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ADOPTION OF WATER EFFICIENT PLUMBING FIXTURES, A CASE STUDY OF A RESIDENTIAL BUILDING

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ABSTRACT

Water crisis is a severe problem in Dhaka and Chittagong city of Bangladesh. The current population of 2.28 crores of these cities is already deprived of clean water along with other basic facilities. In context of this problem, this study has tried to investigate whether use of water sensitive plumbing fixtures in households can minimize water crisis by reducing losses caused by using conventional plumbing fixtures or not. A cost benefit analysis has also been conducted to assess the financial viability of introducing these fixtures in the city. Various water saving equipment such as low flush toilets, low flow showerheads, low flow basin faucets etc. were considered while analyzing the efficiency of water savings. A thorough literature review was conducted to find out water requirement of the proposed and traditional fixtures. Cost of these water sensitive fixtures and also conventional ones were collected from field survey. Around 45% less annual water consumption was found in a typical 5 storied building for the water sensitive fixtures in comparison to traditional ones. The proposed system was also found financially durable as its cost minimization capacity was significantly higher than the conventional system. The results of the study indicate that current water crisis in big cities can be reduced noticeably by introducing water sensitive fixtures in households.

Keywords: *Water crisis, Water sensitive plumbing fixtures, Conventional plumbing fixtures, Water savings, Cost benefit analysis.*

1. INTRODUCTION

In this 21th century, civilization has entered into the flow of development and we are moving forward with a population of more than 6 billion. So sustainable development is utmost essential for reducing the water consumption.

With the rapid increase of population and the development of society and industry, many countries are facing a water shortage. A water shortage does not only result in a shortage of domestic water for people's lives, but also serious food shortages, impacts on eco systems and public health problems. Among other things, food shortages are particularly serious with about 800 million people are currently suffering from malnutrition and the world will become in need of food to sustain 2.4 billion people by 2025 as a result of an increase in the percentage of developing countries. (United Nations Population Estimation, 2017) Various other problems are also emerging, including water pollution caused by insufficient sewage disposal capacity, an increasing number of people dwelling on flood prone lowland areas and resultant flood damage, etc., and there is growing concern that these problems including water shortages will become more serious in future due to the increase in the world population and the impact of climate change.

While the world's population tripled in the 20th century, the use of renewable water resources has grown six-fold. Within the next fifty years, the world population will increase by another 40 to 50 %. This population growth – coupled with industrialization and urbanization – will result in an increasing demand for water and will have serious consequences on the environment.

This thesis will undertake the task of inspecting the water usage by the plumbing fixtures of a residential building. This is a comparative study which gives a message of water efficient fixtures that is eco-friendly. (Wadud Mushfique, 2011) Besides ground water level is decreasing day by day for too much water extraction. If we don't adopt new water usage method our future generation will face a great problem. So adoption of water efficient plumbing fixtures is the only solution to handle the water scarce problems. These types of fixtures may be costly but in the long period it saves too much water as well as money.

2. METHODOLOGY

To check whether the water efficient plumbing fixtures are feasible in the long run or not, two alternative measures are taken. In alternateve-1, water saving tap aerators are fitted internally or externally on existing taps from kitchen, bathroom & wash basins. And also flush valve toilets are used in place of flash tank system toilets. In alternative-2, only wash basin taps those are mentioned as CP Pillar Cock are alternated to sensor based smart taps. The remaining fixtures are kept same as the alternative-1.The whole procedure is explained below with essential figures.

2.1 Installation of Water Saving Aerators

Water Saving Aerators are one of the best innovative water saving solutions for any organization. Whether it is a washbasin, bath shower, sink taps or faucet. These products are created and designed with the purpose of dispensing water at a defined flow rate depending on the amount of liquid required. Most of the devices have the water saving capacity of several litres per day. Equipping these Water Saving Device could give huge water savings either at office or home.

Male fitting tap aerators are fitted internally on your taps while female fitting tap aerators available to order here are used when the tap on which you are fitting the aerator has external treads.

Figure 2.1: Sample of male and female aerators and their ways of installing.

