Statistical Analysis of Mortality and Morbidity Due to Traffic Accidents in Iraq

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ABSTRACT

Undoubtedly, Road Traffic Accidents (RTAs) are a major dilemma in term of mortality and morbidity facing the road users as well as the traffic and road authorities. Since 2002, the population in Iraq has increased by 49 percent and the number of vehicles by three folds. Consequently, these increases were unfortunately combined with rising the RTAs number, mortality and morbidity. Alongside the humanitarian tragedies, every year, there are considerable economic losses in Iraq lost due to the epidemic of RTAs. Given the necessity of understanding the contributory factors related to RTAs for the implementation by traffic and road authorities to improve the road safety, the necessity have been a rise for this research which focuses into two objectives; the first objective is a descriptive analysis for the RTA based on a retrospective analysis during the period of 2002–2015 with the aids of the data obtained from the reports of Iraqi Central Statistical Organization whereas the second objective is to conduct a statistical analysis for RTAs to correlate the criterion variable of accident number, mortality or morbidity to predictor variable which include motorization level or population using traditional statistical regression approach and Artificial Neural Network (ANN) approach.

Key words: road traffic accidents, mortality, morbidity, motorization level.

التحليل الإحصائي للوفيات والجرحى بسبب الحوادث المرورية في العراق

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الخلاصة

حوادث الطرق المرورية (RTAs) هي معضلة رئيسية من حيث الوفيات والجرحى التي تواجه مستخدمي الطرق والجهات المسؤولة عن سلامة المرور والطرق. ومنذ عام 2002، زاد عدد السكان في العراق بنسبة 49 في المئة وعدد المركبات بمقدار ثلاثة أضعاف. ونتيجة لذلك، فإن هذه الزيادات ترافقت مع ارتفاع عدد الحوادث المرورية والوفيات والجرحى. إلى جانب المآسي الإنسانية، فإن هناك خسائر اقتصادية كبيرة في العراق كل عام بسبب وباء الحوادث المرورية. ونظرا لضرورة فهم العوامل المساهمة في الحوادث المرورية من قبل الجهات المسؤولة عن سلامة المرور والطرق من اجل تحسين السلامة المرورية في العراق، فقد برزت الحاجة لهذا البحث الذي يركز على هدفين؛ الأول هو تحليل وصفي للحوادث المرورية استنادا إلى تحليل بأثر رجعي خلال الفترة 2002-2015 بمساعدة المعطيات التي تم الحصول عليها من تقارير منظمة الإحصاء المركزية العراقية في حين أن الهدف الثاني هو إجراء تحليل إحصائي للحوادث المرورية لربط المتغير المعتمد لعدد الحوادث و الوفيات و الجرحى بمتغير مستقل بما في ذلك مستوى امتلاك المركبات أو السكان باستخدام الانحدار الإحصائي التقليدي و الشبكة العصبية الصناعية (ANN).

الكلمات الرئيسية: حوادث الطرق المرورية، الوفيات، الجرحى، مستوى امتلاك المركبات.

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1. INTRODUCTION

Although the road traffic accident (RTA) defined as an event suddenly, inadvertently and unexpectedly occurred under unforeseen circumstances, but identifying the contributory factors as well as circumstances that affect the occurrence of traffic accidents could be helpful in reducing them to its barest minimum through the attraction attention of the traffic agencies to enact an efficient traffic safety regulations to lessen the influence of this dilemma.

Globally, according to the world health organization (WHO), About 1.25 million people die each year as a result of RTA, around 85 percent of these deaths occur in developing countries. Furthermore, up to 50 million people suffer non-fatal injuries, with many incurring a disability as a result of their injury. RTA caused 500 children lose their lives every day. It is the leading cause of death for young people aged 15 to 29 years, and the eighth leading cause of death globally. Alongside the humanitarian tragedies, every year, USD 500 billion is lost due to the epidemic of RTA that represents approximately 3 to 5 percent of the gross national product of the countries. In view of the aforementioned facts, a global target was adopted by the United Nations (UN) framework of Sustainable Development Goals (SDGs) in 2016 to halve deaths and injuries caused by road crashes by 2020.

Locally, according to the WHO report 2015, Iraq is ranked 18th out of the 180 countries in the total number of deaths due to traffic accidents in 2013 (5789 deaths) in which India occupies the top rank (137572). Within the Eastern Mediterranean Region (EMR), Iraq has the 2nd highest road traffic mortality rate based on the report of the WHO in 2013. The highest numbers of mortality due to traffic accidents were among children and young people. Approximately half of mortality in Iraq were pedestrians, a ratio almost double that of any neighboring country, **Leidman, et al., 2016**.

Based on the aforementioned preface, the necessity has been arise for this research which aims two main objectives; analysis the RTAs based on a retrospective analysis during the period of 2002–2015 considering accidents number, accidents types, mortality, morbidity, driver age group, cause of accidents, light condition, monthly distribution of accidents, vehicle type involved in accident, and functional class of highway. The second objective is to conduct a statistical analysis for RTA to correlate the criterion variable of accident number, mortality or morbidity to one or more predictor variables which include motorization level or population, using traditional statistical regression and ANN approaches.

2. BACKGROUND

Road safety is a main concern and aim of highway and traffic engineers. In 1949, **Smeed** has been developed the first statistical model which relates the mortality rate (road death per vehicle) with exposure variable of motorization level (vehicle per capita), the model was based on the analysis of RTAs data that dating back to the year of 1938 for 20 courtiers from different continent of the world. The suggested model which was later known as Smeeds Law has the following hyperbola form:

$$D/N = 0.0003\ (N/P)^{-2/3} \tag{1}$$

where D is annual road deaths, N is number of registered vehicles, and P is population. The main theme which can be abstracted from the Smeeds Law is that the increase of motorization level leads to a decrease in mortality rate.

Although, there was some contradictions existed among the researchers about the Smeed formulas, **Anderson, 1985** and **Adams, 1987**. However, researchers from developed as well as developing countries still use the Smeed laws but with some modification for either the power or intercept of the exposure variable, **Bener,** and **Ofsu, 1991, Ghee, et al., 1997, Koren,** and **Borsos, 2010, Al-Omari, et al., 2013, Hesse,** and **Lamptey, 2014**.

Islam, and **Ahmed, 2012** examined the RTA data of Oman for a period between 2000 and 2009, they stated that the number of accidents fell down from 13,040 cases in 2000 to 7,253 in 2009 with a drop of 44 percent over the study period despite the fact that motorization level has increased over the study period by 26 percent and reach approximately 230 vehicle per 1,000 population in 2009. They finally conclude that 70 percent of the RTA happened to drivers aged 17-36 years.

Al-Omari, et al., 2013 investigated the RTA data of Jordan (1998-2010), they stated that a total of 1,040,112 accidents have occurred over the study period with an average of 80,008 accidents/year. They attributed the increments of RTA which was 223 percent during the study period to the development of motorization level from 82 vehicle/1000 population in the year 1998 to 176 vehicle/1000 population in the year 2010 with an increment of 114.6 percent. Also they stated that majority of RTA have occurred during the summer months with the highest during the month of August in Sundays and Thursdays (the first and last working days in Jordan).

Ghaffar, and **Ahmed, 2015** stated that 19 deaths occur daily and approximately 4 peoples injured every hour in the kingdom of Saudi Arabia due to RTA in the past 10 years (2006-2015), the annual cost for these RTA was about 7 billion US dollars.

Wang, and Chan, 2015 stated that road traffic fatalities (RTF) has increased substantially (134 percent) in china over the period 2002–2012. They believed that the main reason for this increment was the rapid development in motorization level, The number of private vehicles in China has increased from7.7 million in 2001 to 73.2 million in 2011, and the total number of registered vehicles has increased from 65.2 million in 2001 to 209.1 million in 2011. Also, they demonstrated that 57 percent of RTFs occurring among individuals aged 45 and above during 2011–2012.

