Prediction the Crime Motorcycles of Theft using ARIMAX-TFM with Single Input

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Abstract— **The increase in motorcycle theft can be driven by several factors. For example, population growth and density, commuting behavior, motorcycles growth, and so on. This causes difficulties for the police to control and monitor on a regular basis since it requires forecasting and probabilities of theft in a particular time period. This study proposes the development of a computer application model to predict the rate of the crime of motorcycle theft with an approach to take into account external influences by using ARIMAX – transfer function model with single input that is the number motorcycles. The results of this study get best model of ARIMAX with level of accuracy obtained by MAPE and RMSE are 32.30 and 6.68.**

Keywords— Case, motorcycle theft, prediction, ARIMAX, Transfer Function Model

I. INTRODUCTION

The criminal act of motorcycles theft occurred in all regions of Indonesia, including the city of Yogyakarta. The number of population in Yogyakarta continues to grow each year, both in Java and outside Java, which leads to the increasing number of motorcycle ownership. Along with that, also the increase of motorcycles theft in the Yogyakarta area. According to Indonesia statistics center /Badan Pusat Statistik (BPS) report in 2012, the increase in the number of crimes of theft tends to be volatile, around 20 percent [1].

According to the BPS and the Police, the cause of motorcycle theft in Indonesia is because the motorcycle is a vital tool with high mobility and indispensable to life in this modern era. The increase in numbers of motorcycle theft each year, causes difficulties to armed forces to forecast the development of motorcycle theft crime. The results of this forecasting can be used for initial information to perform certain actions that may be to suppress the crime of motorcycle theft in the future by the Police or a related party.

The crime of motorcycle theft occurring almost all the time can establish a pattern of time series data. Motorcycle theft crime cases can be affected by factors of population growth, the number of vehicles, the number of cases/events and the number of unemployed, and so forth. Forecasting the incidence of vulnerability to criminal cases of motorcycle theft will utilize ARIMA with exogenous (ARIMAX) time series method. ARIMAX method is not only able to predict the number of cases of theft of motorcycles but also the influence independent variable for example the number of vehicles.

II. LITERATURE REVIEW

There are several studies related to forecasting in this research. In [2] conduct research develop and test area specific crime prediction models using hierarchical and multi-task learning. These approaches mitigate sparseness by sharing information across different areas, yet they retain the advantages of localized models in addressing non-homogeneous crime patterns. In the future, plan to investigate the use of area-grouping approaches to build spatial hierarchies. While [3] explain Crime analysis and prevention is a systematic approach for identifying and analyzing patterns and trends in crime. In this research, system developed can predict regions which have high probability for crime occurrence and can visualize crime prone areas. And In this paper tested the accuracy of classification and prediction based on different test sets. Classification is done based on the Bayes theorem which showed more than 90% accuracy. System takes factors/attributes of a place and Apriori algorithm gives the frequent patterns of that place. The pattern is used for building a model for decision tree.

In another research, [4] conducted a study to determine factors that cause crime in the city of Manado by finding the correlation coefficient using Path Analysis. The results show that the number of population and unemployment cause direct effects on crime, while numbers of industries and poverty cause indirect effects on crime. While, based on research [5] explained that Crime trend prediction is helpful to make a decision in crime prevention activities. Other than that, law enforcement authority needs several decision options based on crime trend prediction. It is needed because prediction may contain an uncertainty. To obtain that needed a decision making system application is required. This paper presented a proposed decision making system application that can provide information about crime prevention decision options. The decision options are made based on crime forecasting and interval forecasting data.

