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REGIONAL CRIME ANALYSIS OF TURKEY: A TIME SERIES APPROACH

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Abstract: In this study, the most common types of crime in 7 different geographical regions of Turkey have been analyzed via time-series approach. The purpose of the study is; to put forth the most appropriate time series models for each geographical region and make forecasts for the crime rates. In the analysis; the crime data obtained from official sources covering the years 2001-2010 have been used. The stationarity of 7 regions has been tested and the most appropriate time series model for each region has been determined. The validity of the obtained time series models has been tested and the official data for 2011 have been compared with the forecasts made. As a result, importance and effectiveness of the forecasts obtained from the time series models were given. The availability of the time series approach to crime forecasting was shown for planning security.

Key words: Time Series Analysis, Turkeys Crime Rates, Crime Prevention, Security, Forecast.
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1. Introduction

One of the essential tasks of a state is to ensure people to live in safety by preventing crimes and to create a more peaceful community structure. To this end, the state should eliminate possible threats against the safety of citizens and enable the healthy development of the society (Bal, 2003). All of the countries give weight to the crime prevention strategies because of the damage crimes inflict on societies. Costs related with prevention measures taken by the countries reaches very high levels. However, despite crime prevention efforts the rates of crime is increasing day by day throughout the world (İçli, 2007).

The main point of the study is to analyze the crimes occurring in different regions of Turkey via time series analyzing methods. The reason why we need to study such a topic is the importance of crime prevention for Turkey. Peace and security is very important for the community and to ensure them, crime prevention strategies are one of the essential means (Kaygısız and Sever, 2006).

The first aim of this study is to give regional crime models by taking into account the creation process of historical data. The second aim of the study is to understand the regional characteristics of Turkey through crimes rates. Our third aim is to show that consistent forecasting for the future can be done by obtaining the regional crime time series models. The last aim of the study is to bring a different point of view to policy makers for planning their security strategies in the future. In this study; new models are going to be put forward for problems encountered in different geographical regions of Turkey by using time series analysis methods in the field of crime prevention.

In the countries; control and supervision of crime are given to criminal justice and law enforcement institutions. This task includes; preventing crime, arresting and prosecution of criminals quickly, execution of the sentence, social reintegration of the offender back to society (Sutherland

and Cressey, 1966). Factors affecting the internal security of the countries include terrorism, organized crime, smuggling, attacks on virtual environment, drugs, illegal migration, human trafficking and traffic offenses (Williams and McShane, 1999).

Although crime and crime preventive strategies are the subjects of the social sciences, in recent years, different disciplines have begun to give importance to this field. For this reason, many important scientific researches have been made in the area of crime prevention strategies.

To find the right solution to the problems encountered, accurate modeling and analysis needs to be done. Crime prevention strategies for modeling are also important. In accordance with past data to reveal the structures and the creation of models, time series analysis of the data comes to the forefront.

Time series analysis is a source of information and method (Göktaş, 2005). Time series analysis is one of the most widely used methods and may contribute to solution of the problems encountered in social sciences. By looking at problems from different disciplinary perspectives, routines can be demolished and creative and more effective solutions can be found for the existing problems. The creation of new models for the crime and making crime forecasts by these models develops as the time series analysis studies gain popularity.

The steps taken to prevent crimes are important. Threats to effective crime prevention planning in the regions should be studied well. Revealing the correct data structure of the past has a crucial property for efficient forecasts. By means of accurate forecasts, security planning will be successful.

Desired result of this study is to forecast rates of crime in different regions and to assist decision-makers for their crime preventing strategies. Crime rates have been studied in 7 different geographical regions of Turkey[1]. For each region; crimes[2] occurred between the years 2001-2010 have been analyzed by time series analysis on a monthly basis. In the analysis, the appropriate time series models are given for each region, the validations of the models are tested and forecasts have been done. Consistency of the forecasts obtained from the time series models has been compared and checked by the official data of 2011.

In the second section, the basic concepts of time series are given. In the third section, a literature review is presented. In the fourth section, the stationary tests and appropriate time series models; in the fifth section, projections obtained from these models and their comparisons with the official data are given. The results obtained from models are evaluated and illustrated through graphics in the last section.

2. Time Series Analysis A time series is a sequence of data points, measured typically at successive points in time spaced at uniform time intervals. Examples of time series are; amount of product exported monthly from a factory, number of accidents that occur weekly on a highway, monthly precipitation of a city (Akdi, 2010). According to another definition; a time series is the series that created by the arrangement of raw data according to time units such as day, month, year. (Çilingirtürk, 2011). Time series are used in statistics, signal processing, pattern recognition, econometrics, mathematical finance, weather forecasting and earthquake prediction.

Time series analysis comprises methods for analyzing time series data in order to extract meaningful statistics and other characteristics of the data. While being used in the applications, it is necessary that the time series have a trusted extension into the past (Göktaş, 2005).

Time series are analyzed for various purposes. The most important ones among these are; to analyze the series in order to predict the future, to reveal the main features of the series and to

[1] Turkey is divided into 7 regions: Eastern Anatolian, Central Anatolia, Blacksea, Mediterranean, Aegean, Marmara and Southeastern Anatolia.

[2] Most common crimes (murder, assault and battery, offence against property, theft and burglary,coercion and blackmail and forgery) are included in the study. The data including the crime rates (2001-2011) is obtained from Turkish Statistical Instute and Turkish Gendermarie.

explain the relationship between different series. Time series forecasting is the use of a model to predict future values based on previously observed values (Akdi, 2010). While regression analysis is often employed in such a way as to test theories that the current value of one time series affects the current value of another time series, this type of analysis of time series is not called "time series analysis".

