FORECASTING CRIMINAL OFFENSES AGAINST PERSONS USING TIME SERIES MODELS: A CASE STUDY OF MWANZA REGION

Written by **Lucas Salati*** & **Seleman Majige****

*General Studies Department, Institute of Accountancy Arusha, Tanzania

**Research Department, Bank of Tanzania, Dar es Salaam, Tanzania

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ABSTRACT

The study aimed to determine the best statistical forecasting model that best fit the criminal Offenses against persons in Mwanza. The study used yearly time series data of criminal Offenses against persons from Tanzania Police Force for the period of 1960 to 2018. The findings show that yearly average, the criminal Offenses against persons reported in Mwanza region was 269, the maximum was 867 and the minimum was 44. The criminal Offenses against persons reported in Mwanza has upward trend which inconsistent from year to year. The RSME, MAPE, AIC and BIC were used to assess the forecasting accuracy of the models. The models included ARIMA model, SMA and SES. On the basis of RSME, MAPE, AIC and BIC the results shown that ARIMA (1, 1, 1) model is the best model that fits the criminal Offenses against persons in Mwanza region and therefore suitable for forecasting criminal Offenses. The model that has been developed is useful tool for producing reasonably reliable forecasts of criminal Offenses against persons in future years. These forecasts can provide guideline in understanding weather the criminal offence against persons rising or falling.

Keywords: Criminal Offenses, Offenses against persons, Forecasting, Time series Model, Mwanza

INTRODUCTION

The crime and criminal justice have a strong link to development. As recognized by the Open Working Group of the General Assembly on Sustainable Development Goals, reducing different forms of criminal acts that result in violence, environmental degradation or diversion of financial resources should form an integral part of the sustainable development goals and their related targets. (The United Nations, 2015)

Crime is a phenomenon that changes across countries, culture, and society and across time. Activities that are legal in one country (example alcohol consumption) are sometimes illegal in others (example strict in Muslim countries). As cultures change over time, behaviors that once were not criminalized may become criminalized.

Social phenomena like crime can sometimes evolve in subtle but substantial ways that are very difficult to identify using historical data and can take a long time to understand. (Pepper, 2007) The global rates of intentional homicide have decreased, but they still fluctuate regionally. The highest rates were consistently found in the Americas and the lowest in Europe, Asia and Oceania. The United Nations Office on Drugs and Crime (UNODC) estimates that in 2012 around 437,000 people across the world were victims of intentional homicide, corresponding to a global homicide rate of 6.2 per 100,000 people, significantly less than in 2004, when the rate was estimated to be 7.6 per 100,000 people. (The United Nations, 2015)

In East Africa, extremist groups often draw proceeds from illicit activities, carry out campaigns of violence, and commit violent crimes in the name of their ideological motivation with the hope of earning economic profit. The activities of various groups, from AL-SHABAAB to JAHBA EAST AFRICA may vary from country to country, but Kenya has been a consistent target of AL-SHABAAB since 2011, with its most deadly attack to date taking place in April 2015 on the Garissa University campus, this attack claimed the lives of almost 150 individuals. In early 2016, in an attack on a Kenyan military base, they killed military troops, and captured vehicles, weapons and ammunition as well as military equipment. In early 2017, they attacked a Kenyan military base in Somalia, using two suicide car bombs. (INTERPOL, 2018)

In Tanzania for the period of 2015 to 2017, a big number of killings (criminal Offenses against persons) occurred in Pwani Region. The killings in Pwani Region have left the community members in the region living in fear, worried about the situation of security. The police launched a special operation to hunt the killers in the region. Apart from that in the same period it was revealed that 67 cases of killing Persons with Albinism were reported in regions along Lake Victoria. In 2016 to 2017 about 164 number of victims of witchcraft-related killings, the majority of whom are the elderly especially women and particularly those with red eyes, Also, a survey on human rights conducted by LHRC across 20 districts in 2017, revealed that most common forms of violence against women was sexual violence, especially rape, followed by physical violence, according to social welfare officers and majority of the victims of sexual violence are school pupils aged 7 to 14 years. (Legal and Human Rights Centre, 2018)

In Mwanza region, in 2014, the suspects entered into the house with torches and machetes threatening to kill the residents and finally snatched an Albino child and disappeared with her. The motive being superstitious beliefs (Tanzania Police Force, 2015), Further 2015, Police officer was stoned to death by street/ward residents, also Police officer who was accompanied by his leaders visited the hospital for conducting an investigation on the death of political party member whose body was taken to mortuary. Suddenly, a group of people attacked him and caused injuries (Tanzania Police Force, 2016).

