Cost and Returns Analysis of Library First Floor Restroom Renovation and Implications of Conservation Savings for MSU Facilities Replacement Scheduling

by

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Michigan State University has many buildings containing restrooms that were equipped when standard fixtures used considerably more water than building codes permit today. This study evaluates the costs and benefits of renovating the restroom fixtures of the MSU Main Library West Wing first floor restrooms with special attention to the value of water savings. The first floor library restrooms represent an appealing case study because they are heavily used. During the 2007-08 academic year, they received 155,000 visits in fall and 143,000 visits in spring. The finds from this study may offer insights on the potential benefits from comparable renovations in other campus restrooms.

Water conservation could allow the University to delay developing new wells. Like many older MSU buildings, the library restrooms are equipped with toilets and urinals that use 3.0 to 3.5 gallons per flush (gpf) of water. Current code limits toilets to 1.6 gpf and urinals to 1.0 gpf. In addition, contemporary lavatory spigots contain aerators that conserve water beyond traditional models. Hence, renovation simply to meet current building code could offer the substantial water savings. Moving beyond what code requires, ultra-low flow urinals are available that use only 1/8 gpf (also available are more costly zero-flow, waterless urinals).

Apart from water conservation, "touch-free" sensor technology offers the promise of improved hygiene. Health benefits associated with "touch-free" facilities include reduced incidence of common cold and influenza, as well as other virus and bacteria transmitted diseases. "Touch-free" sensors are available to operate electronic flush valves for toilets and urinals as well as lavatory faucets, soap dispensers and paper towel dispensers.

Objectives:

The study aims to evaluate separately the costs associated with water conservation (via lower flow fixtures) and improved hygiene (via electronic "touch-free" fixtures). Because any renovation of plumbing fixtures would require meeting current code, the water conservation study evaluates three scenarios based on manual technology: a) high water conservation (beyond code), b) meeting code now, and c) meeting code after a delay of ten years (see Table below). Automated electronic sensors for

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"touch-free" technology are considered separately as either a) included or b) not included for toilets, urinals, faucets, soap dispensers and paper towel dispensers. Table 1 summarizes the cases examined. Each case is evaluated based on its net present costs over a 30 year period, the annualized equivalent cost, and (for water) the cost per gallon of water saved.

Table 1: Water conservation scenarios.

	Water Conservation Scenarios (manual technology)		
	Baseline	Meet code	Beyond code
Toilet (gpf)	3.5	1.6	1.6
Urinal (gpf)	3.0	1.0	0.13
Lavatory sink	No aerator	Aerator	Aerator

Data and analytical methods

This study was designed to compare water, paper and soap use before and after renovation of the 1st floor restrooms in the West Wing of the Main Library at MSU. These are high-use restrooms that jointly serve an average of over 800 people daily during the academic year. The men's and women's restrooms each contain 5 toilets, 6 sinks, 4 paper towel dispensers, and 4 soap dispensers. The men's room also contains 6 urinals. Water, paper towel and soap use were monitored as described below during Fall term, 2007, before the winter break renovation. The monitoring continued in Spring term 2008, after the renovation. The renovation involved replacing toilets that consumed 3.5 gpf by ones that use only 1.6 gpf; 3.0 gpf urinals were replaced by 0.13 gpf ones; sinks were replaced with new aerated, automatic ones, and paper towel dispensers were replaced by automatic ones.

In the absence of room-level water meters, water use in the restrooms was estimated from the number of restroom users, the probability that a user flushed a toilet or urinal, and metered water flows from the lavatory sinks. Infrared sensors made automated counts of restroom visitors, installed meters measured water use in the sinks, and student enumerators observed the frequency of restroom facility use during random observation periods. Proportions of time that each water use occurred were calculated for each hour-long observation period according to whether the users used a) toilet, b) urinal, or c) sink. Average proportions of facility use over the entire sample were used to calculate estimated water consumption by restroom and facility type. With this information, water usage before and after renovation was calculated as well as the estimated water usage for the different scenarios of analysis considered. The custodial staff provided information on numbers of paper towel rolls, soap cartridges and sensor batteries replaced.

Information on the costs of the different scenarios was obtained by interviewing experts who estimated the costs of purchase and installation of each restroom fixture, as well as of maintenance labor and materials. These typical costs were preferred to actual costs, because the latter included substantial costs associated with research (e.g., installation of water meters for the sinks) and learning (e.g., installation of rechargeable batteries that proved inconsistent with fixture specifications).

