ASSESSMENT OF USER SATISFACTION OF RESTROOMS WITH EXISTING TOILET FIXTURES AND NEW LOW CONSUMPTION FIXTURES

A Thesis

by

NEELIMA RAMAN VANKAMAMIDI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2004

Major Subject: Construction Management

ASSESSMENT OF USER SATISFACTION OF RESTROOMS WITH EXISTING TOILET FIXTURES AND NEW LOW CONSUMPTION FIXTURES

A Thesis

by

NEELIMA RAMAN VANKAMAMIDI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Approved as to style and content by:

Paul Woods
(Chair of Committee)

Ifte Choudhury
(Member)

F. Michael Speed
(Member)

James Smith
(Head of Department)

August 2004

Major Subject: Construction Management

ABSTRACT

Assessment of User Satisfaction of Restrooms with Existing Toilet Fixtures and New Low Consumption Fixtures. (August 2004)

Neelima Raman Vankamamidi, BArch, Jawaharlal Nehru Technological University, Hyderabad, India

Chair of Advisory Committee: Dr. Paul Woods

This research in Langford Building ‘A’, Texas A&M University, is an attempt to determine the user satisfaction of the new, low consumption toilet fixtures and lavatory valves. 253 surveys were given to the subjects, during the four phases of upgrading the restroom fixtures, to find and compare user satisfaction in each phase. The four phases were:

1. The as-is condition of the flush valves and the lavatory valve.
2. Low consumption manual flush valve and low consumption manual lavatory valve.
3. Old style low consumption automatic flush valve and low consumption automatic lavatory valve.
4. Low consumption manual flush valve and low consumption automatic lavatory valve.

The survey analysis for the building showed a positive response from the users for the low consumption valves, but not for the automatic valves, as they did not function as they were expected to.

DEDICATION

To my Parents

ACKNOWLEDGEMENTS

I would like to express my heartfelt gratitude to my advisor, Dr. Paul Woods, for excellent guidance and motivation. His patience and encouragement during the study has been a source of inspiration for me. I would like to thank my committee members, Dr. Ifte Choudhury and Dr. F. M. Speed, for their suggestions and review of my work.

I would like to thank all my friends for giving me constant motivation and encouragement. Finally and most importantly thanks are due to my family for their support and encouragement.

TABLE OF CONTENTS

Page

LIST OF TABLES

TABLE Page

TABLE Page

LIST OF FIGURES

FIGURE Page

1 INTRODUCTION

Water is an essential element to sustain life. Water was once considered an inexhaustible resource with an unlimited renewable capacity, but not anymore (Beekman, 1998). Therefore, the awareness for water conservation, reuse and recycling has been increased. Intermediate water and recycled wastewater can be used repeatedly only for certain purposes, and within a certain range, but not for drinking or human contact (Ould, 1997).

Out of all the other facilities in a building, restrooms consume 73% of indoor water; flushing the toilet consumes about 35% of indoor water (Cheng-Li-Cheng, 2002). Therefore, water conservation in restrooms becomes very important in the overall process of water conservation in a facility. The chief source of conserving the indoor water is by reducing the water flow in restroom fixtures (faucets, commodes and urinals).

The invention of water-flush type commodes traces back to civilizations like Minoan and the Romans. These civilizations created astonishing accomplishment of engineering and produced facilities with piped hot and cold water, water-flushed sewage systems, and steam rooms (Pathak, 1995).

The modern water closet/restroom was invented about 100 years ago (Pathak, 1995). During 1890 we had the first cantilever type of toilet. Since then the world has not

This thesis follows the style and format of Neuropsychology.

witnessed any significant technical change except for some change in shape of toilets and reduction in quantity of water per use. There is no drastic change in its physical form; which could be because of its simple and effective design.

Although U.S. Environmental Protection Agency standards have reduced the quantity of water allowed per flush from 3.5 gallons per flush to 1.6 gallons per flush for new construction, there are still efforts to further reduce the water consumption by requiring the retrofitting of existing lavatories, water closets and urinals with low consumption automatic valves. There are concerns in the industry regarding the potential negative aspects of the low consumption automatic valves, such as, carrying capacities of reduced flows and about the overall cleanliness of the toilets (Reid, 1996). The low water quantities in the low consumption water closets may increase the ratio of solid waste in the drainpipe than the water. Due to this the fluid flowing to the treatment plant may affect the operation of the wastewater treatment plants (Reid, 1996).

Restrooms and their related facilities are the ‘display’ or the ‘emphasis’ areas of any establishment (Brown, 1996; Feldman, 1975). People generally judge the entire facility and its management by the condition of the restroom. Even though from the strict cost-benefit analysis, restrooms are a drain on the operations budget, they should be maintained and upgraded very frequently.

After the facility fulfills all the necessary regulations, the main concern should be to satisfy the users’ needs and comfort. Few surveys were done in the past, which focused on user satisfaction of modern restrooms. But customers were often provided with the complaint boxes to state their opinions rather than complaints about fixture performance.

Restrooms at present face with range of ongoing challenges, from poor fixture performance to access problems and vandalism. Surveys of complaints show that about 30-40% of the users were unhappy about cleanliness in restrooms (Thomas, 1998).

1.1 PROBLEM STATEMENT

The purpose of the study is to analyze and compare the user satisfaction of the restrooms with existing toilet fixtures and new low consumption fixtures.

1.2 RESEARCH OBJECTIVES

1. Determine user satisfaction of restroom for the original fixture, as-is, configuration.
2. Determine user satisfaction of the restroom for low consumption manual flush valve and low consumption manual lavatory valve.
3. Determine user satisfaction of the restroom for old style low consumption automatic flush valve and low consumption automatic lavatory valve.
4. Determine user satisfaction of the restroom for low consumption manual flush valve and low consumption automatic lavatory.

1.3 HYPOTHESIS

User satisfaction will be higher for low consumption restroom fixtures.

1.4 DEFINITIONS

Commode: A toilet.

Effluent: Septic system liquid waste.

Facilities / Facility: It is real property, including all attachments, that functions to fulfill a purpose assigned by an enterprise, for example, an industrial facility exists on a site that functions to fulfill specific, assigned, production requirements. The most obvious facility is a building, e.g., business facility. The term is loosely used to describe an available building, offered for occupancy.

Fitting: Any pipe part used to join together two sections of pipe, such as elbows, couplings, bushings, bends, wyes, etc.

Fixture: In plumbing, the devices that provide a supply of water and/or its disposal, e.g. sinks, tubs, toilets.

Grey Water: The wastewater from washing and dishwashing machines as well as showers and sinks.

HVAC: Heating, ventilation, and air conditioning.

Lavatory: A fixed bowl or basin with running water and drainage for washing. Bathroom sink.

Low Consumption Toilet: A class of toilet designed to flush using 1.6 gallons of water or less. Also known as "Water-saving" toilets.

Payback Period: The amount of time it takes to pay back the fees for getting a loan or investment on a property.

Recycling: A product or packaging, which can be collected, re-processed and resold as a new product (e.g. in NZ - glass, aluminum, paper, and some plastics, water, etc.).

Retrofit: It is a return to something that is complete and functional to remove and/or add parts. The term *retrofitting* is used in facilities management to describe the changing of a building's operational functionality. To *retrofit* is to act to change, modify or upgrade a function.

Sanitary Fitting: Fitting that joins the assorted pipes in a drain, waste and vent system; designed to allow solid material to pass through without clogging.

Sink: A stationary basin connected with a drain and water supply for washing and drainage.

Valve: A device that regulates the flow of water.

Working Pressure: It is the test pressure read when water closets or urinals are flushed because a certain percentage of these fixtures are used simultaneously. Working pressure can also be interpreted as the pressure required at peak periods.

1.5 ASSUMPTIONS

1. The respondent answers the questionnaire sincerely to the best of their knowledge.

2. The respondents to the survey have used and noticed the changes of the restrooms in the building at every phase of the retrofitting.

3. Janitors did not spend more time, effort or care in cleaning the restrooms during the experiment.

1.6 DELIMITATIONS

The study is limited only to the fixture upgrades in the restroom. The study does not include the other facilities like HVAC or the architectural design aspects for the user satisfaction studies.

1.7 LIMITATIONS

The study is limited to a building at Texas A&M University. The restrooms of Langford Building ‘A’ are studied and retrofitted for the purpose.

2 LITERATURE REVIEW

Once considered an inexhaustible and cheap resource, water is now becoming an expensive commodity. Pollution and shortage of fresh water are becoming one of the most critical global problems (Cheng, 2001). With large populations, aging infrastructure and deferred maintenance backlogs, many educational institutions are researching water management solutions. In an effort to reduce water consumption, equipment retrofits and/or upgrades are being used. This can cut water consumption by 25 to 40 percent, with a similar reduction in costs and a high return on investment (Scaramelli, 1997). One of the easiest and most effective ways to reduce water consumption is by using low consumption fixtures. This not only saves fresh water but also energy that would be used treating the wastewater. These low consumption, sensor-operated flush valves help increasing user satisfaction by ensuring restroom hygiene through odor reduction and increased cleanliness.

2.1 WATER CONSERVATION

“Water is scarce. We need to all work together to conserve this precious resource” (Knight, 2002). A few conservators have called water “blue gold” or “the oil of the 21st century”. It has become an irreplaceable commodity in finite supply (Coy, 2002).

“Only 3% of the water in the world in the world is fresh water and the remaining 97% is saline, which is unsustainable for drinking, agricultural and industrial production, or any other important human use. Of the remaining 3% fresh water, 2% is stored in the polar ice caps, whose use is not feasible for techno economic reasons. At the same time, most of the earth's fresh water is found 700m below the surface; this is technically and economically infeasible. Thus, only 1% of the total water is available for human use" (Gonzalez, 1998).

"Currently, 73% of all fresh water used is for irrigation, 21% is accounted for by the industrial sector, and the remaining 6% is used for domestic purposes" (Gonzalez, 1998). There is an ever-rising demand for fresh water due to the increase in the population and industrial activity.

The population and industrial output of the United States expanded rapidly, in the second half of the 20th century, resulting in deleterious effects on the nation's rivers and streams. At the same time, the world population doubled, from 2.3 billion inhabitants to 5.3 billion that led to an increase in water consumption by 300% from1000 km^3 to 4000 km^3. Therefore, the yearly per capita consumption increased fourfold during this period (Beekman, 1998). Even though the Water Pollution Control Act was amended five times by 1965, water quality continued to worsen. This lead to the 1972 amendments, which completely overhauled the way that industries and municipalities approached the matter of wastewater treatment (Landers, 2002).

2.2 WATER RECYCLING

"No country can be economically or socially stable without an assured water supply. Together, the many ways of conserving, recycling and reusing water constitute the makings of an efficiency revolution. The demand for water supply continues to increase, thus its reuse is becoming an important component in the planning, development and overall use of water resources" (Beekman, 1998).

Grey water is a multi-contaminant, highly variable source, meaning there are a lot of contaminants of different types in the water and that both the flow and levels of contamination will vary over a period of time. Grey water is alkaline because two of its main components are soap and washing residues, which tend to be alkaline. It also has many dissolved organic materials (Ould, 1997). The contamination can be removed to a considerable extent by a few chemical reaction and filtration processes. Organic particles cannot be completely removed even after the disinfecting process (chlorination). Therefore this recycled water is not fit for human consumption, but it is mechanically clean and could be used for flushing toilets and washing (Ouano, 1983).

Grey water can be purified to a greater extent by using a reverse osmosis system. This purified water can be reused used for almost all purposes but for drinking, moreover, but this is an expensive process. Hence implementing water conservation techniques like retrofitting with low consumption valves in a restroom is the best alternative to avoid the formation of grey water (Henze, 1995).

2.3 EVOLUTION OF LOW CONSUMPTION VALVES

The Federal Energy Policy Act of 1992 mandated that all commercial plumbing fixtures comply with maximum water use requirements.

- Water closets must now operate on only 1.6 gallons of water per flush (gpf)

- Urinals cannot exceed 1.0 gallon per flush
- Maximum flow of faucets used in public commercial installations can not exceed 0.5 gallon per minute (gpm) or be designed to meter no more than 0.25 gallon of water during a single cycle
- A standard lavatory faucet cannot exceed 2.2 gallons per minute (gpm)

This legislation recognized that the precious resource of water is not inexhaustible and that, plumbing fixtures can be designed to operate on less water and still effectively comply with industry standards (Jahrling, 1999).