2.1. Stationarity One of the important concepts in time series is the stationarity. Prior to the statistical analysis of series; it is necessary to determine the process that generates that series whether constant over time or not. Stationarity of series is usually seen as an assumption. Almost all the statistical inference is done under the assumption of stationarity of the series. Focusing of the stationarity of the time series can be explained simply as follows: If you have a stationary stochastic process, the behavior of the series is valid only for the period under consideration; it cannot be made a generalization for the series about other periods. A stationary process has the property that the mean, variance and autocorrelation structure do not change over time.

Before carrying out a statistical analysis of time series, the stationarity of the process generating the series are created should be investigated whether it is constant over time or not. When an analysis is conducted with non-stationary time series, traditional t and F tests and R^2 value can give biased results (Göktaş, 2005). If a time series is nonstationary, we can study its behavior only for the time period under consideration. Each set of time series data will therefore be valid for a particular episode. As a consequence, it is not possible to generalize it to other time periods. Therefore, for the purpose of forecasting, such (nonstationary) time series may be of little practical value (Gujarati, 2003).

A stochastic process is said to be stationary if its mean and variance are constant over time and the value of the covariance between the two time periods depends only on the distance or gap or lag between the two time periods and not the actual time at which the covariance is computed. In the time series literature, such a stochastic process is known as a weakly stationary, or covariance stationary, or second-order stationary, or wide sense, stochastic process (Gujarati, 2003).

A time series $\{x_t : t \in T\}$ is said to be stationary if it satisfies the following conditions:

$E(X_t)$ is free of time,

$Cov(X_t, X_s)$ is only a function of $|t-s|$.

If a time series is not stationary in the sense just defined, it is called a nonstationary time series (weak stationarity). In other words, a nonstationary time series will have a time varying mean or a time-varying variance or both.

2.2. Unit Root A test of stationarity (or nonstationarity) that has become widely popular over the past several years is the unit root test. Systematically investigating the existence of unit root test in a series has been put forward by the Dickey and Fuller (1979).

Dickey and Fuller developed unit root test to test for stationarity of time series in their (1979) and (1981) studies. Unit root series are the series with AR component. The most commonly used unit root tests of Dickey-Fuller indicates whether the parameters of time series can be expressed with autoregressive variables (AR) or not. Let

$$X_t = \alpha + \beta X_{t-1} + u_t \tag{2.1}$$

is given.

If we subtract X_{t-1} from both sides of equation (1), we can write,

$$X_t - X_{t-1} = \alpha + \beta X_{t-1} - X_{t-1} + u_t \tag{2.2}$$

$$(X_t - X_{t-1}) = \alpha + (\beta - 1)X_{t-1} + u_t \tag{2.3}$$

The hypotheses for testing stationarity can be expressed as;

H_0 :There is a unit root ($\beta = 1$) series is not stationary.

H_1 :There is no unit root ($\beta < 1$) series is not stationary.

If the equation (1) is an auto regressive process (AR) and coefficient of X_{t-1} is equal to one ($|\beta| = 1$) it shows the presence of unit root.

A stochastic process is said to be purely random if it has zero mean, constant variance σ^2 and is serially uncorrelated. u_t is assumed to be a white noise process which is independently and identically distributed as a normal distribution with zero mean and constant variance.

Dickey-Fuller uses three different regression equations for the existence of unit root.

$$\Delta X_t = \gamma X_{t-1} + u_t \tag{2.4}$$

$$\Delta X_t = \alpha_0 + \gamma X_{t-1} + u_t \tag{2.5}$$

$$\Delta X_t = \alpha_0 + \gamma X_{t-1} + \beta_t + u_t \tag{2.6}$$

In the equations where t is the time or trend variable; (4) is the random walk; equation (5) is the random walk with drift; equation (6) shows the state with drift around a stochastic trend.

In each case, the null hypothesis is that $\gamma = 0$; that is, there is a unit root the time series is nonstationary. The alternative hypothesis is that γ is less than zero; that is, the time series is stationary. If the null hypothesis is rejected, it means that X_t is a stationary time series with zero mean in the case of (4), that X_t is stationary with a nonzero mean in the case of (5), and that X_t is stationary around a deterministic trend in (6). Dickey and Fuller have shown that under the null hypothesis that $\delta = 0$ the estimated t value of the coefficient of X_t in (4) follows the τ (tau) statistic. These authors have computed the critical values of the tau statistic on the basis of Monte Carlo simulations.

2.3. Determining the Appropriate Time Series Model Autocorrelation coefficients of a time series refer to the strength of the relationship between the different periods of observation. If the coefficients of the variables are high that means previous period is dependent on each other; if they are low that indicates they are random variables. Autocorrelation function (ρ_k) shows any correlation between the observation values of the series; namely it means the dependence of each other.

The partial correlation between two variables is the correlation that remains if possible impact of all other random variables has been eliminated. To define the partial autocorrelation coefficient, another notation is being used;

$$x_t = \phi_{k1}x_{t-1} + \phi_{k2}x_{t-2} + ... + \phi_{kk}x_{t-k} + u_t$$

where ϕ_{ki} is the coefficient of the variable with lag "i"if the process is of order "k". The coefficients ϕ_{kk} are the partial autocorrelation coefficients (of order k), k=1,2,... . The partial autocorrelation measures the correlation between x_t and x_{t-k} which includes the influences of $x_{t-1}, x_{t-2}, ..., x_{t-k+1}$ on x_t when x_{t-k} has been eliminated (Kirchgassner and Wolters, 2007).

