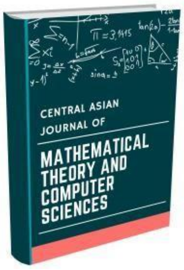

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Article

Predicting The Number of Traffic Accidents Using Box-Jenkins Models to Contribute to Reducing These Accidents (An Applied Study in Baghdad Governorate)

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Abstract: This research aims to analyze the time series of the number of recorded accidents in Baghdad during the period using Box-Jenkins models to find the best and most efficient predictive model for the number of accidents during the period. The results، based on comparison criteria (AIC، SCH، HQC) for the significant models and the comparison between the proposed parameters and models، showed that the suitable model for estimating the number of accidents is the ARIMA(1،1،2) model. The predictive values have shown consistency with their counterparts in the time series with the actual values in the trend، indicating the efficiency of the model.

Keywords: Reported Incidents، Box-Jenkins Models، Predicating، Time Series، ARIMA models

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1. Introduction

Traffic accidents are considered major problems in most countries of the world, as they are not only a drain on the human and material resources of society, but also cause security, psychological and social problems, and therefore they are a source of concern for all members of society as one of the main causes of deaths. Addressing this problem requires a scientific basis based on diverse efforts, interdisciplinary cooperation, and the availability of relevant data on the problem. In this study, and as the city of Baghdad is witnessing a significant increase in population density and the increase in the number of vehicles of all kinds, the importance of the study came from the possibility of proposing a prediction model for (Box-Jenkins) for the purpose of predicting the number of traffic accidents during the period and contributing to reducing them to the maximum extent possible and recording information in order to develop plans and strategies and put them into practice to reduce these accidents, address their causes and mitigate their impact. The importance of the research lies through the analysis of time series based on the monthly data of traffic accidents for the period, obtained from the Central Bureau of Statistics, and using (BOX-Jenkins) models as one of the forecasting techniques in building a model with high accuracy to predict the number of traffic accidents during the period.[1]

Research problem:

Studying ways to contribute to reducing the number of traffic accidents to the lowest level and predicting them during the time period according to determining the appropriate model of (BOX-Jenkins).

2. Materials and Methods

The research aims to follow a scientific method to determine the best and most efficient statistical model to predict the number of traffic accidents during the years using (BOX-Jenkins) models so that the relevant authorities can develop the necessary plans and measures to reduce them.[2]

Time Series

The time series is a set of documented measurements according to a specific time stamp, where time series are one of the important methods in future prediction, by relying on proven data during specific time periods and the change that occurs in the data is a function in time, which can be represented graphically, as it contributes to making information smoother before studying it closely. As the study of time series and analysis according to an advanced method constitutes a quality and great importance of the phenomenon, as the changes and factors caused by the phenomenon during the time period enable decision-makers to develop appropriate plans and treatments, where the concept of time series can be summarized with a set of observations or data that are generated respectively during a specific period of time and arranged according to a specific chronology, as the data or observations depend on each other and are often independent. Time series analysis is the analysis and interpretation of variables that occur during a specific time period for a phenomenon. Where it is possible to compare the values recorded by the phenomenon and draw the graph of the time series of the phenomenon, where the graph shows

$$St = S0 + bt \quad (1)$$

where St represents the time series value predicted for the time period (t), S0 represents the estimated value of the time series (regression constant) in the base period (t = 0), (b) represents the recorded phenomenon data and (t) is the time period in which the time series is predicted. The main objective of time series analysis is to identify their basic components, by determining the relationship of the series with its components.[3]

General trend vehicle: It is the change that occurs to the time series during a long-term period of time, and is expressed by the sequential change in the data of the phenomenon as a result of being affected by certain factors, and it is in two cases, either in an increasing trend or in the case of decreasing, such as the relationship between income and the bank, or as an increase in population during a long period of time and represents the general trend. In the study of general trend, it is preferable to have a large time series[4].

