

Projecting the Water and Electric Consumption of Polytechnic University of the Philippines

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Abstract. This study investigates water and electric consumption in Polytechnic University of the Philippines – Sta. Mesa using a time series analysis. The researchers analyzed the water and electric usage separately. Electric consumption was examined in terms of pesos and kilowatt-hour, while water consumption was analyzed in pesos and cubic meter. The data are gathered from the university limited only from January 2009 to July 2015 in a monthly based record. The aim is to forecast the water and electric usage of the university for the years 2016 and 2017. There are two main statistical treatments that the researchers conducted to be able to formulate mathematical models that can estimate the water and electric consumption of the said school. Using Seasonal Autoregressive Integrated Moving Average (SARIMA), electric usage was forecasted in peso and kilowatt-hour, and water usage in peso and cubic meter. Moreover, the predicted values of the consumptions are compared to the actual values using Paired T-test to examine whether there is a significant difference. Forecasting accurately the water and electric consumption would be helpful to manage the budget allotted for the water and electric consumption of PUP – Sta. Mesa for the next two years.

1. Introduction

For the past few years, the Philippine economy continues to boom in terms of its Gross Domestic Product (GDP), with an average growth rate of 6.3 percent from 2010 to 2014. Together with this growth is the increase in supply and demand across sectors [1]. The growth of the Philippine economy drives the demand for electricity [2]. Electric power consumption in Philippines was last measured at 646.96 kilowatt-hour per capita in 2011, according to the World Bank. Electric power consumption measures the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants [3].

The aim of this paper is to project the water and electric consumption of Polytechnic University of the Philippines – Sta. Mesa for the next two years to be able to manage the budget of the university for



the these expenses. This paper will be helpful to the school administration in allotting budget for the projects and other expenses of the university. Analyzing the water and electricity consumption is not only essential for managing expenses but also for the allocation and proper distribution of water and electricity, as well as conserving them.

1.1. Objective of the Study

The purpose of this study is to formulate mathematical models for estimating the water and electric consumption of Polytechnic University of the Philippines – Sta. Mesa. The researchers are to forecast the water and electric consumption of the university for the target year 2016 to 2017. Moreover, forecasting an accurate water and electric consumption would be helpful to manage the budget allotted for the water and electric consumption of PUP – Sta. Mesa for the next two years.

1.2. Research Paradigm

The researchers make use of the monthly data of electric consumption in terms of pesos and kilowatt-hour of PUP – Sta. Mesa. Also, the researchers input the monthly data of water consumption of the university in pesos and cubic meter.

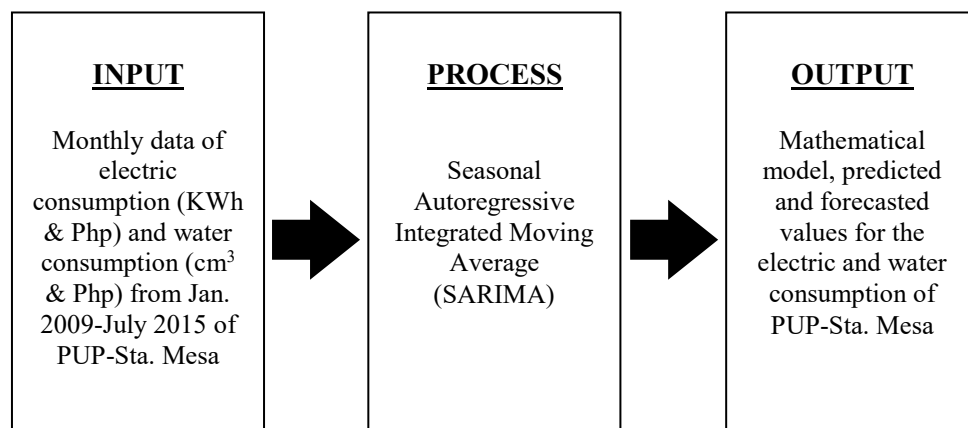


Figure 1. Research paradigm.

They applied Seasonal Autoregressive Integrated Moving Average (SARIMA) in estimating water and electric consumption. The anticipated outputs are the mathematical models, the predicted values, and the forecasted values of electricity and water consumption in pesos, kilowatt per hour, and cubic meter.

