ANALYSIS OF DOMESTIC WATER CONSUMPTION IN MALAYSIA

FILZAH BINTI ALI HASSAN

UNIVERSITI TEKNOLOGI MALAYSIA

ANALYSIS OF DOMESTIC WATER CONSUMPTION IN MALAYSIA

FILZAH BINTI ALI HASSAN

A project report submitted in partial fulfillment of the requirements for the award of the degree of Master of Engineering (Civil - Hydraulics & Hydrology)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

JANUARY 2013

ACKNOWLEDGEMENT

In the name of ALLAH, the Most Gracious and the Most Merciful.

All praises to ALLAH for the strengths and His blessing in completing this project. My appreciation to the following parties for their kind cooperation and permission in providing access to information on the study: Water Supply Department-Ministry of Energy, Water and Green Technology, Economic Planning Unit, Statistical Department, National Water Services Commission (SPAN), The Malaysian Water Association (MWA) and Department of Irrigation and Drainage (DID).

This project would not have been possible without the guidance and constant support of my supervisor, Assoc. Prof. Dr. Shamsuddin Shahid and several individuals who in one way or another contributed and extended their valuable assistance in the preparation and completion of this study.

ABSTRACT

Knowledge about water consumption is very important for water resources development, management and planning at both short-and long-term scales as well as sustainable development of a country. As water demand depends on various factors, it is very important to identify those factors and to know the influence of those factors in water consumption in order to better manage the water resources. The objective of the present research is to assess the trend of water consumption per capita in different states in Malaysia over the time period of 1991-2010, where it is found that all states have significantly increase their water consumption per capita with highest magnitude of increment +7 litres per capita per year for Negeri Sembilan. Other objective is to measure the influence of various factors on domestic water consumption in different states of Malaysia. As economic and climate variables have significant effects on water consumption, data of domestic water use, water price, per capita GDP and averaged annual rainfall of different states of Malaysia over the time period 1991-2010 are analysed in this project by using various statistical methods such as partial correlation and multiple-regression in order to measure the influence of different factors on domestic water consumption. It is found that the most influential factor on water consumption in Malaysia is GDP. In Johor, water price and rainfall are found to be the influence factors, while in Terengganu water price found to be the significant influential factor. Sensitivity analysis is also carried out to understand how variation of these factors changes water consumptions. Both statistical methods; multi-linear regression and artificial neural network can examine the extend of linear and non-linear relationship between the variables that have impact on water consumption level and predict accurately with reasonable amount of error.

ABSTRAK

Pengetahuan mengenai penggunaan air adalah sangat penting dalam pembangunan sumber air, pengurusan, perancangan jangka pendek dan jangka panjang dan juga terhadap kelestarian pembangunan sesebuah negara secara keseluruhannya. Memandangkan permintaan air bergantung kepada pelbagai faktor, adalah sangat penting untuk kita mengenalpasti faktor-faktor ini dan pengaruhnya ke atas permintaan air supaya sumber air dapat diuruskan dengan lebih baik. Objektif kajian ini ialah untuk mengetahui trend penggunaan air di negeri-negeri di Malaysia sepanjang tempoh 1991-2010 di mana didapati bahawa kesemua negeri menunjukkan trend menaik dengan magnitud terbesar ialah +7 liter per kapita per tahun untuk Negeri Sembilan. Objektif lain ialah untuk mengkaji pengaruh ekonomi dan iklim ke atas penggunaan air domestik. Sehubungan dengan itu, data-data penggunaan air domestik, tarif air, GDP per kapita dan purata hujan tahunan untuk negeri-negeri di Malaysia dari tahun 1991 hingga 2010 dianalisa menggunakan pelbagai kaedah statistik seperti kaedah separa–kolerasi dan regresi-berbilang bagi mengukur pengaruh faktor-faktor ini terhadap penggunaan air di negeri-negeri di Malaysia. Didapati faktor yang paling berpengaruh ke atas penggunaan air di Malaysia ialah GDP. Di Johor, kadar harga air dan hujan adalah berpengaruh sementara di Terengganu didapati kadar harga air adalah berpengaruh. Analisis sensitif juga dibuat supaya sebarang perubahan kepada faktor berpengaruh ini dapat difahami kesannya terdapat permintaan air. Kedua-dua kaedah statistik iaitu regresi-berbilang dan artificial neural network didapati berupaya memberi hubungan linear dan tidak linear di antara pembolehubah yang memberi impak kepada kadar penggunaan air. Kaedah-kaedah tersebut juga dapat meramal dengan agak tepat pengunaan air domestik per kapita di masa depan dengan kadar ralat yang munasabah.