Bashar, et al., 2013 utilized the traffic accidents data in Jordan for thirteen years period 1998 to 2010 to develop the following power model that correlate number of traffic accident per year (ACC) with motorization level (number of registered vehicles per 1000 population (M):

$$ACC = 56.47\, M^{1.57} \tag{2}$$

Also, they suggested the following polynomial model that predicts the traffic accidents fatalities per year (F) using motorization level (M) as independent variable:

$$F = -\,9.109\, M^{2} + 2847M - 9879 \tag{3}$$

Ibrahim, 2014 utilizes time series methods to fit and forecast rates of traffic fatalities in the United Arab Emirates (UAE) , the accident fatality data were divided into two parts, A training dataset, 1977 to 2003, which is used to describe trend and to develop traffic fatality prediction models, and a validation dataset, 2004 to 2008, which is used to validate the developed models. ARMA like model with an autoregressive component (AR) of order 1 was applied by the author and the following best fit model was suggested:

$$Log(F/V)_{t} = 0.7425 – 0.7675t + 0.66641 \log (F/V)_{t-1} \tag{4}$$

Where F is the number of traffic fatalities, V is the number of vehicles and t is the time in years. The author concluded that there is a downward trend in the UAE traffic fatality rates, forecasts of traffic fatalities per 1000 registered vehicles for 2013 is 0.4847 with a reduction approximately 30 than that of 2008 rate.

With the abundance of global scientific research in the RTA field, the number of local researches does not exceed the fingers of hand in this field, **Al-Jameel, 2016** was developed an Expert system for RTA that provides expert consultation in the domain of highway safety in Iraq. The system consisted of two phases. The first one is the diagnostic phase and the second one is the remedy phase. The objective of the developed expert system was to reduce the number of RTA.

Aljoborae, and **Al Humairi, 2014** conducted a hospital based cross sectional study in Hillah city based on the data obtained from the central hospital within the city for five months' time period (May- November 2013). The aim of the study was to investigate some the socio-demographic characteristics of the RTA victims, the authors concluded about half of the drivers had no driving permits and 59 percent of the victims had a history of previous exposure to RTA, Also 83 percent of victims were male, 76 percent came from urban areas and 69 percent of victims were exposed to RTA during daytime. **Leidman, et al., 2016** investigated the fatalities RTA that occurred between January 2010 and 31 December 2013 in eight governorates of Iraq (out of 18 governorates): Baghdad, Al-Anbar, Basrah, Erbil, Kerbala, Maysan, Ninevah, and Al-Sulaimaniya. The data were obtained from the Iraqi Ministry of Health (MoH). The authors concluded that the highest numbers of road traffic fatalities were among males 15 to 34 years of age and children of both sexes under 5 years of age, approximately eight out of ten road traffic fatalities in Iraq were males, and rates of road traffic fatalities ranged from 8.6 to 10.7 per 100,000 population.

3. DATA SOURCE

This study is based on the RTAs data obtained from Central Statistical Organization (CSO) in the ministry of planning. CSO were collected the accidents data from the police affairs agency in the ministry of interior that receive the data from the police stations distributed within each city in Iraq. The accidents data were available from 2002 to 2015 for Iraq (except Kurdistan region, the northern three governorates).

4. ANALYSIS OF ACCIDENTS DATA

4.1 Number of Accidents

The annual distribution of the 109067 RTAs occurred during 2002-2015 is presented in **Fig. 1** with the annual average RTAs of 7790, as well. It's obvious there was a small drop in RTAs in 2003 (outbreaks of the war) then raised gradually in the next three years to reach 9010 in 2005. The maximum downward divergence from the annual average RTAs was recorded in 2007, the RTAs dropped to 3135. the matter which can be attributed to the "even and odd policy" which was followed in Iraq to improve the traffic operational conditions of the highways network, the vehicles that end with an even plate number are permitted to drive in even calendar days whereas those end with an odd plate number can drive in odd calendar days. The application of this policy was terminated in 2008. Then, between 2007 and 2012 there was a noticeable rise in RTAs which finally peaked at 10709 in 2012. This increment associated with the improved level of average annual income for the people. The Gross Domestic Product (GDP) reached to 6,619 USD per capita as

compared to 3,125 USD in 2007. In June 2013, the Iraqi governorates reactivated the "even and odd policy" and the RTAs steadily decrease until 2014 then the RTAs stagnated and leveled off at 8836 in 2015.
Although the fluctuation of the RTAs data presented in **Fig.1** is graphically obvious, further investigation was carried out using Mann-Kendall test to explore any statistically significant trend in the data. The null hypothesis H0 represents no trend. At significance level (α) = .05, 2-tailed test. The obtained Z statistic is z = 1.53 which is lower than 1.96, therefore the null hypothesis is accepted since there is not enough evidence to determine that there is a downward or upward trend in the data.

4.2 Type of Accidents

When the RTA data sorted according to the type of accidents, it is obvious that the most common type of accident during the period 2002 to 2015 is run over which accounted for 45.7 percent of the total number of accidents that have been occurred as shown in **Fig. 2**. This type of accident is the most dangerous type due to the direct contact between the vehicle and the pedestrian involved in the accident. The high mortality rate is belonged to this type of accident, for example, in 2014, the mortalities resulting from the run over constituted approximately 44.3 percent of the total number of mortalities due to the RTA which is the highest mortality rate whereas the morbidities from the same type of accidents composed approximately 36.9 percent of the total number of morbidities representing the second highest morbidity rate after that recorded due to the collision. The collision is the second most common type of RTA, 47226 accidents of this type have been recorded out of 109067 total accident numbers during 2002-2015, this figure represent approximately 43.3 percent which is slightly lesser than the percentage of the first type. Collectively, run over and collision scored together approximately 89 percent of the total number of accidents. As an annual mean, 2101 persons lost their lives and 7590 persons suffered from the morbidities due to these types of accident. In the third rank of RTA there is the turnover; with a rate of 10 percent which is considered low when compared with run over or collision. Finally, 1 percent of RTA was recorded as “others” which denoted the accident like vehicles fire or falling downhill in river.

4.3 Mortality and Morbidity

RTAS have an awful influence on humans, societies and countries. In Iraq around 29415 persons were lost their lives during the period from 2002 to 2015, beside 106259 persons suffered from morbidities due to the RTA. Based on the victims data presented in **Fig. 3** below, the annual average numbers of mortalities and morbidities during 2002-2015 are 2101 and 7590, respectively. Recalling to the mind that the number of accident within this period has an annual average of 7790, it can be easily concluded in each one accident the mortality rate was 0.27 (each 3.7 accidents resulted in one death) whereas the morbidity rate was 0.97.
During 2002 to 2015, both the number of mortality and morbidity reached a low of 1151 for the first and 3033 for the later in 2006, then the mortality rised gradually and morbidity goes up drastically, both of them reached the peak in 2012, the same year that witnessed the highest level of RTAs in Iraq, the recorded mortality and morbidity are 3132 and 11009, respectively.
In order to inspect the existence of any statically useful trend in both the mortality and morbidity data, Mann-Kendall tests were used with a significance level (α) = .05, 2-tailed test. The null hypothesis H_0 represents no trend whereas Ha refers to the existence of an upward trend in the data.

The obtained Z statistic is z = 3.06 for mortality and z = 2.62 for the morbidity, both values more than 1.96. Therefore, the null hypothesis H_0 is rejected for both cases and the evidence is enough to determine that there is an upward trend in both mortality and morbidity data.

