Research Article

A Time Series Model for Assessing the Trend and Forecasting the Road Traffic Accident Mortality

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Abstract

Background: Road traffic accident (RTA) is one of the main causes of trauma and known as a growing public health concern worldwide, especially in developing countries. Assessing the trend of fatalities in the past years and forecasting it enables us to make the appropriate planning for prevention and control.

Objectives: This study aimed to assess the trend of RTAs and forecast it in the next years by using time series modeling.

Materials and Methods: In this historical analytical study, the RTA mortalities in Zanjan Province, Iran, were evaluated during 2007 - 2013. The time series analyses including Box-Jenkins models were used to assess the trend of accident fatalities in previous years and forecast it for the next 4 years.

Results: The mean age of the victims was 37.22 years (SD = 20.01). From a total of 2571 deaths, 77.5% (n = 1992) were males and 22.5% (n = 579) were females. The study models showed a descending trend of fatalities in the study years. The SARIMA (1, 1, 3) (0, 1, 0) 12 model was recognized as a best fit model in forecasting the trend of fatalities. Forecasting model also showed a descending trend of traffic accident mortalities in the next 4 years.

Conclusions: There was a decreasing trend in the study and the future years. It seems that implementation of some interventions in the recent decade has had a positive effect on the decline of RTA fatalities. Nevertheless, there is still a need to pay more attention in order to prevent the occurrence and the mortalities related to traffic accidents.

Keywords: Traffic Accidents, Mortality, Forecasting, Trends

1. Background

Road traffic accident (RTA) is one of the main causes of injuries and fatalities worldwide (1). According to world health organization (WHO), approximately 1.2 million people are killed and up to 50 million are injured annually due to RTA (2). It is estimated that RTA will become the 6th leading cause of death in the world and take the third place of disability by the year 2020 (3). Injuries, deaths and disabilities resulting from RTA are considered as a major public health concerns to which inadequate attention has been paid so far (4, 5).

Road traffic accident has a decreasing trend in developed countries; however, the higher number of injuries is occurring in developing nations (5, 6). The burden mortalities, disabilities and injuries due to traffic accidents has a worse effect on health, social and economic developments of many nations, especially low and middle-income countries (2, 4). Injuries due to RTA are one of the main health care problems, which are preventable as the experience of many developed countries (7-9). Therefore, making related specific health policies should be one of the main priorities for the government and the health care system (5).

In Iran, RTA is considered as one of the main causes of deaths (10, 11). The number of people killed due to RTA during a five year period (1999 - 2003) is 19000 - 27000 Annually, as 36 person per 100,000 persons (11).

According to the Iranian fourth development plan, the government has been charged to decrease the trends of RTA by 10% annually (12). To achieve this goal, some interventions have been done to prevent and control the occurrence and mortalities of traffic accidents. For instance, some new laws have been enforced especially in the recent years which show a decrease in fatal and no-fatal injuries and deaths (13).

For implementing the appropriate programs for prevention and control of health events, assessing the previous and current situations and indicating possible future

outcomes are required (14). For example, Noland and Quddus (2004) showed that the progression of medical technology and medical care in UK reduced the traffic-related fatalities (15). Moreover, the result of a study in USA using time series analysis for forecasting showed that changing the enforcement of the seat belt law can reduce the risk of RTAs (16). Trend assessment and forecasting the data can provide useful information, which ultimately leads to increase the quality of decision making by policy makers (14). There are different statistical methods to forecast future condition. Time series analysis is a kind of statistical methods whose main purpose is the modeling and forecasting (17).

2. Objectives

In this study, we used time series analysis to assess the trend of RTAs in Zanjan Province, Iran, during 2007 - 2013 and forecast the RTA mortality in the next 4 years.

3. Materials and Methods

In this retrospective-analytical study, we extracted the recorded data of road traffic victims between 2007and 2013 from the RAHVAR traffic police of Zanjan Province. Zanjan Province is located in north-west of Iran. Total population of Zanjan Province in the year of 2011 is 1015,734. Of total population 62.5% are urban while other rural (18). The source of data contains the number of traffic accidents contributed to drivers, passengers and pedestrians. Victim's demographic data including age and sex were considered.