TABLE OF CONTENTS

CHAPTER	TITLE		PAGE
	DECLARATION		ii
	ACKNOWLEDGEMENTS		iii
	ABSTRACT		iv
	ABSTRAK		v
	TABLE OF CONTENTS		vi-ix
	LIST OF TABLES		x-xi
	LIST OF FIGURES		xii
	LIST OF ABBREVIATIONS/SYMBOLS		xiii
	LIST OF APPENDICES		xiv
1	**INTRODUCTION**		**1**
	1.1	Introduction	1
	1.2	Problem Statement	3
	1.3	Objectives of the Study	3
	1.4	Scope Limit	4
	1.5	Significant of the Study	4
2	**LITERATURE REVIEW**		**5**
	2.1	Water Resources	
		2.1.1 Global Water Resources	5
		2.1.2 Malaysia Water Resources	6
		2.1.3 Status of National Water Use	7
		2.1.4 Competition for Water	9
	2.2	Water Consumption	9

	2.2.1	Definition	9
	2.2.2	Comparison with Selected Countries	10
	2.2.3	Defining Basic Water Requirement	11
2.3	Water Price		14
	2.3.1	General	14
	2.3.2	Water Tariff Structure	17
	2.3.3	Tariff Design Options	18
	2.3.4	Current Charging Structure	20
	2.3.5	Disagreement Over Water Pricing	22
	2.3.6	Objectives of Water Tariff Design	23
2.4	GDP		24
	2.4.1	Definition	24
	2.4.2	GDP Approach	25
	2.4.3	Malaysia GDP in Comparison with Selected Countries	26
2.5	Factors Affecting DWC per Capita		27
	2.5.1	General	27
	2.5.2	Economic Factors	28
	2.5.3	Price Elasticity	29
	2.5.4	Climatic Factors	29
3	**METHODOLOGY**		**31**
3.1	Introduction		31
3.2	Study Area		33
3.3	Collection of Data		33
	3.3.1	Domestic Water Consumption	33
	3.3.2	GDP Data	35
	3.3.3	Water Price Data	38
	3.3.4	Rainfall Data	39
3.4	Trend Analysis		41
	3.4.1	Mann Kendall Trend Test	41
	3.4.2	Sen’s Slope Method	42
3.5	Correlation Analysis		43
	3.5.1	Correlation Coefficient	43

	3.5.2	Partial Correlation	44
	3.5.3	Kendall τ Rank Correlation	46
3.6	Linear Regression		48
	3.6.1	Multi Linear Regression	49
	3.6.2	The Goodness Fit	52
3.7	Artificial Neural Network		53
	3.7.1	Multilayer Perceptron NN Model	53
	3.7.2	Multilayer Perceptron Architecture	54
	3.7.3	Activation Function	55
	3.7.4	Training	56
4	**RESULT AND DISCUSSION**		**57**
4.1	Data Observation on year 2010		57
	4.1.1	DWC and GDP	57
	4.1.2	DWC and Water Price	60
	4.1.3	DWC and Rainfall	62
4.2	Summarization of Data		65
4.3	Trend Analysis		66
	4.3.1	Summarization of DWC by States	66
	4.3.2	Summarization of DWC by Year	67
	4.3.3	Application of Software	69
4.4	Partial Correlation and Kendall tau Rank Correlation (Calibration Stage)		72
	4.4.1	GDP	72
	4.4.2	Water Price	73
	4.4.3	Rainfall	75
4.5	Multi Linear Regression (Calibration Stage)		76
	4.5.1	Elasticity of Income	77
	4.5.2	Elasticity of Price	78
4.6	Multi Linear Regression (Testing Stage)		79
4.7	Artificial Neural Network		81
	4.7.1	Training and Testing Stage	81
	4.7.2	Training and Testing Stage (Selangor)	82

