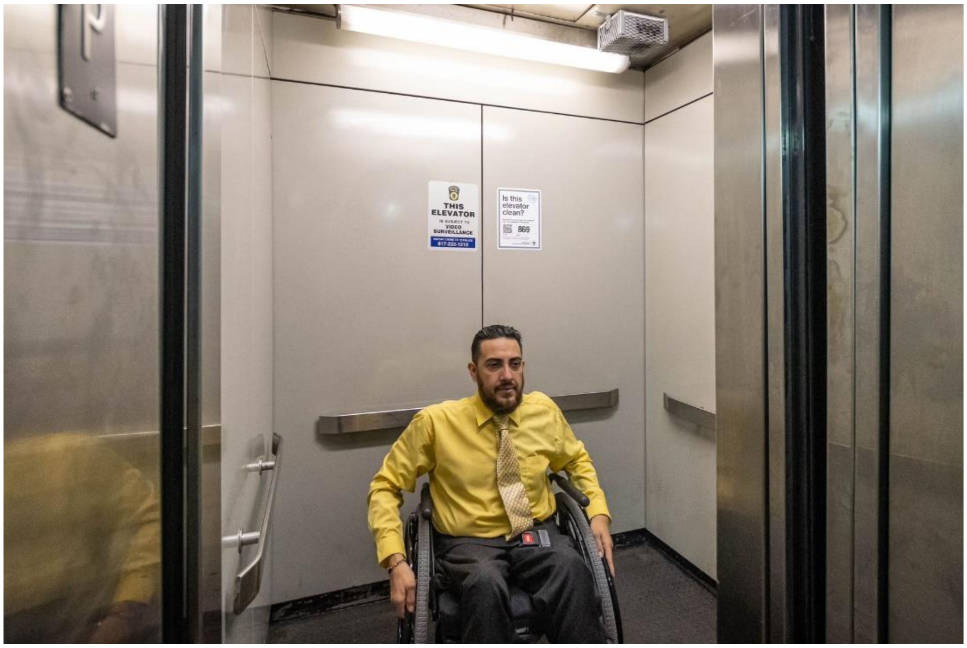
Urine Detection in Elevators: Pilot Report

Massachusetts Bay Transit Authority (MBTA), May 2023



A rider who uses a wheelchair mobility device in an MBTA elevator with a urine detection sensor on the ceiling (top right).

Executive Summary

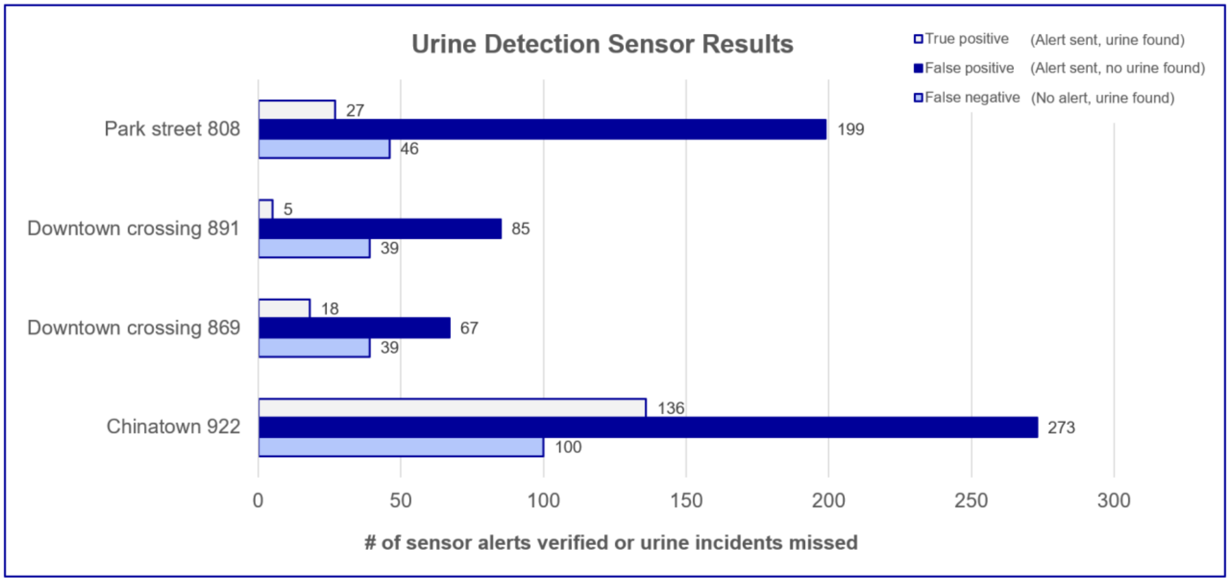
We ran a pilot to evaluate the effectiveness of a sensor that detects the presence of urine in an elevator cab. The pilot ran in four elevators in three downtown stations—Chinatown, Downtown Crossing, and Park Street—for just under three months, from October 2022 to January 2023. Elevator cleanliness is a major problem for riders and an expensive problem for the MBTA. We wanted to determine whether this urine-detection sensor might be a cost-effective addition to our current elevator cleanliness methods.

Our objective was to be able to answer the following questions:

1. How reliably does the sensor detect urine?
2. How reliably does the sensor detect cleaning solutions?
3. How reliably does the sensor operate?
4. Do we have the resources & processes to support these sensors at scale?

What we concluded about each of these questions:

1. The sensor did not reliably detect urine. The sensors' error rate varied dramatically across elevators and time.



Pilot elevator	True positive rate (TP / # urine incidents)	False positive rate (FP / # urine incidents)	False negative rate (FN / # urine incidents)
Park street 808	37%	273%	63%
Downtown crossing 891	11%	193%	89%
Downtown crossing 869	32%	117%	68%
Chinatown 922	58%	116%	42%

2. We couldn't assess cleaning agent detection of the sensors. It wasn't operationally feasible for the cleaning vendor to verify sensor alerts.
3. The sensors' operability got worse over time. In the second month, there were two multi-day outages and seven hard (i.e., on-site) resets required due to server issues.
4. We do not believe the sensors would add value to our current protocols, with or without additional resources.

The pilot showed us that a variety of real-world conditions—temperature, people camping in elevators, cigarette & marijuana smoke, smells on riders' clothing, etc.—make isolating actual urine, not just the smell of it, very difficult for the sensors. As such, the sensor was not nearly as accurate as we'd hoped, and is not a cost-effective addition to our current elevator cleanliness methods. We do not recommend the continued use, or expansion, of this urine detection sensor.

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Background

What's the Problem

The MBTA manages more than 180 elevators system-wide. Many riders depend on them for their daily mobility: people who use a mobility device, families with strollers, people who are transit-dependent for groceries, tourists with luggage, or people who aren't able to take the stairs. Elevators make our transportation system more accessible to everyone.

Unfortunately, people often use those elevators as restrooms. That's a huge problem for riders, and for the MBTA teams who clean and maintain the elevators. Human waste is not only unsanitary, it's also corrosive.

What's Been Tried So Far

MBTA

In 2018, the MBTA established a cross-departmental task force dedicated to elevator cleanliness. The task force created a plan for keeping our elevators clean, including but not limited to:

- A performance-based station cleaning contract
- Replacing elevator flooring, using materials that don't allow liquids to be absorbed into the floorboards
- Increased monitoring by station officials and the transit police
- Having station officials and Transit Ambassadors conduct frequent checks of every elevator over the course of their shift

The task force also maintains data, and a monthly dashboard, on how often each elevator located at stations staffed by Transit Ambassadors are found to be unclean.