Before performing the time series analysis, the quality of collected data was assessed in terms of absence of censoring in data sequence. The monthly time lag was used in this study. The time series modeling is meaningful if only when the stationary of time sequence in mean and variance be established. Moreover, when the data have a seasonal effect, removing it from the data is important. Therefore, the stationary of a series observation was examined through plotting the trend series, before the forecasting procedure. The Box-Cox transformation was used to remove nonstationary in variance. Also, for removing seasonality variation and trend from observed time series, seasonal differencing and order differencing were applied for data, respectively. In this study, major numbers of models including AR (auto regressive), MA (moving average), ARMA (auto regressive moving average), ARIMA (autoregressive moving integrated moving average), and SARIMA (seasonality autoregressive moving integrated moving average) were identified through the analysis of the auto-correlation function (ACF) and the partial autocorrelation function (PACF) plots.

In order to diagnose the best fit model, the identified models were compared by least mean square error (MSE) and residuals ACF and PACF plots as a goodness of fit criterions. The lowest value of MSE represents the goodness of fitness among the identified models. The analysis of residuals of model was based on ACF and PACF plots of residuals. To select the best fit model by residual analysis, the ACF and PACF plots of residuals should not be significantly different from zero. In other words, no spike should be observed from the boundary lines around the ACF and PACF functions with 95% confidence intervals. The correlation coefficient was used to examine the quality of selected model in comparison with actual data. After examining different models, the ARIMA model was used for forecasting. The parameters of p, d and q represent the auto-regressive, integrated and moving average model in nonseasonal part.

The best diagnosed fit model was used to forecast death-related accidents in Zanjan Province for the next 4 years (January 2014 - December 2018). All analyses were performed using the Minitab 16 software.

4. Results

There were 2571 deaths between 2007 and 2013, which 77.5% (n = 1992) were males and 22.5% (n = 579) females (Table 1). The mean age of the victims was 37.22 years (SD = 20.01).

The result of the trend analysis illustration showed a descending trend of the fatalities due to traffic accidents. In comparing the number of accidents fatalities in years of the study, it was shown that the highest values of fatalities have occurred in 2008 with 13.40% growth compared to the year 2007. Also, the lowest values of fatalities have occurred in 2013 with 20.61% reduction in comparison to 2007 (Table 2).

It also has a seasonality pattern according to decomposition with lag 12 (Figure 1). Assessing the trend shows that there is a nonstationary in the mean, variance and seasonality variation.

In addition, the autocorrelation and partial autocorrelation function illustrations were evaluated. These Illustrations demonstrated that the auto-correlation function hardly tends toward zero, which shows non-static in the mean. The partial auto-correlation function hardly tends towards zero, which shows a non-stationary in variance.

The Box-Cox transformation was used to remove the nonstationary condition in variance. Then, seasonality variation was removed by seasonality differencing with lag 12.

Table 1. Demographic Characteristics of Road Traffic Accident Victims

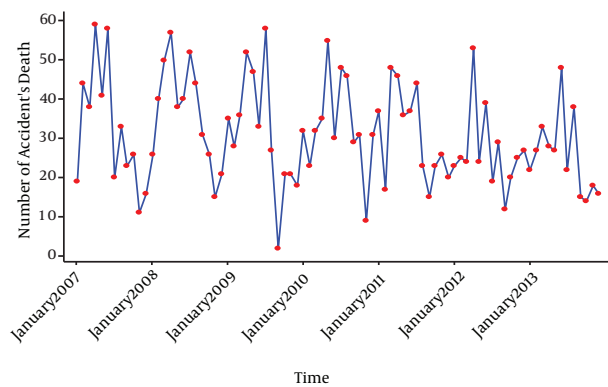| Age, y	Male Deaths, No. (%)	Female Deaths, No. (%)	Total Deaths, No. (%)
0 - 10	111 (5.6)	86 (14.9)	197 (7.6)
11 - 20	252 (12.7)	54 (9.4)	306 (11.9)
21 - 30	507 (25.5)	78 (13.5)	585 (22.8)
31 - 40	337 (16.8)	94 (16.2)	431 (16.8)
41 - 50	281 (14.1)	76 (13.1)	357 (13.9)
51 - 60	210 (10.5)	84 (14.5)	294 (11.4)
61 - 70	111 (5.6)	43 (7.4)	154 (6)
≤ 71	136 (6.8)	54 (9.3)	190 (7.4)
Missed data	47 (2.4)	10 (1.7)	57 (2.2)

