Flushing Away Water Wastage: A novel automatic toilet design

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Summary:

Automatic toilets unnecessarily waste water due to a phenomenon called phantom flushing, the activation of a flush at times other than when required, usually due to movement triggering the motion sensor. Because manual toilets cannot have phantom flushes, some professionals believe automatic toilets are less efficient than manual ones. In fact, automatic toilets waste 54% more water than manual ones (Maximum Performance Testing, 2010).

My project strives to create a cost efficient and environmentally friendly novel automatic toilet design that ensures automatic toilets don't waste water through phantom flushing. This is done by using a load sensor under the toilet seat that detects when someone sits down, and only then will the motion sensor be activated to trigger a flush. I coded an Arduino prototype to demonstrate the concept of how the sensors inside the toilet would work. The prototype shows that when someone sits down on the toilet seat housing the load sensor underneath, the sensor is activated. Once the sensor is released, a 15 second delay will begin before the flush occurs.

Background Research & Problem

- Water wastage occurring in washrooms is subtle and often overlooked. Approximately 30% of the total water use of Canadians is from using toilets.[1]
- Automatic-flush toilets are often seen as a more hygienic, no-touch alternative to traditional toilets. After they first appeared in the 1990s, they quickly gained popularity in airports, malls, office buildings and other facilities with high-traffic public restrooms.[2]
- However, research has shown that automatic toilets actually use 54% more water than manual toilets.[3]
- The main reason that automatic toilets waste so water is a concept known as the "**Phantom Flush".**[2]
  - A phantom flush is when the toilet flushes at times it is not required.
  - Phantom flushes usually occur when the motion sensor is triggered by someone walking by the stall, someone closes/opens the door, or other movements within the stall.[2]
    - Since manual toilets cannot phantom flush, they are often considered more water efficient.[4]
- While a single phantom flush does not cause a lot of water wastage, it quickly adds up when it occurs multiple times a day. Even a few automatic toilets can lead to hundreds of litres of water wasted every year. If you multiply that by how many automatic toilets there are, you've got millions of litres of water wasted every year due to this faulty design. It's estimated that there are about 27 million automatic flush toilets in the USA (data not available for Canada).[5]
- If automatic toilets were replaced with manual toilets in the Los Angeles and San Francisco airports, it is estimated that 80 million gallons of water would be saved each year.[6]
- By developing an automatic toilet that will not phantom flush, the benefits of automatic toilets can still be had without the associated water wastage.

Purpose

Create a novel, efficient, and environmentally-friendly design of an automatic toilet that can prevent water wastage and save money.

The design should eliminate the problem of phantom flushing and provide an efficient way to use the concept of an automatic toilet without wasting water and saving the owners money.

Procedure

1. Brainstorm ideas.

2. Create design model and sketch preliminary designs of toilet.

3. Create the prototype showing proof of concept for the toilet using Arduino Uno.

4. Calculate water wastage and environmental impact of toilet design and determine estimated associated cost savings of design.

5. Redesign/adjust the prototype as necessary.

Design Criteria

My Design should include the following criteria:

- Automatic flushing of toilets, where individuals do not need to touch the flush lever themselves
- Save water by preventing phantom flushes
- Provide a better alternative to the designs currently that waste water on a daily basis

Proposed Design

An automatic toilet that has a load sensor underneath the toilet seat was designed to eliminate the problem of phantom flushes (Figure 1).

- There is a load cell housed in the rim of toilet bowl that can sense >5+kg weight. This allows the toilet to detect someone sitting down at the toilet.
- Load cell senses when weight is removed and sends signal to control panel to flush toilet after a 15 second delay.
- Load cell is positioned on front quarter of toilet rim to maximize its sensitivity, forming a 3rd class lever.
- There is also a manual flush lever connected to the control panel in case of standing or in case someone needs to manually flush.
- When someone sits down on the toilet seat housing the load sensor underneath, the sensor will be activated. When they stand up and the sensor is released, a 15 second delay will begin before the flush is triggered. This prevents phantom flushing from occurring since the toilet must be in use in order to flush.

