



# Analyzing and Predicting Traffic Accident Trends Considering Gender and Seasonal Patterns: A Case Study of Al-Sulaymaniyah City

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## Abstract

In developing countries, the most significant issue is road traffic accidents (RTAs). In fact, the road accident has an important influence on the health and social policy. Al Sulaymaniyah city, in the northern part of Iraq, was considered as a case study. The rapid urbanization and motorization increase these problems in the city. The current study takes into account the gender disparity, seasonal patterns, and the severity of the traffic accidents. Thus, this study aims to analyze and forecast the gender disparity in road traffic crash rates. The Chi-square test and SARIMA model were employed on the collected data. The outcomes show that male drivers contribute at a higher rate of fatalities and injuries than female drivers. Furthermore, the seasonal patterns indicate that the fluctuations are affected by weather conditions and post-pandemic mobility changes. A valuable insight was provided for policymakers and urban planners via the critical patterns. This insight is crucial for local authorities to develop strategies that improve road safety and reduce the negative impact of traffic accidents on health and social life.

*Keywords:* Road crashes, SARIMA model, time series, forecasting, road safety.

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## 1. Introduction

Road traffic accidents (RTAs) are increasingly emerging as global health and safety threats due to the growth in injuries, fatalities, and economic losses (WHO, 2023). The majority of RTAs are caused by human activity, making it a major contributing element (K. S. Ismael & Razzaq, 2017). However, a significant obstacle in the realm of road safety is obtaining comprehensive data on the socio-demographic drivers (McCarty & Kim, 2024) (Abdullah & Sipos, 2023). Unfortunately, developing countries (i.e. Iraqi governorates) suffer from higher rates of traffic accident casualties compared with the rates of casualties around the world (Albayati & Lateef, 2019). The population density and number of automobiles in Iraq's Kurdistan Region (KRI) have expanded considerably

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since 2005 as a result of its relative stability and economic progress. Similarly, the study shows the average number of vehicles per household grew from 0.39 to 0.83 during the same period. Notable regional disparities in car ownership rates exist among the Kurdistan, central, and southern regions of Iraq. The Kurdistan region, in particular, has exceptionally high car ownership rates, even by global standards. In northern Iraq, car ownership per 1,000 people was 126 in 2003 and surged to 435 by 2013 (Al-Obaedi, 2019). This rapid growth has led to various undesirable consequences, including a significant rise in RTAs, posing serious social, technical, and economic challenges with intend to use more private car (Ismael & Duleba, 2022; Kriswardhana et al., 2025).

According to the World Health Organization (WHO, 2023) mentioned that the traffic accidents cause more than 1.25 million deaths around the world each year, especially in developing countries. In Iraq, the RTAs had 5,789 ranks the country in the 18th out of 180 nations, which kills one-person every four hours and causes injuries to at least three others. Meanwhile, India placed first with about 137,572 accidents annually (Al-Jameel & AbdAbas, 2018). According to the KRI Ministry of health, the country had the lowest level of traffic safety compared to its neighbours, where the RTAs result in around 850 deaths and more than 10,000 injuries per year (Aldoski et al., 2023). Therefore, a close attention has to be paid to the consequences of the accident rate in Iraq in order to implement the proper solutions.

In the previous studies, a gap has been found regarding researching certain issues in this region. Al Sulaymaniyah city is facing a number of issues, however, the most notable of which is the increase the traffic accidents (Mohammed et al., 2019). To develop policies on road safety, reliable information is required. The governorates provide statistical data on traffic and insurgency-related deaths every month, but these data could be more informative if they were analysed frequently. Although men are expected to be involved in the road accidents, the health impacts for women are still important (Moreno González & Labeaga Azcona, 2024). Several factors influence the traffic accidents such as high speed, road conditions, absence of public transport, and excessive number of private vehicles (Bermúdez Rey et al., 2016).

Several studies mentioned that both men and women are involved in traffic accidents at different rates, despite the high percentage of male drivers. Therefore, considering the gender disparity is crucial in order to understand the dynamics of these incidents. As an example, (Özkan & Lajunen, 2006) found that males' riskier driving behavior is the main reason for their higher accident rates, while external environmental conditions (e.g. different weather conditions) are the main cause of accidents involving females. Due to the fact that seasonality has a significant impact on traffic patterns, road conditions, and driver behavior, it is vital to conduct a comprehensive investigation into temporal trends and seasonal variations in accident rates in order to resolve these inconsistencies (K. S. Ismael & Razzaq, 2017).