In 2019, we shared this problem statement with the Startup in Residence (STIR) program and, through an open solicitation run by STIR, were matched with a company that proposed a urine-detection sensor. In 2020, they ran a successful proof-of-concept in one MBTA elevator, resulting in this pilot.

Why not just build more bathrooms?

Sometimes it's not feasible, and we've found that more bathrooms don't always solve the problem. Building new bathrooms at existing stations is complex, and many MBTA stations don't have the space for it. Restrooms are available for riders at a number of our stations. However, people often use elevators as restrooms even when they are available.

MARTA

Metropolitan Atlanta Rapid Transit Authority (MARTA) was the first transit agency in the US to pilot a urine detection device (UDD) in an elevator for one month in 2013. The UDD (20 sensors) was installed around the base of the elevator and worked by:

- Sensing a liquid splash
- Flashing a strobe light and sounding an alarm
- Alerting MARTA police

A hidden camera captured footage of any violators and a sign was posted in the elevator (”ARMED WITH URINE DETECTION DEVICE”) to deter urination and inform people that public urination is an act of public indecency. The pilot reduced urine incidents from a daily occurrence down to one incident and caught one person who was arrested by the police. It was deemed successful, and the UDD was planned to scale to all 111 elevators for $1M.

By 2017, UDDs had been installed in 13 elevators at a cost of $10,000 per elevator. But the program has since run into issues: the cost, complexity, and maintenance burden of the electrical work required to support the UDDs has become too onerous, and occasionally affected elevator uptime.

Singapore

Singapore invented the first urine detection device (UDD) used in public elevators and Parliament implemented them in the nineties. When the UDD detected urine it would lock the person in the elevator while a camera recorded them. The police were notified and would charge the person with a fine. Singapore’s Housing and Development Board (HDB) agency has since installed CCTV cameras in lifts and phased out UDDs entirely.

BART

Bay Area Rapid Transit (BART) in San Francisco uses elevator attendants at some of their stations after a successful pilot of the concept in 2018. The pilot was designed to address elevator cleanliness, safety, and accessibility due to the level homelessness, mental illness and drug addiction in the city. In the first three months of the pilot, the elevators with attendants had virtually zero incidents of inappropriate use. Customer feedback on the attendants was uniformly positive and most reported they felt safe and clean using the elevators. The program cost $1.6M in 2018-19 and expanded to more stations in 2022 at an estimated cost of $3.3M.

About our Pilot

What We Hoped to Learn

We ran this pilot to determine whether this urine-detection sensor might be a cost-effective addition to our current elevator cleanliness methods.

Our objective was to be able to answer the following questions:

1. **How reliably does the sensor detect urine?** As with all sensors, false positives and false negatives have different implications, so we needed to know error rates—i.e., which type of error is more common.
2. **How reliably does the sensor detect cleaning solutions?** This could be helpful not just to elevator cleanliness efforts, but could also generate data through which to monitor the MBTA's cleaning vendor.
3. **How reliably does the sensor operate?** In other words, how often did the unit go offline or get vandalized.
4. **Do we have the resources & processes to support these sensors at scale?** Several departments took on additional responsibilities to launch this pilot, including Vertical Transportation. Given the costs of installation, maintenance, and new operational procedures, what would the MBTA need to support 25, 50, or 100 sensors?

How We Set Up the Pilot

Chinatown 922 | Downtown Crossing 869 | Downtown Crossing 891 | Park Street 808

A urine detection sensor mounted to the ceiling of the pilot elevator in Chinatown 922, Downtown Crossing 869, Downtown Crossing 891, and Park Street 808.

Scope, Schedule & Cost

The pilot ran in four elevators in three downtown stations—Chinatown, Downtown Crossing, and Park Street—for just under 3 months, from October 2022 to January 2023. We selected elevators that:

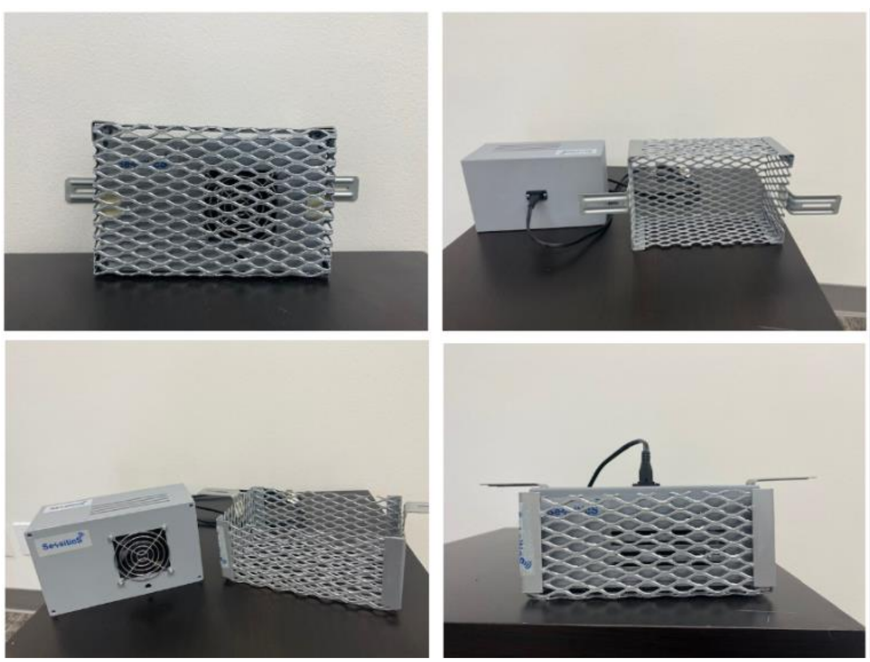
- Have some of the highest "unclean rates," based on existing, internal data
- Are in stations covered by the MBTA Transit Ambassador program and an on-call cleaning contract
- Have functioning power, different cab sizes and roof designs, good cellular connectivity & exposure to the elements

Each of the four sensors cost $12.5K. The overall cost of the pilot—development of the sensors, anti-vandalism cages, calibration, and support—was about $125K. One spare sensor cost $2.5K. This did not include the cost of a dedicated project manager.

Who Was Involved

Organization	Pilot Role
System-wide Accessibility	Leads overarching discussions regarding elevator cleanliness initiatives and sponsored the pilot
Customer Technology	Designed and managed the pilot
Vertical Transportation	Assessed the sensor prototype and manages the elevator vendor who installed the sensors
Customer Experience	Manages Transit Ambassadors who check elevators and verified sensor alerts
Transit Facilities Maintenance	Manages the cleaning vendor who cleans the elevators
Sensor Vendor	Developed the hardware and software for the sensor (they are based in CA and operated remotely)

About the Sensor



Urine detection sensor with anti-vandalism cage; front, back, and side angle of sensor

Size & Function

The sensor housing is a little bit bigger than the size of a box of pasta (21.5cm x 13cm x 9.5cm). It has a fan that pulls in air towards a metal oxide semiconductor that detects volatile organic compounds. When a programmed volatile organic compound is detected at a defined threshold for a certain period of time, an alert is sent over a cellular connection to the vendor's server.

Power & Mounting

- **Power –** The sensor was powered by a standard two prong A/C plug like most household devices and connected to the elevator power directly. A ¾ inch hole was drilled into the elevator cab ceiling so the power cord could connect to the power source.
- **Mounting –** The ¾ inch hole allowed the sensor to be mounted flush to the ceiling with no wires exposed for safety reasons. A metal honeycomb anti-vandalism cage fit snugly over the sensor with two L-bracket "ears" welded to the sides so that it could be screwed into the elevator cab ceiling. The fan side of the sensor faced the floor of the elevator (where urine would be).

