

# Trends and Modeling of Traffic Accidents in Jordan

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**Abstract--** Road traffic accidents globally responsible for the death of 1.35 million people in 2016, it considered the 9<sup>th</sup> leading cause of death for people of all ages in 2012-2016. The road traffic accidents considered the third cause of death in Jordan during the year 2010. According to this study, the traffic accident data in Jordan from 1981 to 2017 were analyzed. The traffic accidents in Jordan were increasing due to the increase in population and auto ownership, which increased from 15 in 1981 to 6.3 person/vehicle in 2017. The general trend of accidents was increasing from 13567 in 1981 to 150226 in 2017; resulted in 685 deaths and injuries of 16246 injuries, with an average of 104 thousand accidents /year for the last 17 years. In spite of growing the motorization level (# registered vehicles/1000 population) from 68 in 1981 to 157.5 in 2017, the severity rate (the total number of fatal and injury in the total accidents) decreasing from 0.718 in 1981 to 0.124 in 2017. According to this study, the relationships between traffic accidents and their caused factors seemed strength with  $R^2 > 0.93$ , where the rate of casualty accidents decreasing with  $R^2 > 0.80$ . The time factors considered the significant essential variable in most models, then the growth of auto ownership. The traffic accident rate was analyzed considering several indexes such as motorization and severity levels. Despite that the motorization index is increasing with time in a similar trend as the accident rate, the severity level is decreasing due to the reduction of casualty accidents. Most of the regression models ( $R^2 \geq 0.900$ ) obtained from these accidents data could be used to predict the accidents and other related variables in the future.

**Keywords:** Traffic accident, Jordan, Accidents trends, Traffic models, Safety.

## I. INTRODUCTION / LITERATURE REVIEW

Death and injuries resulting from road traffic crashes remain a serious problem globally, and current trends suggest that this will continue to be the case in the foreseeable future. The report stated that 1.35 million person deaths in 2016, the 9th leading cause of death for people of all ages during 2012-2016, the first cause of death for children and young adults 5-29 years of age, 3 times higher death rates in low-income countries than in high-income countries. Despite the increase in absolute number, the rate of road traffic accident death has remained constant at around 18 deaths per 100,000 populations over the last 15 years. And this is the same for Eastern Mediterranean countries. During the same period, the number of vehicles worldwide has steadily increased, while death rates declined from 135 deaths for every 100,000 vehicles in 2000 to approximately 64 deaths for every 100,000 vehicles in 2016. At 2016, high-income countries have 15% population, 40% world's motor vehicles, and 7% of road traffic deaths. Middle-income countries have 76% of the population, 59% world's motor vehicles and 80% of the death of road accidents. Only 1% of the world's motor vehicles are in low-income countries, 13% of deaths occur in these countries which have 9% of the population [1].

Jordan, like other developed countries in the world, has a steady increase in the number of population and vehicles. In the year 2017, the population reached 10.053 million, and the number of registered vehicles reached 1.583,485 million vehicles, in addition to the entry of 458.009 thousand foreign vehicles to the Kingdom. 150,226 traffic accidents; of which 10446 casualty accidents resulted in 685 deaths and injuries of 16246 injuries, and a financial cost of 308 million dinars [2].

In Jordan, during the period (1981-2017) and (2001- 2017), about 2.264 and 1.765 million accidents occurred respectively, with an average of 104 thousand accidents/year at the last one. There are many studies conducted to analyze the trends and characteristics of traffic accidents.

Al-Masaaid et al. [3] studied and estimated the economic costs of traffic accidents in Jordan during the year of 1996. For the people, these costs, including loss-of-output, the loss quality of life, the community and family losses, the temporary and permanent losses, and medical treatment costs estimated. The authors reported that the additional costs were; the vehicle repair cost, detention period cost, and public and private costs accounted for calculating the unit cost of property damages. The results indicate that the 1996 traffic accidents cost the country about JD 103 million (\$US 146.3 million).

Al-Masaeid [4] investigated the characteristics of traffic accidents in Jordan and evaluated the safety impact of policy measures undertaken in 2008. Accidents' data from 1998 through 2007 were analyzed. The author concluded that Jordan had experienced huge human and economic losses. For pedestrian accident risk, children, young and elderly have been exposed to it. For the drivers' ages, young (less than 25 years) and elderly (over 60 years) were over-involved in accidents. In the analysis of the reasons, carelessness and aggressive driving behavior were the major causes of traffic accidents. The results indicated that the motorization level could be used to explain variations in traffic accidents and fatalities. In another aspect, the author concluded that the intensifying of traffic enforcement and implementing traffic law with stiff penalty levels were found to have a strong positive safety impact on accidents and fatalities.

Al-Hyari et al. [5] investigated the present and the future magnitude of road traffic accidents. Possible countermeasures are identified and evaluated by examining the attitudes of road users toward the effectiveness and favorability of these measures. The authors developed a model:  $F = -1114.8 + 0.000243 P - 0.000312 V + 0.103 L$ , where: F is the predicted number of fatalities. P is the population. V is the number of registered vehicles. L is the total length of paved roads (km).

Al-Omari and Obaidat [6] analyzed pedestrian accidents in Irbid city- Jordan. They noticed that pedestrians represented 32.5% of all traffic accident fatalities and 23.8% of all traffic accident injuries during the year 2010. The study analyzed a total of 1090 pedestrian accidents that have occurred in the city during the year (1999 – 2001) based on all factors related to accident causes. The results showed that the majority of pedestrian accidents have occurred at non-intersection locations, during clear and sunny weather, on a dry surface, during daylight, and at low-speed limits. Also, more pedestrian accidents have occurred during the afternoons, on Thursdays, and during July.

Al-Omari et al. [7] investigated the trends and characteristics the traffic accidents data in Jordan for the years between 1998 and 2010. Therefore, traffic accidents were analyzed according to several variables, including; accident type, driver age, speed limit, time of the day, the day of the week, the month of the year, weather condition, pavement surface condition, and severity level. Good regression models were developed to predict the number of traffic accidents per year and the number of traffic accident fatalities per year per registered vehicles as a function of the motorization level. The models were:

$ACC = 56.47 M^{1.51}$ , where: ACC = number of traffic accidents per year, M = motorization level (number of registered vehicles/1000 population) with  $R^2 = 0.97$  and 99% significance level.

$F = -9.109M^2 + 28.47M - 987.9$ , where: F = traffic accident fatalities per year M = motorization level with  $R^2 = 0.87$ .

$F/V = 287.65M^{1.15}$ , better model than the previous one, traffic accident fatalities per year per number of registered vehicles (x1000) with motorization level.

Magableh [8] investigated the human factors influencing driver behavior and traffic law enforcement in Jordan. The research was carried out using two separate survey studies (drivers and Police officers) that aimed to determine the factors that are significantly associated with receiving traffic fines, being involved in crashes, to investigate the perceptions of drivers, traffic Police concerning traffic law enforcement and driver behavior. The first study focused on driver attitudes, behavior and compliance factors. The results showed that gender modified the relationship between some independent factors and study outcomes. Crashes for males were significantly associated with previously receiving distraction fines, instances of being stopped by the police, being intimidated by other drivers and already receiving traffic fines. Crashes for females were significantly associated with violating traffic signs, being threatened by other drivers and already receiving traffic fines.

Msallam et al. [9] investigated highway safety and its skid resistance of Jordan's National Highway Network (primary and secondary highways). They used the portable skid resistance tester; British pendulum skid tester to perform nondestructive tests. The study included surveying 38 locations on the right slow lane. The results showed that 66% of the tested roads had skid resistance levels lower than the minimum acceptable standards. Therefore, this considers as one cause of accidents. The authors recommended that maintenance plans should be performed to improve road safety in Jordan.

Al-Omari et al. [10] investigated the essential elements which will reduce traffic accidents, and may reduce the impact of accidents. The authors used Accident Hazard Scale (AHS) to achieve the objective. The authors concluded that the most dangerous Jordanian governors were Al-Mafraq, Irbid, Amman, and Al-Zarqa. Due to time analysis, the most hazardous months were July, August, September, and June, while Fridays and Thursdays had the highest accident during the week. For the most days, the evening peak hours (2 - 4 PM), was the most hazardous period.

Naghawi and Bannoura[11] investigated the driving behavior in Jordan. One of the significant sides in the study was aggressive driving behaviors, which include honking, tailgating, speeding, running a red light, flashing high beams and rude gesturing. The data obtained from a survey questionnaire. From the results; it found that Jordanians adopted some of the worst driving habits, and there were significant differences between male and female drivers in the following driving behaviors. For gap acceptance, there were statistically significant differences between male and female.