The analyses are based first on physical savings in water, paper towels and soap. The cost analysis calculates net present cost NPC for the cash flows was calculated, as well as annualized equivalent costs, AEC (see annex for the associated formulas). The analysis assumes no inflation, but uses a discount rate

of 5% to reflect the value of potential benefits that could be realized by investing elsewhere in the University. The costs associated with water conservation are presented as costs per thousand gallons saved, and these costs are compared to the cost of acquiring hard water from MSU wells or softened water from the East Lansing water utility.

Results

Water conservation scenarios: Gains compared to baseline

The water conservation results are reported in Table 2 and Figure 1. Associated costs appear in Table 3 and 4. Key results are as follows:

1. Beyond code renovation: The renovation beyond code, including ultra-low flow urinals, saved an estimated 612,000 gallons of water per year (Table 1), a 62% reduction from the baseline scenario (Figure 1). The cost of the initial investment is $12,800. The cash flow net present cost (NPC) at a 5% discount rate considering the initial investment and maintenance costs is of $12,800 and the annualized equivalent cost (AEC) is $830 (see annex 1 and 2 for details on calculations).

2. Meet current code now: The renovation to meet current code saved an estimated 545,900 gallons of water per year, a 56% reduction from the baseline scenario (Figure 2). The initial investment cost is $11,600, $1000 less than in scenario #1 (Table 1), due to the cost difference for ultra low flow urinals. Maintenance costs are expected to be no different from those at present.

3. Meet current code after 10 years: This scenario is the same as scenario #2, but entails the University continuing to incur the costs of current water consumption for another ten years (at a cost for MSU unsoftened water of $2.20 per thousand gallons), plus the (future discounted) cost of the renovation to meet code at that time.

Touch-free technology: Gains compared to baseline

The initial investment cost for renovating with touch-free technology along with the "beyond code" water saving scenario is $19,800 for the new fixtures and installation (Table 5). Since the automatic devices require batteries, the maintenance cost during the life cycle of the equipment includes the annual battery replacement cost (batteries and labor). The NPC at a 5% discount rate is $23,530 (see Annex 2).

The installation of touch-free technology had modest effects of rates of paper towel and soap use. Paper towel use increases by 6% or 35 rolls annually, at an estimated cost of $94[2]. On the other hand, despite a 60% reduction in the quantity of soap cartridges used (to 46 per year), the cost of soap increases because the automatic dispensers cost $25.13 per cartridge, compared to $11.00 for the manual dispensers (see Annex 2).

[2] The recorded paper use increase may be an artifact of start-up problems with the touch-free paper dispensers, resulting in rolls of paper being left out for restroom visitors. Continued monitoring could confirm whether and how paper use changes.

Conclusions

Water conservation

MSU can make dramatic savings in water use and cost of water provision by renovating heavily used restrooms outfitted before 1992 to meet current building code. That change alone would reduce water consumption by 56%. Making such a change now, rather than delaying ten years, would save water at a cost of only 53¢ per thousand gallons saved—one quarter MSU's internal cost of water provision ($2.20 per 1000 gal). Taking the added step of installing ultra-low flow urinals would cut restroom water use by an additional 7% at a marginal cost of $1.16¢ per 1000 gallons, still below MSU's internal water cost (Tables 3 and 4).

Touch-free hygienic technology

Touch-free technology can reduce disease transmission as well as reducing bathroom odors by insuring flushing. The added annualized cost of $1,785 is substantial, but works out to roughly ½¢ per restroom visit. While we have no measure of benefits, those can be expected to include reduced costs of health care and absences by staff, faculty and students, as well as improved bathroom ambience. Given the cost of touch-free technology, it would be prudent to confirm evidence of compensating benefits (whether to MSU directly, or to members of the MSU community indirectly), before expanding investment in this technology.

Implications and recommendations for water conservation in the University

This case study demonstrates that proactive renovation of plumbing facilities can save money for the university while conserving water. Strictly speaking, the Main Library first floor restrooms represent a special case where heavy traffic allows the investment costs of water conserving renovations to be recouped by water savings from many users. But for well-used restrooms in general, it is cost-effective to replace old plumbing fixtures with water conserving ones that meet current code. ***Based on current renovation costs, water use per fixture, and MSU's cost of delivering water, it is cost-effective for the university to renovate restroom fixtures that receive an average of 16 or more users per day*** (Table 6).