The analysis of the accidents data based on the age group of deaths presented in **Fig. 4** shows that about 61 percent of mortality due to RTAs are within the age group range of (18-47) years. It is evident that the youth is the most vulnerable to traffic accidents; therefore the problem becomes catastrophic since most of mortality represents the labor force of the Iraqi community.

Globally, nearly three times more male than female died due to road traffic accidents (WHO, 2013). In Iraq, the death possibility for male due to traffic accidents more than female by approximately four times as illustrated in **Fig. 5**, the same figure shows that the exposure for morbidity due to traffic accidents for male is higher than that for female by 62 percent.

4.4 Drivers Age

The distribution of RTAs based on the drivers age group is presented in **Fig. 6**, it is evident from the exhibited data that the RTAs distribution is skewed towards the younger age group with a mean of 26 years old and maximum occurrences of 24 percent in the age group 24-29 years. followed by those in the age group 30-35 with 21 percent , and 18-23 with 19 percent. Collectively, these three age groups are involved in around two thirds of total RTAs during the period 2002-2015, this result can be attributed to the fact that the drivers within these age groups are young adults, active and have more tendencies for making trips for educational, work and social purposes than other age groups, the matter which increase the probability to exposure for RTA. The teenage drivers with age less than 17 years old accounting for only 5 percent RTAs since the drivers within this age group are not permitted to have driving license according to Iraqi rules that stated the minimum age for obtaining a driving license is 18 years. The RTAs reached a minimum of 2 percent for elderly drivers with age more than 60 years as compared to other age groups due to the facts of limited trips that they need.

4.5 Causes of Accidents

RTAs distribution according to the contributory causal factors is presented in **Fig. 7**. The factors are classified into the following categories; drivers, vehicle, road, pedestrian, passengers and other factors (i.e., animal or obstruction). Based on the presented data, the drivers are the major contributor factor for the RTAs in Iraq with a percentage rate of 72 because many of them do not abide the principle driving rules and safety regulations. For instance, although the local regulations stated that the speed limits for the urban and rural road are 60 km/hr and 100 km/hr, respectively, the enforcement level for this regulation is just 3 out of 10 degree, **WHO, 2015**. The same matters are also applicable for the helmet use for motorcycle drivers and seat belt wear for the vehicle drivers, the enforcement level for the former is just 2 whereas for the latter is 5.

Following the drivers, the vehicle is the second main cause for the RTAs with 11 percent. Poor roadway conditions, structurally presence of sever rutting (loss of steering control) as well as functionally improper geometric design features, are responsible for about 6 percent of traffic accidents in Iraq. The crossing of pedestrian from the undesignated crossing lines in highways other than using the crossing lines or footing bridge resulted in about 7 percent of RTAs. The remaining causes for RTAs consist of passengers and the "other factors", each of them had 2 percent, denoting the lowest involvement rate as compared to the other causes.

4.6 Light Conditions

One of the major environmental non-behavioral factors which considerably affect RTAs is lighting conditions due to the visibility restrictions in darkness. Based on the availability for data, the numbers of RTAs for four light conditions within the day were recorded. The light conditions consisted; daylight, dark, sunrise and sunset. The total number of RTAs for each light condition (at the time of accident) is shown graphically in **Fig. 8**. Although it was expected that the number of RTAs in the darkness be more than that at under daylight condition, the result showed the contrast. The majority of RTAs in Iraq, 69 percent, happened under the day light condition whereas just 10 percent of RTAs occurred during darkness. This discrepancy could be attributed to the existed vehicles curfew in night (12 am – 5 am) for the period 2007 to 2015 in Baghdad (capital) as well as some other Iraqi governorates. Other light conditions, sunset and sunrise, account for about 10 percent of the RTAs, for each one of them.

It was found that around 69% of the road traffic incidents happened under the day light condition, and all other light conditions had same percentages with a rate of (10 %) for each one of them. In other words, the majority of road traffic crashes revolving in Iraq are taking place during the day light condition because imposed a curfew in night (12 am – 5 am) due to security situation in Iraq at the period from 2003 to 2015.

4.7 Monthly Distribution

Fig. 9 shows how the average number of RTAs for each month changed over the period of 2002 to 2015. January has the lowest number of RTAs; it contributes to about 7 percent from the total number of the RTAs that occurred during the year. Thereafter, slight differences in RTAs monthly distribution can be observed until august. During the last third of the year, the RTAs show detectable fluctuation in the monthly distribution as compared to the first two thirds of the year. The RTAs increase steadily during September and October; the peak number of RTAs occurred in October, within this month there is 753 RTAs which represent 10 percent from the total number of RTAs in the year, this could be attributed to the beginning of the academic year in the colleges as well as all types of schools. Following October, the RTAs decrease in November and then slightly increase in December.

However, the visual inspection for the monthly distribution of RTAs may be considered not enough to conclude either there is significant differences in the average number of RTAs between the months of year or not. Statistics can be serves as a good tool to ascertain the truth. For this purpose, Poisson mean analysis was performed using Minitab V16 software.

For $\alpha = 0.05$, the result is shown in the **Fig. 10**, below. It is evident that the mean number of RTAs in each month is 627 and the LDL and UDL are 558 and 695, respectively. Also, the figure pointed out that there are no significant differences in the mean number of RTAs for all the months of the year, since they are all laying within the limits of decision, except January and October, the former fall below the LDL indicating the month with minimum number of RTAs whereas the latter fall above the UDL referring to the month with the maximum number of RTAs in the year.

4.8 Vehicle Type

The transport system in Iraq is mainly based on the passenger car. For example, the distribution of the registered vehicle in 2015 which is presented in **Fig. 11** revealed that 84 % of registered vehicle is passenger car followed by 9% trucks and 3 % buses beside 3 % motor cycle and pedal cycle as well as 1 % for other types of vehicles (a.e., construction and agricultural).
Based on the aforementioned facts, passenger car was expected to be over-represented in the occurrences of RTAs in Iraq. The inspection of the data presented in **Fig. 12** which exhibits the contribution of each type of vehicle in the RTAs agreed with this expectation. About two thirds of RTAs are caused by passenger car followed by motor cycle which accounted for 11 percent of the total number of accidents. The trucks and buses shared in RTAs with 9 percent for each one whereas the contribution of pedal cycle and other types of vehicles were 3 and 1 percent, respectively.

4.9 Highway Functional Class

Based on the functional classification of highways and their effect on the geometric characteristics as well as traffic characteristic (speed and volume) of the highways, the contribution of each type of highways in RTAs is differ than the others. Obviously in **Fig. 13**, about 59 percent of RTAs occurred in arterial roads, perhaps this class of highway has a high geometric design characteristic that allows high speed and carry high volume of traffic, the matter which rises the probability of an accident also the majority of transportation network in Iraq consisted from this type of highway. Following the arterial highways, the collector highways accounting for 17 percent from the total number of RTAs whereas the expressway and local road accounting for 10 and 5 percent, respectively.

5. POPULATION AND REGISTERED VEHICLES TRENDS

As the number of vehicle and population increases throughout the world, the number and severity of traffic accidents also increases. Referring to **Fig. 14**, the population in Iraq has increased by 49 percent during the period from 2002 to 2015 and approximately the number of registered vehicles in 2015 has more than that in 2002 by three folds.
Furthermore, the high motorization level (number of vehicle per 1000 populations) is a major factor which responsible for the increased number of mortality and morbidity rates due to traffic accidents in Iraq. The motorization level has increased approximately from 54 in 2002 to 141 in 2015 as illustrated in **Fig. 15**. In other words, the vehicle ownership (persons per vehicle) has changed from 18 in 2002 to 7 in 2015.
The use of mortality rate (deaths per 100,000 populations or per 10,000 vehicles) or morbidity rate (injuries per 100,000 populations or per 10,000 vehicles) is more useful to evaluate the severity of the traffic accidents problems than the absolute number. Use of the total number of mortality or morbidity alone can be deceptive, because it neglects the effect of population size for countries, **WHO, 2013**. Also, in the period from 1995 to 2009, the mortality rates in road traffic accidents ranges between (4-7) deaths per 100,000 populations in Iraq. The current data analysis concluded that the mortality rate in road traffic accidents has risen to 9 deaths per 100,000 in the early 2010 and reached a peak of 11 deaths per 100,000 in 2012 which consider the highest rate of mortality due to traffic accidents over the last 30 years. Furthermore, the same year of 2012, has witnessed the highest morbidity rate during the last 30 years of (3.7).