Mujalli [12] tried to determine the main factors that contribute to characterizing crashes in a specific year according to severity. Therefore, aggregate annual crash reports for 18 years were used. The author found the main contributing factors which were: a higher number of traffic control device violations, speeding, a higher number of run-off-road crashes and a higher number of pedestrian crashes.

Uddin and Huynh [13] investigated factors affecting injury severity of crashes involving HAZMAT (Hazardous Materials) large trucks. It uses the crash data in the state of California from the Highway Safety Information System, from 2005 to 2011. The critical factors include occupant, crash, vehicle, roadway, environmental, and temporal characteristics. The authors estimated both fixed and random parameter models. The model resulted in that the probability of major injuries increased with the occupants being male, truck drivers, crashes occurring in rural locations, under dark-unlighted, under dark-lighted conditions, and on weekdays.

Ratanavaraha and Suangka [14] predicted the accident severity through formulating Multiple Logistic Regression Model to analyze the probability of an injury accident and a fatal accident in comparison with a property damage only accident. Therefore, they utilized accident data on expressway networks in Thailand. That is covering nine expressway routes covering distances totaling over 207 km with a record of 2194 crashes. The results found that speed on a road section was the only factor influencing the severity of accidents on the expressway with significance; hence speed limits on expressways should be mandated for drivers by a speed monitoring under regulations. As well, increasing awareness of accident severity caused by driving at excessive speeds should be promoted to reduce the risks and levels of accident severity.

Altwaijri et al. [15] explored factors affecting the severity and frequency of road crashes in Riyadh city using appropriate statistical models aiming to establish effective safety policies ready to be implemented to reduce the severity and frequency of road crashes in Riyadh city. They reported that in 2005, there were a total of 47,341 injury traffic crashes occurred in Riyadh city (19% of total KSA crashes), and 9% of these were severe. Two nominal response models have developed: a standard multinomial logit model (MNL) and a mixed logit model to injury-related crash data. The results from both multinomial and binary response models were found to be reasonably consistent. But the results from the random parameter model seem more reasonable. Age and nationality of the driver, excessive speed, wet road surface, and dark conditions and single vehicle crashes are associated with increased probability of fatal crashes.

## II. OBJECTIVE

The following are the objectives of this research:

- 1- To investigate the traffic accident trends in Jordan.
- 2- To develop models those predict traffic accidents and related factors (variables).

## III. DATA RESOURCES

The development of population was taken from the reports published by the Jordanian Department of Statistics [16]. The traffic accident data obtained from the yearly reports published by the Jordanian Traffic Institute [2].

## IV. DATA ANALYSIS AND METHODS

The number of vehicles increasing with time in Jordan, if calculated the ratio between the number of vehicles to the population, which recorded according to the years, it found that in 1971 there is 58 person for each vehicle and decrease to 15 people for each vehicle at 1981, until reach 6.3 person for each vehicle. Figure 1 shows the trend of this relationship, and it could be represented by Equation (1) with  $R^2 = 0.933$  as follows:

$$Y_1 = 49.962 X_1^{-0.892} \quad (1)$$

Where:  $Y_1$ : auto ownership (person/ vehicle), and  $X_1$ : year.

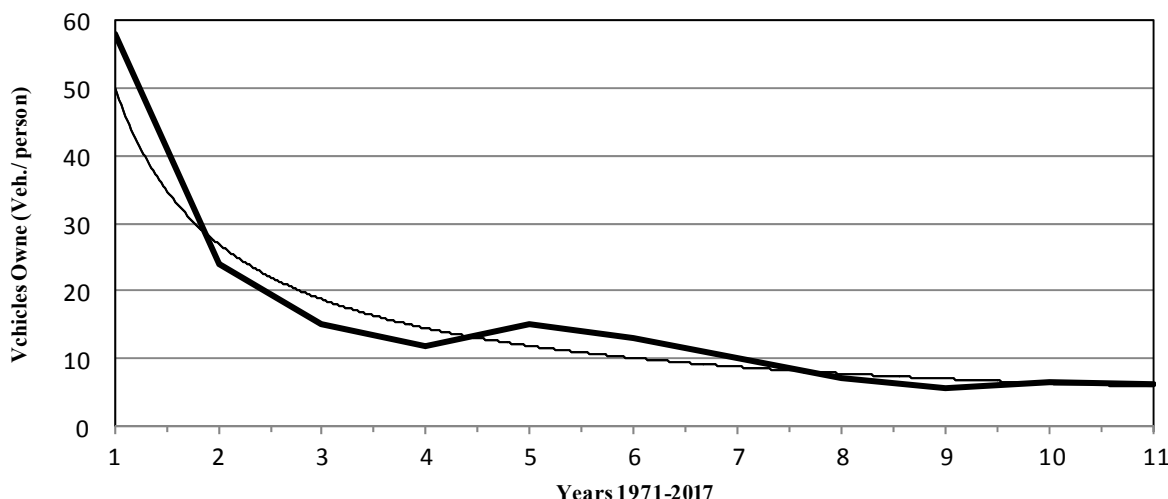


Fig.1. Development of vehicles owner with years.

In general, the population is increasing with time with a steady state for the citizen, but there was some sudden increasing due to forced migration from outsiders, that was happening three times during the study periods: at 1991 from Kuwait, at 2003 from Iraq, and the latest was from Syria 2012 to 2014. The Department of Statistics reported the latest increase at the year of 2015 in their reports; in 2014 the population was 6.675 million increased to 9.531, 9.798, and 10.053 million for the years of 2015, 2016 and 2017. Figure 2 shows the trend of this relationship, and it could be represented by Equation (2) with  $R^2 = 0.949$  as follows:

$$Y_2 = 23636 e^{0.0351 X_1} \quad (2)$$

Where:  $Y_2$ : population, and  $X_1$ : year.

The number of registered vehicles was increasing as in Figure 2, from 156924 vehicles in 1981 until reaching to 1583458 in 2017. Figure 2 shows the trend of this relationship, and it could be represented by Equation (3) with  $R^2 = 0.981$  as follows:

$$Y_3 = 14084 e^{0.0644 X_1} \quad (3)$$

Where:  $Y_3$ : registered vehicles, and  $X_1$ : year.

The number of reported accidents was increasing as in Figure 2, from 13567 accidents in 1981 until reaching 150226 in 2017. Some notable increase happened in 2009 to 2011, which were 122793, 140014, and 142588 accidents, then reduced to 112817 in 2012. Figure 2 shows the trend of this relationship, and it could be represented by Equation (4) with  $R^2 = 0.957$  as follows:

$$Y_4 = 10435e^{0.0763 X_1} \quad (4)$$

Where:  $Y_4$ : accidents, and  $X_1$ : year.

The number of fatal and injuries were increasing as in Figure 2, from 8896 people in 1981 until reaching to 16931 in 2017. Some significant increase happened in 1999 to 2003 which are 19691, 19528, 19615, 18139, and 20200 people, then reduced to 17545, 18369, 18918 in the next three years until reaching to 16931 in 2017. Figure 2 shows the trend of this relationship, and it could be represented by Equation (5) with  $R^2 = 0.808$  as follows:

$$Y_{5a} = 5402.2 + 870.54 X_1 + (-15.084) X_1^2 \quad (5)$$

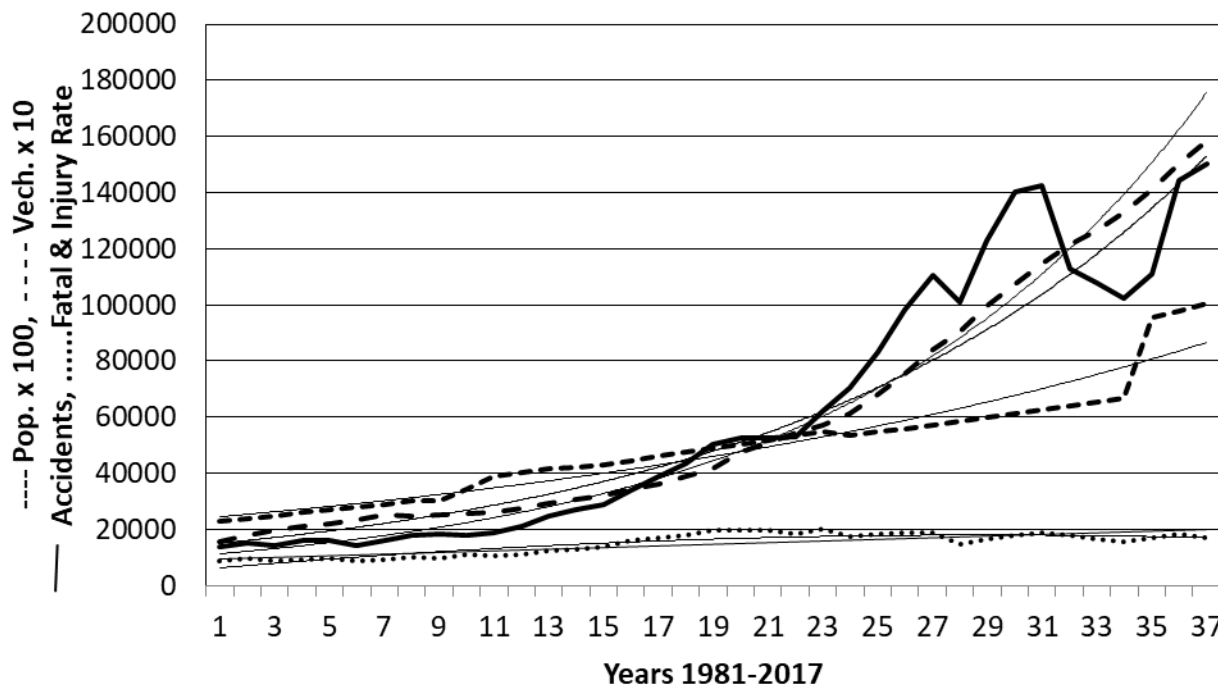


Fig. 2. Development of population, vehicles, accidents, and fatalities and injuries with years.