Seasonal changes: It represents the changes during the seasons or seasons of the year that occur to the phenomenon during a specific period of time and usually repeat itself, and usually do not occur during regular periods during the season of the time series and does not exceed the length of the year, such as climate, weather conditions or social customs and traditions.[12]

Cyclical changes: Changes that occur on the values of the time series on a regular basis and its duration exceeds the year.

Random changes: They are changes in the value of the phenomenon under study as a result of sudden and accidental factors. In other words, they are irregular and separate movements that sometimes occur as a result of war or natural disasters. These changes are not repeated regularly, as in the seasonal and periodic changes, so the statistical model that represents the time series is: -

$$Y=T+S+C+I \quad (2)$$

T = general trend component. S = seasonal seasonal changes. C = cyclical changes. I= random changes.[13]

The BOX-Jenkins methodology contains an algorithm that illustrates the detailed steps from the available data to the forecasting stage, noting that there are steps that cannot be repeated, which are providing data and checking the stability of the chain, while the rest of the other steps are iterative basic and include the Box-Jenkins methodology[5].

Box-Jenkins methodology

The researcher relied on building the model on the number of traffic accidents in Baghdad Governorate for the time period, where the Box-Jenkins method includes an algorithm that explains in detail the steps from the existing data to the forecast. As there are non-repeatable steps, including verifying the stability of the time series, while the rest are basic iteration, and include several stages (checking the stability of the time series, defining the appropriate model according to (ARIMA), estimating the model, examining the model) and how to use it in the field of forecasting, depending on the autocorrelation function and the partial autocorrelation function for the purpose of determining the rank of the model [6].

3. Results

AR(p) General Autoregressive model

In the autoregression model, the value of the current variable depends on its previous value, as this is known as the current value of the time series (Yt), and the value of a variable during the current period Yt depends on the value of the same variable in previous time periods(Y_{t-1}, Y_{t-2}, ………., Y_{t-n})Therefore, this model is called the autoregressive model

$$y_t = \mu + \emptyset_1 Y_{t-1} + \emptyset_2 Y_{t-2} + \cdots \dots \dots \dots + \emptyset_p Y_{t-p} + e_t \qquad (3)$$

(Y_t) represents the value of the current series in time (t), (Y_{t-1}) represents the previous observation in the time series, (p) represents the order of the model and ($\emptyset_p$) a constant parameter estimated from the data, (e_t) .

Moving Average Model –MA

To estimate the general trend of the time series and pave the time series data from ridding it of short-term changes that occur as a result of sudden irregular changes (or seasonal changes if they occur) through the moving averages model, and the model is estimated by the simple arithmetic mean of the consecutive values of the time series, and by taking the moving average model the error value, as shown in the following:

$$Y_t = \mu + e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} - \cdots - \theta_q e_{t-q} \quad (4)$$

e_t ‘e_{t-1} ‘……….‘ e_{t-q}

(θ) represents the moving averages parameter to be estimated and explains the previous random change of series (Y_t) The current observation is expressed linearly in the current variable et and the previous random variable (et−1), and (q) represents the order of the model.[10]

Autoregressive integrated moving average ARIMA

It is called "mixed model (self-regression model and moving media)" and is written as ARIMA(p, d, q), where (p) represents the number of parameters of the autoregressive model, and (q) represents the number of parameters of the moving media model. This model is used in the case of unstable time series by giving it a degree of differentiation d called the degree of chain integration to convert it into a stable series, and is the first to use a model in the analysis of time series in 1970. 1990: 95[11])

$$y_t = \mu + \emptyset_1 Y_{t-1} + \emptyset_2 Y_{t-2} + \cdots + \emptyset_p Y_{t-p} + e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} - \cdots - \theta_q e_{t-q} \quad (5)$$

Stationary Time Series

It means the stability of the behavior of the time series on the time horizon. It is characterized by statistical properties that do not change over time and the series is stable in the mean and variance if the average of (y) is constant over time, that is, ($E(Y_t) = \mu$) and variance is constant over time $\text{Var}(Y_t) = \sigma_y^2$), where the time series is stable when it has a homogeneous behavior over time (Cryer, 1986: 20), the stability of data in the analysis of time series is very important, as stability contributes to finding the appropriate predictive model, and it can be said that the series Stable temporality when stability conditions are met [7].

