UF Restrooms Sensor Installment Team
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December 9, 2020

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To the office of Contracts and Grants,

On October 28th, 2020, we received an RFP from the University of Florida Office of Sponsored Research. This is funded by the US Department of Commerce and US Department of Energy. The RFP was for an engineering idea that could improve the quality of student life on the campus of UF. Attached is a proposal in response to the RFP.

We propose to install sensors in the paper towel holders that are in the UF on-campus restrooms to increase the availability of paper towels for all UF students, faculty, and staff. During the COVID-19 season, our research has shown that handwashing with paper towels is a highly effective way to prevent the spread of COVID-19 at UF. We want to encourage this habit by making paper towels more available in the restrooms by semi-automating the restocking process of the paper towels. We have devised a plan to distribute these sensors across campus and have pin-pointed which buildings could benefit from this technology.

We have contacted several students who visit campus regularly that say they use the restroom and experience no paper towels after washing their hands. Not only does this discourage hand washing, it increases the spread of germs because wet hands are more likely to spread bacteria and viruses.The solution is adding sensor technology to the restocking process. Every empty paper towel holder will cause a staff member to be alerted and the holder can promptly be restocked. This will benefit both the student and the staff by increasing paper towel availability and decreasing the amount of unnecessary checks.

We are excited about this project and think it is a very feasible and beneficial solution for our campus. We believe our proposal will have value. Thank you for your time and please contact our team by phone (407-432-9343), email (andrewmichael@ufl.edu), or at the address above.

Sincerely,
Christopher Crouch, Andrew Michael, Derek Pearson, Caleb Wong

UF Restrooms Sensor Installment Team

Creating a Safer Campus for Students and Faculty

Christopher Crouch, Andrew Michael, Derek Pearson, Caleb Wong
December 9th, 2020
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Executive Summary

COVID-19 has brought several new ways of life and challenges, and one of these challenges has been keeping college campuses safe for students to go to classes or popular buildings, such as libraries and gyms. The pandemic has made cleanliness and practices to keep frequently used buildings as safe and clean as possible an important priority. Keeping bacteria off hands is now more important than ever, and one of the most effective ways to do that is by frequently washing hands. However, less mentioned is the method of drying hands. There is a significant difference in how much bacteria stays on the hands depending on the method with which hands are dried. Using paper towels is the most hygienic method to dry hands. Unfortunately, popular bathrooms on campus frequently run out of paper towels, leaving students and employees no safe way to dry their hands. In response, we propose a system to monitor the paper towel supply and ensure the bathroom does not run out of paper towels.

The system will prevent bathrooms from running out of paper towels and allow employees to efficiently stock the bathroom when needed. The units installed in the bathrooms will consist of an optical sensor, microcontroller, battery, and a transceiver. Each unit will monitor the paper towel supply with the optical sensor. This information will be sent to the microcontroller. If the supply is low, the microcontroller will send an alert to the UF employee system through the transceiver.

The initial budget of $500,000 will cover the cost of buying the parts to create the units, the labor involved in creating the units, installation fees, and software development and integration with the UF employee system. Assuming the units are properly built and installed, maintenance of the system will be inexpensive as each unit should last at least one year. Our estimate of yearly maintenance will be around $10,000. The project is scheduled to be complete and ready for installation by June 1, 2022. The system will be evaluated for effectiveness during the Fall of 2022. With acceptance of this proposal, this paper towel monitoring system will improve the quality of life of everyone at the University of Florida by creating a clean and safe environment, helping to prevent the spread of COVID-19 and other infectious diseases.

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Problem Statement

On October 28, 2020 we received an RFP by the University of Florida Office of Sponsored Research. This RFP is funded by the US Department of Commerce and US Department of Energy to stimulate new research opportunities for emerging technologies. The sponsors are looking for proposals that "significantly improve the quality of life for individual American citizens at home, at work, or at school, or directly and immediately improve the quality and competitiveness of American industry within the global marketplace." Our proposal will improve the quality of life of students and employees at the University of Florida.

A global pandemic has taken over 2020 with no end in sight. More than nine months after the initial outbreak, new daily cases are still breaking all-time highs. Governments and health organizations urge people to do their part in preventing the spread of COVID-19 by wearing masks, washing hands frequently, and social distancing [1]. At a time like this, each step is as important as ever.