6. ECONOMIC COSTS OF TRAFFIC ACCIDENTS

The RTAs cost countries approximately 3 to 5 percent of their Gross Domestic Product, **WHO, 2015**. In USA, the statistics report of the National Highway Traffic Safety Administration (NHTSA) estimated the economic cost of the traffic accidents nearly $242 billion in 2010, **NHTSA, 2016**.
Based on feasibility study for rehabilitation and upgrading the expressway No. 1, **CC, 2013**, the average costs of road accident in Iraq was 250,000 USD per mortality and 70,000 USD per morbidity. The economic costs of traffic accidents accounted for 14.8 billion USD over the study period (14 years, 2002-2015), representing about 2.9 million USD per day as listed in table (1). The presented cost components cover productivity of casualties, possessions damage, medical bills costs, and emergency services such as ambulance, police, and fire services.

7. DEVELOPMENT OF STATISTICAL MODELS

In statistical modeling the overall objective is to develop a predictive equation relating a criterion variable to one or more predictor variables. Three types of models were attempted in the next sections. In the first type the criterion variable is the number of traffic accident per 10,000 registered vehicles whereas in the second and third types the criterion variables are the mortality per 10,000 registered vehicles and morbidity per 10,000 registered vehicles, respectively. Motorization level or population is the predictor variable in all types of models. Using the data presented in table (2), MINITAB V16 software was adopted to perform the necessary analysis.

7.1 Accidents Models

Different model structures are attempted to improve the explained variation (R^2) which assess the adequacy of the proposed regression models. Due to its simplicity, first it was decided to examine the linear relationship between the criterion variable accidents per 10,000 registered vehicle (A/10,000 V) and the predictor variable motorization level (M) the adopted linear model presented in table (3) yields an R^2 of 0.49, this value is substantially low. Alternatively, polynomial regression models, second and third order, were attempted to improve the explained variation. As shown in table 2, the obtained R^2 for the second order and the third order polynomial models are 0.711 and 0.723, respectively. Accordingly, the replacement of the predictor variable population (P) instead of M in the third order polynomial regression model yields improves the R^2 value to 0.817 which has the implication that only 18.3 percent of the observed variation is unexplained by the developed model.

7.2 Mortality Models

As shown in table (4) are the models examined for the prediction of mortality. The first one is linear model with criterion variable mortality per 10,000 registered vehicles and predictor variable motorization level. Unfortunately, the explained variation by this model is 0.365. The second and the third model are polynomial with second and third order, respectively. The R^2 duplicated in case of using third order polynomial model as compared to the linear model. The use of Population (P) as predictor variable in the third order polynomial model results in some improvement in the explained variation (R^2 = 0.78).

7.3 Morbidity Models

The attempted models for the prediction of the morbidity per 10,000 registered vehicles as well as the obtained R^2 are found to be similar into large extent to those models listed above for the prediction of mortality. From the model presented in table 5 below, it can be concluded that the criterion variable morbidity per 10,000 registered vehicles, at best can be predicted with a correlation to the criterion variable of population (P), the resulted R^2 was 0.775.

8. ARTIFICIAL NEURAL NETWORK (ANN)

Artificial Neural Network (ANN) is considered as an effective tool to solve complex wide variety of civil engineering problems. The ANN was used in this research with an aim of improving the adequacy of the prediction models and to achieve better accuracy than those models obtained using the traditional statistical regression approach. The structure of the network used consists of 1 layer of input with 1 nodes (predictor variable), 1 output layer with 1 node (criterion variable), and one hidden layer with 3 nodes, as shown in **Fig. 16**.

The training algorithm used was the Levenberg-Marquardt back propagation algorithm (named trainlm) which is considered one of the most efficient and fastest algorithms, and 85 percent of the data were selected for training and 15 percent for testing for 14 data point. The ANN code was produced using an academic version of MATLAB 2015.

Three ANN models were developed in this research, the output of model no.1, no.2 and no.3 represent accident per 10,000 vehicles, mortality per 10,000 vehicle and morbidity for per 10, 000 vehicles, respectively. Whereas the input of these models was the motorization level. The results of ANN prediction models are shown in **Fig. 17, 18** and **19** for the models no.1, no.2 and no.3, respectively.

The performance of the proposed ANN models were evaluated by using the explained variation (R^2) which represent the square of R value (correlation coefficient between the actual and the predicted values) existed in **Fig. 17, 18** and **19**. The R^2 values for the model no. 1, no.2 and no.3 were 0.978, 0.981 and 0.997, respectively. These R^2 values prove that ANN models has superior abilities in the prediction of the RTAs as well as mortality and morbidity as compared to those models obtained using the traditional statistical regression approach.

9. CONCLUSIONS

Based on the findings of the investigations for the RTAs data over the study period 2002-2015, the following salient conclusions can be drawn:

1. A total of 109067 RTAs has been occurred during the study period with an annual average of 7790. The maximum downward and upward divergence from the annual average RTAs recorded in 2007 and 2013, respectively. The corresponding RTAs were 3135 and 10709.

2. The most common type of accidents was run over which accounted for 45.7 percent of the total number of RTAs, followed by 43.3 percent collision accident type and 10 percent turnover accident type.

3. 29415 persons lost their life beside 106259 persons suffered from morbidity due to RTAs. In each one accident the mortality rate was 0.27 (each 3.7 accidents resulted in one death) whereas the morbidity rate was 0.97 (each 1.03 accidents resulted in one injury).

4. Most of the mortality represents the labor force of the Iraqi community. Based on the age group of deaths, about 61 percent of mortality due to RTAs is within the age group range of (18-47) years.

5. Due to RTAs, the death possibility for male more than female by approximately four times whereas the exposure for morbidity of male is higher than that for female by 63%.
6. Based on the age of drivers that cause RTAs, the RTAs distribution is skewed towards the younger age group with a mean of 26 years old and maximum occurrences of 24 percent in the age group 24-29 years followed by those in the age group 30-35 with 21 percent , and 18-23 with 19 percent.
7. The drivers are the major contributor factor for the RTAs in Iraq with a percentage rate of 72 followed by vehicle with 11 percent then by pedestrian with 7 percent and road by 6 percent.
8. The majority of RTAs in Iraq, 69 percent, happened under the day light condition whereas just 10 percent of RTAs occurred during darkness.
9. January has the lowest number of RTAs; in average it contributes to about 7 percent from the total number of the RTAs that occurred during the year whereas peak number of RTAs occurred in October with an average of 10 percent.
10. About two thirds of RTAs are caused by passenger car followed by motor cycle which accounted for 11 percent of the total number of accidents. The trucks and buses shared in RTAs with 9 percent for each one.
11. About 59 percent of RTAs occurred in arterial roads. The collector highways accounting for 17 percent from the total number of RTAs whereas the expressway and local road accounting for 10 and 5 percent, respectively.
12. Alongside the humanitarian tragedies, the economic costs of traffic accidents accounted for 14.8 billion USD over the study period representing about 2.9 million USD per day.
13. The models obtained by ANN technique showed superior abilities in the prediction of the RTAs as well as mortality and morbidity as compared to those models obtained using the traditional statistical regression approach.