Installation

Vertical Transportation worked with our elevator vendor to install the sensors in the four pilot elevators. The vendor noted the ideal location for the sensor would be near the exhaust fan, which could aid in pulling in air towards the sensor. This wasn't feasible for all of the pilot elevators due to constraints like drop ceilings and electrical wiring. Each installation took less than half a day, with the exception of one sensor that took a week because of an especially thick, steel cab ceiling. After each installation, we shared photos with the vendor to confirm that the sensor had been mounted correctly.

Calibration & Testing

The sensor needed at least two weeks of calibration from the time of installation to create a baseline of each elevator's unique environment. Each sensor needed to sustain a level range of volatile organic compound numbers that were registered over the two week period to establish the baseline. After calibration, we conducted two rounds of controlled testing in two of the pilot elevators.

Controlled Testing 1

System-wide Accessibility (SWA) coordinated with Operations to take two pilot elevators out-of-service for two hours each. We poured four different urine samples on the elevator floor to mimic real-life incidents, and had the cleaners perform their normal cleaning. We found that that higher concentration (i.e., smellier) urine and cleaning agents were detected more quickly.

Controlled Testing 2 / Test Run

We did a "test run" of the pilot processes (see below for an explanation of these processes) at two pilot elevators with all relevant stakeholders. This served as both a training session for them and a second controlled testing session. In this case, we poured urine into trays, instead of on the floor of the elevators since our focus was on running through protocols. We walked through data collection steps with Transit Ambassadors and cleaners; we showed Transit Ambassadors how to reset an offline sensor; and more. Though time consuming, this kind of detailed testing and training helped us overcome operational issues later.

Notably, the sensor detected urine more quickly and accurately when poured into a tray, than when poured on the floor. When poured into a tray, we got alerts in 1-5 minutes; when poured on the floor, we got alerts in 6-27 minutes. This reinforced to us the value of real-world testing, and the limitations of lab testing.

Sensor Monitoring

Past experience with internet-connected hardware pilots has taught us that it's important to learn about hardware resilience and uptime. And also that entrusting this to a vendor—for them to report on their own resilience and uptime *in real-time*—is a sub-optimal way to learn. We identified the sensor's operability and uptime as a risk (see "Pilot Risks" below). And so we developed our own sensor monitoring, logging a "heartbeat" from each sensor to our own data management platform, from which to receive notifications as soon as one went offline.

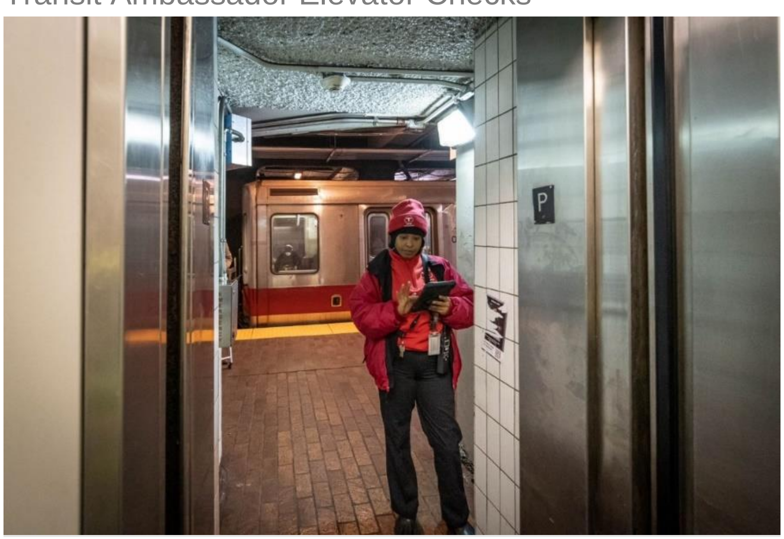
This proved to be very helpful: sensors did go offline, we got immediate email notifications from our monitoring system, and we worked with Transit Ambassadors to reset devices in response. Without this, not only would our response times have likely been much slower but we might not be able, at the end of the pilot, to know exactly how many offline incidents there were, and exactly how long they lasted.

How We Ran the Pilot

Existing Processes

To evaluate the effectiveness of the sensor, we needed to know whether each notification from the sensor was correct or not. And to do that, we depended on existing people managing existing processes in our stations.

Transit Ambassador Elevator Checks

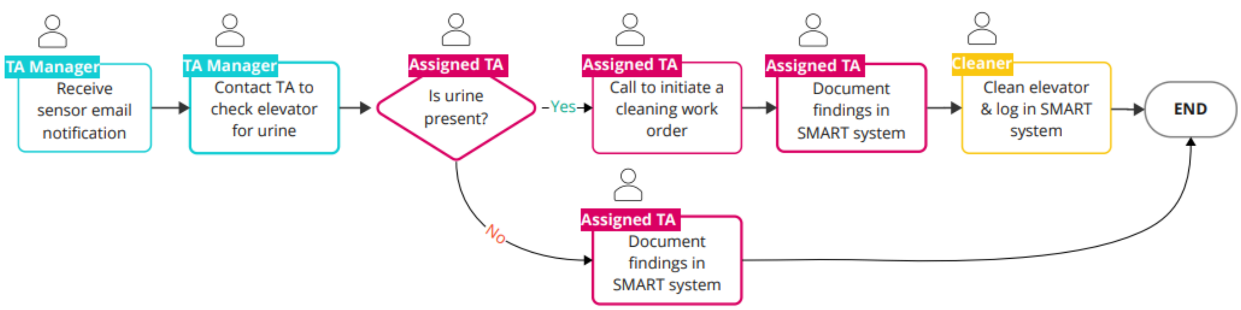


Transit Ambassadors wear bright red polo shirts, sweaters, or jackets with T logos and can be found at stations throughout our system. They help riders with services like buying tickets, navigating the system, and providing real-time travel information. They are also trained to inspect stations for cleanliness and safety. As noted above, the MBTA already had processes in place to have Transit Ambassadors conduct periodic elevator cleanliness checks. At Downtown Crossing, Park Street, and Chinatown—stations that have Transit Ambassadors on duty throughout the service day— Transit Ambassadors conduct a cleanliness check of each elevator every 30 minutes, and record their findings in a software application (called “SMART”) on their tablet. This is how we identified false negatives—instances when the sensor did not sent a notification, but a routine elevator check found urine nonetheless.

Cleaning Vendor Maintenance Requests

The MBTA has contracts with two vendors for station cleaning. We worked with the one whose coverage area includes most downtown stations. The cleaning vendor has cleaners located throughout the system that conduct routine cleaning rounds and respond to maintenance requests. They also log elevator cleanings in SMART app on their mobile devices but theirs is a separate instance of the app than the one used by Transit Ambassadors, with a separate back-end. Part of this vendor’s service level agreement with the MBTA is to clean an incident within one hour of notification.