Figure 1. Trend of Road Traffic Accident Mortality During 2007 - 2013
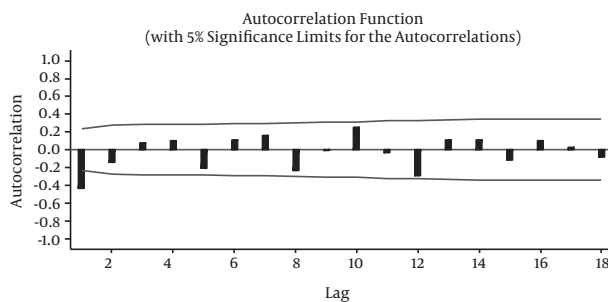

Figure 2. Autocorrelation Function Plots of Accidents Mortality in Zanjan After Removing the Nonstationary in Data

Non-stationary in mean was removed through ordinary differencing with lag 1. The probable models of ARIMA or SARIMA were identified through ACF and PACF function plots.

The diagnosed models by the autocorrelation and partial autocorrelation functions of suggested models are

shown as below:

SARIMA $(p, d, q)(P, D, Q)$.
SARIMA $(1, 1, 1)(0, 1, 0)$ 12.
SARIMA $(1, 1, 2)(0, 1, 0)$ 12.
SARIMA $(1, 1, 3)(0, 1, 0)$ 12.

The best diagnosed model was based on the lowest value of mean square error (MSE). The model of SARIMA $(1, 1, 3)(0, 1, 0)$ 12 had the lowest MSE value compared to others. The evaluation of ACF and PACF error illustrations showed no significant difference between the model and the actual series $(P > 0.05)$. Therefore, the model of SARIMA $(1, 1, 3)(0, 1, 0)$ 12 was considered as the best fit model in this study (Table 3).

By identifying the best fit model, forecasting the trend of traffic accidents mortality was done for the next 4 years with 95% confidence interval (Figure 4).
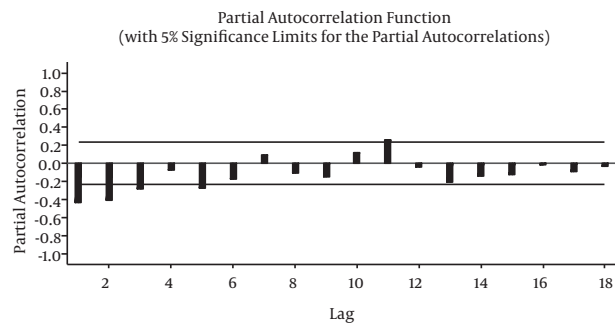

Figure 3. Partial Autocorrelation Function Plots of Accidents Mortality in Zanjan After Removing the Nonstationary in Data
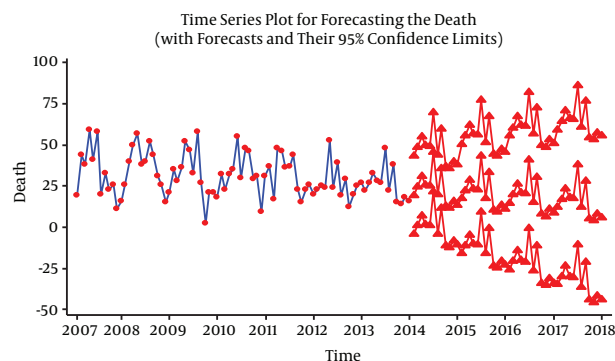

Figure 4. Forecasting Plot of Traffic Accidents Mortality

According to the forecasted values, the future traffic accidents mortality will have an descending trend. Moreover, we will expect that most deaths occur in the warm months of the years (August - September) and the least will be in the months of winter (December - January).

