road is in the form of cantilever beams, which can completely cover 3 lanes, as shown in Figure 2.

2.2. Data Acquisition Method. The data acquisition devices are mainly cameras. The central point of the traffic violation monitoring area in this paper refers to the center point of the visual field of the traffic violation monitoring camera. One video device each is set up at the center of the traffic violation monitoring area as well as 100 m before and after it, and these devices are used to measure the speed of the same vehicle passing through the three places. Traffic violation monitoring is typically installed above the road. The installation height is generally 4.5 m, and the monitoring device is at an angle of approximately 60° to the road plane. Therefore, the center of the monitoring area is approximately 8 m ahead of the monitoring device.

The data collection took two days and was completed four times; each recording took thirty minutes. The collection time is concentrated in the common period. The data collection section is a representative urban main road section with a speed limit of 40 km/h. The vehicle speed measurement method is shown in Figure 3.

The speed measurement steps are as follows:

- (1) Place cameras at points 1, 2, and 3, install and debug the cameras, and make preparations. Make sure that the camera has no visual field barrier at the shooting site.
- (2) Set three background markers on the opposite side of the road and find three background markers on the camera screen.
- (3) When the camera, vehicle, and background markers are aligned, make a vertical line from the vehicle to the roadside and record the vertical points as S_1 , S_2 , and S_3 .
- (4) After the data have been collected in the field, the video is processed, and the required data are recorded. The speed and acceleration of the vehicle cannot be directly obtained from the video but can be calculated based on the collected data.

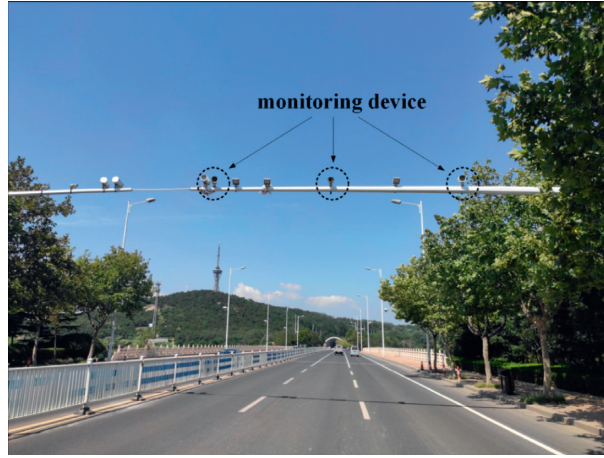


FIGURE 2: Actual road conditions of the data collection road section.

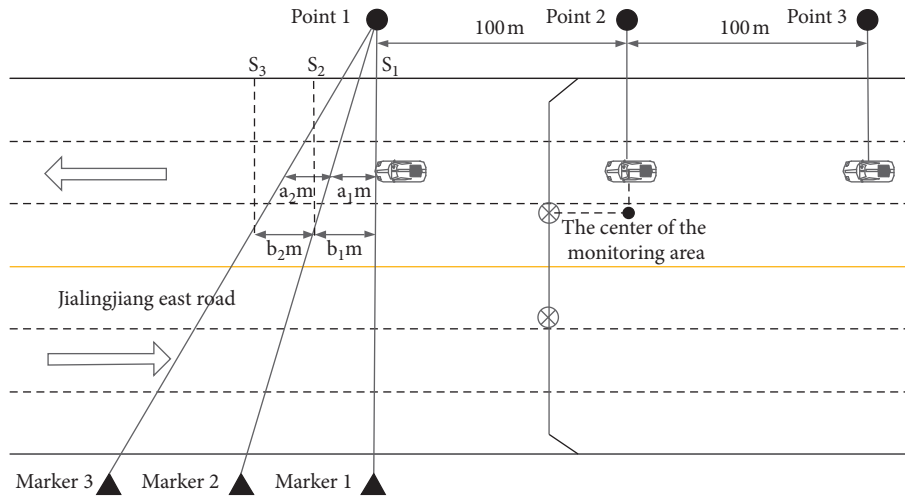


FIGURE 3: Vehicle speed measurement method.

$$V = \frac{S_{13}}{T_{13}}, \tag{1}$$

$$a = \frac{(V_{23} - V_{12})}{T_{13}}.$$

In the formula, V is the average speed of the corresponding section. Because the distances among signs 1, 2, and 3 are relatively small, V can also be considered the instantaneous speed, S is the length of the corresponding section, T is the time difference between vehicles passing through the section, and a is the average acceleration of the vehicle passing the corresponding section. Since the distance between marker 1 and marker 3 is relatively small, the acceleration can be considered the instantaneous acceleration.

The data acquisition and data processing of measurement points 2 and 3 are identical to those of measurement point 1. After screening, 515 groups were obtained, totaling 1,545 valid vehicle data.