In another paper [6] explain that advanced space–time autoregressive (ST-AR) model is used to forecast US, regional and state rates of violent and property crime. The disaggregate state (Florida) violent crime model includes murder, rape, robbery, and assault, while the property crime model includes burglary, larceny, and motor vehicle theft. In experimental forecasts, ST-AR RMSEs are compared to those for aggregate univariate AR(p) models, vector autoregressions (VAR), Bayesian VARs (BVAR), and two naïve models that predict future crime rates either as the most recent rate or according to the most recent change in rates. According to research [7] explained that, in the As a result of steadily increasing urbanization, by 2030 more than sixty percent of the global population will live in cities. This phenomenon is stimulating significant economic and social transformations. Nevertheless, new technologies are enabling police departments to access growing volumes of crime-related data that can be analyzed to understand patterns and trends. Such knowledge is useful to anticipate criminal activity and thus to optimize public safety resource allocation through mathematical techniques to predict crimes. This paper presents an approach, based on auto-regressive models, for reliably forecasting crime trends in urban areas. In particular, the main goal of the work is to design a predictive model to forecast the number of crimes that will happen in rolling time horizons. Experimental evaluation shows that the proposed methodology predicts the number of crimes with an accuracy of 84% on one-year-ahead forecasts and of 80% on two-year-ahead forecasts.

While, [8] explain Crime distribution forecasting has a positive impact on social stability and has drew much attention in academia. In their research, build the Vector Motion Model and propose a new algorithm named as TPML-WMA (Transition Probability Matrix Learning and Weighted Moving Average algorithm) to predict a future robbery distribution and figure out how it transfers. At the same time, compare the proposed algorithm with the classical linear regression method based on the least square method. The results illustrate that the prediction performance of TPML-WMA is greatly improved compared with the linear regression method.

Forecasting methods have also been used for forecasting crime as in [9] suggested that the ARIMA time series model of which is used to make short-term forecasting of property crime in a city in China. Forecasting results compared with other two forecasting tools SES and HES. The results showed that the ARIMA model fits the data well and make better accuracy in forecasting compared the other two models. [10] use a forecasting method to predict the number of malaria incidence in the US based on monthly data. The prediction model adapted and developed using SARIMA models based on historical data. While [11] research with SARIMAX for elspot electricity price. This paper develops a seasonal ARIMA model with exogenous variables (SARIMAX) to predict day-ahead electricity prices in Elspot market, the largest day-ahead market for power trading in the world. Compared with the basic ARIMA model, SARIMAX has two distinct features: 1) a seasonal component is introduced to cope with weekly effect on price fluctuations. 2) exogenous variables that exert influence on electricity prices are incorporated to make price predictions in the context of an integrated energy market.

In research [12] using ARIMA and ARIMAX approach to analyze and forecast macroeconomic time series and to conclude whether ARIMAX model can provide better results than ARIMA. In this research, transfer function model was built (ARIMAX) for gross domestic product per capita as output and unemployment rate as an input. The model used was adequate and residuals that have white noise. R-Squared statistic indicates that the model used to provide accuracy of 92.7% of the variability in gross domestic product per capita. [13] conduct research by comparing SARIMAX, SARIMA, Modified SARIMA and ANN for short term forecasting. In this paper explains that Interesting results regarding the necessity and the advantages of using exogenous factors in a time series model are concluded from this comparison. Finally, intra-day forecasts updates are implemented to evaluate the forecasting errors of the SARIMA and the SARIMAX models. Their comparison highlights differences in accuracy between the two models. All models are compared in terms of the Normalized (with respect to the PV installed capacity) Root Mean Square Error (NRMSE) criterion.

The research proposed [14] predict the temperature driven electricity load, SARIMAX and Neural Network are performed as well as adding an exogenous namely temperature to be included into these models. The results showed that the ANN model perform better than SARIMAX at the estimation stage, yet it gets worse in the forecasting stage. In the forecast period, the model SARIMAX yield of 2.98% MAPE and RMSE of 62.61 MW. Better than 3.57% MAPE and RMSE of 72.92 MW from the ANN model. While [15] conduct research about traffic accident estimation model. In their paper explains To overcome the deficiency of traditional traffic accident estimation models, this paper introduced a new way. It gave two categories on traffic accident affected factors and selected the main ones, using stepwise regression model. ARIMAX model, a dynamic regression one, was used to forecast traffic accident volumes. The former job ensures the precision of estimation, while the latter one owns both regression and ETS models' merits. Based on research [16], ARIMA and ARIMAX model with Google Trends data are implemented in order to forecast the number of dengue fever cases. The research shows that the addition of Google Trends into ARIMAX model improves forecasting performance. The best ARIMAX with Google Trends model improves MAPE value by 3%.

