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Forecasting the Fatality Rate of Traffic Accidents in Jordan: Applications of Time-Series, Curve Estimation, and Multiple Linear Regression Models

Belal Edries[1] and Ahmad H. Alomari[2,*]

[1]*Department of Civil, Structural and Environmental Engineering, Trinity College Dublin, Dublin 2, Ireland.*
[2]*Civil Engineering, Yarmouk University (YU), P.O. Box 566 - Irbid 21163, Jordan*

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Abstract

This paper investigates the trends in the traffic fatality rate per 100,000 population, population growth, gross domestic product (GDP), and registered vehicles per 100,000 population over 39 years (from 1981 to 2020). Traffic accidents data were obtained from the Jordan Public Security Directorate (JPSD) published reports for the selected years in Jordan. Data were analyzed to predict the annual fatality rate using time-series, curve estimation, and multiple linear regression models. Among the various available models for curve estimation, the cubic model outperformed the rest by capturing 79.4% of the variance. Also, multiple linear regression results showed that increasing the length of the road network can play a role in decreasing the fatality rate of road accidents. While time series analysis offers numerous techniques, it is determined that the Jordanian fatality rate is best suited for using the exponential smoothing approach. Results indicated that the time series model produces the lowest mean absolute percentage errors (MAPE), followed by multiple linear regression, and finally by the curve estimate (cubic) model. It is essential to see how these variables have changed over the study period, which helps decision-makers, engineers, and researchers predict future trends and suggest suitable measures to lower the fatality rate.

Keywords: Forecasting; Traffic Accidents; Fatality Rate; Time-Series; Curve Estimation; Multiple Linear Regression.

1. Introduction

Traffic accidents are often considered among the most significant challenges facing the world today, as they pose a serious threat to human life on a global scale. In Jordan, a developing country, traffic accidents are a significant public health problem. They are the second leading cause of death [1]. Jordan's total population reached 10,203,134 inhabitants in 2020, with a total of 1,729,343 registered vehicles [2].

Traffic accidents are a severe challenge in Jordan, where approximately two people die each day in car crashes, and the country loses 2-3% of its gross domestic product (GDP) due to this problem [3]. According to the Jordan Public Security Directorate's traffic accident yearly report [4], the total number of traffic collisions in Jordan in 2020 reached 122,970, resulting in 461 fatalities and 12,690 injuries, at an estimated cost of $296 million US dollars. Traffic safety investigations involve three significant categories: humans, vehicles, and highway infrastructure [5]. It is essential to study all th
e characteristics related to these three elements. Such studies help us understand the most important causes of traffic accidents. Therefore, based on their findings, we can identify the most meaningful practical solutions. This also means that the proposed solutions will vary according to the specificity of each dangerous site with a high frequency of accidents.

Many studies have been conducted in Jordan to investigate traffic accidents using different approaches. Obaidat and Ramadan [6] investigated traffic accidents at hazardous locations on Jordanian urban roads using various stepwise statistical regression models. The logarithmic and linear models were the most significant and appropriate models for predicting the relationship between the expected number of accidents as a dependent variable and several other variables as independent variables. The following independent variables were identified as significant contributors to traffic accidents in hazardous locations: "*average running speed, posted speed, the maximum and average degree of horizontal curves, number of vertical curves, median width, road surface type, lighting (day or night), number of vehicles per hour, number of pedestrian crossing facilities, and percentage of trucks*" [6]. Al-Masaeid [1] examined the types of accidents in Jordan, including the involvement rates of pedestrians, drivers, and vehicles, and the safety effects of policy changes made from 1997 to 2008. These changes included more police enforcement and stricter traffic laws, which made the roads safer. According to the findings, accidents were primarily caused by carelessness and aggressive driving behavior. In addition, it was found that more traffic enforcement and stricter enforcement of traffic laws led to a significant drop in accidents and fatalities.

Al-Omari et al. [7] examined traffic accident trends in Jordan from 1998 to 2010. The majority of traffic accidents were reported at or below the 50 km/hour speed limit, and the trend continued to decline as the speed limit increased. Also, great bulk of traffic accidents occurred between 12:00 and 5:00 PM, with the highest severity levels occurring during this period (3:00–6:00 AM). Sundays and Thursdays (the first and last working days in Jordan, respectively) saw the highest number of traffic accidents, while Friday (the national holiday) saw the highest severity level. The summer months have seen the highest number of traffic accidents, with August seeing the highest number. Al-Abdallat et al. [8] took blood

*E-mail address: alomarish@yu.edu.jo
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samples from accident victims to determine the prevalence of alcohol and psychotropic drugs in fatal road traffic accidents in Jordan from 2008 to 2014. Alcohol and psychotropic drugs were found in 36.5% of the cases. Pedestrians made up the lion's share of the victims (49.8%). Furthermore, 29.6% of cases involved people aged 19–29. Al-Rousan et al. [9] investigated the characteristics of distracted driving crashes on rural and suburban roadways in Jordan using descriptive analysis and independent sample t-tests. Distracted driving was found to be the second most common driver error that caused crashes and the second most common cause of fatalities and injuries on both rural and suburban roads. Distracted driving appears to be more deadly on rural highways, and thus resulting in more severe injury crashes on suburban roads.