Where:  $Y_{5a}$ : fatalities and injuries persons, and  $X_1$ : year.

If the same type of the equations used, the equation would be as  $Y_5 = 9256.9 e^{0.0225 X_1}$ , with  $R^2 = 0.692$ , therefore we choose the high value of  $R^2$ .

The relationships between the accident rate and the population (x100) and the registered vehicles (x10) numbers show gradually increasing trend, in spite of the forced migrations as in Figure 3, and it could be represented by Equation (6-a) for a registered vehicle with  $R^2 = 0.995$  as follows:

$$Y_{4a} = 25265 + (-1733.1) Y_3 + 144.67 Y_3^2 \quad (6-a)$$

Where:  $Y_{4a}$ : accident rate, and  $Y_3$ : registered vehicles.

The second relationship in Figure 3 is with population (x100), and it could be represented by Equation (6-b) for population with  $R^2 = 0.948$  as follows:

$$Y_{4b} = 23636 e^{0.0351 Y_2} \quad (6-b)$$

Where:  $Y_{4b}$ : accident rate, and  $Y_2$ : population.

The number of reported accidents per 100000 population and 10000 vehicles was increasing as in Figure 4 until reaching 2290 and 1302 respectively in the year 2010, then decreasing to 1494 and 949 in 2017. That seems like the same trends as in Figure 2. Figure 4 shows the trend of this relationship, and it could be represented concerning the population by Equation (7-a) with  $R^2 = 0.58$  as follows:

$$Y_{5a} = 297.17 X_1^{0.439} \quad (7-a)$$

Where:  $Y_{5a}$ : reported accidents/100000 population, and  $X_1$ : year.

And it could be represented with respect to population by Equation (7-b) with  $R^2 = 0.49$  as follows:

$$Y_{5b} = 537.19 + 42.601 X_1 - 0.8355 X_1^2 \quad (7-b)$$

Where:  $Y_{5b}$ : reported accidents/10000 vehicle, and  $X_1$ : year.

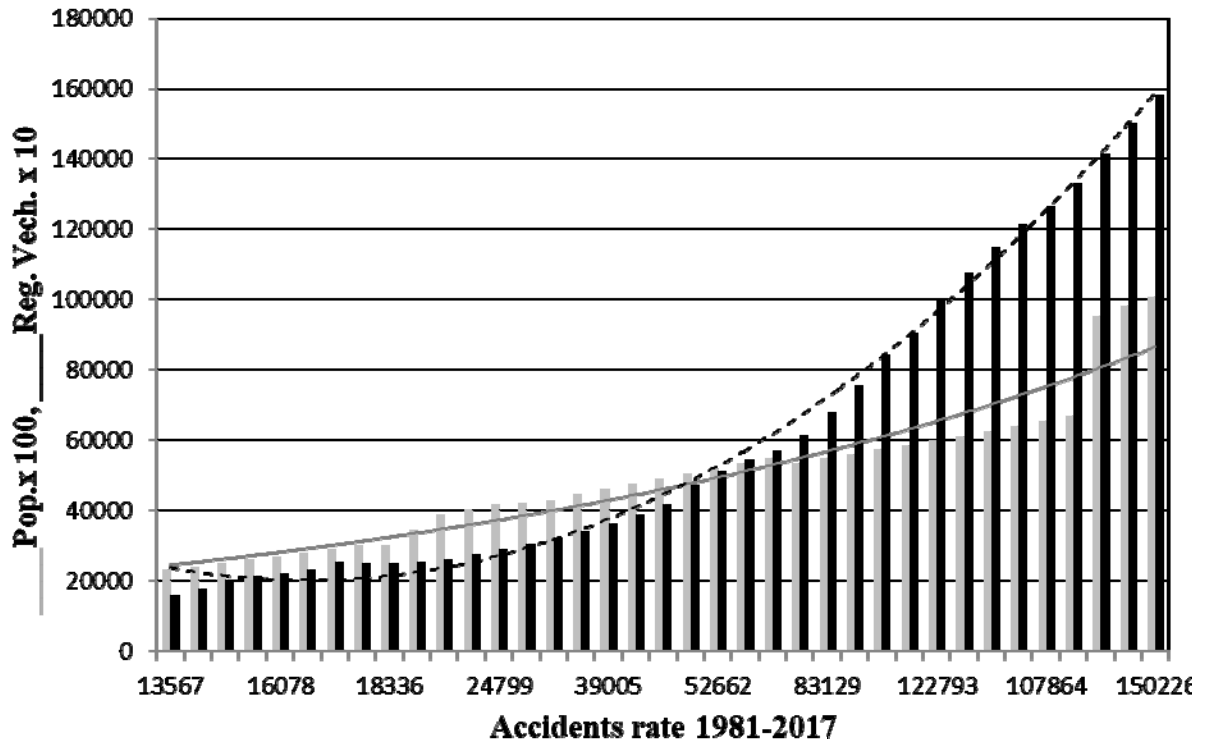


Fig. 3. Development of accident rate with population and registered vehicle (1981-2017).

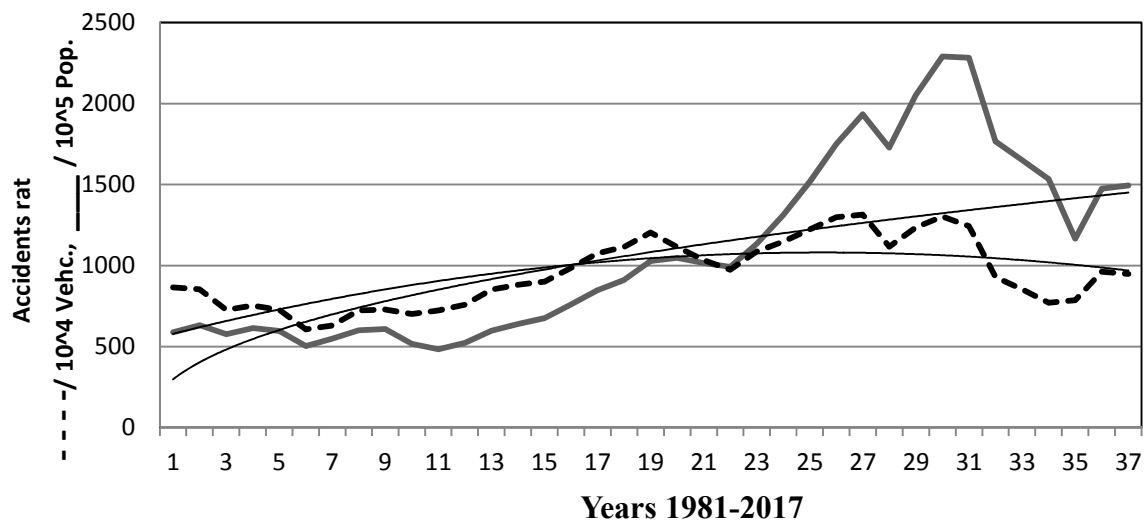


Fig. 4. Development of accidents rate /10000 vehicles and /100000 population with years.

The number of injuries due to accidents was increasing as in Figure 5 until reaching 19368, and then the trend decreasing until reaching 16246 in 2017. Figure 5 shows the trend of this relationship, and it could be represented by Equation (8) with  $R^2 = 0.809$  as follows:

$$Y_6 = 509.13 + 84.89 X_1 + (-1.4836) X_1^2 \quad (8)$$

Where:  $Y_6$ : injury, and  $X_1$ : year.