(Rashid & Ismail, 2023) have investigated, in Kurdistan's main city of Erbil, young males are more likely to be in traffic accidents and have lower limb injuries. It is also commented that safety measures like seatbelts protect prevent RTAs. Speed and recklessness were the main causes of road accidents because human behaviour distraction, hitting, and abrupt appearance was linked to road injuries. Taking these steps and raising awareness is necessary. The state can form a dedicated team to address this issue, and practical steps must be taken to lower the percentage of injuries.

On the other hand, it was also shown that factors such as driving experience, level of education, and socioeconomic status did not have a significant impact on the number of

accidents that occurred (Mohamed & Bromfield, 2017). The purpose of this study is to evaluate the impact of gender, together with other time characteristic and type of severity, on accident involvement. This study is a complement to earlier efforts in the field regarding accident involvement. On the basis of the empirical facts, tailored solutions, which may include governmental interventions that engage the local Kurdistan, Iraq community.

According to an additional study, the genders of victims of fatal and injury-type RTAs, makes it quite evident that men died at a rate four times greater than women. RTAs caused injuries about 79.5% more often in men than in women (Albayati & Lateef, 2019). This finding supports the hypothesis that aggressive and careless driving are more common among males than women. One possible explanation for the aforementioned results could be the gender gap in driving in Iraq (Albayati & Lateef, 2019). Furthermore, in Iraq, this difference is pronounced, with males being more than four times as likely to experience fatal results, and 84% of the injured individuals being men, in contrast to 16% who are women. In 2020, the COVID-19 lockdown imposed stringent mobility limitations, resulting in an 18.4% decline in traffic fatalities, from 2,636 in 2019 to 2,152 in 2020 (Latief et al., 2023). Another instance in March and April 2020 (Italian lockdown), road traffic accidents dropped by over 70% compared to 2019's comparable months, although mortality changed less, more varied among regions (Valent, 2022). Without doubt during the epidemic, the use of different transport modes was drastically reduced across the board (K. Ismael et al., 2023). According to study breakdowns of accidents by time of occurrence and severity of injuries reveal significant shifts before and after COVID-19 and shows a substantial reduction from March to June 2020.

Additionally, the study pointed out a great variation in the change between countries/regions with significant heterogeneity (i.e. different socioeconomic status and their travel restriction policies) were not the same which required further investigation (Lee et al., 2023).

(Abdulla et al., 2023) found that road traffic accidents (RTAs) in Al-Sulaymaniyah city are mostly influenced by characteristics such as excessive speeding, low educational attainment, gender, youth, and alcohol consumption, with individuals aged 19-33 being the most vulnerable.

Several other studies have focused on the issue of gender and its relation to accidents. (Al-Balbissi, 2003), for instance, examined the influence of gender in traffic accidents and demonstrated that the rates of accidents for men are noticeably higher. The study demonstrated that males experienced a greater impact from the pediatric head, spinal cord, and peripheral nerve injuries than females across all age groups. However, another researcher pointed out that new drivers, female drivers are more likely to have fatal accidents than male drivers (Bener & Crundall, 2008).

Furthermore, according to a study based on accident data from the Danish Road Directorate, there are gender differences in traffic behavior and accident involvement. In general, males take longer journeys and drive more. Women travel more, but they do so on shorter journeys and more often by bicycle or foot. Men are engaged in traffic accidents twice as often as women, despite the fact that they spend the same amount of time in traffic. Men are involved in 66% of traffic accidents and account for 62% of all fatalities and injuries (Visby & Lundholt, 2018). Previous research suggests that preventive programs should target men, both young and elderly, motorcyclists, and long-distance drivers, as they are more likely to sustain serious and fatal injuries. The study analysis was limited in the analysis suggested to including data on road traffic accidents

over multiple years can provide valuable insights (González-Sánchez et al., 2018). Furthermore, male drivers were more likely to be involved in speeding/lane departure-related crashes, resulting in severe injuries. Female drivers were marginally more prone to distracted driving collisions and injuries (Billah et al., 2022).

