safety

MDPI

Article

Evaluating the Impact of Increased Fuel Cost and Iran's Currency Devaluation on Road Traffic Volume and Offenses in Iran, 2011–2019

Milad Delavary [1,2], Zahra Ghayeninezhad [3] and Martin Lavallière [1,2,*]

1 Department of Health Sciences, Université du Québec à Chicoutimi, Chicoutimi, QC G7H 2B1, Canada; mdelavaryf@etu.uqac.ca
2 Laboratoire BioNR and Centre intersectoriel en santé durable (CISD), Université du Québec à Chicoutimi, Chicoutimi, QC G7H 2B1, Canada
3 Department of Civil Engineering, Ferdowsi University of Mashhad, Mashhad, Razavi Khorasan 9177948974, Iran; qayenizahra@gmail.com
* Correspondence: Martin_Lavalliere@uqac.ca

Received: 19 August 2020; Accepted: 21 October 2020; Published: 26 October 2020

Abstract: Trends and underlying patterns should be identified in the timely distribution of road traffic offenses to increase traffic safety. In this study, a time series analysis was used to study the incidence rate of road traffic violations on Iranian rural roads. Road traffic volume and offenses data from March 2011 to October 2019 were aggregated. Interrupted time series were used to evaluate the impact of increasing fuel cost in June of 2013 and July of 2014 and the currency devaluation of Rial vs. US dollars in July of 2017 on trends and patterns, traffic volume, and number of offenses. A change-point detection (CPD) analysis was also used to identify singular changes in the frequency of traffic offenses. Results show a general decline in the number of overtaking and speeding offenses of −24.31% and −13.23%, respectively, due to the first increase in fuel cost. The second increase only reduced overtaking by 20.97%. In addition, Iran's currency devaluation reduced the number of overtaking offenses by 26.39%. Modeling a change-point detection and a Mann-Kendall Test of traffic offenses in Iran, it was found that the burden of violations was reduced.

Keywords: road related offenses; traffic safety; change-point detection; statistical methods; interrupted time series

1. Introduction

Road traffic injuries and fatalities are an important worldwide concern for public health and global programs have been initiated to decrease their number [1–3]. Based on the Global Status Report on Road Safety, each day, 3700 people lose their lives due to road related crashes [4]. Traffic accidents will be ranked the seventh cause of death by 2030.

Undeveloped and developing countries (or low and middle income countries–LMIC) are mostly represented in all these traffic deaths, with 93% of the world's fatalities. And this is despite the fact that these countries only possess 60% of the world's fleet of vehicles. Almost half of the road related injuries in LMIC occur among vulnerable users, such as pedestrians, bicycle riders, and motorcyclists. According to reports from the World Health Organization (W.H.O.), the cost of road traffic injuries in 2018 represents 3% of most countries' Gross Domestic Product (G.D.P.) [5].

In Iran, more than 16,900 road users died in crashes from March 2018 to February 2019, which translates to 20.5 fatalities per 100,000 people per year [5,6]. And while each individual road related death has considerable effects on the families and friends of the victims, the high economic cost of fatalities has also come to the attention of legislators. Considering estimations of the judiciary governmental organization, if the cost of each person (from birth to adulthood) along with education is 3.2 billion Iranian Rial (approximately 74,000 USD), the economic burden of road related fatalities in Iran amounts to approximately 1.2 billion USD per year for 16,000 traffic deaths in 2019. Hence, decreasing the number of road related fatalities would not only save lives, but also prevent high economic losses [7].

To decrease road related injuries and fatalities, Iran has implemented a Road Safety Strategic Plan, drawn up by the Road Safety Commission Secretariat [8], which highlights the importance of increasing road safety in the country for all users. The initial target of this strategic plan was a decrease in traffic fatalities of nine deaths per 100,000 people per year until 2020. With an estimated 20.5 fatalities per 100,000 in 2016, this goal will likely not be achieved. The Iranian National Road Safety Strategy has now selected 2028 as the long term horizon of its road safety plan. According to three defined scenarios in the Iranian Safety Commission of the Ministry of Roads and Urban Development, the objectives of each of these scenarios for total road traffic mortality up to the year 2027 are 12,000, 10,000, and 8000, respectively. The first scenario involves road safety measures and the second scenario involves increasing the use of public transportation by increasing fuel cost, while the third scenario combines them both. Hence, a comprehensive analysis of road related offenses in Iran is necessary to identify ways to reduce fatalities in order to achieve this goal.

For safety measures, researchers have done studies on the impact of various traffic interventions on crashes and mortalities. For instance, Lim and Chi found a decrease in young drivers' fatalities aged 14 to 20 when a cell phone use prohibition while driving was introduced among this age group in the Unites States [9]. In England and Wales, Steinbach et al. evaluated the effectiveness of a reduced street lighting condition on traffic mortalities and crime [10]. Generally, by decreasing economic activities, travel will be reduced, thus improving traffic safety. However, past studies suggest that economic problems have a dissimilar effect on driver behaviors and situations [11]. In this case of economic downturn, a variety of factors, including vehicle kilometers traveled (VKT), traffic composition, road user behavior, less disposable income for leisure activities, and vehicle fleet purchase can improve traffic safety [12–14]. For instance, Scuffham et al. studied the relationship between the unemployment rate (UER), Real Gross Domestic Product Per Capita (RGDP), and some other factors on traffic crashes and found that increasing either RGDP or UER led to a decrease in fatal crashes [15]. Besides that, Litman estimated that pricing changes such as a growth in fuel tax and parking costs should decrease the traffic fatalities in North America by 40% to 60%. [16]. Although previous studies investigated the impact of increasing economic factors like Gross Domestic Product (GDP) on traffic safety and driver behavior, there is comparatively less research on this factor associated with traffic offenses and traffic volume as surrogate measures for traffic accidents and safety. Though there are a huge number of crashes and collisions in the world, the report of such frequent events are often incomplete or insufficient. Therefore, when facing poor quality data regarding crash statistics or infrequent events, researchers have used surrogate measures of traffic safety to evaluate the impact of road safety interventions. As an example, Tsui Moreno et al. evaluated the effect of Traffic Calming Measure (TCM) on crosstown roads' safety using continuous speed recordings in the absence of crash data [17]. Similarly, Habtemichael et al. studied the effect of aggressive driving on the occurrence of accidents on motorways by using tailgating (car following), speeding, and weaving in and out through traffic as surrogate measures [18].

