Journal of Civil Engineering and Environmental Technology
Print ISSN: 2349-8404; Online ISSN: 2349-879X; Volume 1, Number 4; August, 2014 pp. 71 – 77

http://www.krishisanskriti.org/jceet.html

Residential Water Demand Estimation in Urban Poor Area of Developing Country

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Abstract: **Water stressed urban environment of developing countries are prone to suffer water scarcity due to increasing pressure of socio-economic and demographic variables. Thus, it is critical to assess which factors are more critical both in theory terms and also in technical and policy related matter with reference to residential water use (RWU). In this study empirical studies are used to understand the behavior of socio-economic and demographic variables on RWU in urban poor area of Jaipur city. This study examined the impact of household income (I), age of respondent (A_R), household size (SIZE), age of home (A_H), wealth (W), asset score (AS), dwelling status (DWELL), monthly expenditure on water supply (EXP_WS), number of bathrooms (BATHR), temperature (TEMP) and number of rooms (RMS) on RWU using a multivariate regression analysis technique. Empirical studies reveal that RWU is mainly characterized by SIZE, I and TEMP and little effects have been observed for other socio-economic and demographic variables. Household size mainly determined the water demand in comparison to other socio-economic demographic variables. Therefore major saving should be achieved by the behavioral change in their water using practices. This is explained by the fact that water consumption are already at threshold level due to meager living standard. Therefore there is need of upgrading the water supply service by in-house connections and behavioural changes in water using practices.**

Key Words: Socio-Economic and Demographic Variables, Residential Water Use (RWU), Urban poor, behavioral changes

INTRODUCTION

Most of the urban centers in developing countries are facing shortage of municipal water supplies. There is limit to development of available water resources for urban water supplies. The household water demand management turns out to be an attractive option for managing scarcely available water resource. Forecasting of residential water demand is a crucial component in the successful operation and management of water supply system of a city[9].Most of the previous water demand studies reveal that residential water demand is determined by the number of households socio-economic and demographic variables viz; household size, monthly household income, wealth of household, water price, seasonal variation in temperature and population etc[12,2,3,5.4.11.6.10].Econometric model of residential water demand is used to assess the effect of independent socio-economic and demographic variables on residential water use [15].Econometric forecasting approach captured all socio-economic and demographic variables in water demand studies. It is based on statistically estimating historical relationship between independent variablesand water consumption assuming that this relationship will continue into the future [11].

This paper gave a deep insight on identifying the factors affecting urban water consumption in urban poor area of Jaipur city. Most households living in urban poor area of the city are forced to cope with inadequate and unreliable water supply, spend time and money on expensive and unsafe substitutes.

DESCRIPTION OF THE STUDY AREA

Jaipur (Figure 1) is the capital of Rajasthan, India. It is located in $26^0$25' N latitude and $75^0$52' longitude in eastern part of Rajasthan [12]. In the last few decades high growth rate of urbanization (44.56%), migration of rural peoplestowards urban area for better earnings and high living standard has created the urban slum. Approximately 29.1% of the city population living in these informal squatters at the foothills, near drain, along road side, near bus station, railway station and near solid waste dumping sites at the periphery of the city [13]. This type of upsurge in population exerts tremendouspressure on the city's infrastructure and urban utilities services like water supply. They don't have access toin-houseservicecorrection and face water insecurity problems.

SURVEY DESIGN

To accomplish the specific objectives of the study, primary data collections was done for household socio-economic and demographic variables from households through well designed questionnaire using a stratified random sampling method and main preference were given to female respondents because they generally faces the water insecurity problems. Questionnaire used for the present

study was designed on the basis of previous literature and consultation with the experts from Rajasthan State Water Supply Department, academician and local representatives [14]. The designed questionnaire was first pre-tested on a sample group of representatives to minimize the strategic, hypothetical and compliances biases arises during the survey. Problematic and ambiguous questions were rephrased during the pre-testing of questionnaire if the respondents were not responding on that question. Developed questionnaire solicit information on household socio-economic, demographic characteristics, water supply conditions and water use. The detailed description of the study area and sampling profile enlisted in Table 1. To take a whole representation of the city slum population, four sampling locations were selected as deemed fit and shown in Table 1 and Figure 1.