Touch-free technology has relatively smaller initial investment costs but substantial maintenance costs. While the annualized cost of touch-free technology would decline with fewer restroom users, the cost per user would likely rise. ***Consequently, touch-free technology is not directly cost-effective to the university and should only be installed if evidence of compensating health and other benefits is documented.***

TABLES AND FIGURES

Table 2: Net present cost and annualized equivalent cost for water conservation scenarios, 1st floor Main Library restroom scenarios (manual technology, 30 year time horizon)

Water conservation scenario	NPC @ 5%	AEC
1. Beyond code now	$12,800	$833
2. Meet code now	$11,600	$755
3. Meet code after 10 years	$16,050	$1,044
Gain from going beyond code now (#1-#2)	$1,200	$78
Gain from meeting code now rather than in 10 years (#3-#2)	$4,450	$289

Note: NPC: net present cost, AEC: annualized equivalent cost. #1, #2 and #3 refer to the different scenarios.

Table 3: Annual water savings compared to baseline, 1st floor Main Library restroom water conservation scenarios

Water conservation scenario	Water (gallons)
1. Beyond code now	612,930
2. Meet code (now or later)	545,900

Table 4. Annualized water cost per 1000 gallons for water saved, two scenarios.

Beyond code now, rather than just meet code now	$1.16
Meet code now, rather than in 10 years	$0.53

NB: Compare to cost of hard water from MSU ($2.20 per 1000 gal.) or soft water from East Lansing ($6.10 per 1000 gal.)[3]

Table 5: Changes in annualized use and costs for adding "touch-free" electronic fixtures

	Change in quantity	Change in NPC over 30 years	Change in AEC
Water	No change	$10,735	$698
Paper towels (rolls)	35	$1,450	$94
Soap (cartridges)	-46	$15,900	$993
Total cost		$28,085	$1,785

[3] MSU water price from Lynda Boomer (personal communication). East Lansing water utility retail price from http://www.cityofeastlansing.com/CITYGOV/Treasurer/WaterSewerBillingInfo.asp.

Table 6: Breakeven number of restroom users to justify water-conserving renovation.

Water use parameters for each fixture	Toilet	Urinal: Standard	Urinal: Ultra-low flow
Old manual fixture (gpf)	3.5	3.0	3.0
New manual fixture (gpf)	1.6	1.0	0.13
Water saving per use (gpf)	1.9	2.0	2.875
Value of water savings ($/flush @ MSU cost = $0.0022/gallon)	$0.00418	$0.00440	$0.00633

Cash flow	Toilet	Urinal: Std.	Urinal: ULF
Year 1	$400	$400	$600
Years 2 – 30	0	0	0
Net present cost (NPC) @ 5% discount rate	**$380.95**	**$380.95**	**$571.43**
Annual equivalent cost (AEC) @ 5% discount rate	**$24.78**	**$24.78**	**$37.17**
Number of flushes per year to cover renovation costs by water savings	**5,929**	**5,632**	**5,877**
Average flushes per day to cover renovation costs with water savings	**16**	**15**	**16**