Another important factor for studying traffic offenses in rural areas is that according to the research reports of Iranian Legal Medicine, rural areas are over represented when compared to urban areas due to their higher rate of mortalities [5]. Also, based on the Iranian Traffic Police (ITP), one of the most important parameters explaining traffic mortalities is speeding and tailgating, which was studied in the current research [19]. Based on these results, this study evaluates the effectiveness of increased fuel costs and Iranian economic conditions (i.e., devaluation of the Rial, Iran's currency) on traffic safety by using traffic volume and offenses data as surrogate measures to see whether this relationship between economic factors and road safety measures actually happened in rural areas in Iran.

1.1. Data Collection

Data for road related offenses in Iran is available through the Iranian Road Ministry, which publishes numbers for each of Iran's 31 provinces on a monthly basis [5], with data for each traffic safety camera in rural areas. It is noteworthy that these data are only available publicly for rural roads that connect two or more cities and that are maintained by the Iranian Road Ministry's jurisdiction, while urban roads are within the legal boundaries of the city, most of which are maintained by the Municipality and for which such data is not publicly available [8].

Road Traffic Offenses (R.T.O.) data are available as monthly provincial averages from March 2011 to February 2019. Therefore, all the final time series shown in Figure 1 were obtained from aggregating the available data for each province and each camera. In epidemiology, incidence and prevalence rates are normally employed for epidemic diseases. Therefore, the incidence rate was considered in this study. Beck et al. used the number of fatalities per 100 million person-trips to compare the traffic road injuries and mortality of different modes of transportation [20]. Moreover, Zhang et al. used the number of fatalities per 100,000 people for the monthly rate of road traffic injuries [21]. This figure shows the incidence rate of traffic offenses per 100,000 vehicles, including three broad observations in Iran from March 2011 to October 2019. As shown in this figure, road cameras recorded more tailgating than other traffic violations. R.T.O. in rural roads was calculated based on the ratio of offenses per 100,000 vehicles observed by cameras.

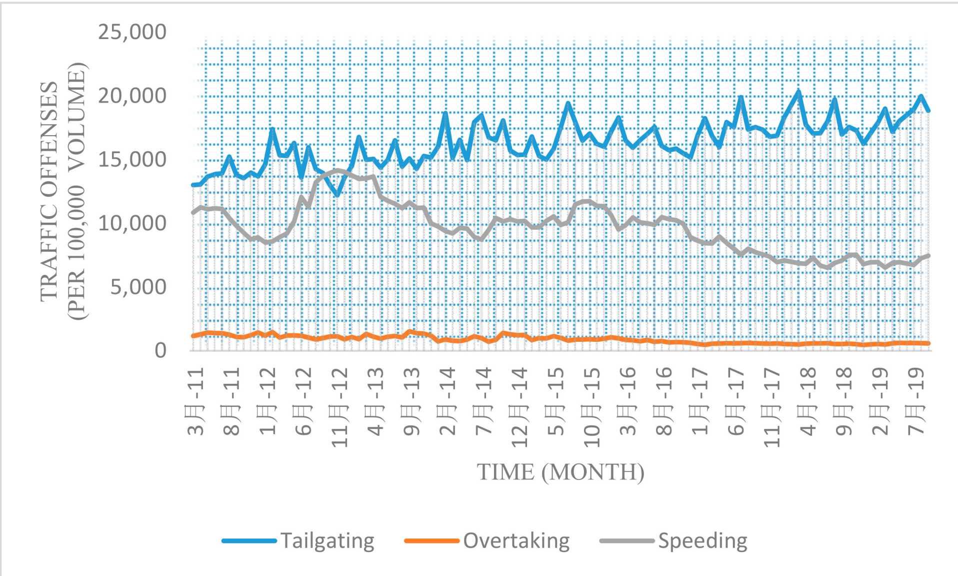

Figure 1. Incidence rate of traffic offenses per 100,000 vehicles in Iran between March 2011 and October 2019.

1.2. Statistical Analysis

1.2.1. Time Series Modeling

Interrupted Time Series with Seasonal Autoregressive Integrated Moving Average (Sarima).

To analyze data that are collected at multiple consecutive points in time, so called time series modeling is used [22]. Dynamic regression, which was proposed by Box and Tiao, can be used to assess the impact of road safety interventions [20,23]. In this regard, implementing new police enforcement procedures can reduce new cases of traffic offenses, fatalities, and injuries and therefore impact variables' responses. This method is similar to that of Delavary et al., who used an interrupted time series to evaluate law enforcement as traffic interventions [24]. The equation of dynamic region with error terms as SARIMA is as below:

$$Y_t = a + \omega X_t + N_t, \quad (1)$$

where Y_t, X_t, and N_t shows dependent, explanatory, and error variables, respectively (known as the SARIMA model). The explanatory variable, which is a dummy, will take values "zero" and "one" before and after the intervention, respectively. In this study, Y_t is traffic volume or offenses and X_t is the level shift interventional variable to model the impact of increased fuel costs and devaluation of Rial vs. US Dollar.

In SARIMA modeling, time series must be stationary over some period, which means the points of time series should be relatively the same at any time. The differences with seasonal and trend lags may be use if the time series is not stationary on average. [25]. Dickey-Fuller (D.F.), which consist of a unit root test, is used to know whether the time series is stationary or not [26,27].

Finally, uncorrelated residuals should be evaluated with the Ljung–Box test [28]. In addition, zero mean and normality were evaluated with the residual graph and the Kolmogorov-Smirnov (K.S.) test, respectively [25].

Additive Decomposition of Time Series

The decomposition of time series is a measurable undertaking that deconstructs a time series into a few parts, each speaking to one of the fundamental classes of examples. This function includes additives and multiplications. The additive model is utilized when the variance of the time series does not change over time; otherwise, multiplicative models can be used. In this paper, due to the stationarity of time series, an additive model, which consists of an aggregation of trend, season, and error components, was used to see the trend, season, and random patterns in R software [29].