Pilot Process



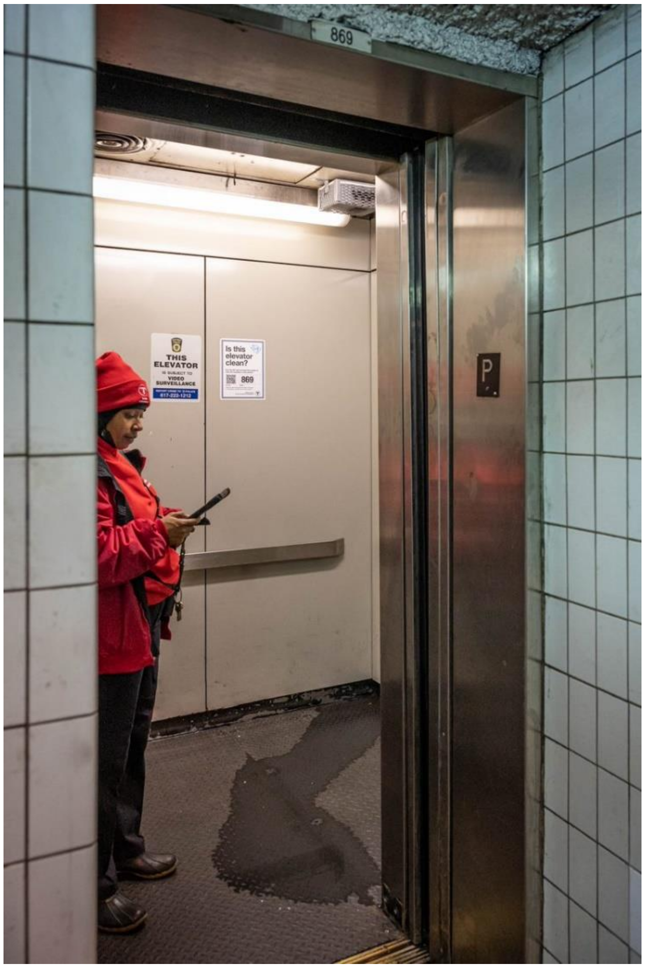
Flow diagram of the pilot process to verify true positives and false positives from urine detection sensor alerts

Verifying true positives and false positives

The process by which we evaluated the sensor’s effectiveness was very similar to the Transit Ambassador elevator checks described above. In order to verify true positives (the sensor sent an alert and urine was present) and false positives (the sensor sent an alert but no urine) from the sensor:

- A sensor email alert was sent to the Transit Ambassador Manager-on-Duty
- The Transit Ambassador Manager-on-Duty contacted the Transit Ambassador assigned to that station to check the elevator for urine
- The Transit Ambassador checked the elevator
- If there was urine found, the Transit Ambassador submitted a maintenance request for the urine to be cleaned.
- The Transit Ambassador updated the SMART system urine detection pilot form on their tablet with key information such as the elevator number, Yes Urine (true positive) or No

Urine (false positive), and whether any odors were present (to understand if a certain smell triggers false positives). *See Appendix D for the form*



A Transit Ambassador updating a tablet in an MBTA elevator with urine in it for the urine detection pilot

Identifying false negatives

We identified false negatives—i.e., cases in which someone had urinated in an elevator but the sensor failed to send a notification—by having a value added to Transit Ambassadors' regular elevator check form: "Unclean - urine."

Risks

Before the pilot, we identified what we thought the primary risks were to our objectives.

Data quality

To evaluate the sensor's accuracy, we had to know whether each alert it sent was a true positive or a false positive. And, as described above, that relied on a "golden dataset" which was generated by two different MBTA vendors in software that we don't control.

Mitigation: We wrote out clear process instructions with diagrams and vetted them with stakeholders. From these process instructions we created step-by-step job aides and performed the training ourselves directly with the staff that was collecting the data. We also monitored every sensor alert and SMART system submission ourselves, especially at the beginning of the pilot.

Not enough data to inform decision

We ran the pilot in elevators with the highest "unclean rates," according to the existing monitoring data. But because those data don't specify the sources of "uncleanliness," we didn't know if, or how often, people actually urinate in MBTA elevators. In other words, we didn't know whether the pilot would generate enough data—whether people would urinate in the four pilot elevators—sufficiently and frequently enough to generate a meaningful data set on sensor accuracy.

Mitigation: The contract was amended to include additional funds for a 3-month extension if needed. We later learned this would not be needed since there were plenty of urine incidents during the pilot. In fact, we picked an optimal time for the pilot, as the elevator unclean rate increased as the weather got colder (*see Appendix C*).

Sensor uptime

To detect urine, sensors need to be online and working. We didn't know how often a sensor might break, go offline, or get vandalized.

Mitigation: Remote monitoring was set-up to alert us immediately if the sensor went offline. A spare sensor was purchased and was available on deck if needed.

Data Used to Evaluate the Pilot

The sections above described the *processes* that we used to collect data. This section describes the actual data collected.

Sensor effectiveness

In order to assess sensor effectiveness, we used several data sources (examples below) to calculate two error rates:

1. False positive error rate
2. False negative error rate

We calculated the error rate by dividing the number of each type of error by the number of actual urine incidents. For example, if there were 10 urine incidents in Chinatown 922:

- False positive error rate: 200% = 20 false positives / 10 urine incidents
- False negative error rate 50% = 5 false negatives / 10 urine incidents

We counted two or more true positives or false negatives in the same elevator in the same hour since initial discovery or alert as one urine incident. This is based on the cleaning vendor service level agreement (SLA) to clean within one hour of notification.

Transit Ambassador Urine Detection Pilot Form

Below is a sample excerpt of the data generated by Transit Ambassadors after checking on a sensor alert. We exported these data from the SMART system every few days.

User	Time	Amount	Alert #	Zone	Status	MOD Time of Request	Odor	Response	Elevator #
TA Name	12/16/2022 23:31	1	679	Park St Red	No Urine Present	12/16/2022 23:30	No Smell Present	No Call Made	Park street 808
TA Name	12/16/2022 23:17	1	432	Chinatown South	Yes Urine Present	12/16/2022 23:17	Urine	Call Made	Chinatown 922
TA Name	12/16/2022 22:14	1	418	Chinatown South	Yes Urine Present	12/16/2022 22:14	Urine	Call Made	Chinatown 922
TA Name	12/16/2022 20:36	1	265	Downtown Crossing North	No Urine Present	12/16/2022 20:25	No Smell Present	No Call Made	Downtown crossing 891
TA Name	12/16/2022 16:29	1	366	Chinatown South	Yes Urine Present	12/16/2022 16:29	Urine	Call Made	Chinatown 922
TA Name	12/16/2022 15:25	1	108	Downtown Crossing North	No Urine Present	12/16/2022 15:24	No Smell Present	No Call Made	Downtown crossing 891
TA Name	12/16/2022 9:45	1	321	Chinatown South	Yes Urine Present	12/16/2022 9:42	No Smell Present	Call Made	Chinatown 922
TA Name	12/17/2022 14:18	1	288	Chinatown South	No Urine Present	12/17/2022 14:18	Urine	No Call Made	Chinatown 922
TA Name	12/17/2022 14:10	1	1873	Park West	Yes Urine Present	12/17/2022 14:04	Urine	Call Made	Park street 808
TA Name	12/17/2022 13:20	1	528	Chinatown South	No Urine Present	12/17/2022 13:19	Urine	No Call Made	Chinatown 922

Transit Ambassadors' Routine Elevator Check

As mentioned in the "Existing Processes" section above, we used the existing Transit Ambassador Elevator Check to identify false negatives. We had the vendor add a new value to the "Status" field, "Not Clean – Urine."

If there was a "Not Clean – Urine" status within one hour of a true positive, we didn't count it as a false negative. We also exported this from the SMART system every few days.