To achieve this low water consumption requirement for the plumbing fixtures, manufacturers decreased the size of the opening and trap of the existing gravity bowl. This resulted in a stronger siphonic action to withdraw the waste, but the results of this evolution were not very fruitful. The user had many problems. The user had to double flush and hold down the handle longer to clear the bowl. The toilets clogged more often and so toilets had to be cleaned more often.

Pressure-assist technology was developed to combat these problems. The design of the bowl was changed to accommodate the strong force from pressure which otherwise is not built into the gravity bowl. Double flushing was eliminated; and bowl stoppages were reduced by 95 percent compared to the older 3.5 GPF toilets. Water consumption was also reduced by 39 percent. User satisfaction survey also says that results were impressive (Baz, 1997).

The newest advancement in low consumption pressure flush equipment is the sensor-operated flushing device or electronic plumbing devices. Sensor flushometers are expected to meet the strict water use requirements mandated by the Energy Policy Act of 1992. A sensor flush valve is designed to guarantee one flush per use. According to Westercamp, these devices ensure not only consistent water use and low maintenance of the restrooms but also cleanliness and hygiene (Westerkamp, 2000).

2.4 FACTORS TO BE CONSIDERED FOR RETROFITTING RESTROOM FIXTURES

- Drain capacity, slope, diameter and horizontal run from the fixtures should be checked and evaluated to find out if conditions are adequate for a retrofit. (Manoukian, 1997)

- The age of the drain line is an important factor to determine its strength. Therefore, the pressure withstanding capacity of the drain line should be determined in consideration of its age (Martin, 1999)

- The distance between the flushometer and the fixture should be properly considered according to manufactures' specifications (Manoukian, 1997)

- If sensors are installed as part of the retrofitting, their proper selection, orientation, and adjustment should be considered (Manoukian, 1997)

- As infrared light and other sensing signals are invisible to the human eye, so the installer must ensure that the product is installed as per all manufacturer requirements and recommendations (Sloan, 2003)

- As every bathroom design may vary slightly, fine-tuning or adjustment of the sensing range is often required and expected after the valve is installed (Sloan, 2003)

- Electronic flushometer must also be matched to the proper urinal and water closet fixture to ensure that the valve and fixture are matched for water use and connection compatibility (Manoukian, 1997)

- Position of the electric box can be raised or lowered by 1" (25mm) if in conflict with the handicap grab bars (Sloan, 2003)

- Failure to properly position the electrical boxes to the plumbing rough in will result in improper installation and impair product performance. All tradesmen (plumbers, electricians, tile setters, etc.) involved with the installation of this product must coordinate their work to assure proper product installation (Sloan, 2003)

2.5 RESTROOM DESIGN

Restroom design reflects the users' architectural and hygiene preferences. It also reflects ones culture, manners and etiquette.

For example, in some ways European restrooms have more privacy than American restrooms (IPA, 2001). The stalls in the European restrooms are fully enclosed like bathrooms in homes. Some people consider this US-style toilet as an intrusion into ones personal space as sounds and odor from within the stalls can easily transmit into other areas of the restroom. But these partially partitioned stalls are designed to have more ventilation and also to eliminate dirty doorknobs in a closed restroom and vandalism (IPA, 2001).

Design criteria of restrooms depends first and foremost on

- Psychological and cultural attitudes
- Basic physiological and anatomical considerations
- Physical or the 'human engineering' problems of performing the activity (Kira, 1976)

Other major concerns in restroom design are

- Lack of privacy
- Lack of sufficient number of stalls
- Odors
- Noise levels
- Lighting

- Cleanliness and appearance
- Fixture condition and maintenance
- Sanitation (drain pipe capacity)
- Vandalism
- Physical safety (IPA, 2001)

Spending some extra time upfront in designing the restroom is better than wasting lot of time in maintenance later on (Allyn, 1999). Attention to details in the restroom layout is very important in the design of a restroom. Kennedy (2001) lists a few design options:

- Considering the issues regarding traffic pattern & accessibility, fixture & building material, natural lighting & ventilation, and preventing vandalism
- Concealed flush valves to keep destruction of the restroom property to a minimum and automatic faucets reduce wear and tear while improving hygiene
- Motion sensors instead of light switches
- Plastic stalls with heavy weight hinges
- Urinals without edges to prevent crusty building up
- Toilets seats made with anti-bacterial coating to improve hygiene

- Hanging toilets to ease maintenance
- Ceramic tiling on floors and walls to enhance appearance

2.5.1 Privacy

2.5.1.1 Degrees of privacy

Privacy demands of a particular facility emerge as the predominant factor for deciding the number of stalls and their usage (Heir, Robbin, 2000). Moreover, the privacy factor in the restroom is relative, and depends on various factors in addition to its purely personal aspects. It is a value that is related to a particular culture, socioeconomic sense, and is a response to particular social situation. In other words, we must have privacy so as not to violate the socio-cultural norms requiring that certain things be done in private. These privacy levels cannot be quantified but can be broadly divided into three major categories,

- Privacy of being heard by but not seen
- Privacy of not being seen or heard
- Privacy of not being heard, seen, or sensed (Soifer, 2000)

The location of the bathroom with respect to the other areas of the building, the acoustical treatment of the space, the location and size of the restroom openings (windows, ventilators) should also be taken into account after deciding on one of the above categories.

2.5.1.2 Publicness

The fear that someone else has used and touched the fixtures before us is the concept of publicness. Whenever one uses the facility, he psychologically possesses that particular place for that instant. This is known as a sense of 'mineness'. This illusion shatters once any trace of previous users is found. Therefore, spotlessly clean toilets can help the user in pretending that he is in a private facility, thereby determining the 'territories of the self' (Kira, 1976). Hence, the more spotless the facilities, the less overt and tangible evidence there is to remind the user of the fact that it is indeed a public facility that they are sharing with others, either simultaneously or sequentially (Alexander, 1976).

Such territorial violations can come in many forms, such as:

- Visual
- Auditory
- Olfactory
- Tactile
- Physical (like warm seats)

2.5.2 Number of stalls

If the facility is a school or a work place, where people come every day and use the same restroom regularly, then they generally tend to go only into a specific stall. This tendency is observed because of the users' association of 'mineness' with that particular stall. The user would not like to go to any other stall in case the restroom is busy. So having sufficient number of restroom stalls is very important (Heir, Robbin, 2000).

If the facility is a public facility like a cinema, theater or an airport where there are many users, then the number of stalls plays an important role so as to avoid queues. Here the users are one-time users, so here cleanliness plays an important role in the hygienic point of view and also to establish temporary 'territories of self' that very moment.

2.5.3 Storage spaces

Proper storage is an essential item in terms of the whole facility. The storage includes, the open storage such as the coat hangers, soap dispensers, tissue paper holders etc.; trash disposal and personal hygiene disposals; and closed storage for the various equipment.

2.5.4 Material usage

2.5.4.1 Surfacing material

Materials used in the facility for fixtures, partitions and flooring are important in the overall design of a restroom. This is true not only from the aesthetic point of view, but also in terms of the moisture content/wear and tear for the restrooms (Kira, 1976). The appropriateness of materials to be used are influenced by many factors such as:

- Budget
- Kind of usage

- Number and frequency of usage
- Kind of image required for the facility

2.5.4.2 Fixture material

The fixture material selection should be done carefully and should be tested for the following performance characteristics:

- Structural soundness
- Dimensional stability
- Chemical stability and inertness
- Abrasion resistance
- Stain resistance
- Non-absorption
- Freedom from odor retention
- Visual and bactericidal clean ability (Kira, 1976)

2.5.4.3 Wall material

The wall material such as the insulation, cladding, paint etc, should be selected carefully to withstand the harsh usage. There are a lot of constraints like moisture, maintenance, acoustical, and odor in finalizing the material to be used in the restrooms (Kira, 1976).

2.5.4.4 Flooring material

The flooring in the restroom is often wet and so its selection becomes very critical. The flooring should be chosen keeping in mind safety more than aesthetics (Kira, 1976). The flooring:

- Should not skid when it is wet
- Should dry fast
- Waste material should not stick to the surface
- Should be easily cleanable
- Should not leave stains when cleaned (Kira, 1976)

2.5.5 Acoustics

One considerable concern and embarrassment to people is the matter of noise. Any restroom sounds, either produced by the fixtures or the human tend to be pronounced, locationally indefinable, and hence embarrassing to both the user and the listener. A few users flush the toilet before starting to use it to cover the sounds that they are going to produce while using the toilet (IPA, 2001). This results in double flushing, which doubles the water consumption per user. Some facilities therefore use light background music. In some other facilities they provide users an option of making an artificial flush sound in order to cover the sounds they produce (IPA, 2001).

In any matter, the sound of a flushing water closet is also considered objectionable, both because of modesty and because of the loud noise (Kira, 1976). Therefore the walls, floor and ceiling should be insulated properly with acoustic material to cut down on the noise.

2.5.6 Heat and ventilation

2.5.6.1 Harmful gases

Activities in restrooms produce lot of odor (Kira, 1976). Therefore, restrooms should be designed so as to provide more ventilation to remove these harmful odors (Griffin, 1998).

2.5.6.2 Moisture content

Ventilating a bathroom eliminates moisture, mold growth and a variety of problems that cause materials in the bathroom to degrade. Moisture in the restrooms:

- Loosens tiles
- Encourages mildew
- Traps dirt on surfaces
- Makes drywall soggy
- Makes fixtures rust
- Doors swell to un-closable proportions

- Paint peel inside and outside the restrooms (National Kitchen and Bath Association, 1997)

Moisture problems can sometimes show up in the attic in the form of wet roof framing, or in insulation, where condensation diminishes the insulating value (Kira, 1976).

2.5.6.3 Temperature

The temperature also should be kept little higher in the restrooms than the other areas in the facility as people might feel cold because they have to remove their warm clothing partly to perform their toilet activities. The restroom involves activities with water, so it is preferable to have additional heaters in the restrooms for quick heating. The main criteria in the restroom should be to keep the air quality high, and heat loss low (Kira, 1976).

2.5.7 Lighting

Proper lighting should be provided not only from safety standpoint but also for the facility to look clean. Researchers at Massachusetts Institute of Technology and National Institute of Mental Health have discovered that there is a growing link between the lighting (may it be natural or artificial) and health (Kira, 1976). It is always advisable to provide extra lighting in all areas so the room does not appear dark and dingy (Griffin, 1998). Adequate lighting also creates a feeling of spaciousness in a cramped restroom (National Kitchen and Bath Association, 1997).

2.5.7.1 Hygiene concerns

Cleaning the restroom becomes difficult without proper lighting, consequently, letting the bacteria grow in the unclean areas. Research conducted at the Massachusetts Institute of Technology and National Institute of Mental Health reports link between the lighting and health. The results of the study also states that due to inadequate lighting, there is

- Increase in fatigue
- Decrease in performance
- Diminished immunological defenses
- Possibly impaired fertility (National Kitchen and Bath Association, 1997)

2.5.7.2 Safety and vandalism

Adequate light should be provided to avoid vandalism and promote safety. The floor in the restrooms is likely to be wet sometimes and so there is a possibility of skidding in the absence of insufficient lighting. So adequate lighting should be provided for the user to watch for the wet floors. Vandalism also might increase if the lighting is dim (Kira, 1976).

2.5.7.3 Natural lighting

Ultraviolet light is necessary for our bodies to synthesize vitamin D, which in turn is necessary for calcium absorption (Kira, 1976). This Ultraviolet light can be got into the restrooms through the windows, ventilators or skylights. Although natural lighting is good for a facility from a hygienic point of view, it has the privacy constraints. In such cases, openings can be placed nearer to the ceiling with inclined horizontal frosted glass strips, which would ensure privacy.

2.5.7.4 Choosing the artificial light fixtures

Care should be taken with the choice of light fixtures especially in the ladies toilet, not to distort the natural colors as women tend to use the restroom for make up too (Kira, 1976).

Successful bathrooms have a balance of 3 lighting types:

- General lighting
- Task lighting
- Accent lighting

These three lighting types are achieved by any one, or combination of three different light effects, which are:

- Down light
- Indirect light
- Up light (National Kitchen and Bath Association, 1997)

2.5.8 Hygiene in restroom

2.5.8.1 Transmittable bacteria

There has been a change in the characteristics of the restroom user. They have new attitudes, expectations and concerns regarding restroom design. The users have become keenly aware of transmittable bacteria and viruses by hand contact with the restroom fixtures. This has been due to the rapid education through the media about communicable pathogens (Jahrling, 2002). When a person touches the handle on a faucet or a flush valve, residue on that person's hand or fingers may be physically transmitted to the handle of the product. This residue (bacteria) can than be transferred to the next person touching the handle causing cross contamination (Lauer, 2000).