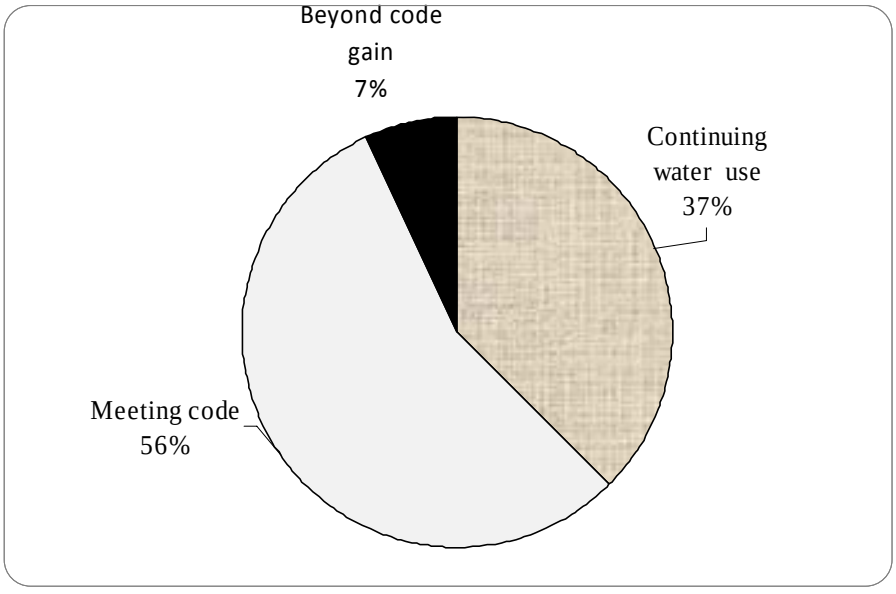

Figure 1: Annual water savings percentages compared to baseline.

Annex 1: Analytical methods.

Net Present Cost (NPC) measures the current value of accumulated future cash flows from an investment. To determine their present value, all cash flows must be discounted to reflect the fact that a dollar today could be invested otherwise to yield more than a dollar in the future. The sum of present values over a planning horizon is the net present value. (For clarity we refer to net present cost, because only costs are included in this analysis.)

$$NPC = \sum_{t=0}^{T} cashflow_t \frac{1}{(1-i)^t}$$

Where:
NPC: Net present cost
$Cashflow_t$: net income or net loss of the year "t"
i: discount rate, or the opportunity cost of investments
T: number of years included in the analysis

Annual Equivalent Cost (AEC) is the annual payment that would give the equivalent net present value at the same discount rate. The equation used in the NPC calculation has cash flows that vary by year. The AEC equation calculates the cash flow payment that if paid annually would equal the NPC.

$$AEC = \frac{NPC}{\frac{1}{i} - \frac{1}{i(1-i)^T}}$$

Where:
AEC: Annual equivalent cost
NPC: Net present cost
i: discount rate, or the opportunity cost of investments
T: number of years included in the analysis

Adapted from Godsey, Larry D. (2008). *Economic Budgeting for Agroforestry Practices.* Agroforestry in Action report AF1006 - 2008. Center of Agroforestry, University of Missouri, Columbia, MO. http://www.centerforagroforestry.org/pubs/economichandbook.pdf

Annex 2: Supplementary tables.

Annex Table 1: Projected cash flows by system and break even costs per scenario of analysis

Scenario 1. Renovation beyond code immediately.

	Unit cost	Number of units	Installation Cost	Year	Labor cost of maintenance	Battery replacement	Cost cash flow
Urinal, Ultralow flow	600	6	3600	Year 1	0	0	12,800
Toilet	400	10	4,000	Year 2	0	0	0
Lavatory and faucet	400	12	4,800	Year 3	0	0	0
Paper towel dispenser	25	8	200	Year 4	0	0	0
Soap dispenser	25	8	200	Year 5	0	0	0
Initial Investment			**12,800**	Year 6	0	0	0
				Year 7	0	0	0
				Year 8	0	0	0
				Year 9	0	0	0
				Year 10	0	0	0
				Year 11	0	0	0
				Year 12	0	0	0
				Year 13	0	0	0
				Year 14	0	0	0
				Year 15	0	0	0
				Year 16	0	0	0
				Year 17	0	0	0
				Year 18	0	0	0
				Year 19	0	0	0
				Year 20	0	0	0
				Year 21	0	0	0
				Year 22	0	0	0
				Year 23	0	0	0
				Year 24	0	0	0
				Year 25	0	0	0
				Year 26	0	0	0
				Year 27	0	0	0
				Year 28	0	0	0
				Year 29	0	0	0
				Year 30	0	0	0
						NPC	**12,800.00**
						AEC	**832.66**

Annex Table 2: Scenario 2. Renovate to meet current code immediately.