- Stability in the average: In other words, the value of the series is stable at a fixed and time-independent arithmetic average:-

$$E(Y_t) = \mu \quad (6)$$

By Calculating the differences in the case of the series is unstable on average, stability can be achieved when achieving the appropriate differences for the time series, which is achieved when the series does not show a general trend, that is, the time series fluctuates around a fixed medium, and stability can be achieved by taking the differences between the data, according to the formula: -

$$w_t = \nabla^d y_t \quad (7)$$

$$w_t = y_t - y_{t-1} \quad (8)$$

- Stability in variance: achieved when no divergent oscillations appear in the form of the time series

$$\text{Var}(Y_t) = E(Y_t - \mu)^2 = \sigma_y^2 \quad (9)$$

.(أغا و زاده, 2017: 90)

Logarithmic transformation to make the series stable in variance according to the following formula-:

$$Z_t = \text{Log}_{z_t} \quad (10)$$

Or through the radical conversion of time series data according to the following equation:

$$Z_t = \sqrt{\mathbf{z}_{z_t}} \quad (11)$$

Autocorrelation Function & Partial Autocorrelation Function

- The autocorrelation function measures the level of relationship between the values of the time series with itself with a difference of different displacements, as it gives the degree of self-correlation between the values of the time series at the first point in time and the second point in time, and helps in knowing the pattern and behavior of the time series and contributes to determining the stability of the time series and diagnosing the initial model of forecasting, and defines the autocorrelation coefficient between the two variables (Y_t،Y_{t+k}):-

$$pk = \frac{cov(Y_t،Y_{t+k})}{\sqrt{var(Y_t).var(Y_{t+k})}} = \frac{E(Y_t-\mu)(Y_{t+k}-\mu)}{\sqrt{E(Y_t-\mu)^2.E(Y_{t+k}-\mu)^2}} \quad (12)$$

- This coefficient measures the degree of linear correlation between two variables that are two units of time away from each other and after omitting the effect of the variable that falls between them, that is, assuming the stability of the variable, where the partial correlation measures the strength of the linear relationship between (Y1 ، Y3)After deleting the effect of (Y2), which represents the vocabulary of the time series, as well as the rest of the vocabulary, and is used to know and diagnose the behavior of the series and to estimate the partial autocorrelation coefficient according to the following formula:-

$$\hat{\phi}_{k+1,k+1} = \frac{\hat{p}_{k+1} - \sum_{j=1}^{k} \hat{\phi}_{kj}\, \hat{p}_{k+1-j}}{1 - \sum_{j=1}^{k} \hat{\phi}_{kj}\, \hat{p}_j} \quad (13)$$

Dickey-Fuller test

The Dickie Fuller test is used in the study of time series stability, which is used to search for time series stability. Stability is also checked on average by taking the appropriate number of differences[8].

- The difference

$$\Delta Y_{t-1} = \boldsymbol{y_{t-1}} - \boldsymbol{y_{t-2}} \quad (14)$$

$$\Delta Y_{t-2} = \boldsymbol{y_{t-2}} - \boldsymbol{y_{t-3}} \quad (15)$$

As well as until stability is achieved in the Mediterranean. The Dickey-Fuller test is based on three models that are estimated, and allows us to know the context of the time series-.

$$\Delta Y_t = \boldsymbol{\alpha_1 y_{t-1}} + \boldsymbol{\varepsilon_t} \quad (16)$$

$$\Delta Y_t = \alpha_0 + \boldsymbol{\alpha_1 y_{t-1}} + \boldsymbol{\varepsilon_t} \quad (17)$$

$$\Delta Y_t = \alpha_0 + \beta_t + \boldsymbol{\alpha_1 y_{t-1}} + \varepsilon_t \quad (18)$$