Some studies in Jordan have examined the economic and financial costs of road accidents. Alrahamneh and AlBtoush [10] developed a model for the burden cost of road accidents in Jordan over fifteen years (1995–2010). The findings indicated that traffic accidents are costly in Jordan. Additionally, it proved that the response variable (time) significantly impacts the dependent variable (financial costs for the traffic accidents). Ghadi et al. [3] studied the economic costs of road accidents for three years (2011–2013) in Jordan. The findings indicated that Jordan is still suffering from a constant increase in road accident expenses. This is despite the substantial growth in the registered vehicles and population (during the study period), particularly in the aftermath of the Syrian refugee crisis. The anticipated total expenses of accidents in 2011, 2012, and 2013 were approximately (3814, 4718, and 5146 US $ per accident, respectively, which accounted for 2.5 percent, 2.3 percent, and 2.25 percent of the country's total GDP in those years.

Geographic Information Systems (GIS) have been used in several studies to investigate traffic accidents in Jordan. Al-Omari and Obaidat [11] utilized GIS to analyze pedestrian accidents in Irbid, Jordan. The study's findings indicated that most pedestrian accidents occurred outside intersections, in clear and sunny weather, on a dry surface, during daylight hours, and at low-speed limits. Additionally, pedestrian accidents have occurred more frequently in the afternoons, on Thursdays, and during July, which is confirmed by Al-Omari et al. [7]. In another study by Al-Omari et al. [12], they aimed to predict accident hot spots in various locations in Irbid, Jordan, using GIS and fuzzy logic, based on traffic accidents between 2013 and 2015. Spatial-temporal analysis was also used to investigate fatalities and injuries. Based on the results, eight hot spots had been identified; three are road segments, and five are major intersections that were analyzed to ascertain accident-causing factors and recommend appropriate remedies. Alkhadour et al. [13] also used GIS to investigate traffic accidents in Amman, Jordan, in temporal and spatial contexts. The findings confirmed that hotspots were concentrated primarily in commercial/residential, and industrial/zones located in and around the study area's central regions. This is justified because such regions have high population densities and public infrastructure, resulting in high traffic volumes and low-speed limits.

Predicting traffic crashes is critical to grasping the scope of the problem and expediting decision-making toward its resolution. Yousif and AlRababaa [14] employed a neural network technique to forecast traffic accidents in Jordan. Efforts are made to analyze the recorded data on traffic accidents, such as the number of accidents, their types, and their causes. The results demonstrated a high degree of accuracy in classifying the type of accident. This research presented an analytical investigation of traffic accidents in Jordan. Furthermore, it has developed a set of equations that are likely to aid in regulating the reduction of traffic accidents. Jadaan et al. [15] used Artificial Neural Networks (ANN) to forecast road traffic accidents in Jordan. The results revealed that the number of the predicted traffic accidents was sufficiently close to the number of real traffic accidents. The model was validated and found to perform well in Jordanian traffic conditions, indicating that it can confidently forecast future traffic accidents.

Hmaid and Imam [16] developed various crash prediction models for Jordanian roadway segments. The study used crash data from the Jordan Traffic Institute (JTI) for 24 arterial roads in and around Amman from 2014 to 2018. The results indicated that crash occurrence increased with the increment of the speed limit, annual average daily traffic (AADT), and segment length. Additionally, the results indicated that driving in the dark, snowy weather, or above the speed limit of 60 km/h significantly increased the risk of fatal crashes. Alomari and Taamneh [5] applied logistic regression to examine seatbelt compliance in Jordan among front-seat occupants (FSOs), drivers, and front-seat passengers (FSPs). Only 13% of drivers and 8% of FSPs were found to be wearing seatbelts. The driver's obligation to wear a seatbelt significantly impacts the FSP, either positively or negatively. The logistic regression analysis results indicated that the roadway classification and gender were statistically significant predictor variables for driver seatbelt use, whereas the road classification, gender, and driver seatbelt use were significant predictor variables for the FSP. Khasawneh et al. [17] used time series analysis to forecast traffic accidents in Jordan to improve traffic safety measures. The results indicated that time series analysis was an effective technique for assessing the state of traffic accidents.

