Water Management Design and Model Construction for Water Managers

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ABSTRACT

This is an intervention assessment study concerned with technology-enabled allocation of water at the end-user level. Sourcing and distribution of water has always been a societal problem as well as to government. The methodology employed in this study involves collection of base data, intervention using a laboratory designed microprocessor model and collection of post intervention data. Descriptive statistical approach was used in analysing the data collected. The result of the study showed that water resource has been grossly abused through unaccounted water along with energy used. The study recommends this model to water managers where water remains a public utility and where water rate subsidy operates.

Keywords-- Microprocessor model, Public water, Water management, Energy waste

I. INTRODUCTION

The issue of water wastage is a global concern especially the use of potable water at homes, schools and public places. Water wastage is a critical phenomenon measured in different forms and it does occur mostly in the form of over-volume usage, spillage and leakage. This translates to cost, which can be in the form of water supply cost, health associated, impact on structural facilities, social nuisance, and environmental degradation, and all these causes noise in the socio-economic system. A lot of research work is ongoing on water security and search for alternatives to sources of water, Singapore in particular is considered to be in the forefront in that regard, (Tortajada & Joshi, 2013; flush-for-good.com, 2013; Tortajada, 2006).

While individuals have always been meticulous in managing personal resources, similar prudence has not been accorded public utilities, in particular water. Governments have sought for best approaches and practices for sourcing, conservation and distribution of resources that are safe to both the public and environment and in a cost effective manner. However, the public have shown apathy and lack of diligence in utilizing these resources. Water sourcing, provision and particularly usage has come under numerous contentions, where some advocate that it should be an economic commodity (Elnaboulsi, 2009; European Parliament, 2000), others like the World Council of Churches (WCC) advocates that water should be provided as a public commodity under government control (WCC, 2006). There are yet others who view it from marketing and sociological perspectives which come under many themes including; ethical consumption, fair trade, greening, sustainability, consumer responsibility, immoral consumption, environmentally responsible consumption, amoral consumption, and unethical consumption (McGregor, 2008; Caruana, 2007; Haron, Paim, & Yahaya, 2005; Schaeffer & Crane, 2004; Follows & Jobber, 2000; Prothero, 1990).

The enforcement of rules guiding the proper, safe and sustainable use of public resources to some extent is a factor of the attitude of the general public toward public utilities (Sykes & Matza, 1957). For example, to avoid further use of a faulty water sink the water faucets were stopped with patches of polythene bags and some junks were used to cover it (Fig. 4 in appendix), however, a resident insist on removing these items just because this individual wants to wash utensils. This test was performed prior to the experiment in order to assess the attitudinal behaviour of the subject toward public utilities. When confronted of irresponsible behaviour this individual complained against the managers of the facility. The study intend to address attitude toward public utilities and how technology can assist in attitudinal change.

It subscribe to the closed system economy where Kotler and Levy proposed the managerial adaptation called ‘de-marketing’ (Kotler, 1973) this helps in checking bad consumption habits.
Environmental sensitivity in water use allows for availability of water for other users and a sustainable environment as a measure of human reasonability (Environment Office, University of Aberdeen, 2008). Experimental objective is to design and develop a microprocessor based model that will aid in curtailing wastage of potable water at public places and homes at the same time help water managers in their task of ensuring proper usage of water at the user-end. This approach is intended to serve for both priced water and in none priced domains. The intended outcome is to have a community of consumers whose action and attitude toward public utility is changed for good, whether these users pay for it or not and also to contribute to environmental preservation. The technology is readily available off the shelf and also affordable, suitable for application in both rural and urban settings.

II. METHODOLOGY

This study introduces a microprocessor-based intervention model designed to allocate specific volume of water per individual for usage over a predefined period of time. It is expected to effectively control water wastage and resultant inculcation of sense of responsibility and prudence in individuals toward public utilities.