Table 2. Comparison of Decrease and Increase in the Road Traffic Mortality Trend During 2007 - 2013

Years	Mortality (n)	The Changes of Mortality Rate Compared to the Year 2007	The Changes of Mortality Rate Compared to the Last Year
2007	388	-	-
2008	440	+13.40	+13.40
2009	378	-2.57	-14.09
2010	401	+3.35	+6.08
2011	372	-4.12	-7.23
2012	320	-17.52	-13.97
2013	308	-20.61	-3.75

Table 3. Estimating Parameters for the Identified Models

Type of Model	Coefficients	SE	P-Value	MS
SARIMA (1, 1, 1) (0, 1, 0)				154.4
AR1	-0.02	0.12	0.8	
MA1	0.98	0.05	<0.001	
Constant	-0.07	0.09	0.4	
SARIMA (1, 1, 2) (0, 1, 0)				156.3
AR1	-0.4	1.6	0.8	
MA1	0.59	1.6	0.7	
MA2	0.4	1.6	0.8	
Constant	-0.11	0.16	0.5	
SARIMA (1, 1, 3) (0, 1, 0)				148.51
AR1	-0.9	0.08	<0.001	
MA1	0.1	0.16	0.56	
MA2	0.9	0.03	<0.001	
MA3	0.08	0.13	0.54	
Constant	-0.03	0.004	<0.001	

5. Discussion

The purpose of this study was to assess the trend of RTA mortalities between the 2007 and 2013 and forecast it for the next 4 years by using the time series analysis. Our study findings showed a decreasing trend over the past and future years. Also, results showed a higher percentage of fatalities in the years 2008 in comparison to 2007. On the other hand, lower percentage of fatalities was seen in the years 2013. These outcomes can be related to different traffic policies and interventions, which have been implemented in the recent years. Some of these programs are as follows: training and education of safety programs especially for drivers and motorists, enforcement of rules for using car seat belts, safety helmets for motorists, and increased fines (4, 5). Enforcing these interventions in other countries had a positive effect on the decline of mortalities related to traffic accidents. For example in the USA, seat belt use has an increasing trend since 1995 to 2013 that reached up to 87%, which is accompanied by a remarkable decline in the percentage of passenger fatalities (19). The results of the Orsi et al. study conducted to assess the trends of motor vehicle crash mortalities in European countries, during 1980 - 2007, showed that the trend of mortality had a decreasing pattern in northern and western Europe. In this study, the researchers concluded that the trend reduction was due to implementation of some national road safety programs such as speed limits (8).

In Iran, new traffic policies have decreased the mortality rate up to 8.7% and the rate of injury to 33.3% due to the recent traffic policies (20). The results of another study in the year 2013 showed a decreasing trend in RTAs in Iran (5).

In Nigeria, a study was done by Fagoyinbo et al. in 2014, in which the least square methods were used to forecast the number of road accidents, which had a decreasing trend in RTA mortalities (21).

In Nigerian study, it was explained that a decreasing pattern in trend analysis of RTAs is related to government's effort in enforcement of new traffic laws, controlling the transportation, training programs for drivers, and fixation of the roads in the recent years (21, 22).

Comparison of RTAs per 100.000 populations in Iran (747) with Turkmenistan (28), Turkey (98), Australia (534), USA (675) shows an urgent need for a bigger consideration in traffic policies and the health care systems (5). Based on these statistics, there is still a high fatality rate in Iran compared to other countries (5).

To achieve the Iranian government's goal for reducing the trend of traffic accidents by 10% annually since the year 2005, we need to pay more attention to prevent the occurrence and mortality due to traffic accidents and use the standard programs in prevention and controlling injuries and trauma (5, 12).

Based on the world health organization (WHO) report, all countries should have an inclusive and coordinated system for providing appropriate care in prehospital, hospital and posthospital phases. This system is known as a trauma system (23).