COVID-19 has brought several new ways of life and challenges, one of these challenges has been keeping college campuses safe for students to go to classes or popular buildings, such as libraries and gyms. The global pandemic has made cleanliness and practices to keep frequently used buildings as safe and clean as possible an important priority.

Washing hands is always mentioned for keeping hands clean. However, drying them is just as important. There is a significant difference in how much bacteria stays on people's hands depending on the method with which hands are dried [2][3]. Keeping bacteria off hands is now more important than ever. Our group tackles the issue of hand washing and drying.

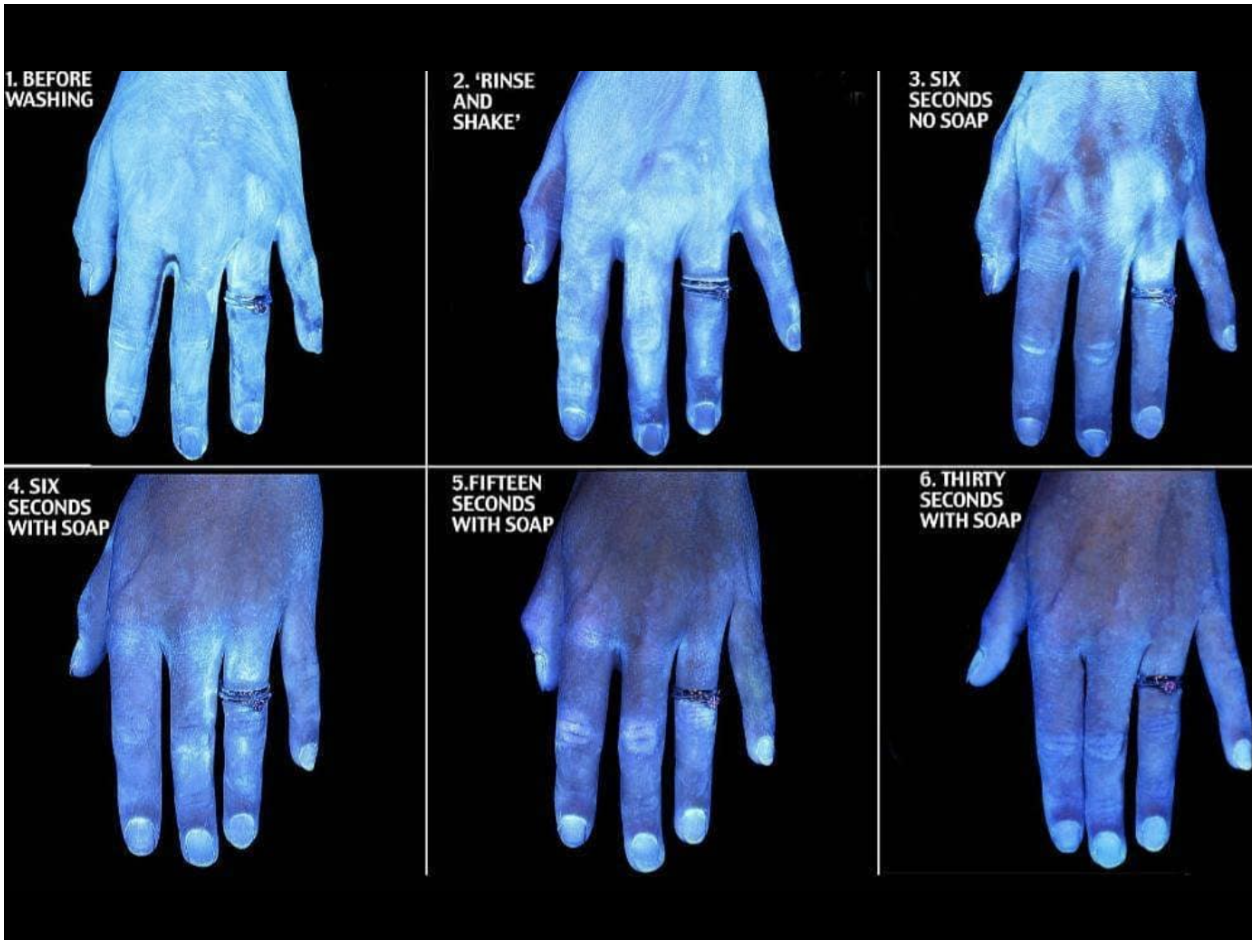

Figure 1 - Black light photos demonstrating effectiveness of hand washing [1]