2.3. Sample Size Test of the Data. Due to the error of the measuring device and limited ability of the observer to identify the organ, there will be errors in the placement, sighting, and reading of the instrument

In addition, external conditions such as temperature, humidity, wind, and atmospheric refraction during the observation will directly affect the observed data. Therefore, to ensure the accuracy of the experimental results and reduce the impact of errors on the experimental results, the amount of measurement data must be guaranteed. Only when the sample size reaches the minimum sample size requirement do the experimental results become credible, and whether the sample size of the test data satisfies the requirements can be determined by the following formula:

$$N = \frac{Z^2 p(1 - p)}{E^2}. \tag{2}$$

In the formula, N is the minimum number of samples required for the experiment; Z is the confidence coefficient, which is used to characterize the reliability. When the

confidence is 90%, $Z = 1.65$, and when the confidence is 95%, $Z = 1.96$; with higher confidence, a larger sample size is required; E is the maximum allowable error in data measurement. The smaller the allowable error, the larger the sample size required; and P is the ratio of the number of measured samples to the total traffic flow during the measurement period. In this paper, the maximum allowable error is 5%, and the confidence is 95%. After the calculation, the minimum sample size is 384. The sample size of this paper is much larger than the minimum sample size, so the sample size of this paper satisfies the requirements.

3. Data Analysis and Results

3.1. Speed Analysis. The vehicle speed statistics and vehicle speed distribution are shown in Table 1 and Figures 4 and 5.

Table 1 shows that the average speed and maximum speed within the traffic violation monitoring area are significantly slower than those before and after the traffic violation monitoring area. Thus, the road traffic violation monitoring system can effectively alert the driver to follow the traffic regulations and suppress the occurrence of speeding. In turn, the probability of traffic accidents decreases. When the vehicle passes through the sections before, within, and after the road traffic violation monitoring, the general trend of the average speed is first a reduction and subsequently an increase, which indicates that the road traffic violation monitoring interferes with the typical driving behavior and induces the occurrence of traffic accidents [25, 26]. The road traffic violation monitoring is not absolute for traffic safety. On the one hand, road traffic violation monitoring can reduce the probability of accidents in the active area; on the other hand, traffic violation monitoring may increase the probability of accidents within the transitional areas before and after the traffic violation monitoring.

Figure 4 shows that before the traffic violation monitoring area, the maximum speed is greater than 40 km/h in 70.1% of the cases; the second most common speed range is 30–40 km/h, occurring in 26.4% of the cases; and the least common speed range is less than 30 km/h, occurring in 3.5% of the cases. Within the traffic violation monitoring area, the most common maximum speed is 30–40 km/h (more than 70%), the second most common range is greater than 40 km/h (15.9%), and the least common range is less than 30 km/h (11.8%). After the traffic violation monitoring area, the most common maximum speed is greater than 40 km/h (80.2%), the second most common range is 30–40 km/h (18.4%), and the least common range is less than 30 km/h (1.4%). When a vehicle is driving within the traffic violation monitoring area, speeding is obviously reduced. Most drivers drive at a speed slightly lower than the speed limit standard. When they leave the traffic violation monitoring area, the frequency of speeding is the highest, which is related to factors such as the psychological relaxation of the driver immediately after leaving the traffic violation monitoring area and the personal characteristics of the drivers.

Figure 5 consists of 515 sets of vehicle speed data, arranged according to the order of data collection. Figure 5 shows that within a given set of speed data, the speed of the

vehicle before and after the monitoring area is generally higher, and the speed of the vehicle within the monitoring area is generally the lowest. Thus, for a single vehicle, when it passes through the three sections before, within, and after the traffic violation monitoring area, the speed trend has a greater probability of first decreasing and subsequently increasing. According to statistics, among the 515 sets of data, 358 sets of data had the slowest speed in the monitoring area, which accounts for 70% of the total sample. Hence, 70% of the vehicles have the obvious behavior of first decelerating and subsequently accelerating when passing through the road traffic violation monitoring area. It can also be understood that when a vehicle passes through the road traffic violation monitoring area, there is a 70% probability that it will first decelerate and subsequently accelerate.

3.2. Hypothesis Test. Whether the road traffic violation monitoring significantly affects the driving behaviors and speeds is related to the rationale of road traffic violation monitoring installation. To determine whether the road traffic violation monitoring will affect vehicle speed, the single-factor hypothesis test is conducted for the data.

