Jurnal Teknologi, 41(B) Dis. 2004: 47–56

WATER USE TREND AT UNIVERSITI TEKNOLOGI MALAYSIA: APPLICATION OF *ARIMA* MODEL

AYOB KATIMON[1] & AMAT SAIRIN DEMUN[2]

Abstract. The paper describes the application of autoregressive integrated moving average (ARIMA) model to represent water use behaviour at Universiti Teknologi Malaysia (UTM) campus. Using autocorrelation function (ACF), partial autocorrelation function (PACF), and Akaike's Information Criterion (AIC), monthly campus water use series can be best presented using ARIMA *(2,0,0)* model. The estimated parameter of the model ϕ_1 and ϕ_2 are 0.2747 and 0.4194 respectively. This implies that water consumption in UTM campus at the present month is not necessarily influenced by water consumption of immediate previous month. Analysis shows that ARIMA *(2,0,0)* model provides a reasonable forecasting tool for campus water use.

Keywords: Water use, university campus, time series, ARIMA model

Abstrak. Kertas kerja ini menerangkan aplikasi kaedah permodelan (*ARIMA*) bagi mewakili perilaku penggunaan air di kampus Universiti Teknologi Malaysia. Menggunakan fungsi-fungsi *ACF*, *PACF* dan *AIC*, siri masa penggunaan air bulanan di kampus UTM boleh dinyatakan dalam model *ARIMA (2,0,0)*. Anggaran parameter model ϕ_1 dan ϕ_2 ialah 0.2747 dan 0.4194. Keadaan tersebut menggambarkan bahawa penggunaan air pada bulan semasa tidak semestinya dipengaruhi dengan tepat oleh kadar penggunaan air pada bulan sebelumnya. Analisis juga menunjukkan model *ARIMA (2,0,0)* boleh diguna sebagai model ramalan guna air di kampus universiti.

Kata kunci: Guna air, kampus universiti, siri masa, model *ARIMA*

1.0 INTRODUCTION

Fresh water supply is an important aspect of public utility to all kinds of building premises. Unlike in housing and residential areas, where the number of household and water use behavior is a pre-determinant factor, public university campus is quite different in terms of population and water usage. The type of building in a university campus is a mix between student residential colleges, office buildings, sport complexes, laboratories, and cafeterias. In addition, the number of people living on-campus varies according to the university academic calendar. For instance, while a large percentage of students live out-campus during the semester break, there are also visiting people staying on-campus during that period. As such, the estimate of the campus water supply is not very direct and need some specific methodology.

[1&2] Department of Hydraulics and Hydrology, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor. E-mail: ayobkatimon@utm.my

The consumption of domestic water at Universiti Teknologi Malaysia (UTM), Skudai campus has been increasing rapidly throughout the years as its population increases. This situation had caused some financial constraint to the university management to acquire and optimise their annual budget. For example, as shown in Figure 1, the total volume of water consumed by both, student residential colleges and academic buildings, had increased from 2.2 million cubic meters in 1998 to about 3.05 million cubic meter in 2002, with an annual increase rate of about 9.7%. This had caused UTM to spend more than RM0.4 million annually just for obtaining fresh water supply from the water board authority. Factors that contributed to such increase are inter alia, the increase in student and staff population, and the increase in new buildings and laboratories.