A model depends on three main elements, where the fixed limit (α_0) was adopted in the second mathematical formula and the adoption of an end to the general direction that represents time (β_t) with the fixed limit in the third formula. Where the hypothesis of nothingness (Ho: $\alpha = 0$) represents the presence of a root alone, that is, the series is not stable, while the alternative hypothesis (H1: $\alpha \neq 0$) is in the absence of a root alone, that is, in other words, the time series is stable, where the statistical value is compared to The calculated with the critical value scheduled, and the acceptance of the alternative hypothesis in the case of the calculated is less than the scheduled, which indicates that the time series is stable or through a value test (P-Value) where the time series is stable if the value is less than (5%) for a Fuller test And accept the alternative hypothesis.

4. Discussion

Case Study

1. **Data collection**: The data was obtained from (Ministry of Planning - Central Bureau of Statistics) for the time period from (1-1-2015 to 31-12-2023) represented by the number of monthly incidents in the city of Baghdad based on data The time series consists of 108 views and the time series data will be analyzed through the (Gretl) program to build the best predictive model and identify and estimate its features, and through the application of the (Box-Jenkins) methodology.

2. **Stationary time series** :The first step is to draw the original time series data, through which it is the first stage in the analysis of any time series. Figure 1 shows the shape of the time **series.**

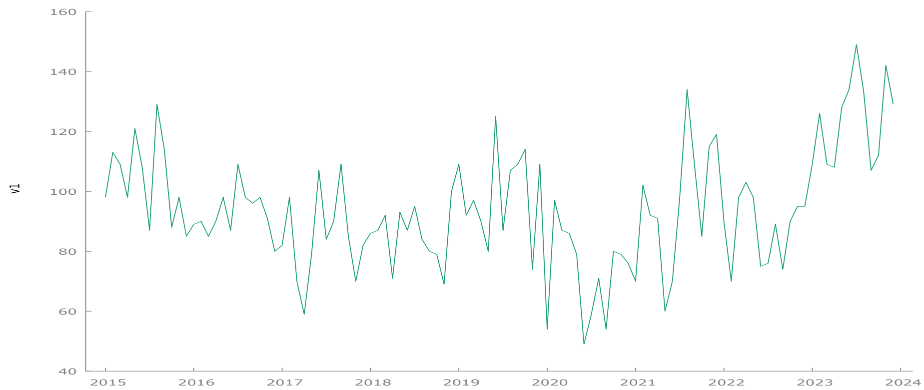

Figure (1) Original time series format

We note that the time series has a general trend and to verify the stability of the time series was tested using the Dickey Fuller test as shown in the following table 1:

Table (1) Dickie Fuller Test for the original time series

Augmented Dickey-Fuller	test with constant	with constant and trend
estimated value	-0.238926	-0.267209
test statistic:	-2.08656	-2.31132
asymptotic p-value	**0.2503**	**0.4272**
1st-order autocorrelation	-0.014	-0.004
lagged differences F(3، 99)	3.672 [0.0148]	3.585 [0.0165]

We note through the above table that includes the outputs of the program (GRETL), where the test value of asymptotic p-value for the test was recorded (0.2503) for the model with the fixed limit and (0.4272) with the fixed limit and direction, which is greater than the probability value at the level of (5%), which documents the instability of the time series, as well as we note through the drawing of the partial autocorrelation functions (PACF) and the autocorrelation function (ACF) the instability of the time series, as shown in Figure (2):-