However, another study found no significant mistake relationship was discovered between male and female drivers. Significant differences were found in six driving skill items between male and female drivers. Meanwhile, data analysis in the study found considerably higher accident rates for male drivers compared to female drivers (Bener & Crundall, 2008). Overall, all, the findings of this investigation align with the majority of current literature. Effective preventive actions are necessary to minimize traffic accidents and their severity (Bener & Crundall, 2008). It is also recommended that to employ various measurement methodologies and tools on diverse driver samples across different nations to better investigate the potential correlations between sex, gender, and overall driving style (Özkan & Lajunen, 2006).

After thorough the literature, we thought it was important to look into it more and see how it played out in a different society. This study aims to determine the gender effect on accident rates and to find out the disparities association with variations in time particularly in developing country. Transport operators of initiatives to lessen the frequency of accidents will reap significant rewards from this.

To the best of our knowledge, no study has yet demonstrated longitudinal data about gender and types of accidents in Iraq at least.

Therefore, this study focuses on Sulaimani City, a major urban center in northern Iraq, where the increase in traffic crashes has posed serious social and economic challenges. Hence, the main aim is to analyze and forecast gender differences in traffic accident rates. By identifying seasonal patterns and critical periods of heightened risk, this study provides valuable insights to support policymakers in implementing gender-sensitive traffic safety measures, improving regulations, and reducing accident rate. To achieve the aim of this study, a statistical analysis and machine learning method are used.

In order to facilitate the evaluation of accident differences and offer sufficient justifications, the current analyses aim to address the following queries:

1. Is the difference in accident rates between the two gender groups?
2. Does the difference have any association with variations in time?
3. What are the implications of these differences?
4. What is the projected future trend in the number of accidents for each gender group?
5. To what extent does gender influence the type and severity?

This paper is organized as follows. Section 2 presents the methodology section includes study area, data collection and the methodology used in the paper. Section 3 presents the results of the statistical and descriptive analysis and Machin Learning method for the RTAs data. Section 4 presents the final discussion and future research, and section 5 shows the final marks, conclusion and policy implications.

## 2. Methodology

### 2.1 Study area and the collected data

Al Sulaymaniyah City (See Figure 1) was chosen as the study area for several reasons: it has its unique characteristics as a Northern of Iraq such as, being a tourist attraction. Additionally, the city served as the capital of the historic principality. The rapid urbanization of the city due to the increase in the population over recent years to and has the largest concentration of urban population in Iraq (2020 population: around 1 million) (KRSO, 2023). Al Sulaymaniyah City is experiencing fast economic growth, and motorization. Rapid growth and development and increase of vehicles, possibly leads to increase of traffic accidents, which is motivated this study to choose the city.



Figure 1 Map of Iraq and the province of Sulaymaniyah, which is the location where the field research was carried out (www.wpmap.org, 2024).

The data presented were obtained from the Central Statistical Organization (CSO) General Directorate of Traffic Police in Sulaymani city and correspond to the period 2014–2023 (STD, 2024). The collected data include gender groups, the number of accidents, the number of injuries, and numbers of death along with months and years of accidents. Data pertaining to the genders of the victim were also available. Several steps have been conducted in order to preprocessing the collected data. Handling the missing values was the first step that can be represented by removing the missing values from the dataset. Additionally, the categorical data were encoded to numerical values to create a well-suited format for the time series analysis (Mahdi & Esztergár-Kiss, 2023). Data splitting also was implemented on the collected data where this process involve allocation a portion of the data to estimate the SARIMA model, where about 70% of data use for this purpose. However, the rest of the data (30%) is used for validation purpose (Mahdi & Esztergár-Kiss, 2024).

## 2.2. Chi-Square Test

It is a non-parametric statistical test designed to determine whether there is a significant association between two categorical variables. It assesses the relationship between observed frequencies and expected frequencies under the assumption that the variables are independent. The mathematical expression of this test can be expressed in formula (1)(McHugh, 2013):

$$x^2 = \sum_{i=1}^n \frac{(o - e)^2}{e} \quad (1)$$

Where  $o$  refers to the observed data,  $e$  represents the expected value, and  $x^2$  refer to the sum of the squared differences between the observed and expected values.