Trauma system is an organized, integrated and coordinated system in a defined geographic area that delivers the full range of care, primary prevention to tertiary prevention, to all injured patients. Different actors are involved in the trauma system as police force, road operators, fire brigades, medical assistance and other organizations (8). Integrated actions of the involved organizations can prevent avoidable deaths due to motor vehicle crashes (8). The trauma system in developed countries like the USA, Australia and Canada, causes to reduce the morbidities and mortalities related to trauma (9, 24, 25). Based on the findings of some studies on evaluation of the effectiveness of the trauma system, the mortality rate in severely injured patients can be reduced up to 25% in a 10 years period (26-28).

In our country, we have not any such integrated and inclusive system. However, according to the government's third development plan in 2000, the government has been responsible of developing trauma system to deliver optimal care to injured patients and decrease the occurrence and mortality, especially in RTAs (29).

Overall, reviewing the successful countries in trauma issues shows that establishing the trauma system in Iran can be considered as an effective plan in prevention and controlling the traffic accidents' injuries and fatalities.

References

1. Rahman MZ, Ahmad M, Rahman FN, Islam SMK, Rahman KGM, Haque MR. Abundance of road traffic accidents among medicolegal postmortem cases. *Faridpur Med College J.* 2011;**6**(1):28–31.

2. Peden M. Global collaboration on road traffic injury prevention. *Int J Inj Contr Saf Promot.* 2005;**12**(2):85–91. doi: 10.1080/15660970500086130. [PubMed: 16156532].

3. Gomes E, Araujo R, Carneiro A, Dias C, Lecky FE, Costa-Pereira A. Mortality Distribution in a Trauma System: From Data to Health Policy Recommendations. *Eur J Trauma Emerg Surg.* 2008;**34**(6):561–9. doi: 10.1007/s00068-007-6189-3. [PubMed: 26816280].

4. Razzaghi A, Bahrampour A, Baneshi MR, Zolala F. Assessment of trend and seasonality in road accident data: an Iranian case study. *Int J Health Policy Manag.* 2013;**1**(1):51–5. doi: 10.15171/ijhpm.2013.08. [PubMed: 24596836].

5. Bahadorimonfared A, Soori H, Mehrabi Y, Delpisheh A, Esmaili A, Salehi M, et al. Trends of fatal road traffic injuries in Iran (2004-2011). *PLoS One.* 2013;**8**(5):e65198. doi: 10.1371/journal.pone.0065198. [PubMed: 23724132].

6. Esmael M, Sasaki K, Nishii K. Road traffic accident trend in developing countries-the policy implications. *EASTS.* 2013;**10**:1978–90.

7. Sanaei-Zadeh H, Vahabi R, Nazparvar B, Amoei M. An epidemiological study and determination of causes of traffic accident-related deaths in Tehran, Iran (during 2000-2001). *J Clin Forensic Med.* 2002;**9**(2):74–7. doi: 10.1054/jcfm.2002.0547. [PubMed: 16083690].

8. Orsi C, Bertuccio P, Morandi A, Levi F, Bosetti C, La Vecchia C. Trends in motor vehicle crash mortality in Europe, 1980-2007. *Safety Sci.* 2012;**50**(4):1009–18.

9. Gabbe BJ, Lyons RA, Fitzgerald MC, Judson R, Richardson J, Cameron PA. Reduced population burden of road transport-related major trauma after introduction of an inclusive trauma system. *Ann Surg.* 2015;**261**(3):565–72. doi: 10.1097/SLA.0000000000000522. [PubMed: 24424142].

10. Shams Vahdati S, GhafarZad A, Rahmani F, Panahi F, Omrani Rad A. Patterns of Road Traffic Accidents in North West of Iran during 2013 New Year Holidays: Complications and Casualties. *Bull Emerg Trauma.* 2014;**2**(2):82–5. [PubMed: 27162871].

11. Tavakoli R, Sanainasab H. Prevalence and factors affecting on road traffic accidents in Sepah Pasdaran ground forces in Tehran. *Mil Med J.* 2006;**8**:279–83.

12. Monfared A, Soori H, Mehrabi Y, Hatami H, Delpisheh A. Prediction of fatal road traffic crashes in iran using the box-jenkins time series model. *J Asian Sci Res.* 2013;**3**(4):425.