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11. NOMENCLATURE

RTAs	road traffic accidents
ICSO	iraqi central statistical organization
ANN	artificial neural network
WHO	world health organization
UN	united nations
SDGs	sustainable development goals

EMR	eastern mediterranean
D	annual road deaths
N	number of registered vehicles
P	population
RTF	road traffic fatalities
ACC	number of traffic accidents per year
M	motorization level
F	traffic accidents fatalities
AR	auto regression component
V	number of vehicles
t	time in Year
MoH	ministry of health
CSO	central statistical organization
GDP	gross domestic product
Ho	null hypothesis
α	significance level
A	accidents
Mt	mortality
Mb	morbidity

Table 1. Cost of mortality and morbidity due to traffic accidents.

Year	Cost of Mortality $	Cost of Morbidity $	Total Cost $
2002	423,250,000	495,040,000	918,290,000
2003	338,750,000	395,990,000	734,740,000
2004	406,500,000	475,160,000	881,660,000
2005	447,250,000	522,690,000	969,940,000
2006	287,750,000	212,310,000	500,060,000
2007	302,500,000	227,640,000	530,140,000
2008	465,750,000	384,930,000	850,680,000
2009	537,750,000	556,850,000	1,094,600,000
2010	627,000,000	629,720,000	1,256,720,000
2011	675,750,000	713,860,000	1,389,610,000
2012	783,000,000	770,630,000	1,553,630,000
2013	737,750,000	748,580,000	1,486,330,000
2014	692,250,000	644,700,000	1,336,950,000
2015	628,500,000	660,030,000	1,288,530,000
Total	7,353,750,000	7,438,130,000	14,791,880,000

Table 2. Populations, vehicles, traffic Accidents, mortalities and morbidities in Iraq.

Year	Population (P)	Registered Vehicle (V)	Accidents (A)	Mortality (Mt)	Morbidity (Mb)
2002	21,200,000	1,152,702	8,535	1,693	7,072
2003	21,700,000	1,652,723	6,826	1,355	5,657
2004	22,404,800	1,842,512	8,191	1,626	6,788
2005	23,010,000	2,028,301	9,010	1,789	7,467
2006	24,993,000	2,386,612	3,389	1,151	3,033
2007	25,740,000	2,471,461	3,135	1,210	3,252
2008	26,508,000	2,491,711	5,502	1,863	5,499
2009	27,296,000	2,527,335	7,452	2,151	7,955
2010	28,102,000	2,662,946	8,861	2,508	8,996
2011	28,500,000	2,763,667	10,082	2,703	10,198
2012	29,207,000	3,043,975	10,709	3,132	11,009
2013	30,095,000	3,527,534	9,725	2,951	10,694
2014	31,004,000	4,239,818	8,814	2,769	9,210
2015	31,634,000	4,458,780	8,836	2,514	9,429

Table 3. Accidents model.

Model No.	Model Equation	R^2	F	P
1	$A/10{,}000V = 81.1 - 0.497\,M$	0.492	11.63	0.005
2	$A/10{,}000V = 186 - 2.66\,M + 0.0107\,M^2$	0.711	13.51	0.001
3	$A/10{,}000\,V = 291.5 - 6.325\,M + 0.0505\,M^2 - 0.0001372\,M^3$	0.723	8.68	0.004
4	$A/10{,}000\,V = 6591 - 734.4\,P + 27.214\,P^2 - 0.33404P^3$	0.817	14.93	0.001

Table 4. Mortality models.

Model No.	Model Equation	R^2	F	P
1	$Mt/10{,}000V = 15 - 0.0682\,M$	0.365	6.91	0.022
2	$Mt/10{,}000V = 27.4 - 0.325\,M + 0.00126\,M^2$	0.486	5.21	0.026
3	$Mt/10{,}000\,V = 85.5 - 2.34\,M + 0.0233\,M^2 - 0.000076\,M^3$	0.629	5.64	0.016
4	$Mt/10{,}000\,V = 1445.5 - 164\,P + 6.16\,P^2 - 0.0767\,P^3$	0.780	11.8	0.001

Table 5. Morbidity models.

Model No.	Model Equation	R^2	F	P
1	Mb/10,000V = 63.6 - 0.337 M	0.376	7.23	0.020
2	Mb/10,000V = 137 – 1.86 M + 0.00748 M^2	0.554	6.84	0.012
3	Mb/10,000 V = 308 – 7.78 M + 0.072 M^2 – 0.000222 M^3	0.600	5.12	0.021
4	Mb/10,000 V = 6244 - 702 P + 26.2 P^2 – 0.324 P^3	0.775	11.47	0.001

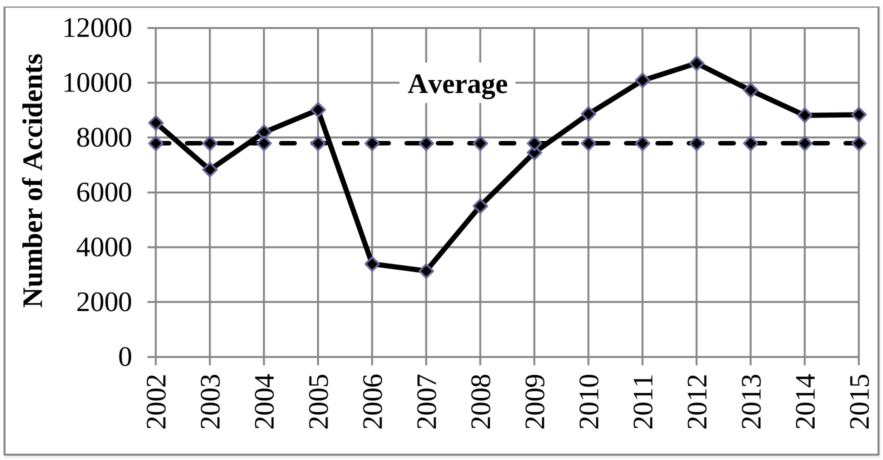

Figure 1. Annual distribution of RTAs.

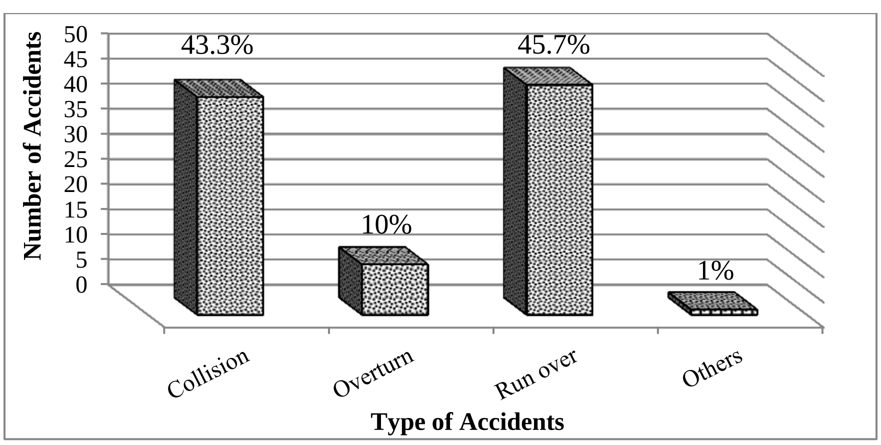

Figure 2. RTA distribution according to the types.