Multiple Change Point Detection (CPD)

Traffic interventions or economic events can impact the different traffic-related behaviors and how they vary overtime. Therefore, CPD can show which points changed during the studied period of data. When statistical properties of a sequence of observations change at a specific point, it will be identified as a change-point [30]. A single change point can be extended to multiple change points if m points divide the data into m + 1 parts. Various procedures exist to find multiple CPD [30]. Three methods, including change point estimation by pruned objective via E statistics (e.cp3o) and energy divisive (E.divisive) change point estimation by pruned objective via Kolmogorov-Smirnov statistics (ks.cp3o), were used by the package "ecp" in R software [31]. In this case, e.cp3o and ks.cp3o algorithms, which use the E-statistic and Kolmogorov Smirnov statistic as the goodness-of-fit measures, respectively, utilize dynamic programming and pruning for multiple CPD. In addition, E.divisive is a divisive hierarchical estimation algorithm for multiple CPD [31]. Besides "ecp", the "trend" package can be used for CPD. In this study, Lanzante and Pettitt tests were used to find the location of the level shift in the time series [32].

Trend and Seasonal Tests

In this study, the following statistical tests were used to analyze the trend of the studied time series: Bartels, Nonparametric Cox and Stuart Trend, Nonparametric Wallis and Moore Phase-Frequency, Nonparametric Wald-Wolfowitz, and Mann- Kendall Tests. Kruskall Wallis, QS, and Webel-Ollech Overall Seasonality Tests were also utilized for seasonal analysis. The functions of these tests are in the "trend" package of R software [32]. The Mann-Kendall (MK) test as a nonparametric approach is another test for knowing whether the time series has a monotonic trend or not, based on the Kendall rank correlation of z[t] and t [33].

2. Results

Decomposing the incidence rate for monthly traffic volume and offenses in Iranian rural areas is presented in Figures 2–5 between March 2011 and October 2019. It should be noted that an additive method was used to decompose these time series. According to the figures, trend, season, and random are components of the observed time series. In other words, these components are all added together to obtain the actual times series.

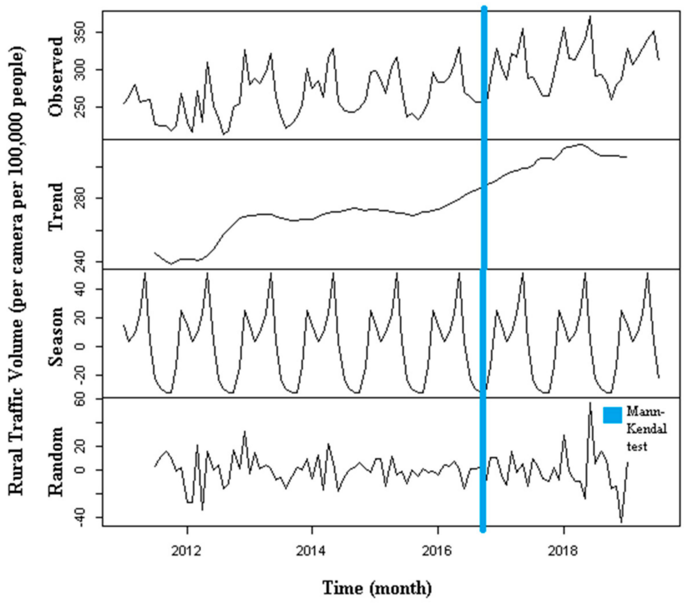

Figure 2. Decomposing the additive time series for monthly rural traffic volume (per camera per 100,000 people) in Iran, with blue vertical lines showing the points analyzed with a Mann-Kendall Test, from March 2011 to October 2019.

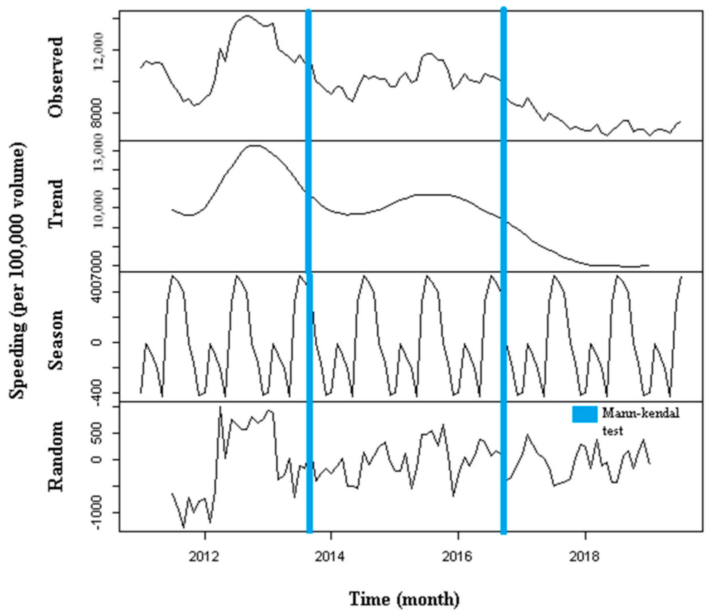

Figure 3. Decomposing the additive time series on a monthly basis for speeding per 100,000 vehicles in Iran, with blue vertical lines showing the points analyzed with a Mann-Kendall Test, from March 2011 to October 2019.