The analysis of the correlogram of the autocorrelation and partial autocorrelation functions is used in determining the Autoregressive (AR) and Moving Average (MA) models. Because autoregressive process explains a variable with its lagged values, partial autocorrelation function is used to determine the order of the process. Autocorrelation coefficients are used in the determination of the order of the moving average model.

An autocorrelation and partial autocorrelation functions of a stationary time series may approach to zero value slowly. In this case, it can be said that time series model have both AR and MA process at the same time.

3. Literature Review There are studies in which time series analysis, panel data studies and panel cointegration analysis is applied to different type of crime data. As a general evaluation, studies were largely carried out in order to contribute to econometrics literature. The vast majority of the studies are related to identify the relations between the society's economic, social, demographic, justice and security features with various crimes. Questions whose answers investigated are; "What is the relationship between social structure and crimes? How the effects of economic development to a particular crime can be modeled? What are the effects of the demographic structure to the crime types? How unemployment rates affect crime amounts? What are the effects of income inequality to crime rates?".

Looking at the general framework, common property of the econometric models given in this problem field aims to give to a formula for understanding the problems encountered. In this study, we aimed to give rather than an econometric model; we prefer to give a time-series model. Economic modeling approach to crime has gained momentum after the 1960s. The model put forward in the article "Crime and Punishment: an Economic Approach"published in 1968 by Gary Becker is accepted as the first model in the economic literature. Following the work of Becker, a large literature has emerged examining potential relationships between crime rates and a number of economic variables.

Identifying and modeling the scientific elements of the crime helps to produce more effective policies to combat with crime. Although modeling crime as an economic model is a new field of study; recently, many economists have developed "econometric models"and in these models especially the relation between crime and econometrics is kept at the forefront. In reviewing the literature on the economic models of crime, important models are; The Traditional Economic Model, The Econometric Model, The Expectations Theory Model and The Expected Utility Model (Akkuş, 2003).

Şanlı (1998), studied the structure of criminality in Turkey according to socio-economic factors and grouped the provinces according to crime regions. Study was based on the socio-economic indicators showing the socio-ecological indicators of provinces and indicators of criminal offenders in prisons; the relation between multivariate statistical analysis and two variables data set was determined.

Beki, Zeelenberg, and Montfort (1999) in their study for the Netherlands, analyzed the tendencies of various crimes by using the data including years 1950-1993.

Deadman's (2000) study for England; econometric and time series analysis has been used to estimate the trend of burglary from houses.

Andrienko (2001), for Russia, using the data between the period 1990-1998 belong to 70 settlement aimed to find out the factors which affect the crime trends.

Sookram et al. (2010), using the time series data obtained from Trinidad and Tobago, examined the major crimes rates and long-term cointegration relationship between the various socio-economic indicators.

Cook and Cook (2011), in their study of "Are US Crime Rates Really Unit Root Processes?"; showed the unit root hypothesis to be rejected for all classifications of criminal activity examined over the period 1960-2007.

Aslan and Öcal (2012), have done a study for the continuity of crime rates in Turkey, in their study they used the unit root test for heterogeneous panels, the continuity of the crime rates for the provinces have been analyzed and the convergence of crimes were studied.

4. Applied Method Since the stationary of a time series is important, the entire series is tested whether they are stationary or not. Firstly; model and model parameters are estimated, secondly; tests have been done for the given models. As a last step we have used the models for forecasting the crime rates. Stationary test is applied the equations (4), (5) and (6) respectively.

If the significance levels of the critical values of the ADF test values of variables are greater than absolute value of the series, the series is stationary and there is no unit root. If the absolute value is less than the critical value, the series has a unit root and it is not stationary. In this case, the first difference of the series on the stationary test is applied again. Process continues until the series is stationary.

5. Results For testing stationarity of time series EViews.7 and obtaining time series model and for predictions SAS 9.1 programs were used. After the stationary test; models for each region were obtained. For appropriate time series models especially (AR) models were taken into account because (AR) models are more sensitive for forecasts.

The time-series graphs, correlograms of autocorrelation and partial autocorrelation of the series are given in Figure-1, 2, 3, 4, 5, 6 and 7. Data between years 2001 and 2010 for Region-1 has been given in Figure-1. In each year, crime amounts increase in months June, July and August. ACF graph has a periodical characteristic.

According to partial ACF graph of Region-1; first, second, seventh, eighth, tenth, eleventh and thirteenth lags are outside of the borders. These lags were taken into account while obtaining appropriate time series (AR) model.