The deaths were increasing to 992 in 2007, and then decreasing to 685 in 2017. Figure 5 shows the trend of this relationship, and it could be represented by Equation (9) with  $R^2 = 0.603$  as follows:

$$Y_7 = 306.06 + 22.545 X_1 - 0.2692 X_1^2 \quad (9)$$

Where:  $Y_7$ : fatal, and  $X_1$ : year.

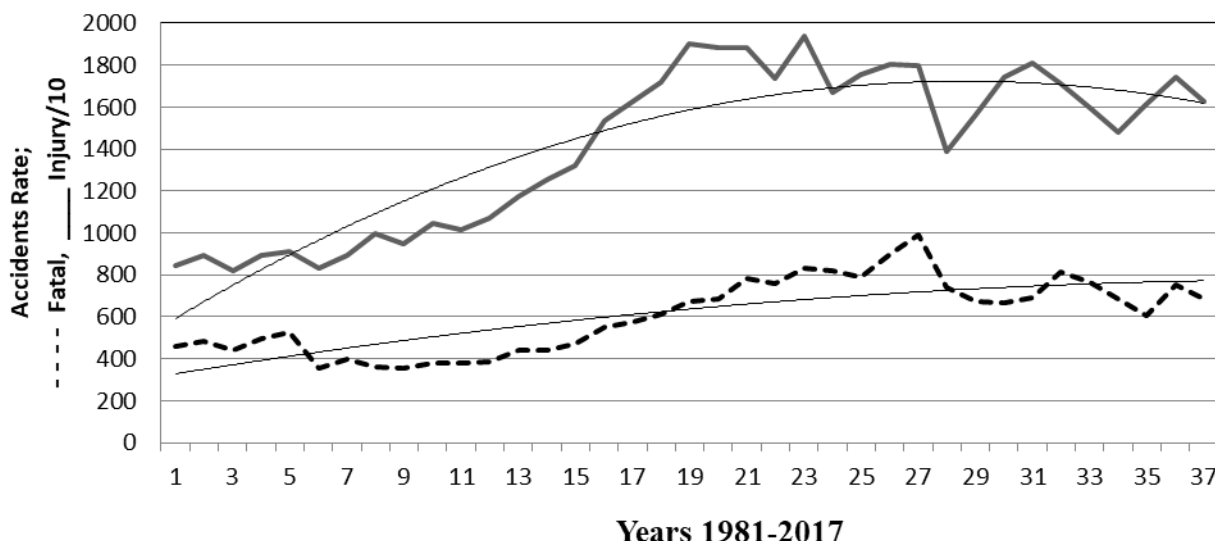


Fig. 5. Development of Accidents Rate; Injuries and Fatalities with Years.

That seems like the same trends as in Figure 4 which reflecting the successes of the plan that put into reducing the total and the casualty accidents by the police department. The obvious trend to explain this goal is to take the severity rate (index), which is equal to the total number of fatal and injury to the total accidents. Figure 6 shows this relationship, which indicates that the trend of severity rate (index) is decreasing with time. At the first of this study period, it was 0.656 in 1981, then decreasing to less than 20 until it reached 0.113 in 2017. Figure 6 shows the trend of this relationship, and it could be represented by Equation (10-a) with  $R^2 = 0.954$  as follows:

$$Y_{8a} = 0.70 - 0.017 X_1 \tag{10-a}$$

Where:  $Y_{8a}$ : severity rate, and  $X_1$ : year.

But this model may approach zero after some years, therefore, the exponential model preferred which shown in Equation (10-b) with  $R^2 = 0.912$  as follows:

$$Y_{8b} = 0.8871e^{-0.054X_1} \tag{10-b}$$

Where:  $Y_{8b}$ : severity rate, and  $X_1$ : year.

To accomplish the effect of two variables; population and registered vehicles together, the motorization index was considered. It's calculated as a number of vehicles/1000 populations. Figure 7 shows this relationship, which indicates that the trend of motorization index is increasing with time. At the first of this study period, it was 68 in 1981, then increasing to 199.5 in 2014 then decreasing and reaches 157.5 in 2017. Figure (7-a) shows the trend of this relationship, and it could be represented by Equation (9) with  $R^2 = 0.836$  as follows:

$$Y_{9a} = 75.931 - 1.141 X_1 + 0.12 X_1^2 \tag{11-a}$$

Where:  $Y_{9a}$ : motorization index, and  $X_1$ : year.

In spite of the high value of  $R^2$ , the next model seems better representation about the true population rate far away from a sudden increase in population due to the refugee of Syrian people as shown in Figure (7-b). The following equation shows this relationship with  $R^2 = 0.783$ :

$$Y_{9b} = 59.587 e^{0.0294X_1} \tag{11-b}$$

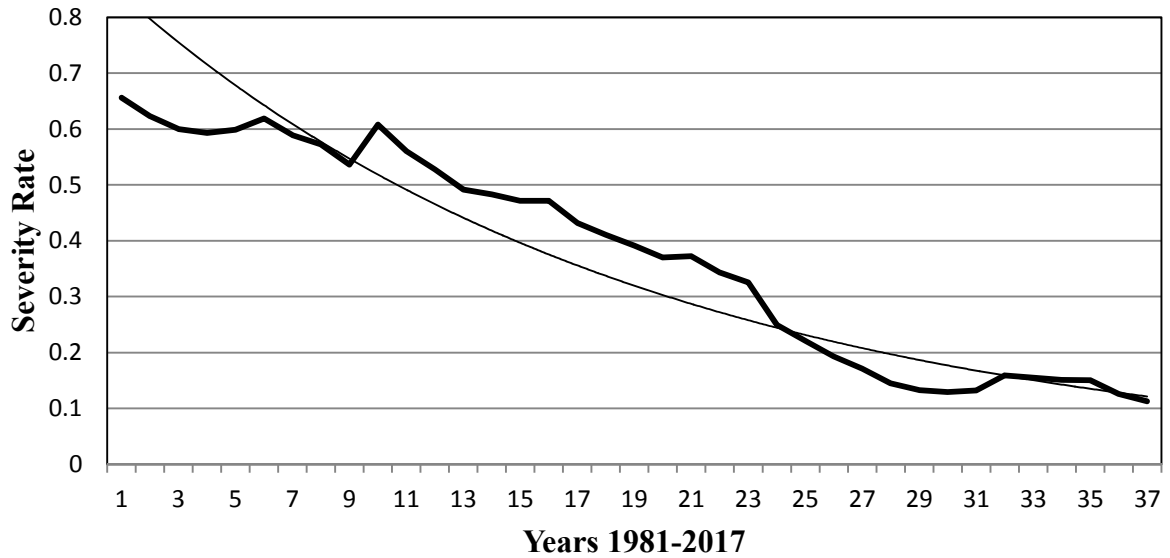


Fig. 6. Severity rate by years.

The relationships between the casualty accidents rate and the motorization level show gradually increasing trends until 2007 (11329), then after at 2011 (11516), then decreasing until reach 10464 in 2017 as in Figure 8. This trend is similar to that of accidents which reached to 110630 in 2007 and again rose to 142588 in 2011 as shown in Figure (2), and it could be represented by Equation (12-a) for a registered vehicle with  $R^2 = 0.931$  as follows:

$$Y_{10a} = (-17538) + (326.86) Y_9 + (-0.941) Y_9^2 \quad (12-a)$$

Where:  $Y_{10a}$ : casualty accident rate, and  $Y_9$ : motorization level.

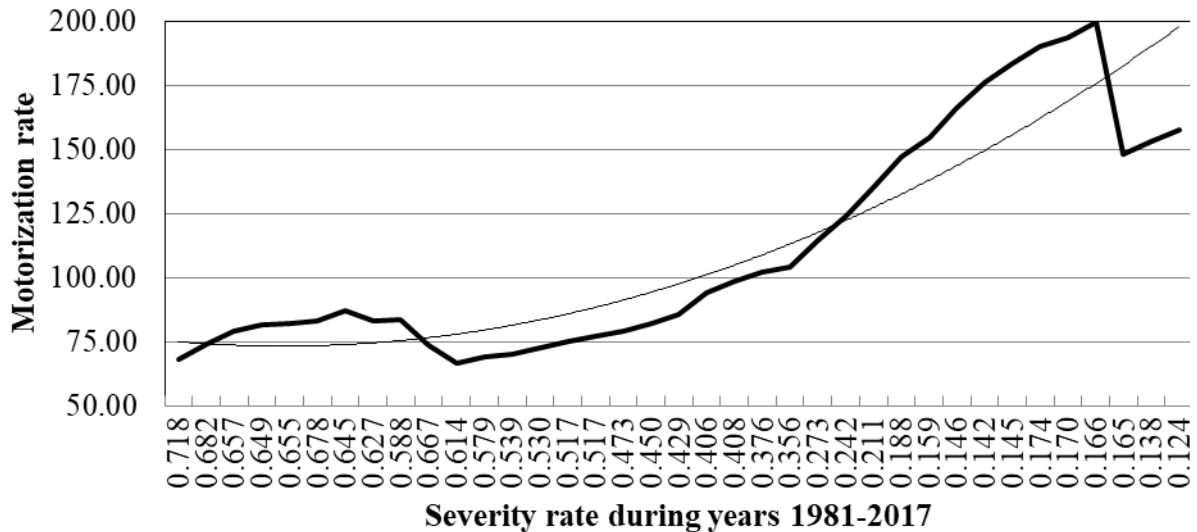


Fig. 7a. Motorization index with severity rate during the years 1981-2017.