DESCRIPTION OF DATA SETS

Socio-demographic data needed for the analysis was extracted from in-personal questionnaire survey interview. The socio-economic demographic variables used for the water demand estimation study were household income (I), age of respondent (A_R), household size (SIZE), age of home (A_H) , wealth of household (W), asset score (AS) , dwelling status (DWELL), monthly expenditure on water supply (EXP_WS), number of bathrooms (BATHR) , number of rooms (RMS) and seasonal variation in temperature (TEMP) etc as shown in Table 2

METHODOLOGY

The sets of independent data used for water demand modeling are socio-economic and demographic variables. These data sets were first checked for normality, linearity and homogeneity and the variables which didn't match the assumptions were excluded. Then among the n sets of independent variables, significant variables were selected on the basis of factor score through Principal Component Analysis (PCA). Then econometric water demand model was developed by using the significant independent variables and dependent variable through multivariate regression analysis method.Software used for the present study is XLSTAT 2010. It is a leading data analysis and statistical software for Microsoft Excel [1].

ANALYTICAL APPROACH

In order to find out the structural relationship between residential water use and socio-economic and demographic variables, multivariate statistical analysis was used [14]. The general model used for the present study is given by the equation (1).

$$RWU=f(X_1, X_2,\ldots\ldots X_n)+u\ldots\ldots\ldots\ldots..(1)$$

Where, RWU is the quantitative household water use, u is the error term and *f*(.) denotes the function of explanatory independent socio-economic and demographic variables. In this study specific household socio-economic and demographic variables were used to assess their influence on residential water use (RWU). These variables were used because they were deemed to most likely influence the domestic water demand.

RESULTS AND DISCUSSION

Residential water use is characterized by SIZE, I and TEMP. Standardized model coefficients value of SIZE, I and TEMP are 0.694, 0.172 and 0.168 respectively at 95% confidence interval as shown in the Figure 2. Standardized model coefficients account for the dependence of different parameter magnitudes by scaling the equation coefficients by their estimated standard deviations. Hence RWU increase with increase in the value of these variables and decrease vice versa. More is the SIZE, I and TEMPmore is the demand of water for daily household routine activities. Water use increased with temperature due to more water demand of water for indoor and outdoor activities in summer season. To incorporate seasonal effects, same monitoring and survey has been carried out in peak (summer) or off-peak (winter) season. Negligible effect has been observed with respect to other socio-economic and demographic variables (I, A_R, A_H, W, AS, DWELL, EXP_WS, BATHR, TEMP and RMS) on RWU. This is explained by the fact that most of the respondent living in this study area are under BPL (below poverty line). So they don't have adequate infrastructure services and survive at meager living standard. Their water consumption is already at a threshold level due to absence of in-house water supply connections and lowliving standards as shown in Table 2. The same study has been confirmed by the comparative analysis with previous studies as shown in the Table 4. Therefore in designing and policy formulation of water supply is slum area, main contribution should be given to SIZE, TEMP and I variables.

Goodness of fit statistics reveals that coefficient of determination (R^2) is 0.768 (Figure 3). Therefore estimated simulated water demand equation is considered as an equation of very good fit and 76.8 % of the variation in water use is explained by independent variables and remaining 23.2% is unexplained by the model. This discrepancies in the result were found (76.8%) indicates that additional factors are influencing domestic water demand that could not be explained by the model.

CONCLUSION

Residential water demand of the slum area of Jaipur city is characterized by household size (SIZE), income (I) and temperature (TEMP), where SIZE (0.694) has major influence on RWU as shown by their high standardized model coefficients value at 95% confidence interval. Little or negligible effects have been observed for other socio-economic and demographic variables. This is explained by

the fact that most of the respondent are at meager living standard and have absence of basic infrastructure services. (water supply &sanitation), assets and water consuming appliances (WCA). Their water consumption are already at threshold level due to meager living standard, so here there is need of upgrading the water supply service by in-house connections and behavioural changes in water using practices for secure water supply.

ACKNOWLEDGMENT

We would like to express our sincere gratitude to our esteem institutes, University of engineering and Management, Jaipur and Malaviya National Institute of Technology, Jaipur, for providing all the necessary facilities. We would also thankful to Public Health Engineering Department for their assistance and guidance in providing in preparing questionnaire.

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LIST OF TABLES

Table 1: Sampling Profile of the Study Area

S. No.	Study Area ID	Sampling Locations	Ward Number	No. of representative samples
1	I	Madina Colony	10	59
2	II	Shastri Nagar KatchiBasties	7	100
3	III	Kathputli Slum	11	100
4	IV	Valmiki Colony	27	89