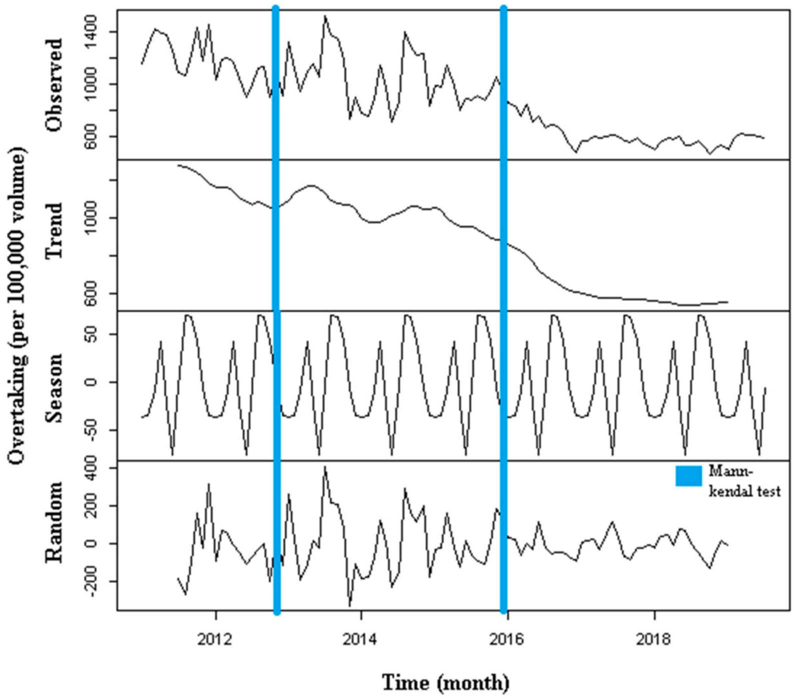

Figure 4. Decomposing the additive time series on a monthly basis for overtaking per 100,000 vehicles in Iran, with blue vertical lines showing the points analyzed with a Mann-Kendall Test, from March 2011 to October 2019.

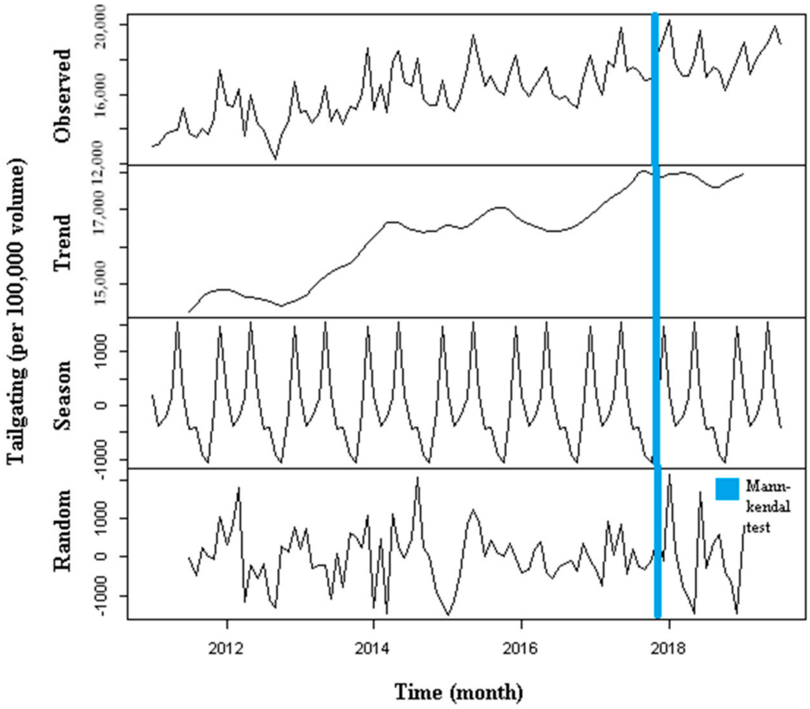

Figure 5. Decomposing the additive time series on a monthly basis for tailgating per 100,000 vehicles in Iran, with blue vertical lines showing the points analyzed with a Mann-Kendall Test, from March 2011 to October 2019.

When comparing different traffic offenses, tailgating had the highest incidence rate, followed by overtaking and speeding. While tailgating has an increasing trend, overtaking and speeding have a decreasing trend. The seasonal pattern can be seen in these time series, which means that the fluctuation over a year happened repeatedly as well as randomly.

The time period for this study consisted of three change points, including the first and second times for fuel cost increase, and devaluation of Rial vs. US Dollar. Fuel cost increased from 4000 to 7000 and 10,000 Rial per liter for the first and second time in June 2013 and July 2014 in Iran, respectively. Furthermore, the third intervention was implemented in July 2017 due to the devaluation of Rial vs. US Dollar.

Dynamic regression was employed to evaluate the effectiveness of increased fuel costs and the devaluation of Rial vs. the US Dollar on the rate of traffic violations. Table 1 shows the results of interrupted time series modeling on volume and traffic violations in Iran. In this table, the estimated values for the coefficients of each variable and other criteria such as Akaike Information Criterion (A.I.C.) and Bayesian Information Criterion (B.I.C.), which are estimators of the relative quality of statistical models, are shown.

The first time fuel cost, which was increased from 4000 Rial to 7000 Rial, decreased overtaking and speeding by −24.31% (−3.52 to −45.11, 95% CI) and −13.23% (−3.85 to −22.61, 95% CI), respectively. The second fuel cost increase from 7000 to 10,000 Rial had an impact on all traffic violations. However, this effectiveness was not negative for all the time series. In this respect, although this second intervention reduced overtaking by −20.97% (−7.26 to −34.69, 95% CI), speeding and tailgating increased significantly by 11.72% (20.4 to 3.04, 95%CI) and 10.99% (19.47 to 2.5, 95%CI), respectively.

On the other hand, Iran's currency devaluation had no impact on the traffic volume in rural areas, but reduced the number of instances of overtaking by −26.39% (−1.77 to −51.01, 95% CI). The prevalence of speeding and tailgating was not influenced by the devaluation of the Rial.

The un-correlation, normality, and zero means of residuals were confirmed by the results of LB, the KS test in Table 1, and are observed in the graph of residuals, respectively.

Table 2 shows the p-values for the statistical tests that analyzed trend and seasonal patterns. The null hypothesis for each test is shown. According to the result, Nonparametric Cox and Stuart Trend, Nonparametric Wallis, and Moore Phase-Frequency, Nonparametric Wald-Wolfowitz rejected the null hypothesis, which is related to the monotonic trend. Furthermore, Kruskall Wallis, QS, Webel-Ollech accepted the seasonal hypothesis. Hence, the time series including traffic offenses and traffic volume has trend and seasonal patterns over the period studied.