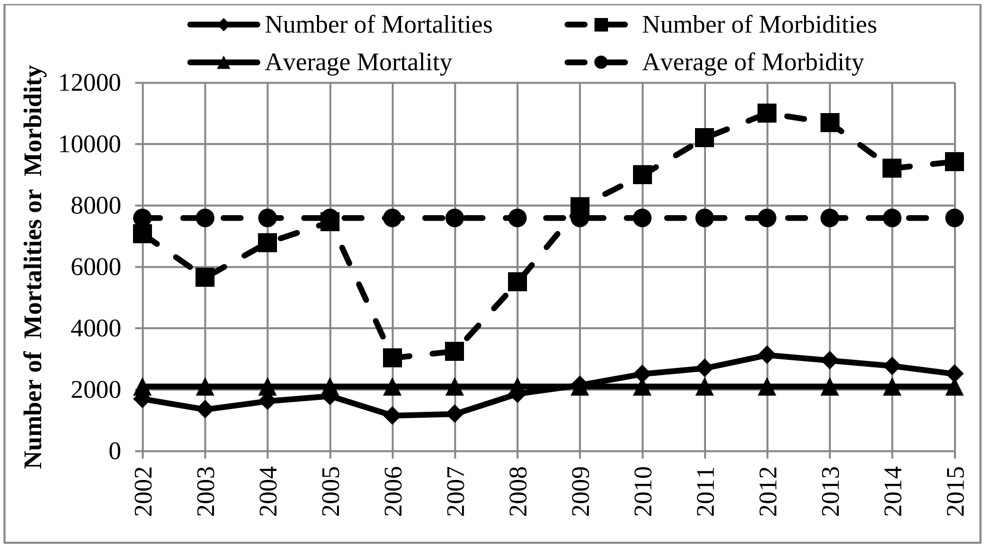

Figure 3. Mortality and morbidity due to RTAs.

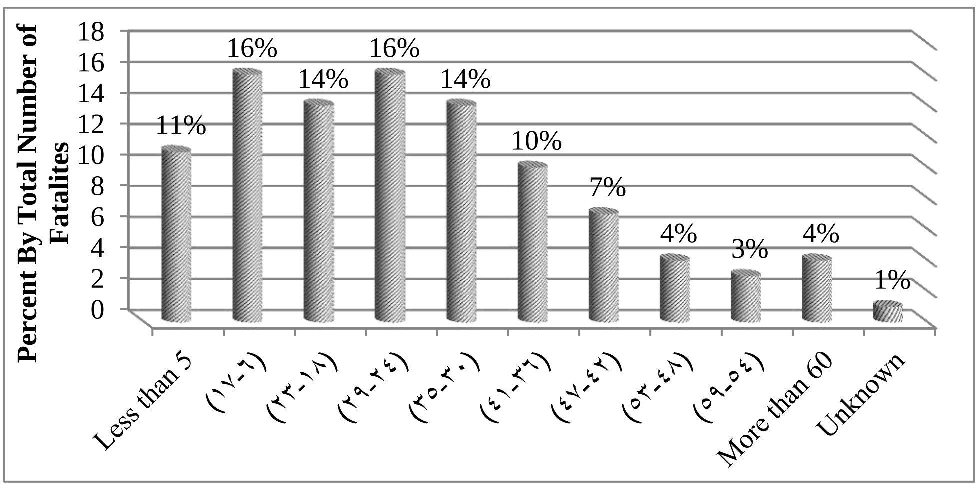

Figure 4. Age group for RTAs mortality.

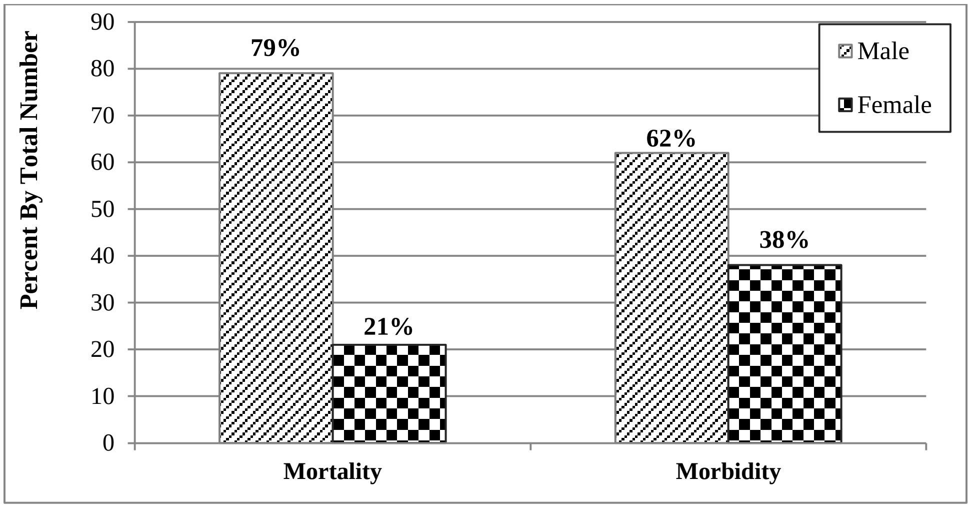

Figure 5. Gender of mortality and morbidity due to RTAs.

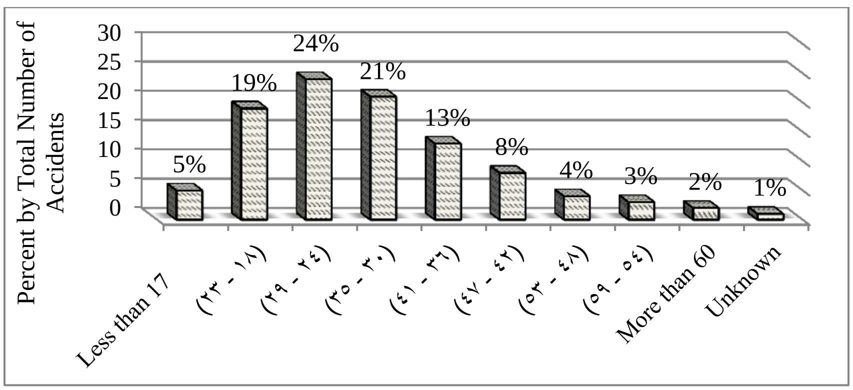

Figure 6. The distribution of RTAs based on driver age.

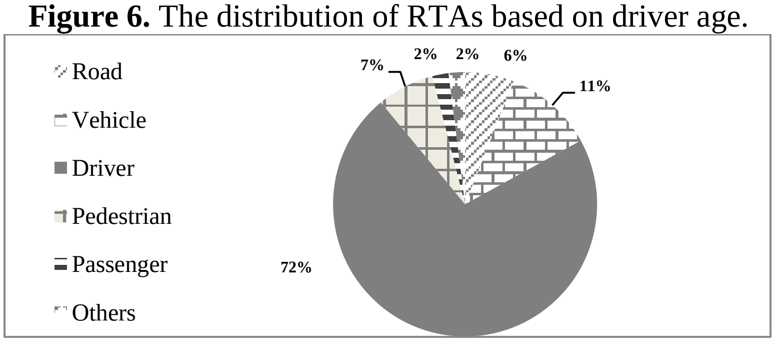

Figure 7. The distribution of RTAs based on causal factors.

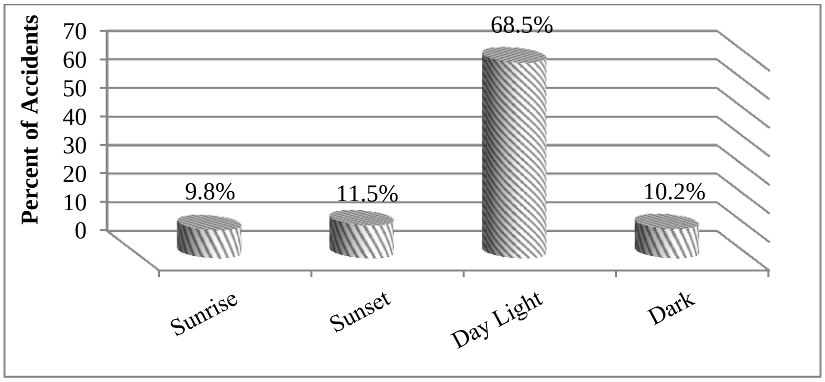

Figure 8. The distribution of RTAs based on light condition.