Whereas according to [17] in his research related to the area vulnerability forecasting of bicycle theft crime which combines the (S) ARIMA method and the Decision Tree CART Classification Method obtained the forecasting results (S) ARIMA conducted with each of the variables in a forecasting model and forecasting error value that varies based on the data pattern of each of those variables. The results of classification by CART score an accuracy of 91.7% for the city of Yogyakarta and 87.5% for DIY. Based on the research, forecasting results (S) ARIMA and CART can be used to predict the vulnerability of the region for the crime act of motorcycle theft.

Based on the literature described earlier, this research is a development research or continuation of research [17] using data that is the same number of events or cases of motorcycle theft. To provide a different perspective on the accuracy of forecasting results made on motorcycle theft, this research proposes the development of a forecasting model of an area's vulnerability to motorcycle theft crime by utilizing data timeseries or data and using Timeseries forecasting method, ARIMAX - Transfer Function Model with single input so that the expected forecasting results from this research can be used as one of the periodic control and supervision materials in handling the crime of motorcycle theft by the police

III. Crime and Crime Forecasting

Crime is an antisocial act that causes harm, disobedient in the society which causes anxiety and to establish order the state must penalize those who commit such acts. Crime is a social problem that is faced by every society in this world. According to Chen et al [18] in Crime Data Mining, criminal acts are divided into several categories according to the level of its territory, local and national/international. Locally, criminal acts can be divided into eight categories as follows:

a. Traffic violation, such as running a red light, hit and run, etc.
b. Sexual abuse, such as prostitution, rape, and sexual harassment.
c. Theft, such as home and motor vehicle theft.
d. Arson, such as deliberately setting fire on the property.
e. Illicit drugs, such as possession and sale of illegal drugs.
f. Violent crime such as murder, assault, and robbery.
g. Fraud, such as money laundering, corruption, and forgery.
h. Cybercrime, such as credit card fraud via the internet.

Gorr and Harries [19] explains that Crime forecasting is not widely by police. While there are numerous econometric studies of crime or incorporating crime in the literature, one is hard-pressed to find police department or other police organization making regular use of forecasting-econometric for deployment of limited resources. The major targer of police tactitcs had been persons and their criminality.

IV. Method of Forecasting Time Series Data

A. Autoregressive Integrated Moving Average (ARIMA)

Time series data is a collection of an observation made in a row or sequential in time. Based on the type of data, there are two types of time series, that is the continuous time series and discrete time series. A time series is said to be continuous if the ranks of the observations noted in continuous time with a predetermined time, for example, forecasting rainfall calculated without monthly, Fourier transformation and harmonic analysis based on frequency. A time series is said to be discrete when observations are recorded by taking a certain value at a certain time and usually within the same or intermittent, for example, monthly exports and daily calculated rainfall [20].

ARIMA forecasting method is a method that does not use independent variables as a comparison so that the calculation is done using only the dependent variable. ARIMA model can occur because there is a difference between the original data. Differencing caused by the process of the ARMA model becomes ARIMA because the insertion of the letter I, which means integrative. The Integrative shows the differencing process. In general, the form of the ARIMA model of order (p, d, q) with a difference of d shown in equation (1) [21], or in the form of parameter autoregressive model order p, the amount of differentiation d, moving average model order q and constant θ_0 denoted as ARIMA (p, d, q)[17].

$$\emptyset(B)(1-B)^d Y_t = \theta_0 + \theta_q(B) a_t \quad (1)$$

B. ARIMAX - Transfer Function Model Method

ARIMA models known to be effective when a component of a series of time series of rapidly changing from time to time. This model has proven useful in forecasting short-term volatility. Unlike Univariate ARIMA models, ARIMA models with eXogenous (ARIMAX) adds an exogenous variable or independent variable with ARIMA model, which describes changes in a variable can affect the dependent variable [22].