Table 3 shows results of the seasonal Mann-Kendall Test for all the time series. It should be noted that due to existing autocorrelation, the block bootstrap was used to obtain an improved significance test [33]. In this case, tau statistics and two-sided p-value can be seen before and after the blue vertical line in Figures 2–5 for each offense. It should be noted that this test was used for the observed values.

Table 1. The effects of traffic interventions on road traffic offenses and volume in Iranian rural areas, SARIMA models.

Output	Estimate	Monthly Average	S.E.	Z	*p*-value	Change		AIC [d]	BIC [e]	LB [f]	KS [g]
						Percent Level	95%CI				
Volume (point 38th, 51st, 87th)		278.12									
Impact (I1 [a])	18.14		10.37	1.74	0.08	6.38	[13.67,−0.91]				
Impact (I2 [b])	7.65		10.26	0.75	0.46	2.86	[10.54,−4.82]				
Impact (I3 [c])	5.6		12.09	0.46	0.64	1.79	[9.52,−5.94]				
Noise	(1,0,0)(0,0,1)							937.78	956.22	0.06	0.9
Tailgating (point 38th, 51st, 87th)		16322.54									
Impact (I1)	1.02×10^3		7.0×10^2	1.45	0.15	6.17	[14.63,−2.3]				
Impact (I2)	1.74×10^3		6.72×10^2	2.6	0.01	10.99	[19.47,2.5]				
Impact (I3)	-1.65×10^3		8.49×10^2	−1.94	0.05	−9.68	[0.28,−19.65]				
Noise	(1,0,1)(1,0,0)							1727.58	1748.66	0.7	0.96
Overtaking (point 38th, 51st, 87th)		887.41									
Impact (I1)	−185.26		79.23	−2.34	0.019	−24.31	[−3.52,−45.11]				
Impact (I2)	−241.57		78.99	−3.06	0.00	−20.97	[−7.26,−34.69]				
Impact (I3)	−154.93		72.28	−2.14	0.03	−26.39	[−1.77,−51.01]				
Noise	(0,0,2)(0,0,0)							1327.91	1346.36	0.07	0.94
Speeding (point 34th, 51st, 87th)		9632.55									
Impact (I1)	-1.2755×10^3		4.52×10^2	−2.83	0.01	−13.23	[−3.85,−22.61]				
Impact (I2)	1.2343×10^3		4.57×10^2	2.70	0.01	11.72	[20.4,3.04]				
Impact (I3)	6.4394×10^2		5.27×10^2	1.22	0.22	8.83	[23.28,−5.62]				
Noise	(1,0,0)(1,1,0)							1427.64	1442.7	0.18	0.96

[a] Intervention 1: Increased fuel cost (7000 Rial per liter) [b] Intervention 2: Increased fuel cost (10,000 Rial per liter) [c] Intervention 3: Devaluation of Rial vs. US Dollar [d] Ljung-Box [e] Kolmogorov-Smirnov [f] Akaike Information Criterion [g] Bayesian Information Criterion.

Table 2. Results of Seasonal and Trend tests.

Test	Description	p Value			
		Volume	Tailgating	Overtaking	Speeding
Bartels Test	Null hypothesis: Randomness	1.31×10^{-12}	6.79×10^{-13}	$<2.2 \times 10^{-16}$	$<2.2 \times 10^{-16}$
Nonparametric Cox and Stuart Trend Test	Null hypothesis: Monotonic test	1.19×10^{-5}	9.16×10^{-9}	1.15×10^{-9}	1.15×10^{-9}
Nonparametric Wallis and Moore Phase-Frequency Test	Null hypothesis: Randomness	1.54×10^{-5}	0.02	0.02	4.91×10^{-7}
Nonparametric Wald-Wolfowitz Test	Null hypothesis: Independence and Stationarity	9.11×10^{-12}	8.22×10^{-12}	$<2.2 \times 10^{-16}$	$<2.2 \times 10^{-16}$
Kruskall Wallis Test	Null hypothesis: Seasonality	1	1	1	1
Q.S. Test	Null hypothesis: Seasonality	1	1	1	0.45
Webel-Ollech Overall Seasonality Test	Null hypothesis: Seasonality	1	1	1	0.44

Table 3. Results of Seasonal Mann-Kendall Test.

Mann-Kendall Test		Before	After	Before	After
Volume (70th point)	tau	0.21	0.13	-	-
two-sided p value	0.01	0.29	-	-	
Tailgating (35th and 83rd points)	tau	0.31	0.14	0.14	0.59
two-sided p value	0.01	0.15	0.15	0.01	
Overtaking (23rd and 61st points)	tau	−0.44	−0.2	−0.2	−0.37
two-sided p value	0.00	0.8	0.8	0.00	
Speeding (33rd point and 71st points)	tau	0.28	0.16	0.16	−0.49
two-sided p value	0.02	0.16	0.16	8.7×10^{-5}	

The results show that after the blue line for traffic offenses, there is no reduction for the observed database on a two-sided p-value for the Mann-Kendall Test. This demonstrates that the devaluation of Rial to US Dollar had no impact on traffic volume in Iran. In addition, this test shows that there is a steady trend between two vertical blue lines for all the traffic offenses according to Figures 3–5. This means that all the interventions, including increased fuel costs on the 38th and 60th points, had no impact on tailgating, speeding, and overtaking. However, after the 61st point in overtaking, there is a significant reduction, confirming the results of Delavary et al. In this earlier study, this point was assumed as increased traffic fines significantly reduce overtaking [24].

Nonparametric multiple CPD was used in R software with the "ecf" package to evaluate the changes during the studied periods. The result of five algorithms for the detection of these points is shown in Table 4. After the CPD analysis, it is helpful to plot the change points on the original data to visually inspect whether the estimated change points are reasonable. It should be noted that the 35th and 60th points for the overtaking time series confirm the results of interrupted time series. E.cp3o, e.diverse, and Ks.cp3o methods show that points near the first increased fuel cost intervention changed for all the time series including tailgating, speeding, overtaking, and traffic violation.

Table 4. Change Point Detection for Traffic Volume and Offenses in Rural Areas.