Different studies used statistical time series to forecast crime in different areas. Shrivastav (2012) conduct study on applicability of Box Jenkins ARIMA Model in Crime Forecasting: A case study of counterfeiting in Gujarat, also Meenai, (2011) conducted study on crime forecasting system. Chen et al (2008) use ARIMA model to make short-term forecasting of property crime for one city of China after comparing with the other two exponential smoothing models. It is found that ARIMA model fits the series better than SES and HES. There are variations in the statistical techniques, Methods and area of the study.

There are no study has been conducted on this subject in Tanzania. Therefore, the objective of this study was to determine the best statistical forecasting model that best fit the criminal Offenses against persons in Mwanza region.

MATERIAL AND METHODS

Data type and Source

The study used secondary data from Tanzania Police Force under Office of Director of Criminal Investigation for the period of 1960 to 2018 which focus on criminal Offenses against persons reported yearly in Mwanza region.

Data analysis

The study first analyzed data by examining the behavior of distribution from graph as indicate in Figure 1 and testing for stationarity using Augmented Dickey-Fuller (ADF) as shown in Table 1 and Table 2. The study uses three statistical time series techniques which are Simple Moving Average, ARIMA model and Simple Exponential smoothing. The Root Square Mean Error (RSME) and Mean Absolute Percentage Error (MAPE) as well as Akaike's information criterion (AIC) and Bayesian information criterion (BIC) were used to assess the forecasting accuracy of the models.

Unit root test for stationarity

Augmented Dickey-Fuller (ADF) was used to test stationarity. The null hypothesis of the test is that a variable is non-stationary against the alternative that it is stationary. Therefore, if start off with a non-stationary time series, it will first need to 'difference' the time series until stationary time series is obtained.

Simple Moving Average

The simple moving average is a linear data smoother, or a linear filter, because it replaces each observation y_t with a linear combination of the other data points that are near to it in time. The weights in the linear combination are equal, so the linear combination here is an average (Montgomery et al. 2008)

The study used three years moving average. The simple moving average of period n assigns weights $1/n$ to the most recent n observations $y_t + y_{t-1} + \cdots + y_{t-n+1}$, and weight zero to all other observations.

Then let M_t be the moving average, then the n-period moving average at time period t is given by;

$$M_t = \frac{y_t + y_{t-1} + \cdots + y_{t-n+1}}{n} = \frac{1}{n}\sum_{t-n+1}^{n} y_t$$

Where;

M_t is Simple moving average

y_t is observed value (criminal Offenses against persons)

n is number of periods specified in the moving average technique

ARIMA Model

ARIMA model (p, d, q) are defined for stationary time series. Where p, q are orders of the AR model and MA model, d is the number of series difference, (p, d, and q) are all integers. ARIMA model is made up of AR, I and MA where; AR is the variable regressed on own lagged or prior values, I indicates that data values have been replaced with the difference between their values and previous values, MA regression error representing the linear combination of error terms of repeated values

The autocorrelation function (ACF) and partial autocorrelation functions (PACF) graphs through correlogram used to establish different values of AR (p) and MA (q) while the number of differencing used to identify the value of I (d). The mathematical formulation of the ARIMA (p,d,q) model is given by

$\varphi(L)(1-L)^d y_t = \theta(L)\varepsilon_t$

Where; $\varphi(L) = \left(1 - \sum_{i=1}^{p} \varphi_i L^i\right)$, y $\theta(L) = \left(1 - \sum_{j=1}^{q} \theta_j L^j\right)$.