Washing hands with soap and water is useful for killing bacteria and viruses [2], however, drying hands is also important to ensure hands stay clean. There are three main methods for drying hands: paper towels, air dryers, and self-drying (shaking hands or using a shirt). Studies have shown that hands that are self-dried after washing are most likely to retain bacteria [3]. Air dryers are similarly effective in removing bacteria as using paper towels. However, air dryers can cross-contaminate by dispersing bacteria up to 2 meters [3]. Paper towels are the most clean and effective method of drying hands.

Figure 2 - Public bathrooms in the Reitz Union

The University of Florida has over 50,000 students and it is important to keep the campus as clean and safe as possible. With hygiene and hand-washing more important than ever, our group's goal is to promote hygiene and help prevent the spread of infectious diseases, specifically COVID-19. At the University of Florida, the only hand-drying options in the bathroom is with paper towels. So, to help promote hygiene at UF, we must ask the question: "How often do students experience a lack of paper towels in the bathroom at UF?" If this is a significant problem, then the University of Florida should consider adding sensors to paper towel dispensers to alert employees and avoid running out of paper towels on campus.

Background Research

Introduction

COVID-19 has brought several new ways of life and challenges, one of these challenges has been keeping college campuses safe for students to go to classes or popular buildings, such as libraries and gyms. The global pandemic has made cleanliness and practices to keep frequently used buildings as safe and clean as possible a priority. College campuses were predicted to be some of the highest concentration areas for COVID-19 and running out of paper towels in bathrooms on campus is only going to aid in the spread. Handwashing is a major way to slow the spread of the virus, hence restrooms and frequently touched areas must be supplied with hand sanitizer and handwashing supplies for students and faculty to use [5].

Specifically, paper towels play a major role in the hand washing process during the age of COVID. Doctors recommend using a paper towel to dry hands and then a separate towel to open the door, because of the extra precautions more paper towels are being used at a faster rate than usual making it necessary for paper towels to be replaced more often [4]. Many discussions about the cleanest and most effective method to dry one's' hands have taken place since the start of the coronavirus. Research was conducted on the best methods for hand drying and the current options for hand drying include air dryers, paper towels, shaking ones' hands dry, or wiping dry on ones' clothing [6]. In research, it was found that jet air dryers would cause cross-contamination because they interact with the air and that paper towels should be used in environments which need to be kept sterile or have a larger amount of germs present, which is now every public space because of COVID-19 [7].

There has also been research conducted on how viable air hand dryers and paper towels are. The air dryers have a lesser effect on the environment and do not take from the natural resources that are necessary to produce paper towels, though paper towels were shown to be better for human hygiene [8]. This information is crucial in determining that paper towels are in higher demand during the Coronavirus Pandemic. Because most large Universities, such as The University of Florida, have upwards of 50,000 students it is crucial that hand washing is made a priority, and this starts with the proper supplier.

Therefore, it will be investigated if smart sensor technology should be implemented in high-traffic university restrooms to alert staff when stock is low so that students never have to resort to wiping their hands on their clothes, which is the least hygienic of the three-hand drying methods. Since this is a novel virus, and there has never been as much emphasis on washing hands as there is today, so there exists no current solution to solve the issue we are proposing to fix. But, the effort for our research and proposal is validated by the fact other companies are attempting to implement a similar system in their facilities. CWS-Bosco International GmbH began test trials on a new sensor system for bathroom maintenance in 2017 [9]. They saw the need to solve the frustrations of the restrooms even greater than the need on the UF campus, and implemented a holistic sensor system [8] that covers hand soaps, paper towels, and toilet paper. A large reason for their implementation was to reduce the workload of custodial staff members by reducing the number of unnecessary checks of the bathroom. Instead, workers would be notified when an amenity would reach a critically low level and act accordingly. This is the type of system we are proposing to implement at the University of Florida.

Methods

The data was collected using two methodologies, through a survey distributed to the student and faculty population at the University of Florida and from in-person observations.

Participants

In total, there were 96 participants in the survey that was conducted. All of the participants were either students or faculty and the University of Florida, with the majority of responses coming from undergraduate students who frequented campus.