Our study used the Chi-Square Test of Independence to assess the relationship between the two adopted variables, i.e., the gender (Male or female) and the severity variable as (injury and fatality). It is worth mentioning that the p-value has been used to assess the probability of observing such a discrepancy if the variables are truly independent, where a p-value less or equal to 0.05 (Mahdi & Esztergár-Kiss, 2023), and that is mean that the two variables are not independent and suggests a potential association between them (Franke et al., 2012).

## 2.3 Seasonal Decomposition and SARIMA Model

This study applied the decomposition of time series and SARIMA (Seasonal Autoregressive Integrated Moving Average) to describe the pattern and seasonal factors in the observed accident data. The reason behind using this mode is the nature of our data, which has seasonal patterns. Seasonal decomposition breaks down à time series into its fundamental components : trend, seasonality, cyclic variations, and irregular fluctuations. The regular seasonal behaviour of long-term trends can be identified and visualized (Ray et al., 2021). The mathematical expression of SARIMA model can be explained in formula (2) (Xu & Zeng, 2024):

$$\Phi_p(B) \cdot \Phi_p(B^m) \cdot \nabla^d \cdot \nabla_m^D \cdot Y_t = \theta_q(B) \cdot \theta_q(B^m) \cdot \varepsilon_t \quad (2)$$

Where:

- $\Phi_p(B)$  is the non-seasonal autoregressive polynomial,  $p$  here refers to order of the autoregressive term.
- $\Phi_p(B^m)$  is the seasonal autoregressive polynomial, where  $m$  represents the seasonal period.
- $\nabla^d$  is the non-seasonal difference, and  $d$  represents the degree of the non-seasonal difference.
- $\nabla_m^D$  is the seasonal difference, and  $D$  represents the degree of the seasonal difference.

- $Y_t$  is the observed value at time  $t$ .
- $\theta_q(B)$  is the non-seasonal of moving average polynomial.
- $\theta_Q(B^m)$  is the seasonal of moving average polynomial, and  $Q$  refers to the seasonal order.
- $\varepsilon_t$  represents the error term.

Together, seasonal decomposition and SARIMA provide a robust framework for understanding and predicting time series behaviors across various domains. The model is used to forecast the accident pattern of the collected data.

### 3. Results

#### 3.1 Descriptive statistics

The bar chart (Figure 2) shows the distribution of injuries and fatalities by gender in traffic accidents. The difference between males and females is noticeable. The male injuries represent the highest count of the accident data, while Female injuries are fewer, reflecting a more cautious driving behaviour. Furthermore, the male fatalities are greater than the female fatalities, which may result from fewer high-risk driving situations of females. Like most of the developing countries and Iraqis' regions, the percentage of licensed male drivers in Al Sulaymaniyah city is greater than that of females, and this is consistent with the accident outcomes. The percentage of male drivers in Al Sulaymaniyah is about 85% and the rest of the drivers are females (Abdulla, 2023).