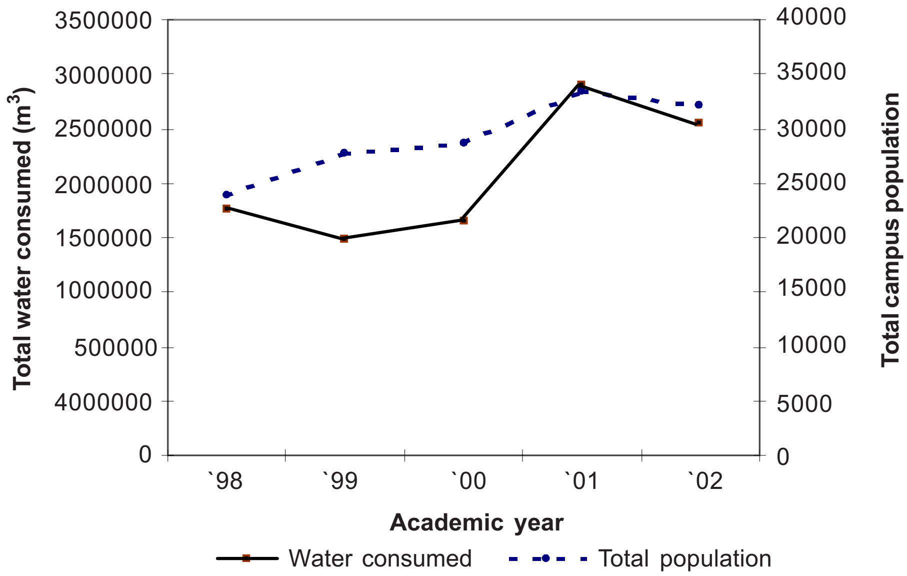

Figure 1 The trend of total water consumption and population at Universiti Teknologi Malaysia from 1998 to 2002 [1]

As indicated in Figure 1, the campus population had increased from 23,870 people in 1998 to 32,082 in 2002, an annual increase rate of about 8.6%. The water consumption rate per person (or per capita) in UTM campus is 94-95 m^3/person/year or 0.26 m^3/person/day. It is known that the majority of people living in the campus are students, which are not fully-residence at all time. Most registered students stay out of campus for several months in a year during the semester break. Comparing the water usage per person in the campus to that of the standard water use rate design for domestic and public building purposes in Malaysia and USA (Table 1), the rate quoted above is considered as high.

The main objective of this study is to analyse the behaviour of water use in a campus environment using time series modeling approach. Using monthly data from 1998 to

Table 1 Water requirement design standard

Use	Quantity (m^3/person/day)
Hostels*	0.18
Day schools*	0.30
Government offices*	0.07
Mosques*	0.014
Domestic**	0.25
Commercial and industrial**	0.15
Public uses**	0.075

Reference: * Malaysian Water Association [2], ** Linsley and Franzini [3]

2002, the study presents some important descriptive statistics to explain the behaviour of absolute and relative water usage. Auto-Regressive-Integrated-Moving-Average (ARIMA) modeling approach was employed to the data set to further investigate the behavioural change in the water usage of a campus environment. The result of the study can be used as a reference guideline to the university campus water budget in particular, and to the annual budget as a whole. Authority from newly established public university campuses would probably find the output of the present study useful in their development planning.

2.0 THE STUDY AREA AND DATA AQUISITION

2.1 The Study Site

(1) Location: The campus at Skudai (UTM), Johor, covering an area of 11.45 km^2 is the main campus of Universiti Teknologi Malaysia. It is located at Skudai District in Johor, Malaysia, and situated at 1°33′35″ N and 103°38′28″ E (Figure 2). The first development work of the campus started in 1983 and subsequently the academic programs started in 1989.

(2) Weather: Due to its close proximity to the equatorial line, the weather of humid tropics climate with abundant rainfall spreads uniformly throughout the year. The annual rainfall is about 2500 mm and relative humidity ranges between 85-87% while air temperature ranges between 22-32°C.

(3) Land use: The general landform of the campus area is hilly type. With the highest spot of the area 152 m above mean sea level (m.s.l.), and the lowest part is 12 m above sea level (m.s.l.), the area is very undulating. A number of small streams, both natural and man-made, exists within the campus area. Most of the