[20] explains that in the transfer function, there is time series output (Yt) expected to be influenced by the input time series (Xt) and other inputs which combined into a single group called noise n_t. In ARIMAX, multivariate or multi-input, there are several X input variables included in the modeling. The general form of ARIMAX-TFM shown in equation (2):

$$Y_t = \sum_{j=1}^{k} v_j(B)\, X_{jt} + n_t + C \quad (2)$$

with Y_t is the output series (tdependent variable) which is the result of forecasting of the case variables; X_t is the input series (independent variable) which is a variable that influences forecasting results, namely the variable number of vehicles; C is a constant; n_t is noise; $v_j(B)X_t$ is the transfer function (or the impulse function) which allows X as input variables affect Y; and B is the backward operator for the back timeseries data period.

V. Research Design

The research uses ARIMAX method. It is used to predict the time series data from theft case that affected the number of motorcycles. ARIMAX forecasting flowchart described in Figure 1.

VI. Results

Data used for forecasting ARIMAX-TFM Single input is data of theft case (Y_t) [17] as data of output series (dependent variable) and data on the number of motorcycle (X_t) as data of input series (independent variable) in the city of Yogyakarta and starts from the period January 2011 - December 2015. The use of forecasting methods is applied to predict the number of motorcycle theft cases based on monthly data, so that data is obtained as much as 60 months/period as historical data/timeseries data for each variable. Below is ARIMAX-TFM single-input forecast model with the number of vehicle (motorbike) as input.

A. Identification Model

At this step, process performed is:

1) Plotting Data

Plotting Data for input and output series are shown in Figure 2. Figure 2 describes the plotting period and data of variables used is the case variable and the number of vehicles as much as 60 periods.