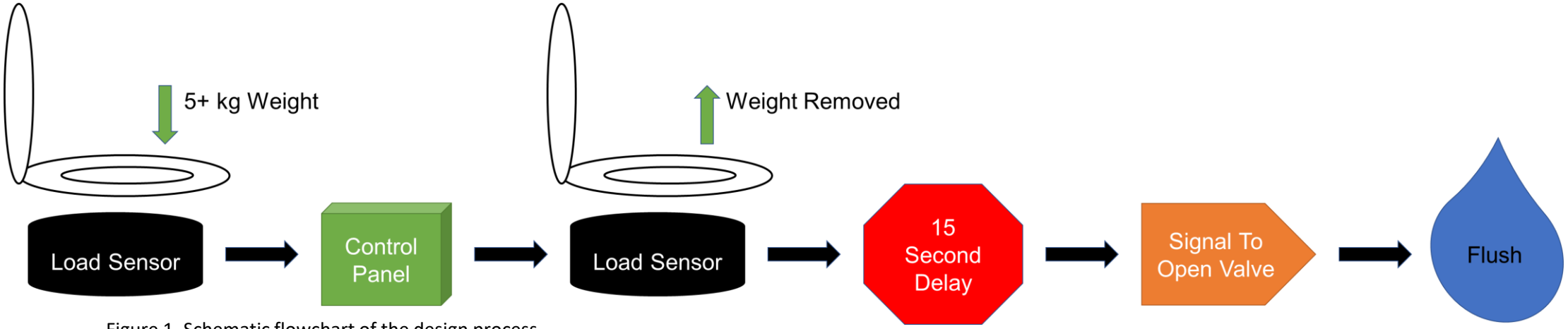
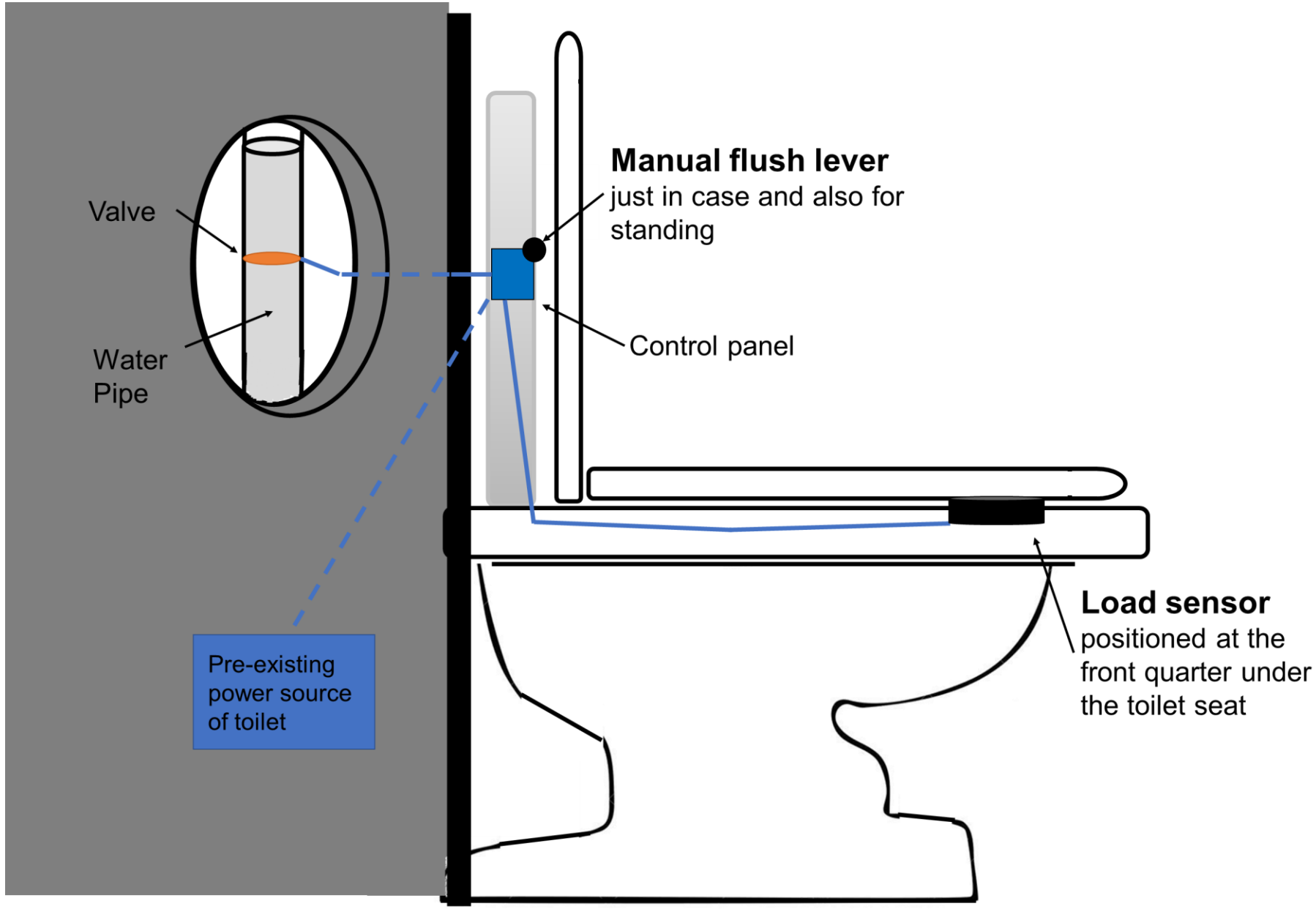