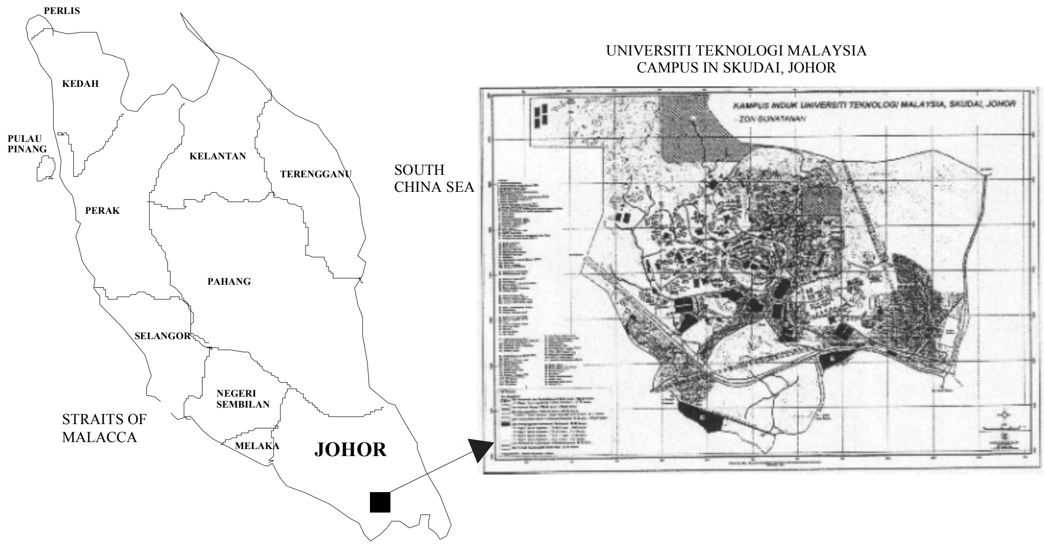

Figure 2 The study site location and UTM campus

streams are ephemeral-type in nature, where they tend to dry up during prolonged dry periods. The overall paved and unpaved ratio of the campus area is about 0.3, indicating that the total built areas including buildings and paved road, covers only about 2.7 km^2 of the total campus area [2].

(4) Academic faculties: Presently, there are eleven faculties of various disciplines operating in the campus. Being the largest technical-based university in the country, all faculties belong to engineering discipline, except the Faculty of Education, Management and Human Resources, and also Faculty of Science. Some of the engineering faculties are offering subjects that are related to water science. These include the Hydraulics and Environmental Engineering Laboratory of the Faculty of Civil Engineering, and Marine Engineering Laboratory of the Mechanical Engineering Faculty. These facilities are considered as water intensive laboratories in the sense that a large volume of water supply is required for the experimental works.

2.2 Data Aquisition

The analysis is based on the monthly water use and campus population data during 1998 to 2002 of the academic years. The total monthly water use in m^3 for 5 consecutive years (60 months) were obtained from the utility section of the Asset & Construction Management Office, UTM (Pejabat Hartabina). However, the population data was obtained in terms of yearly basis only. The breakdown of the people on-campus is given in Table 2 and the summary of the data has been partially presented in Figure 1.

Table 2 Campus population and total water consumed during 1998-2002 [2]

Academic year	Total population			Total water used (m^3) $\times 10^6$
	Student	Academic staff	Non-academic staff	
1998	20657	1387	1826	2.25
1999	23855	1538	2297	1.98
2000	24703	1545	2418	2.15
2001	29393	1547	2453	3.39
2002	28169	1634	2279	3.05

3.0 RESULTS AND DISCUSSION

3.1 ARIMA Model of Water Use

In this study, an appropriate ARIMA model for Campus Water Use (CWU) is investigated. One of the tools for ARIMA model identification is the autocorrelation function (ACF) r(k), and partial autocorrelation function (PACF) of a time series data set $x(t)$ obtained from autocovariance, as follows:

$$\phi(k) = \frac{1}{N}\sum_{i=1}^{N-k}(x_t - \overline{x})(x_{t+k} - \overline{x}) \quad (1)$$

$$r(k) = \frac{\phi(k)}{\phi(0)} = \frac{\phi(k)}{\sigma_x^2} \quad (2)$$

where, k is the time lag, ϕ is the auto-correlation coefficient, N is the length of the series, $\overline{x}$ is the overall mean, and σ_x^2 is the variance.

In ordinary time series modeling, Aikaike Information Criteria (AIC) values and *t-test* are normally used together with ACF and PACF during the identification of the best-fit model.

AIC is defined as [4]:

$$\text{AIC} = -2ln(ML) + 2k \quad (3)$$

where, ML is the minimum likelihood, $ln(ML)$ is the maximized log likelihood function, and k is the number of independently adjusted parameter within the model.

The first term $-2\ ln\ ML$ reflects the statistical fit while the term $2k$ accounts for robustness or parsimonious of the model fit.