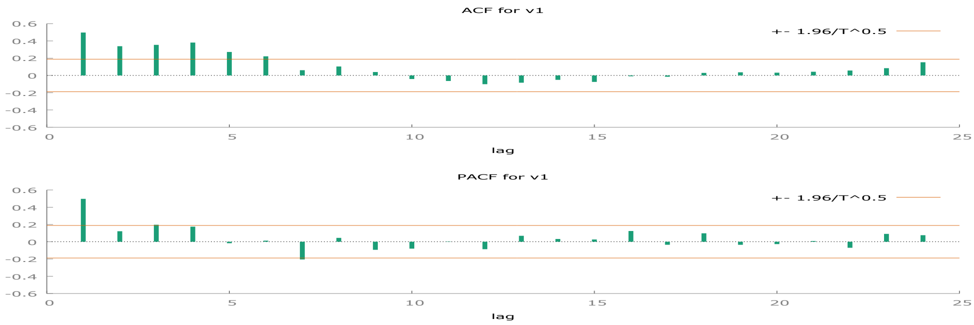

Figure (2) Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF)

We note from Figure (2) that the parameters of the autocorrelation coefficient and the partial autocorrelation coefficient are outside the confidence limits at a significant level (95%) and this is an indicator of the instability of the time series, which requires calculating the first difference of the time series and the natural logarithm to achieve stability in the mean and variance, Dickie Fuller was re-tested for the time series after calculating the first difference of the time series and the natural logarithm as shown in the following(Table 2) :

Table (2) Dickie Fuller's time series test after the first difference and logarithm

Augmented Dickey-Fuller	test with constant	with constant and trend
estimated value	-2.30594	-2.32921
test statistic:	-9.88989	-9.94586
asymptotic p-value	0.000	0.000
1st-order autocorrelation	-0.014	-0.019
lagged differences F(2، 100)	10.239 [0.0001]	10.561 [0.0001]

We note from Table (2) that the series has become stable and the value of (asymptotic p-value) was smaller than the level of significance (5%), where it was recorded (0.000) with the fixed limit and (0.000) with the fixed limit and direction, and thus the stability and stability of the time series may be achieved after the first difference of the series and the natural logarithm, and the following figure 3 shows the drawing of the time series after achieving Stationary-:

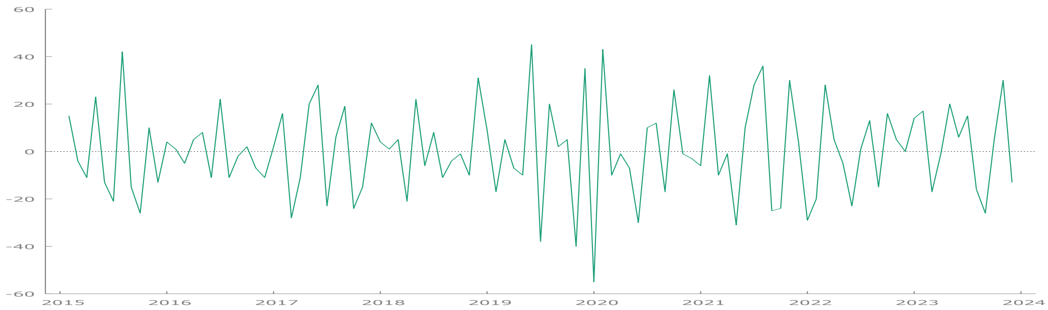

Figure (3) Time series after the first difference and logarithm

Also, the stability of the time series can be observed by drawing the autocorrelation and partial autocorrelation coefficient functions after calculating the first difference and the natural logarithm, shown in the following figure 4 :

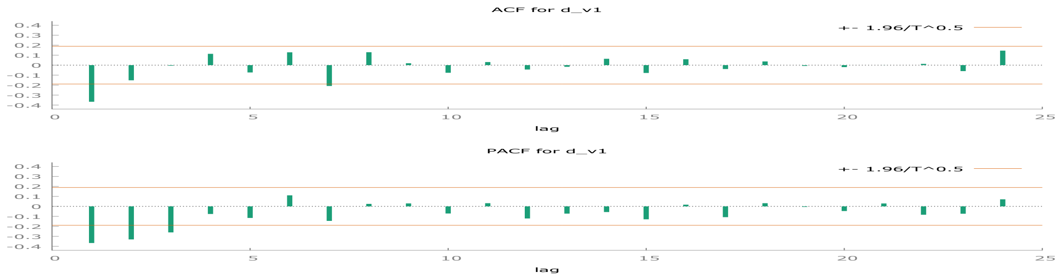

Figure (4) Autocorrelation function and partial autocorrelation function after the first difference of the time series