The conceptual model for this experiment is described by the figure (Fig. 1 in Appendix). The conceptual model design for this experiment was based on the assumption that all other factors being equal, with ‘Y’ serving as a moderator variable the relationship between $X_1$ and $X_2$ significantly influenced results in behavioural change to the extent that the direct path ($X_1$ (attitude) - $X_2$ (resource)) drastically reduced as a result of the moderator effect ($Y$), engendering attitudinal change on public utility ($X_2$).

Where $X_1$ is the subject (user),

- $X_2$ is the object (water)
- $Y$ is the technology (intervention technology)

Other associated results that are expected to be achieved, due to the drop in the consumption of ‘$X_2$’ (object) are proportionate drop in cost of production (water-energy nexus), clean environment, drop in lava breeding and improved social environment.

The Microprocessor Model

The microprocessor-based model designed for this experiment comprises a PLC, solenoid valve and card-writer/reader. The PLC is configure to allocate a proportionate units to a specific volume of water into a platter card, the solenoid valve is activated to open position on insertion of a loaded card into the card reader, the solenoid valve closes on subsequent removal of the card from the card reader (Fig. 2 in appendix).

The experiment is a non-contrived intervention research; baseline data is collected followed by intervention and then post intervention data collected carefully monitored over the assigned period (Fig. 3 in appendix). A correlation between the two data sets was determined whether it is a value different from zero.

The baseline data for this research was obtained at site recording, flow time was computed from playback, a 20ltr pale was also used to estimate the volume an individual uses based on similar flow rates during recorded baths and it took a minute to fill up. The rate to fill the pale was then computed against the duration of average flow time during the recorded baths. Also measured was the time it took for a dripping tap to fill a 500ml bottle, physical observations were also done on faucet conditions the number of faucet points per wing per level per block of student dormitory was counted, then faulty ones were isolated and rate of drip evaluated.

III. CONCEPTUAL ISSUES AND THEORETICAL FRAMEWORK

Technological advancement has triggered rise in productivity and behaviours associated to income rise which include consumption, this has encouraged significant increase in pollution resulting to resource depletion. Yet, there seem to be little concern shown by the general public of the aftermath of their activities especially toward water use and sustenance. Since humans need water to survive there should be responsible consumption which can translate to rational and efficient use of water in line with global desires of the need to protect and have a safe environment. For a sustainable supply, distribution and use of water, consumer right should go along with responsibility (Fisk, 1973). For example, as part of enforcement of responsible consumption behaviour and avoidance of infringing on the right and safety of other users of the high way, governments are using technologies in order to make the roads safe through the use of a technology that enforce prohibition of cell phone use behind the stirring wheel (Shabeer & Banu, 2012). Numerous proposition and policies for efficient water management emerged from different schools of thought in the literature this include, pricing, public good (Biswas & Kirchherr, 2012; Elnaboulsi, 2009; WCC, 2006). The proponents of water pricing have pointed to reasons for pricing water like; reduced water losses, reduce over use, reduce cost of water services, promote sustainability and efficient water use (SCU, 2012).

However, until lately researchers are still considering that pricing water should not be a stand alone policy but should run concurrently with other policies related to provision and use of water. Experiences from different countries show that whether water remain under public domain or classified as an economic commodity, handling attitude of water by the public remains an issue (Aidam, 2015).

The concept of water wastage is very complex in the sense that research has shown that so many factors do contribute to it. For example, Garcia-Cuerva, et al, looked at it from public perception of water shortage; Garcia-Cuerva, et al reported that only a small percentage of the population are concerned about water...
shortage though ethnicity, education level, metro/non-metro, and income showed significant effects (Garcia-Cuerva, et al., 2016). Urien used the constructs of generativity and self-enhancement in attempting to explain individual consumption values, the study reported individuals scoring high on generativity showed more likelihood to have eco-friendly intentions and exhibit more responsible consumption behaviours (Urien & Kilbourne, 2011). However, Bamberg and Moses attributed water wastage to emotional reactions; their study supports existing literature highlighting the important role of emotions in predicting environmental engagement (Coelho, Gouveia, Souza, Milfont, & Barros, 2016; Bamberg, & Möser, 2007). From the foregoing, there seem to be a common factor which can be viewed as the main issue that is, the public inability to follow their moral compass (Lennick & Kiel, 2005).