2.5.8.2 Odor

Another great hygiene concern in public restrooms is odor. In many public restrooms, some people do not flush the toilets or urinals, as they don't want to touch the handles on the fittings. Due to this, the restrooms produce unwanted odor. Sometimes, if the restroom is not cleaned for a long time, effluent gases produced from the residue can harm the users (Rosen, 2003).

2.5.8.3 Waste pipe buildup

In schools and universities during vacations and breaks when the fixtures are not used for some time, waste Pipe Buildup- can develop in urinal and waste pipes (Lauer, 2000).

Researchers and Manufactures found a solution for all the above-mentioned problems by inventing sensor operated flush valves for urinals, faucets and toilets. These sensor flush valves were designed to ensure the following:

- Follow the Federal Energy Policy Act of 1992 of the quantity per flush
- The user is not required to touch the fixture, thus not bothering about the transmittable bacteria
- Sensor flushing devices ensure flushing after each use, thus avoiding the problem of standing urine or waste in the fixture
- They flush automatically at least once in every 24 hours, avoiding stagnating the waste even if there is some residue left
- The sensor-equipped restrooms on the whole are manufactured to provide more aesthetic and clean restrooms (Lauer, 2000)

2.6 CONTROVERSIES ABOUT LOW CONSUMPTION FIXTURES

Low consumption fixtures had many criticisms when they were first introduced into the market; there was much opposition against them. “Most of them work just fine when they're new, but as they get older, a significant number do develop one or more problems” (Tobin, 2001). It was experimentally proven that the low-flow toilets save water, but there were doubts regarding their workability in practical situations initially.

The reason for these doubts regarding low consumption valves is because of its failure when it was first developed. There were problems in flushing out the bowl at the first flush, and hence required double flushing. Reducing passageway diameter later to around 1.5" solved these problems partially. The smaller diameter of the outlets increased the velocity of the flush and helped cleaning of the bowl and, at the same time increased the danger of clogging and overflowing of the toilet. To avoid this situation, it is always advisable to reduce the size of the cast iron pipe running to the toilet to accommodate the newer design and boost efficiency (Baz, 1997).

One of the other reasons for fixture to malfunction after certain time is due to the insufficient diameter of the drain line. Reducing the volume per flush has negative benefits in draining, carrying solids in flows and increasing deposits inside piping. In addition, the fluid flowing to the treatment plant contains more solids compared to the water and effects the operation of the plants (Henze, 1995). ANSI established a (laboratory) test standard that would ensure that low consumption toilets would work in the field without causing clogs.

Many experiments were also conducted for economic feasibility and user satisfaction of low consumption fixtures, and the results were positive in almost all the cases (Woodard 2000).

2.7 EXPERIMENTAL RESULTS

2.7.1 Experiment I

Conservation program at Sandia National Laboratories conducted a full-scale evaluation of low-flow restroom fixtures in comparison with conventional high-flow fixtures. The metering system used includes several metering points and a communication system to allow monitoring them in real time. A central control/display system allowed operators to control metering points and display instantaneous and totalized flow data. The evaluation involved retrofitting all restrooms in one of the buildings at Sandia with low-flow toilets and urinals. The building has 6 restrooms and approximately 400 daily users.

The result is that low-flow fixtures installed at Sandia have saved 40 to 60 percent water as compared to high-flow fixtures and have presented no extra maintenance burden. For the whole building, water usage for toilets and urinals is down from 3,200 gallons per day before the retrofit to 1,400 to 1,500 gallons per day with the new fixtures.

The cost of replacing 25 toilets and eight urinals was a little over $13,200. At a typical water cost of $3.00 per 1,000 gallons, the water savings will repay the initial cost in 6.2 years (Sandia National Laboratories, 1997).

2.7.2 Experiment II

This experiment was conducted by the Dept. of Water and Power (DWP) at Van Nuys Federal Building in Los Angeles in 1996 to study how water conservation efforts were successfully implemented by retrofitting existing plumbing. The challenge involved in this project was to pay for itself and not create maintenance problems for building management.

The Van Nuys Federal Building is a four-story facility with 143,000 sq ft of occupiable space housing approximately 622 individuals. Most of the plumbing was the original equipment installed when the building was constructed in 1970 with wall-hung 3.5gpf water closet, 3.0gpf urinals and 2.5gpm faucets.

The overall water savings for urinals was 744 gal per day after retrofitting which is around 54% reduction in water. Replacing the faucets reduced the water consumption from 1037gal to 259 gal per day which accounts up to 80% savings in water. For toilets the water savings was 2397 gal per day. Compared to the savings prior to the renovation, approximately, 1637 hcf (1.22 million gal) per year were saved, which is a 40% difference in the water consumption (Manoukian, 1997).

“The project at Van Nuys Federal Building demonstrates that water conservation project efforts can be successfully implemented in office buildings if plumbing technology is properly applied. Water and dollars were saved, and Van Nuys Federal Building has no plumbing problems since completion of this water conservation project” (Manoukian, 1997).

Table 1
Retrofitting toilet fixtures at Van Nuys Federal Building

Existing fixtures	Replaced fixture
Wall-hung 3.5 gpf type water closets with pedestal mount valves	1.6 gpf types with new flush valves, vacuum breaker pipe supports, and escutcheons (required by local plumbing code)
3.0gpf urinals with pedestal-mount	Low-flow 1.0gpf battery operated automatic flushing urinals
2.5gpm two-handle, center set faucets	Reduced flow units of 0.5gpm aerators, with Single control fixtures and new angle stops, supplies, grid drains, and high temperature limit stop, meeting the ANSI code.

2.7.3 Experiment III

In another experiment in Toronto, Canada, in March 2002, City Council approved the 2002 Water and Wastewater Capital Works Program Budget, which included funds in the amount of $4,031,000 for financial incentives to replace approximately 67,550 high water consumption (13 to 20) liter toilets with ultra-low flush toilets in the multi-unit residential sector. Funds in the amount of $937,000 were accepted for a monitored pilot program to replace approximately 14,700 high water consumption toilets with ultra-low flush toilets in the single family residential sector.

The results were that, 13,635 multi-unit residences were retrofitted with ultra-low flush toilets, faucets aerators and showerheads. Water savings in this experiment was around 254 liters per multi-residential suit per day. This translates to an estimated savings of 7.8 million litres of water for 3 years for the 34,998 multi-residential suites which have participated in the program.

"This costs approximately $2.3 million for 3 years since 1999, where as, the equivalent expansion in water and wastewater treatment infrastructure to service this water consumption demand would cost the City an estimated $8.8 million. The cost of the program therefore is considered good value to the City and represents about 26 percent of the cost of constructing the equivalent expansion in water and wastewater infrastructure" (Council of the City of Toronto, 2002).

2.8 USER SATISFACTION INDEX

The user satisfaction surveys conducted in many places show that most frequent complaints about restrooms are cleanliness, which can represent 30-40 percent of all complaints (Westerkamp, 2000). Experiments show that these complaints were reduced to a considerable extent after retrofitting hands-free sensor-operated fixtures. The user satisfaction survey results may not be the same for all the cases. It depends on many factors for the low consumption fixtures to perform well in a building like:

- Age and function of the building
- The existing plumbing lines and its capacity to accept and withstand changes
- Skilled technicians to retrofit
- People's expectations

To know if the retrofitting is a success, user satisfaction surveys should be conducted for each facility.

3 METHODOLOGY

The study is intended to determine the water savings in buildings after retrofitting existing restrooms with low consumption fixtures. A study of restrooms in Langford Building 'A' in Texas A&M University was done in various phases of retrofitting to measure the user satisfaction index. Survey respondents were limited to the faculty, students and staff of the same building. The survey is given to the students in classrooms.

The class schedule listing of Langford Building 'A' will be obtained from the class enrolment listing. A systematic sampling method will be used in the selection of the classes to be surveyed out of the obtained classroom listing. Around ten classes will then be selected for each round of survey. Four rounds of survey will be done:

- First, in the present conditions, as-is condition
- Second, after replacing the existing valves with low consumption manual flush valve and low consumption
- Third, after replacing the low consumption manual flush valve and low consumption with old style low consumption automatic flush valve and low consumption automatic lavatory valve
- Fourth after replacing the old style low consumption automatic flush valve with low consumption manual flush valve and low consumption where as leaving the low consumption automatic lavatory valve as is from the third

phase. The data will be subjected to descriptive statistics to analyze the user satisfaction index

4 SIGNIFICANCE OF THE STUDY

The study will attempt to conclude if the retrofitting of the restroom can be implemented successfully in an existing facility (The restrooms of the Langford Building ‘A’, Texas A&M). The study can show the differences in the overall cleanliness and hygienic conditions of the restrooms. This also can be used as the condition assessment index of the facility for future renovation. The study will show potential reasons for retrofitting of the restrooms in terms of user satisfaction.

5 THE DATA

5.1 INSTRUMENT

- Restroom is not kept as clean as I would like
- Lighting is good in restrooms
- Rest rooms have poor air quality / ventilation
- Plumbing fixtures are kept in good repair
- A single flush is not enough to empty the toilet
- The door latch on the toilet stall does not work properly
- I frequently observe that the restroom floor is wet
- Lavatory counter tops are usually dry
- I only use cold water for hand washing
- I do not feel comfortable touching fixture handles
- I would prefer a restroom with more privacy
- I do not find the coat hook on the back of the toilet stall door convenient

5.1.1 Scale

Each question asked to select from among the following 5 choices:

- Strongly agree
- Agree
- Disagree
- Strongly disagree
- Unimportant

5.1.2 Assigned values

The following values were assigned to the survey results:

- Strongly agree - 4
- Agree - 3
- Disagree - 2
- Strongly disagree - 1
- Unimportant - Were not counted for the analysis

5.1.3 Positive negative

Few statements in the survey were positive where as few were negative, therefore all the statements were made positive and then the values were assigned respectively. For example, if a survey statement is made positive, and the choice for that statement was strongly agree, then the value assigned for that statement in the actual analysis would be 1 not 4 since the statement has been reversed so as the answer would.

5.2 NORMALIZED STATEMENTS

The statements in the survey instrument were all normalized to positive statements:

- Restroom is kept as clean as I would like
- Lighting is good in restrooms
- Restrooms have good air quality / ventilation
- Plumbing fixtures are kept in good repair
- A single flush is enough to empty the toilet
- The door latch on the toilet stalls work properly
- The restroom floor is normally dry
- Lavatory counter tops are usually dry
- I only use cold water for hand washing
- I feel comfortable touching fixture handles
- I would prefer a restroom with more privacy
- I find the coat hook on the back of the toilet stall door convenient

5.3 RANDOMIZATION

The surveys were given out to the students in their classrooms in the Langford Building ‘A’ at Texas A&M University before the lecture would begin. Ten classes were selected for each of the four phases of survey from the list of the classes’ taught in that particular semester in building Langford Building ‘A’ as mentioned in the methodology. The ten classes were selected in the systematic random sampling method, that is, if there were 50 classes taught that semester in that building, every 5th class would be selected from the list of classes obtained from the class enrolment list.

6 ANALYSIS

6.1 STATISTICS USED

1. Analysis of variance

NOTE: Phase 3 was not considered in ANOVA because its sample size (n-19) was very small when compared to the other 3 phases.

Phases that were considered in ANOVA are:

Phase 1: As-is

Phase 2: Low consumption manual flush valve

Phase 4: Low consumption manual flush valve and automatic lavatory valve

2. Bar graphs

The phases that were considered in bar graphs are:

Phase 1: As-is

Phase 2: Low consumption manual flush valve

Phase 3: Old style low consumption automatic flush valve and low consumption automatic lavatory valve

Phase 4: Low consumption manual flush valve and automatic lavatory valve

6.2 SURVEY RESULTS AND INFERENCES

6.2.1 Statement 1 - Restroom is kept as clean as I would like (Q1)

The statistical results are presented in Tables 2-5.