They will reduce the water flow in your tap to just 4.5 litres per minute helping in reducing both water charges and energy bill when using hot water. These water saving tap aerators are self-cleaning with an anti-lime stainless steel sieve ensuring they are not susceptible to lime scale build up. Housed in a polished and chromed brass that one will get a soft comfort jet spray from taps when these are fitted which ensures no water splashes through the mixing of air and water.

Ideal for kitchen and bathroom taps these great tap aerators are very low maintenance due to the self-cleansing feature and come with a 12-month manufacturer's guarantee. The water saver faucet aerator is devised in such a way that it can be set-up on all kinds of tap faucets.

An aerated flow is when air mixes into the water. It produces a larger, whiter stream that is soft to the touch and non-splashing. This stream is the perfect choice for residential faucets and can go a long way to help one reducing domestic bills.

Figure 2.2: Water flow after installing aerator

Figure 2.3: Aerated vs Non-aerated flow

2.2 Installation of Water Efficient Showerheads & Flush Valve Toilets

Showering is one of the leading ways we use water in the home, accounting for nearly 17 percent of residential indoor water use. New high efficiency showerheads use less water than standard models without sacrificing performance, helping us conserve water and saving on energy.

Figure 2.4: Standard model showerheads vs. high efficiency shower heads.

Commercial toilets, or flush meter-valve toilets, are typically found in commercial, institutional, or industrial restrooms in such places as airports, theatres, stadiums, schools, and office buildings. These types of toilets have two main components—the toilet bowl and the flush meter valve.
By replacing old, inefficient flushometer-valve toilets a 10-story office building with 1,000 occupants could save nearly 1.2 million gallons of water and nearly $10,000 per year. Of those savings, nearly 870,000 gallons of water and $7,600 in water costs per year can be achieved by replacing the toilets in the women's restrooms alone.

Most of the old toilets have flush volumes as high as 3.0 to 7.0 gallons per flush (gpf)—far more water than the BNBC standard of 1.6 gpf. These flushometer-valve toilets, whether single- or dual-flush, use no more than 1.28 gpf, which is a 20 percent savings over the BNBC standard of 1.6 gpf.

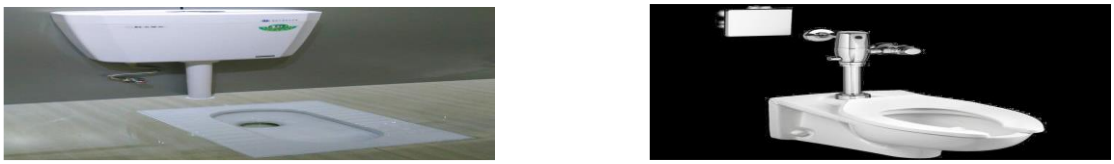

Figure 2.5: A typical long pan with flush tank system vs. a typical flushometer-valve toilet.

2.3 Installation of Sensor Based Faucets

Millions of gallons of water are wasted every year through faucets that are left running for too long or not closed properly after use. Simply going through the daily early morning routine of personal hygiene, cleaning one's teeth, washing the face, etc. sees gallons running unused down the drain because few people think to turn the water on and off during this process.

Installing sensor faucets will reduce this kind of waste by stopping the water flow every time the hands are removed. So instead of the water continuing to run while teeth are being scrubbed, it stops until it is time to rinse. The same applies to the process of soaping the face and body.

It is believed that installing motion sensor faucets can save as much as 30% to 50% on overall water use, a saving that should not be taken likely both on financial and environmental cost.

Figure 2.6: A typical standard water faucet vs. a typical water efficient sensor faucet.