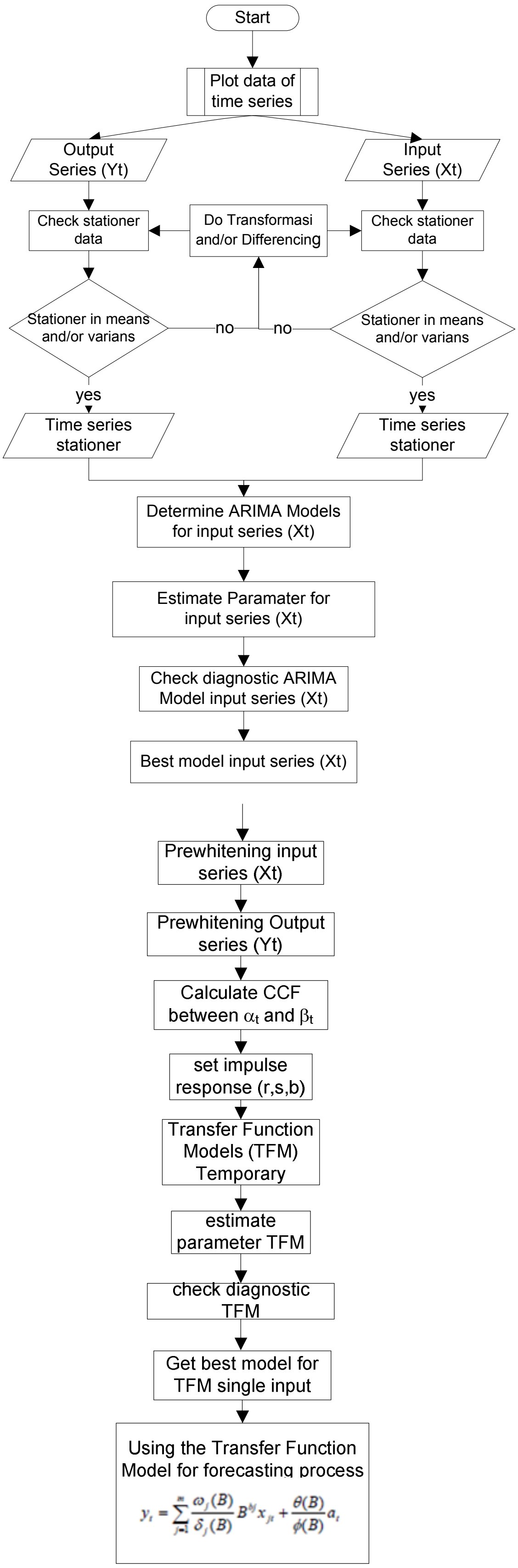


Fig. 1. ARIMAX-TFM with sigle input process

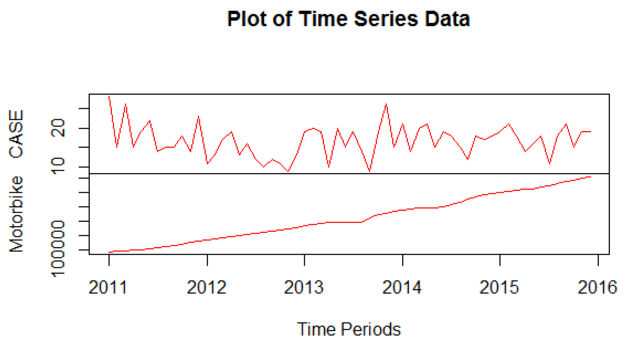


Fig. 2. Plot Data output and input series

2) *Determine the ARIMA models*

Determine the ARIMA models for input series of vehicle (motorcycle) shown in Figure 3. Figure 3 illustrates first differencing results of the independent variables or data of input series (X_t).

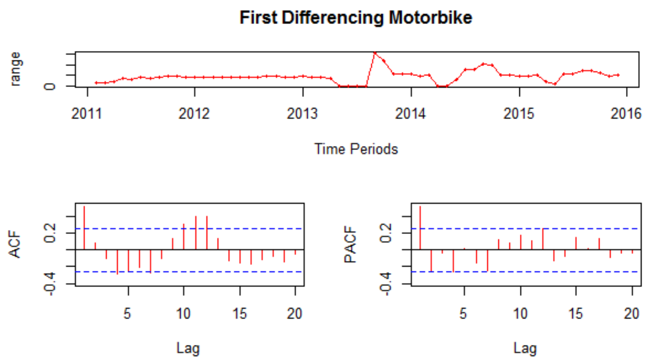


Fig. 3. First differencing input series

Based on the plot in Figure 2 and 3, the most suited ARIMA model to the input of the vehicle is obtained, that is ARIMA (0,0,1) so that the equation can be written:

$$Y_t = \mu + e_t(1 - \theta_1 B) \qquad (3)$$

3) *Prewhitening input and output series*

After getting an ARIMA model for input series, then prewhitening for input series (α_t) and output series (β_t) is performed.

a. Prewhitening input series (α_t)

The prewhitening input series result is shown in Figure 4.

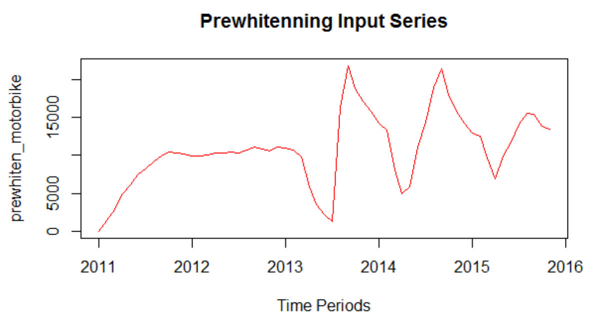


Fig. 4. Prewhitening input series

b. Prewhitening output series (β_t)

The prewhitening output series result is shown in Figure 5.

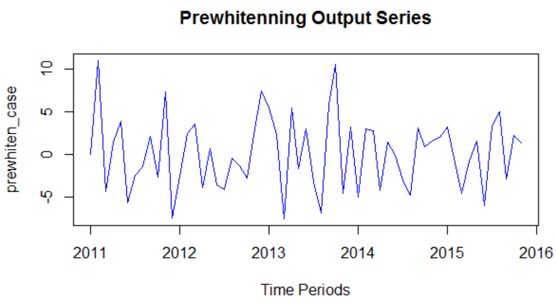


Fig. 5. Prewhitening output series

4) *Cross Correlation function*

Cross Correlation function between input series, output series, and impulse response weight estimate. At this stage, the cross-correlation calculation performed on each input and output series that has been "prewhitening". The goal is to find out if there is a relationship over time that affects the series. Cross Correlation Function results are shown in Figure 6.