Test hypothesis

$$H_0: u_1 = u_2 = u_3. \quad (3)$$

In other words, road traffic violation monitoring has no significant impact on speeds:

$$H_1: u_1, u_2, u_3 \text{ not all equal.} \quad (4)$$

In other words, road traffic violation monitoring has a significant impact on speeds:

$$\begin{aligned} SST &= \sum_{j=1}^S \sum_{i=1}^{n_j} (X_{ij} - \bar{X})^2, \\ SSA &= \sum_{j=1}^S \sum_{i=1}^{n_j} (X_{.j} - \bar{X})^2, \\ SSE &= \sum_{j=1}^S \sum_{i=1}^{n_j} (X_{ij} - \bar{X}_{.j})^2, \\ MSA &= \frac{SSA}{f_A}, \\ MSE &= \frac{SSE}{f_e}. \end{aligned} \quad (5)$$

In the formula, u_1 , u_2 , and u_3 are the speeds before, within, and after the road traffic violation monitoring area, respectively; SST is the total variation, which is the reflection of the difference among all test data; SSE is the error square sum, i.e., the sum of squares of deviations between the measured values of different measurement positions and the average values of the positions. SSE can reflect the fluctuations caused by the average errors; SSA is the sum of the squared effects, which is the sum of the squares of the deviations between the average of the measured values at

TABLE 1: Speed statistics.

Position	Before the traffic violation monitoring area	Within the traffic violation monitoring area	After the traffic violation monitoring area
Average (km/h)	48.0	37.8	50.3
Variance	100.0	49.0	94.1
Standard deviation	10.0	7.0	9.7
Range	46.0	46.0	45.0
Coefficient of variation	20.9	18.2	19.3
Skewness	0.6	1.4	0.4
Kurtosis	2.8	3.9	2.3
Maximum (km/h)	71.0	70.0	71.0
Minimum (km/h)	26.0	24.0	27.0

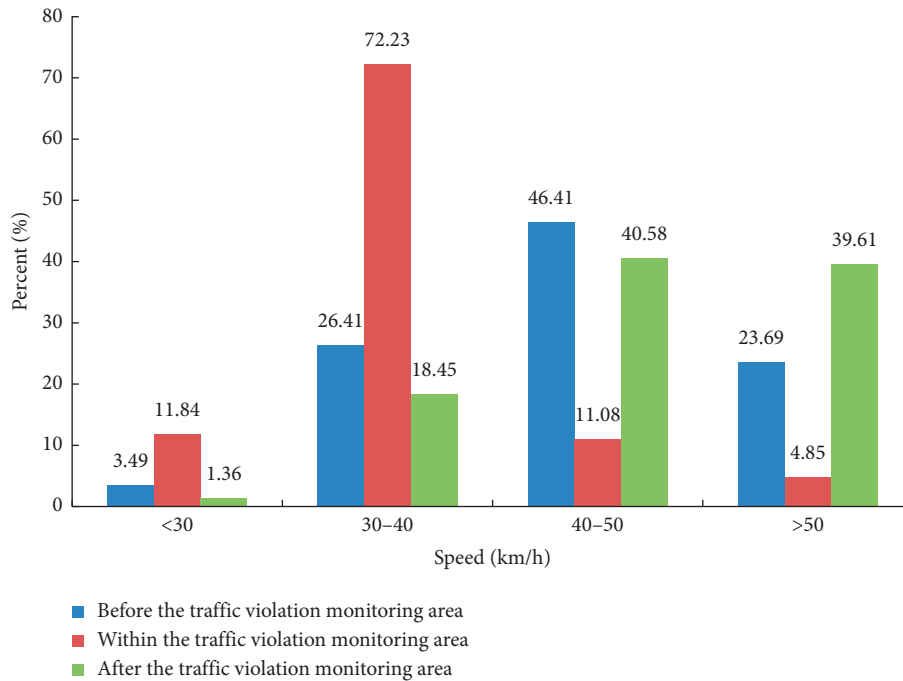


FIGURE 4: Vehicle speed distribution.

different points and the total average; n is the total number of vehicle speed data; s is the number of groups of vehicle speed data; f_T is the degree of freedom between groups, $f_T = n - 1$; f_e is the degree of freedom in the group, $f_e = n - s$; f_A is the overall degree of freedom, $f_A = S - 1$; MSA is the variance within the group; and MSE is the variance between groups.

The variance analysis table is obtained by processing the vehicle speed data using MATLAB software, as shown in Table 2.

Since $F_0 > F_{0.01}(2, 1542)$, H_0 is rejected; i.e., the road traffic violation monitoring has a significant impact on vehicle speeds.

3.3. Acceleration Analysis. The acceleration statistics and acceleration distribution are shown in Table 3 and Figures 6, and 7.

Table 3 shows that the average acceleration at different positions (before, within, and after the traffic violation

monitoring area) is significantly different. Generally, before the road traffic violation monitoring area, the driver tends to slow down; in the road traffic violation monitoring area, the driver tends to travel at a constant speed; and after the road traffic violation monitoring area, the driver tends to accelerate. In addition, when the vehicle passes through the road traffic violation monitoring area, the overall trend of the vehicle speeds is first a decrease and subsequently an increase.