Table 2: Description of the Data Used in Water Demand Modeling

S. No.	Particular	Abbreviation	Unit	min	max	mean
1	Age of Home	A_H	years	5	40	21.871
2	Age of Respondents	A_R	years	20	55	33.52
3	Number of Bathrooms	BATHR	number	0	1	0.45
4	Number of Rooms	RMS	number	1	2	1.01
5	Monthly household income	I	Indian Currency (Rs)/INR	2000	10000	4633.0645
6	Expenditure on Water Supply	EXP_WS	Indian Currency (Rs)/ INR	0	150	42
7	Age of Meters		years	1	15	2.45
8	Asset Score	AS	number	0	3	1.05
9	Water Use	Dobs	Liter (total volume of water used)	200	1620	677.62
10	Temperature	TEMP	degree centigrade	20.41	42	33.53
10	end-use-analysis	cooking	liter/day	5.88	42.336	21.58
		dishwashing	liter/day	1.47	105.84	53.96
		laundry	liter/day	29.41	211.57	107.96
		bathing	liter/day	20.588	148.233	75.57
		drinking	liter/day	5.88	42.336	21.58
		outdoor use	liter/day	5.88	717	24.35
		toilet	liter/day	11.76	84.67	43.17
		cleaning	liter/day	5.88	42.336	21.56
S. No	Particular	Abbreviation	Unit	Option	Percentage	
11	Dwelling	DWELL	dummy variable	single storey	95.565	
				double/multi-storey	4.4.35	
12	Wealth	W	dummy variable	owner	72.581	
				rental	27.419	
13	meter condition		dummy variable	working	10.23%	
				out-of-order (non-functional faulty meters)	89.477%	

Table 4: Comparative Analysis of Outcome Water Demand Model with Previous Studies

S. No	Variable	Description	Unit	Expected Effect on Dependent Variable		Explanatory Remark
				Previous Studies	Model Outcome	
1	I	Monthly Household Income (*Hoffmann et al., 2006; Domene et al., 2005*)	Rupees	+	+	Very little positive effect was observed, because they are under below poverty line, so their income have little or marginal effect on water use.
2	A_R	Age of Respondent (*Mazzantiand Montini2006*)	Years	(-)ive	NA	Negligible effect has been observed, because during monitoring main concentration was given on the people in productive age, and tried to avoid the old and children from survey.
3	SIZE	Household size (*Lux2008)*	Number	+	+	More is the SIZ, more is the water demand. Major influencing and determining variable of RWU.
4	A_H	Age of Home (*Lux 2008*)	Year	+	NA	NA
5	W	Wealth of Household (HS), ownership of HS (0=owner; 1=rental); *Lux 2008*	Dummy	+	NA	Living in dilapidated and infirm houses (pucca house) and lack of basic services as safe drinking water, improved toilet facilities. One single room is shared by more than 5-6 peoples.
6	EXP_WS	Monthly expenditure on water supply	Rupees	(-)ive	NA	Govt subsidized the water supply service to this weaker section of society at free of cost through public stand post and they usually fetch their water from distant municipal water source at free of cost.
7	TEMP	Average daily temperature (*Gato et al., 2007; Hoffmann et al., 2006*)	Degree centigrade	(+) ive	(+)ive	Water use increase with increase in temperature; and decrease vice versa irrespective of the living standard.
8	AS	Asset Index(1-cooler; 2-washing machine; 1.5-2 wheelers; 5-car)	Number	(+)ive	NA	Living at meager living standard and don't have a water consuming appliance. Only few HSs have cooler and 2-wheelers.
9	DWELL	Type of dwelling (0-single; 1-double/multistory) (*Brooks 2006*)	Dummy	(+)ive	NA	Having pucca-and semi-pucca houses, and a single room is share by more than 5-6 members.
10	RMS	Total number of rooms under one roof shared by one family (*Brooks 2006*)	Number	(+)ive	NA	Most of the families have one room house in depilated condition
11	BATHR	Total number of bathrooms under one roof shared by one family (*Brooks 2006*)	Number	(+)ive	NA	Doesn't have a sanitation facilities.

Note: 1. To examine the explanatory effect of temperature on water use, we did the monitoring in two weather