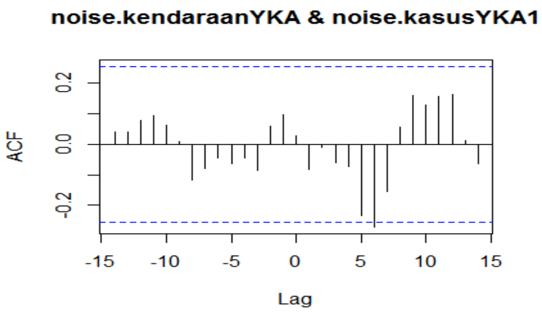


Fig. 6. Cross Correlation Function

In this stage, to produce weight impulse response using the results obtained in the cross-correlation but negative values are not used in the valuation of direct weighting impulse response so that the weight of the impulse response obtained from k = 0,1, ..., 14, or based on cross-correlation function (CCF) plot. Based on the CCF plot result and impulse response weight calculation shows that at lag 5th delay value from b cross-correlation plot affecting significantly. Then followed the values of r and s that contributed to the subsequent lag (r = 2, s = 1). Current estimates are obtained for the transfer function model for vehicle data with vehicle theft cases data, that is (2,1,5) suitable with the parameters (r, s, b). Transfer function model with order (2,1,5) can generally be written in the equation (4):

$$Y_t = \frac{(\omega_0 - \omega_1 B)}{(1 - \delta_1 B - \delta_2 B^2)} X_{t-5} + n_t \qquad (4)$$

5) *Estimate Initial noise series (n_t)*

The next step is to calculate the estimate of the initial noise components of the transfer function model using the following equation (5).

$$n_t = y_t - v_0 x_t - v_1 x_{t-1} - v_2 x_{t-2} - \cdots - v_{14} x_{t-14} \quad (5)$$

Results of noise series shown in Table 1.

TABLE 1. RESULT NOISE SERIES

Periode	Noise	Periode	Noise	Periode	Noise
1	3.81	16	12.82	31	-0.06
2	-5.57	17	-9.51	32	-2.24
3	5.17	18	-6.64	33	4.77
4	-4.06	19	11.75	34	2.33
5	-2.15	20	6.84	35	9.08
6	1.85	21	-14.28	36	3.33
7	6.02	22	5.93	37	2.10
8	-6.79	23	-5.04	38	5.10
9	8.28	24	13.73	39	-5.18
10	8.23	25	9.50	40	-3.99
11	3.32	26	-1.81	41	4.29
12	-0.68	27	-0.61	42	1.66
13	-11.70	28	5.56	43	-6.95
14	15.21	29	-2.67	44	3.66
15	-8.11	30	-7.06	45	2.05

6) *Identification of ARIMA model of noise series*

Identification of ARIMA models of noise series (n_t) is done by looking at the autocorrelation and partial autocorrelation of the residuals models from output results. From ACF and PACF residual transfer function model, p_n and q_n values can be determined for autoregressive and moving average with standard ARIMA method. Noise series plot results are shown in Figure 7.

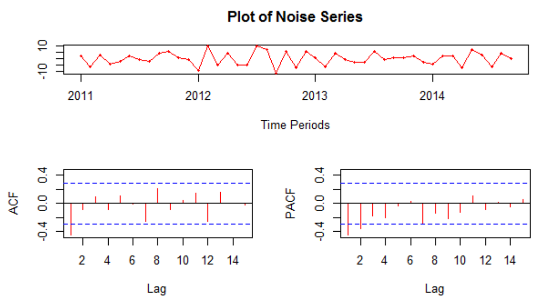


Fig. 7. Plot of noise series

Based on the plot result in Figure 7, ARIMA models that are considered most appropriate that is ARIMA (0, 0, 1).