Figure 6 consists of 515 sets of acceleration data, arranged according to the order of acquisition. Figure 6 shows that the acceleration before the monitoring area is mostly distributed in $(-1.3, -0.5)$, the acceleration in the monitoring area is mostly distributed in $(-0.4, 0.4)$, and the acceleration after the monitoring area is mostly distributed in $(0.6, 1.4)$. Hence, before the monitoring area, the driver tends to slow down; in the monitoring area, the driver tends to drive at a uniform speed; and after the monitoring area, the driver tends to accelerate. Taking any of the 515 sets of

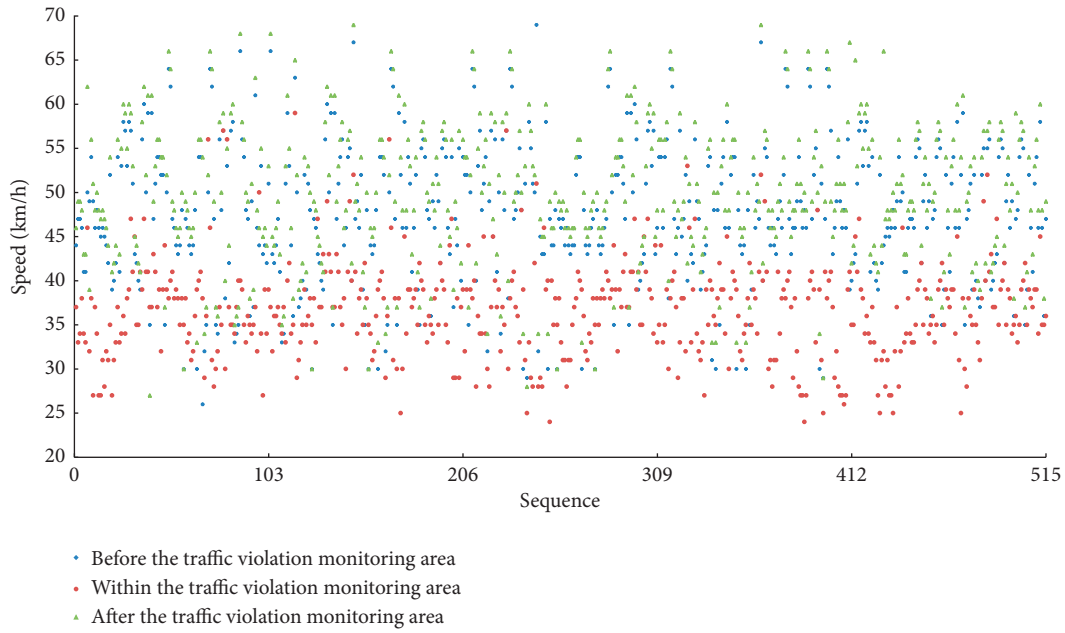


FIGURE 5: Vehicle speed distribution.

TABLE 2: Analysis of variance.

Source of variance	Square of deviance	Degree	Variance	F	F_{α}	Significance
Between groups	107.95	2	202.98	$F_0 = 4.55$	$F_{0.05}(2, 1542) = 3.00$	Significant
Within group	67.91	1542	70.92	—	$F_{0.01}(2, 1542) = 4.61$	—
Sum	175.86	1544	—	—	—	—

TABLE 3: Acceleration statistics.

Position	Before the traffic violation monitoring area	Within the traffic violation monitoring area	After the traffic violation monitoring area
Average (m/s^2)	-0.76	0.03	0.92
Variance	0.4	0.1	0.2
Standard deviation	0.6	0.3	0.4
Range	2.0	1.6	1.7
Coefficient of variation	-78.5	51.9	59.0
Skewness	-0.8	0.5	-0.3
Kurtosis	-0.3	2.6	-0.9
Maximum (m/s^2)	0.5	1.1	2.9
Minimum (m/s^2)	-2.7	-1.2	-0.6

data, the acceleration rate is very likely less than 0 before the monitoring area, approximately 0 in the monitoring area, and greater than 0 after the monitoring area. Thus, near the traffic violation monitoring area, a single driver has a high probability of first decelerating, subsequently driving at a constant speed, and finally accelerating.

Figure 7 shows that the acceleration range in the traffic violation monitoring area is the smallest, followed by that before the monitoring area and that after the monitoring area, where the acceleration is most dispersed. Thus, the traffic order within the traffic violation monitoring area of the road section is the best, the traffic violation monitoring area before the road section is second best, and the order

after the traffic violation monitoring area of the road section is the most chaotic, which increases the probability of rear-end accidents before the road traffic violation monitoring area and the probability of speeding and illegal overtaking after the road traffic violation monitoring area.