Here, p, d and q are integers greater than or equal to zero and refer to the order of the autoregressive, integrated, and moving average parts of the model respectively. The integer d controls the level of differencing. Generally d=1 is enough in most cases.

When d=0, then it reduces to an ARMA (p,q) model. Then $\varphi(L)$ and $\theta(L)$ are polynomial in L of degree p and q, L are the backward shift operator

Simple Exponential Smoothing

Exponential Smoothing is the forecasting technique that assigns exponentially decreasing weights as the observation get older. The simple exponential smoothing use to make short-term forecast. The mathematical formulation of the Simple Exponential Smoothing is given by

$\hat{y}_{t=}\ \alpha y_t + \ (1-\alpha)\hat{y}_{t-1}$

Where; α is smoothing coefficient $(0 \leq \alpha \leq 1)$

y_t is observations

$\hat{y}_t$ is forecasting results and t is time period

Model selection

The forecasting accuracy of the models were assessed using Root Square Mean Error (RSME) and Mean Absolute Percentage Error (MAPE) as well as Akaike's information criterion (AIC) and Bayesian information criterion (BIC). The RSME is the standard deviation of the residuals (prediction error), and MAPE defined as average absolute for each period. The best fit statistical model should have small value of RSME and MAPE.

The AIC is often used for model selection, especially in the time series context, it introduced by Akaike, (1974) and the BIC introduced by Schwarz (1978). This study use AIC and BIC for comparing ARIMA models, the one with the lower BIC and AIC is generally better statistical model. During model estimation, the data series was divide into two groups: data from 1960 to 2016 used for estimation and data from 2017 to 2018 used for validation.

Ethical Consideration

This study was approved by Eastern Africa Statistical Training Centre (EASTC) with reference letter SE/MOS/1/2017/18/04/4 and the Office of the Director of Criminal Investigation approved for data with reference CID/HQ/C.5/4/3/VOL.V/123. The ethical clearance was approved for Master's Degree dissertation. Confidentiality, anonymity and privacy were also considered.

RESULTS AND DISCUSSION

Results

The findings show that on the average for the year the criminal Offenses against persons reported in Mwanza region was 269, the standard deviation for the criminal Offenses against persons is very high (232) an indication of existence of dispersion in Offenses reported in Mwanza region from year to year and the maximum criminal Offenses reported was 867 and the minimum was 44

Figure 1 represent the time series plot which suggests that the given time series data cannot have constant mean and variance hence the primary assumption of time series (stationary) is missing. The results show that the series exhibits upward and downward trend with no hint of seasonal variations, generally it appears that seasonality is not a prominent feature of the data.

Figure 1; Time series plot of the nature of the Criminal Offenses against persons

The Augmented Dickey-Fuller (ADF) used to examine the stationarity of crime against person incidents in Mwanza region with the important assumption that error terms are uncorrelated. Table 1 present the ADF test for stationarity

Table 1; Augmented Dickey-Fuller (ADF) test

Dickey-Fuller test for unit root				
	Interpolated Dickey-Fuller			
	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-1.387	-3.569	-2.924	-2.597

MacKinnon approximate p-value for Z(t) = 0.5885

Table 1 shows the result of Dickey Fuller test show that absolute value of test statistic which is 1.387 is a small number than the reported critical values, and the p-value is insignificant, Thus, the Dickey Fuller test null hypothesis is not rejected. Therefore statistically suggest that the criminal Offenses against persons is non-stationary. Hence first order differencing of time series variable (criminal Offenses against persons) is required to be made.

Table 2: Augmented Dickey-Fuller (ADF) test for first order differencing

Dickey-Fuller test for unit root				
	Interpolated Dickey-Fuller			
	Test Statistic	1% Critical value	5% Critical value	10% Critical value
Z(t)	-8.783	-3.57	-2.924	-2.597

MacKinnon approximate p-value for Z(t) = 0.000

Table 2 shows that the Dickey Fuller test result for criminal Offenses against persons to examine existence of stationary, review two values; Z(t) and Mackinnon p-value. It seen that, absolute value for Z(t) is 8.783 which is large number (as compared to Z(t) for critical value) and p-value is also found significant at any reported level of significance (1%, 5% and 10%), Thus, null hypothesis of Dickey Fuller test is rejected. Therefore the first differenced time series Criminal Offenses against persons is stationary. Both graphical method and Dickey-Fuller test for stationary give out the same result