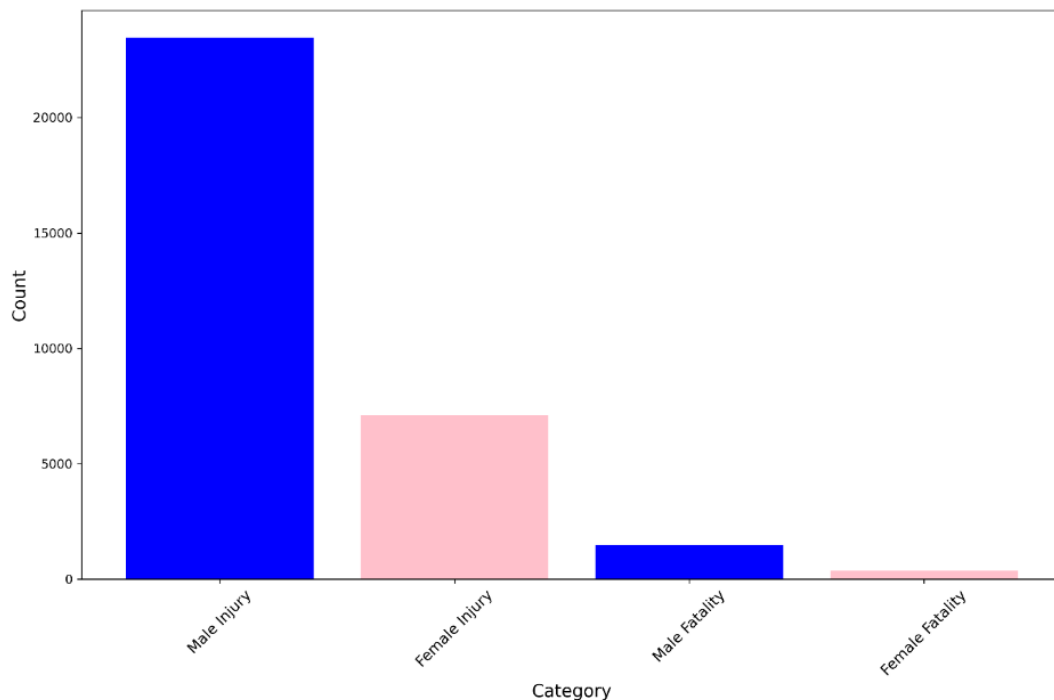


Figure 2. Distribution of casualties by gender and severity

Figure 3. Shows the trends in traffic accidents for males and females over the period (January 2014 to December 2023), in Al- Sulaimani city. Male accidents always exceeded female accidents. It is obvious the significant changes with periodic peaks, point to higher male involvement in traffic incidents. In contrast, female accidents exhibit a more stable and calm trend with fewer fluctuations. The difference between the two curves emphasizes a gender difference in traffic accident patterns.

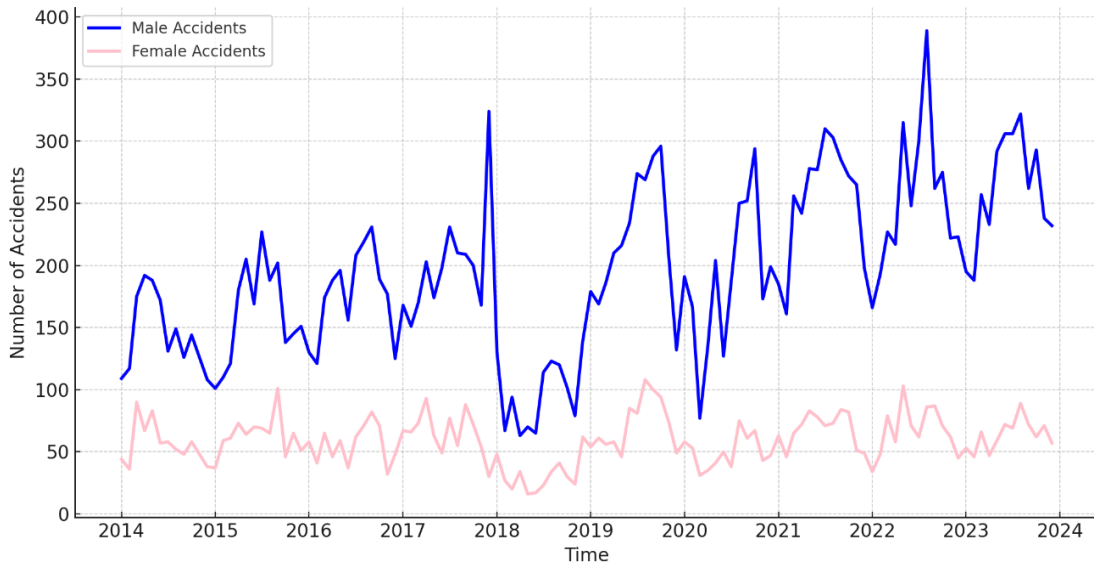


Figure 3. Total accidents over the period (01/01/2014 to 01/12/2023)

### 3.2 Chi-square result

Table (1) shows the chi-square outcomes, where a significant relationship between gender and accident severity is provided. A Chi-square statistic of 7.56 demonstrates a significant difference between observed and expected counts. The p-value is less than 0.05, which means that the variables are not independent. The expected frequencies are found the following results :

- Male injuries : 23513.27
- Male fatalities : 1443.73
- Female injuries : 7072.73
- Female fatalities : 434.27

Based on the provided outcomes, it is indicated that the gender factor represents an influential factor on the severity of traffic accidents.