13. Ainy E, Soori H, Riahi M, Vahabzadeh E, Mohebi A, Amiri M. The effect of new road traffic laws on fatal and non-fatal injury rates in Iran. *Int J Epidemiol Res.* 2014;**1**(1):16–23.

14. Lemos M, Finan T, Fox RW, Nelson DR, Tucker J. The use of seasonal climate forecasting in policymaking: lessons from Northeast Brazil. *Climatic Change.* 2002;**55**(4):479–507.

15. Noland RB, Quddus MA. Improvements in medical care and technology and reductions in traffic-related fatalities in Great Britain. *Accid Anal Prev.* 2004;**36**(1):103–13. [PubMed: 14572832].

16. Houston DJ, Richardson LJ. Traffic safety and the switch to a primary seat belt law: the California experience. *Accid Anal Prev.* 2002;**34**(6):743–51. [PubMed: 12371779].

17. Commandeur JJ, Bijleveld FD, Bergel-Hayat R, Antoniou C, Yannis G, Papadimitriou E. On statistical inference in time series analysis of the evolution of road safety. *Accid Anal Prev.* 2013;**60**:424–34. doi: 10.1016/j.aap.2012.11.006. [PubMed: 23260716].

18. Statical Center of Iran . 2016. Available from: https://www.amar.org.ir/.

19. Road safety annual report. 2014.

20. Soori H, Ainy E, Vahabzadeh E, Mohebi A. The effect of the new traffic law on the the fatality and injury rate of dangerous infractions (in Persian). *Rahvar.* 2012;**18**(9):27–38.

21. Fagoyinbo I, Akinbo R, Ajibode I. Forecasting road accident using least square method: A case study of lagos state, Nigeria.. *Developing coun-* *try studies.* 2014;**4**(23):8–14.

22. Salako RJ, Adegoke BO, Akanmu TA. Time series analysis for modeling and detecting seasonality pattern of auto-crash cases recorded at federal road safety commission, osun sector command (rs 111), osogbo. *ijeat.* 2014;**2**(4):25–34.

23. WHO . Model trauma system policy Available from: http://www.who.int/violence_injury_prevention/services/traumacare/model/en.

24. Moore L, Turgeon AF, Sirois MJ, Lavoie A. Trauma centre outcome performance: a comparison of young adults and geriatric patients in an inclusive trauma system. *Injury.* 2012;**43**(9):1580–5. doi: 10.1016/j.injury.2011.02.010. [PubMed: 21382620].

25. Staudenmayer K, Wang NE, Weiser TG, Maggio P, Mackersie RC, Spain D, et al. The Triage of Injured Patients: Mechanism of Injury, Regardless of Injury Severity, Determines Hospital Destination. *Am Surg.* 2016;**82**(4):356–61. [PubMed: 27097630].

26. Celso B, Tepas J, Langland-Orban B, Pracht E, Papa L, Lottenberg L, et al. A systematic review and meta-analysis comparing outcome of severely injured patients treated in trauma centers following the establishment of trauma systems. *J Trauma.* 2006;**60**(2):371–8. doi: 10.1097/01.ta.0000197916.99629.eb. [PubMed: 16508498] discussion 378.

27. Cudnik MT, Newgard CD, Sayre MR, Steinberg SM. Level I versus Level II trauma centers: an outcomes-based assessment. *J Trauma.* 2009;**66**(5):1321–6. doi: 10.1097/TA.0b013e3181929e2b. [PubMed: 19430234].

28. Demetriades D, Martin M, Salim A, Rhee P, Brown C, Doucet J, et al. Relationship between American College of Surgeons trauma center designation and mortality in patients with severe trauma (injury severity score > 15). *J Am Coll Surg.* 2006;**202**(2):212–5. doi: 10.1016/j.jamcollsurg.2005.09.027. [PubMed: 16427544] quiz A45.

29. Zargar M, Kalantar Motamedi SM, Karbakhsh M, Ghodsi SM, Rahimi-Movaghar V, Panahi F, et al. Trauma care system in Iran. *Chin J Traumatol.* 2011;**14**(3):131–6. [PubMed: 21635797].