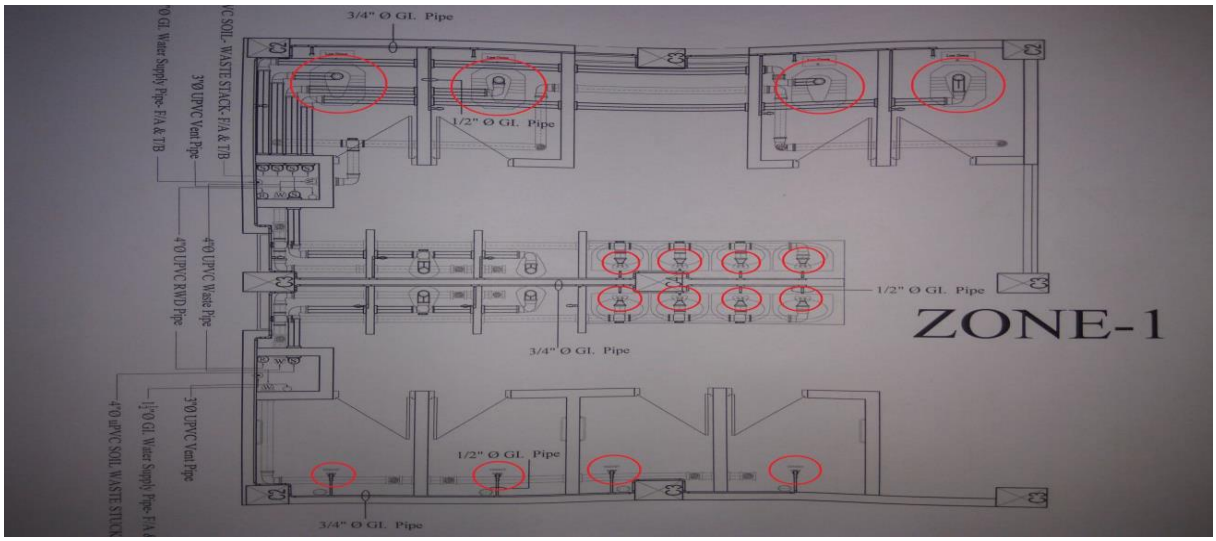

Figure 2.7: Plan of the washroom (zone-1), Sheikh Rasel Hall, CUET.
[Note: Red circles indicated the fixtures those are to be replaced by water efficient fixtures.]

3. ILLUSTRATIONS

3.1 Cost-Benefit Analysis

There are different types or methods of analysis to determine the economic efficiency of a project. The types those are covered in this thesis are:

1. Present Worth Method
2. Annual Worth Method

Present Worth Method:

Present worth method is the method of evaluating present value (PV) or current worth of a future sum of money or stream of cash flows given a specified rate of return. Future cash flows are discounted at the discount rate, and the higher the discount rate, the lower the present value of the future cash flows.

Annual Worth Method:

The annual method is commonly used for comparing alternatives. As illustrated in Chapter 4, AW means that all incomes and disbursements (irregular and uniform) are converted into an equivalent uniform annual (end-of-period) amount, which is the same each period.

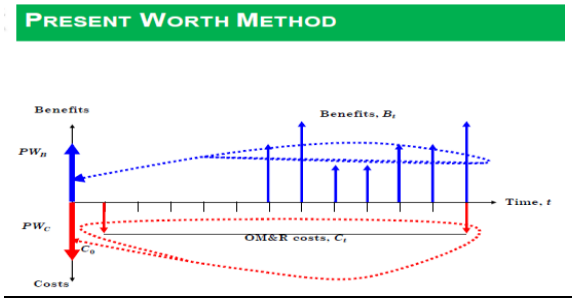

Figure 3.1: Present worth method

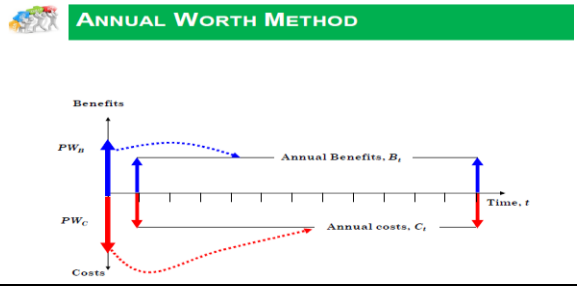

Figure 3.2: Annual worth method

present worth - annual payments

$PV = A \times \frac{(1+i)^n - 1}{i(1+i)^n}$	present value or worth
$A = \frac{PV}{\frac{(1+i)^n - 1}{i(1+i)^n}}$	annual payment or cost