Survey

The survey was conducted using Qualtrics and distributed online. It consisted of two questions for students and three questions for employees. The questions were focused on determining which of the most frequented places on campus did the paper towel supply run out the most. The questions are shown in Figure 3. These questions were designed to determine from the popular places on campus such as libraries and gyms, which bathrooms ran out of paper towels the most. The data was composed into two graphs, one for the most frequented buildings and the second for the number of times a lack of paper towels was experienced.

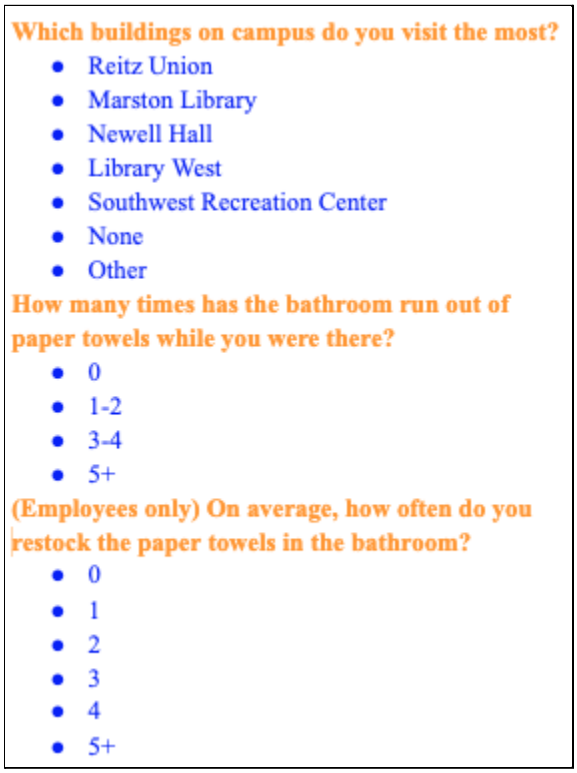

Figure 3 - Survey Questions used for Study

Observational Study

From the researcher's experience and the preliminary survey results, the four most frequented buildings by students and faculty were chosen to be observed. These buildings, in the order of most visited, were Marston Science Library, the Reitz Union, Southwest Recreational Center, and Newell Hall. Each location's bathroom was checked twice a day at 12 pm and 6 pm for the level of paper towels present. During the observation, a score of full, half, low, or empty was given. This data was composed into a chart to illustrate the level of paper towels over time at each location.

Results

From the 96 students and faculty surveyed at The University of Florida, Marston Science Library was the most popular building visited (Figure 4). This was followed by in the order of popularity, the Reitz Union, Southwest Recreational Center, Library West, Newell Hall, and Norman Library (Figure 4).

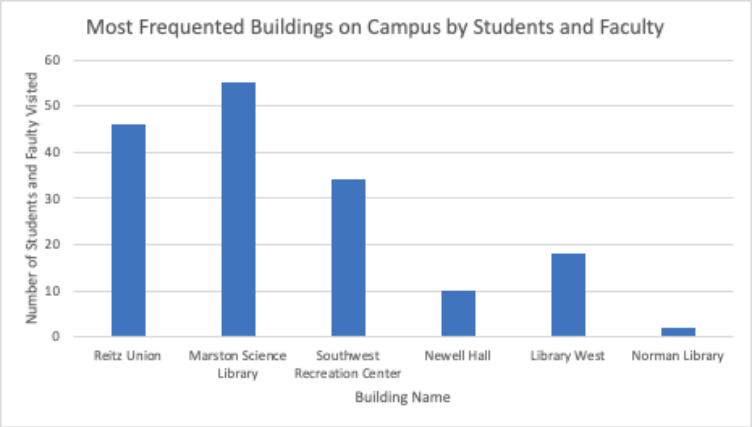

Figure 4 - Bar graph of the most popular buildings on campus from survey data

From the survey data, 41 students and faculty experienced a lack of paper towels 1-2 times at the previously mentioned buildings in Figure 1 (Figure 2). 34 respondents indicated that they had never experienced a lack of paper towels, while 11 respondents specified that they have experienced five or more times of an absence of paper towels. Only 9 people denoted that they had experienced 3-4 occasions of an absence of paper towels, making it the least popular choice in the survey. Overall, approximately 65% of students had at least one experience where there were not any paper towels in the bathroom at one of the popular locations on campus.