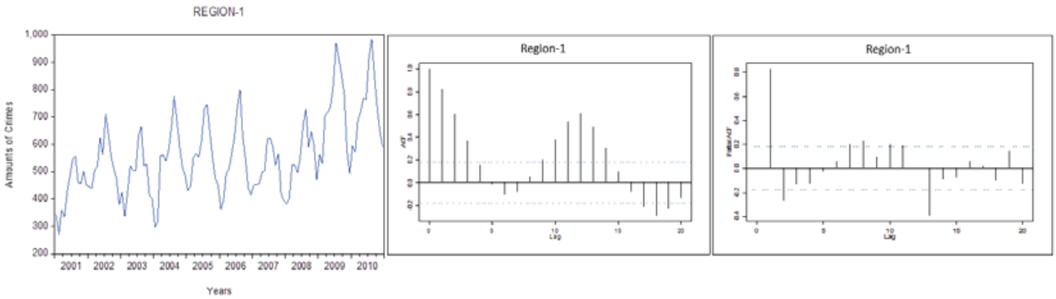

FIGURE 1. Time Series Graph and Correlogram of Region-1

Data between years 2001 and 2010 for Region-2 has been given in Figure-2. As seen from ACF graph Region-2 has periodical characteristic. According to partial ACF graph of Region-2; first, second, third, fourth, seventh, ninth, tenth and eleventh lags are outside of the borders. These lags were taken into account while obtaining appropriate time series (AR) model.

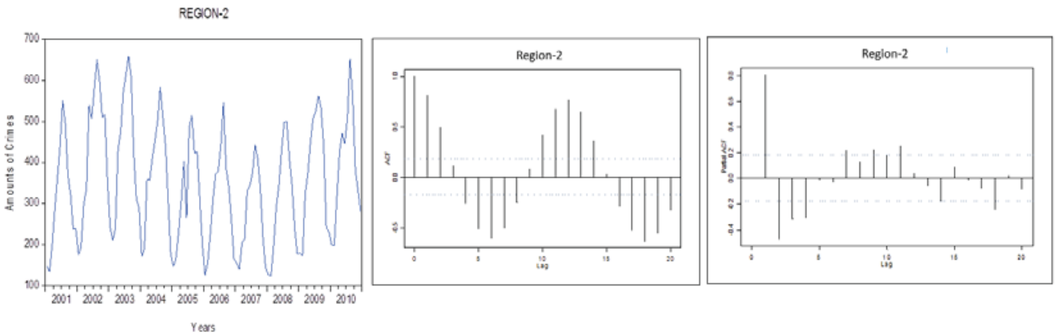

FIGURE 2. Time Series Graph and Correlogram of Region-2

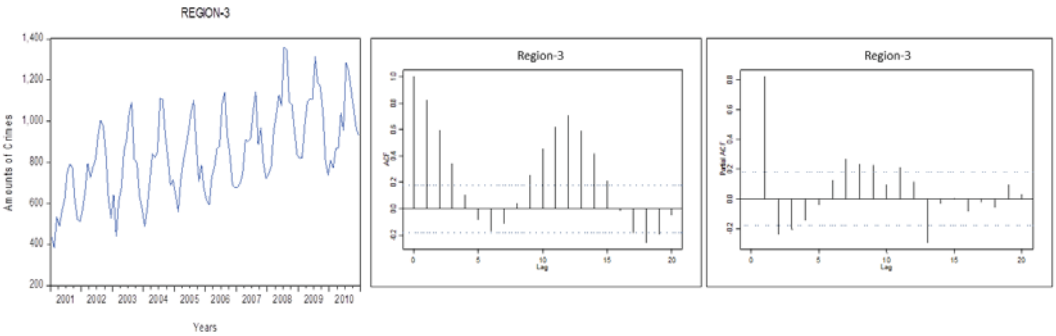

Figure 3. Time Series Graph and Correlogram of Region-3

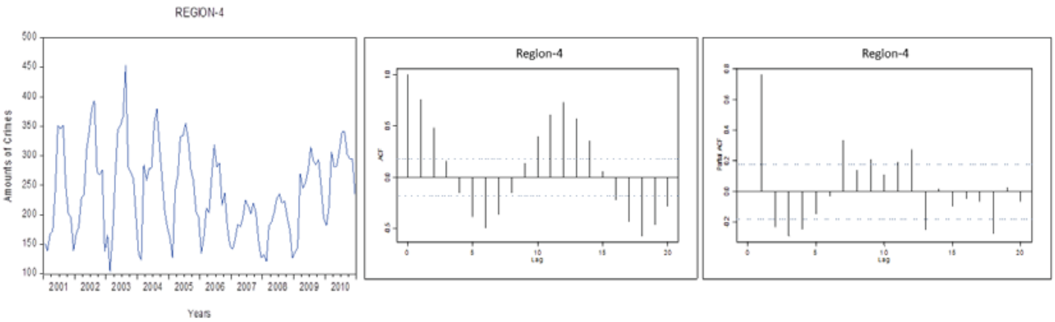

Figure 4. Time Series Graph and Correlogram of Region-4

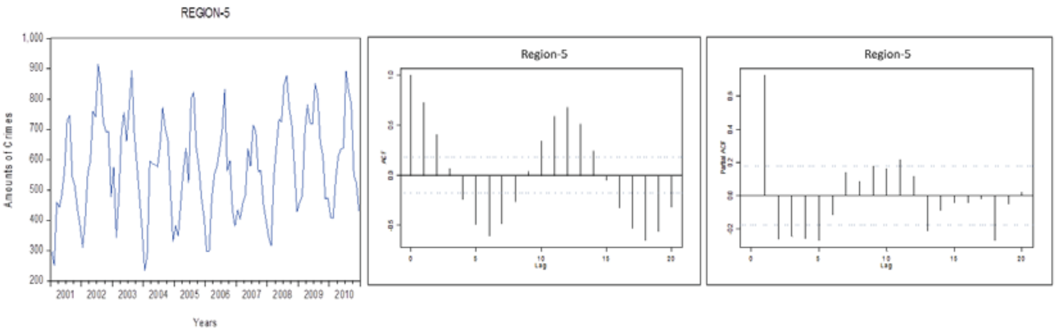

Figure 5. Time Series Graph and Correlogram of Region-5

The other graphs of regions and data have been examined with the same manner. They have been given in Figure-3, 4, 5, 6 and 7.