The observed monthly Campus Water Use (CWU) for sixty months from 1998 to 2002 is shown in Figure 3. The plot of the ACFs and PACF of the monthly CWU in Figures 4 and 5 indicate that the ACFs decline gradually, implying non-stationary. There is some unclear seasonality trend of the graph. This phenomenon is mainly due to the peak water usage in the campus, which only occurred during the semester session. A true ARIMA seasonal model should contain a more pronounced sinusoidal ACF pattern. However, in this case, the observation period is too short to make a conclusion. Now, it is worth to proceed with ARIMA modeling work by neglecting their seasonal component. The PACFs of the series show two significant spikes at lag 1 and 2, indicating that the series might belong to ARIMA (2,0,0). Nevertheless, the ACFs plot contain a non-stationarities element. Thus, the moving average (MA) of the model is worth considering.

The summary of the statistical output of various trials is presented in Table 3. The model with the smallest Aikaike Information Criteria (AIC) and acceptable *t-test* value is chosen as the best model fitted to the series. After experimenting with various lags of various combinations of ARIMAs, it is found that the series is best fit to ARIMA

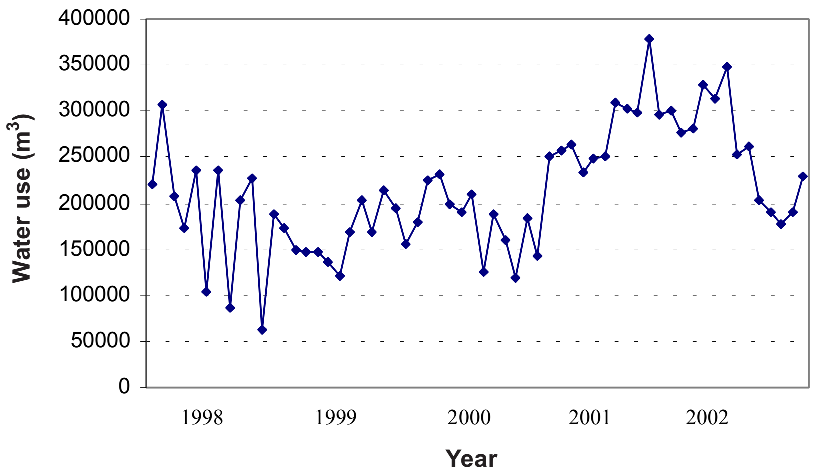

Figure 3 Observed water use data

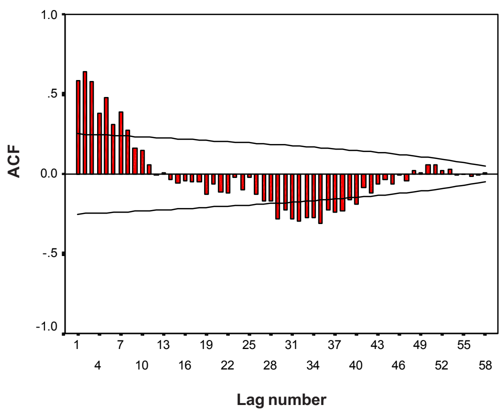

Figure 4 Autocorrelation function plot of CWU

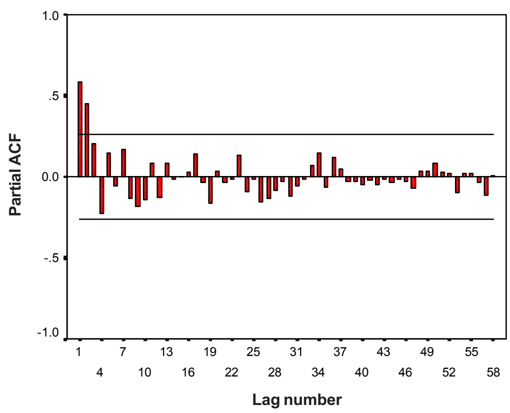

Figure 5 Partial autocorrelation function plot of CWU

Table 3 The fitting of an ARIMA model for monthly CWU series

Model option	Parameter estimates	σ_s *	t-test	AIC's*	C*
ARIMA (1,0,0)	$\phi_1 = 0.4376$	0.1188	3.6847	1478	160342
ARIMA (2,0,0)	$\phi_1 = 0.2747$	0.1214	2.2626	1470	180650
	$\phi_2 = 0.4194$	0.1195	3.5092		
ARIMA (3,0,0)	$\phi_1 = 0.2012$	0.1331	1.5111	1470	194166
	$\phi_2 = 0.3804$	0.1236	3.0777		
	$\phi_3 = 0.1856$	0.1324	1.4024		
ARIMA (1,0,1)	$\phi_1 = 0.8567$	0.1062	8.0658	1473	18382
	$\theta_1 = 0.4950$	0.1854	2.6699		