User	Time	Amount	Zone	Operable / Non-Operable	Status	Response	Notes	Elevator Unit ID #
TA Name	12/16/2022 23:23	2	Chinatown South	Operable	Not Clean - Urine	Cleaners-called	Urine inside	Chinatown 922
TA Name	12/16/2022 22:15	1	Chinatown South	Operable	Not Clean - Urine	No-call-made	Urine inside	Chinatown 922
TA Name	12/16/2022 20:56	1	Chinatown South	Operable	Not Clean - Urine	Cleaners-called	Clean	Chinatown 922
TA Name	12/16/2022 19:17	1	Chinatown South	Operable	Not Clean - Urine	No-call-made	Urine inside	Chinatown 922
TA Name	12/16/2022 18:47	2	Chinatown South	Operable	Not Clean - Urine	Cleaners-called	Urine inside	Chinatown 922
TA Name	12/16/2022 17:13	1	Chinatown South	Operable	Not Clean - Urine	No-call-made	Urine inside	Chinatown 922
TA Name	12/16/2022 16:31	1	Chinatown South	Operable	Not Clean - Urine	Cleaners-called	Urine inside	Chinatown 922
TA Name	12/16/2022 12:34	1	Chinatown South	Operable	Not Clean - Urine	Cleaners-called	South	Chinatown 922
TA Name	12/16/2022 12:21	1	Chinatown South	Operable	Not Clean - Urine	Cleaners-called	South	Chinatown 922

User	Time	Amount	Zone	Operable / Non-Operable	Status	Response	Notes	Elevator Unit ID #
TA Name	12/16/2022 11:58	1	Chinatown South	Operable	Not Clean - Urine	Cleaners-called	South	Chinatown 922

Sensor Vendor's Report

The vendor sent us a weekly report to verify the alerts sent by each sensor. To arrive at a unique list of alerts, we cross-referenced the vendor's report, the Transit Ambassadors outputs, and actual email alerts. This was *extremely laborious* but ultimately useful and necessary because of software and cellular issues.

SENT DATE (EDT)	LOCATION	SENSOR_NAME	UNIQUE ID (UID)	STATUS
12/16/2022 9:32	China 922	sdombta1ads0	U-00321	UrineDetected Detected
12/16/2022 16:26	China 922	sdombta1ads0	U-00366	UrineDetected Detected
12/16/2022 20:12	DTX 891	sdombta4ads0	U-00265	UrineDetected Detected
12/16/2022 21:52	China 922	sdombta1ads0	U-00418	UrineDetected Detected
12/16/2022 22:54	China 922	sdombta1ads0	U-00432	UrineDetected Detected
12/17/2022 1:15	China 922	sdombta1ads0	U-00466	UrineDetected Detected
12/17/2022 2:55	Park 808	sdombta3ads0	U-01843	UrineDetected Detected
12/17/2022 7:04	China 922	sdombta5ads0	U-00488	UrineDetected Detected
12/17/2022 10:03	China 922	sdombta1ads0	U-00505	UrineDetected Detected
12/17/2022 11:41	China 922	sdombta1ads0	U-00518	UrineDetected Detected

Sensor operational reliability

We monitored sensor uptime by logging a heartbeat from each sensor, every minute, to our data management platform. This allowed us to use simple queries to calculate uptime: a value of 60 in an hour represented 100% uptime that hour. The section highlighted in red in the example below shows an incident in which the sensor in Chinatown 922 went offline. We got emails every time a sensor's heartbeat fell below 50 in an hour.

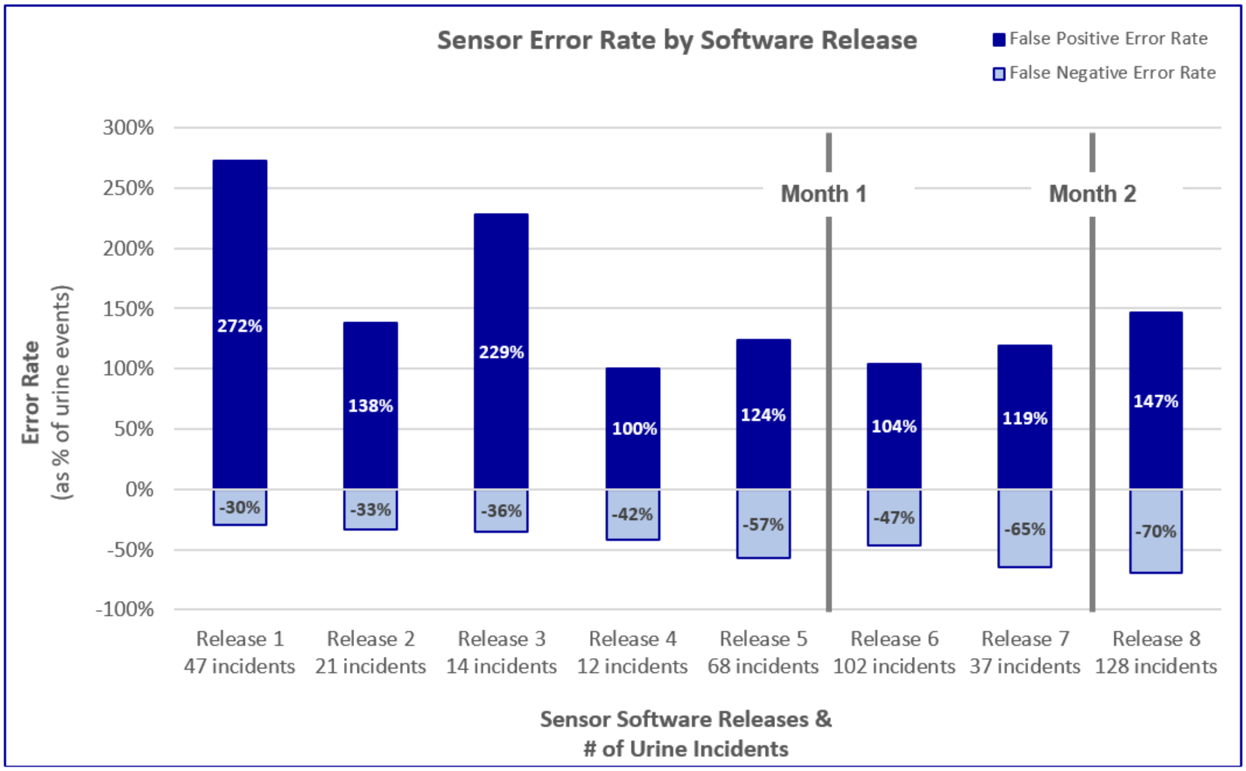
Date	Time	SEN-1 Chinatown 922	SEN-3 Park Street 808	SEN-4 Downtown Crossing 891	SEN-5 Downtown Crossing 869
12/10/2022	02:00:00.000+0000	60	60	60	60
12/10/2022	03:00:00.000+0000	60	60	60	60
12/10/2022	04:00:00.000+0000	60	60	60	59
12/10/2022	05:00:00.000+0000	60	60	60	60
12/10/2022	06:00:00.000+0000	60	60	60	60
12/10/2022	07:00:00.000+0000	41	58	60	60
12/10/2022	08:00:00.000+0000	1	60	60	60
12/10/2022	09:00:00.000+0000	1	60	60	60
12/10/2022	10:00:00.000+0000	1	59	60	60
12/10/2022	11:00:00.000+0000	1	60	60	60

What We Learned From the Pilot

Urine detection effectiveness was not reliable

The first and primary objective of the pilot was to determine how reliably the sensor detects urine. We found that the sensor did not reliably detect urine. Over the course of the pilot, the vendor pushed eight software updates to the sensors to try and improve the logic and thresholds within them, to improve accuracy. But these updates did not reliably improve, or even stabilize, accuracy. Both the false positive and false negative error rates varied significantly across elevators and time.