1.3. Statement of the Problem

This paper aims to provide the models to forecast the water and electric consumption of PUP – Sta. Mesa. In particular, the researchers want to answer the following questions:

1. What is the behavior of the graph of variables?
 - a. Electric Consumption in peso and kilowatt-hour
 - b. Water Consumption peso and cubic meter
2. What are the mathematical models formulated using SARIMA in estimating the water and electric consumption of PUP-Sta. Mesa?
3. What are the forecasted values of the university's water and electric consumption for 2016 to 2017?
 - a. Electric Consumption in peso and kilowatt-hour
 - b. Water Consumption peso and cubic meter
4. Is there a significant difference between the predicted values and the actual values of the university's water and electric consumptions?

1.4. Scope and Limitations

The researchers analysed the monthly data of water and electric consumption of PUP – Sta. Mesa from January 2009 up to July 2015. This research consists of the years including of the actual data retrieved from the university and the forecasted series from the year 2016-2017.

2. Review Related Literature and Studies

The following researches and studies discuss about the electricity and water consumption in different countries like Taiwan, Japan, and Malaysia. These studies aim to forecast or analyze either the electricity or water consumption in a certain area in their country.

In a research entitled “The Determinants of Household Electricity Consumption in Taiwan: Evidence from Quantile Regression,” showed that the effects of demographic, socioeconomic, and household dwelling characteristics on household electricity consumption may differ across quantiles and may change over time. This study found that household income and household size were significant in all quantiles for each year. The characteristics of high-electricity-consuming households were also identified. Households with higher income, larger household size, and more elderly members consumed more electricity. In terms of dwelling attributes, larger housing areas, homes with more appliances, and owner-occupied, business-used, and multi-floor houses contributed to higher household electricity consumption [4]. These study infers that the consumers can be factor on the electricity consumption of a household. Being a university, most of the electricity consumers in the campus are students and professors which affects the total power usage since they use electricity most of the time for school activities.

In a study entitled “Electricity Consumption Forecasting in Thailand Using an Artificial Neural Network and Multiple Linear Regression,” an artificial neural network (ANN) and a regression model are applied to forecast long term electricity consumption in Thailand. Maximum ambient temperature and electricity power demand are used as inputs to predict electricity consumption. According to the forecasting results by the regression and ANN models of the study, the electricity consumption in Thailand in 2015 is almost 188,552 to 174,394 gigawatt-hour (GWh), and it can reach to 216,986 to 188,137 GWh by 2020 [5].

A study titled as “A Comparative Analysis of Techniques for Forecasting Electricity Consumption,” showed that there is a pattern for electricity consumption over the years in the Universiti Malaysia Sarawak (UMS). Using the actual monthly electricity consumption data over the period between 2009 and 2012, a modified Newton’s model was proposed in forecasting electricity consumption. It is found that consumption is high at certain periods and low at other periods and shows an upward trend for electricity consumption. Increase in electricity consumption could be due to the fact that more heating, ventilation and air-conditioning systems are put into use because of increase in student’s population [6]. Analyzing the electricity consumption in UMS in Malaysia is quite the same with this study on forecasting the water and electricity consumption of PUP – Sta. Mesa

In a study entitled “Modelling Water Consumption in Kalmunai using Time Series Models,” the researcher aims to analysis and identify the best fit time series model to the water consumption in the Kalmunai using time series techniques. Several time series models including autoregressive (AR), moving average (MA) and ARMA were developed to the water consumption data, and it emerged that the most adequate models for the data was ARMA (1, 2) [7]. In this paper, the researchers also used a time series model in forecasting the water consumption in Kalmunai through ARMA models. On the other side, this paper applied seasonal autoregressive integrated moving average (SARIMA) in estimating the water consumption of PUP.

A research in Japan titled as “The Measurement of Electric Consumption of Devices and the Estimation of CO₂ Emission Related to Food Consumption at Households,” to clarify the amount of electric energy consumption related to food consumed in households. The first phase of the study was to measure the amount of electric energy used while cooking with the use of rice cooker, microwave and electric pot. They are considered to be the main source of electricity while cooking. The electricity consumption of the three major household electric cooking devises; electric rice cooker, microwave

and electric pot were estimated at 276 kWh per household per year, which was 14.4 KWh per year and accounted for 5.0% of Japanese household electricity consumption [8].