According to the literature findings, various approaches and tools over various periods of time have been used to improve the forecasting of traffic accidents, injuries, and fatalities in developing countries such as Jordan. Accordingly, it is necessary to study the traffic accident trend in Jordan as to the best of the researchers' knowledge; no studies have been conducted to this date that evaluate traffic accidents from 1981 to 2020. Using time-series, curve estimation, and multiple linear regression models, this study aims to look at the fatality rate per 100,000 population in Jordan over the last 39 years (from 1981 to 2020) to see how they have varied and forecast the next ten years.

The remaining part of the paper is organized as follows: the methodology applied in this study is described in Section 2. Section 3 presents the results of this study, followed by its discussion in Section 4. Section 5 proposes a set of recommendations. In the end, Section 6 points to the limitations of this study.

2. Methodology

Two main types of data were used in this study. Firstly, traffic accident-related data (e.g., fatal accidents per year, numbers of registered vehicles) comes from the Jordan Public Security Directorate [4] annual reports about traffic safety in Jordan from 1981 to 2020. Secondly, social-economic data such as population, length of the road network, GDP per capita, and others were obtained from the Jordanian department of statistical [2] reports and the World Bank [18]. The methodology to achieve the previously mentioned goal is shown in Figure 1.

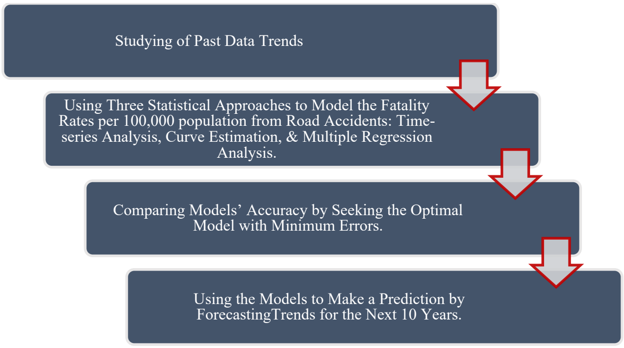


Fig. 1. Methodology Flow Chart

Three data analysis approaches were applied to forecast the rate of fatal accidents per 100,000 populations. These approaches are curve estimation, multiple regression analysis, and time-series analysis.

2.1 Curve Estimation

Curve estimation aims to identify the most appropriate distribution of the dependent variable (the rate of fatal accidents per 100,000 population) with the independent variable (time). Therefore, ten different distributions were tested via SPSS 23.0 [19] software: linear, logarithmic, inverse, quadratic, cubic, compound, power, S, growth, and exponential models. The equations of the models are as follows, respectively:

$$E(y)_t = b_0 + (b_1 \times T) \quad (1)$$

$$E(y)_t = b_0 + (b_1 \times \ln T)) \quad (2)$$

$$E(y)_t = b_0 + (b_1/T) \quad (3)$$

$$E(y)_t = b_0 + (b_1 \times T) + (b_2 \times T^2) \quad (4)$$

$$E(y)_t = b_0 + (b_1 \times T) + (b_2 \times T^2) + (b_3 \times T^3) \quad (5)$$

$$E(y)_t = b_0 \times (b_1)^T \quad (6)$$

$$E(y)_t = b_0 \times (T_1)^b \quad (7)$$

$$E(y)_t = \exp[b_0 + b_1/T] \quad (8)$$

$$E(y)_t = \exp(b_0 + (b_1 \times T)) \quad (9)$$

$$E(y)_t = b_0 \times (exp^{b_1 * T}) \quad (10)$$

Where $E(y)_t$is the predicted value of fatality rate per 100,000 population from road accidents, T is time (T = 1, 2, 3, …, n years), b_0 is a constant (or y-intercept), and b_1–b_3 are coefficients.

2.2 Multiple Linear Regression

Through the utilization of multiple linear regression analysis, the objective is to allow other possible associated variables to influence the dependent variable (the rate of fatal accidents per 100,000 population). The inclusion of independent variables - other than the time - further helps to understand the key contributing variables and their roles. Therefore, it allows to draw more solid conclusions about their influence and suggest more effective policies to overcome their negative effects.

The following equation shows the general form of the multiple linear regression between the independent variable Y and set of dependent variables X_1–X_k.:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + e \quad (11)$$

Where Y is the dependent variable, X_1–X_k. are the independent variables, β_0 is a constant (or y-intercept), and β_1–β_k are the coefficients of the respective variables (loading or partial slopes), which are used to describe the change in the Y value when the X value changes.