3.4. Normality Test. The Kolmogorov–Smirnov test, also called the $K-S$ test, is a commonly used method in statistical analysis. It compares the data required for statistical analysis with another set of standard data to obtain the deviation between it and the standard data. The Kolmogorov–Smirnov test is often used to test the normality of the data

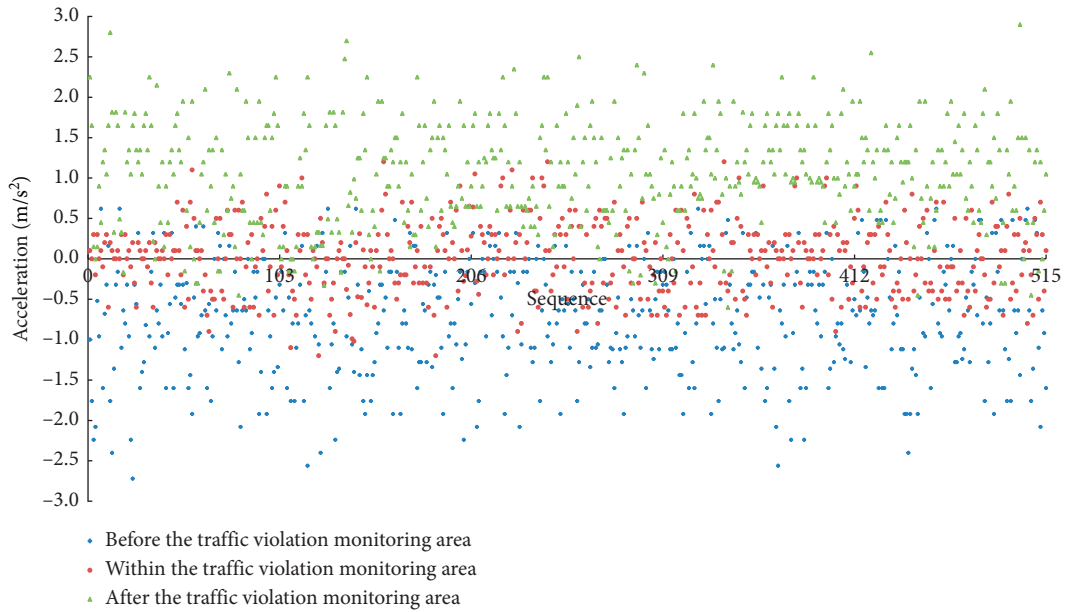


FIGURE 6: Acceleration distribution.

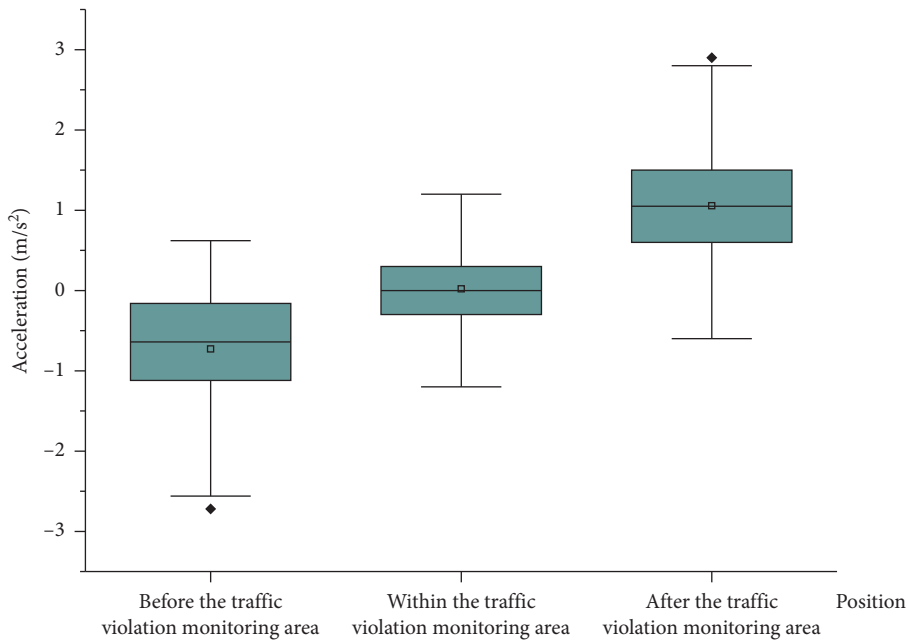


FIGURE 7: Acceleration box diagram.

distribution. When the P value is greater than 0.05, the measured data can be considered to obey a normal distribution [27].

The Shapiro–Wilk test, also called the S - W test, is a method of normal distribution testing for frequency data. When the P value is greater than 0.05, the measured data can be considered to obey a normal distribution [28].