3. Methodology

3.1. Statistical Tool

EViews is a statistical software for quickly and efficiently managing data, performing econometric and statistical analysis, generating forecasts or model simulations, and producing graphs and tables [9]. The results of this study were generated through this software, as well as the graphs and tables in interpreting the output of the study.

3.2. Statistical Treatment

3.2.1. Box Jenkins Methodology. Box - Jenkins Analysis refers to a systematic method of identifying, fitting, checking, and using integrated autoregressive, moving average (ARIMA) time series models [10]. In formulating the model, the researchers followed the three-step process of this method which were identifying, selecting, and assessing the mathematical model for forecasting both the water and electric consumption in PUP-Sta. Mesa.

3.2.2. Augmented Dickey-Fuller Test. The augmented Dickey-Fuller test is one that tests for a unit root in a time series sample. The primary differentiator between the two tests is that the ADF is utilized for a larger and more complicated set of time series models. The augmented Dickey-Fuller statistic used in the ADF test is a negative number, and the more negative it is, the stronger the rejection of the hypothesis that there is a unit root [12]. It is expressed as: [13]

$$X_t = c + \alpha X_{t-1} + \beta_t + \varepsilon_t$$

where X_t is the time series, c is constant, t is the time trend and ε is the residual term. This test is used in this study to determine whether or not the time series of water and electric consumption exhibits stationarity. The data must exhibit stationarity to be able to formulate a forecasting model, if ever that it is non-stationarity, it must undergone a regular differencing until it satisfy the said condition.

3.2.3. Correlogram. A correlogram is simply a plot of the autocorrelation function for sequential values of lag allowing the researcher to see the correlation structure in each lag. The main usage of correlogram is to detect any autocorrelation subsequent to the removal of any deterministic trends or seasonality effects. If it has fitted a time series model then the correlogram helps to justify that the model is well fitted or whether it needs further refinement to remove any additional autocorrelation [14]. Autocorrelation function is written as:

$$r_k = \left[\frac{\sum_{i=1}^{N-k} (y_i - \bar{y})(y_{i+k} - \bar{y})}{\sum_{i=1}^N (y_i - \bar{y})^2} \right]^1$$

where \bar{y} is the overall mean and n is the sample observation. The correlogram analysis examines the time-spatial dependency within the sample data, and focuses on the empirical auto-covariance, auto-correlation, and related statistical tests. The correlogram is a cornerstone for identifying the model and model order [15]. With the help of the correlograms of each variable that is being analyzed, seasonality patterns are detected. Water and electricity consumption in PUP – Sta. Mesa showed to fluctuate seasonally.

3.2.4. Paired T-test. Paired sample t-test is a statistical technique that is used to compare two population means in the case of two samples that are correlated. Paired sample t-test is used in 'before-after' studies, or when the samples are the matched pairs, or when it is a case-control study. In computing the Paired T-test, the formula used is written as:

$$t = \bar{X}(s^2 n^{-1})^{-1/2}$$

where \bar{X} is the mean difference between two samples, s^2 is the sample variance, n is the sample size and t is a paired sample t-test with $n-1$ degrees of freedom [16]. The researchers make use of this test in comparing the actual values of water and electricity consumption to its predicted values which will be obtained using the formulated model.

3.2.5. Seasonal Autoregressive Integrated Moving Average (SARIMA). Seasonal ARIMA is used in the process of formulating the mathematical model for forecasting water and electricity consumption of PUP – Sta. Mesa. It follows some conditions wherein the time series needs to be stationarity. This assumption can be resolved by differencing the data. SARIMA is used in this study, instead of ARIMA because the time series for both variables showed to have seasonal patterns. The model to be formulated follows an equation written in the form of SARIMA (p,d,q) x (P,D,Q)_s where (p,d,q) is the non-seasonal part of the model that contain the autoregressive (AR) and moving average (MA) terms, (P,D,Q) contains the seasonal AR and MA terms; and s accounts to the seasonal period.

4. Results and Discussions

4.1. Water Consumption

The water consumption displays an upward trend but has its lowest consumptions on every last month of each year because of holiday vacations wherein students are out of school so water has been consumed less.