Table 1. Chi-Square Test Results: Relationship Between Gender and Casualty Severity

Metric	Value
Chi-square Statistic	7.56
P-value	0.00596
Degrees of freedom	1

### 3.3 Seasonal decomposition

The seasonal decomposition of the traffic accidents are shown in Figure (4). It was obvious from the figure that the observed data exhibits fluctuation in the period 2014 to 2023. In the trend figure, there was a reduction in accidents from 2020 to 2021 during the pandemic crisis, where road usage had decreased because of the lockdowns due to COVID-19. Then, a rise peaking in 2021, where the normal activity resumed post-lockdown. However, except for the pandemic period, the seasonal pattern reveals consistent, higher and lower frequencies of accidents are occurring at specific times of the year due to weather conditions.

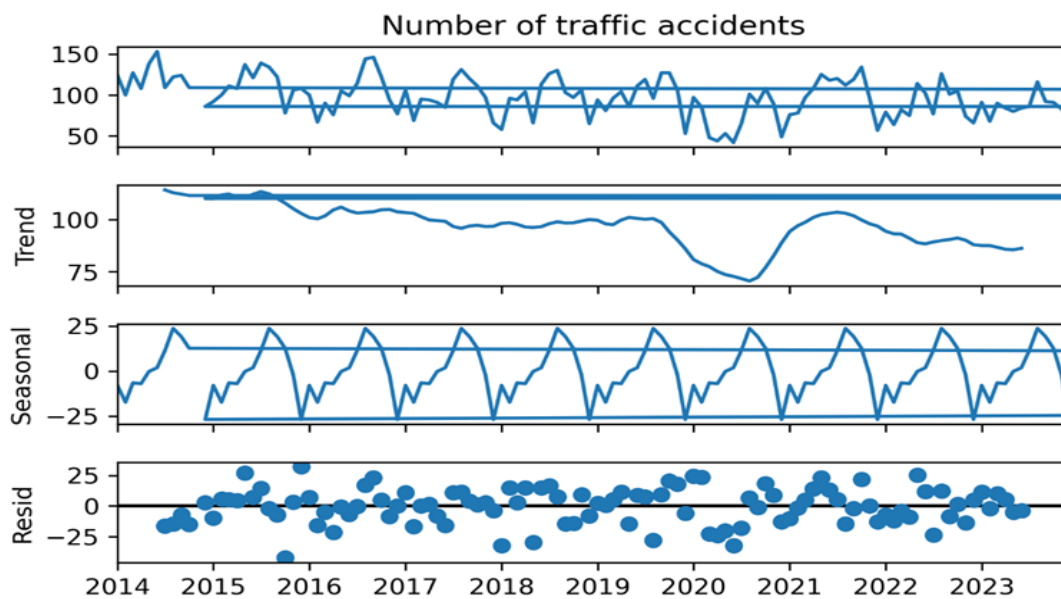


Figure 4. Seasonal decomposition of traffic accident data

The patterns of traffic accidents during the period 2024 to 2026 are shown in Figure (5). The training data from 2014 to 2021 is represented by the historical pattern (blue line). Meanwhile, the orange line refers to the test data during the period 2022 to 2024. After the year 2024 demonstrates the forecasting and the future trend (green line). The predicted pattern is realistic, where a continuous variation is obvious. This emphasizes the ability of the developed model in considering both seasonality and long-term trends. As a result, a valuable model is provided for proactive traffic safety planning.