Figure 3.3: Formula for present worth

present worth analysis

$PV = \frac{F}{(1+i)^n}$	present value or worth
$F = PV \times (1+i)^n$	future value or worth
$i = \left(\frac{F}{PV}\right)^{1/n} - 1$	interest rate

Figure 3.4: Formula for annual worth

3.2 Relevant Data & Considerations Used

- Life Time of the Building = 50 years
- Occupants = 600
- Rate of Interest, i = 10%
- Lifetime of Fixtures used for calculation is given below in Table 3.1
- Price of Fixtures both traditional and WEF are given in Table 3.3, Table 3.4 and Table 3.5.
- According to WASA, 1000 liters of water = 10 taka.
- Throughout the 50 year lifespan lavatories need to be replaced twice and the water faucets need to be replaced 4 times.
- Average shower time per person is taken as 5 minutes.
- Faucet use was taken as 4 minutes per person per day.
- Daily average flushing was taken as 5 flushes per person per day.

Table 3.1: Normal lifetime of various fixtures

Fixtures	Lifetime (Year)	
	Traditional	**Water Efficient**
1. Long Pan	20	20
2. English Commode	20	20
3. Bib Cock	10	10
4. Pillar Cock	10	10
5. Sink Cock	10	10
6. Shower Head	10	10

Table 3.2: Standard flow rate through different fixtures

Fixtures	Water Usage (Old)*	Water Usage (WEF)*
1. Long Pan	3.5 gpm	Not Available
2. English Commode	5.0 gpm	1.28 gpm
3. CP Pillar Cock	3.0 gpm	1.5 gpm
4. CP Bib Cock	3.0 gpm	1.5 gpm
5. CP Sink Cock	4.5 gpm	2.5 gpm
6. Shower Head	2.5 gpm	2.0 gpm

* The values in the former old fixtures were taken according to the BNBC guidelines using Table 8.7.14 and Figure 01.

*The values of water efficient fixtures were taken from manufacture company values. For details www.amazon.in; www.alibaba.com

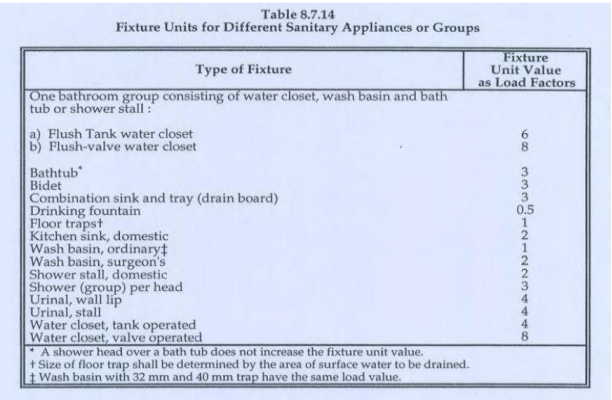

Table 8.7.14
Fixture Units for Different Sanitary Appliances or Groups

Type of Fixture	Fixture Unit Value as Load Factors
One bathroom group consisting of water closet, wash basin and bath tub or shower stall :	
a) Flush Tank water closet	6
b) Flush-valve water closet	8
Bathtub*	3
Bidet	3
Combination sink and tray (drain board)	3
Drinking fountain	0.5
Floor traps†	1
Kitchen sink, domestic	2
Wash basin, ordinary‡	1
Wash basin, surgeon's	2
Shower stall, domestic	2
Shower (group) per head	3
Urinal, wall lip	4
Urinal, stall	4
Water closet, tank operated	4
Water closet, valve operated	8

* A shower head over a bath tub does not increase the fixture unit value.
† Size of floor trap shall be determined by the area of surface water to be drained.
‡ Wash basin with 32 mm and 40 mm trap have the same load value.