The Kolmogorov–Smirnov test and the Shapiro–Wilk test are two commonly used methods for normal distribution detection. The largest difference between them is that

the Kolmogorov–Smirnov test is suitable for the statistical analysis of a large number of data samples, and the Shapiro–Wilk test is suitable for the statistical analysis of a small number of data samples. In this paper, the sample number of vehicle speed data is moderate, so both test methods are used. The speed data are processed by SPSS software, and the results are shown in Table 4.

Table 4 shows that for both the Kolmogorov–Smirnov test and the Shapiro–Wilk test, the P values for vehicle speed before, within, and after the road traffic violation monitoring

area are greater than 0.05, which indicates that the distributions of vehicle speed before, within, and after the road traffic violation monitoring area obey a normal distribution.

3.5. Modeling and Analysis

- (1) The vehicle speed distribution model within the road traffic violation monitoring area is as follows. Table 1 shows that the speeds nearby the road traffic violation monitoring area obey a normal distribution of $N(37.8, 49)$ and that the probability density function is

$$f(x) = \frac{1}{\sqrt{98\pi}} e^{-((x-37.8)^2/98)}. \quad (6)$$

In equation (6), x is the vehicle speed. According to equation (6), the distribution curve is shown as Figure 8, and the average vehicle speed within the road traffic violation monitoring area is slightly lower than the maximum speed limit of the road.

By analogy, it can be concluded that the average speed within the monitoring area is approximately $0.95a$ on a road with a maximum speed limit of a km/h. Hence, on a road with the highest speed limit of a km/h, the vehicle speed probability density model within the road traffic violation monitoring area is

$$f(x) = \frac{1}{\sqrt{98\pi}} e^{-((x-0.95a)/98)}. \quad (7)$$

In equation (7), x is the vehicle speed. From equation (7), the distribution curve is shown as Figure 9, and it can be calculated that when a vehicle with a maximum speed limit of a km/h travels in the monitored area, there is a 68.2% probability that its speeds are in the range of $(0.95a - 7, 0.95a + 7)$ km/h, with a 95% probability in the range of $(0.95a - 14, 0.95a + 14)$ km/h.

- (2) The model of vehicle speed distribution before the road traffic violation monitoring area, i.e., the vehicle speed distribution model within the transition zone before the road traffic violation monitoring area, is as follows. Table 1 shows that the vehicle speeds before the monitoring area obey the normal distribution of $N(48, 100)$, and compared with the values within the monitoring area, the average speed and standard deviation before the monitoring area are slightly higher. Assuming that the length of the transitional zone before the traffic violation monitoring area is 100 m and the transition is completed at 30 m in front of the center of the monitoring area, it is considered that the vehicle uniformly decelerates throughout the transitional area and the variance of the vehicle speed distribution has a positive correlation with the vehicle speed. Therefore, on a road with the maximum speed limit of a km/h, the vehicle speed probability density model at b m in front of the center of the road traffic violation monitoring area is inferred to be

$$f(x) = \frac{1}{\sqrt{2\pi(6.2 + 0.03b)^2}} e^{-([x - (0.84a + 0.0035ab)]^2 / 2(6.2 + 0.03b)^2)},$$

$$30 < b < 130.$$

(8)

In equation (8), x is the vehicle speed. From equation (8), the distribution curve is shown as Figure 10, and it can be calculated that when a vehicle is about to enter the transition zone (before the road traffic violation monitoring with a maximum speed limit of a km/h, there is a 68.2% probability that its speeds are in the range of $(1.3a - 10.1, 1.3a + 10.1)$ km/h and a 95% probability in the range of $(1.3a - 20.2, 1.3a + 20.2)$ km/h; for S_1 at any point in the former transition zone, the distance between S_1 and the center of the traffic violation monitoring area is L -m, and with 68.2% probability, the range of the vehicle speeds at that point is $(0.84a - 0.03L + 0.0035aL - 6.2, 0.84a + 0.03L + 0.0035aL + 6.2)$ km/h, and with 95% probability, the range of vehicle speeds is $(0.84a - 0.06L + 0.0035aL - 12.4, 0.84a + 0.06L + 0.0035aL + 12.4)$ km/h. When a vehicle is about to leave the former transition zone, there is a 68.2% probability that its speeds are in the range of $(0.95a - 7, 0.95a + 7)$ km/h and a 95% probability in the range of $(0.95a - 14, 0.95a + 14)$ km/h.