Table 2

Univariate Analysis of Variance for (Q1)
Dependent Variable: (Q1) **Restroom is kept as clean as I would like**

Phase	Mean	Std. Deviation	N
As-Is	2.3697	.80112	119
Low consumption Manual Flush Valve	2.2833	.73857	60
Low consumption Manual Flush Valve+ Automatic Lavatory	2.3654	.74172	52
Total	2.3463	.76979	231

Table 3

Tests of Between-Subjects Effects for (Q1)
Dependent Variable: (Q1) **Restroom is kept as clean as I would like**

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	.322(a)	2	.161	.270	.763
Intercept	1111.918	1	1111.918	1864.480	.000
Phase	.322	2	.161	.270	.763
Error	135.972	228	.596		
Total	1408.000	231			
Corrected Total	136.294	230			

a. R Squared = .002 (Adjusted R Squared = -.006)

Table 4

Tukey HSD Post Hoc Tests Multiple Comparisons for (Q1)
Dependent Variable: (Q1) **Restroom is kept as clean as I would like**

(I) Phase	(J) Phase	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
As-Is	Low consumption Manual Flush Valve	.0864	.12227	.760	-.2020	.3749
	Low consumption Manual Flush Valve+ Automatic Lavatory	.0044	.12837	.999	-.2985	.3072
Low consumption Manual Flush Valve	As-Is	-.0864	.12227	.760	-.3749	.2020
	Low consumption Manual Flush Valve+ Automatic Lavatory	-.0821	.14632	.841	-.4272	.2631
Low consumption Manual Flush Valve+ Automatic Lavatory	As-Is	-.0044	.12837	.999	-.3072	.2985
	Low consumption Manual Flush Valve	.0821	.14632	.841	-.2631	.4272

Based on observed means.

Table 5

Tukey HSD Homogeneous Subsets for (Q1)
Restroom is kept as clean as I would like

Phase	N	Subset
		1
Low consumption Manual Flush Valve	60	2.2833
Low consumption Manual Flush Valve+ Automatic Lavatory	52	2.3654
As-Is	119	2.3697
Sig.		.792

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square (Error) = .596.
a Uses Harmonic Mean Sample Size = 67.719.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c Alpha = .05.

The null-hypothesis (H_0) according to ANOVA is as follows

$H_0 =$ There is no change in the population means of the sample; it is just by chance but not due to other factors (no difference among treatments)

H_A =There is a change in the population means of the samples.

H_0: $\mu_1=\mu_2=\mu_4$; H_A: $\mu_1\neq\mu_2\neq\mu_4$

Here p-value is 0.763>0.05 at 95% confidence. Therefore, we cannot reject the null hypothesis that all the population means are the same.

Figure 1 shows the bar graph for all 4 phases for statement 1.

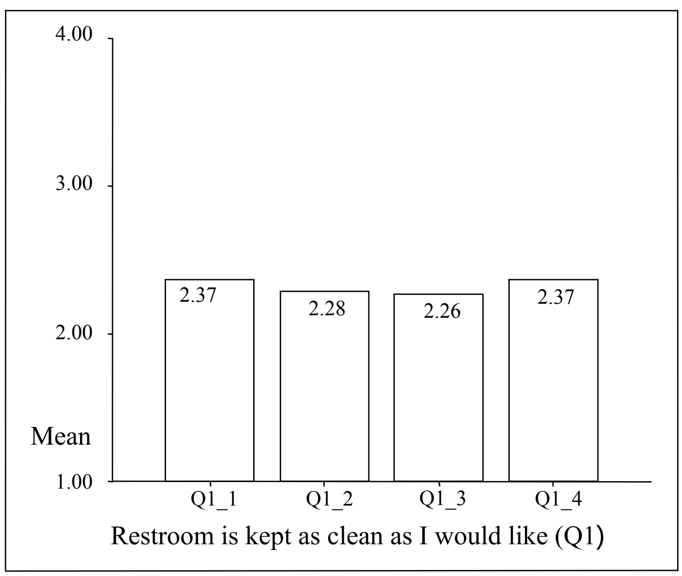

Figure 1. Bar graph of means of Q1 for all 4 phases

According to the bar graphs, we notice that the mean decreases from phase 1 through phase 3, and then increases from phase 3 to phase 4. Thus, we notice an increase in the user satisfaction from the 3rd to the 4th phase, but it remains almost the same for the 1st and 4th.

6.2.1.1 Inference

Even though the bar graph shows that there is a slight difference in the means of the 3 phases, the statistical analysis results show that there is no significant difference between their means. We can thus conclude that the user perception of cleanliness of the restrooms has not changed significantly after the retrofitting of the fixtures.

NOTE: Phase 3 was not considered in ANOVA because its sample size (n-19) was very small when compared to the other 3 phases.

6.2.2 Statement 2 - Lighting is good in restrooms (Q2)

The statistical results are presented in Tables 6-9.

Table 6

Univariate Analysis of Variance for (Q2)
Dependent Variable: (Q2) **Lighting is good in restrooms**

Phase	Mean	Std. Deviation	N
As-Is	2.7542	.71536	118
Low consumption Manual Flush Valve	2.7458	.75643	59
Low consumption Manual Flush Valve+ Automatic Lavatory	3.0000	.59409	52
Total	2.8079	.70570	229

Table 7

Tests of Between-Subjects Effects for (Q2)
Dependent Variable: (Q2) **Lighting is good in restrooms**

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.487(a)	2	1.243	2.530	.082
Intercept	1617.978	1	1617.978	3292.502	.000
Phase	2.487	2	1.243	2.530	.082
Error	111.059	226	.491		
Total	1919.000	229			
Corrected Total	113.546	228			

a R Squared = .022 (Adjusted R Squared = .013)

Table 8

Tukey HSD Post Hoc Tests Multiple Comparisons for (Q2)
Dependent Variable: (Q2) **Lighting is good in restrooms**

(I) Phase	(J) Phase	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
As-Is	Low consumption Manual Flush Valve	.0085	.11177	.997	-.2552	.2722
	Low consumption Manual Flush Valve+ Automatic Lavatory	-.2458	.11668	.091	-.5210	.0295
Low consumption Manual Flush Valve	As-Is	-.0085	.11177	.997	-.2722	.2552
	Low consumption Manual Flush Valve+ Automatic Lavatory	-.2542	.13334	.139	-.5688	.0603
Low consumption Manual Flush Valve+ Automatic Lavatory	As-Is	.2458	.11668	.091	-.0295	.5210
	Low consumption Manual Flush Valve	.2542	.13334	.139	-.0603	.5688

Based on observed means.

Table 9

Tukey HSD Homogeneous Subsets for (Q2)
Lighting is good in restrooms

Phase	N	Subset
		1
Low consumption Manual Flush Valve	59	2.7458
As-Is	118	2.7542
Low consumption Manual Flush Valve+ Automatic Lavatory	52	3.0000
Sig.		.092

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = .491.
a Uses Harmonic Mean Sample Size = 67.182.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c Alpha = .05.

The null-hypothesis (H_0) according to ANOVA is as follows

$H_{0\,=}$ There is no change in the population means of the sample; it is just by chance but not due to other factors (no difference among treatments).

H_A =There is a change in the population means of the samples.

$H_{0:}$ $\mu_{1=}\mu_{2=}\mu_4$; H_A: $\mu_1 \neq \mu_2 \neq \mu_4$

Here p-value is 0.082>0.05 at 95% confidence. Therefore, we cannot reject the null hypothesis that all the population means are the same. But at 90% confidence interval, we could reject the null hypothesis.

Figure 2 shows the bar graph for all 4 phases for statement 2.

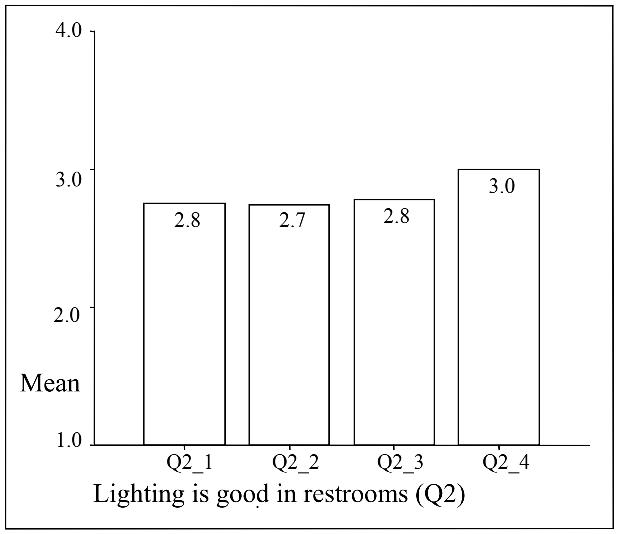

Figure 2. Bar graph of means of Q2 for all 4 phases

According to the bar graphs, we notice that the mean decreases from phase 1 to phase 2, and then increases from phase 3 to phase 4. Thus, we notice an increase in the user satisfaction from the 3rd to the 4th phase, and also the 1st and 4th.

6.2.2.1 Inference

We can infer that there is a possibility for phases to be significantly different at 90% confidence interval. If we see the Tukey table, we can conclude that the difference between phase 1 and phase 4 is significantly different at 90% confidence interval. By seeing the bar graphs we can thus conclude an increase of lighting in the restrooms after retrofitting of the fixtures.

Though there was nothing done to improve lighting, there is an increase of satisfaction of the user in the lighting aspect. This could be because of three reasons,

- Psychologically, the user may perceive the restrooms better illuminated as a consequence of the cleanliness or visa versa
- If the user is satisfied about the restrooms on the whole, he tends to be happy with most of the aspects of the restroom
- May be the time of the year the survey was conducted

NOTE: Phase 3 was not considered in ANOVA because its sample size (n-19) was very small when compared to the other 3 phases.

6.2.3 Statement 3 - Restrooms have good air quality / ventilation (Q3)

The statistical results are presented in Tables 10-13.

Table 10

Univariate Analysis of Variance for (Q3)
Dependent Variable: (Q3) **Restrooms have good air quality / ventilation**

Phase	Mean	Std. Deviation	N
As-Is	2.0684	.84819	117
Low consumption Manual Flush Valve	2.1500	.77733	60
Low consumption Manual Flush Valve+ Automatic Lavatory	2.1538	.80158	52
Total	2.1092	.81722	229

Table 11

Tests of Between-Subjects Effects for (Q3)
Dependent Variable: (Q3) **Restrooms have good air quality / ventilation**

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.399(a)	2	.199	.297	.744
Intercept	913.617	1	913.617	1359.548	.000
Phase	.399	2	.199	.297	.744
Error	151.872	226	.672		
Total	1171.000	229			
Corrected Total	152.271	228			

a R Squared = .003 (Adjusted R Squared = -.006)

Table 12

Tukey HSD Post Hoc Tests Multiple Comparisons for (Q3)
Dependent Variable: (Q3) **Restrooms have good air quality / ventilation**

(I) Phase	(J) Phase	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
As-Is	Low consumption Manual Flush Valve	-.0816	.13017	.805	-.3887	.2255
	Low consumption Manual Flush Valve+ Automatic Lavatory	-.0855	.13663	.806	-.4078	.2369
Low consumption Manual Flush Valve	As-Is	.0816	.13017	.805	-.2255	.3887
	Low consumption Manual Flush Valve+ Automatic Lavatory	-.0038	.15532	1.000	-.3703	.3626
Low consumption Manual Flush Valve+ Automatic Lavatory	As-Is	.0855	.13663	.806	-.2369	.4078
	Low consumption Manual Flush Valve	.0038	.15532	1.000	-.3626	.3703

Based on observed means.

Table 13

Tukey HSD Homogeneous Subsets for (Q3)
Restrooms have good air quality / ventilation

Phase	N	Subset
		1
As-Is	117	2.0684
Low consumption Manual Flush Valve	60	2.1500
Low consumption Manual Flush Valve+ Automatic Lavatory	52	2.1538
Sig.		.817

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = .672.
a Uses Harmonic Mean Sample Size = 67.500.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c Alpha = .05.

The null-hypothesis (H_0) according to ANOVA is as follows

$H_0 =$ There is no change in the population means of the sample; it is just by chance but not due to other factors (no difference among treatments).

H_A =There is a change in the population means of the samples.

H_0: $\mu_1 = \mu_2 = \mu_4$; H_A: $\mu_1 \neq \mu_2 \neq \mu_4$

Here p-value is 0.744>0.05 at 95% confidence. Therefore, we cannot reject the null hypothesis that all the population means are the same.

Figure 3 shows the bar graph for all 4 phases for statement 3.