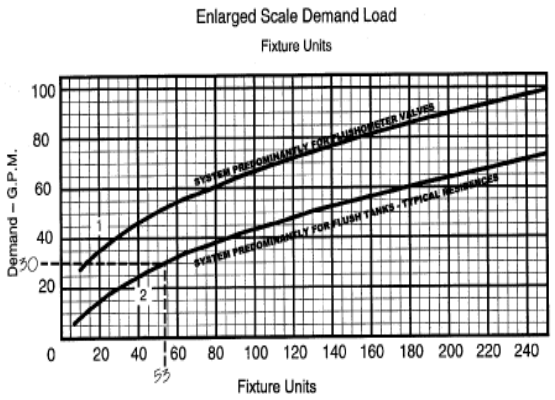

Figure 3.5: Fixture Unit vs Demand (gpm) Graph

Table 3.3: Prices of the traditional fixtures currently used

Fixtures	Quantity	*Unit Price (Tk)	Total Price (Tk)
1. Long Pan (FT)	60	1909	114540.00
2. English Commode (FT)	5	2996	14980.00
3. CP Pillar Cock	120	697	83640.00
4. CP Bib Cock	165	555	91575.00
5. CP Sink cock	4	821	3284.00
6. Shower head	65	679	44135.00
		Total=	3,52,154.00

Table 3.4: Prices of the water efficient fixtures used in Alternative-1 (includes aerator based faucet)

Fixtures	Quantity	*Unit Price (Tk)	Total Price (Tk)
1. English Commode (FT)**	65	5525	3,59,125.00
2. CP Pillar Cock*	120	910	1,09,193.00
3. CP Bib Cock*	165	768	1,26,720.00
4. CP Sink cock*	4	1034	4,136.00
5. Shower head*	65	760	49,400.00
		Total=	6,48,564.00

*The Price of the Cp pillar cock, bib cock & sink cock includes the aerator price (210 tk)
**The Price of English Commode (Flush Valve) was taken form https://www.alibaba.com/showroom/bangladesh-faucet.html

Table 3.5: Prices of the water efficient fixtures used in Alternative-2 (sensor based faucet)

Fixtures	Quantity	*Unit Price (Tk)	Total Price (Tk)
1. English Commode (FT)	65	5525	359125.00
2. CP Pillar Cock**	120	8000	960000.00
3. CP Bib Cock*	165	768	126710.00
4. CP Sink cock*	4	1034	4136.00
5. Shower head*	65	760	49400.00
		Total=	14,99,371.00

*The prices of the cp bib cock & sink cock include the aerator price (210 tk)
**Price of the Sensor based CP Pillar Cock was taken from https://www.alibaba.com/showroom/bangladesh-faucet.html

3.3 Analysis of Water Use by Old Fixtures

Table 3.6: Amount of water used by old fixtures in a year

Fixture	Total No. Fixtures	No. of Uses/ day	Consumption Rate (gpf)	Water Uses (gal/day)	Total Water Use (gal/year)
1. Long Pan FT	60	25	3.5	5250	5,09,13,850
2. English Com.	5	4	5	100	
Fixture		Using Time/day (min)	Consumption Rate (gpm)		
3. Pillar Cock	120	240	3	86400	
4. Bib Cock	165	66	3	32670	
5. Sink Cock	4	300	4.5	5400	
6. Shower Head	65	60	2.5	9750	

Table 3.7: Amount of water used by fixtures in Alternative-1 (includes Aerator based faucet)

Fixture	Total No. Fixtures	No. of Uses/ day	Consumption Rate (gpf)	Water Uses (gal/day)	Total Water Use (gal/year)
1. Long Pan FT	60	25	1.28	1920	2,63,82,419
2. English Com.	5	4	1.28	25.6	
Fixture		Using Time/day (min)	Consumption Rate (gpm)		
3. Pillar Cock	120	240	1.5	43200	
4. Bib Cock	165	66	1.5	16335	
5. Sink Cock	4	300	2.5	3000	
6. Shower Head	65	60	2.0	7800	

3.4 COMPARISON OF INSTALLMENT COST &WATER USE AT FIRST YEAR (ALTERNATIVE-1) (INCLUDES AERATOR BASED FAUCET)

Table 3.8: Instalment cost and water use after first year for Alternative-1

Fixture Type	Instalment cost (Taka)	Water use (gpy)
Conventional	3,52,154	5,09,13,850
WEPF	6,48,564	2,63,82,419
Difference=	2,96,410 Taka*	24531431 gpy*

[*Note: Extra cost for WEPF is 2,96,410 Taka and water saved after first year is 24531431 gallons.]