3. Diagnosis and estimation the model:-

After the stability of the series has been achieved, the rank of the appropriate model for the time series is determined according to the autocorrelation and partial autocorrelation functions, the shape of the autocorrelation function and the partial autocorrelation function of the series shows us the first difference of a series of a number of models prediction according to the values of the autoregressive model and the moving averages model, as shown in the following table 3:

Table(3) Estimated Time Series Model

MODELS	AIC	SCH	HQC	R2
(1,1,0)	-24.22315	-16.26127	-20.99684	0.135210
(2,1,0)	-35.38523	-24.76939	-31.0834	0.237230
(0,1,1)	-36.08828	-27.12639	-31.8619	0.272040
(0,1,2)	-34.09833	-27.48249	-32.4921	0.192161
(1,1,1)	-26.51400	-15.86000	-22.1966	0.147700
(1,1,2)	-43.99344	-30.67624	-38.59591	0.359453
(1,1,3)	-43.85558	-27.87495	-37.37855	0.347485
(2,1,1)	-34.37464	-21.05744	-28.97711	0.228809
(2,1,2)	-42.37260	-26.39197	-35.89556	0.312170
(2,1,3)	-40.80101	-22.15694	22.15694-	0.333526
(3,1,3)	-38.93220	-17.62469	30.29615-	0.304105

Table (4) shows the comparison criteria (AIC, SCH, HQC) for the significant models and the comparison between them for the proposed parameters and models, it is found that the best suitable moral model for prediction is the model ARIMA (1,1,2) and as shown in the following table containing the estimated values of the model parameters-:

Table (4) represents the estimated values of the parameters of the ARIMA (1,1,2)

Parameter	coefficient	std. error	Z	Sig.

Const.	0.000264707	0.000100584	2.632	0.0085***
phi_1. AR(1)	0.243666	0.101540	2.400	0.0164**
theta_1. MA(1)	−1.89401	0.00680818	−278.2	0.0000***
theta_2.MA(2)	0.894009	0.00671095	133.2	0.0000***

$$y_t = 0.000264707 + 0.243666Y_{t-1} + 1.89401\mathrm{e}_{t-1} - 0.894009\mathrm{e}_{t-2} + e_t \quad (20)$$

4. Ljung-Box Q's test and the remainder of the estimated model

The (Ljung-Box Q) test shows us that all values of (P-value) are significant and greater than (5%), as well as we note that the values of the features of the autocorrelation and partial autocorrelation functions were within the scope of significance, and indicate that there is no problem of self-correlation in the series for the rest of the model and this test indicates the significance of the estimated model and its preference over other estimated models as shown in the following table 5 :

Table (5) Remainders of the autocorrelation function and the partial autocorrelation function

LAG	ACF	PACF	Q-stat	[p-value]
1.	0.0062	0.0062		
2.	-0.0810	-0.0810		
3.	0.0193	0.0205	0.7747	0.379
4.	0.1241	0.1181	2.5193	0.284
5.	-0.0001	0.0014	2.5193	0.472
6.	0.0752	0.0953	3.1725	0.529
7.	-0.1531	-0.1636	5.9076	0.315
8.	0.0610	0.0674	6.3458	0.386
9.	0.0118	-0.0471	7.7609	0.498
10.	0.1078	-0.1145	8.1829	0.457
11.	-0.0589	-0.0226	8.1829	0.516
12.	-0.1018	-0.1544	9.4563	0.489
13.	-0.0666	-0.0276	10.0073	0.530
14.	-0.0007	-0.0327	10.0074	0.615
15.	-0.0774	-0.0540	10.7674	0.630
16.	0.0192	0.0689	10.8146	0.701
17.	-0.0248	-0.0615	10.8940	0.760
18.	0.0298	0.0814	11.0103	0.809
19.	0.0036	-0.0239	11.0119	0.856
20.	- 0.0058	-0.0215	11.0164	0.894
21.	0.0196	0.0396	11.0687	0.922
22.	0.0424	-0.0474	11.3160	0.938
23.	0.0314	0.0616	11.4525	0.953
24.	0.1759	0.1372	15.8019	0.826