* σ_s : parameter standard error, AIC: Aikaike Information Criteria, C: Model constant

(2,0,0). This is supported by its smallest residual values and largest t statistic value. The ARIMA equation for CWU is written as follows:

$$\begin{aligned}(1-\phi_1 B-\phi_2 B^2)x_t &= C+a_t \\ (1-0.2747B-0.4194B^2)x_t &= 180650+a_t\end{aligned} \tag{4}$$

where B is the backshift operator ($B^i x_t = x_{t-i}$), x_t is the time series, and a_t is the residual.

3.2 Diagnostic Checking of ARIMA (2,0,0) for Monthly Water Use

The next step of model identification method of time series modeling approach is diagnostic checking. It is aimed at examining the accuracy of the chosen model in ensuring that the modeling assumptions are satisfied. Several procedures can be applied to check the adequacy of the model as to whether the model satisfies the stability or stationary condition, as required in stochastic modeling works [5]. The stationary condition is satisfied when the roots of the characteristics equation lie outside the unit circle [6]. For an ARIMA (2,0,0) model, the following three conditions must be met [7]:

$$|\phi_2| < 1 \tag{5}$$

$$\phi_1 + \phi_2 < 1 \tag{6}$$

$$\phi_2 - \phi_1 < 1 \tag{7}$$

Based on these criterias, it is found that the ARIMA (2,0,0) model of the CWU series (Equation 4) satisfies the stationary condition, in which $|\phi_2| = 0.4149 < 1$, $\phi_1 + \phi_2 = 0.6941 < 1$, and $\phi_2 - \phi_1 = 0.1447 < 1$. To double-check such stationary condition, the graphical method can also be used by examining the ACF and PACF plot of the residual series [8]. For a stable model, the ACF and PACF plot of the model residual should be without pattern and not significantly different from zero. The residual series should be independent, homoscedastic (having constant variance), and normally distributed [4]. In other words, they should be white noise. Figures 6 and 7 show the plot of the ACF and PACF of the residuals series. It is obvious that the plots are without pattern and normally distributed. Hence the model in Equation 4 can be accepted as the best-fit model for the CWU series.

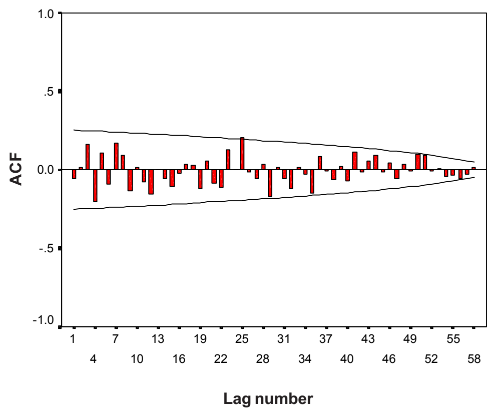

Figure 6 Autocorrelation function plot of ARIMA (2,0,0) residual

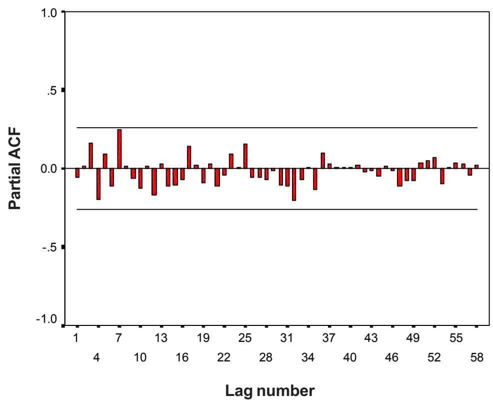

Figure 7 Partial autocorrelation function plot of ARIMA (2,0,0) residual

Equation 4 can be decomposed into,

$$x_t = 180650 + 0.2747 x_{t-1} + 0.4194\, x_{t-2} + a_t \tag{8}$$

where a_t is a white series or $a_t \approx NID(0,\sigma^2)$.