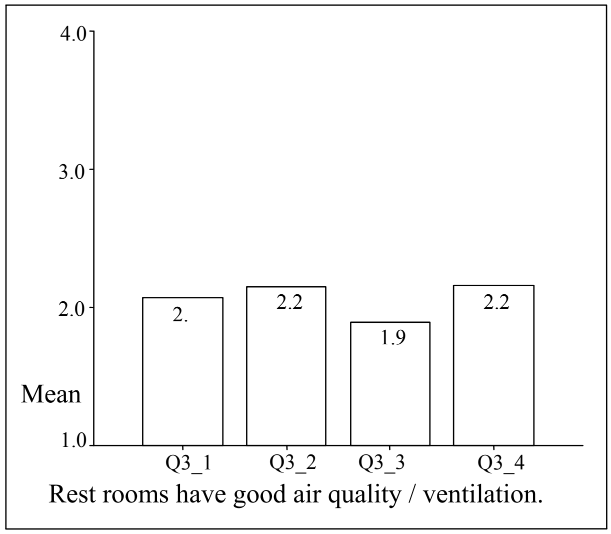

Figure 3. Bar graph of means of Q3 for all 4 phases

According to the bar graphs, we notice that the mean increase from phase 1 to phase 2, and then decreases from phase 2 to phase 3 and then increases to phase 4.

6.2.3.1 Inference

Even though the bar graph shows that there is a slight difference in the means from phase 1 to phase 4, the statistical analysis results show that there is no significant difference between their means. We can thus conclude the user perception of the air quality and ventilation of the restrooms has not changed significantly after the retrofitting of the fixtures.

NOTE: Phase 3 was not considered in ANOVA because its sample size (n-19) was very small when compared to the other 3 phases.

6.2.4 Statement 4 - Plumbing fixtures are kept in good repair (Q4)

The statistical results are presented in Tables 14-17.

Table 14

Univariate Analysis of Variance for (Q4)
Dependent Variable: (Q4) **Plumbing fixtures are kept in good repair**

Phase	Mean	Std. Deviation	N
As-Is	2.5299	.70188	117
Low consumption Manual Flush Valve	2.6500	.68458	60
Low consumption Manual Flush Valve+ Automatic Lavatory	2.6346	.71480	52
Total	2.5852	.69959	229

Table 15

Tests of Between-Subjects Effects for (Q4)
Dependent Variable: (Q4) **Plumbing fixtures are kept in good repair**

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.737(a)	2	.368	.751	.473
Intercept	1374.005	1	1374.005	2801.233	.000
Phase	.737	2	.368	.751	.473
Error	110.853	226	.490		
Total	1642.000	229			
Corrected Total	111.590	228			

a R Squared = .007 (Adjusted R Squared = -.002)

Table 16

Tukey HSD Post Hoc Tests Multiple Comparisons for (Q4)
Dependent Variable: (Q4) **Plumbing fixtures are kept in good repair**

(I) Phase	(J) Phase	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
As-Is	Low consumption Manual Flush Valve	-.1201	.11121	.528	-.3825	.1423
	Low consumption Manual Flush Valve+ Automatic Lavatory	-.1047	.11673	.643	-.3801	.1707
Low consumption Manual Flush Valve	As-Is	.1201	.11121	.528	-.1423	.3825
	Low consumption Manual Flush Valve+ Automatic Lavatory	.0154	.13269	.993	-.2977	.3284
Low consumption Manual Flush Valve+ Automatic Lavatory	As-Is	.1047	.11673	.643	-.1707	.3801
	Low consumption Manual Flush Valve	-.0154	.13269	.993	-.3284	.2977

Based on observed means.

Table 17

Tukey HSD Homogeneous Subsets for (Q4)
Plumbing fixtures are kept in good repair

Phase	N	Subset
		1
As-Is	117	2.5299
Low consumption Manual Flush Valve+ Automatic Lavatory	52	2.6346
Low consumption Manual Flush Valve	60	2.6500
Sig.		.580

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = .490.
a Uses Harmonic Mean Sample Size = 67.500.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c Alpha = .05.

The null-hypothesis (H0) according to ANOVA is as follows

H_0 = There is no change in the population means of the sample; it is just by chance but not due to other factors (no difference among treatments).

H_A =There is a change in the population means of the samples.

H_0: $\mu_1=\mu_2=\mu_4$; H_A: $\mu_1\neq\mu_2\neq\mu_4$

Here p-value is 0.473>0.05 at 95% confidence. Therefore, we cannot reject the null hypothesis that all the population means are the same.

Figure 4 shows the bar graph for all 4 phases for statement 4.

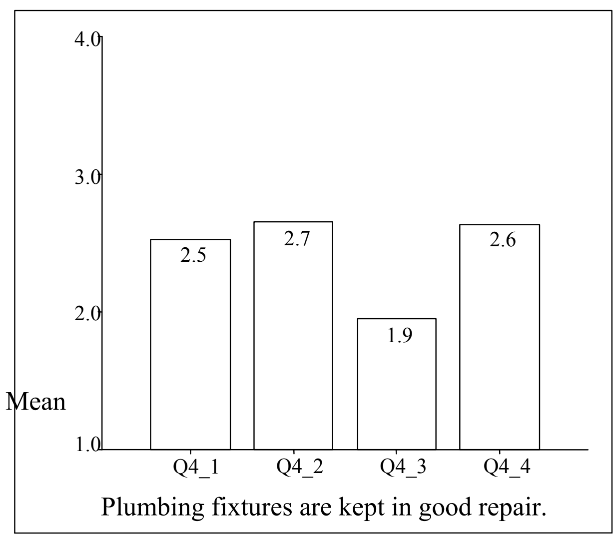

Figure 4. Bar graph of means of Q4 for all 4 phases

According to the bar graphs, we notice that the mean increases from phase 1 to phase 2, and then decreases from phase 2 to phase 3 and then increases from phase 3 to 4. Thus, we notice an increase in the user satisfaction from the 3rd to the 4th phase, and also the 1st and 4th.

6.2.4.1 Inference

Even though the bar graph shows that there is a slight difference in the means from phase 1 to phase 4, the statistical analysis results show that there is no significant difference between their means. We can thus conclude the user perception of the condition of the fixtures of the restrooms has not changed significantly after the retrofitting of the fixtures. This also implies that the fixtures were in good repair when they were retrofitted.

NOTE: Phase 3 was not considered in ANOVA because its sample size (n-19) was very small when compared to the other 3 phases.

6.2.5 Statement 5 - A single flush is enough to empty the toilet (Q5)

The statistical results are presented in Tables 18-21.

Table 18

Univariate Analysis of Variance for (Q5)
Dependent Variable: (Q5) **A single flush is enough to empty the toilet**

Phase	Mean	Std. Deviation	N
As-Is	2.6549	.71676	113
Low consumption Manual Flush Valve	2.7500	.81464	56
Low consumption Manual Flush Valve+ Automatic Lavatory	2.8039	.69339	51
Total	2.7136	.73702	220

Table 19

Tests of Between-Subjects Effects for (Q5)
Dependent Variable: (Q5) **A single flush is enough to empty the toilet**

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.880(a)	2	.440	.809	.447
Intercept	1454.926	1	1454.926	2673.793	.000
Phase	.880	2	.440	.809	.447
Error	118.079	217	.544		
Total	1739.000	220			
Corrected Total	118.959	219			

a R Squared = .007 (Adjusted R Squared = -.002)

Table 20

Tukey HSD Post Hoc Tests Multiple Comparisons for (Q5)
Dependent Variable: (Q5) **A single flush is enough to empty the toilet**

(I) Phase	(J) Phase	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
As-Is	Low consumption Manual Flush Valve	-.0951	.12055	.710	-.3796	.1894
	Low consumption Manual Flush Valve+ Automatic Lavatory	-.1491	.12444	.456	-.4427	.1446
Low consumption Manual Flush Valve	As-Is	.0951	.12055	.710	-.1894	.3796
	Low consumption Manual Flush Valve+ Automatic Lavatory	-.0539	.14278	.924	-.3909	.2830
Low consumption Manual Flush Valve+ Automatic Lavatory	As-Is	.1491	.12444	.456	-.1446	.4427
	Low consumption Manual Flush Valve	.0539	.14278	.924	-.2830	.3909

Based on observed means.

Table 21

Tukey HSD Homogeneous Subsets for (Q5)
A single flush is enough to empty the toilet

Phase	N	Subset
		1
As-Is	113	2.6549
Low consumption Manual Flush Valve	56	2.7500
Low consumption Manual Flush Valve+ Automatic Lavatory	51	2.8039
Sig.		.485

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = .544.
a Uses Harmonic Mean Sample Size = 64.774.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c Alpha = .05.

The null-hypothesis (H_0) according to ANOVA is as follows

$H_{0\,=}$ There is no change in the population means of the sample; it is just by chance but not due to other factors (no difference among treatments).

H_A =There is a change in the population means of the samples.

$H_{0:}\ \mu_{1=}\mu_{2=}\mu_4$; H_A: $\mu_1 \neq \mu_2 \neq \mu_4$

Here p-value is 0.447>0.05 at 95% confidence. Therefore, we cannot reject the null hypothesis that all the population means are the same.

Figure 5 shows the bar graph for all 4 phases for statement 5.

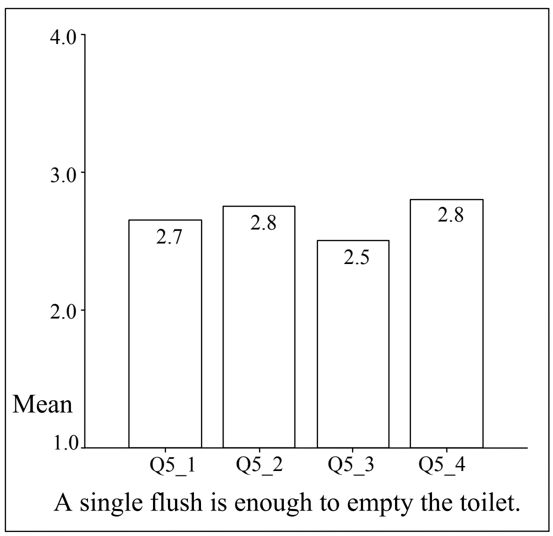

Figure 5. Bar graph of means of Q5 for all 4 phases

According to the bar graphs, we notice that the mean increases from phase 1 to phase 2, and then decreases from phase 2 to phase 3 and then increases from phase 3 to 4. Thus, we notice an increase in the user satisfaction from the 3rd to the 4th phase, and also the 1st and 4th.

6.2.5.1 Inference

Even though the bar graph shows that there is a slight difference in the means from phase 1 to phase 4, the statistical analysis results show that there is no significant difference between their means. We can conclude that there is no difference in the number of flushes required to empty the bowl before and after the retrofit.

We can conclude two things by this,

- There was a decrease in the quantity of water per flush after retrofitting. The same numbers of flushes were used even after retrofitting, thus the user was equally satisfied with the bowl cleaning now as he was before

- There was no improvement in the number of flushes required even after the retrofitting

NOTE: Phase 3 was not considered in ANOVA because its sample size (n-19) was very small when compared to the other 3 phases.

6.2.6 Statement 6 - The door latch on the toilet stall works properly (Q6)

The statistical results are presented in Tables 22-25.

Table 22

Univariate Analysis of Variance for (Q6)
Dependent Variable: (Q6) **The door latch on the toilet stall works properly**

Phase	Mean	Std. Deviation	N
As-Is	2.0000	.88852	115
Low consumption Manual Flush Valve	2.1356	.93694	59
Low consumption Manual Flush Valve+ Automatic Lavatory	2.4286	.95743	49
Total	2.1300	.92811	223

Table 23

Tests of Between-Subjects Effects for (Q6)
Dependent Variable: (Q6) **The door latch on the toilet stall works properly**

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6.313(a)	2	3.157	3.756	.025
Intercept	935.624	1	935.624	1113.144	.000
Phase	6.313	2	3.157	3.756	.025
Error	184.915	220	.841		
Total	1203.000	223			
Corrected Total	191.229	222			

a R Squared = .033 (Adjusted R Squared = .024)

Table 24

Tukey HSD Post Hoc Tests Multiple Comparisons for (Q6)
Dependent Variable: (Q6) **The door latch on the toilet stall work properly**

(I) Phase	(J) Phase	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
As-Is	Low consumption Manual Flush Valve	-.1356	.14682	.626	-.4820	.2108
	Low consumption Manual Flush Valve+ Automatic Lavatory	-.4286(*)	.15640	.018	-.7976	-.0595
Low consumption Manual Flush Valve	As-Is	.1356	.14682	.626	-.2108	.4820
	Low consumption Manual Flush Valve+ Automatic Lavatory	-.2930	.17720	.226	-.7111	.1252
Low consumption Manual Flush Valve+ Automatic Lavatory	As-Is	.4286(*)	.15640	.018	.0595	.7976
	Low consumption Manual Flush Valve	.2930	.17720	.226	-.1252	.7111

Based on observed means.
* The mean difference is significant at the .05 level.