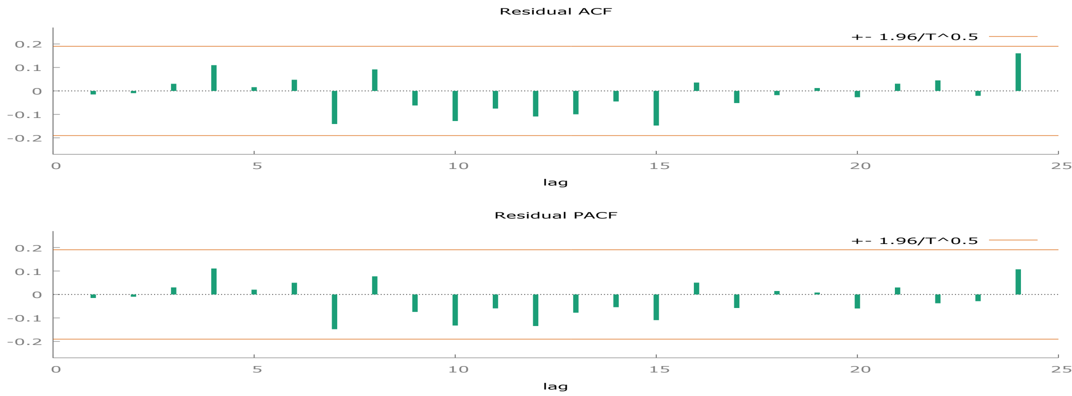

Figure (5) Estimated Model Remainder

We also note through the test ((L jung and Box) that the value of Chi-Square appeared significantly by (9.60839), which is greater than the value of (Q = 0.3831) Ljung-Box at the level of (5%), meaning that the data are subject to normal[9] distribution and the remainder follows the normal distribution, where we note the symmetry of the shape of the normal distribution of the remainders, as shown in the following figure 6 :

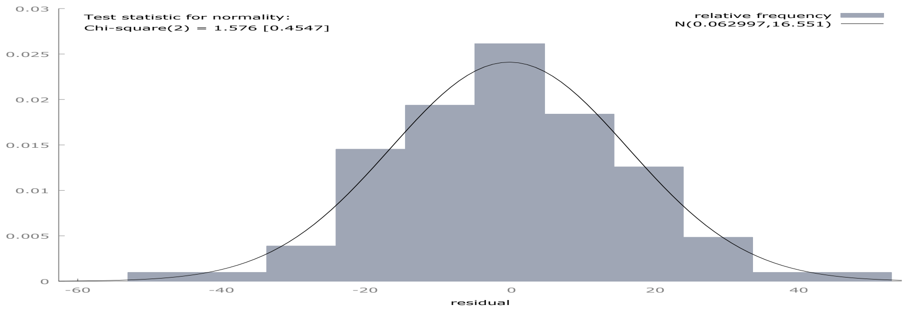

Figure (6) Normal distribution of residues

5. forecasting

Based on the proposed model (1,1,2) ARIMA, the number of monthly accidents for the period from (January 2024 to December 2025) was predicted as in Table (6) and Figure (7).