In this study, the following equations are proposed for using:

$$Y = \beta_0 + \beta_1 \left(\text{I} - 100{,}000\ \text{P}\right) + \beta_2(\text{Length of Road Network}) + \beta_3\left(\text{Reg.}\frac{\text{Veh}}{100{,}000}\text{P}\right) \quad (12)$$

$$Y = \beta_0 + \beta_1(\text{I} / 100{,}000\ \text{P}) + \beta_2((\text{A} / 100{,}000\ \text{P}) + \beta_3(\text{Length of Road Network}) \quad (13)$$

Where Y is the fatality rate per 100,000 population, I / 100,000 P is the number of injuries rate per 100,000 population, A / 100,000 P is the number of accidents rate per 100,000 population, Length of Road Network is the total length of road network in Jordan, and Reg.Veh/100,000 P is the rate of registered vehicles per 100,000 population.

2.3 Time Series Analysis

The time series analysis represents a large umbrella under which several techniques are available (e.g., moving average, single exponential smoothing, double exponential smoothing, tribble exponential smoothing, or Winter's method). In this study, the double exponential smoothing approach was selected since it is appropriate to provide short-term forecasting, a technique that gives decreasing and is recommended to be utilized where the data exhibits a trend without a seasonal pattern. The double exponential smoothing general equations are as follows:

$$L_t = \alpha\, Y_t + (1 - \alpha)(L_{t-1} + T_{t-1}) \quad (14)$$

$$T_t = \beta\,(L_{t-1} + T_{t-1}) + (1 - \beta)\, T_{t-1} \quad (15)$$

$$\hat{Y}_t = L_{t-1} + T_{t-1} \quad (16)$$

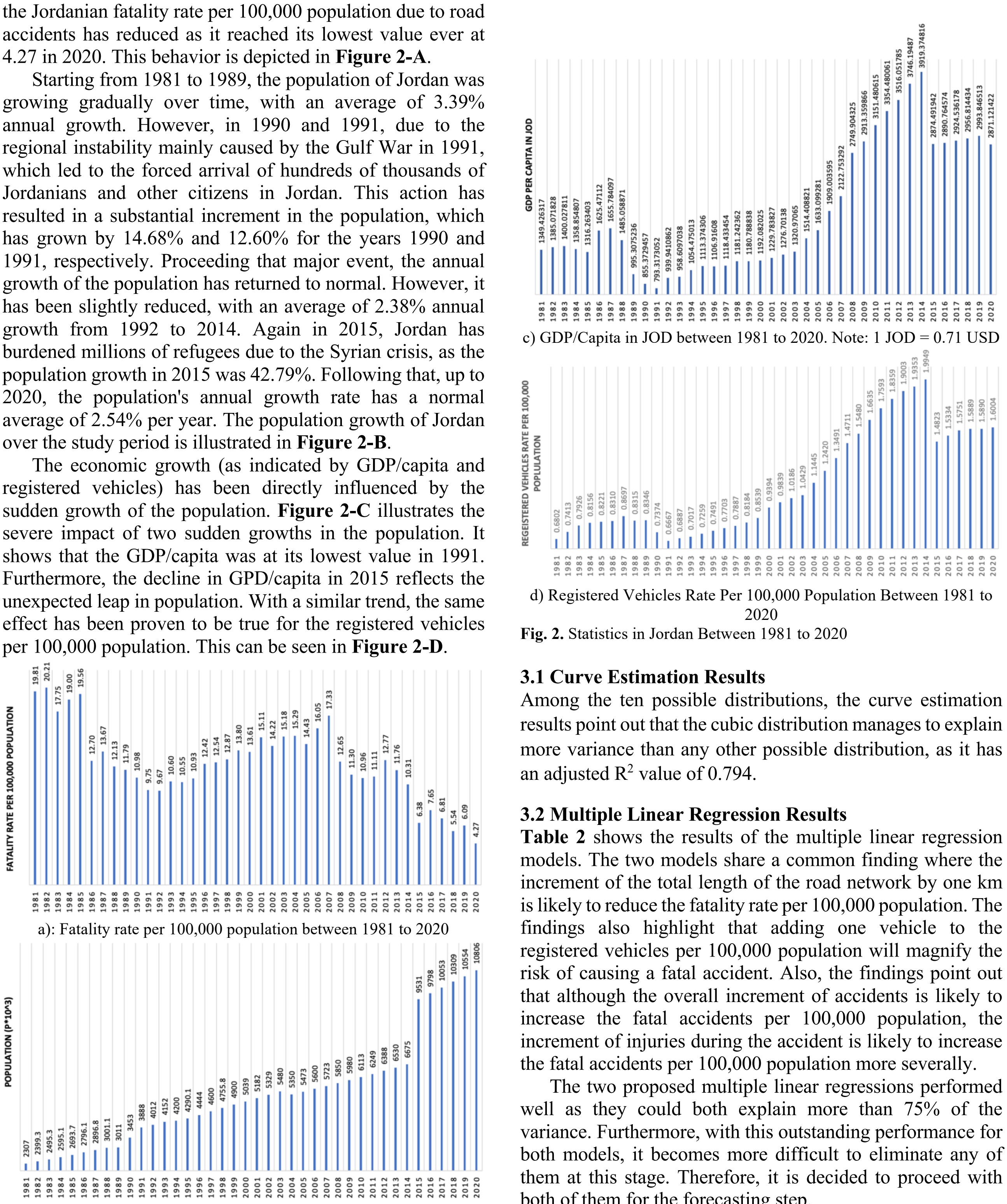
Where L_t is the level at time t, α is the weight (or smoothing constant) for the level, T_t is the trend at time t, β is the weight (or smoothing constant) for the trend, and $\hat{Y}_t$ is the forecasted value of the series at time t with smoothing factors of α and β.