Linnick & Kiel posit that moral intelligence should enable consumers to exhibit mental capacities that can determine the universality of human principles as applied to personal actions (goals and values). Linnick & Kiel listed four principles that should guide an individual’s consumption namely; responsibility, integrity, compassion and forgiveness (Lennick & Kiel, 2005). These principles are expected to form society’s consumption norms whether in the presence or absence of others and whether being watched by others or not. Studies on water waste have proven that a drip per second of water wastes 1,200 ltrs of water in a year; this is translated to about 4litr per day, (Environmental Agency Water Wise, 2013). Applying this to a typical higher education institution student hostel facility, volume waste will be equal to the product of the number of drip points per hostel per total number of Hostels (Table 1 in Appendix). In some cases there are literal flow not drips. These leaks have great implications causing deterioration of pipes, allow weed roots to penetrate and grow causing blockage in the pipes, cause environmental wetness, affects structural facilities by weakening structural materials, it also predisposes inhabitants to health risks through water born diseases, breeding of mosquitoes and also social inconveniences. However, despite all these academic and theoretical endeavours, only few microprocessor-based intervention studies have been designed and deployed particularly for water conservation in the public domain. The available technologies so far are to reduce the volume per turn or timed flushes and complementing these technologies is a management approach that expects individuals to be ‘human’ enough to report cases of leakage or to turn off taps (Browne, 2013; Environment Office, University of Aberdeen, 2008).

**Country specific actions**

Different countries have adopted different approaches to the issue of water highlighted in results and discussion section. For example, even though Malaysia have had experiences of water scarcities mostly due to natural phenomenon (draught) Melaka in 1991, Selangor and Kuala Lumpur in 1998 and the 2014 water crisis with study findings predicting increase and decrease in average rainfall in some selected Malaysian states for the next 40 years (MalayOnline, February 14, 2014). Yet extant literature points out that the vast majority, including the relevant government authorities and water concessionaires, tend to forget quickly (Chan, 1999a). Our survey data (Table 1 in Appendix) corroborated this assertion of ‘it’s over’ or ‘not going to happen again’ syndrome, Table 1 signifies that despite the past experiences no enough precautionary measures have been put in place to address and to sensitize citizens (Malaysians) on water conservation efforts. For Public Utility Board (PUB) of Singapore, the assertion ‘water supply is only half of the water equation’ tends to be the driving force in water management at the user end (PUB Website, 2014). In essence, whatever volume of water is supplied the demand side has to be effectively managed else the effort is defeated. To address the user-end issue of water reticulation and associated infrastructure must be well built and in proper shape to enable accurate assessment, as seen in Aberdeen and Arizona State Universities where infrastructure are in good shape and fully implemented. It is difficult to begin to make assessments of water usage in places where facilities on ground especially where our sample was taken (Figures 4, 5, 6, 7 & 8 in Appendix). Apart from the toilet cisterns which are the 6litr type, all except one (1) bath points have no shower head mounted, the system is just direct flow from pipe and have to be opened to maximum flow in order to get enough pressure so the water can reach where one is standing to bath as the pipe protruding from the wall is short. Thus, horses are attached to toilet faucets for use, as shown in Figures 5, 6 & 8 in Appendix) causing a lot of water going unaccounted (Table 1 in Appendix).