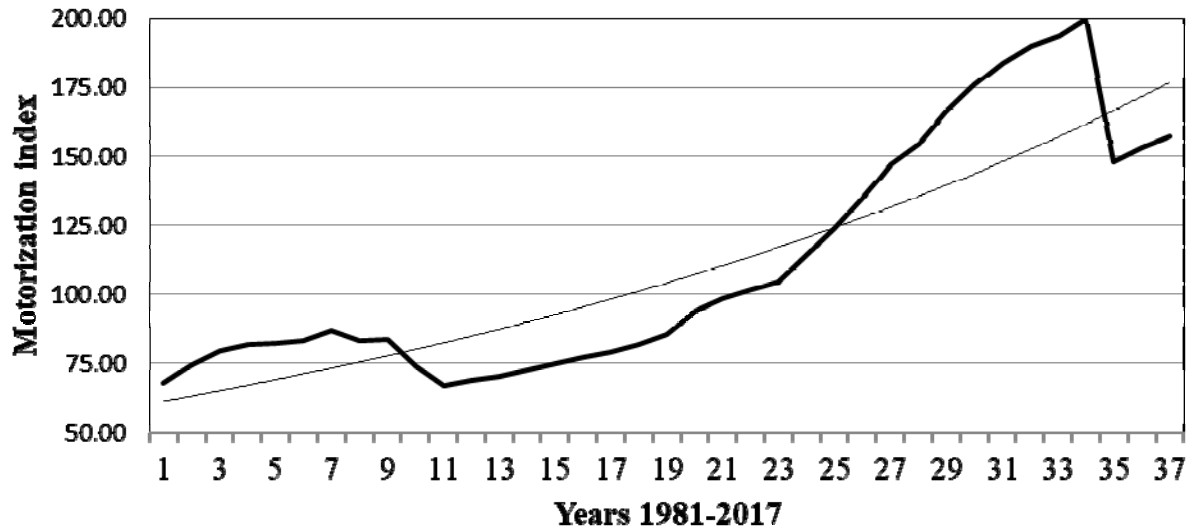


Fig. 7b. Motorization index with years.

The data on casualty accident was limited; it was available only for the period (2001-2017). Therefore, the trends of the accident rate and the casualty accidents with time seem like the same, with some of varying between them as shown in Figure 9. The number of casualty accidents was increasing as in Figure 9, from 5793 accidents in 2001 until reaching to 10446 in 2017. Some significant increase happened in 2007 is equal to 11329, and then reduced. Figure 9 shows the trend of these relationships, and it could be represented by Equation (10-b) with  $R^2 = 0.871$  as follows:

$$Y_{10b} = 4092.2 + 1128 X_1 + (-46.579) X_1^2 \quad (12-b)$$

Where:  $Y_{10b}$ : casualty accidents, and  $X_1$ : year.

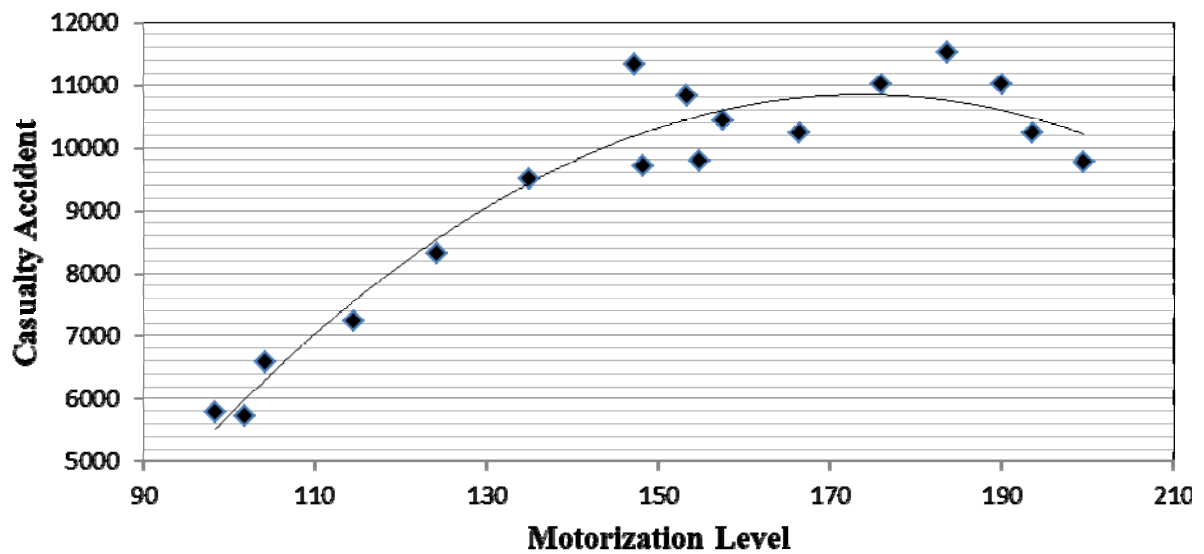


Fig. 8. Relationship between motorization level & casualty accidents (2001-2017).

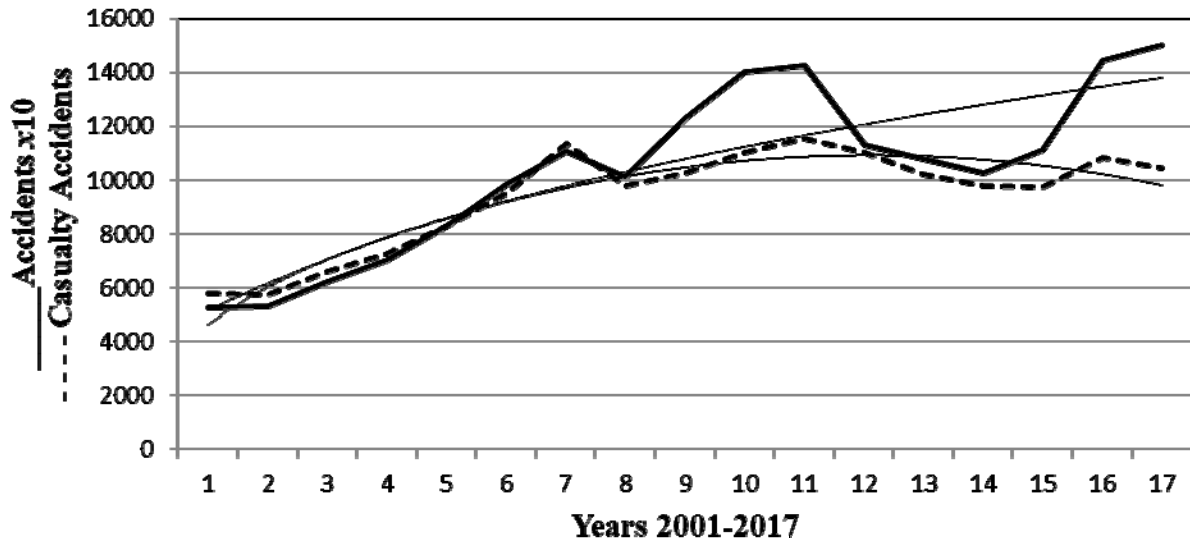


Fig. 9. Development of accidents and casualty accidents with years.

The data on accident costs were limited; it was available only for the period (2001-2017). Therefore the number of accidents with time was represented again as shown in Figures 9 and 10; it was increased from 52662 accidents in 2001 until reaching to 142588 in 2011 then suddenly reducing at 2012 and increasing again to 150226 in 2017. Figure 10 shows the trend of these relationships, and it could be represented by Equation (13) with  $R^2 = 0.833$  as follows:

$$Y_{11} = 46.06 X_1^{0.3873} \tag{13}$$

Where:  $Y_{11}$ : accidents, and  $X_1$ : year.

The cost of accidents was increasing as in Figure 10, from 160 million JD in 2001 until reaching to 308 million JD in 2011. Figure 10 shows the trend of these relationships, and it could be represented by Equation (14) with  $R^2 = 0.804$  as follows:

$$Y_{12} = 153.8 Y_4^{0.2398} \tag{14}$$

Where:  $Y_{12}$ : accidents cost, and  $Y_4$ : accidents number.