The Statistical model that best fit the criminal Offenses against persons

Figure 2, the partial correlogram visualizing the different partial autocorrelation of 1st difference of criminal Offenses against persons (crimeagainstpersons1) at different lags

appear. Since for the lag 1 and 9 the lines are coming out of acceptance region, the series 'crimeagainstpersons1' partially auto correlates with its lagged series at lags 1 and 9. Thus, the AR value of ARIMA model can take the values 1 or 9

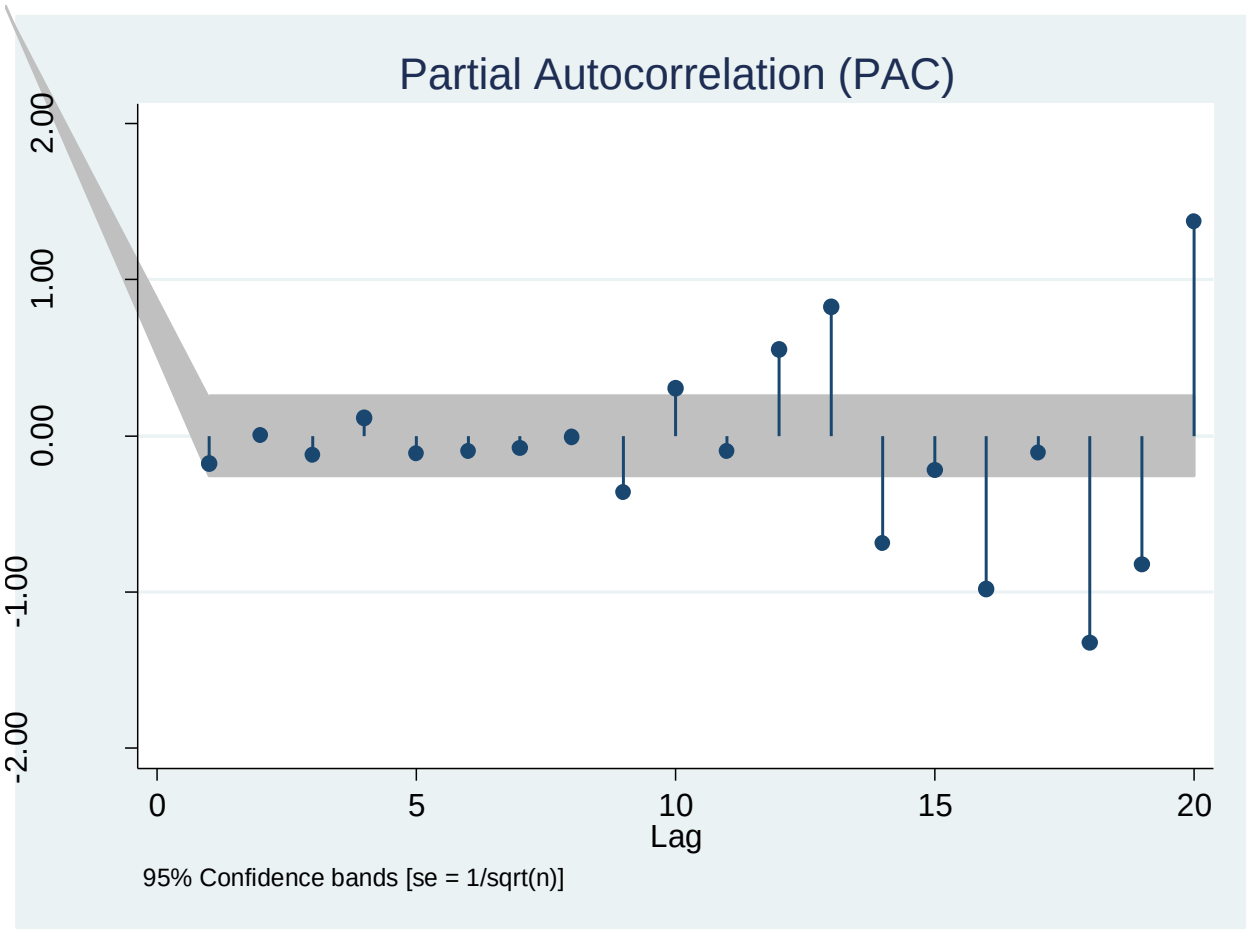

Figure 2: Partial Autocorrelation (PAC) functions of the criminal Offenses against persons with first order differencing