	Unit cost	Number of units	Installation Cost	Year	Labor cost of maintenance	Battery replacement	Cost cash flow
Urinal	400	6	2,400	Year 1	0	0	11,600.00
Toilet	400	10	4,000	Year 2	0	0	0.00
Lavatory and faucet	400	12	4,800	Year 3	0	0	0.00
Paper towel dispenser	25	8	200	Year 4	0	0	0.00
Soap dispenser	25	8	200	Year 5	0	0	0.00
Initial Investment			**11,600**	Year 6	0	0	0.00
				Year 7	0	0	0.00
				Year 8	0	0	0.00
				Year 9	0	0	0.00
				Year 10	0	0	0.00
				Year 11	0	0	0.00
				Year 12	0	0	0.00
				Year 13	0	0	0.00
				Year 14	0	0	0.00
				Year 15	0	0	0.00
				Year 16	0	0	0.00
				Year 17	0	0	0.00
				Year 18	0	0	0.00
				Year 19	0	0	0.00
				Year 20	0	0	0.00
				Year 21	0	0	0.00
				Year 22	0	0	0.00
				Year 23	0	0	0.00
				Year 24	0	0	0.00
				Year 25	0	0	0.00
				Year 26	0	0	0.00
				Year 27	0	0	0.00
				Year 28	0	0	0.00
				Year 29	0	0	0.00
				Year 30	0	0	0.00
						NPC	**11,600.00**
						AEC	**754.60**

Annex Table 3: Scenario 3. Renovate to meet code after 10 years.

	Unit cost	Number of units	Installation Cost	Year	Labor cost of maintenance	Battery replacement	Cost cash flow
Urinal	400	6	2,400	Year 1	0	0	1,201
Toilet	400	10	4,000	Year 2	0	0	1,201
Lavatory and faucet	400	12	4,800	Year 3	0	0	1,201
Paper towel dispenser	25	8	200	Year 4	0	0	1,201
Soap dispenser	25	8	200	Year 5	0	0	1,201
Initial Investment			**11,600**	Year 6	0	0	1,201
				Year 7	0	0	1,201
				Year 8	0	0	1,201
				Year 9	0	0	1,201
				Year 10	0	0	1,201
				Year 11	0	0	11,600
				Year 12	0	0	0
				Year 13	0	0	0
				Year 14	0	0	0
				Year 15	0	0	0
				Year 16	0	0	0
				Year 17	0	0	0
				Year 18	0	0	0
				Year 19	0	0	0
				Year 20	0	0	0
				Year 21	0	0	0
				Year 22	0	0	0
				Year 23	0	0	0
				Year 24	0	0	0
				Year 25	0	0	0
				Year 26	0	0	0
				Year 27	0	0	0
				Year 28	0	0	0
				Year 29	0	0	0
				Year 30	0	0	0
						NPC	**16,056**
						AEC	**1,044**

Annex Table 4: Renovate beyond code immediately (Scenario 1) plus incorporate touch-free technology.

	Unit cost	Number of units	Installation Cost	Year	Paper towel & soap replace-ment	Labor cost of main-tenance	Battery replace-ment	Cost cash flow
Urinal (ultralow flow .125 gal)	800	6	4,800	Year 1	1,087	288	17	21,191
Toilet	600	10	6,000	Year 2	1,087	288	17	1,391
Lavatory and faucet	650	12	7,800	Year 3	1,087	288	17	1,391
Paper towel dispenser	125	8	1,000	Year 4	1,087	288	17	1,391
Soap dispenser	25	8	200	Year 5	1,087	288	17	1,391
Initial Investment			**19,800**	Year 6	1,087	288	17	1,391
				Year 7	1,087	288	17	1,391
				Year 8	1,087	288	17	1,391
				Year 9	1,087	288	17	1,391
				Year 10	1,087	288	17	1,391
				Year 11	1,087	288	17	1,391
				Year 12	1,087	288	17	1,391
				Year 13	1,087	288	17	1,391
				Year 14	1,087	288	17	1,391
				Year 15	1,087	288	17	1,391
				Year 16	1,087	288	17	1,391
				Year 17	1,087	288	17	1,391
				Year 18	1,087	288	17	1,391
				Year 19	1,087	288	17	1,391
				Year 20	1,087	288	17	1,391
				Year 21	1,087	288	17	1,391
				Year 22	1,087	288	17	1,391
				Year 23	1,087	288	17	1,391
				Year 24	1,087	288	17	1,391
				Year 25	1,087	288	17	1,391
				Year 26	1,087	288	17	1,391
				Year 27	1,087	288	17	1,391
				Year 28	1,087	288	17	1,391
				Year 29	1,087	288	17	1,391
				Year 30	1,087	288	17	1,391
							NPC	**40,244**
							AEC	**2,618**