Table 25

Tukey HSD Homogeneous Subsets for (Q6)
The door latch on the toilet stall work properly

Phase	N	Subset	
		1	2
As-Is	115	2.0000	
Low consumption Manual Flush Valve	59	2.1356	2.1356
Low consumption Manual Flush Valve+ Automatic Lavatory	49		2.4286
Sig.		.676	.164

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = .841.
a Uses Harmonic Mean Sample Size = 65.142.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c Alpha = .05.

The null-hypothesis (H_0) according to ANOVA is as follows

$H_{0\,=}$ There is no change in the population means of the sample; it is just by chance but not due to other factors (no difference among treatments).

H_A =There is a change in the population means of the samples.

$H_{0:}\ \mu_1{=}\mu_2{=}\mu_4$; H_A: $\mu_1 \neq \mu_2 \neq \mu_4$

Here p-value is 0.025<0.05 at 95% confidence. Therefore, reject the null hypothesis that all the population means are the same.

Figure 6 shows the bar graph for all 4 phases for statement 6.

Figure 6. Bar graph of means of Q6 for all 4 phases

According to the bar graphs, we notice that the mean increases from phase 1 to phase 2, and then decreases from phase 2 to phase 3 and then increases drastically from phase 3 to 4. Thus, we notice an increase in the user satisfaction from the 3rd to the 4th phase, and also the 1st and 4th phase.

6.2.6.1 Inference

We can infer that there is a significant change in the door latch. Though there was nothing done to improve the door latch consciously during the retrofitting process, the user satisfaction increased.

There could be two reasons for this:

- If the user is satisfied with restroom in general, he tends to be positive and not be critical about small details
- New door latches might have been installed in the restrooms by the maintenance team

NOTE: Phase 3 was not considered in ANOVA because its sample size (n-19) was very small when compared to the other 3 phases.

6.2.7 Statement 7 - The restroom floor is normally dry (Q7)

The statistical results are presented in Tables 26-29.

Table 26

Univariate Analysis of Variance for (Q7)
Dependent Variable: (Q7) **The restroom floor is normally dry**

Phase	Mean	Std. Deviation	N
As-Is	2.3333	.77061	120
Low consumption Manual Flush Valve	2.2881	.69607	59
Low consumption Manual Flush Valve+ Automatic Lavatory	2.8269	.73354	52
Total	2.4329	.77097	231

Table 27

Tests of Between-Subjects Effects for (Q7)
Dependent Variable: (Q7) **The restroom floor is normally dry**

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10.499(a)	2	5.250	9.483	.000
Intercept	1246.338	1	1246.338	2251.513	.000
Phase	10.499	2	5.250	9.483	.000
Error	126.211	228	.554		
Total	1504.000	231			
Corrected Total	136.710	230			

a R Squared = .077 (Adjusted R Squared = .069)

Table 28

Tukey HSD Post Hoc Tests Multiple Comparisons for (Q7)
Dependent Variable: (Q7) **The restroom floor is normally dry**

(I) Phase	(J) Phase	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
As-Is	Low consumption Manual Flush Valve	.0452	.11830	.923	-.2339	.3243
	Low consumption Manual Flush Valve+ Automatic Lavatory	-.4936(*)	.12352	.000	-.7850	-.2022
Low consumption Manual Flush Valve	As-Is	-.0452	.11830	.923	-.3243	.2339
	Low consumption Manual Flush Valve+ Automatic Lavatory	-.5388(*)	.14152	.001	-.8726	-.2049
Low consumption Manual Flush Valve+ Automatic Lavatory	As-Is	.4936(*)	.12352	.000	.2022	.7850
	Low consumption Manual Flush Valve	.5388(*)	.14152	.001	.2049	.8726

Based on observed means.
* The mean difference is significant at the .05 level.

Table 29

Tukey HSD Homogeneous Subsets for (Q7)
The restroom floor is normally dry

Phase	N	Subset	
		1	2
Low consumption Manual Flush Valve	59	2.2881	
As-Is	120	2.3333	
Low consumption Manual Flush Valve+ Automatic Lavatory	52		2.8269
Sig.		.934	1.000

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = .554.
a Uses Harmonic Mean Sample Size = 67.396.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c Alpha = .05.

The null-hypothesis (H_0) according to ANOVA is as follows

H_0 = There is no change in the population means of the sample; it is just by chance but not due to other factors (no difference among treatments).

H_A =There is a change in the population means of the samples.

H_0: $\mu_1=\mu_2=\mu_4$; H_A: $\mu_1\neq\mu_2\neq\mu_4$

Here p-value is $0.00<0.05$ at 95% confidence. Therefore, reject the null hypothesis that all the population means are the same.

Figure 7 shows the bar graph for all 4 phases for statement 7.

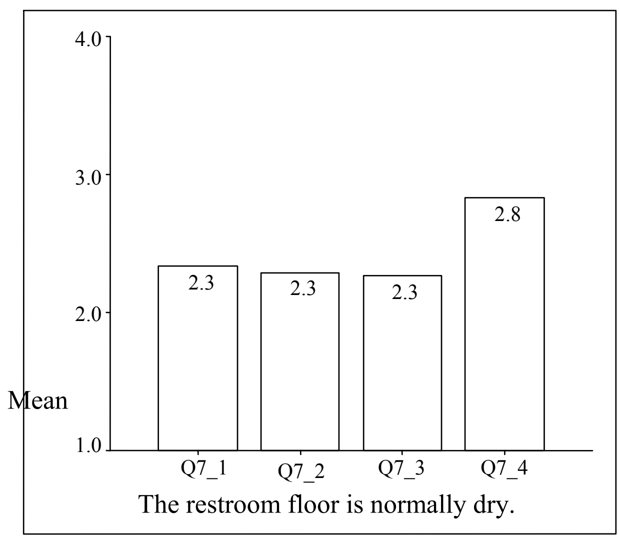

Figure 7. Bar graph of means of Q7 for all 4 phases

According to the bar graphs, we notice that the mean decreases from phase 1 through phase 3, and then increases from phase 3 to phase 4. Thus, we notice an increase in the user satisfaction from the 3rd to the 4th phase, and also the 1st and 4th phase.

6.2.7.1 Inference

There is a significant difference in the dryness of the restroom floor between the 1st and 4th and the 2nd and 4th phase of the retrofitting. This could be a result of one of the following:

1. The fixture quality must have improved from the first phase to the fourth phase and so the floor of the restrooms must have been dry
2. The fixture maintenance must have improved for the restroom floor to remain dry. This improvement in the fixture maintenance could be because of the better quality of the fixture
3. Restroom could have been generally clean because of various reasons like
    a. Good genitor service
    b. Less users of the restroom at that particular period of time and so less water on the floor
    c. Improvement in the ventilation of the restroom due to the change of seasons or rectification of the air-conditioning systems

However, the only reason for improvement in the dryness of the flooring could be the retrofitting of the restrooms, since there were no other conscious changes made to change the restroom during the duration of the experiment,. Thus we can conclude that the floor was dryer after the retrofit than before the retrofit of the restrooms.

NOTE: Phase 3 was not considered in ANOVA because its sample size (n-19) was very small when compared to the other 3 phases.

6.2.8 Statement 8 - Lavatory counter tops are usually dry (Q8)

The statistical results are presented in Tables 30-33.

Table 30

Univariate Analysis of Variance for (Q8)
Dependent Variable: (Q8) **Lavatory counter tops are usually dry**

Phase	Mean	Std. Deviation	N
As-Is	1.9661	.80524	118
Low consumption Manual Flush Valve	1.9322	.73963	59
Low consumption Manual Flush Valve+ Automatic Lavatory	2.2308	.78254	52
Total	2.0175	.78899	229

Table 31

Tests of Between-Subjects Effects for (Q8)
Dependent Variable: (Q8) **Lavatory counter tops are usually dry**

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.106(a)	2	1.553	2.528	.082
Intercept	841.249	1	841.249	1369.520	.000
Phase	3.106	2	1.553	2.528	.082
Error	138.824	226	.614		
Total	1074.000	229			
Corrected Total	141.930	228			

a R Squared = .022 (Adjusted R Squared = .013)

Table 32

Tukey HSD Post Hoc Tests Multiple Comparisons for (Q8)
Dependent Variable: (Q8) **Lavatory counter tops are usually dry**

(I) Phase	(J) Phase	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
As-Is	Low consumption Manual Flush Valve	.0339	.12497	.960	-.2609	.3287
	Low consumption Manual Flush Valve+ Automatic Lavatory	-.2647	.13045	.108	-.5724	.0431
Low consumption Manual Flush Valve	As-Is	-.0339	.12497	.960	-.3287	.2609
	Low consumption Manual Flush Valve+ Automatic Lavatory	-.2986	.14908	.114	-.6503	.0531
Low consumption Manual Flush Valve+ Automatic Lavatory	As-Is	.2647	.13045	.108	-.0431	.5724
	Low consumption Manual Flush Valve	.2986	.14908	.114	-.0531	.6503

Based on observed means.

Table 33

Tukey HSD Homogeneous Subsets for (Q8)
Lavatory counter tops are usually dry

Phase	N	Subset
		1
Low consumption Manual Flush Valve	59	1.9322
As-Is	118	1.9661
Low consumption Manual Flush Valve+ Automatic Lavatory	52	2.2308
Sig.		.072

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = .614.
a Uses Harmonic Mean Sample Size = 67.182.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c Alpha = .05.

The null-hypothesis (H_0) according to ANOVA is as follows

$H_0 =$ There is no change in the population means of the sample; it is just by chance but not due to other factors (no difference among treatments).

H_A =There is a change in the population means of the samples.

$H_0: \mu_1=\mu_2=\mu_4$; $H_A: \mu_1 \neq \mu_2 \neq \mu_4$

Here p-value is 0.082>0.05 at 95% confidence. Therefore, we cannot reject the null hypothesis that all the population means are the same. It is significant at 90% confidence interval.

Figure 8 shows the bar graph for all 4 phases for statement 8.

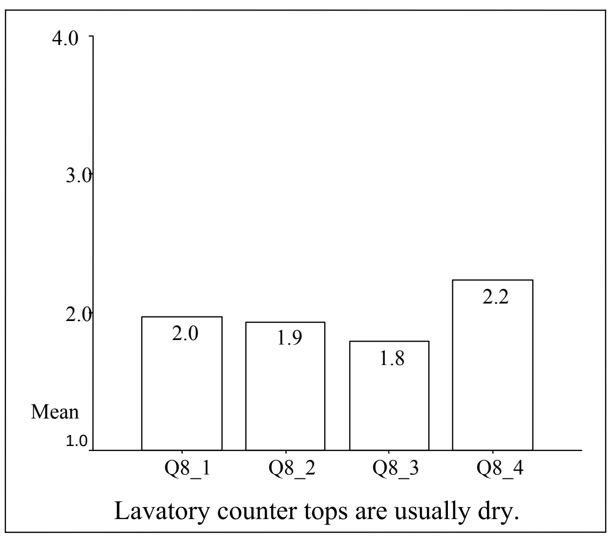

Figure 8. Bar graph of means of Q8 for all 4 phases

According to the bar graphs, we notice that the mean decreases from phase 1 through phase 3, and then increases from phase 3 to phase 4. Thus, we notice an increase in the user satisfaction from the 3rd to the 4th phase, and also the 1st and 4th.

6.2.8.1 Inference

If we see the bar graph, we can conclude that there is an improvement in the user satisfaction of the dryness of the lavatory tops from the 1st phase to the 4th phase and also from the 2nd phase to the 4th phase.

There is a significant difference in the dryness of the restroom lavatory top between the 1st and 4th and 2nd and 4th phase of the retrofitting at 90% confidence level could be because of the following reasons:

- The automatic lavatory fixture quality must be better than the manual lavatory fixture quality and so the lavatory top of the restrooms must have been dry
- The lavatory fixture maintenance must have improved for the restroom lavatory top to remain dry. This improvement in the fixture maintenance could be because of the better quality of the lavatory fixture
- Restroom lavatory top could have been generally clean because of various reasons like

1. Good genitor service

2. Less users of the restroom at that particular period of time and so less water on the top

3. Improvement in the ventilation of the restroom due to the change of seasons or rectification of the air-conditioning systems

None of the above could have been the reasons for the improvement in the dryness of the lavatory top in the restroom but for the retrofitting of the restrooms. As there were no conscious changes made in the restroom condition except for the retrofitting in the restroom during the duration of the experiment, we can conclude that the lavatory top was dryer after the retrofit than before the retrofit of the restrooms at 90% confidence interval.