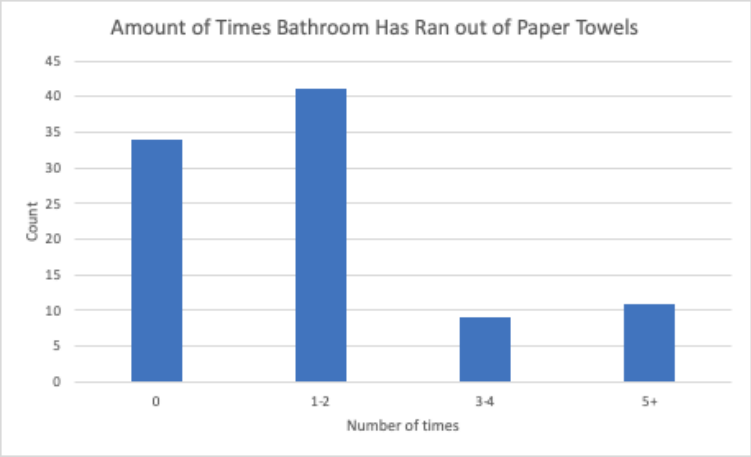

Figure 5 - Bar graph of the number of times a bathroom has run out of paper towels from survey data

During the observational period, it was observed that Marston Science Library was the building that ran out of paper towels the most followed by a tie between Newell Hall and the Reitz Union, then coming in at the most fully stocked was Southwest Recreational Center (Figure 3). Marston Library and the Reitz Union follow a similar trend from the survey data, but the observation of Newell Hall and Southwest Rec

Southwest Rec

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
12pm	Half	Full	Half	Half	Full	Full	Full
6pm	Low	Full	Half	Half	Full	Full	Full

Reitz Union

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
12pm	Full	Half	Low	Half	Low	Half	Full
6pm	Half	Low	Half	Half	Empty	Half	Half

Marston Library

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
12pm	Low	Full	Half	Low	Full	Low	Full
6pm	Empty	Full	Low	Empty	Half	Empty	Half

Newell Hall

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
12pm	Full	Half	Half	Low	Full	Half	Half
6pm	Half	Low	Full	Empty	Half	Low	Half

Figure 6 - Observational data of the paper towel supply across most popular building locations from 11/2/20 - 11/8/20

seems to diverge from the survey data previously collected. Newell Hall was observed to run out of paper towels more often than surveyors reported while Southwest Rec seemed to be more stocked than surveyors concluded.

Discussion

This report aims to investigate how stocked the paper towel dispensers in frequently used restrooms on campus are. In the study and survey that was conducted, it was found that around 65 percent of students in the sample had run out of paper towels in the bathroom. In Figures 2 and 3, which show the survey data and physical bathroom checks respectively, it is clear that the bathrooms often run out of paper towels. A solution to this problem is sensors in paper towel dispensers that alert staff if the stock is low.

The results are from a representative population, but for further research, the bathrooms could be inspected more often, the women's bathroom inspected, and a greater number of students could be asked to take the survey. The study would also need to include more bathrooms on campus to determine the magnitude of the problem, or if it is only an issue in the most popular bathrooms. However, according to past studies, similar issues about the stock of paper towels have been found and remedied with air dryers [4,7,8]; though, with COVID-19, it is crucial to have paper towels, which is the safest way to dry hands [5].

Given these results, going forward with the development and testing of smart sensors would be reasonable. For the development of this product to be feasible, there would need to be more testing at other public places and college campuses. Then, testing on the product and as it is put into use would be needed, so that the custodial staff would know how to properly manage dispensers equipped with the smart sensor.

Technical Plan

Overview

Since sanitation is such a major issue in the world right now, especially for a school like the University of Florida, a product and plan for increasing safety is described below. It can be seen from the background research that the university has some inconsistencies with keeping its popular bathrooms stocked with necessary products like paper towels for students to stay safe. A proposed solution to this problem is the Paper Towel Stock Sensor (PTSS) which will alert employees of which bathrooms need to be stocked remotely and in real time. The PTSS utilizes an optical sensor and a multi protocol transceiver to collect data and then communicate when necessary. The idea is that whenever the sensor notices the stock of paper towel in a specific bathroom is low, it will alert an employee that it needs to be restocked. This would help eliminate any spread of germs from hands not being properly washed along with increasing efficiency of employee time by removing redundant maintenance checks on bathrooms that do not need it.