3. Analysis and Results

Starting from 1981 to 1985, the fatality rate per 100,000 population kept fluctuating, from 19.81 in 1981 to 17.75 in 1983. However, the Jordanian fatality rate per 100,000 populations due to road accidents has experienced a significant drop in 1986, when it was 12.70. While the reduction continued till 1992 as it reached 9.76, the overall trend from 1993 to 2007 illustrates a positive incremental behavior as the fatality rate per 100,000 population due to road accidents became 17.3 in 2007. From 2007 until now, the Jordanian fatality rate per 100,000 population due to road accidents has reduced as it reached its lowest value ever at 4.27 in 2020. This behavior is depicted in **Figure 2-A**.

Starting from 1981 to 1989, the population of Jordan was growing gradually over time, with an average of 3.39% annual growth. However, in 1990 and 1991, due to the regional instability mainly caused by the Gulf War in 1991, which led to the forced arrival of hundreds of thousands of Jordanians and other citizens in Jordan. This action has resulted in a substantial increment in the population, which has grown by 14.68% and 12.60% for the years 1990 and 1991, respectively. Proceeding that major event, the annual growth of the population has returned to normal. However, it has been slightly reduced, with an average of 2.38% annual growth from 1992 to 2014. Again in 2015, Jordan has burdened millions of refugees due to the Syrian crisis, as the population growth in 2015 was 42.79%. Following that, up to 2020, the population's annual growth rate has a normal average of 2.54% per year. The population growth of Jordan over the study period is illustrated in **Figure 2-B**.

The economic growth (as indicated by GDP/capita and registered vehicles) has been directly influenced by the sudden growth of the population. **Figure 2-C** illustrates the severe impact of two sudden growths in the population. It shows that the GDP/capita was at its lowest value in 1991. Furthermore, the decline in GPD/capita in 2015 reflects the unexpected leap in population. With a similar trend, the same effect has been proven to be true for the registered vehicles per 100,000 population. This can be seen in **Figure 2-D**.



a): Fatality rate per 100,000 population between 1981 to 2020

b) Population growth between 1981 to 2020

c) GDP/Capita in JOD between 1981 to 2020. Note: 1 JOD = 0.71 USD

d) Registered Vehicles Rate Per 100,000 Population Between 1981 to 2020

Fig. 2. Statistics in Jordan Between 1981 to 2020

3.1 Curve Estimation Results
Among the ten possible distributions, the curve estimation results point out that the cubic distribution manages to explain more variance than any other possible distribution, as it has an adjusted R^2 value of 0.794.

3.2 Multiple Linear Regression Results
Table 2 shows the results of the multiple linear regression models. The two models share a common finding where the increment of the total length of the road network by one km is likely to reduce the fatality rate per 100,000 population. The findings also highlight that adding one vehicle to the registered vehicles per 100,000 population will magnify the risk of causing a fatal accident. Also, the findings point out that although the overall increment of accidents is likely to increase the fatal accidents per 100,000 population, the increment of injuries during the accident is likely to increase the fatal accidents per 100,000 population more severally.

The two proposed multiple linear regressions performed well as they could both explain more than 75% of the variance. Furthermore, with this outstanding performance for both models, it becomes more difficult to eliminate any of them at this stage. Therefore, it is decided to proceed with both of them for the forecasting step.