Figures 3, the correlogram visualizing the different autocorrelation of 1st difference of criminal Offenses against persons (crimeagainspersons1) at different lags appear. The shaded region indicates the acceptance region and the lines indicate different lags. Since for the first lag, the line is coming out of shaded region, the series 'crimeagainspersons1' is auto correlated with its lagged series at lag 1. Therefore, the MA value of ARIMA model can take the value from 1. Hence from two figures 4 and 5 above, the appropriate ARIMA models are (1, 1, 1) and (9, 1, 1).

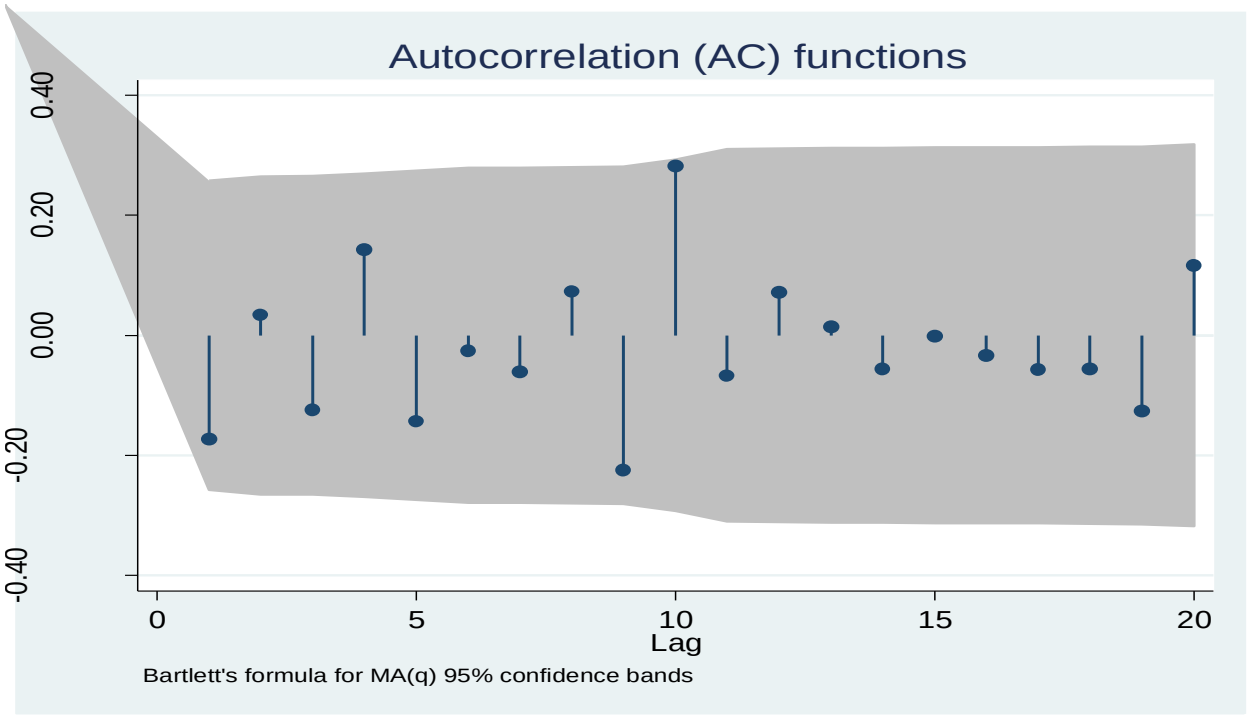

Figure 3: Autocorrelation (AC) functions of the criminal Offenses against persons with first order differencing

This study used Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) for model identification. The model with the lowest value of the AIC and BIC is the best fit model. Table 3, compares the results of fitting different ARIMA models to the criminal Offenses against persons data. The model with the lowest value of the AIC and BIC is ARIMA (1, 1, 1) which has been used to generate the forecasts and compare with other models.