- (3) The model of vehicle speed distribution after the road traffic violation monitoring area, i.e., the vehicle speed distribution model within the transition zone after the road traffic violation monitoring area, is as follows. Table 1 shows that the vehicle speed after the monitoring area obeys the normal distribution of $N(50.3, 94)$, and compared with the values in the monitoring area, the average speed and standard deviation after the monitoring area are slightly higher. Assuming that the length of the transitional section after the traffic violation monitoring area is 100 m and the transition is completed at 30 m past the center of the monitoring area, it is considered that the vehicle is driving uniformly decelerating throughout the transitional area and the variance of the vehicle speed distribution is positively correlated with the vehicle speeds. Therefore, on a road with the maximum speed limit of a km/h, the vehicle speed probability density model at c -m past the center of the road traffic violation monitoring area is inferred to be

$$f(x) = \frac{1}{\sqrt{2\pi(6.2 + 0.03c)^2}} e^{-([x - (0.82a + 0.0044ac)]^2 / 2(6.2 + 0.03c)^2)},$$

$$30 < c < 130.$$

(9)

In equation (9), x is the vehicle speed. From equation (9), the distribution curve is shown as Figure 11, and it can be

TABLE 4: Kolmogorov-Smirnov test and Shapiro-Wilk test results.

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistical	Degree	Sig	Statistical	Degree	Sig
Before the traffic violation monitoring area	0.13	515	0.19	0.93	515	0.22
Within the traffic violation monitoring area	0.13	515	0.30	0.94	515	0.27
After the traffic violation monitoring area	0.06	515	0.17	0.98	515	0.11

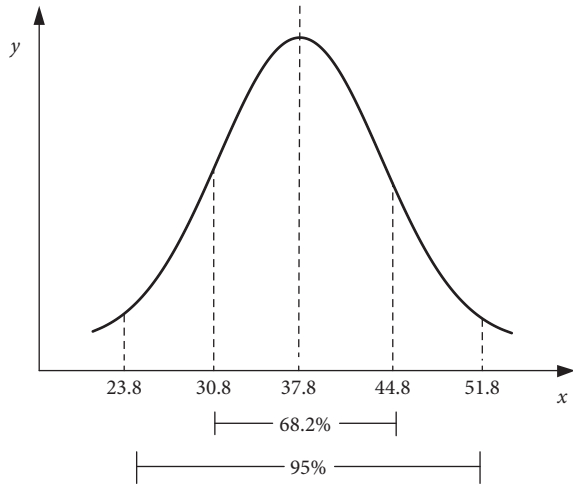


FIGURE 8: Distribution curve of equation (6).

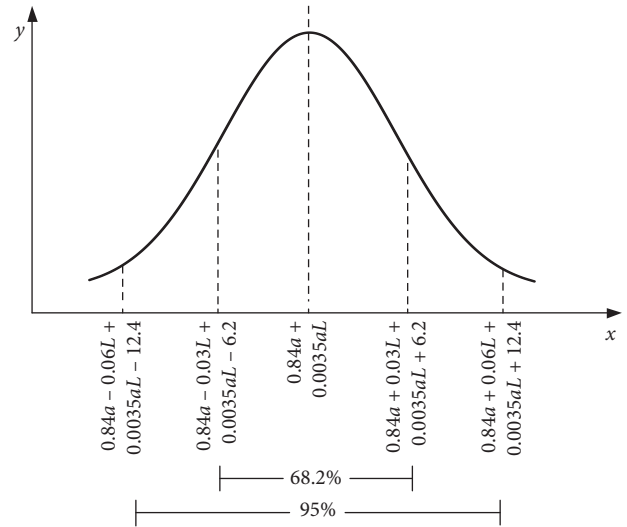


FIGURE 10: Distribution curve of equation (8).

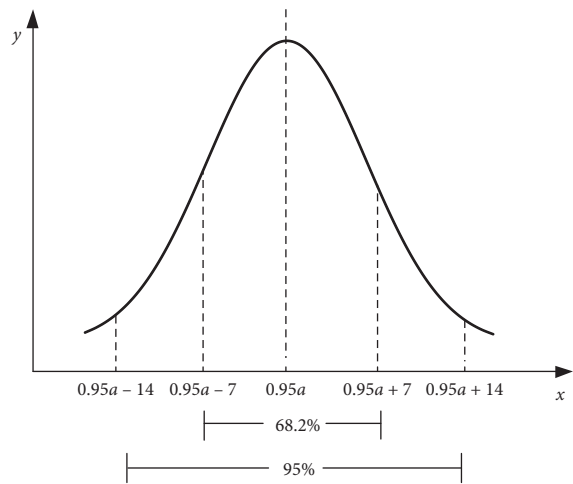


FIGURE 9: Distribution curve of equation (7).