Table 1. Curve estimate model. R2, determination coefficient; SE, standard error

Model	R^2	Adjusted R^2	F	SE of the Estimate	Equation
Linear	0.422	0.407	27.741	3.000	$E(y)_t = 16.92 - 0.216T$
Logarithmic	0.438	0.423	29.579	2.959	$E(y)_t = 20.63 - 2.95\ln(T)$
Inverse	0.318	0.300	17.711	3.259	$E(y)_t = 11.13 + (12.72/T)$
Quadratic	0.435	0.405	14.248	3.006	$E(y)_t = 15.87 - 0.065T - 0.004T^2$
Cubic	0.809	0.794	50.960	1.770	$E(y)_t = 23.10 - 2.06T + 0.12T^2 - 0.002T^3$
Compound	0.434	0.419	29.153	0.269	$E(y)_t = 17.78 \times (0.98)^T$

Power	0.363	0.346	21.637	0.286	$E(y)_t = 23.15 \times (T_1)^{-0.244}$
S	0.214	0.194	10.363	0.317	$E(y)_t = \exp[2.37 + 0.95/T]$
Growth	0.434	0.419	29.153	0.269	$E(y)_t = \exp(2.88 - 0.020T))$
Exponential	0.434	0.419	29.153	0.269	$E(y)_t = 17.78 \times (exp^{-0.020*T})$

$$Y = 4.038 + 0.047\ (\text{I / 100,000 P}) - 0.001333\ (\text{Length of Road Network}) + 3.395\ (\text{Reg. Veh/100,000 P}) \quad (17)$$

$$Y = 9.340 + 0.03832\ (\text{I / 100,000 P}) - 0.00157\ (\text{Length of Road Network}) + 0.002458\ (\text{A / 100,000 P}) \quad (18)$$

Table 2. Results of multiple linear regression

Model 1	**(Y = Fatality Rate/100,000 Population)**	
	B	**p-Value**
Length of Road Network	-0.001333	***
I / 100,000 P	0.047	***
Reg.Veh/100,000 P	3.395	***
Constant	4.038	n.s
F-test	42.163	
Adjusted R2	76.0	
Model 2	**(Y = Fatality Rate/100,000 Population)**	
	B	**p-Value**
Length of Road Network	-0.001570	***
I / 100,000 P	0.03832	***
A / 100,000 P	0.002458	***
Constant	9.340	***
F-test	41.64	
Adjusted R2	75.76	

Significance level: *p<0.10, **p<0.05, ***p<0.01, n.s = not significant

3.3 Time Series Analysis Results

With double exponential smoothing, the approach was applied to determine the data trend without seasonal influences. The results indicated that optimal values for the level and trend coefficients are (0.873689) and (0.039288), respectively.

3.4 Evaluation of the Model Performances

Using different statistical approaches, four different models have been developed to predict the fatality rate per 100,000 population. The mean absolute percentage error (MAPE) is chosen to assess the proposed model's efficiency. MAPE is calculated based on the following equation:

$$\text{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{F_i - O_i}{O_i}\right| \times 100 \quad (19)$$

Where F_i is the predictive fatalities rate per 100,000 population value for each year, O_i is the actual fatalities rate per 100,000 population for each year and n = 40 years.

The comparison results (Table 3) have presented that the time series model outperformed the rest of the other models with the lowest MAPE value (11.045%), followed by multiple regression linear model 2, multiple regression linear model 1, and curve estimation (cubic) with MAPE values of 12.621%, 12.770%, and 13.264%, respectively.

Table 3. Comparison of the mean absolute percentage error (MAPE) of different methods.

	Model	**Year**					**Value**
		1981	**1991**	**2001**	**2011**	**2020**	**MAPE***
1	Curve estimate (cubic)	21.16	12.30	14.24	14.98	4.70	13.264
2	Multiple linear regression (Model 1)	17.90	10.33	14.78	14.38	2.77	12.770
3	Multiple linear regression (Model 2)	18.11	10.81	14.32	14.82	2.22	12.621
4	Time series analysis	20.73	10.25	13.17	10.60	5.54	11.045

MAPE, mean absolute percentage errors; *, average MAPE 1981–2020

3.5 Forecasting the Fatality Rate from Road Accidents

Using the model with the lowest MAPE the independent variables (e.g., length of the road network) taking part in the different models are predicted for the ten years horizon (Table 4).