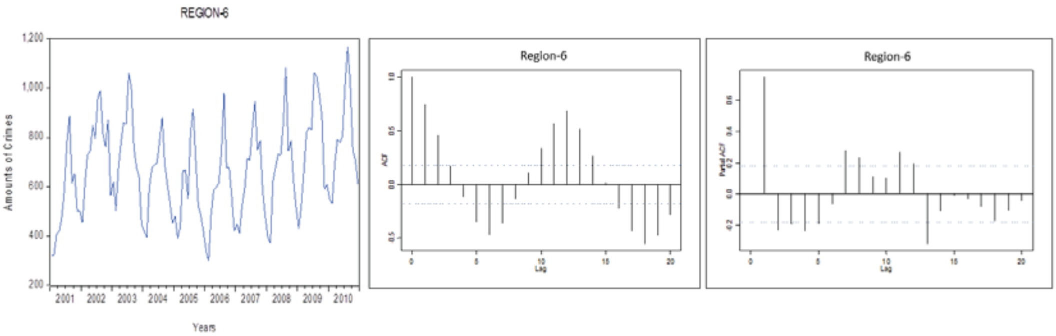

FIGURE 6. Time Series Graph and Correlogram of Region-6

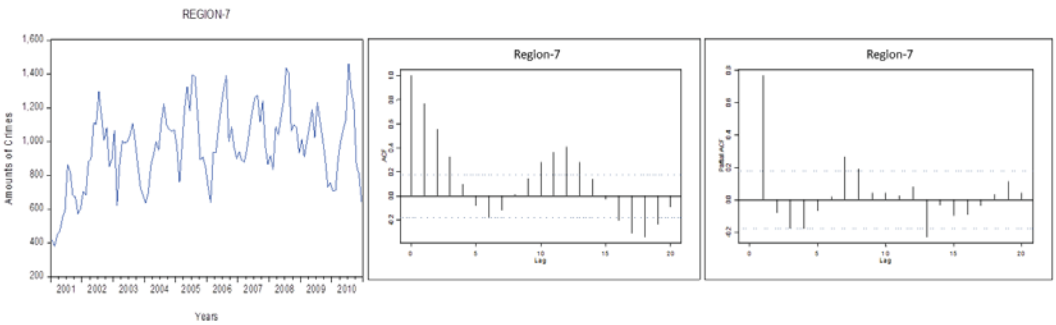

FIGURE 7. Time Series Graph and Correlogram of Region-7

6. The Time Series Models for Eeach Region According to the values of AIC (Akaike Info Criterion) and SBC (Schwarz Bayesian Criterion) statistics, the best model for the i^{th} region is proposed.

$$X_{it} = \alpha_1 X_{i,t-1} + \alpha_2 X_{i,t-2} + ... + \alpha_p X_{i,t-p} + \varepsilon_t$$

In the proposed models; $\varepsilon_t \sim WN(0, \sigma^2)$ and $X_{i,t}$ is the numbers of crime in the i^{th} region at the t^{th} month. The plots of ACF and PACF functions are also support the validity of the model. The model parameters have been estimated by PROC ARIMA in SAS:

6.1. Time Series Model For Region-1

$$\hat{X}_{i,t} = -0,83745X_{t-1} + 0,01874X_{t-2} + 0,1374X_{t-7} - 0,11687X_{t-8}$$
$$-0,02213X_{t-10} - 0,4169X_{t-11} + 0,23722X_{t-13} + u_t$$

After the determinations of the models and estimation procedures have been completed, we observed that for all regions the crime rates are stationary according to the ADF (Augmented Dickey Fuller) results. The values of the ADF test results have been tabulated for each region below. In each table, ADF values and their critical values of three models (model without intercept, with intercept, with intercept and trend) are given. When ADF value of the model is bigger than the critical value first time, it is written in bold. In every table Lag=1.

After obtaining the appropriate time series models for the regions, second part of the study has been done. Since the proposed model is stationary, it is meaning to make forecast for the future. We calculated the values of monthly forecasts for the 2011. The data of the year 2011 has been obtained from official sources at the completion stage of the study. Forecasts and the official data

Table 1. ADF and Critical Values for Region-1

ADF None	Critical Value (%1, %5, %10)	ADF Intercept	Critical Value (%1, %5, %10)	ADF Intercept and Trend	Critical Value (%1, %5, %10)
-3.491809	**-2.586753** -1.943853 -1.614749	-3.674406	**-3.492523** -2.888669 -2.581313	-3.700911	-4.046072 -3.452358 **-3.151673**

of the year 2011 are given in the graphics below (Figure-8, 9, 10, 11, 12, 13 and 14).