Table 3: AIC and BIC

Model	AIC	BIC
ARIMA (1, 1, 1)	677.072	685.314
ARIMA (9, 1, 1)	685.378	710.103

Table 4, compares the results of fitting different models to the data by using estimation and validation periods based on RMSE and MAPE. The model with the lowest value of the Root mean Square Error (RSME) and Mean Absolute Percentage Error (MAPE) is ARIMA (1, 1, 1) model for estimation period, but for validation period SMA has small value of MAPE but not

satisfy to be best because the primary criteria is RSME, hence ARIMA (1, 1, 1) model that has higher fitting and forecasting accuracy than SMA and SES. Statistically suggest that the ARIMA (1, 1, 1) model is the best fit statistical model of the criminal Offenses against persons in Mwanza region to make forecast. Thus the ARIMA (1, 1, 1) model is the statistical model used to generate forecasts of criminal Offenses against persons for the next five years.

Table 4: RSME and MAPE resulting from SMA, ARIMA (1, 1, 1) model and SES

	Estimation Period		Validation Period	
Model	**RSME**	**MAPE**	**RSME**	**MAPE**
SMA	93.42	17.36	53.77	7.83
ARIMA (1, 1, 1)	78.08	14.59	50.13	10.28
SES	78.96	15.80	56.14	11.93

Forecasting criminal Offenses against persons for the next five years

After performing modeling and to select the best fit model which is ARIMA model, the time series criminal Offenses against persons modelled through ARIMA (1, 1, 1) and the forecasting for the next five years done.

Table 5, show the summary statistics of the ARIMA (1, 1, 1) model, AR (1) has coefficient -0.94 and MA (1) has the coefficient 0.86, all coefficients are statistical significant at any level of significance (1%, 5% and 10%). Statistically suggest that the ARIMA (1, 1, 1) model is statistically significant and best fit model to the data, also can be used to generate the forecasts

Table 5: Statistic summary of ARIMA (1, 1, 1) model

Sample: 1961 - 2018				**Number of obs = 58**	
Log likelihood = -334.5361				**Wald chi2(2) = 141.89**	
				Prob > chi2 = 0.000	
CRIMEAGAINSTPERSONS	Coef.	Std. Err.	z	P>|z|	[95%Conf.Interval]
CRIMEAGAINSTPERSONS _cons	6.934	11.762	0.59	0.556	-16.120 29.987
ar L1.	-0.94	0 .125	-7.48	0.000	-1.183 -0.692
ma L1.	0.86	0.196	4.39	0.000	0.476 1.243

/sigma	77.27	4.824	16.02	0.000	67.814	86.724

Figure 4 show the forecasts result for the estimation period 1960 to 2016 and 2017 to 2018, its shown that the ARIMA (1, 1, 1) is the best fit statistical model to forecast the criminal Offenses against persons reported in Mwanza region, which has the minimum residuals (observed – forested values), also the graph show that the ARIMA (1, 1, 1) model is the best fit model to the data