B. *Parameter estimation of Transfer Function Model*

After identification of model is completed, the next step is to estimate the parameters of transfer function model. In the previous step, the determination of the value of (r, s, b) have identified a single input transfer function model// and also obtained ARIMA model to noise series then transfer function model has been obtained. The next step is to determine parameters of transfer function model based on the value (r, s, b). Here are the results of parameter estimation single input transfer function model shown Table 2.

TABLE 2. SIGNIFICANT TEST RESULT

Parameter	Estimate	Standard Error	T_table	T_value (absolut)
Omega_0	-0.000543	0.0000179	1.671	30.33
Omega_1	-0.0000388	0.00000288	1.671	13.47
Delta_1	-0.252	0.132	1.671	1.91
Delta_2	-0.356	0.202	1.671	1.76
Theta_predict	1.01784	0.00873	1.671	116.59

After the transfer function model order (2,1,5) and valid parameters obtained, the model can be used as a forecasting model. The equation for the transfer function model (2,1,5) can be written as follows:

$$y_t = \delta_1 y_{t-1} + \delta_2 y_{t-2} + \omega_0 x_{t-5} - \omega_1 x_{t-6}$$

$$+a_t - \delta_1 a_{t-1} - \delta_2 a_{t-2} - \theta_1 a_{t-1}$$
$$+\delta_1\theta_1 a_{t-2} + \delta_2\theta_1 a_{t-3} + \mu$$

C. Diagnostic tests on transfer function model

At this step, the autocorrelation check of residual is performed to see whether the residual was random and cross-correlation analysis between input series that has been "prewhitening" (α_t) with residual (error) transfer function model (a_t). Diagnostic Test for transfer function model is done by using Ljung-Box test shown in Table 3.

TABLE 3 AUTOCORRELATION CHECK OF RESIDUALS

Lag	Chi-square_hitung (t-value)	df	Chi-square (t_table)	p-value
1	0.044832	1	3.84	0.8323
3	2.136	3	7.81	0.5447
6	3.1398	6	12.59	0.7911
9	4.1573	9	16.92	0.9008
12	5.5144	12	21.03	0.9386

Based on table 2, all p-value ≥ 0.05, which means that autocorrelation of residual from noise model is not significant or there is no correlation between lag. It can be concluded that residual has met assumption of white noise. Next, the cross-correlation diagnostic test is performed to know whether the correlation between the input series and its residual value is insignificant. The results are shown in Table 4.

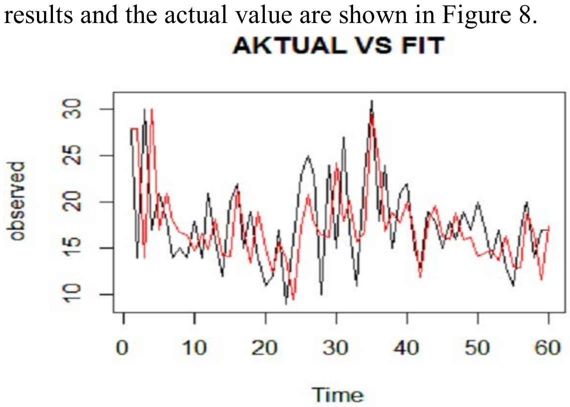
TABLE 4. CROSS-CORRELATION CHECK OF RESIDUALS

Lag	Chi-square_hitung (t-value)	df	Chi-square (t-table)	p-value
1	0.66902	1	3.84	0.4134
3	2.5337	3	7.81	0.4692
6	4.9337	6	12.59	0.5523
9	7.6342	9	16.92	0.5714
12	8.921	12	21.03	0.7097

D. Transfer Function Model for Forecasting

1) *Fit forecasting process (*back forecasting*)*

Based on the previous calculation, Q-value < t-table and p-value $\geq$ 0.05, which means that the autocorrelation of residuals for noise model is not significant or there is no correlation between lags. It can be concluded that residual has met assumption of white noise. After transfer function model is sufficient, it can be used as forecasting model to test the accuracy of the model. The plot of fit forecasting results and the actual value are shown in Figure 8.