This trend is similar to that of accidents as shown in the same figure and expressed in Eqn. (13).

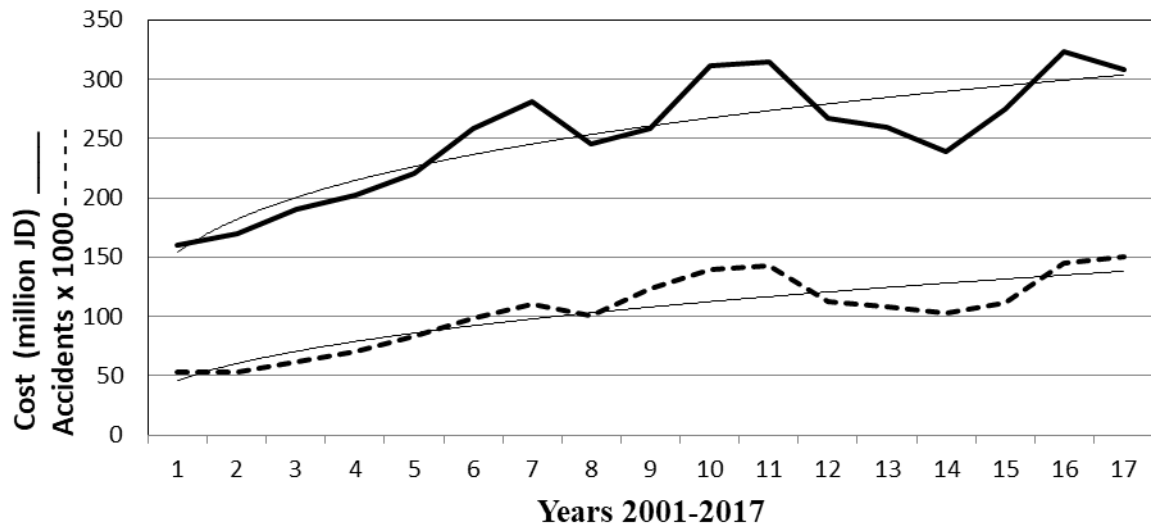


Fig. 10. Development of accidents cost and accidents with years (2010-2017).

## V. RESULTS AND DISCUSSION

The data analysis of 37 years in the previous section gave trends for the traffic accidents that were increasing with time with some fluctuations in a few years. Most of the models are functions of time so that the variables of the time were significant in the models. For Example, models in Equations (1-5) that for auto ownership, population, registered vehicles, reported accidents, and fatalities and injuries persons are functions of time (years) only and have  $R^2 = 0.933, 0.949, 0.981, 0.957,$  and  $0.808$  respectively. It's clear that the first four models are very highly correlated and depend on time, where the five one has well correlated. Therefore, when wrote the models of accident rate in another way (Equations 6); depend on other variables; registered vehicles and population, the rise in  $R^2$  were  $0.995$  and  $0.948$  which were not farther than that of Equation (4)  $R^2 = 0.957$  that depend on time only, this because both variables (registered vehicles and population) is time-dependent.

The population is growing with steady state, but there was some sudden increasing due to forced migration from outsiders; that was happening three times during the study periods. At 1991 due to the First Gulf War, hundreds of thousands of Jordanian and Palestinian people were coming from Kuwait, most of them with their vehicles. The second migration was in 2003 due to the Second Gulf War, hundreds of thousands of Iraqi and Palestinian people were coming from Iraq, some of them with their vehicles. At 2012 to 2015, near one million Syrian people were refugees to Jordan due to the war in their countries, very few of them had vehicles and more the half was rested at refugee camps. The Department of Statistics reported this increase at the year of 2015 in their reports; in 2014 the population was 6.675 million increased to 9.531, 9.798, and 10.053 million for the years of 2015, 2016 and 2017.

For the reported accidents for each /100000 population, and /10000 vehicle and with time (Equations 7), also had  $R^2 = 0.58,$  and  $0.49$  respectively. These relations seem weak because of the fluctuation of the trend in this formula due to some reasons. One of these; was that in 1983 a sudden decrease in accidents was happening; from 15163 in 1982 to 14372 in 1983, then rose to 15917 in 1984, which caused to reduce the accident rate to 576/100000 population and 727/10000 vehicle. Another example, that in 2008 a sudden high increase in fuel prices has reduced the private car usage causing less exposure for traffic accidents that were 1728 /100000 population, and 1116 /10000 vehicle. Another one that a sudden decrease in total accidents happened, that was dropped from 142588 in 2011 to 112817 in 2012, which led to crashes to be 1766/100000 population and 929/10000 vehicle. Regardless, this trend, the casualty accidents was increased; the fatal jumped from 694 in 2011 to 816 2012, which led to increase in severity level to 0.175 with varying to the total decreasing trend.

For the reported accidents resulted in injuries and fatalities were represented by the models, as in Equations (8,9) with  $R^2 = 0.809$  and  $0.603$  respectively. The first relation seems good, where the second seems weak for the reasons discussed for Equations (7).

The severity rate could be used to assess the general danger of accidents. Equations (10) represent these models with highly  $R^2 = 0.954$  or  $0.912$  which is more suitable to predict future cases. This trend is going as the global trend in many countries, that is, despite the growth of population and auto ownership, the ratio of dangerous goes down.

Both factors; population and registered vehicle growth can rate at motorization index. Equations (11) represent these models with good  $R^2 = 0.836$  or  $0.783$  which is more suitable to predict the future cases, which seems better representation about the actual population rate far away from a sudden increase in population due to the refugee of the Syrian people.

The casualty accidents were available for the latest 17 years; it could be correlated with the motorization level as in Equation (12-a)  $R^2 = 0.931$ . This relationship represents a better correlation than in Eqn. (12-b) that depends on time (year) with  $R^2 = 0.871$ .

The costs of accidents were increasing with time. Equation (13) represents this model with good  $R^2 = 0.833$ , which also reflects the increasing number of accidents occurred. The cost in 2016 estimated about 323 million JD (455 million \$), which represents about 1.19 % of the Gross National Product of Jordan at 2017 that was 38,349,657 \$ US. In 2017 was estimated about 308 million JD (434 million \$), which represents about 1.09 % of the Gross National Product of Jordan at 2017 that was 39,861,970 \$ US. There are numbers of accidents that did not report. Usually, these accidents are simple with low costs, and some time had different reasons not to report. It was difficult to estimate these accidents, so, it is recommended to develop studies about these.

## VI. DEVELOPMENT OF MODELS AND RESULTS

The models were developed using the Statistical Package for Social Sciences (SPSS) that represents a statistical analysis software program. Table 1 shows the correlation measures between variables and sets their significant at the 0.01 level (2-tailed) for traffic data according to 37 years used in the regression modeling. Table 1 shows that for 9 dependent and independent variables; there are 3 variables have  $R^2 \geq 0.95$ , 13 variables have  $0.95 < R^2 \leq 0.90$ , 7 variables have  $0.90 < R^2 \leq 0.85$ , 5 variables have  $0.85 < R^2 \leq 0.80$ , 3 variables have  $0.80 < R^2 \leq 0.70$ , 1 variable has  $0.70 < R^2 \leq 0.60$ , and 3 variables have  $0.60 < R^2 \leq 0.50$ . All correlations are significant at the 0.01 level (2-tailed) except one has 0.002 with lowest  $R^2 = 0.501$ , that is for casualty accidents

with injury/ 1000 vehicles. In general, the correlations of casualty accidents with most variables are low, except with time, and they're weak with the motorization level, fatal/1000 vehicles, and lowest with injury/ 1000 vehicles. In contrast, all variables are correlated with time with high values of  $R^2$ , except casualty accidents has  $R^2 = 0.809$ , that emphasized the analyzed of steady-state behavior for accidents and related factors.