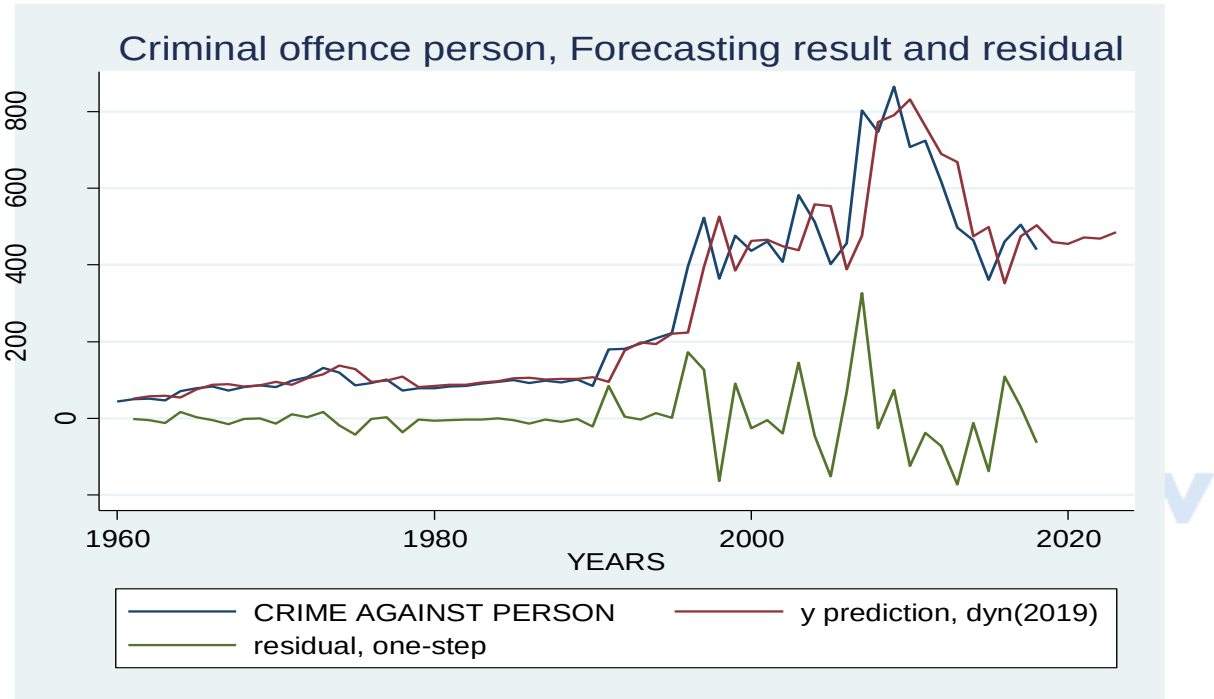

Figure 4: Time series plot of criminal Offenses against persons for estimation period 1960 to 2018 and Forecasting period 2019 to 2023 and residuals

Table 5 show the forecasts result for the forecasting period 2019 to 2023, the forecast was done using ARIMA (1, 1, 1) which is the best fit statistical model to forecast the criminal Offenses against persons reported in Mwanza region.

Table 5: Forecasts of criminal Offenses against persons for the next five years

YEARS	FORECAST
2019	459

2020	455
2021	472
2022	469
2023	486

Discussion of the Findings

The study used historical information (official statistics) from the Director of Criminal Investigation in Tanzania (Tanzania Police Force) for the period of 1960 to 2018 to make short term forecasting, the results show that ARIMA (1, 1, 1) model is the best fit and can be useful for police force and government to forecast criminal Offenses against persons.

The study is similar with the study conducted in Karachi city on "Crime Forecasting System" (Meenai, 2011) also used historical information maintained by the local Police to predict crime patterns with the support of a huge and self-updating database. Another study used ARIMA model to make short-term forecasting of property crime for one city of China conducted by Chen, Yuan, & Shu, (2008). This study use statistical time series model (ARIMA Model) to forecast criminal Offenses against persons which was not done in Tanzania

CONCLUSION

The ARIMA (1, 1, 1) model is the best fit for forecast the criminal Offenses against persons reported in Mwanza region compared to SMA and SES. The forecasts for the periods of five years from 2019 to 2023 have an upward trend (increase at small rate). Furthermore, this study recommend the government of Tanzania through Tanzania police force and policy makers to continuous implementing reforms in order to mitigate pressure arise due to crime as well as introduce the programs and policies. The forecasting model can provide a support tool capable of adapting to address the issue of rising crime in the societies due to the future understating after forecast. The study considered univariate models for forecasting criminal Offenses against persons which are function of time. However, criminal Offenses against persons do not depend on time only. Further studies can be conducted to include other factors such as demographic and other socio economic variables.

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CONFLICT OF INTEREST

Authors have no conflict of interest to declare

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