According to WASA cost of 1000 liters = 10 Taka.
Therefore, cost replaced by water saving after first year = 9,29,220 Taka

3.5 Economic Analysis for 50 Years (Old Fixtures)

Installment Cost at first year = 3,52,154tk
For Toilets = 1,29,520tk
Future worth after 50 years = 4,56,13,374tk (Includes two time changes at 20th year
And 40th year.)
For Others = 2,22,634tk
Future worth after 50 years = 13,06,75,958tk (Includes four time changes at 10th, 20th, 30th & 40th year.)
Therefore, total future worth after 50 years = 17,62,89,332 Taka

3.6 Economic Analysis for 50 Years (Alternative-1) (Includes Aerator Based Faucet)

Installment Cost at first year = 6,48,564tk
For Toilets = 3,59,125tk
Future worth after 50 years = 12,64,79,362tk
For Others= 2,89,440tk
Future worth after 50 years = 16,98,87,986tk
Therefore, net future worth after 50 years= 29,63,61,948tk

3.7 Cost Comparison Between Both for 50 Years (Alternative-1) (Includes Aerator Based Faucet)

Extra cost of instalments after 50 years = (296361948 -176289332) = 120072616 tk
Extra cost of installments after 50 years (in present worth) = 1022844 tk
Water saving after 50 year is (24531431*50) = 1226571550 gallons which is equivalent to 5454526514 tk.
This value of water in present worth is approximately 46464660 tk.
[Note: According to WASA, price of 264 gallons is 10tk which worths 1174tk after 50 years. (i=10%)]

3.8 Analysis of Water Use by Alternative-2 (includes sensor based faucet)

Table 3.9: Amount of water used by fixtures in Alternative-2

Fixture	Total No. Fixtures	No. Of Uses/ Day	Consumption Rate (gpf)	Water Uses (gal/day)	Total Water Use (gal/year)
1. Long Pan FT	60	25	1.28	1920	2,00,75,219
2. English Com.	5	4	1.28	25.6	
Fixture		Using Time/day (min)	Consumption Rate (gpm)		
3. Pillar Cock	120	144	1.5	25920	
4. Bib Cock	165	66	1.5	16335	
5. Sink Cock	4	300	2.5	3000	
6. Shower Head	65	60	2.0	7800	

By following the previous steps, we can compare calculations with the Conventional Type Fixture and can estimate the cost replaced by water saving after first year = 11,68,130 Taka

3.9 Economic Analysis 50 Years (Alternative-2) (Includes Sensor Based Faucet)

Installment Cost at first year = 1499371 tk
For Toilets = 3,59,125tk
Future worth after 50 years =12,64,79,362tk
For Others= 11,40,246 tk
Future worth after 50 years = 66,92,74,541tk
Therefore, net future worth after 50 years= 79,57,48,503 tk

3.10 Economic Analysis Between Both (Alternative-2) (Includes Sensor Based Faucet)

Extra cost of installments after 50 years = (795748503-176289332) = 61,94,59,171tk
Extra cost of installments after 50 years (in present worth) = 52,76,894tk
Water saving after 50 years is (30838631*50) = 1541931550 gallons which is equivalent to 6856922878tk bill.
This water bill in present worth is approximately 5,84,11,050 tk.
[*Note: According to WASA, price of 264 gallons is 10tk which worth 1174tk after 50 years. (i=10%)]

4. CONCLUSIONS

Based on the analysis the following conclusions have been drawn:

1. From the water consumption analysis water efficient fixtures with alternate-1 (including aerator based faucet) saves 48% water yearly by the adopted fixtures.
2. In the alternate-2 (including sensor based faucets) it saves more than 60% without hampering its performance and user's comfort.
3. From the economic analysis both the alternates become feasible amazingly from 50 years cost analysis.
4. Alternative-1 requires less initial cost, less replacements and maintenance is easier than the other alternative. It is most suited for public and institutional buildings where the fixtures will be roughly used.
5. Alternative-2 looks a bit costly at first but it gives more returns than expected both economically and from the view of water saving.
6. Though the analysis was for 50 years but it is quite clear that the economic returns will increase greatly with the increase in the lifetime of the building.

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