**IV. OPERATIONAL THEORIES**

The study assumes that people are not or refused to be responsible, as such, the government in fulfilling her obligation of providing water for all will employ the ‘carrot and stick’ approach and also the ‘operant conditioning’ of Skinner in the study on consequences that shape behaviour. Skinner asserted that reinforcement and punishment are the main tools for operant conditioning. The negative punishment (penalty) tool will be used in this study to curtail the excesses in the use of public utilities, this is also referred to as “punishment by contingent withdrawal”: this is when a behaviour is followed by the removal of a stimulus, a classical example by Skinner is taking away a child’s toy following an undesired behaviour, resulting in a decrease in that behaviour (Skinner, 1938). The designed model is a ‘digital wallet’ the digital wallet ensures appropriate quantity is apportioned to individuals. The control of water availability (punishment) leads to consequence in behaviour (water abuse) to occur with less frequency. The study anticipates that by conditioning the minds of the water end-users to a predefined volume per period of time the users learn to plan usage and over time the mind frame will adjust, be more responsible users and
ultimately consider public utilities as valuable resource that needs to be properly utilised. This is in line with the ‘Theory of Responsible Consumption’, Fisk predicted that world population will reach 7-billion by year 2000 and that population crash is imminent if irresponsible resource use from high level mass consumption especially in industrialised nations is not checked (Fisk, 1973).

V. RESULTS AND DISCUSSION

Components of the device consist of PLC, Solenoid valve, card reader and writer. The components are connected to form the bases for intervention (fig 2 appendix). The constructed and tested model is referred to as microprocessor model. The model was tested and was found to be effective and applicable to areas where water waste and management is a challenge. Quite a number of environments are crying on how to harness water into an economic way but lack the device to solve such challenges. It is glaring that water scientist have devised several methods of managing portable water but not able to device the model that can arrest public water challenges. That is why microprocessor model is designed, constructed and tested.

The baseline data collected (Table 1 in Appendix). Represent restroom drip per day (480ltrs/day) this agrees with University of Aberdeen’s quick drip giving 479 litres per day. In general the study yield a result that proves the volume of water wasted is more than what an individual needs per day grossly outside common practices (Table 2 in Appendix). Singapore desiring to drop its daily water use from about 160ltr/capita/day to 150ltr/capita/day, while in Malaysia so much is wasted due to lack of education, faulty or current standard equipments. Examples of water saving technologies are installed in kitchen and bathroom faucets, this model control the rate of flow from a faucet to a maximum rate of one gallon per minute (1.0gpm), this is contrary to this study location of direct flow from the pipe (at a moderated rate) leading up to six times the model controlled flow, older showers use twenty (20) litres/minute (Table 2 in Appendix). Post intervention data collected was not applicable because the required number of the equipment was up to the sample size.

Some of the technological advancements used in some institutions include, push head taps in toilets limiting water use, spray mixer taps with sensors, another one is automatic flush controls which limits flushing by urinals being more effective outside operating hours, also modified cisterns, large volume cisterns (13 litres) are changed to low volume cisterns 6 litres (vide Figure 6), but mounted with greater pressures to flush same solids with the available quantity of water. These measures have significantly contributed to a reduction of over 100,000 cubic metres (equivalent to 100,000 tonnes of water) per year, (Environment Office, University of Aberdeen, 2008).

Despite all these efforts the water scheme equation is yet to balance, as Pedro pointed out that even the claim by the millennium development goal report was overstatement, which reported that 91% of the world’s people have access to sustainable safe drinking water. This is due to the use of unsuitable benchmarks and over emphasised indicators since some sources are still contaminated, unreliable or unaffordable (Pedro, 2017). The study on management of water waste should be encouraged to bring an enduring solution through innovation. The study result concord earlier studies conducted by Balami, 2011; Dunlap, Liere, Mertig & Jones, 2000; Jones & Dunlap, 1992 and suggested that in terms of gender, the female is more positive to environmental issues (Wolfers, 2013; Zelezny, Chua & Aldrich, 2000).

VI. CONCLUSION AND RECOMMENDATIONS

The study result expected that anywhere the technology is deployed the intervention will give a positive yield; economically reducing the volume of water wasted or overused and consequently drop in electric wattage use (water-energy nexus), change in attitude toward public utility, enhanced public prudence to scarce resources, less effort and resource toward water conservation campaign, fast track achievement of lesser litre/day/capita and efficient management model for water managers (Table 2 in Appendix). Policy makers can employ and deploy available legal means to educate and to begin implementing water saving schemes especially in the countries where awareness is less or is lacking. This same technology will serve well for areas facing draught and even areas where water shortage is not pronounced, as it is more costly to manage crisis. The study recommend for a comprehensive test of the model in different environments in order to assess its effectiveness and efficiency in reduction of water waste and attitudinal change among the public toward public utilities.