Software updates didn't improve, or stabilize, sensor effectiveness



Every time the sensor sent an alert, volatile organic compound levels over time were registered on the back-end, which the sensor vendor analyzed. When new patterns were identified, the vendor tried to refine the parameters for more accurate sensing through software updates, and pushed a new release to the sensors remotely.

Over time we generally found that software updates aimed at improving sensitivity (i.e., reducing false positives) worsened specificity (i.e., increased false negatives), with the exception of release 6. The sensor vendor was not able to return the sensor to earlier performance levels.

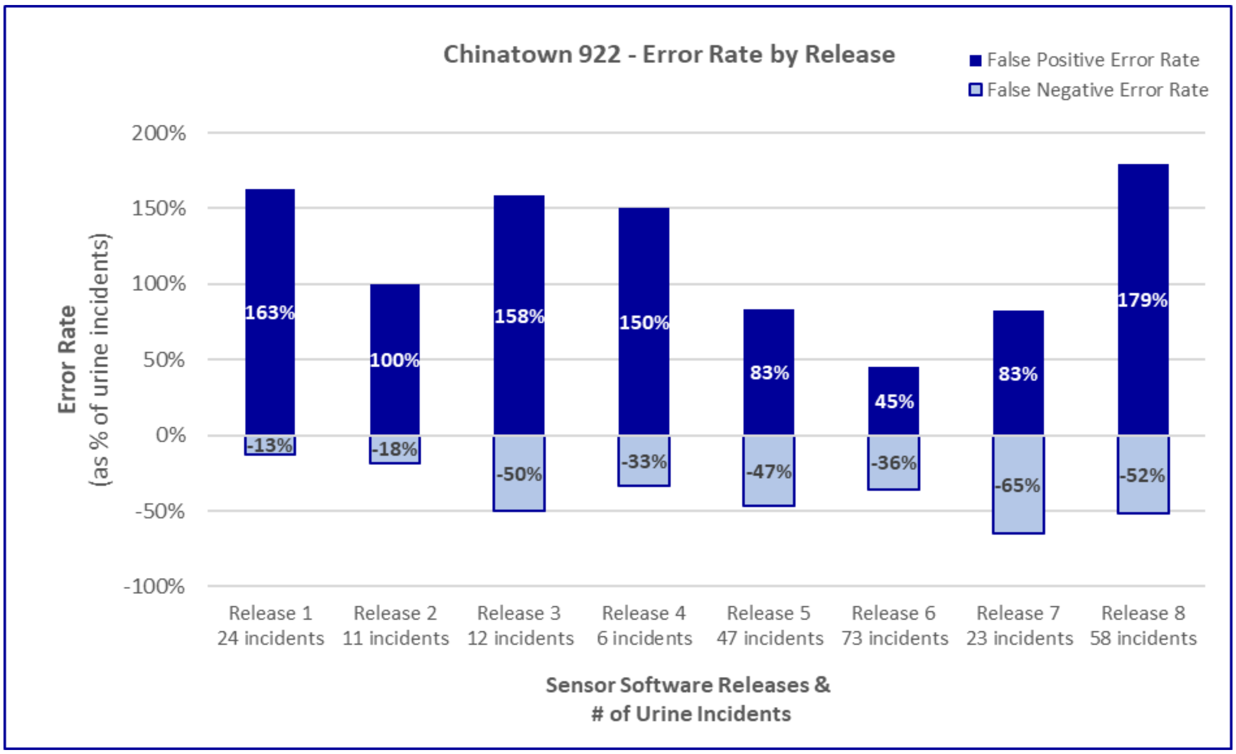
Sensor error rate varied across elevators and time

Sensor effectiveness varied a lot across elevators and time, as shown in the error rate charts for each elevator in *Appendix F*.

We learned that:

- Smoke (cigarette or marijuana) triggers false positives
- Mounting conditions affected sensor performance, e.g. Downtown Crossing 891 has a large cab and a high ceiling (at least a foot taller than the other three pilot elevators) and had the worst performance with the highest false negative error rate.
- Colder temperatures could have affected the sensors' sensitivity due to changes in air flow from the exhaust fan or heater
- People who smell strongly of urine, but didn't actually urinate in the elevator, triggers false positives. We gradually increased the ramp time before a sensor sent an alert to try and account for this, but it couldn't account for all instances. In one case at Park Street 808, an individual who was unhoused and smelled of urine, was encamped next to one of the pilot elevators, and generated a huge spike in false positives.
- Elevators get dirty from things like rail dust, which could have also impacted the sensors' effectiveness

The highest-accuracy location ran into operational issues



Chinatown 922 was, initially, the location with the best-performing sensor. We attributed this to the fact that the sensor had the most training data (i.e., the most urine incidents), and that its mounting conditions were optimal (small elevator, low ceiling, sensor next to the exhaust fan).

A Transit Ambassador Manager standing on a step stool in an elevator to hard reset a urine detection sensor

Unfortunately, that sensor's performance got worse after release 6—and worse after it went offline and needed several resets (see next section on sensor operability). Even after coming back online reliably, the vendor could not get the sensor back to its previous accuracy levels, and could not explain why setting software parameters to their prior levels wasn't sufficient.

We Couldn't Assess Cleaning Agent Detection

Assessing the sensor's ability to detect the presence of a cleaning agent in our elevators was the second objective of this pilot.

We worked with the MBTA's cleaning vendor to create a form (*Appendix E*) that they could use to validate sensor notifications. But it wasn't operationally feasible for them to include it in their daily workflows. So we did not collect any data against this objective during the pilot.

Sensor Operability Got Worse Over Time

Sensor uptime

The sensors remained online in the first month of the pilot. In the second, though, we began to see issues with them going offline. The table below summarizes those incidents, and the resulting uptime of each sensor. The vendor managed to bring three sensors back online with a remote reboot but the sensor in Chinatown 922 needed to be reset locally, by a Transit Ambassador Manager-on-Duty, seven times. The vendor attributed this series of incidents to "server issues" and couldn't tell us more.

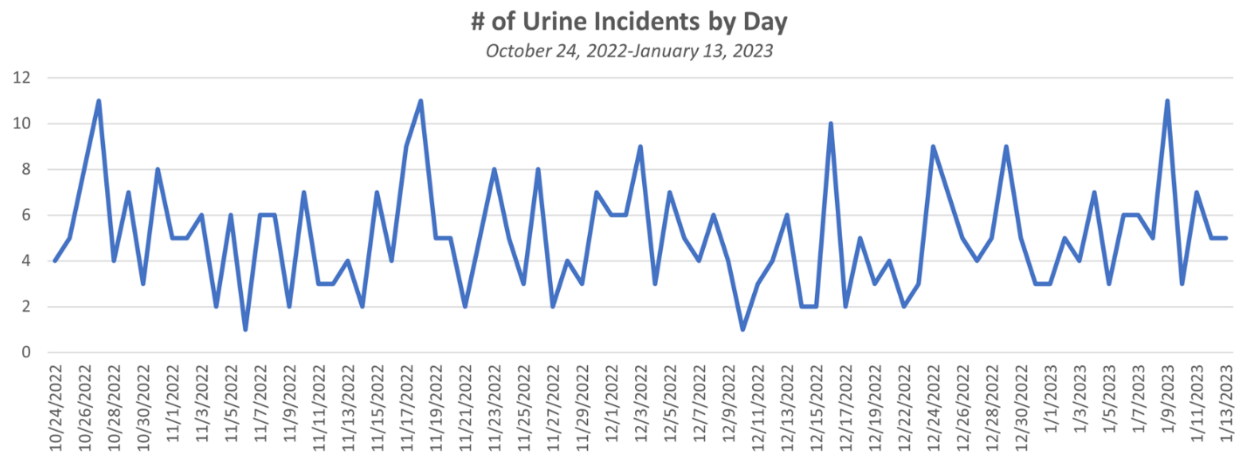
Elevator Sensor	# of Outages	Offline Duration Total (hours)	% Uptime
Chinatown 922	8 outages (7 hard resets) Multi-day outages • 12/10/22-12/12/22 • 12/26/22-12/27/22	83	95.78%
Downtown Crossing 869	3 outages (2 soft resets)	18	99.11%

Downtown Crossing 891	3 outages (2 soft resets)	18	99.08%
Park Street 808	3 outages (2 soft resets)	18	99.10%

Vandalism

There were no vandalism incidents during the pilot. One of the sensors in Downtown Crossing was completely exposed, not hidden or protected by a drop ceiling, and nothing happened to it during the pilot.