Region	Algorithm Methods	Change Point Locations	Location and Most Important Events
Volume (per Camera/per 100,000 People)	e.cp3o	24, 30, 36, 42, 71	36th point: Near to increased fuel cost 59th point: Near to increased traffic fines
	e.divisive	24, 30, 72, 104	
	ks.cp3o	24, 30, 36, 71	
	lanzante.test	59	
	pettitt.test	59	
Tailgating (per 100,000 Volume)	e.cp3o	35, 66, 75	35th point: Near to increased fuel cost
	e.divisive	36, 75, 104	
	ks.cp3o	12, 18, 35	
	lanzante.test	39	
	pettitt.test	39	
Overtaking (per 100,000 Volume)	e.cp3o	13, 35, 44, 52, 66	35th point: Near to increased fuel cost 60th point: increased traffic fines
	e.divisive	13, 35, 44, 53, 65, 71, 104	
	ks.cp3o	35, 67, 90, 98	
	lanzante.test	60	
	pettitt.test	60	
Speeding (per 100,000 volume)	e.cp3o	7, 16, 27, 71	34th point: Near to increased fuel cost 69th point: Near to increased traffic fines
	e.divisive	7, 18, 28, 34, 43, 54, 60, 72, 80, 104	
	ks.cp3o	16, 34	
	Lanzante.test	69	
	Pettitt.test	69	

In addition, Lanzante and Pettitt algorithms indicate the 59th, 39th, 60th, and 69th points in volume, tailgating, overtaking, and speeding, respectively, which show a level shift in these time series. The 59th and 60th points really confirm that increased traffic fines impact volume and overtaking, which confirms the results of the study conducted on the impact of law enforcement and increased traffic fines on fatalities, injuries, and traffic offenses in Iran [24]. These increased traffic offense fines were implemented on 1 March 2016 (60th point). In addition, Lanzante and Pettitt methods proved that the first cost increase influenced tailgating.

3. Discussion

In this study, the impact of increased fuel costs and the devaluation of Rial vs. Dollar was analyzed with interrupted time series, Mann-Kendall Test, and change-point detection (CPD) to evaluate whether these elements might reduce the number of road traffic offenses. Overall, it can be observed that increasing fuel costs cannot systematically reduce traffic offenses and therefore, improve road safety in Iranian rural areas. These interventions as an action plan for improving traffic safety should therefore be considered case by case by governments and agencies responsible for road safety. As an example, increasing traffic ticket fines is often preferred as an economic parameter for punishing dangerous drivers [24]. It should be noted that this research completes the previous studies for documenting the impact of traffic interventions on road safety by using traffic offenses as surrogate measures of collisions to evaluate how economic factors can positively affect road safety measures.

Road Traffic Offenses (R.T.O.) were aggregated as monthly data for each state in Iran from March 2011 to October 2019. Comparing the time series shows that the number of recorded events of tailgating is more than other traffic violations. While tailgating tends to increase, overtaking and speeding have decreased. Also, a yearly seasonal component is apparent in all the studied time series.

The first increase in fuel cost significantly reduced instances of overtaking and speeding by −24.31% (−3.52 to −45.11, 95% CI) and −13.23% (−3.85 to −22.61, 95% CI). This may be due to the impact of increasing fuel costs on the economic condition of Iranians. Hence, they may have driven more conservatively in rural areas. This result is confirmed by the change point detections. E.cp3o, e.diverse, and Ks.cp3o methods show that points near the first increased fuel cost intervention changed for all the time series, including traffic offenses and volume.

The second increase in fuel cost to 10,000 Rial per liter had an impact on all traffic violations. In this context, the intervention reduced overtaking by −20.97% (−7.26 to −34.69, 95% CI). However, this effectiveness was not negative for all the time series. In addition, the interrupted time series analysis did not show any significant changes in traffic volume when increasing the cost of fuel for the first and second times. So, increasing fuel cost may not always have an impact on reducing traffic volume and offenses and also may not have a consistent impact on traffic safety. So, this should be considered case-by-case for decreasing accidents as a safety plan.

Previous studies have identified a relation between economic factors and traffic safety [13,15,16,34,35]. This study found that the devaluation of the Rial vs. US Dollar had no impact on traffic volume in rural areas, but it reduced overtaking by −26.39% (−1.77 to −51.01, 95% CI). Furthermore, the Mann-Kendall Test supported the results of the interrupted time series analysis for traffic volume. In this case, Razzaghi et al. showed that the population density and Gross Domestic Product (GDP) were significantly correlated with road traffic deaths in Iran. In this particular case, if the GDP grows by a unit (Million Rial), the fatalities reduce by as much as 0.0014 per 100,000 people in Iran [36]. In the current study, the Mann-Kendall test showed that all the interventions between the 38th and 60th points had no impact on tailgating, speeding, and overtaking, which means that increased fuel costs had no effect on traffic offenses. However, results obtained for overtaking show a reduction after increased traffic fines, at the 60th point, and this result is similar to the findings of Delavary et al., who showed that increased traffic fines significantly reduced overtaking [24]. Also, Level shift change point detection including Lanzante and Pettitt algorithms indicates that increased traffic fines influence volume and overtaking. This traffic offense was implemented on 1 March 2016, 60th point, in Iran.

The current results show that there is no relation between increasing fuel costs and decreasing all of the traffic offenses including tailgating, speeding, and overtaking. Other economical parameters in traffic safety like increasing traffic ticket fines and the presence of law enforcements are also known to have a possible impact on reducing traffic offenses and volume as surrogate measures of accidents. These types of interventions should therefore be considered in combination with other measures when addressing opportunities for reducing crashes and inappropriate driving behaviors and improving the country's road safety. For future studies, evaluating the impact of increasing fuel costs on crashes and road related deaths is suggested. Moreover, traffic offenses could also be used as predictors of these crashes and fatalities. Finally, it would be of interest to document the differences between traffic offenses and accidents in rural and urban areas if data were available in Iran for urban settings since the current study only addressed traffic volume and violations in rural areas.