Equation (5) can also be expressed as,

Modeled CWU (x_t) = (slope*previous month x_t) + (slope* present two-month's) + error + a constant value

The modeled values of WCUs using ARIMA (2,0,0) compared to the actual water used (observed) are presented in Figure 8.

4.0 CONCLUDING REMARKS

This paper examined the time series behaviour of water uses in UTM campus. The campus water use rate per capita is 0.26 m^3 per day. The results from the fitted ARIMA models indicate that the water use series are generated by autoregressive processes of the second degree (ARIMA 2,0,0). This implied that the present month water use was

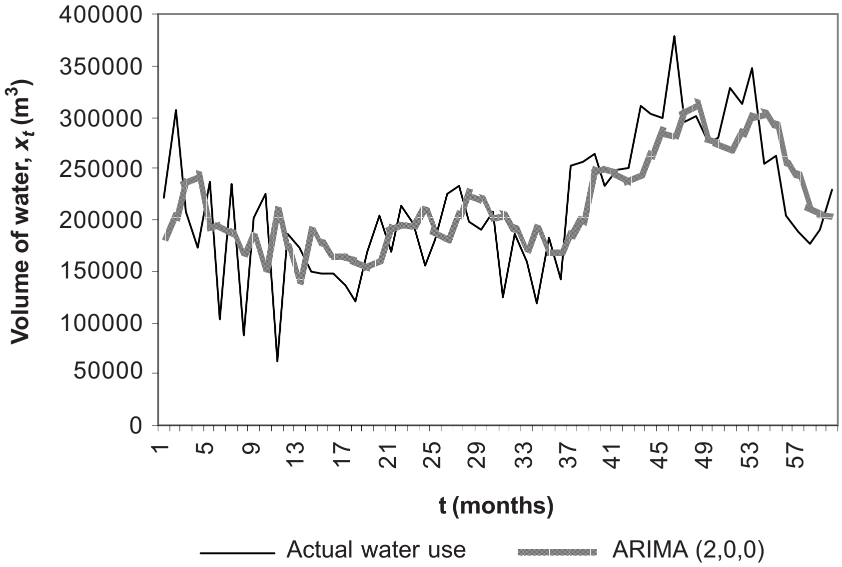

Figure 8 Model fitted values from ARIMA procedures compared to the observes values

not exactly influenced by the immediate previous month water use. In other words, the autoregressive time series model of the monthly water use in UTM campus has had little memory effect in the sense that the water use trend does not simply follow a Markovian process. This has to be expected since the total campus population and water use volume are changing according to university's calendar, and schedules for various programs and activities.

ACKNOWLEDGEMENT

The authors would like to thank Miss Judy Kullan anak Edward Inyok for the data collection, the engineers from Pejabat Hartabina UTM for providing assistance in this study, and Mr Raduan Shaari for providing some surveying information. Constructive comments from the referees are also appreciated.

REFERENCES

[1] Edward Inyok, J. K. 2004. Kajian Sumber Air Berpotensi di Universiti Teknologi Malaysia Menggunakan Program Perisian HEC-HMS. *Laporan Projek Sarjana Muda*. Universiti Teknologi Malaysia.

[2] Malaysia Water Association. 1994. *Design Guideline for Water Supply System*. Kuala Lumpur: Percetakan Nasional Malaysia Berhad.

[3] Linsley, R. K., and J. B. Franzini. 1979. *Water Resources Engineering*. Singapore: McGraw-Hill.

[4] Hipel, K.W., and A. I. McLeod. 1994. *Time Series Modeling of Water Resources and Environmental Systems*. Amsterdam: Elsevier.

[5] Haan, C. T. 1979. *Statistical Methods in Hydrology*. Ames: Iowa State University Press. 275-288.

[6] Box, G. E. P., G. M. Jenkins., and G. C. Reisel. 1994. *Time Series Analysis Forecasting and Control*. 3rd ed. New Jersey: Prentice Hall.

[7] Pankratz, A. 1991. *Forecasting with Dynamic Regression Models*. United States: John Wiley.
[8] Ahmad, S., I. H. Khan, and B. P. Parida. 2001. Performance of Stochastic Approaches for Forecasting River Water Quality. *Water Research* 35(18): 4261-4266.