People Urinate in MBTA Elevators—a lot



In 12 weeks, there were 410 separate instances of people urinating in the four pilot elevators. Chinatown 922 accounted for more than half of all of these incidents.

Urine in Chinatown elevator 922

Recommendation

We cannot recommend that the MBTA continue, or expand, its use of this urine-detection sensor. It was not nearly as accurate as we'd hoped and its operability got worse over time.

The variety of real-world conditions—temperature, people camping in elevators, cigarette & marijuana smoke, smells on riders' clothing, etc.—make isolating actual urine, not just the smell of it, very difficult. So until or unless we learned of a dramatic improvement in the accuracy of this technology, we aren't likely to recommend pursuing this remote sensing approach, generally. Our pilot wasn't a laboratory to make this particular sensor better, so we decided to end it a bit early, having learned what we think could.

The MBTA still has a lot of work to do to make our elevators cleaner and more comfortable for riders.

Appendix

Appendix A – Sensor Specs

Plastic enclosure

- 21.5cm x 13.1cm x 9.5cm
- ~1.0 lbs sensor weight
- 3-D printed in Europe so further enclosure modifications add $ and time for shipping

Anti-vandalism metal enclosure

- 24cm x 15.2cm x 9.7cm
- Add ~2.0lbs to sensor weight, total ~3.0lbs
- Honeycomb heavy metal cage
- L-bracket “ears” are welded to the cage
- Side corners have padding inside to help secure sensor from elevator vibrations

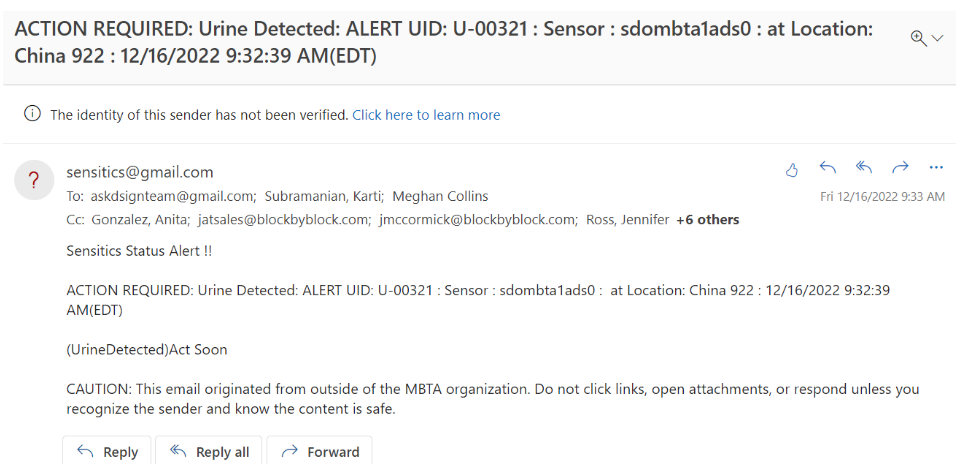
Mounting

- Two L-brackets are welded to the sides of the anti-vandalism metal cage
- The holes on the L-bracket will be the same size; can drill new holes or use washers if the hole size needs to be adjusted due to the type of elevator
- Location - the sensor must be mounted near the exhaust fan of the cab ceiling or on the edge of tight drop ceiling
- Position - Fan should always face the floor and vents should face the doors of the elevator

Cellular connectivity

- The sensor contains cellular components that connect to the T-Mobile 4G network, which allows it to transmit data and send alerts to email/mobile devices.

Appendix B – Sensor Alert for Urine Detection


ACTION REQUIRED: Urine Detected: ALERT UID: U-00321 : Sensor : sdombta1ads0 : at Location: China 922 : 12/16/2022 9:32:39 AM(EDT)

The identity of this sender has not been verified. Click here to learn more

sensitics@gmail.com
To: askdsignteam@gmail.com; Subramanian, Karti; Meghan Collins
Cc: Gonzalez, Anita; jatsales@blockbyblock.com; jmccormick@blockbyblock.com; Ross, Jennifer **+6 others**
Fri 12/16/2022 9:33 AM

Sensitics Status Alert !!

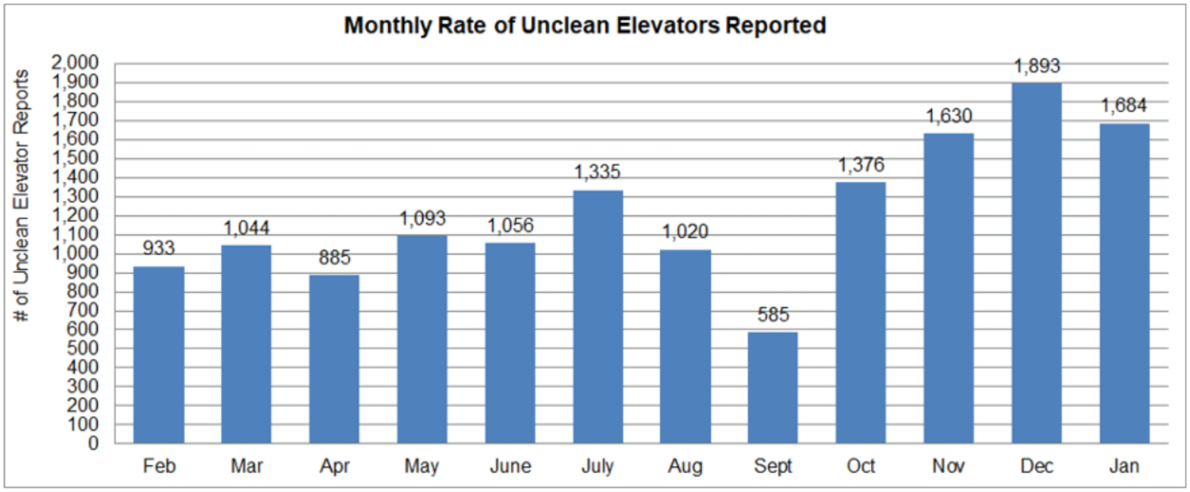
ACTION REQUIRED: Urine Detected: ALERT UID: U-00321 : Sensor : sdombta1ads0 : at Location: China 922 : 12/16/2022 9:32:39 AM(EDT)