Table 4. Predictive results, including the variables and prediction to be used in the models

Year	**Length of Road Network**	**A/ 100,000 P**	**I / 100,000 P**	**Reg.Veh / 100,000 P**
2020	9171.00	1137.98	117.435	1.60035
2021	9512.80	1087.88	106.112	1.61457
2022	9843.50	1088.48	100.929	1.62895
2023	10174.3	1089.08	95.747	1.64332
2024	105050	1089.67	90.565	1.65770
2025	10835.7	1090.27	85.383	1.67208

2026	11166.5	1090.87	80.200	1.68646
2027	11497.2	1091.47	75.018	1.70083
2028	118280	1092.07	69.836	1.71521
2029	12158.7	1092.66	64.653	1.72959
2030	12489.4	1093.26	59.471	1.74397

The forecasting results for all the proposed models exhibit a damping trend behavior. This is in line with a general trend of fatalities over the last 40 years The comparison among the four proposed models is depicted in Fig. 3, where the **big black triangle** refers to the start of the forecasting period.

Table 5. Fatality Rate from Road Accidents Per 100,000 Population as Predicted by the Models Used.

Year	Curve Estimate (Cubic)	Multiple Linear Regression Model 1	Multiple Linear Regression Model 2	Time Series Analysis
2021	2.52	1.83	1.13	3.94629
2022	0.08	1.19	0.42	3.4655
2023	-	0.55	-	2.98472
2024	-	-	-	2.50393
2025	-	-	-	2.02315
2026	-	-	-	1.54236
2027	-	-	-	1.06158
2028	-	-	-	0.58079
2029	-	-	-	0.10000
2030	-	-	-	-

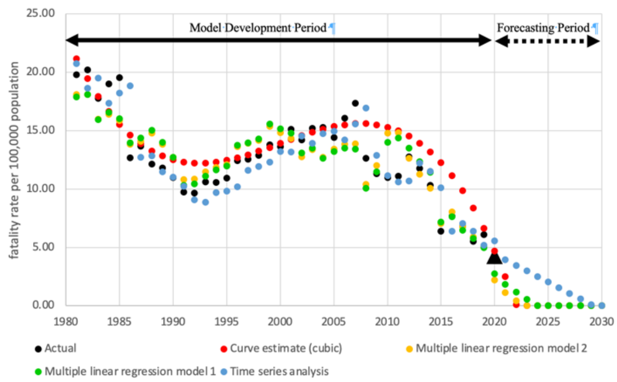


Fig. 3. Comparison of Prediction Results Using Different Techniques

4. Discussion & Conclusions

The socioeconomic status of Jordan and the regional conflicts have played a significant role in influencing road safety in Jordan. The depreciation of the Jordanian dinar against the US dollar between 1985 and 1989 (from 1 JOD ≈ 3.44 USD to 1 JOD ≈ 1.41 USD) stands to be likely a unique moment in Jordan's history. It gives a demonstration of the economic role in other areas. From 1990 to 1991, Jordan received waves of refugees due to the Gulf War in Iraq. It is among the historical examples that show the effects of the conflicts in the neighboring countries on road safety in Jordan. It is worth mentioning that the drop-in fatality rate per 100,000 population between 1990 and 1992 was, in fact, due to the sudden increase in the population. This can explain why the fatality rate per 100,000 population regained its momentum after 1992.

From 1992 to 2014, economic growth has kicked off with decent GPD growth. It was also going in parallel with an undesired increment in the fatality rate per 100,000 population up to 2007. After the traffic law modification in 2008, the fatality rate per 100,000 population has been slightly dampened, with an average of 11.37 for the consecutive six years up to 2014, while it was 12.65 back in 2008. While the Syrian crisis started in 2011, the bulk of refugees came in 2015, which led to a historical population growth rate, with it almost hitting 43%. It also came with recording a fatality rate per 100,000 population below 10% for the first time in Jordan.

Furthermore, the Traffic Points System Regulation was introduced in 2018. It brings hope that the fatality rate per 100,000 population is going to be below 10% for many coming years. In comparison to other similar and more developed nations, it is evident that Jordan's international ranking for the fatality rate per 100,000 population has been improved over the last 20 years (Figure 4). Utilizing the statistical data available from the Jordan Traffic Institute's annual reports about traffic safety in Jordan, this study aimed to forecast the future of the fatality rate per 100,000 population in Jordan for the next ten years. This study had applied different techniques: multiple linear regression, curve estimation, and time series analysis. The results are:

1) Among the different available models applied within the curve estimation, the cubic model has outperformed by a huge distance with its ability to capture 79.4 % of the variance.
2) Multiple linear regression 1 has opened our eyes to an interesting finding that increasing the length of the road network can play a role in decreasing the fatality rate per 100,000 population of road accidents.
3) Multiple linear regression 2 main function is to quantify the risk of the total number of accidents accounted for by the inclusion of the accident rate per 100,000 population. The findings suggest that out of 100,000 individuals being involved in road accidents, we are likely to have about 246 fatalities, with the assumption that neither of the other independent variables has changed.
4) The time series has many techniques to offer; however, it is found that the Jordanian fatality rate per 100,000 was most suited for using the exponential smoothing approach.