LIST OF FIGURE

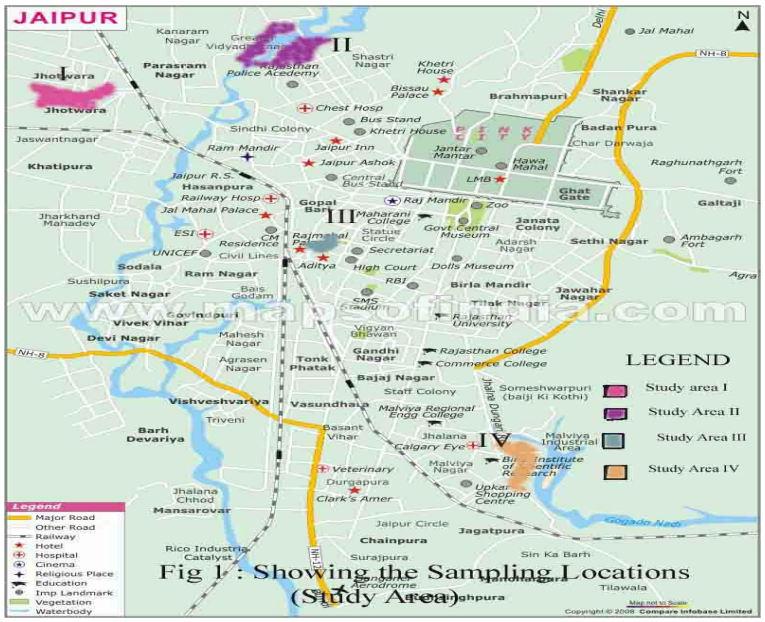

Figure 1: Study Area (Showing Sampling Locations)

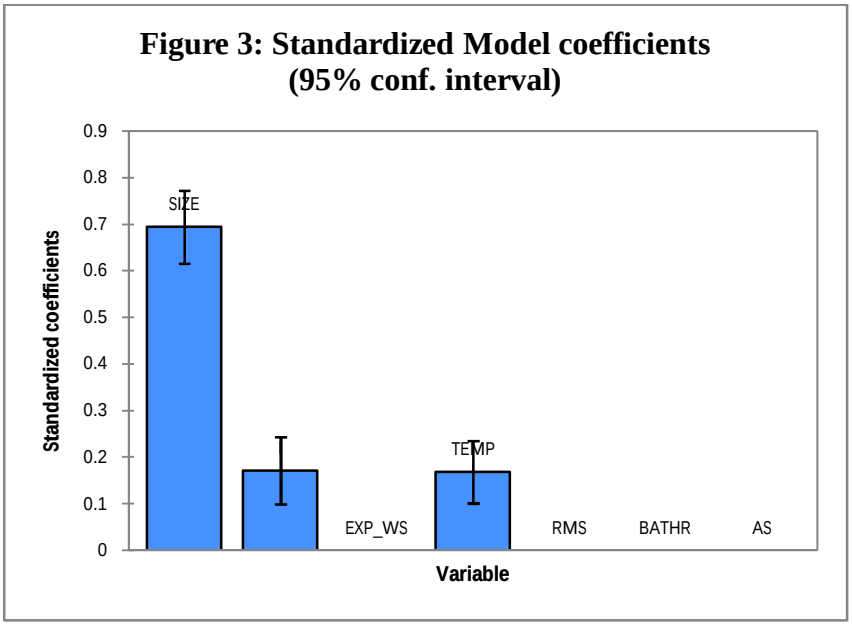

Figure 2: Standardized Model Coefficient

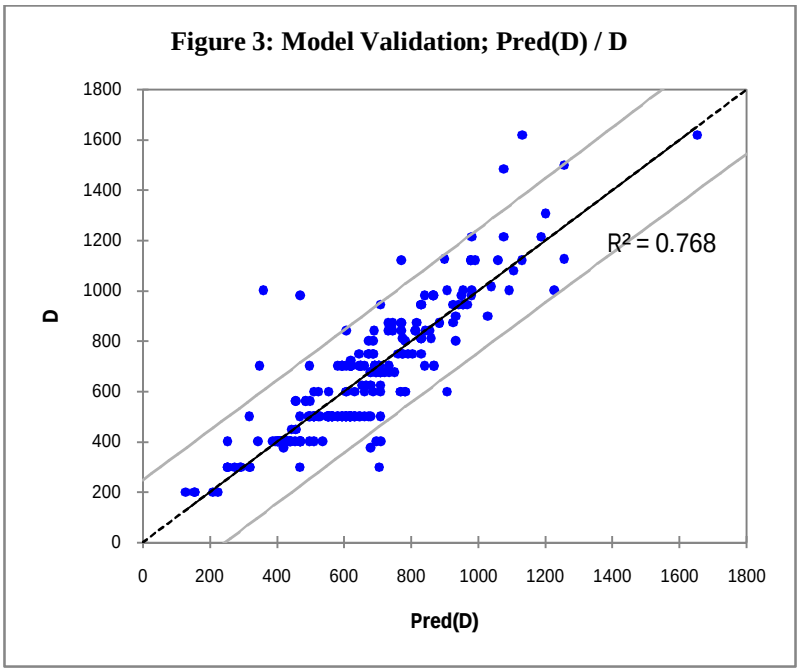

Figure 3: Model Validation