Components and Parts

The overall design of the product is quite simple with two main parts, the optical sensor and the transceiver. The optical sensor used is a TCRT5000 Photoelectric Sensor which can sense the presence of an object, such as paper towels. The transceiver is a ESP8266, a wifi module that is used for serial communication to microcontrollers over a wifi network. In order for these parts to work together, a central processing unit is required. So an Arduino Uno Rev 3 was selected for its price and functionality. The optical sensor and transceiver are both compatible with the arduino microcontroller allowing for simple construction of the product. The PTSS will draw its power from a Battery to DC connector equipped with 4 AA batteries. This will be enough power for the device to have 40 hours of on time [10]. The device will not be running constantly as changing the batteries every 40 hours would be extremely inefficient. Instead a real time clock module will be attached to the microcontroller. The RTC sends a small pulse to the Arduino that will wake it and power on for around 1 minute at a time. Checking the current stock of the paper towels will be done around 4-5 times per day. With an on time of only 5 minutes per day the device can run on its own for 480 days. To add a buffer for unforeseen circumstances the device should be checked once a year and have its batteries replaced. After all the electronic components have been assembled, the whole device needs to put in a protective case so that the wires are not going to be obstructed or damaged. There would be an opening for the optical sensor to still function properly and an access point to easily replace the batteries when needed.

Software

Each of the microcontrollers will be preloaded with code so that they will know what to do and how to send information to employees. In order for the employees to be able to receive the information, there needs to be a medium set up so that communication is established. As included in the budget, a software developer would need to be employed to create a program that employees can log in to while they are at work that can display the information from the devices in an organized way. This program will allow employees to check in real time if the paper towels are low on stock in a specific bathroom. Once the paper towels are restocked, the device will automatically sense it when the next check occurs and will be shown on the program. Once the program is set up, each device needs to be titled with an electronic ID so that the employees will

know which bathroom needs to be restocked. During setup, a test message can be sent and then the device can be marked and ID'd. Each device will have its internet settings configured so that anytime it turns on, it will automatically connect to the University of Florida network and be able to communicate remotely.