TABLE 1. The Correlation between Variables with a Significant Level

Correlations: Pearson Correlation, N=37									
	Year	Regs. veh. x10	Pop. x100	Accident	Casualty accident	Severity rate	Motor. level	Fatal/ 1000 veh.	Injury/ 1000 veh.
Year	1	.937**	.936**	.939**	.809**	-.977**	.867**	-.900**	-.888**
		.000	.000	.000	.000	.000	.000	.000	.000
	37	37	37	37	37	37	37	37	37
Registered vehicle x10	.937**	1	.930**	.952**	.604**	-.918**	.923**	-.858**	-.942**
	.000		.000	.000	.000	.000	.000	.000	.000
	37	37	37	37	37	37	37	37	37
Population x100	.936**	.930**	1	.882**	.705**	-.879**	.738**	-.838**	-.827**
	.000	.000		.000	.000	.000	.000	.000	.000
	37	37	37	37	37	37	37	37	37
Accidents	.939**	.952**	.882**	1	.704**	-.964**	.921**	-.831**	-.915**
	.000	.000	.000		.000	.000	.000	.000	.000
	37	37	37	37	37	37	37	37	37
Casualty accidents	.809**	.604**	.705**	.704**	1	-.797**	.553**	-.590**	-.501**
	.000	.000	.000	.000		.000	.000	.000	.002
	37	37	37	37	37	37	37	37	37
Severity rate	-.977**	-.918**	-.879**	-.964**	-.797**	1	-.901**	.853**	.900**
	.000	.000	.000	.000	.000		.000	.000	.000
	37	37	37	37	37	37	37	37	37
Motorization level	.867**	.923**	.738**	.921**	.553**	-.901**	1	-.802**	-.939**
	.000	.000	.000	.000	.000	.000		.000	.000
	37	37	37	37	37	37	37	37	37
Fatal/1000 vehicle	-.900**	-.858**	-.838**	-.831**	-.590**	.853**	-.802**	1	.894**
	.000	.000	.000	.000	.000	.000	.000		.000
	37	37	37	37	37	37	37	37	37
Injury/1000 vehicle	-.888**	-.942**	-.827**	-.915**	-.501**	.900**	-.939**	.894**	1
	.000	.000	.000	.000	.002	.000	.000	.000	
	37	37	37	37	37	37	37	37	37

\*\* Correlation is significant at the 0.01 level (2-tailed).

Many predicted regression models directly dependent on time and other compound variables, mainly the population or/ and registered vehicle developed under a risk level of 0.05 significant level. Table 2 shows these models and their F and  $R^2$  values, besides the independent variables with significant level. Most of these models depend on time, which resulted in very good and excellent relationships. As discussed earlier in section 5, the registered vehicles and population came in the second rank after time variable and resulted in increasing the values of  $R^2$  to be excellent. Some data were available only for the last 17 years, such as cost. From the Table 2, the most relationships seem to be significant, except that for fatalities and injuries which give small values of  $R^2$  (Models 24-31). When these indicators linked with a registered vehicle as (Fatal/1000 Vehicle or Injury/1000 Vehicle) they rise up to have good and excellent  $R^2$  (Models 34-37).

According to these models, the population, registered vehicles, number of accidents, casualty accidents, severity rate, fatalities, injuries, and costs of accidents can predict in the future with a highly significant degree, and the most significance models were chosen and marked by '**Bold**' as shown in Table 2.

TABLE 2. The Regression Models and Variables with Significant Levels.

Model No.	Dependent Variable	Variables	Sig.	Model	R <sup>2</sup>	Sig reg.	F value
1	Y <sub>2</sub> : Pop.x100	Constant X <sub>1</sub> : time	.000 .000	$Y_2 = 17385.91 + 1691.40 X_1$	.876	.000	246.7
2	<b>Y<sub>2</sub>: Pop.x100 Exponential</b>	<b>Constant X<sub>1</sub>: time</b>	<b>.000 .000</b>	<b><math>Y_{2e} = 23636.04 e^{.035 X_1}</math></b>	<b>.949</b>	<b>.000</b>	<b>646.9</b>
3	Y <sub>3a</sub> : Rigs. Veh.x10	Constant X <sub>1</sub> : time	.052 .000	$Y_3 = -10467.35 + 3764.17 X_1$	.877	.000	249.6
4	<b>Y<sub>3a</sub>: Rigs. Veh.x10 Quadratic</b>	<b>Constant X<sub>1</sub>: time</b>	<b>.000 .000</b>	<b><math>Y_{3quad} = 25265.02 - 1733.12X_1 + 144.665 X_1^2</math></b>	<b>.995</b>	<b>.000</b>	<b>3330</b>
5	<b>Y<sub>3a</sub>: Rigs. Veh.x10 Cubic</b>	<b>Constant X<sub>1</sub>: time</b>	<b>.000 .000</b>	<b><math>Y_{3cub} = 20637.85 - 362.46X_1 + 55.682X_1^2 + 1.561X_1^3</math></b>	<b>.996</b>	<b>.000</b>	<b>2825</b>
6	Y <sub>3b</sub> : Rigs. Veh.x10	Constant X <sub>1</sub> : time Y <sub>2</sub> : Pop.x100	.001 .001 .009	$Y_{3b} = -27052.43 + 2150.68 X_1 + 0.954 Y_1$	.900	.000	152.8
7	Y <sub>4</sub> : Accidents	Constant X <sub>1</sub> : time Y <sub>2</sub> : Pop.x100 Y <sub>3</sub> : Veh.x10	.554 .001 .000 .060	$Y_4 = 4691.57 + 2256.15 X_1 - 0.65 Y_2 + 0.75 Y_3$	.932	.000	151.9
8	<b>Y<sub>4</sub>: Accidents Power</b>	<b>Constant Veh.x10</b>	<b>.000 .000</b>	<b><math>Y_{4p} = 0.151 X_1^{1.168}</math></b>	<b>.951</b>	<b>.000</b>	<b>680.2</b>
9	Y <sub>4</sub> : Accidents Cubic	Constant Y <sub>2</sub> : Pop.x100	.000 .000	$Y_{4cub} = 201734.71 - 14.41 Y_2 - 1.887E-00 Y_2^3$	.897	.000	95.54
10	Y <sub>4</sub> : Accidents Power	Constant Y <sub>2</sub> : Pop.x100	.000 .000	$Y_{4p} = 1.683E-005 e^{2.021 Y_2}$	.871	.000	235.8
11	Y <sub>4a</sub> : Accidents	Constant X <sub>1</sub> : time	.011 .000	$Y_{4a} = -14472.37 + 3982.19 X_1$	.882	.000	260.9
12	<b>Y<sub>4a</sub>: Accidents Exponential</b>	<b>Constant X<sub>1</sub>: time</b>	<b>.000 .000</b>	<b><math>Y_{4e} = 10434.7e^{1.079 X_1}</math></b>	<b>.957</b>	<b>.000</b>	<b>779.1</b>
13	Y <sub>4b2</sub> : Accidents 37	Constant Y <sub>9</sub> : Motorization Level	.000 .000	$Y_{4b} = -49055.9 + 991.53 Y_9$	.848	.000	194.6
14	<b>Y<sub>4b2</sub>: Accidents Cubic</b>	<b>Constant Y<sub>9</sub>: Motorization Level</b>	<b>.000 .000</b>	<b><math>Y_{4cub} = 205157.73 - 6525.629 Y_9 + 69.12 Y_9^2 - .195 Y_9^3</math></b>	<b>.939</b>	<b>.000</b>	<b>169.9</b>
15	Y <sub>10</sub> : Casualty Accident	Constant X <sub>1</sub> : time Y <sub>2</sub> : Pop.x100 Y <sub>3</sub> : Vec.x10 Y <sub>4</sub> : Accidents	.000 .000 .156 .000 .021	$Y_{10} = 7130.54 + 585.58 X_1 + 0.062 Y_2 - 0.16 Y_3 + 0.05 Y_4$	.872	.000	54.7
16	Y <sub>10a</sub> : Casualty Accident	Constant X <sub>1</sub> : time Y <sub>9</sub> : Motorization Level	.000 .000 .002	$Y_{10a} = 1027.48 + 64.17 X_1 + 16.3 Y_9$	.743	.000	49.1