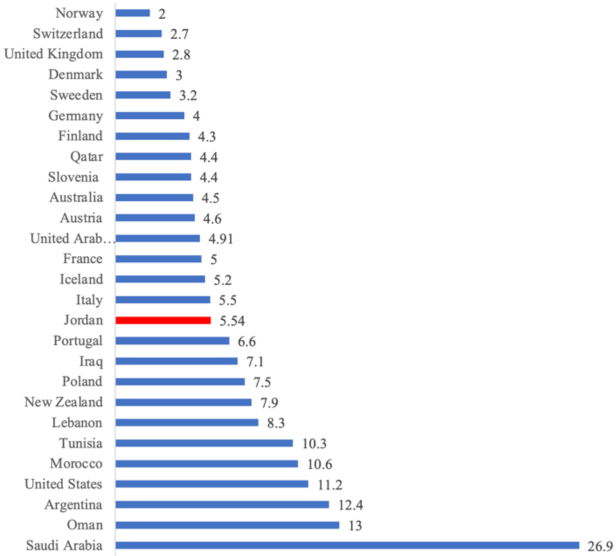


Fig. 4. International Comparison for fatalities per 100,000 in 2018 [20]

The quality of all the proposed models has been quantified through their ability to recreate the past. Therefore, their performances have been evaluated by MAPE, which stands for mean absolute percentage errors. The results have shown that the time series model has the lowest MAPE, followed by multiple linear regression (Model 2), which is followed by multiple linear regression (Model 1), and finally comes the curve estimate (cubic) model with the highest MAPE. The results of forecasting for the next ten years have clearly illustrated that the direction of the fatality rate per 100,000 population will decline. However, as all the models expect, time series analysis has forecasted zero values and, therefore, is inappropriate for long-term forecasting. As time-series analysis is chosen to be the most recommended approach to use. However, some might still point out that the last year of 2030 is forecasted to be zero. Therefore, to fill the gap, we are presenting the confidence interval levels of the time series analysis in Table 6 to present the possible range around the estimate.

Table 6. Forecast Accuracy using Time Series Analysis

Year	Forecast	Confidence Interval 95 %	
		Lower	Upper
2021	3.94629	0.6964	7.1962
2022	3.46550	-1.1036	8.0346
2023	2.98472	-2.9901	8.9595
2024	2.50393	-4.9140	9.9218
2025	2.02315	-6.8571	10.9034
2026	1.54236	-8.8113	11.8960
2027	1.06158	-10.7725	12.8956
2028	0.58079	-12.7382	13.8998
2029	0.10000	-14.7072	14.9072
2030	-0.38078	-16.6786	15.9170

Mode parameters: α (level) = 0.873689, γ (trend) = 0.039288, Model accuracy measure: MAPE= 11.045

5. Recommendations

The number of fatalities on the roads is predicted to reduce over the next ten years due to the numerous policies put in place. The economic and transportation elements analyzed, which characterize the country's economic progress, had direct and indirect effects on the number of fatalities on the road. Some statistics, particularly the number of registered automobiles on the roads, which is directly related to the number of accidents, could be beneficial for directing government decisions and creating preventive initiatives to minimize the causes of road accidents if examined in depth. To reduce fatal accidents in the public sector, adequate policies are essential. Given Jordan's mixed traffic circumstances, trucks and other heavy vehicles share the road with small and medium-sized vehicles, potentially resulting in dangerous situations and accidents. The government should create laws that strictly regulate driving speeds for all sorts of vehicles, with dedicated lanes for freight vehicles. To own a car, the government must adopt regulations connected to the control of vehicles possession, involving harsher requirements such as demanding the declaration of a driver's license and taking into account traffic infractions and accident history. This strategy would agree with the outcomes of models 1 and 2 of multiple linear regression.

6. Limitations

The lack of a complete data set, including all the details about each accident, and limited data availability have seriously hindered the application of different analysis methods. It also handcuffs our ability to include a set of potential variables that are thought to be hugely influential in predicting and forecasting the fatality rate per 100,000, such as speed limit, vehicle characteristics, road characteristics, age and gender of the driver, and more.

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