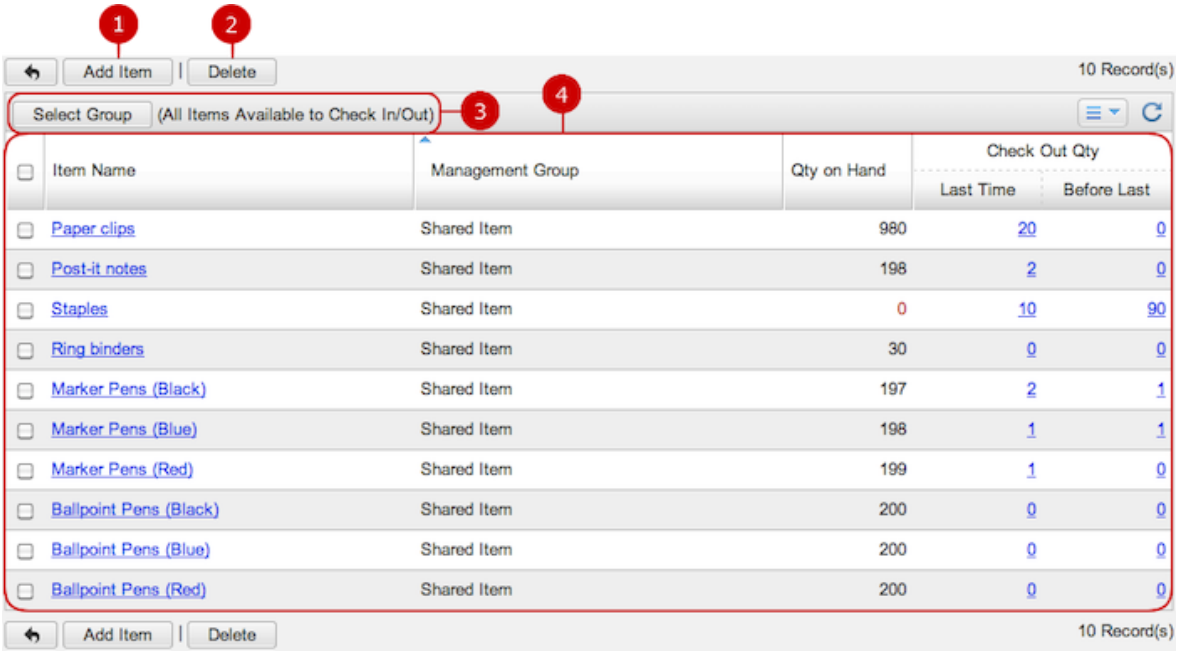

Figure 7 - Example program interface for employees

Implementation

Once the devices are assembled and the code has been uploaded with the program ready for employees to utilize, they can start to be installed. A contractor can be employed to install the devices, which was accounted for in the budget. Installation would be simple since during setup, each device was labeled or marked and designated for a specific bathroom. A small hole will need to be made in the side of the paper towel dispenser for the optical sensor to have vision. The PTSS will be installed on the side of the paper towel dispenser. It is lightweight enough that 2 screws will be enough to keep it attached. Lastly for installation a new set of batteries will be put in and the device will automatically start checking stock.

Model Creation

An optional and possibly more beneficial aspect of this proposal would be a model creation. As the devices are detecting when the paper towels are low on stock, that data can be recorded by the software and after one year, a model could be created for that bathroom. A trend could be found in the data so that a schedule is made to try and estimate when the bathroom would start to run out of paper towels. If this model turned out to be accurate, the sensor could be moved to another bathroom allowing for the same cycle to occur again.

Budget and Schedule

Budget

The bulk of the budget will be allocated to the purchase of components and the purchase of installation. Each estimate for a major component was directly made from the retail price of the components on Amazon.com. Each unit will cost $47.22. For installation, we thought it would be best to hire two full time installers with an annual salary of $100,000. These positions would be filled until all necessary sensors are installed. Additionally, a software engineer with a salary of $200,000 will lead in the software design of the sensors and continue to make the system more functional and user friendly. Furthermore, multiplying the unit cost by 100 and also multiplying that product by three, which is about the average number of paper towel holders in a UF restroom, the cost for 200 restrooms to have sensors installed is $28,332.00. A primary maintenance cost is added for the replacement of batteries. Other maintenance costs could be considered as well. Last, we planned for $75,000 for an operating room with proper equipment. This will provide a space for a staff member to analyze the entire system. This also accounts for any mobile devices used to check the system. Our total first year estimated budget is $506,932. Included is a table with the specific component names that we will be using for our sensors.

Initial Year Budget	
Components	**Cost**
Optical Sensor	$ 0.22
Transceiver	$ 5.00
Micro Controller	$ 25.00
Power Source	$ 6.00
Real Time Clock	$ 8.00
Installation Hardware	$ 3.00
Total Per Unit	$ 47.22
Total Per 200 Restrooms	$ 28,332.00
Labor	
Software Engineer	$ 200,000.00
Installers x2	$ 100,000.00
Total Labor	$ 400,000.00
Maintenance	
Battery Replacement	$ 6.00
Total Yearly Maintenance	$ 3,600.00
Operating Room Cost	$ 75,000.00
Overall Total	$ 506,932.00

Figure 8 - Budget

Product	Specific Component Name

Optical Sensor	XLX TCRT5000L TCRT5000 $0.22
Transceiver	ESP8266 $5
Micro Controller	Adruino Uno Rev 3 $25
Power Source	Battery to DC Connector (4xAA) $6
Real Time Clock	DS3231 $8
Device Case	3D Printed Casing $10

Figure 9 - Major Product List

Schedule

The program for the installation of the PTSS will begin in the Summer of 2022 on June 1, 2022. After our proposal would be accepted, the initial cost of the first 100 restrooms would be funded to begin installing sensors in the major buildings that have been prioritized in the Research Report. The summer installation date will allow for the initial round of sensors to be installed before the beginning of the Fall 2022 semester so that proper testing of the first sensors can take place. After the sensors have been tested periodically during the Fall 2022 semester, the remaining additional components will begin to be purchased and installed beginning in the Spring 2023 semester for all necessary restrooms on the UF campus.