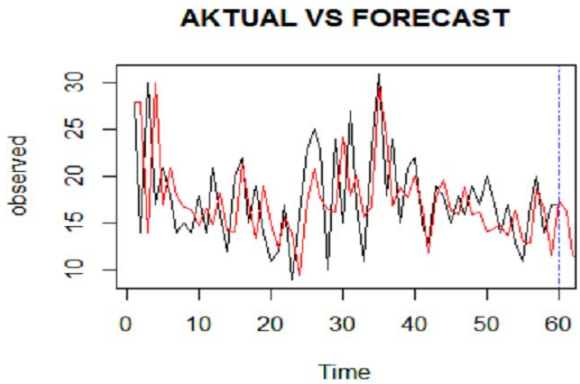
explanation:
= fit forecasting results (backforecasting)
= actual value

Figure 8. Plot Backforecasting vs aktual data

Based on Figure 8, statistical description obtained for forecasting fit model accuracy values with actual values as RMSE = 6.679792 and MAPE = 32.304.

2) *Forecasting Using Transfer Function Model for n-periods ahead*

After the transfer function model derived, the model can be used as a forecasting model to find the theft value in the period ahead. Forecasting results are shown in Figure 9 and Table 5.



explanation:
= forecasting (ahead-periods)
= actual value

Fig. 9. Forecast Results vs Actual Data

Table 5 shows the results of forecasting ARIMAX-TFM with Single Input for 6-periods ahead (January 2016 – June 2016) based on the previous historical data/time series data of 60 periods/months from January 2011 – December 2015.

TABLE 5. FORECAST RESULTS

Period	Forecast result	Upper limit	Lower limit
61	16.39	24.04	10.8
62	11.6	22.96	9.82
63	10.92	18.16	5.04
64	11.85	17.42	4.42
65	10.85	18.30	5.4
66	10.01	4.45	17.25

The following is the example of manual calculation for the 61st forecasting period:

$$y_t = \delta_1 y_{t-1} + \delta_2 y_{t-2} + \omega_0 x_{t-5} - \omega_1 x_{t-6} + a_t$$
$$-\delta_1 a_{t-1} - \delta_2 a_{t-2} - \theta_1 a_{t-1} \ + \delta_1\theta_1 a_{t-2}$$
$$+\delta_2\theta_1 a_{t-3} + \mu$$
$$y_{60} = -0.252 y_{59} - 0.356 y_{58} - 0.000543 x_{55}$$
$$-0.0000388 x_{54} + a_{60} + 0.252 a_{59} + 0.252 a_{58}$$
$$-1.017841 a_{59} - (0.252 * 1.017841 a_{58})$$
$$-(0.356 * 1.017841 a_{57} + \mu$$
$$y_{60} = \text{-}1.02828851$$
$$Y_{61} = Y_{60} + y_{60}$$
$$Y_{61} = 16.39$$

VII. CONCLUSION

Based on the results, it can be concluded that the relationship between the number of cases of motorcycle theft and the number of vehicles can be predicted with single input transfer function model which the best transfer function model as follows:

$$y_t = \emptyset_1 y_{t-1} + \emptyset_2 y_{t-2} - \delta_1 y_{t-1} - (\emptyset_1 \delta_1 y_{t-2}) - (\emptyset_2 \delta_2 y_{t-3})$$

$$+\omega_0 x_{t-3} - \omega_0 \emptyset_1 x_{t-4} - \omega_0 \emptyset_2 x_{t-5} - \omega_1 x_{t-4}$$

$$+\omega_1 \emptyset_1 x_{t-5} + \omega_1 \emptyset_2 x_{t-6} + a_t - \delta_1 a_{t-1} + \mu$$

With the level of accuracy obtained by MAPE and RMSE is 32.30 and 6.68. From the best single input transfer function model, motor vehicle theft cases in the Police of region Yogyakarta areas forecasting results are obtained for six periods ahead, from January 2016 - June 2016.

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