Figure 1. Schematic flowchart of the design process.

Schematic Diagram of Design



Prototype of Automatic Toilet with Load Sensor

- Arduino Uno was used to create a prototype. The Arduino Prototype shows how the load sensors will work in the proposed design of the automatic toilet.

In the prototype:

1. A load is detected by the push button:
   →The LED light turns on to show that the sensor is activated.
2. Once the load is removed, a 15 second delay in flushing occurs:
   → The LED light flashes 4 times to symbolize the delay.
3. After the delay, the toilet flushes automatically.
   → The LED turns on for 2.5 seconds to symbolize the flush.
4. Resets for next use.

Note: I used a push button to represent a load sensor in my prototype because I did not have an actual load sensor. However, I decided a push button was a suitable alternative because it can still “detect a load” when someone presses on it.

Please See Included Video Demonstrating Prototype

Coding the Arduino

- I ran into an issue coding the Arduino prototype because at different stages of the code I wanted an unpressed button to do 2 different things:
  - At the beginning, the button is unpressed prior to detecting a load. Here, I did not want the code to do anything.
  - Right after the button has been released after detecting a load, the button is unpressed. Here, I wanted the code to begin the delay and flush sequence.
- I needed to distinguish between an unpressed button that has never been pressed, and an unpressed button that was just released.
- I couldn't find an example of this on open-source websites, so I decided to create a variable called "tracker".
  - When you start the code, the tracker equals 0. This tells the Arduino that the button has not been pressed yet. As soon as the button is pressed, the tracker variable becomes equal to 1.
  - Having the tracker variable allows the code to distinguish between an unpressed button at the beginning (when tracker=0) and an unpressed button that has just been released (when tracker=1). This lets it do 2 different actions at different stages of the code!
  - Once the delay and flush sequence has been finished, the tracker becomes equal to zero again to reset the code and prepare it for the next load (Figure 2).