		4.7.3 Forecasting Domestic Water Consumption (for Selangor)	84
5	**CONCLUSION**		**87**
	5.1	Conclusion	87
	5.2	Recommendation	88
REFERENCES			**89-91**
Appendices A			**92**
Appendices B			**95**
Appendices C			**113**
Appendices D			**133-145**

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Global water resources	6
2.2	Total domestic, industrial and industrial demand	8
2.3	Standard for water consumption	12
2.4	Domestic water use by distance to water source	12
2.5	Rural household water use	13
2.6	Recommended basic water requirement	14
2.7	Domestic water rates for year 2011	15
2.8	Summarize performance of tariff structure type	21
3.1	Calculated DWC for every states	35
3.2	GDP per capita for year 1990	36
3.3	GDP per capita for year 1995 & 2000	37
3.4	Domestic water rates by block tariff structure	38
3.5	Calculated water price	39
3.6	Averaged annual rainfall data	40
3.7	Sample of partial correlation output	45
3.8	Sample of Kendall Ƭ output	47
4.1	DWC and GDP data for year 2010	59
4.2	DWC and water price data for year 2010	62
4.3	DWC and rainfall data for year 2010	64
4.4	Summarization of variables	65
4.5	Summarization of water consumption by state	67
4.6	Summarization of water consumption by year	68
4.7	Trend and magnitude of DWC for different states	70
4.8	Mann Kendall and Sen’s slope result	71

4.9	Correlation between DWC and GDP	73
4.10	Correlation between DWC and water price	74
4.11	Correlation between DWC and rainfall	75
4.12	MLR equation produced by calibration stage	76
4.13	Prediction of DWC from MLR equation	80
4.14	Percentage of data sample use for training and testing	81
4.15	Error during training and testing stage	82
4.16	ANN prediction result for Selangor	84
4.17	DWC forecasted by ANN	86

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	Percentage of global water resources	6
2.2	Water demand for Peninsular Malaysia	8
2.3	Daily water consumption in selected countries	10
2.4	Hierarchy of water requirement	11
2.5	Basic types of water tariff structure	18
2.6	Price of water versus quantity of water	19
2.7	Monthly water bill versus quantity of water used	20
2.8	GDP of selected countries	26
2.9	GDP per capita of selected countries	27
3.1	Methodology flowchart	32
3.2	Partial correlation relationship	45
3.3	Multilayer perceptron of ANN	54
3.4	Multilayer perceptron of architecture	55
4.1	DWC versus GDP for year 2010	58
4.2	Water Use / GDP for year 2010	60
4.3	DWC versus water price for year 2010	61
4.4	DWC versus rainfall for year 2010	63
4.5	Variation of DWC over time for Negeri Sembilan	71
4.6	Influencing factors by MLR	77
4.7	The value of R2 during testing stage for Perak	80
4.8	Selangor multilayer network ANN	83
4.9	Actual and prediction of DWC for Selangor	85

LIST OF ABBREVIATION / SYMBOLS

DWC	-	Domestic Water Consumption per capita per day
GDP	-	Gross Domestic Product
LPD	-	Litre per capita per day
RF	-	Rainfall
WP	-	Water Price

LIST OF APPENDICES

APPENDIX.	TITLE	PAGE
A	Trend Test and Sen's Slope Output	92
B	Partial Correlation Output for Selangor	95
C	Regression Output for Selangor	113
D	ANN Output for Selangor	133

CHAPTER 1

INTRODUCTION

1.1 Introduction

Providing water is never free; the water needs to be collected, stored, treated and distributed. Providing too much water is a waste of money. Taking too much water from a limited source may deprive people elsewhere of water and have adverse environmental and health impacts.