NOTE: Phase 3 was not considered in ANOVA because its sample size (n-19) was very small when compared to the other 3 phases.

6.2.9 Statement 9 - I only use cold water for hand washing (Q9)

The statistical results are presented in Tables 34-37.

Table 34

Univariate Analysis of Variance for (Q9)
Dependent Variable: (Q9) **I only use cold water for hand washing**

Phase	Mean	Std. Deviation	N
As-Is	2.2807	.90728	114
Low consumption Manual Flush Valve	2.3158	.86928	57
Low consumption Manual Flush Valve+ Automatic Lavatory	2.2667	.91453	45
Total	2.2870	.89496	216

Table 35

Tests of Between-Subjects Effects for (Q9)
Dependent Variable: (Q9) **I only use cold water for hand washing**

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7.037E-02(a)	2	3.519E-02	.044	.957
Intercept	970.434	1	970.434	1200.827	.000
Phase	7.037E-02	2	3.519E-02	.044	.957
Error	172.133	213	.808		
Total	1302.000	216			
Corrected Total	172.204	215			

a R Squared = .000 (Adjusted R Squared = -.009)

Table 36

Tukey HSD Post Hoc Tests Multiple Comparisons for (Q9)
Dependent Variable: (Q9) **I only use cold water for hand washing**

(I) Phase	(J) Phase	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
As-Is	Low consumption Manual Flush Valve	-.0351	.14583	.969	-.3793	.3091
	Low consumption Manual Flush Valve+ Automatic Lavatory	.0140	.15826	.996	-.3595	.3876
Low consumption Manual Flush Valve	As-Is	.0351	.14583	.969	-.3091	.3793
	Low consumption Manual Flush Valve+ Automatic Lavatory	.0491	.17927	.959	-.3740	.4722
Low consumption Manual Flush Valve+ Automatic Lavatory	As-Is	-.0140	.15826	.996	-.3876	.3595
	Low consumption Manual Flush Valve	-.0491	.17927	.959	-.4722	.3740

Based on observed means.

Table 37

Tukey HSD Homogeneous Subsets for (Q9)
I only use cold water for hand washing

Phase	N	Subset
		1
Low consumption Manual Flush Valve+ Automatic Lavatory	45	2.2667
As-Is	114	2.2807
Low consumption Manual Flush Valve	57	2.3158
Sig.		.950

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = .808.
a Uses Harmonic Mean Sample Size = 61.807.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c Alpha = .05.

The null-hypothesis (H_0) according to ANOVA is as follows

$H_{0\,=}$ There is no change in the population means of the sample; it is just by chance but not due to other factors (no difference among treatments).

H_A =There is a change in the population means of the samples.

$H_{0:}\ \mu_{1=}\mu_{2=}\mu_4$; H_A: $\mu_1 \neq \mu_2 \neq \mu_4$

Here p-value is 0.957>0.05 at 95% confidence. Therefore, we cannot reject the null hypothesis that all the population means are the same.

Figure 9 shows the bar graph for all 4 phases for statement 9.

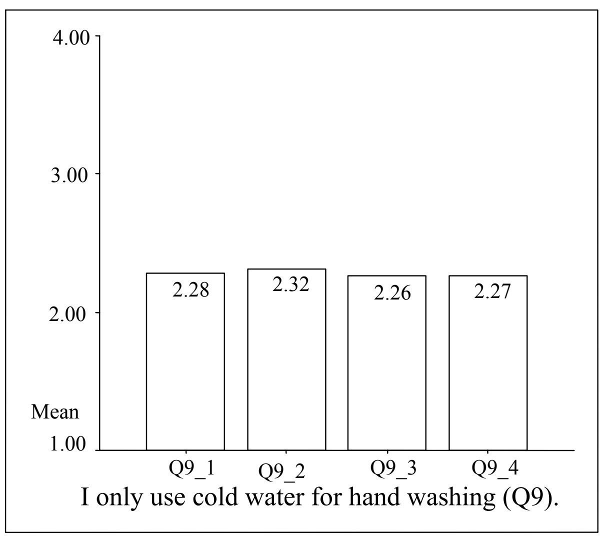

Figure 9. Bar graph of means of Q9 for all 4 phases

According to the bar graphs, we notice that there is a very slight difference in the means in all 4 phases.

6.2.9.1 Inference

We can conclude that there is no significant change in the user's perception about using the cold water for hand washing.

NOTE: Phase 3 was not considered in ANOVA because its sample size (n-19) was very small when compared to the other 3 phases.

6.2.10 Statement 10 - I feel comfortable touching fixture handles (Q10)

The statistical results are presented in Tables 38-41.

Table 38

Univariate Analysis of Variance for (Q10)
Dependent Variable: (Q10) **I feel comfortable touching fixture handles**

Phase	Mean	Std. Deviation	N
As-Is	2.1947	.82222	113
Low consumption Manual Flush Valve	2.2143	.82494	56
Low consumption Manual Flush Valve+ Automatic Lavatory	2.3000	.95298	50
Total	2.2237	.85143	219

Table 39

Tests of Between-Subjects Effects for (Q10)
Dependent Variable: (Q10) **I feel comfortable touching fixture handles**

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.391(a)	2	.196	.268	.765
Intercept	963.681	1	963.681	1320.401	.000
Phase	.391	2	.196	.268	.765
Error	157.645	216	.730		
Total	1241.000	219			
Corrected Total	158.037	218			

a. R Squared = .002 (Adjusted R Squared = -.007)

Table 40

Tukey HSD Post Hoc Tests Multiple Comparisons for (Q10)
Dependent Variable: (Q10) **I feel comfortable touching fixture handles**

(I) Phase	(J) Phase	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
As-Is	Low consumption Manual Flush Valve	-.0196	.13961	.989	-.3491	.3099
	Low consumption Manual Flush Valve+ Automatic Lavatory	-.1053	.14511	.749	-.4478	.2371
Low consumption Manual Flush Valve	As-Is	.0196	.13961	.989	-.3099	.3491
	Low consumption Manual Flush Valve+ Automatic Lavatory	-.0857	.16622	.864	-.4780	.3066
Low consumption Manual Flush Valve+ Automatic Lavatory	As-Is	.1053	.14511	.749	-.2371	.4478
	Low consumption Manual Flush Valve	.0857	.16622	.864	-.3066	.4780

Based on observed means.

Table 41

Tukey HSD Homogeneous Subsets for (Q10)
I feel comfortable touching fixture handles

Phase	N	Subset
		1
As-Is	113	2.1947
Low consumption Manual Flush Valve	56	2.2143
Low consumption Manual Flush Valve+ Automatic Lavatory	50	2.3000
Sig.		.765

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = .730.
a Uses Harmonic Mean Sample Size = 64.231.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c Alpha = .05.

The null-hypothesis (H_0) according to ANOVA is as follows

$H_{0\,=}$ There is no change in the population means of the sample; it is just by chance but not due to other factors (no difference among treatments).

H_A =There is a change in the population means of the samples.

H0: $\mu 1=\mu 2=\mu 4$; HA: $\mu 1\neq\mu 2\neq\mu 4$

Here p-value is 0.765>0.05 at 95% confidence. Therefore, we cannot reject the null hypothesis that all the population means are the same.

Figure 10 shows the bar graph for all 4 phases for statement 10.

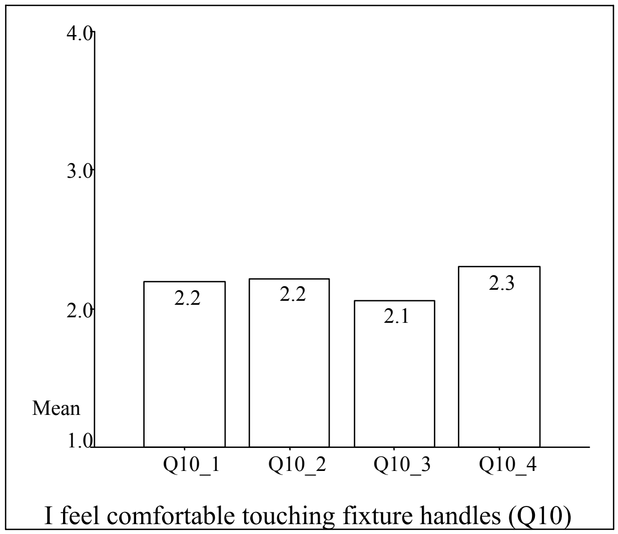

Figure 10. Bar graph of means of Q10 for all 4 phases

According to the bar graphs, we notice that there is a very slight difference in the means in all 4 phases.

6.2.10.1 Inference

There was no significant difference in the user satisfaction of touching the fixtures. This might be because the user would have been mentally prepared to come and touch the fixtures to use them. If we see the bar graph, we observe that although it is not very prominent, there is a certain decrease in the user's satisfaction to touch the fixtures in the third phase. This could be the result of the fact that the user would have been mentally prepared to use an automatic fixture, where as he had to touch fixture instead, as they were not functioning properly.

NOTE: Phase 3 was not considered in ANOVA because its sample size (n-19) was very small when compared to the other 3 phases.

6.2.11 Statement 11 - I would prefer a restroom with more privacy (Q11)

The statistical results are presented in Tables 42-45.

Table 42

Univariate Analysis of Variance for (Q11)
Dependent Variable: (Q11) **I would prefer a restroom with more privacy**

Phase	Mean	Std. Deviation	N
As-Is	2.9245	.81297	106
Low consumption Manual Flush Valve	3.0566	.81842	53
Low consumption Manual Flush Valve+ Automatic Lavatory	2.7778	.73512	45
Total	2.9265	.79993	204

Table 43

Tests of Between-Subjects Effects for (Q11)
Dependent Variable: (Q11) **I would prefer a restroom with more privacy**

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.893(a)	2	.946	1.486	.229
Intercept	1518.453	1	1518.453	2384.368	.000
Phase	1.893	2	.946	1.486	.229
Error	128.004	201	.637		
Total	1877.000	204			
Corrected Total	129.897	203			

Table 44

Tukey HSD Post Hoc Tests Multiple Comparisons for (Q11)
Dependent Variable: (Q11) **I would prefer a restroom with more privacy**

(I) Phase	(J) Phase	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
As-Is	Low consumption Manual Flush Valve	-.1321	.13425	.588	-.4491	.1849
	Low consumption Manual Flush Valve+ Automatic Lavatory	.1468	.14199	.557	-.1885	.4820
Low consumption Manual Flush Valve	As-Is	.1321	.13425	.588	-.1849	.4491
	Low consumption Manual Flush Valve+ Automatic Lavatory	.2788	.16176	.199	-.1031	.6608
Low consumption Manual Flush Valve+ Automatic Lavatory	As-Is	-.1468	.14199	.557	-.4820	.1885
	Low consumption Manual Flush Valve	-.2788	.16176	.199	-.6608	.1031

Based on observed means.

Table 45

Tukey HSD Homogeneous Subsets for (Q11)
I would prefer a restroom with more privacy

Phase	N	Subset
		1
Low consumption Manual Flush Valve+ Automatic Lavatory	45	2.7778
As-Is	106	2.9245
Low consumption Manual Flush Valve	53	3.0566
Sig.		.140

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = .637.
a Uses Harmonic Mean Sample Size = 59.378.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c Alpha = .05.

The null-hypothesis (H_0) according to ANOVA is as follows

$H_0 =$ There is no change in the population means of the sample; it is just by chance but not due to other factors (no difference among treatments).

H_A =There is a change in the population means of the samples.

H_0: $\mu_1=\mu_2=\mu_4$; H_A: $\mu_1\neq\mu_2\neq\mu_4$

Here p-value is 0.229>0.05 at 95% confidence. Therefore, we cannot reject the null hypothesis that all the population means are the same.

Figure 11 shows the bar graph for all 4 phases for statement 11.

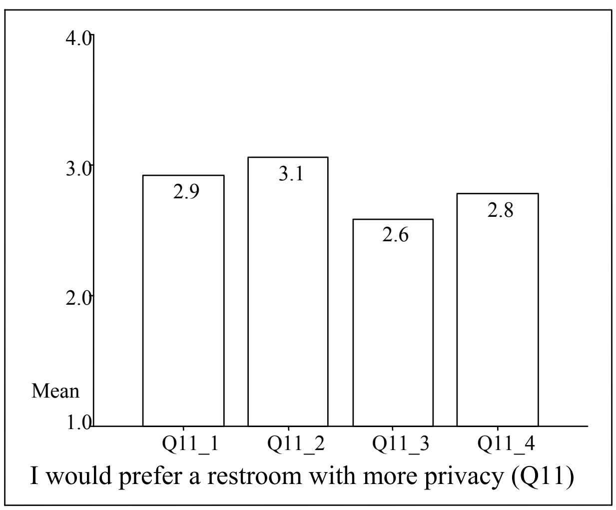

Figure 11. Bar graph of means of Q11 for all 4 phases

According to the bar graphs, we notice that the mean increases from phase 1 through phase 2, and then decreases from phase 2 to phase 3, and again increases from phase 3 to phase 4. Thus, we notice a decrease from the 1st to 4th phase.