Limitations

This study presents the number of traffic violations by 100,000 vehicles observed in each camera. Traffic volume is presented with 100,000 people per camera because length of trips per person is not available in Iran. Therefore, it is currently not feasible to differentiate if part of the observations noted in the results is solely due to the impact of the three interventions on behaviors behind the wheel or due to a change in population-level travel patterns. It is plausible that people might choose to reduce distances traveled (for leisure purposes, for instance) when the cost of driving increases [37] or when the economy is low [38]. The impact of an economic downturn is not consistent across every country and some results show that despite a reduction in fatalities per kilometer of travel, which is probably associated with changes in road user behaviors, kilometers driven did not vary much as a result of the recession [15]. Therefore, more targeted data collection based on individual characteristics [15,39] and vehicle kinematics [40,41] is necessary to document the traveling behaviors of drivers in Iran with more accuracy.

As noted in the methods section, the current results and their application to road safety enhancement only apply to rural areas since data published by the Iran road maintenance and transportation organization are only available for traffic offenses collected by cameras for these areas [8]. However, each municipality is responsible for publishing the urban data, but there is no common website to gather this information and make it public. In addition, different types of interventions and road safety enforcement might differ depending on their location and it would be of utmost interest to compare the results obtained between urban and rural settings to tailor more specific strategies to enhance road safety if a variation is observed in the collected measures [42,43].

The national road safety plan in Iran does not currently address interventions such as increasing enforcement with the help of photo radars [44] and/or public awareness campaigns [45], which could very well explain some of the effects observed with our model. These interventions could potentiate the effect of increasing fuel cost and the devaluation of the Rial and should thus be evaluated.

4. Conclusions

Overall, the current analyses show that the increase of fuel cost on two occasions (June 2013 and July 2014) and the economic devaluation of the national currency of Iran (Rial) (July 2017) were associated with a reduction in some traffic violations. By modeling a changepoint detection (CPD) and completing a Mann-Kendall Test of traffic offenses in Iran, it was found that the burden of these violations was significantly reduced. Also, there is no relation between decreasing the traffic volume and these interventions. So, there is no relevance between increasing transport costs and reducing traffic congestion and volume and, therefore, improving traffic safety. Further studies should focus on the relationship between economic problems and the psychological impact of these factors on traffic safety to see why people may want to especially reduce their driving offenses when faced with economic problems.

Author Contributions: Conceptualization, M.D., Z.G., and M.L.; methodology, M.D.; formal analysis and investigation, M.D. and M.L.; data collection, M.D. and Z.G.; writing—original draft preparation, M.D. and M.L.; writing—review and editing, M.D. and M.L.; All authors have read and agreed to the published version of the manuscript.

Funding: This research was not funded.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. World Health Organization. *Global Status Report on Road Safety: Time for Action*; WHO: Geneva, Switzerland, 2008.
2. United Nations. General Assembly Resolution 64/255, Improving Global Road Safety, A/64/L.44. Available online: http://undocs.org/A/RES/64/255 (accessed on 2 March 2010).
3. United Nations. General Assembly Resolution 70/1, Transforming Our World: The 2030 Agenda for Sustainable Development. A/70/L.1. Available online: http://undocs.org/A/RES/70/1 (accessed on 24 March 2010).
4. World Health Organization. Available online: https://www.who.int/violence_injury_prevention/road_safety_status/2018/en/ (accessed on 30 December 2018).
5. Legal Medicine Organization. Road Related Statistics. Available online: https://lmo.ir/web_directory/53999%D8%AA%D8%B5%D8%A7%D8%AF%D9%81%D8%A7%D8%AA.html (accessed on 1 January 2020).
6. World Health Organization. Fact Sheet. Available online: http://www.who.int/mediacentre/factsheets/fs358/en/ (accessed on 7 February 2020).
7. Iranian Nationwide Judicial System. Road Related Statistics. Available online: http://www.dadiran.ir/ (accessed on 1 January 2020).
8. Road Maintenance and Transportation Organization. Available online: http://www.rmto.ir/en/SitePages/Road%20Maintenance%20And%20Transportation%20Organization.aspx (accessed on 1 January 2020).
9. Lim, S.H.; Chi, J. Are cell phone laws in the U.S. effective in reducing fatal crashes involving young drivers? *Transp. Policy* **2013**, *27*, 158–163. [CrossRef]