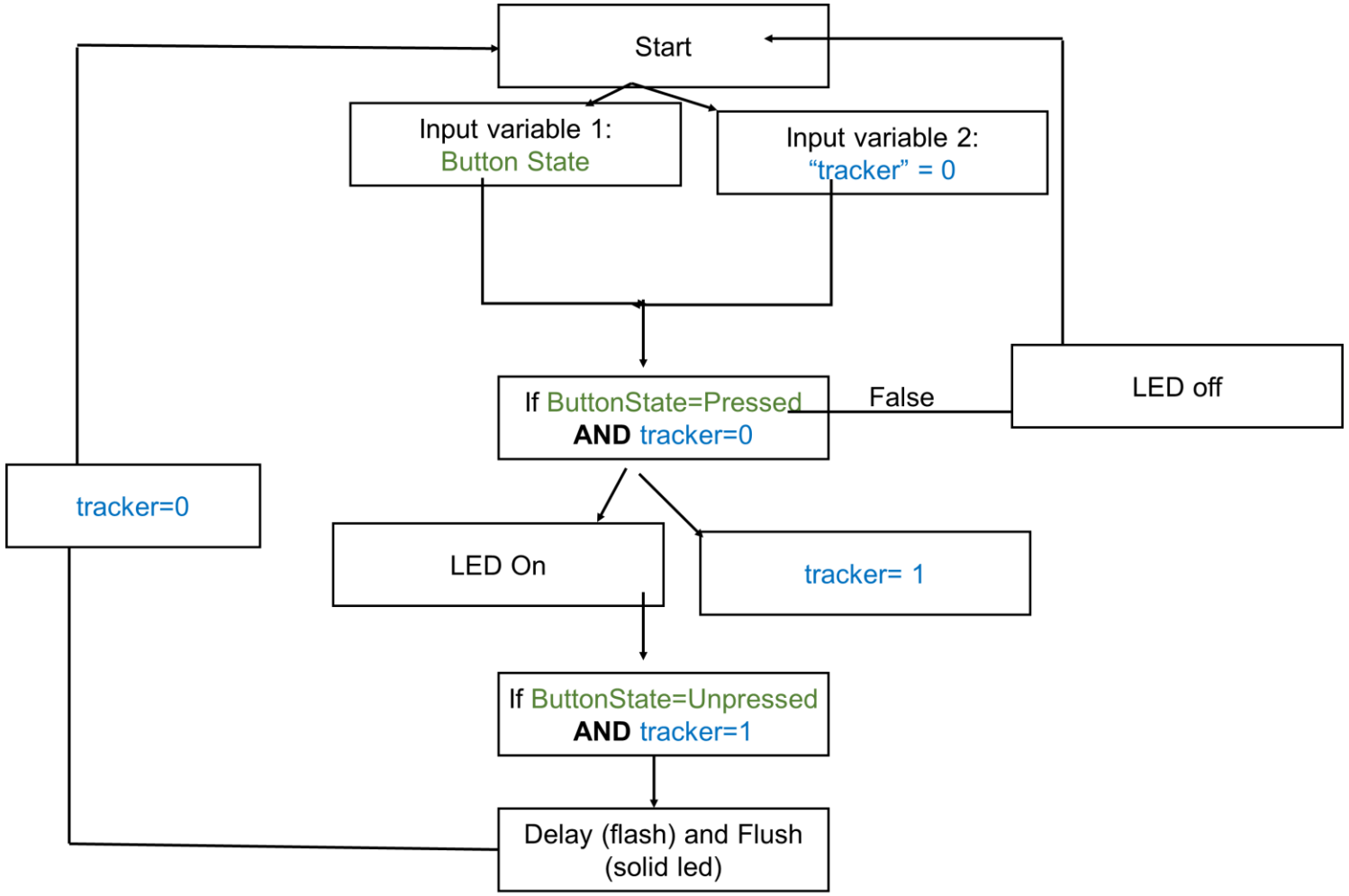


Figure 2. Flowchart to explain how the code works with the different variables.