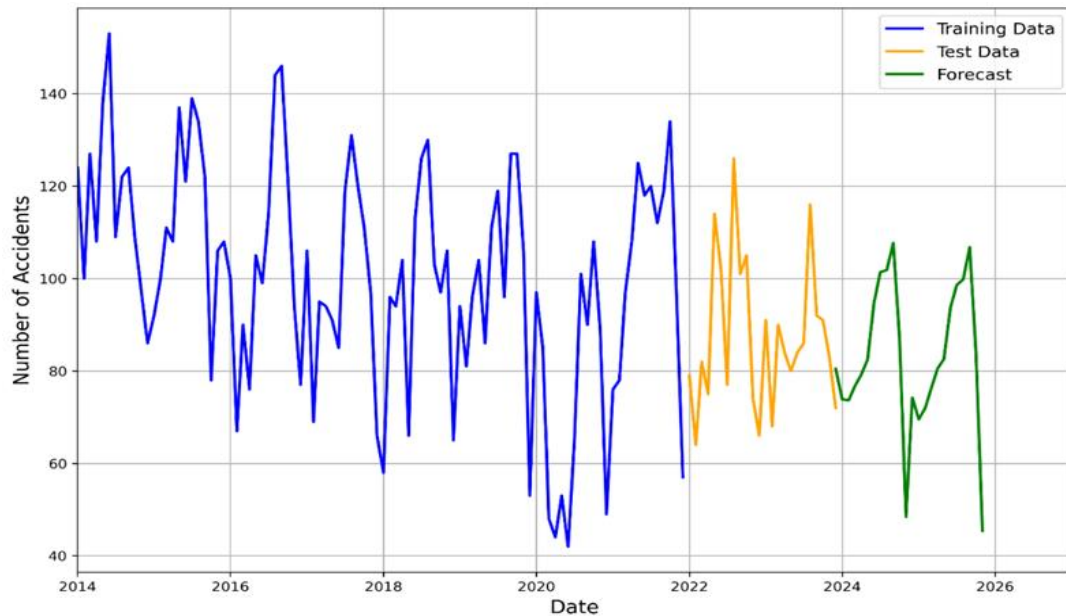


Figure 5. SARIMA Model Forecast: Predicted Trends in Traffic Accidents

#### 4. Discussion

The current study confirms the gender disparity in the accident severity and frequency. The male drivers hold the majority of accident fatalities and injuries, as illustrated in Figure (3), which is consistent with the previous studies (Özkan & Lajunen, 2006; Rashid & Ismail, 2023). The higher number of males in traffic accidents is not solely a function of the dominance of male drivers, but it is also behavioral directions such as higher speeds, and lower adherence to safety, as mentioned in prior studies. The men driver are more likely to drive at high speeds, while female tend to drive carefully (Al-Balbissi, 2003; Billah et al., 2022). The outcomes of this study highlight the important rôle of the seasonal and time related trends in accidents. Figure (4) explained the differences in weather conditions and its impact on road usage, where the peak frequencies are clear during the certian times of the year. This in in line with the previous study that mentioned the influence of temporal factors on traffic accidents (González-Sánchez et al., 2018). A strong relationships was declared between gender and accident severity according to the Chi-square results, where men drivers are involved in high severity accidents than women because of their behavior (Billah et al., 2022). Furthermore, a strong framwork was provided through the time series analysis that help in understanding and predicting the accident trends. Figure (5) exhibits a significant increase in traffic accidents after 2021 due to the end of the pandemic restrictions, where the increased mobility and other activities are observed after the releasing of the lockdown around world (Franke et al., 2023; Lee et al., 2023; Ismael et al., 2023).

Several implications could be gained from the current study for urban planners, specifically for regions with rapid urbanisation. Al Sulaymaniyah city has an increased number of private vehicle users (Al-Obaedi, 2019). Thus, the current outcomes highlighted the urgent requirements for a comprehensive policy that fixes the road

limitations and provides a safer driving. The improvement of urban traffic control could be achieved through the integration of technology such as intelligent traffic control and real time monitoring. The predictive models, like SARIMA, could support the traffic policies by predicting and addressing the seasonal points of accidents.

Several limitations are found in the current study. The forecasting is established to 2026, which may limit the long term insights. Due to the data limitation, the generalizability of the models to other regions with different contexts is restricted. Additionally, other factors such as sociodemographic and road characteristics were not considered and explored. Future studies may extend the current research by involving such factors to provide a comprehensive analysis of accident causes. The generalizability of models could be improved by considering other geographic regions. A comparative analysis evaluating the various road users, including passenger cars, transit, active modes of transportation, and micromobility, is recommended.

## 5. Conclusions

A comprehensive insight into the RTAs of the study area is provided. Gender disparities, seasonal trends, and accident severity have been considered. Staisitcal and predictive models were employed, and the outcomes highlight the gender disparity effect on the accidents. Males have the greater rates of fatalities and injuries compared to female drivers. The influence of temporal factors such as seasonality and post-COVID-19 has been studied, and the impact on shaping traffic accident trends has been emphasized.

A significant tool for monitoring road traffic in the study area is provided, which could guide the decision makers to avert casualties via the developed predictive model of the road safety measures. In order to prevent accidents and potential injuries, awareness campaigns, road safety training, legislative acts and other enforcement strategies are required.

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