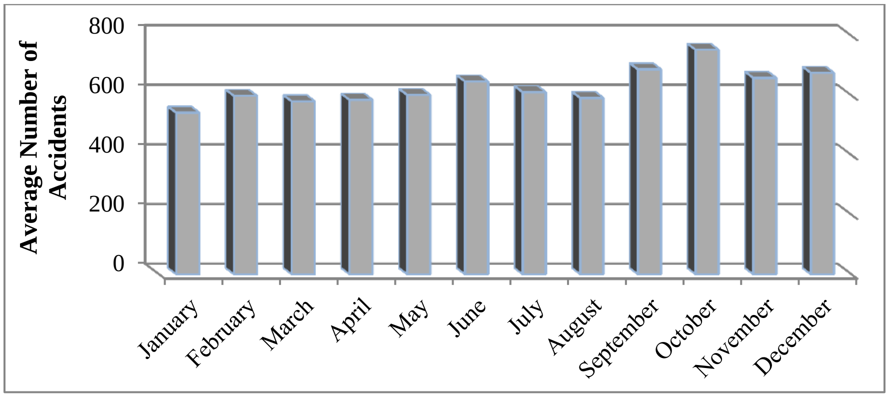

Figure 9. The monthly distribution for RTAs.

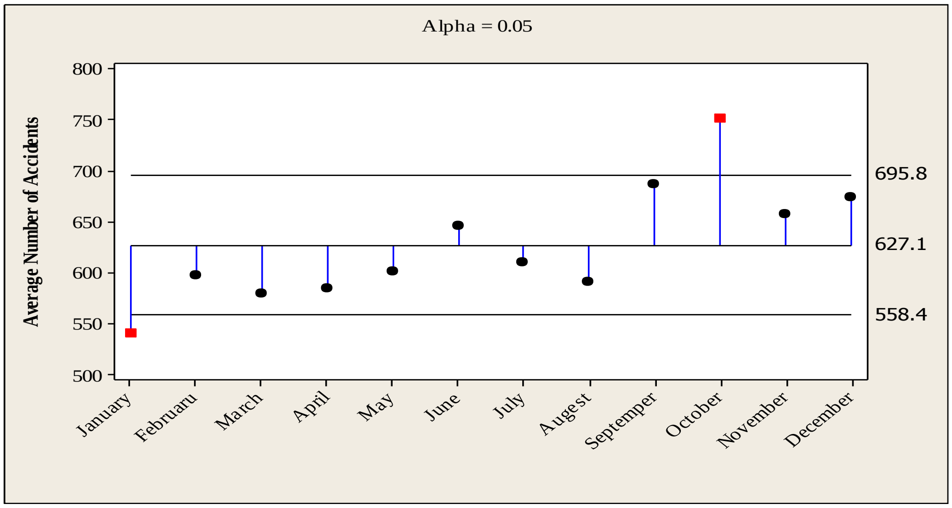

Figure 10. The difference in the mean number of accidents for the months of the year.

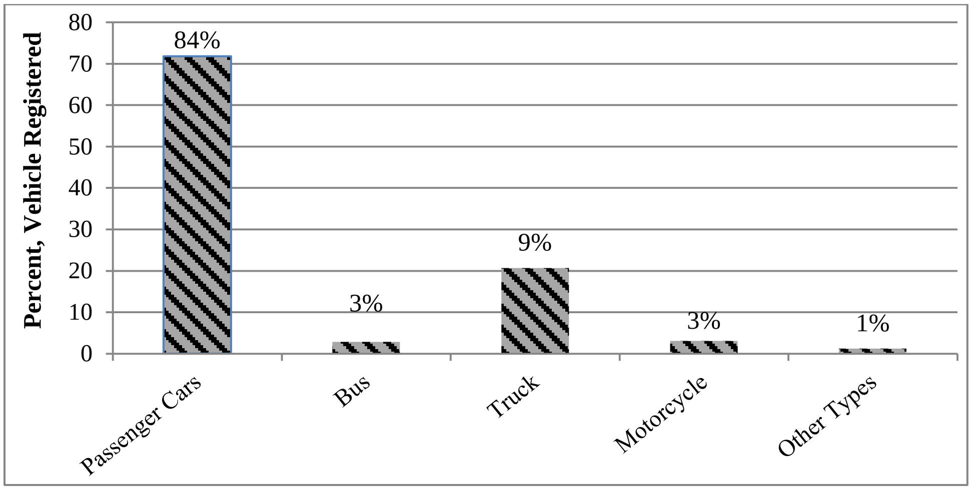

Figure 11. Registered vehicles types in 2015.

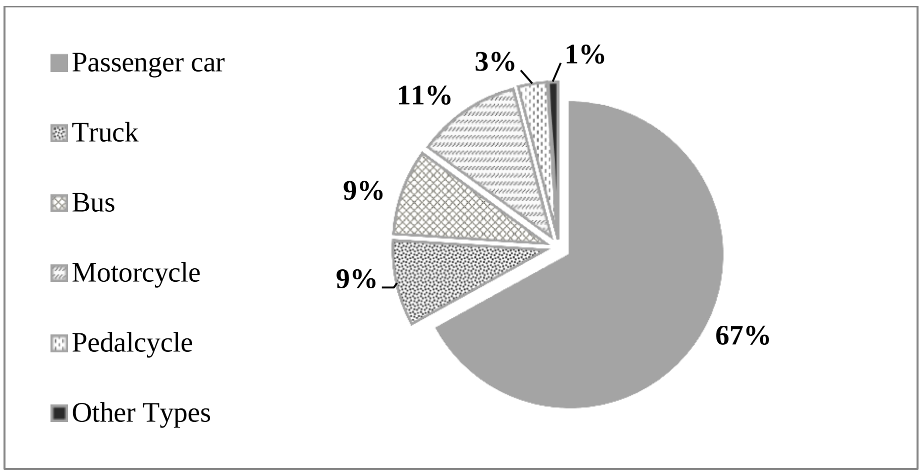

Figure 12. The distribution of RTAs based on vehicle type.

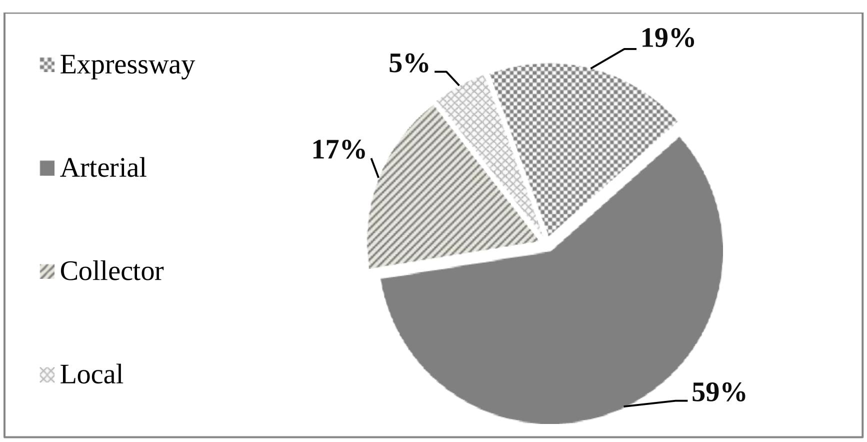

Figure 13. RTAs distribution based on highway functional class.