Arduino Code

```
//defining constant variables (const int) that will not change:
const int buttonPin = 2; //the pin number of the pushbutton
const int ledPin =  13;   //the pin number of the LED

//defining variables (int) that will change:
int buttonState = 0;   //variable for reading the state of the pushbutton
int tracker = 0;  //variable for keeping track of if the pushbutton has been pressed

void setup() {
  //defining LED as an output (turning on):
  pinMode(ledPin, OUTPUT);
  //defining pushbutton as an input (being pressed):
  pinMode(buttonPin, INPUT);
  tracker = 0;
}

void loop() {
  //reading the state of button (if it's pressed down):
  buttonState = digitalRead(buttonPin);

  //Check if pushbutton is pressed. If pushbutton is pressed, buttonState is high AND
If tracker=0 meaning the button has not been pressed:
  if (buttonState == HIGH && tracker == 0) {
    digitalWrite(ledPin, HIGH);    //turn LED on:
    delay(50);
    tracker = 1; //tracker variable changes to 1
  }

  //check when pushbutton is released. When it is, buttonState=LOW and tracker will
not equal 0, so flush sequence will start:
  if (buttonState == LOW && tracker != 0) {
    //  LED flashes 4 times (symbolizing delay):
    for (int i = 0; i < 5; i++) {
      digitalWrite(ledPin, LOW);
      delay(500);
      digitalWrite(ledPin, HIGH);
      delay(500);
    }
    //LED goes solid for 2500 milliseconds (2.5 seconds) symbolizing the flush:
    digitalWrite(ledPin, HIGH);
    delay(2500);
    digitalWrite(ledPin, LOW);
    delay(500);
    //tracker variable resets to 0 to reset for next load
    tracker = 0;
  }
}
```

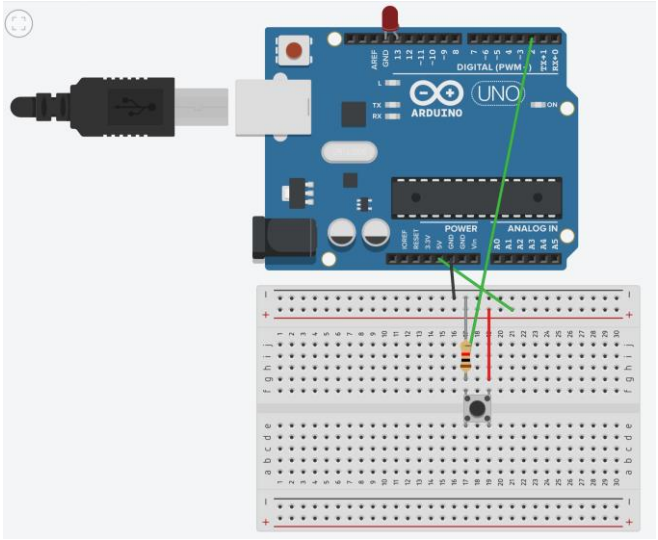


Figure 3. Circuit diagram showing how to assemble Arudino prototype (made with TinkerCad).

Discussion

- As a solution to the water wastage that occurs whenever an automatic toilet flushes unnecessarily, a load sensor embedded in the toilet seat was proposed to help prevent water wastage. I created a novel design that allows automatic toilets to not waste water by eliminating phantom flushes. The load sensor makes it so that the toilet must be in use in order to flush.
- Device met all the pre-specified design criteria:
  - It helps reduce water wastage by making a stricter criteria for the automatic flush
- The following benefits of my design were calculated:
  - The average office building in Ontario would save approximately 8.13 million litres of water per year by replacing their automatic toilets with my design.
  - This is equal to a 16% reduction in annual total water use.
  - This would save them $32,208, based on water prices in Toronto in 2019.[7]
    - (Calculations based on data from [1], [3], [7], [8]).
- Other things that could be considered to progress this design:
  - How long should the delay last for
  - Is a 5kg load threshold enough?
  - Optimal placement of loadcell

Conclusion

- This prototype design is of a novel automatic toilet that prevents water wastage in a cost efficient and environmentally friendly manner.
- My device would be beneficial to help save water by reducing the number of faulty flushes that overall would reduce the amount of water wasted by current automatic toilets daily.
- Ideally, this load cell design could be incorporated into current automatic toilets to minimize the initial costs associated with implementation and encourage fast adaptation of the improved design.
- A way to improve this design is to optimize the placement of the load cell.
- Overall, this design effectively achieved the purpose of this project and a novel automatic toilet that saves water in an effective and efficient manner has been developed.

References

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