REFERENCES

sustainable water consumption’. *The London School of Economics and Political Science.*


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**Web References**

http://www.flushforgood.com/#ChampionToilet
APPENDIX

Table 1: Unaccounted for/wasted water

<table>
<thead>
<tr>
<th>Points / level</th>
<th>Total Levels /block</th>
<th>Total points/block</th>
<th>Avrg. Dripping points/block</th>
<th>Avrg. Vol. Drips/point/day (Ltrs)</th>
<th>Drips/Total Vol/day/block (Ltrs)</th>
<th>Avrg. Vol/day/block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washing area (28)</td>
<td>5</td>
<td>140</td>
<td>5</td>
<td>240 @ rate 500mls/3min</td>
<td>1,200</td>
<td></td>
</tr>
<tr>
<td>Pantry (2)</td>
<td>5</td>
<td>10</td>
<td>3</td>
<td>144 @ rate 500mls/5min</td>
<td>432</td>
<td></td>
</tr>
<tr>
<td>Rest room (14)</td>
<td>5</td>
<td>120</td>
<td>2</td>
<td>240 @ rate 500mls/3min</td>
<td>480</td>
<td></td>
</tr>
<tr>
<td>Bath cubicles (14)</td>
<td>5</td>
<td>120</td>
<td>10</td>
<td>144 @ rate 500mls/5min</td>
<td>1,440</td>
<td></td>
</tr>
<tr>
<td>Individual Bath /day</td>
<td>-</td>
<td>-</td>
<td>60 ltrs/Bath</td>
<td>120/2 baths/day</td>
<td>9,600</td>
<td></td>
</tr>
</tbody>
</table>

Source – compiled by author. All data and observations were as at the date of survey
Unaccounted for water: hidden leaks, cooking, washing (machine and manual (Fig. 5)) and toilet flushes

Table 2: Typical water use at US home

<table>
<thead>
<tr>
<th>Activity</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bath</td>
<td>A full tub is about 36 gallons.</td>
</tr>
<tr>
<td>Shower</td>
<td>2 gallons per minute. Old shower heads use as much as 5 gallons per minute.</td>
</tr>
<tr>
<td>Teeth brushing</td>
<td>&lt;1 gallon, especially if water is turned off while brushing. Newer bath faucets use about 1 gallon per minute, whereas older models use over 2 gallons.</td>
</tr>
<tr>
<td>Hands/face washing</td>
<td>1 gallon</td>
</tr>
<tr>
<td>Face/leg shaving</td>
<td>1 gallon</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>4 to 10 gallons/load, depending of efficiency of dishwasher</td>
</tr>
<tr>
<td>Dishwashing by hand</td>
<td>20 gallons. Newer kitchen faucets use about 2.2 gallons per minutes, whereas older faucets use more.</td>
</tr>
<tr>
<td>Clothes washer</td>
<td>25 gallons/load for newer washers. Older models use about 40 gallons per load.</td>
</tr>
<tr>
<td>Toilet flush</td>
<td>3 gallons. Most all new toilets use 1.6 gallons per flush, but many older toilets used about 4 gallons.</td>
</tr>
</tbody>
</table>

Adapted from – USGS website (2014)

![Fig. 1 - model variable path analysis](image1)

![Fig. 2 - model design](image2)
Group ‘A’ (purposively assigned) (control group)  
Group ‘B’ (intervention group) 

baseline data collection 
no intervention 

intervention and observations (for specified period) 

post intervention data collection 
Outcome (cost saving and acceptance of technology) 

Fig. 3 - Data collection and intervention design 

Fig. 4 - Wash basin in pantry  
Fig. 5 - Wash area direct flow  

Fig. 6 - Rest room  
Fig. 7 - A 6ltr Water cistern 

Fig. 8 –bathroom without shower head