In 1970s, a person in Malaysia use only less than 200 litres of water per day, then the amount increase to 250 litres in 1980s and now more than 300 litres (Chan,2004). As comparison, water use recommended by United Nation for Malaysia is only 200 litres.

With the growth of population, economic development, rapid urbanization and climate change, countries of the world is facing to a condition of water scarcity. Malaysia is blessed with abundant of rainfall that contributed to abundant of water resources, but inefficient management and abuse of water usage have resulted in water crisis that caused hardships.

In 1997 prolonged dry-spelled reduced water supply and compelled people to adopt water demand management. For sustainable management of water resources, countries of the world is bit by bit shifting from supply based water management to demand based water management. Policy of Malaysian government is also to achieve sustainability of water resources.

For efficient and sustainable management of water resources, it is very essential to understand the pattern of water consumption. Usually, water consumption pattern depends on certain socio-economic and climatic factors. Numerous studies have been carried out so far in various parts of the world to understand how different factors influences water consumption. However, only a few research has been done on estimation of water demand in Malaysia.

Rapid urbanization, industrialisation, growth of population and irrigated agricultural causing growing demands and pressure on water resources. In region of high demand such as Klang Valley, the practicable limit of surface water resources development has been reached. In cities, current approach is supply-driven; where when there is shortage, new sources are developed. However, this traditional approach is no longer sustainable because of the ever-increasing demand of water. The appropriate approach would be water demand management that emphasize on water conservation measure.

Therefore, in the context of environmental change it is necessary to know the trend of domestic water consumption per capita, the significant factors contributing the increment of consumption rate and quantitative impacts of these factors on water consumption in different states of Malaysia.

1.2 Problem Statement

i. What are the factors affecting domestic water consumption and the measure of the influence of this factors?

ii. How is GDP can be related to domestic water consumption? Do highly urbanized and industrialized states (with high GDP rate) consume more water in their household compared to states with lower GDP?

iii. Is climatic factors like rainfall are less influence compared to economic factors like water price and GDP?

1.3 Objectives

The major objective of the proposed research is to use various statistical methods to identify the trends in water consumptions and the factors contributing consumptions in different states in Malaysia. The detail objectives are:

i. to assess the trend of water consumption per capita in different states in Malaysia over the time period (1991-2010)

ii. to assess the significance of various economic and climatic factors on domestic water consumption in different states of Malaysia

iii. to estimate the sensitivity of domestic water consumption to various economic and climatic factors in different states of Malaysia

iv. to use Artificial Neural Network (ANN) for forecasting water consumption from economic and climatic factors.

1.4 Scope of Study

i. This study covers data from year 1991-2010.
ii. Area of study includes all states in Malaysia except Federal Territory of Labuan
iii. Data used for this study are domestic water consumption per capita, GDP per capita, domestic water price and averaged annual rainfall.
iv. Data were acquired from the publication by the Government agencies which are Malaysian Water Association, Department of Irrigation and Drainage, Department of Statistic and Economic Planning Unit.
v. Research only focus on domestic water consumption since 86.7% (year 2010) of the water supply use goes to domestic sector.

1.5 Significant of the Study

It is expected that the study will help to understand possible change of water consumption in Malaysia due to economic development, water pricing and climate change.

It is also expected that this study would enable the industry to know with reasonable confidence how changes in water prices would affect the quantity of water customers would use and probably from there we might know whether or not prices changed would affect customers' behaviour toward usage of water.

REFERENCES

Abdullah, K. & Mohamed, A. (1998). Water-A situation Appraisal and Possible Actions at the Community Level. Seminar on Local Communities and the Environment II, Environment Protection Society Malaysia, Petaling Jaya

Al-Quanibet, M.H., Johnston, R.S., (1985). Municipal demand for water in Kuwait: methodological issues and empirical results. Water Resources Research 2(4):433-438.