Table (6) Predictive values and confidence limits for the number of monthly accidents

Period	Prediction	95% interval
2024:01	126.524	(94.6188، 158.430)
2024:02	127.437	(93.0207، 161.853)
2024:03	127.497	(91.9806، 163.014)
2024:04	127.740	(90.9338، 164.547)
2024:05	127.944	(89.9393، 165.949)
2024:06	128.156	(88.9800، 167.333)
2024:07	128.367	(88.0550، 168.679)
2024:08	128.578	(87.1610، 169.994)
2024:09	128.788	(86.2958، 171.281)
2024:10	128.999	(85.4571، 172.541)
2024:11	129.210	(84.6432، 173.777)
2024:12	129.421	(83.8523، 174.989)
2025:01	129.632	(83.0829، 176.180)
2025:02	129.842	(82.3338، 177.351)
2025:03	130.053	(81.6036، 178.502)
2025:04	130.264	(80.8914، 179.636)
2025:05	130.475	(80.1962، 180.753)

2025:06	130.685	(79.5169، 181.854)
2025:07	130.896	(78.8529، 182.939)
2025:08	131.107	(78.2034، 184.010)
2025:09	131.318	(77.5676، 185.068)
2025:10	131.528	(76.9450، 186.112)
2025:11	131.739	(76.3349، 187.143)
2025:12	131.950	(75.7367، 188.163)

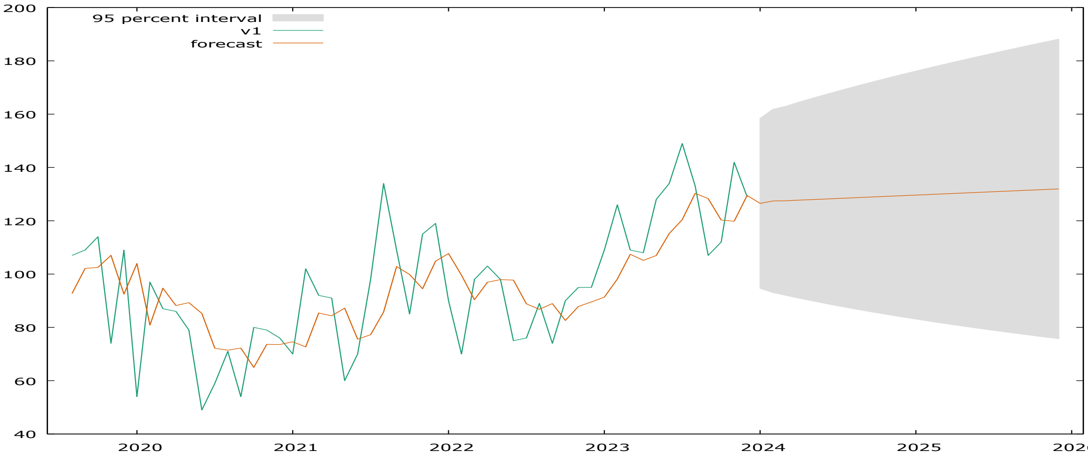

Figure (7) The chart shows the original and predictive values and confidence limits for the time series.

5. Conclusion

We note that the time series of the number of monthly incidents for the city of Baghdad was unstable in average and variation during the time period (2015 to 2023) as it had a general trend. The stability state was reached after taking the logarithmic transformation and first-degree differences of the time series.

It was found that the best suitable model for the time series after using the comparison criteria (AIC, SCH, HQC) was the autoregressive model and moving averages (1,1,2) because it had the lowest value among the values of the comparison criteria that other significant models possessed.

The significance of the proposed model ARIMA (1,1,2) was examined statistically by means of estimated parameter significance tests and analysis of the autocorrelation function of the residues and the normal distribution of the remainders, where it was shown that the residue series is distributed normally.

A period of 24 months was predicted for the period from (2024 to 2025) based on the proposed model, and the predictive values showed consistency with their counterparts in the time series.

The results of the forecast indicate an increase in the percentage of the number of monthly accidents for the time period (2024-2025) in a consistent manner, so it is necessary to take the necessary measures from the competent and relevant authorities..

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