Table 1. Test for Seasonality for Water Consumption

F-stat Value	0.856104
@trend F-stat Value	0.000000

The seasonality test of the data resulted at 0.856104 that is higher than the hypothesized F-statistic probability value at 0.001, which the researchers concede it to be indicating the failure of rejection of the null hypothesis that there is no seasonality within the data series, and it implies no presence of seasonality. But the data shows an obvious trend in which the pattern starts to exhibit direct upward at the start of every summer seasons. When at trend, the results shows 0.0000 that is obviously lower than the F-stat probability hypothesized value which indicates the rejection of the null hypothesis, that means that there is a necessity for using seasonal differencing for the data series. SARIMA model, where autoregressive, moving average and the seasonal AR and MA terms are produced using the actual data that has undergone non-seasonal and seasonal differencing, are to be regressed and utilized in forecasting the Water consumption of PUP Main campus in the next two years and five months.

Table 2. Unit root testing for the Water Consumption

Augmented Dickey-Fuller Test		
Level	Intercept	0.433235832
	Trend and Intercept	0.003014275
	None	0.047683014
1st difference	Intercept	0
	Trend and Intercept	0
	None	0

When the data has been differenced, the trend has been minimized making the data stationary and deduced it from displaying seasonal recurrence of the data. This indicates that the data now is stationary. Its variance also does not waver vigorously enough to be considered non-stationary. In the correlogram, the differenced data now, exhibits no seasonality, and it indicates that the processed data now can be used to produce combinations of Autoregressive and Moving average terms to choose the fitted model for forecasting the electric consumption of the PUP Main Campus. Also, the correlogram exhibits a positive Autocorrelation indicating the necessity of having seasonal moving average terms. Autoregressive terms may be also included for balancing the equation to satisfy the model fitting assumptions.

Table 3. Model Combinations, r-Square, Durbin-Watson, and MA&AR Processes for Water Consumption

AR and MA terms									R-squared	Durbin-Watson	MA Processes	AR Processes
ar(1)	ar(3)	ar(11)	ma(1)	ma(4)	ma(11)	ma(12)	ma(13)	sar(24)	0.85447	2.51686	Non-invertible	Stationary
ar(1)	ar(3)	ar(11)	ma(1)	ma(4)	ma(11)	ma(12)	sar(24)		0.72702	2.11599	Non-invertible	Stationary
ar(1)	ar(3)	ar(11)	ma(1)	sma(12)		sar(12)			0.71217	2.02298	Invertible	Stationary
ar(1)	ar(3)	ar(11)	ma(1)	ma(4)	sma(12)		sar(12)		0.71187	2.00974	Invertible	Stationary
ar(1)	ar(11)		ma(1)	sma(12)		sar(12)			0.70830	1.99056	Invertible	Stationary

Among the combinations listed, the model has passed the utmost needed assumptions for choosing model in forecasting, where its R-square probability value was approximately 0.7083 which is quite enough for it to be considered fitted, and the model was also based with the Durbin-Watson, and, the Moving Average invertibility and Auto-regressive stationary Processes. The plotted graph of the actual and forecasted data follows a trend which has gone down quite favorably indicating lower expenses in the water consumption in the PUP Main Campus. Therefore, excess budget for the water consumption can be allocated to other expenses of the university. The graph shows that it has not gone beyond 3 million but slightly fall off lower than 2 million pesos at the end of the forecasted series.

Table 4. Paired T-test for Water Consumption

Value	0.46009248056
Probability	0.64700917653

Paired T-test that has failed to reject the null hypothesis, indicates that the mean difference between the paired observations is in close proximity to zero. It means the observations does not differ that much from each other, or these observations be somewhat have values that are close enough for so to compromise that the model is in the vicinity of being fit for the data.

4.2. Electric Consumption

Electric consumption of PUP Main Campus, has its sudden drop of its value seen in the graph line when ever the last month of the year ends. This might probably be, because of Christmas season which the students are having few weeks vacation. The graph shows the bottommost of the line was on the last part of 2009 and 2010, then the graph continued to waver following a slight trend going upward and emanated to its downward trend started from the end of 2013 until the last of the available data collected from the campus.

Table 5. Test for Seasonality for Electric Consumption

F-stat Value	0.856104
@trend F-stat Value	0.000050

The seasonality test shows a probability of F-statistical Probability Value where it has been conceded that the actual data has a seasonality. At 0.1% alpha considered by the investigators, the results shows 0.00005 which has a lower value than the considered alpha for Probability F-stat Value, it means that the null hypothesis is ponderedly rejected indicating the acceptance of the alternative hypothesis that there the data series exhibits seasonal patterns. The correlogram shows also that the actual data exhibits the seasonality visibly on the 12th lag. Autocorrelation (ACF) has its seasonality on the 12th lag, which is positive, directs that the data needs seasonal moving average term which most of the SARIMA models are. Seasonal autoregressive terms may be necessary for balancing out the equation, for MA terms may not be able to be inverted.