10. Steinbach, R.; Perkins, C.; Tompson, L.; Johnson, S.; Armstrong, B.; Green, J.; Grundy, C.; Wilkinson, P.; Edwards, P. The effect of reduced street lighting on road casualties and crime in England and Wales: Controlled interrupted time series analysis. *J. Epidemiol. Community Health* **2015**, *69*, 1118–1124. [CrossRef]
11. Lloyd, L.; Wallbank, C.; Broughton, J. A collection of evidence for the impact of the economic recession on road fatalities in Great Britain. *Accid. Anal. Prev.* **2015**, *80*, 274–285. [CrossRef]
12. Organization for Economic Cooperation and Development/International Transport Forum (OECD/ITF). Why Does Road Safety Improve When Economic Times Are Hard? Available online: https://www.itf-oecd.org/sites/default/files/docs/15irtadeconomictimes.pdf (accessed on 6 October 2015).
13. Wegman, F.; Allsop, R.; Antoniou, C.; Bergel-Hayat, R.; Elvik, R.; Lassarre, S.; Wijnen, W. How did the economic recession (2008–2010) influence traffic fatalities in OECD-countries? *Accid. Anal. Prev.* **2017**, *102*, 51–59. [CrossRef]
14. Yannis, G.; Papadimitriou, E.; Folla, K. Effect of GDP changes on road traffic fatalities. *Saf. Sci.* **2014**, *63*, 42–49. [CrossRef]
15. Scuffham, P.A. Economic factors and traffic crashes in New Zealand. *Appl. Econ.* **2003**, *35*, 179–188. [CrossRef]
16. Litman, T. Pricing for Traffic Safety. *Transp. Res. Rec. J. Transp. Res. Board* **2012**, *2318*, 16–22. [CrossRef]
17. Moreno, A.T.; García, A. Use of speed profile as surrogate measure: Effect of traffic calming devices on crosstown road safety performance. *Accid. Anal. Prev.* **2013**, *61*, 23–32. [CrossRef]
18. Habtemichael, F.G.; Santos, L.D.P. Crash risk evaluation of aggressive driving on motorways: Microscopic traffic simulation approach. *Transp. Res. Part F Traffic Psychol. Behav.* **2014**, *23*, 101–112. [CrossRef]
19. Iranian Traffic Police (ITP). Available online: http://rahvar120.ir/ (accessed on 30 April 2018).
20. Beck, L.F.; Dellinger, A.M.; O'Neil, M.E. Motor Vehicle Crash Injury Rates by Mode of Travel, United States: Using Exposure-Based Methods to Quantify Differences. *Am. J. Epidemiol.* **2007**, *166*, 212–218. [CrossRef]
21. Zhang, X.; Pang, Y.; Cui, M.; Stallones, L.; Xiang, H. Forecasting mortality of road traffic injuries in China using seasonal autoregressive integrated moving average model. *Ann. Epidemiol.* **2015**, *25*, 101–106. [CrossRef]
22. Chatfield, C.; Xing, H. *The Analysis of Time Series: An Introduction with R*; CRC Press: Boca Raton, FL, USA, 2019.
23. Box, G.E.P.; Tiao, G.C. Intervention analysis with applications to economic and environmental problems. *J. Am. Stat. Assoc.* **1975**, *70*, 70–79. [CrossRef]
24. Foroutaghe, M.D.; Moghaddam, A.M.; Fakoor, V. Impact of law enforcement and increased traffic fines policy on road traffic fatality, injuries and offenses in Iran: Interrupted time series analysis. *PLoS ONE* **2020**, *15*, e0231182. [CrossRef]
25. Hyndman, R.J.; Athanasopoulos, G. *Forecasting: Principle and Practice*; OTexts: Melbourne, Australia, 2012.
26. Dickey, D.A.; Fuller, W.A. Distribution of the estimators for autoregressive time series with a unit root. *J. Am. Stat. Assoc.* **1979**, *74*, 427–431.
27. Dickey, D.A.; Bell, W.R.; Miller, R.B. Unit roots in time series models: Tests and implications. *Am. Stat.* **1986**, *40*, 12–26.
28. Ljung, G.M.; Box, G.E. On a measure of lack of fit in time series models. *Biometrica* **1978**, *65*, 297–303. [CrossRef]
29. Kendall, M.; Stuart, A. *The Advanced Theory of Statistics*; CRC Press: Boca Raton, FL, USA, 1983; Volume 3, pp. 410–414.
30. Aminikhanghahi, S.; Cook, D.J. A survey of methods for time series change point detection. *Knowl. Inf. Syst.* **2017**, *51*, 339–367. [CrossRef]
31. James, N.A.; Zhang, W.; Matteson, D.S. *Non-Parametric Multiple Change-Point Analysis of Multivariate Data, Package 'Ecp'*; R Software: Ithaca, NY, USA, 2019.
32. Pohlert, T. *Nonparametric Trend Tests and Change-Point Detection, Package 'Trend'*; R Software: Koblenz, Germany, 2020.
33. McLeod, A.I. *Kendall Rank Correlation and Mann-Kendall Trend Test, Package 'Kendall'*; R Software: London, UK, 2015.
34. Lamm, R.; Choueiri, E.M.; Kloeckner, J.H. Accidents in the US and Europe: 1970–1980. *Accid. Anal. Prev.* **1985**, *17*, 429–438. [CrossRef]
35. Wagenaar, A.C. Effects of macroeconomic conditions on the incidence of motor vehicle accidents. *Accid. Anal. Prev.* **1984**, *16*, 191–205. [CrossRef]
36. Razzaghi, A.; Soori, H.; Kavousi, A.; Abadi, A.; Khosravi, A. Factors with the Highest Impact on Road Traffic Deaths in Iran; an Ecological Study. *Arch. Acad. Emerg. Med.* **2019**, *7*, 38.

37. Chi, G.; Cosby, A.G.; Quddus, M.A.; Gilbert, P.A.; Levinson, D. Gasoline prices and traffic safety in Mississippi. *J. Saf. Res.* **2010**, *41*, 493–500. [CrossRef] [PubMed]
38. He, M.M. Driving through the Great Recession: Why does motor vehicle fatality decrease when the economy slows down? *Soc. Sci. Med.* **2016**, *155*, 1–11. [CrossRef] [PubMed]
39. Starkey, N.J.; Charlton, S.G. The role of control in risk perception on rural roads. *Accid. Anal. Prev.* **2020**, *142*, 105573. [CrossRef] [PubMed]
40. Yokoo, T.; Levinson, D. Measures of speeding from a GPS-based travel behavior survey. *Traffic Inj. Prev.* **2019**, *20*, 158–163. [CrossRef]
41. Choukou, M.-A.; Bluteau, C.; Germain-Robitaille, M.; Simoneau, M.; Lavallière, M.; Moskowicz, T.; Laurendeau, D.; Teasdale, N. Étude naturalistique de la négociation des intersections et du respect des limites de vitesse chez les conducteurs âgés de 65 ans et plus. *Rev. Rech. Transp. Sécur.* **2014**, *30*, 271–281. [CrossRef]
42. Värnild, A.; Larm, P.; Tillgren, P. Incidence of seriously injured road users in a Swedish region, 2003-2014, from the perspective of a national road safety policy. *BMC Public Health* **2019**, *19*, 1576. [CrossRef] [PubMed]
43. Zabihi, F.; Davoodi, S.R.; Nordfjærn, T. The role of perceived risk, reasons for non-seat belt use and demographic characteristics for seat belt use on urban and rural roads. *Int. J. Inj. Control Saf.* **2019**, *26*, 431–441. [CrossRef]
44. Diamantopolou, K.; Cameron, M. *An Evaluation of the Effectiveness of Overt and Covert Speed Enforcement Achieved Through Mobile Radar Operations*; Report 187; Monash University Accident Research Centre: Victoria, Australia, 2002.
45. Phillips, R.O.; Ulleberg, P.; Vaa, T. Meta-analysis of the effect of road safety campaigns on accidents. *Accid. Anal. Prev.* **2011**, *43*, 1204–1218. [CrossRef]

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.