17	<b>Y<sub>10</sub>: Casualty Accident Cubic (17yr)</b>	<b>Constant Y<sub>4</sub>: Accidents</b>	<b>.000 .000</b>	<b>Y<sub>10</sub> = -839.97 + .129 Y<sub>4</sub> - 2.268E-012 Y<sub>4</sub><sup>3</sup></b>	<b>.954</b>	<b>.000</b>	<b>146.6</b>
18	<b>Y<sub>8a</sub>: Severity Rate</b>	<b>Constant X<sub>1</sub>: time Y<sub>2</sub>: Pop.x100 Y<sub>3</sub>: Vec.x10 Y<sub>4</sub>: Accidents</b>	<b>.000 .000 .004 .051 .000</b>	<b>Y<sub>8a</sub> = 0.640 - 0.015 X<sub>1</sub> + 2.153E-006 Y<sub>2</sub> + 7.932E-007 Y<sub>3</sub> - 2.116E-006 Y<sub>4</sub></b>	<b>.985</b>	<b>.000</b>	<b>535.5</b>
19	Y <sub>8b</sub> : Severity Rate	Constant Y <sub>9</sub> : Motorization Level	.000 .000	Y <sub>5b</sub> = 0.820 - 0.004 Y <sub>9</sub>	.811	.000	150.2
20	<b>Y<sub>8</sub>: Severity Rate/ Cubic</b>	<b>Constant X<sub>1</sub>: time</b>		<b>Y<sub>8cub</sub> = .597 + .012 X<sub>1</sub> - .002 X<sub>1</sub><sup>2</sup> + 3.246E-005 X<sub>1</sub><sup>3</sup></b>	<b>.982</b>	<b>.000</b>	<b>587.0</b>
21	<b>Y<sub>8</sub>: Severity Rate Quadratic</b>	<b>Constant Y<sub>4</sub>: Accidents</b>	<b>.000 .000</b>	<b>Y<sub>8qd</sub> = .719 - 8.508E-006 Y<sub>4</sub> + 3.047E-011 Y<sub>4</sub><sup>2</sup></b>	<b>.99</b>	<b>.000</b>	<b>1662</b>
22	Y <sub>8</sub> : Severity Rate Power	Constant Y <sub>9</sub> : Motorization Level	.000 .000	Y <sub>8p</sub> = 581.298 + e <sup>-1.616Y<sub>9</sub></sup>	.908	.000	346.2
23	<b>Y<sub>8</sub>: Severity Rate (17 yr) Quadratic</b>	<b>Constant Y<sub>9</sub>: Motorization Level</b>	<b>.000 .000</b>	<b>Y<sub>8qd</sub> = 1.451 - .0164 Y<sub>9</sub> + .560E-005 Y<sub>9</sub><sup>2</sup></b>	<b>.980</b>	<b>.000</b>	<b>342.4</b>
24	Y <sub>7b</sub> : Fatality (17 yr)	Constant X <sub>1</sub> : time Y <sub>9</sub> : Motorization Level	.000 .775 .127	Y <sub>7b</sub> = 816.054 - 10.92 X <sub>1</sub> + 0.300 Y <sub>9</sub>	.262	.119	2.5
25	Y <sub>7b</sub> : Fatality (17 yr) Exponential	Constant Y <sub>9</sub> : Motorization Level		Y <sub>7e</sub> = 923.152 + e <sup>-.001Y<sub>9</sub></sup>	.132	.152	2.27
26	Y <sub>7b</sub> : Fatality Cubic (17 yr)	Constant X <sub>1</sub> : time		Y <sub>7b</sub> = 706.71 + 62.279 X <sub>1</sub> - 689 X <sub>1</sub> <sup>2</sup> + .296 X <sub>1</sub> <sup>3</sup>	.371	.100	2.6
27	Y <sub>7b</sub> : Fatality Cubic (17 yr)	Constant Y <sub>3</sub> : Veh.		Y <sub>7b</sub> = -106.68 + .003 Y <sub>3</sub> - 3.269E-009 Y <sub>3</sub> <sup>2</sup> + 1.021E-015 Y <sub>3</sub> <sup>3</sup>	.381	.091	2.67
28	Y <sub>6b</sub> : Injury (17 yr)	Constant X <sub>1</sub> : time Y <sub>9</sub> : Motorization Level	.000 .384 .589	Y <sub>6b</sub> = 19373.03 - 52.82 X <sub>1</sub> - 13.18 Y <sub>9</sub>	.252	.131	2.4
29	Y <sub>6b</sub> : Injury Cubic (17 yr)	Constant Y <sub>3</sub> : Vec		Y <sub>6b</sub> = 24928.24 - .020 Y <sub>3</sub> + 1.489E-008 Y <sub>3</sub> <sup>2</sup> - 3.720E-015 Y <sub>3</sub> <sup>3</sup>	.253	.268	1.47
30	Y <sub>6b</sub> : Injury Inverse (17 yr)	Constant Y <sub>9</sub> : Motorization Level		Y <sub>6b</sub> = 14144.81 + (1/395947.54 Y <sub>9</sub> )	.255	.039	5.14
31	Y <sub>6b</sub> : Injury (17 yr) Quadratic	Constant X <sub>1</sub> : time		Y <sub>6b</sub> = 18772.13 - 364.22 X <sub>1</sub> + 13.60 X <sub>1</sub> <sup>2</sup>	.260	.122	2.46
32	<b>Y<sub>12</sub>: Cost Cubic (17yr)</b>	<b>Constant Y<sub>4</sub>: Accidents</b>		<b>Y<sub>12cub</sub> = 313.248 - .006 Y<sub>4</sub> + 8.766E-008 Y<sub>4</sub><sup>2</sup> - 3.044E-013 Y<sub>4</sub><sup>3</sup></b>	<b>.898</b>	<b>.000</b>	<b>32.31</b>
33	Y <sub>12</sub> : Cost (17 yr)	Constant Y <sub>4</sub> : Accidents Y <sub>10</sub> : Casualty	.033 .193 .232	Y <sub>12</sub> = 120.074 + .001 Y <sub>4</sub> - .016 Y <sub>10</sub> + .869 Y <sub>9</sub>	.660	.006	7.12

		Accd. Y <sub>9</sub> :Motoriz- ation Level	.011				
34	Y <sub>7c</sub> : Fatal/1000 Vehicle	Constant Y <sub>9</sub> :Motoriz- ation Level	.000 .000	$Y_{7c} = 2.648 -.012 Y_9$	.643	.000	63.0
35	<b>Y<sub>7c</sub>: Fatal/1000 Vehicle Exponential</b>	<b>Constant Y<sub>9</sub>:Motoriz- ation Level</b>		$Y_{7c} = 3.868 e^{-.010Y_9}$	<b>.755</b>	<b>.000</b>	<b>107.9</b>
36	Y <sub>6c</sub> : Injury/1000 Vehicle	Constant Y <sub>9</sub> :Motoriz- ation Level	.000 .000	$Y_{6c} = 63.61 -.287 Y_9$	.882	.000	260.6
37	<b>Y<sub>6c</sub>: Injury/1000 Vehicle Cubic</b>	<b>Constant Y<sub>9</sub>:Motoriz- ation Level</b>	.000 .000	$Y_{6c} = 24.74 +.899Y_9 -.011Y_9^2 + 3.232E-005Y_9^3$	<b>.919</b>	<b>.000</b>	<b>125.0</b>

## VII. CONCLUSIONS

The following conclusions can be drawn from this study:

1. The numbers of traffic accidents have increased over the study period 1981-2017 and 2001-2017 with a total increment of 1100% and 285% respectively as a result of increased population, auto ownership, and motorization level (registered vehicles/1000 population).
2. The severity level of traffic accidents (number of casualties/ number of accidents) showed a decreasing trend over the study period 1981-2017 from 0.718 to 0.113 and 0.372 to 0.113.
3. The number of accidents/100,000 population showed a decreasing trend, while the number of the accidents /10,000 registered vehicles showed an increasing trend until 2010, and 2011(2290) and (1302) then started decreasing.
4. The number of fatal traffic accidents showed an increasing trend until 2007 reach (992), 17.4 fatal/100,000 population and 117.83 fatalities /10,000 registered vehicles, then started decreasing until reaching to 6.8 fatalities/100,000 population and 43.3 fatalities /10,000 registered vehicles.
5. Good regression models were developed to predict the following items, which can estimate in the future with a highly significant degree (= 0.000):
  - a- Population depend on time (Exponential;  $R^2 = 0.949$ ,  $F = 646.9$ ).
  - b- Registered vehicles depend on time (Quadratic;  $R^2 = 0.995$ ,  $F = 3329.8$ , Cubic;  $R^2 = 0.996$ ,  $F = 2824.6$ ).
  - c- Number of accidents depend on registered vehicle (Power;  $R^2 = 0.951$ ,  $F = 680.2$ ).
  - d- Number of casualty accidents depend on accidents, for the late 17 years data (Cubic;  $R^2 = 0.954$ ,  $F = 146.63$ ).
  - e- Severity rate depend on time, population, registered vehicle and accidents (Linear:  $R^2 = 0.985$ ,  $F = 535.5$ ), depend on time (Cubic;  $R^2 = .982$ ,  $F = 587$ ) depend on accidents (Quadratic;  $R^2 = .99$ ,  $F = 1662$ ), and depend on motorization level, for the late 17 years data (Quadratic;  $R^2 = 0.980$ ,  $F = 342.44$ ).
  - f- Number of injuries (injury/1000 vehicle) depend on the motorization level (Cubic;  $R^2 = 0.919$ ,  $F = 125.0$ ).
  - h- Number of fatalities (fatal/1000 vehicle) depend on the motorization level (Exponential;  $R^2 = 0.755$ ,  $F = 107.9$ ).
  - i- Costs of accidents depend on the number of accidents, for the late 17 years data (Cubic  $R^2 = 0.898$ ,  $F = 32.3$ ).

## CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this paper.

## DATA AVAILABILITY

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

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## AUTHOR PROFILE

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