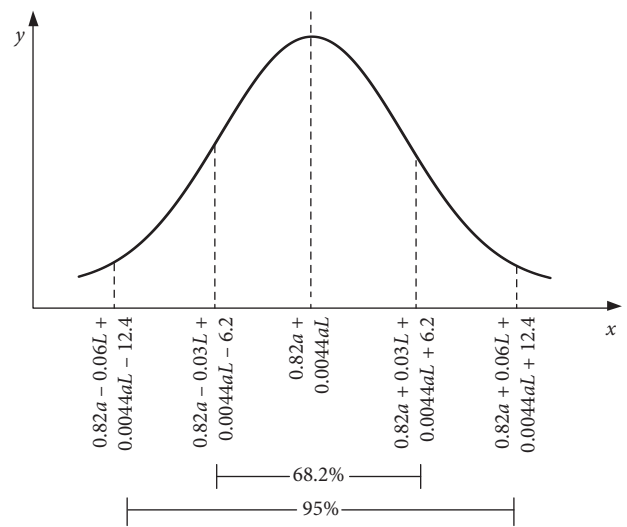


FIGURE 11: Distribution curve of equation (9).

calculated that when a vehicle is about to enter the transition zone after the road traffic violation monitoring area with a maximum speed limit of a km/h, there is a 68.2% probability that its speeds are in the range of $(0.95a - 7, 0.95a + 7)$ km/h and a 95% probability in the range of $(0.95a - 14, 0.95a + 14)$ km/h; for S_2 at any point in the posttransition zone, the distance between S_2 and the center of the traffic violation monitoring area is $L \cdot m$. With 68.2% probability, the vehicle speeds at that point are in the range of $(0.82a - 0.03L + 0.0044aL - 6.2, 0.82a + 0.03L + 0.0044aL + 6.2)$ km/h, and with a 95% probability, its speeds are in the range of $(0.82a - 0.06L + 0.0044aL - 12.4, 0.82a + 0.06L + 0.0044aL$

$+12.4)$ km/h. When a vehicle is about to leave the post-transition zone, there is a 68.2% probability that its speeds are in the range of $(1.39a - 10.1, 1.39a + 10.1)$ km/h and a 95% probability in the range of $(1.39a - 20.2, 1.39a + 20.2)$ km/h.

By comparing equations (8) and (9), we find that the entry of the road traffic violation monitoring area from the former transition zone and the entry of the posttransition zone following the road traffic violation monitoring area form a pair of approximately opposite processes.

4. Discussion and Conclusions

To further study the impact of road traffic violation monitoring on vehicle speeds, the following issues require further study:

- (1) In the case of constant road facilities, weather conditions often affect vehicle speed distribution. The time period during which the data were collected by the institute had normal weather on sunny days. If the weather is raining, snowy, or foggy, the condition or pattern may differ from the results of this study.
- (2) The concept of traffic safety among different drivers often varies. Therefore, the behavioral responses of different drivers who encounter traffic violation monitoring often vary. This study randomly collected vehicle data and cannot understand the drivers' traffic safety conceptions. In this case, there is a lack of understanding of the drivers' traffic safety conceptions.
- (3) The road selected in this study is an urban main road. Traffic violation monitoring on different functional levels may have different effects on vehicle speeds. Other situations require further study.

By analyzing the impact of road traffic violation monitoring on the vehicle speeds, this paper produces the following conclusions:

- (1) The vehicle speed distributions before, within, and after the road traffic violation monitoring area are all normally distributed. The average speed of vehicles within the monitoring area is slightly lower than the maximum speed limit of the road. The average speed of vehicles before and after the monitoring area is higher than the speed limit of the road of 40 km/h.
- (2) Before and after the road traffic violation monitoring area, the traffic order is chaotic, and the probability of speeding and other behaviors is large. The road traffic violation monitoring is within its scope, which can effectively regulate driving behaviors and reduce the occurrence of illegal activities such as speeding, but its scope of action is limited to a small area. If a driver lacks safety awareness, deterrence that relies solely on traffic violation monitoring does not guarantee sustained traffic safety.
- (3) The distribution of vehicle speeds can be calculated from vehicle speed probability density models. In the road with a maximum speed limit of a km/h, there is a 68.2% probability that the vehicle speeds are in the range of $(0.84a - 0.03L + 0.0035aL - 6.2, 0.84a + 0.03L + 0.0035aL + 6.2)$ km/h and a 95% probability in the range of $(0.84a - 0.06L + 0.0035aL - 12.4, 0.84a + 0.06L + 0.0035aL + 12.4)$ km/h before the traffic violation monitoring area; there is a 68.2% probability that the vehicle speeds are in the range of $(0.95a - 7, 0.95a + 7)$ km/h and a 95% probability in the range of $(0.95a - 14, 0.95a + 14)$ km/h within the traffic violation monitoring area; and there is a 68.2% probability that the vehicle speed is in the range of

$(0.82a - 0.03L + 0.0044aL - 6.2, 0.82a + 0.03L + 0.0044aL + 6.2)$ km/h and a 95% probability in the range of $(0.82a - 0.06L + 0.0044aL - 12.4, 0.82a + 0.06L + 0.0044aL + 12.4)$ km/h after the traffic violation monitoring area.

- (4) The traffic phenomena of vehicles entering the road traffic violation monitoring area from the former transition zone and vehicles entering the post-transition zone past the road traffic violation monitoring area are approximately opposite.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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