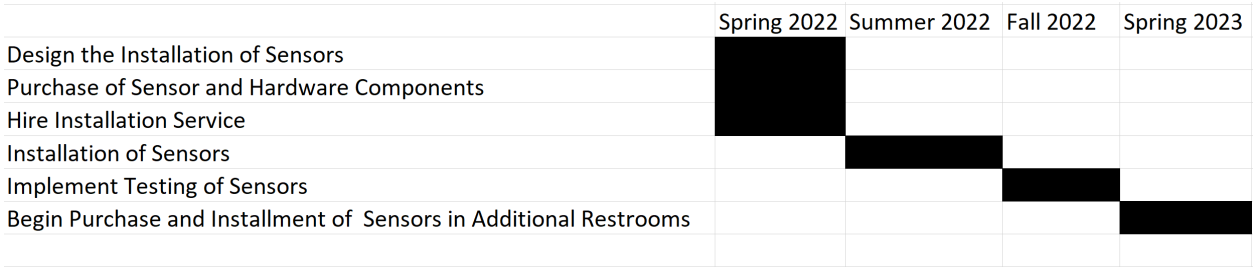

Figure 10 - Schedule

Evaluation Plan

Our plan is effective in that our sensors will continuously monitor the supply of paper towels from different bathrooms around campus and provide employees with essential information necessary to keep the bathroom's paper towel supply in stock throughout the day. This data will be used to find patterns and perhaps identify similar buildings that need the sensor system installed as well.

We recognize that our sensors will have more value in some restrooms over other restrooms. Since the implementation of our plan will take effort assessing its effectiveness and production, finding the restrooms that have the highest use of our sensors will be valuable for our team. We can use our time efficiently to test our sensors where they matter the most. Furthermore, understanding these locations can help us record data to more clearly see the benefits of our sensors.

Once our sensors are installed in bathrooms, they will be thoroughly tested to ensure they are accurate. This will be tested jointly with the software communication in the employee system. These should alert employees when the paper towel supply is low or empty. These alerts need to be accurate and prompt and should not spam or disrupt the employee system in any way.

The effectiveness of this system will be determined through a survey a month after the first wave of sensors are installed in the most popular buildings. The survey will be very similar to our preliminary survey and ask two main questions:

1. Which buildings do you visit the most on campus?
2. How many times has the bathroom run out of paper towels while you were there?

In addition to this survey, we have a separate survey for employees only. This survey will ask the same two questions as before, but also include a question about the effectiveness and experience of the sensor and software system in the bathroom.

An additional method for testing the effectiveness of the sensors is through storing the data they collect. As the sensor keeps notifying employees when the paper towel stock is low, each bathroom can be modeled and employees can begin to predict when bathrooms would go out of stock and adjust their schedules accordingly. If this is done well and the sensors can accurately model specific bathrooms, the sensors can then be moved to different bathrooms for the same process.

Once the initial sensors and software package are installed in the most-frequented bathrooms on campus, an analysis will be concluded on the cost of the product solution and the ongoing maintenance that will be needed to keep them up and running. As this is being carried out, a decision will be made if the benefits of this system combined with the effectiveness of the sensors for keeping paper-towels stocked, outweigh the costs to the University. If it is concluded that the sensors employ a net-positive gain, this solution will be rolled out to the remaining public bathrooms on campus.

The data gathered to determine the effectiveness of our system will be put into progress reports, which will be regularly sent out to the leaders of our project.

Appendix

Which buildings on campus do you visit the most?

- Reitz Union
- Marston Library
- Newell Hall
- Library West
- Southwest Recreation Center
- None
- Other

How many times has the bathroom run out of paper towels while you were there?

- 0
- 1-2
- 3-4
- 5+

(Employees only) On average, how often do you restock the paper towels in the bathroom?

- 0
- 1
- 2
- 3
- 4
- 5+

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Visual Aids

[1] Black light photos demonstrating effectiveness of hand washing
https://static.independent.co.uk/s3fs-public/thumbnails/image/2020/03/07/10/screenshot-2020-03-07-at-10.26.55.png

[2] Public bathrooms in the Reitz Union
https://www.collegemagazine.com/wp-content/uploads/2016/07/TRUEreitz.jpg

[3] Survey Questions used for Study
https://ufl.qualtrics.com/jfe/form/SV_6A0cxB0PZ8QIa0J

[7] Example program interface for employees
https://www.desknets.com/neo/help/en_US/manage/stock/001.html