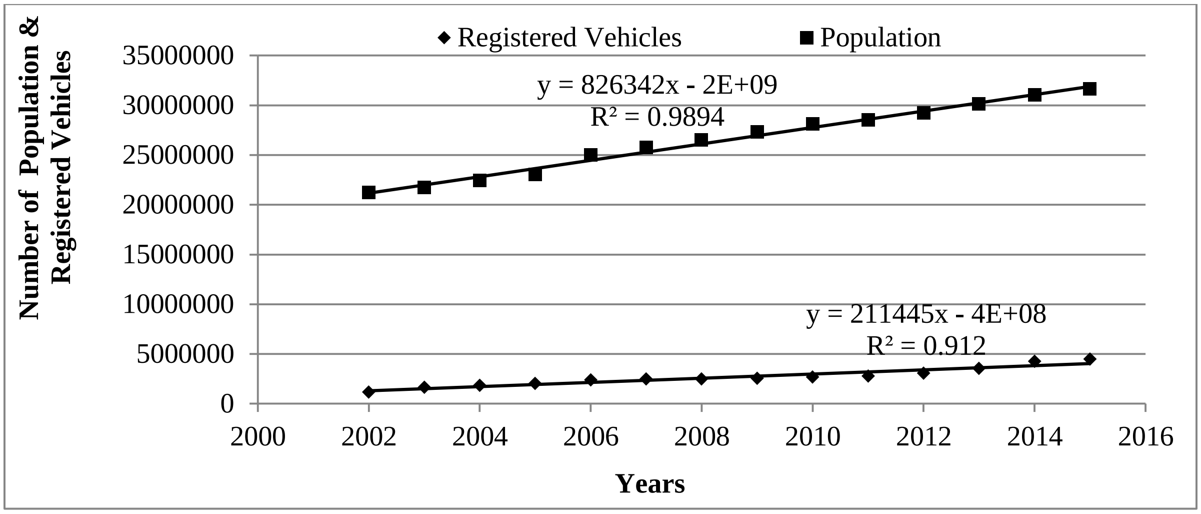

Figure 14. Growth of population and registered vehicles with time.

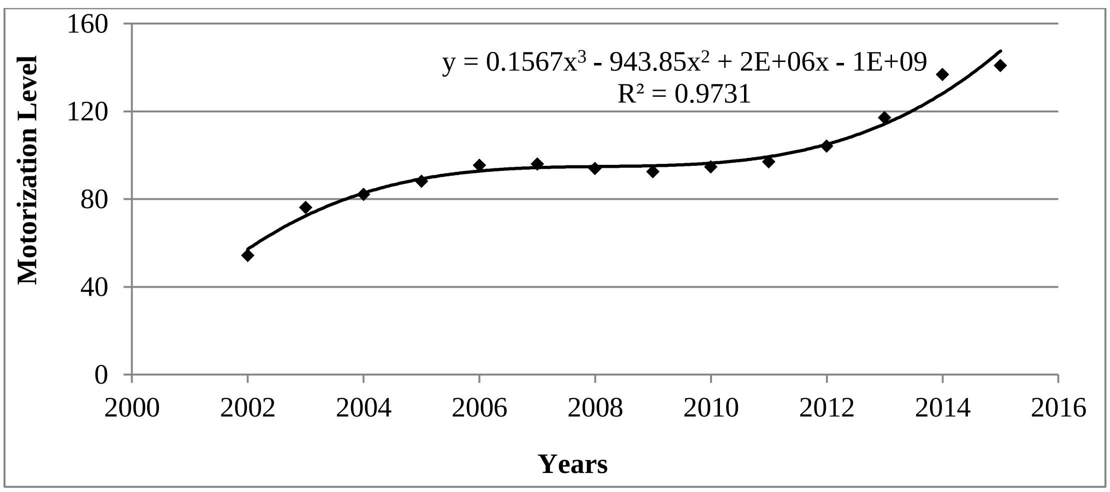

Figure 15. Motorization level with time.

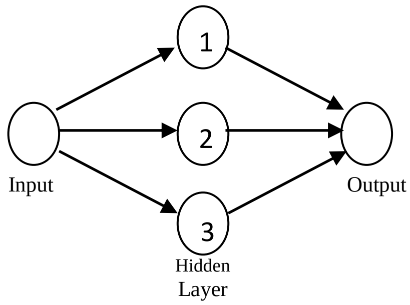

Figure 16. Structure of ANN.

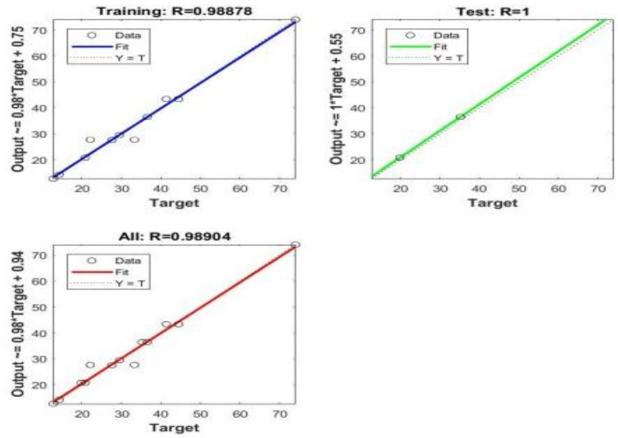

Figure 17. Results of the ANN prediction model no.1 (accident).

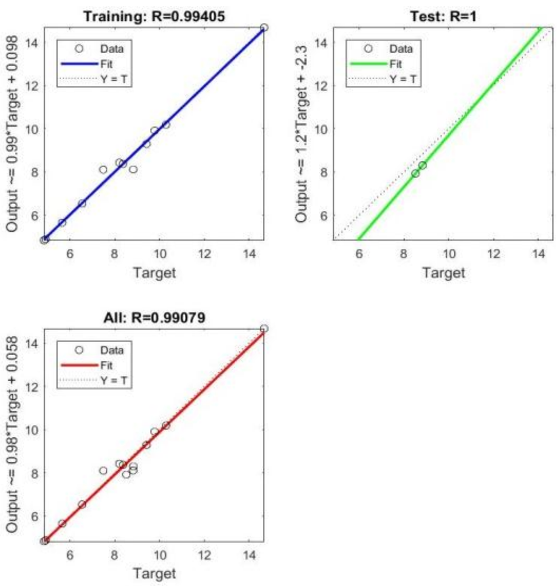

Figure 18. Results of the ANN prediction model no.2 (mortality).

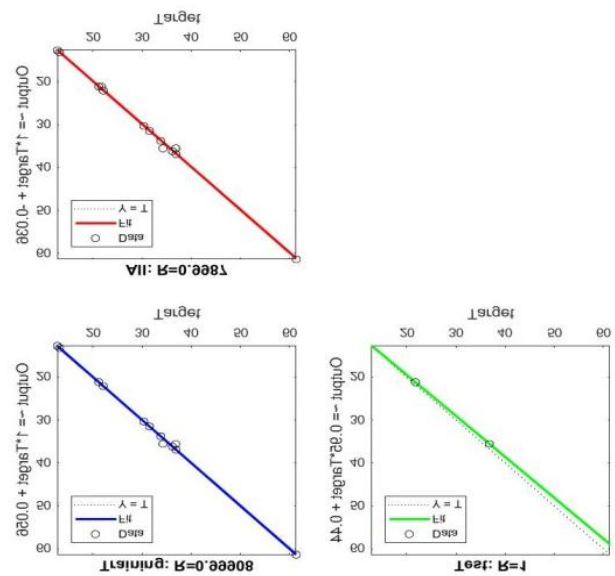

Figure 19. Results of the ANN prediction model no.3 (morbidity).