Table 6. Unit root testing for the Electric Consumption

Level	Intercept	0.005345186
	Trend and Intercept	0.697542501
	None	0.971813173
1st difference	Intercept	0
	Trend and Intercept	0
	None	0

When the data has been differenced, its graph shows that the trend has been minimized making the data stationary and deduced it from displaying seasonal recurrence of the data. This indicates that the data now is stationary by just looking onto the graph. Its variance also does not waver vigorously enough to be considered non-stationary. In the correlogram, the differenced data now, exhibits no seasonality, and it indicates that the processed data now can be used to produce combinations of Autoregressive and Moving average terms to choose the fitted model for forecasting the electric consumption of the PUP Main Campus. Also, the correlogram exhibits a positive Autocorrelation indicating the necessity of having seasonal moving average terms. Auto regressive terms may be also included for balancing the equation to satisfy the model fitting assumptions.

Table 7. Model Combinations, R-Square, Durbin-Watson, and MA&AR Processes for Electric Consumption

AR and MA terms	R-squared	Durbin-Watson	MA Processes	AR Processes
ar(1) ar(3) ar(11) ma(1) ma(4) ma(11) ma(12) ma(13) sar(24)	0.85447	2.51686	Non-invertible	Stationary
ar(1) ar(3) ar(11) ma(1) ma(4) ma(11) ma(12) sar(24)	0.72702	2.11599	Non-invertible	Stationary
ar(1) ar(3) ar(11) ma(1) sma(12) sar(12)	0.71217	2.02298	Invertible	Stationary
ar(1) ar(3) ar(11) ma(1) ma(4) sma(12) sar(12)	0.71187	2.00974	Invertible	Stationary
ar(1) ar(11) ma(1) sma(12) sar(12)	0.70330	1.99056	Invertible	Stationary

The table of combinations listed where the investigators have chosen a model with 71% R-squared Probability assumption for model fitting, where this model is the third highest R-square probability. All three highest probability has passed Durbin-Watson normality test for data distribution and are stationary with their Auto-regressive Processes but only the third model, SARIMA (2, 0, 4) x (1, 1, 0)₁₂, has been conceded for it passed the Moving Average invertibility process. The model has 3 AR terms, 1 MA term, 1 Seasonal AR term and a Seasonal MA term, which will be used to forecast the actual data. The researchers utilized the model to provide values forecasted of electricity consumption, ranges from the following month of the last of the available data gathered until the last month of 2017. Using dynamic forecasting, further two years and five months of forecasted values has been made. The forecasted data has no observable trend but it wavers less vigorous. That indicates the forecasted values, does not increase or decrease in a huge variations. The values also, does not fall lower than 2

million nor increased higher than three million. Predicted values of electricity consumption produced using the model, were almost having the nearest values with the actual. The predicted also establish a sudden drop as how the actual did at every last month of the year and having the same slight trend that the actual data has time-honoured.

Table 8. Paired T-test for Electric Consumption

probability	p-value
0.461022685	0.742368909

Also, the paired T-test shows that it has failed to reject the null hypothesis, indicates that the mean difference between the paired observations is zero. That means the paired observations does not differ from each other or these observations are rather having values that are close enough for so to concede that the model is nearly fitted.

5. Conclusion and Recommendations

Results revealed perceptible model each for the water and electric consumption of PUP-Main Campus and the forecasted series of the actual data for the next 29 months which were considerably favorable. The models were SARIMA (2,1,2) x (1,1,1)₁₂ for water consumption data series while SARIMA (2,0,4) x (1,1,0)₁₂ for the electric consumption data series. These models are used in predicting the future values of the data series while satisfying the supposition in procreating Seasonal ARIMA Models in which these two have abide by.

Researchers recommend collection of new time series data for further studies. The forecasted series may serve as a basis in planning the water and electricity distribution in the campus. It can also help in reducing and minimizing the expenses of Main Campus in terms of water and electricity consumptions to help with quicker and more accurate decision-making regarding the financial statements. Also to give more attention to other priorities school enhances for students' necessities and for the own new developments for the campus itself.

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