Agthe, D. E., and R. B. Billings (1980), Dynamic models of residential water demand, Water Resour. Res., 16(3), 476–480, doi:10.1029/WR016i003p00476.

Azhar, M. (2000). Managing malaysian water resources development. Buletin Kesihatan Masyarakat Isu Khas 2000, 40–58.

Boland, J.J.; Whittington, D. (2000): Water Tariff Design in Developing Countries: Disadvantages of Increasing Block Tariffs and Advantages of Uniform Price with Rebate Designs. Ottawa, ON, Canada: IDRC Research Paper. URL [Accessed: 20.07.2010]. PDF

Chan N.W. (2000), Water Resourced Management in Malaysia: NGO Perspectives http://www.waterwatchpenang.org/upload_files/12/Water%20Resources%20Management%20in%20Malaysia-NGO%20Perspectives.pdf

Daihuisenm J.M. Florax, R.J.G.M de Groot, H.L.F. & Hijkamp P. (2003). Price and Income Elasticity of Residential Water Demand: A Meta-Analysis. Land Economics, 79(2), 292-308

Espey, M. Espey J and Shaw W.D (1997) Price Elasticity of residential Demand for Water: A Meta-Analysis. Water Resources Research, 33 (6), 1369-74

Gleick, P.H and M.IWRA (1996) Basic Water Requirement For Human Activities: Meeting Basic Needs Water International (1996) Volume: 21, Issue: 2, Publisher: Routledge, Pages: 83-92

Griffin, R.C., Chang, C., (1990). Pre-test analysis of water demand in thirty communities.Water Resources Research26 (10), 2251–2255.

Government of Malaysia, 8th Malaysia Plan, 7th Malaysia Plan: Economic Planning Unit, Prime Minister Department, Malaysia

Government of Malaysia (2012), Statistical Department of Malaysia http://www.epu.gov.my/html/themes/epu/images/common/pdf/eco_stat/pdf/2.1.1.pdf

Hewitt, J. A. and Hanemann (1995) W. M. Land Economics Vol. 71, No. 2 (May, 1995), pp. 173-192

Lee, C. (2005). Water Tariff and Development : The Case of Malaysia: Universiti Malaya June 2005

Lee K.Y. (2006) Paying for Water Services: Understanding the Basics, Water Malaysia Issue No:12 (January 2006), Pages: 11-13

Martinez A.J, Schlupmann,K, (1992) La ecologia y la economia. Fondo de Cultura Economica, Madrid

Nieswiadomy, M. L. and Molina, D. J. (1988), Urban Water Demand Estimates Under Increasing Block Rates. Growth and Change, 19: 1–12. doi: 10.1111/j.1468-2257.1988.tb00458.x

Renwick, M.E. & Archibald, S.O. (1998) Demand side management policies for residential water use: Land Economics, 74 (3), 343-60

Oliver, A. (2006): Water Tariff Increase in Manaus (Brazil): An Evaluation Of The Impact On Households. Paris: DIAL. URL [Accessed: 20.07.2010]. PDF

Sahid S. (2012) Lecture Notes MAL 1303 Faculty of Civil Engineering E-Learning Universiti Teknologi Malaysia, Malaysia

Serrano, A., Duarte, R., & Pinilla, V. (2000) Looking backward to look forward : Water use and economic growth from a long-term perspective, 1–29.

The Malaysian Water Association, Malaysia Water Industry Guide Year 2011, 2010, 2009, 2007, 2006, 2005, 2004, 2003, 2002, 2001

UN Water (2012). Retrieved from http://www.unwater.org/statistics_res.html

Water Supply Branch, Public Works Department Malaysia, Malaysia Water Industry Report Year 94/95, 95/96, 96/97, 98/99

Yuan Zhou, Richard S.J. Tol (2005) Water Use in China's Domestic, Industrial and Agricultural Sectors: An Empirical Analysis, Water Science and Technology: Water Supply, 5 (6), 85-93