6.2.11.1 Inference

There is no significant difference in the user satisfaction for restroom privacy. This privacy is also related to the cleanliness of the restroom. As we did not have significant difference in the cleanliness aspect, we would not expect any change in the privacy aspect as well.

NOTE: Phase 3 was not considered in ANOVA because its sample size (n-19) was very small when compared to the other 3 phases.

6.2.12 Statement 12 - I find the coat hook on the back of the toilet stall door convenient (Q12)

The statistical results are presented in Tables 46-49.

Table 46

Univariate Analysis of Variance for (Q12)
Dependent Variable: (Q12) **I find the coat hook on the back of the toilet stall door convenient**

Phase	Mean	Std. Deviation	N
As-Is	2.5347	.94408	101
Low consumption Manual Flush Valve	2.5370	1.05889	54
Low consumption Manual Flush Valve+ Automatic Lavatory	2.4130	.90863	46
Total	2.5075	.96498	201

Table 47

Tests of Between-Subjects Effects for (Q12)
Dependent Variable: (Q12) **I find the coat hook on the back of the toilet stall door convenient**

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.532(a)	2	.266	.284	.753
Intercept	1116.881	1	1116.881	1190.815	.000
Phase	.532	2	.266	.284	.753
Error	185.707	198	.938		
Total	1450.000	201			
Corrected Total	186.239	200			

a R Squared = .003 (Adjusted R Squared = -.007)

Table 48

Tukey HSD Post Hoc Tests Multiple Comparisons for (Q12)
Dependent Variable: (Q12) **I find the coat hook on the back of the toilet stall door convenient**

(I) Phase	(J) Phase	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
As-Is	Low consumption Manual Flush Valve	-.0024	.16326	1.000	-.3879	.3832
	Low consumption Manual Flush Valve+ Automatic Lavatory	.1216	.17227	.760	-.2852	.5284
Low consumption Manual Flush Valve	As-Is	.0024	.16326	1.000	-.3832	.3879
	Low consumption Manual Flush Valve+ Automatic Lavatory	.1240	.19431	.799	-.3349	.5829
Low consumption Manual Flush Valve+ Automatic Lavatory	As-Is	-.1216	.17227	.760	-.5284	.2852
	Low consumption Manual Flush Valve	-.1240	.19431	.799	-.5829	.3349

Based on observed means.

Table 49

Tukey HSD Homogeneous Subsets for (Q12)
I find the coat hook on the back of the toilet stall door convenient

Phase	N	Subset
		1
Low consumption Manual Flush Valve+ Automatic Lavatory	46	2.4130
As-Is	101	2.5347
Low consumption Manual Flush Valve	54	2.5370
Sig.		.764

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = .938.
a Uses Harmonic Mean Sample Size = 59.810.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c Alpha = .05.

The null-hypothesis (H_0) according to ANOVA is as follows

$H_{0\,=}$ There is no change in the population means of the sample; it is just by chance but not due to other factors (no difference among treatments).

H_A =There is a change in the population means of the samples.

$H_{0:}$ $\mu_1=\mu_2=\mu_4$; H_A: $\mu_1\neq\mu_2\neq\mu_4$

Here p-value is 0.753>0.05 at 95% confidence. Therefore, we cannot reject the null hypothesis that all the population means are the same.

Figure 12 shows the bar graph for all 4 phases for statement 12.

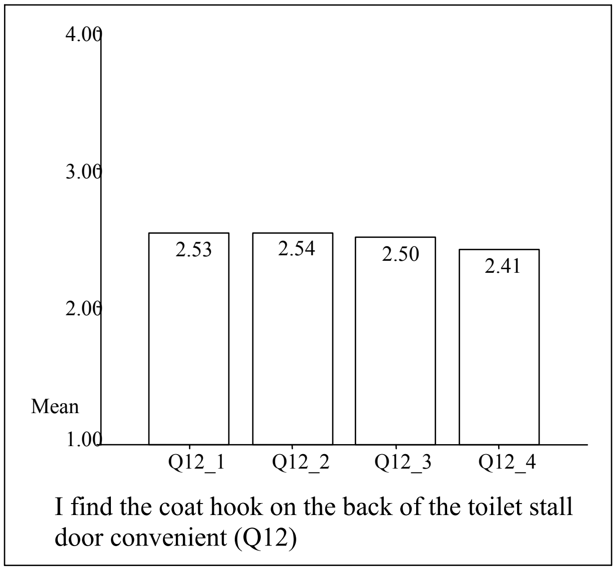

Figure 12. Bar graph of means of Q12 for all 4 phases

According to the bar graphs, we notice that the mean increases from phase 1 through phase 2, and then decreases from phase 2 to phase 4. Thus, we notice a decrease in the user satisfaction from the 2nd to the 4th phase, and also the 1st and 4th phase.

6.2.12.1 *Inference*

Most of the users found this aspect of the restrooms unimportant. We cannot see any significant difference in the user satisfaction of the coat hook in the restrooms.

NOTE: Phase 3 was not considered in ANOVA because its sample size (n-19) was very small when compared to the other 3 phases.

7 CONCLUSION

Table 50
The summary of the significance between-subjects

	Statement	Sig. at 95% Confidence	Hypothesis
1	Restroom is kept as clean as I would like	.763	**Cannot reject**
2	Lighting is good in restrooms	.082	**Reject at 90% confidence**
3	Restrooms have good air quality / ventilation	.744	**Cannot reject**
4	Plumbing fixtures are kept in good repair	.473	**Cannot reject**
5	A single flush is enough to empty the toilet	.477	**Cannot reject**
6	The door latch on the toilet stall works properly	.025	**Reject**
7	The restroom floor is normally dry	.000	**Reject**
8	Lavatory counter tops are usually dry	.082	**Reject at 90% confidence**
9	I only use cold water for hand washing	.957	**Cannot reject**
10	I feel comfortable touching fixture handles	.765	**Cannot reject**
11	I would prefer a restroom with more privacy	.229	**Cannot reject**
12	I find the coat hook on the back of the toilet stall door convenient	.753	**Cannot reject**

We can see in Table 49 that out of 12 statements, only 2 statements show an improvement in the user satisfaction at 95% confidence level and another 2 statements at 90% confidence level. All the rest of the statements do not show any significant difference in the perception of the user after the retrofitting the restrooms.

We can thus conclude the following from the survey:

- The lighting in the restroom has significantly improved after the retrofitting of the restrooms. Though there is no direct relationship between the restroom fixture retrofitting and the improvement in lighting, we can still consider that the reason for that perception of the user could be because of improved cleanliness in the restroom

- User satisfaction for improvement in the working of the door latch is higher after the retrofitting

- User perceives that the floor is drier after the retrofitting of the restrooms than the as-is state, which can again be taken as a credit for better working condition of the new fixtures

- Lavatory tops are also drier than the as-is condition which can again be associated with the better working conditions of the lavatory automatic fixtures

REFERENCES

Allyn, N. (1999). Hygienic by design: Improve image and cleanliness, reduce waste through careful restroom planning. *Building, 93,* 24.

Baz, J. (1997). Flushing out solutions. *American School & University.* Retrieved October 22, 2002, from http://asumag.com/ar/university_flushing_solutions/

Beekman, G.B. (1998). Water conservation, recycling and reuse. *Water Resources Development, 14,* 353-364. Retrieved October 20, 2002, from http://www.epnet.com/default.asp

Brown, R. (1996). Plumbing new heights. *Buildings, 90,* 2.

Cheng, C.L. (2002). Evaluating water conservation measures for Green building in Taiwan. *Building and Environment, 38,* 369-379. Retrieved October 18, 2002, from http://www.sciencedirect.com

Coy, D.G. (2002). Looking at water: a view from Wall Street. *Impact, 14,* 14-18. Retrieved October 16, 2002, from http://www.awra.org/impact/0201impact.pdf

Feldman, E. (1975). *Building design for maintainability.* New York: McGraw-Hill.

Gonzalez, C.E.A. (1998). Water management in the Americas. *Water Resources Development, 14,* 289-291. Retrieved October 15, 2002, from http://www.epnet.com/default.asp

Henze, M. (1995). *Wastewater treatment: Biological and chemical processes.* NewYork:Springer Verlag.

Hossein, A. (1994). *Questionnaire design and surveys sampling*. Baltimore, Maryland: University of Baltimore, Decision Science and Statistics.

Jahrling, P. (2002). Plumbing sensor technology brings innovative solutions to bathroom design. *Architectural Record, 190,* 179-184. Retrieved October 12, 2002, from http://www.epnet.com/default.asp

Kennedy, S. (2001). Washrooms: keeping the dialogue flowing - clear communication can help create an effective and efficient layout. *AS&U: American School & University*, *73*, 34-41. Retrieved November 12, 2002, from http://firstsearch.oclc.org

Kira, A. (1976). *The bathroom*. New York: Viking Press.

Knight, B.I. (2002). Water for the future. *Vital Speeches of the Day, 68,* 796-798. Retrieved October 17, 2002, from http://www.epnet.com/default.asp

Lauer, J. (2000). The plumbing electronic retrofit option: why contractors should consider electronics for upgrading restrooms. *Architectural Record, 190,* 179-183. Retrieved October 19, 2002, from http://www.epnet.com/default.asp

Manoukian, R. (1997). Plumbing retrofit for federal building conserves water. *Heating/Piping/Air Conditioning, 69,* 81-84. Retrieved June 25, 2003, from http://www.hpac.com/microsites/egb/pdfs/manoukia_0997.pdf

Martin, R.B. (n.d.). *Is the drainline carry test really necessary?* Retrieved September 21, 2002, from http://www.chicagofaucets.com/pf2/drainline.php

National Kitchen and Bath Association (1997). *The essential bathroom design guide (U.S.).* New York: Wiley.

Ouano, E. A. R. (1983). *Principles of wastewater treatment*. Englewood Cliffs, NJ: Penntice-Hall.

Ould, B. (1997). State of independence. *HD: Hospital Development, 28,* 35-36.

Pathak, B. (1995). History of toilets. *Sulabh International Museum of Toilets.* Retrieved January 22, 2003, from http://www.sulabhtoiletmuseum.org

P.G. (1994). Recycling grey water into color. *Environment, 36,* 24. Retrieved October 16, 2002, from http://www.epnet.com/default.asp

Reid, R. N. (1996). *Water quality & systems: a guide for facility managers.* New York: Fairmont Press.

Rosen, M. (2003). *Electronic fixtures can provide the clean solution for buildings in which hygiene is a major concern*. Retrieved May 9, 2003, from http://www.pmengineer.com

Sandia National Laboratories (1997). *Water conservation initiative*. Retrieved October 20, 2002 from http://www.sandia.gov/aqua/aqua.htm

Scaramelli, A.B. (1997). Liquid assets. *American School & University Magazine.* Retrieved October 23, 2002, from http://www.h2omatrix.com/ASU%20article.htm.

Thomas J. M. (1998). Water conservation program cuts spiraling costs. *Facility Management Journal.* Retrieved October 20, 2002, from http://www.h2omatrix.com/FMJ%20article.htm.

Tobin, M. (2001). The low flow false flush. *The Environmental Magazine, 12,* 15-16.

Westerkamp, T. A. (2000). Two-for-one restroom savings. *Maintenance Solutions.* Retrieved October 16, 2002, from http://www.facilitiesnet.com/ms/Jul00/jul00housekeeping.shtml.

Woodard, G. (2000). *Functioning of aging low consumption toilets in Tucson.* Tucson, AZ: Water Resource Research Center.

VITA

Neelima Raman Vankamamidi

23 Janakpuri, Picket

Secunderabad, AP 300009

neelimav@neo.tamu.edu

Neelima Raman Vankamamidi, of Hyderabad, India, was born on March 31, 1977 in Khammam, India. In 2000 she graduated from Jawaharlal Nehru Technical University where she obtained a Bachelor of Architecture. She then attended Texas A&M University to obtain a Master of Science in Construction Management in August 2004. She plans on residing in Atlanta, Georgia, and initiating her career in the construction industry following her graduation.