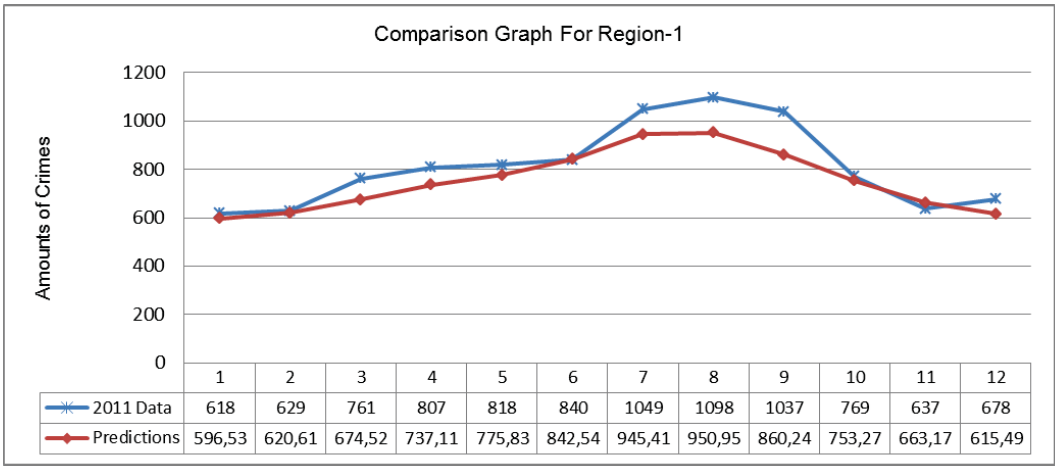

Figure 8. Forecast results and comparison with the official data of 2011

In the following part of our study; since the steps for obtaining appropriate time series models are similar; firstly, the models are given; secondly, ADF and Critical Values are tabulated; lastly, forecast results and the comparison with the official data are given below for each region.

6.2. Time Series Model For Region-2

$$\hat{X}_{i,t} = -0,77873X_{t-2} + 0,07717X_{t-3} + 0,25684X_{t-4} \\ -0,08707X_{t-7} - 0,00293X_{t-9} - 0,33291X_{t-11} + u_t$$

Table 2. ADF and Critical Values for Region-2

ADF None	Critical Value (%1, %5, %10)	ADF Intercept	Critical Value (%1, %5, %10)	ADF Intercept and Trend	Critical Value (%1, %5, %10)
-9.527197	**-2.586350** -1.943796 -1.614784	-9.530497	**-3.491345** -2.888157 -2.581041	-9.479919	**-4.044415** -3.451568 -3.151211

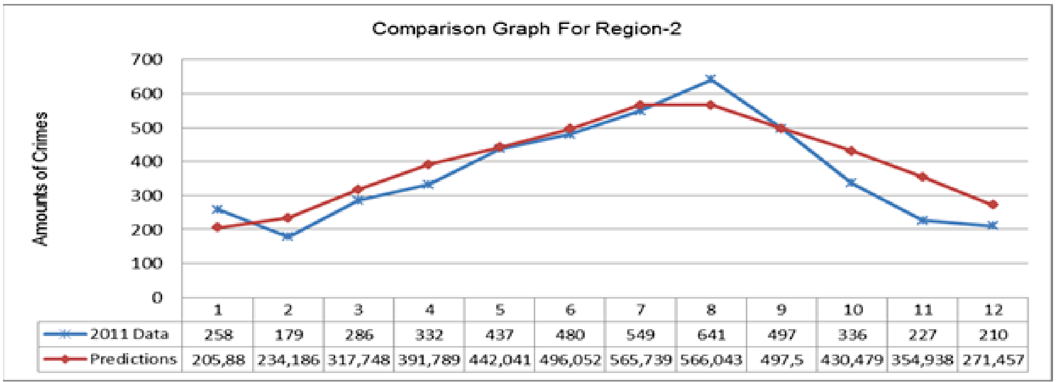

FIGURE 9. Forecast Results and comparison with the official data of 2011

6.3. Time Series Model For Region-3

$$\hat{X}_{i,t} = -0,73514X_{t-1} - 0,01151X_{t-2} + 0,0186X_{t-3} + 0,09953X_{t-7}$$
$$-0,00827X_{t-8} - 0,12157X_{t-9} - 0,36734X_{t-11} + 0,1257X_{t-13} + u_t$$

TABLE 3. ADF and Critical Values for Region-3

ADF None	Critical Value (%1, %5, %10)	ADF Intercept	Critical Value (%1, %5, %10)	ADF Intercept and Trend	Critical Value (%1, %5, %10)
-4.296026	**-2.586753** -1.943853 -1.614749	-4.688885	**-3.492523** -2.888669 -2.581313	-4.742223	**-4.046072** -3.452358 -3.151673

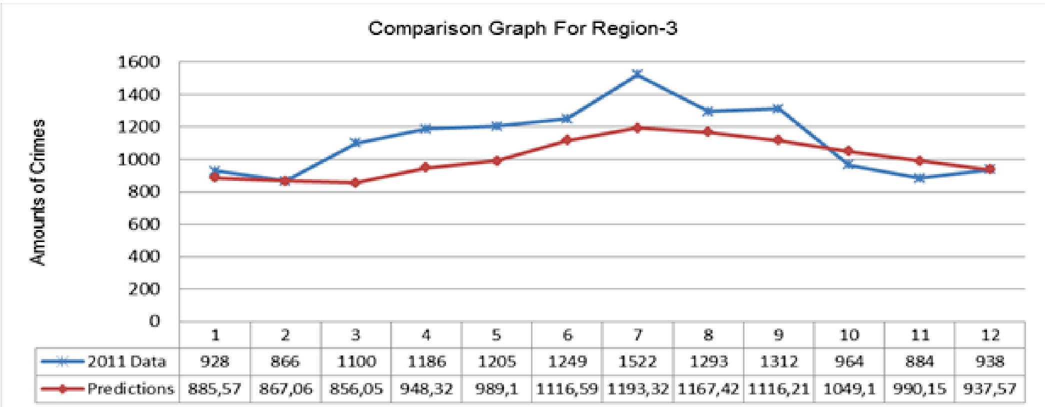

FIGURE 10. Forecast results and comparison with the official data of 2011

6.4. Time Series Model For Region-4

$$\hat{X}_{i,t} = -0,61133X_{t-1} - 0,05883X_{t-2} + 0,03797X_{t-3} + 0,03677X_{t-4} - 0,16113X_{t-7} - 0,3301X_{t-8} - 0,08722X_{t-11} - 0,41816X_{t-12} + 0,25105X_{t-13} + 0,27284X_{t-18} + u_t$$

Table 4. ADF and Critical Values for Region-4

ADF None	Critical Value (%1, %5, %10)	ADF Intercept	Critical Value (%1, %5, %10)	ADF Intercept and Trend	Critical Value (%1, %5, %10)
-4.571116	**-2.586753** -1.943853 -1.614749	-4.599893	**-3.492523** -2.888669 -2.581313	-4.665432	**-4.046072** -3.452358 -3.151673

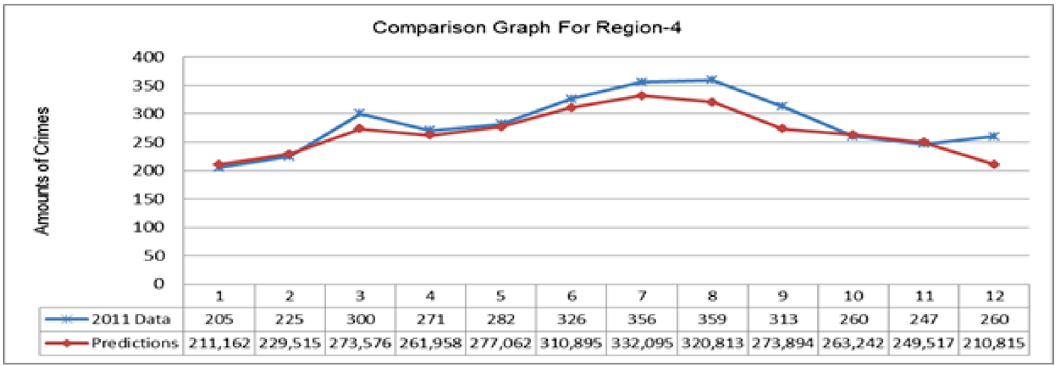

Figure 11. Forecast results and comparison with the official data of 2011

6.5. Time Series Model For Region-5:

$$\hat{X}_{i,t} = 0,6792X_{t-1} + 0,02044X_{t-2} + 0,07192X_{t-3} + 0,0271X_{t-4} - 0,16718X_{t-5} + 0,113591X_{t-9} + 0,3615X_{t-11} - 0,11764X_{t-13} + u_t$$

Table 5. ADF and Critical Values for Region-5

ADF None	Critical Value (%1, %5, %10)	ADF Intercept	Critical Value (%1, %5, %10)	ADF Intercept and Trend	Critical Value (%1, %5, %10)
-4.637666	**-2.586753** -1.943853 -1.614749	-4.645565	**-3.492523** -2.888669 -2.581313	-4.680710	**-4.046072** -3.452358 -3.151673

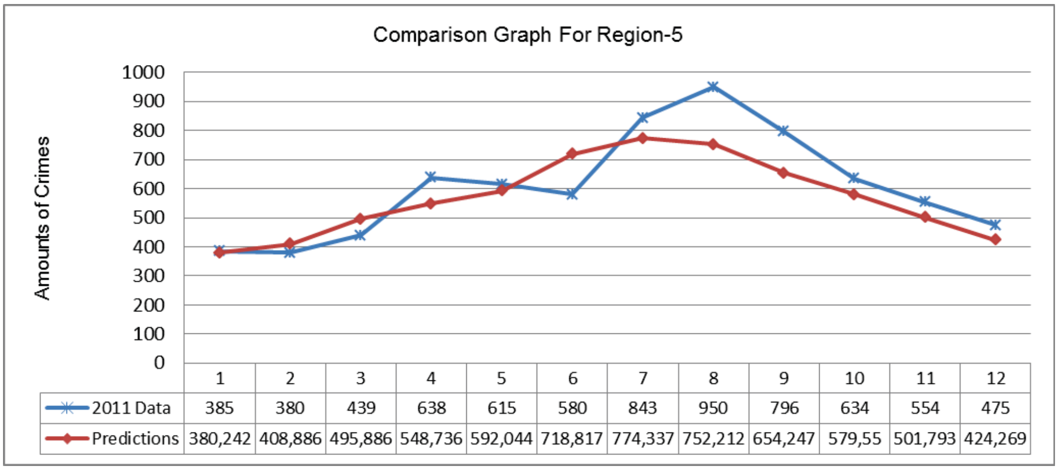

FIGURE 12. Forecast results and comparison with the official data of 2011

TABLE 6. ADF and Critical Values for Region-6

ADF None	Critical Value (%1, %5, %10)	ADF Intercept	Critical Value (%1, %5, %10)	ADF Intercept and Trend	Critical Value (%1, %5, %10)
-3.337469	**-2.586960** -1.943882 -1.614731	-3.326160	-3.493129 **-2.888932** -2.581453	-3.292586	4.046925 -3.452764 **-3.151911**

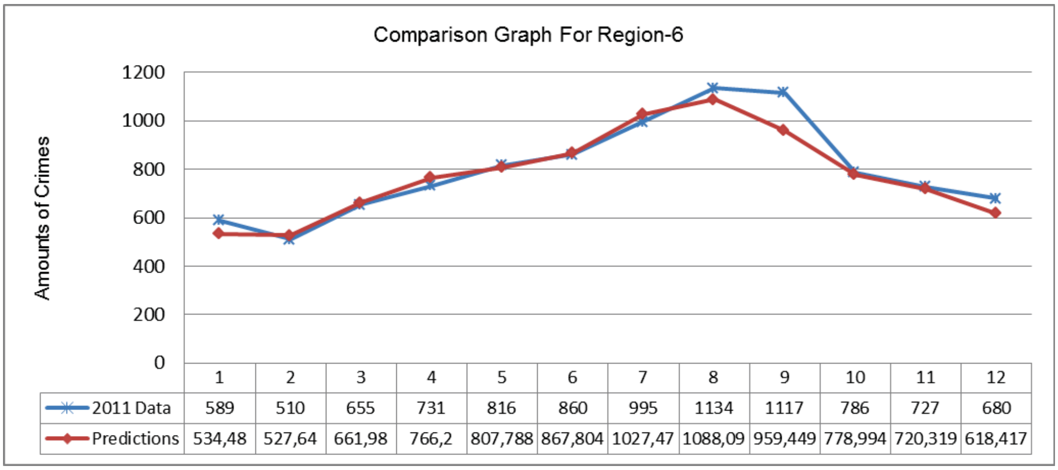

FIGURE 13. Forecast results and comparison with the official data of 2011

6.6. Time Series Model For Region-6:

$$\hat{X}_{i,t} = -0,63943X_{t-1} - 0,08464X_{t-2} - 0,00427X_{t-3} + 0,0122X_{t-4} + 0,09045X_{t-5}$$
$$+0,03248X_{t-7} - 0,11765X_{t-8} - 0,14541X_{t-11} - 0,50249X_{t-12} + 0,35876X_{t-13} + u_t$$

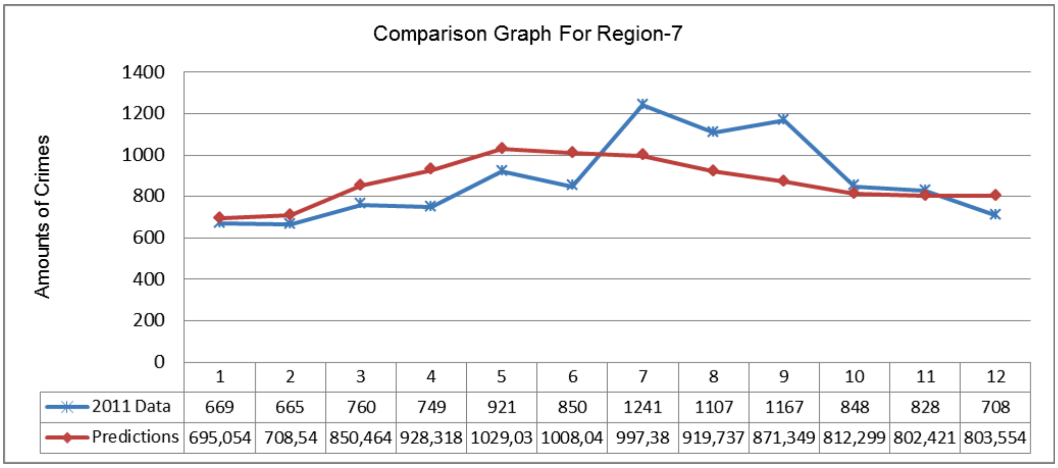

FIGURE 14. Forecast results and comparison with the official data of 2011

6.7. Time Series Model For Region-7

$$\hat{X}_{i,t} = 0,91328X_{t-1} + 0,13268X_{t-3} - 0,30161X_{t-4} + 0,01122X_{t-7}$$
$$+0,24756X_{t-8} - 0,0097X_{t-13} + u_t$$

TABLE 7. ADF and Critical Values for Region-7

ADF None	Critical Value (%1, %5, %10)	ADF Intercept	Critical Value (%1, %5, %10)	ADF Intercept and Trend	Critical Value (%1, %5, %10)
-9.044708	**-2.585773** -1.943714 -1.614834	-9.018054	**-3.489659** -2.887425 -2.580651	-9.169162	**-4.042042** -3.450436 -3.150549

7. Conclusion This paper investigates and introduces a practical approach of using time series to forecast crime rates. The first responsibility of each state is to ensure safety and prevent crime. While obtaining crime prevention strategies, we need an accurate analysis of past data. Trend of the data, relationships between them, influence each other and by the help of these factors accurate forecasts can be done for the future.

The security policies for governments are very crucial and to provide against crimes lots of expedients are taken into account. Since time series analysis can be used to obtain forecasts for the future with the help of historical data; we aimed to give a different point of view for security policy makers by using time series approach for forecast.

In this study, time series analysis has been applied to historical data of crimes occurred in different regions of Turkey in period 2001-2011. Time series models suitable to each region have been obtained with the aid of these data. With the help of models, forecasts have been done. The forecasts have been compared with the official data. Determining the amount of crime in future periods of these regions is important for planning the security measures to be taken in this study area.

Finally, this paper shows that being aware of this kind of solution in crime preventing strategies may be useful for security policy makers.

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