(UrineDetected)Act Soon

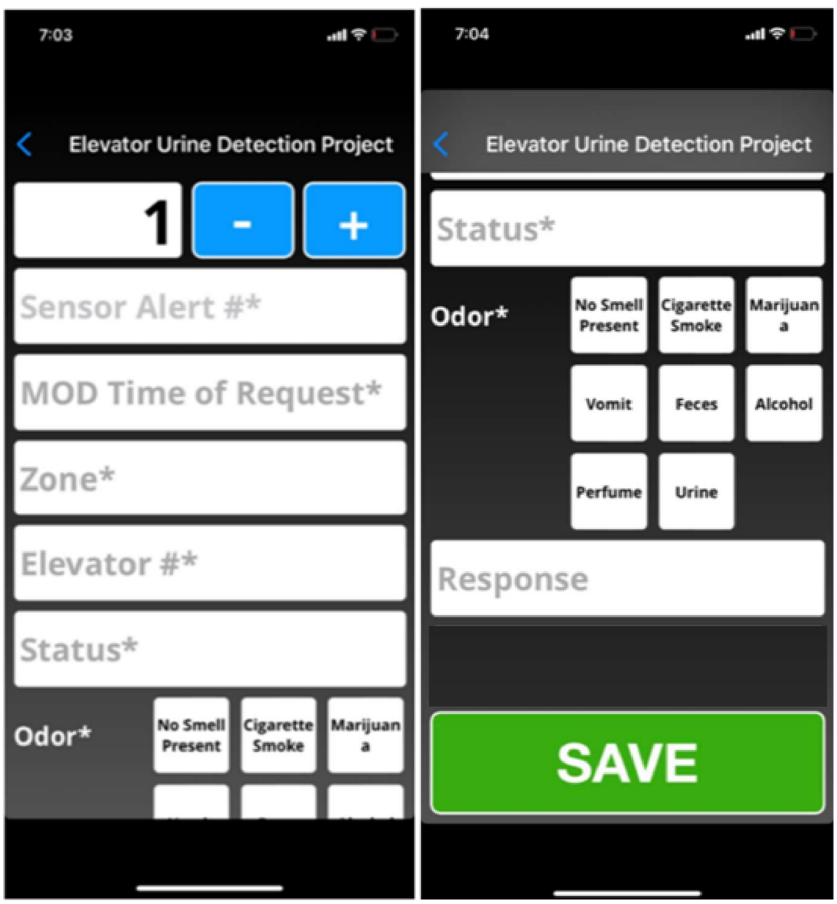
CAUTION: This email originated from outside of the MBTA organization. Do not click links, open attachments, or respond unless you recognize the sender and know the content is safe.

Reply | Reply all | Forward

Appendix C – Monthly Rate of Unclean Elevators from Elevator Checks

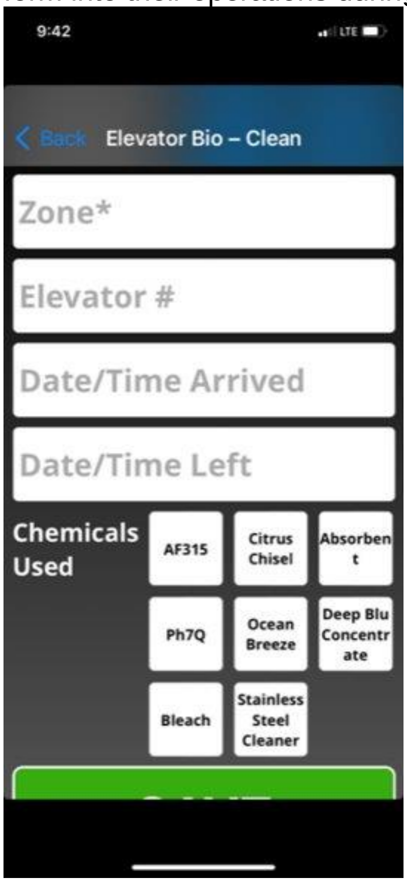


Appendix D – Elevator Urine Detection Project SMART form

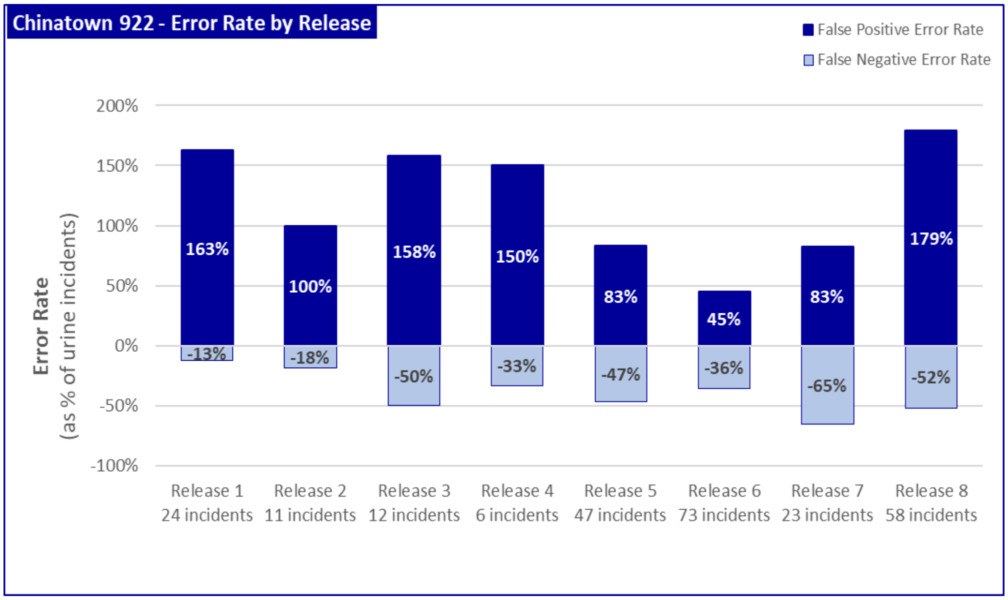


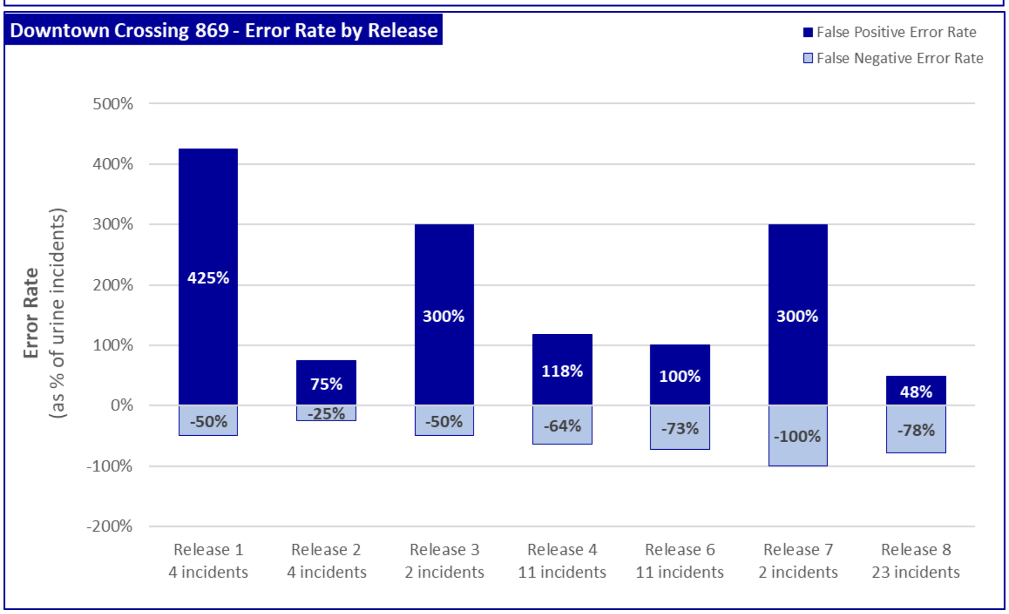
Appendix E – Cleaning Agent Detection SMART form

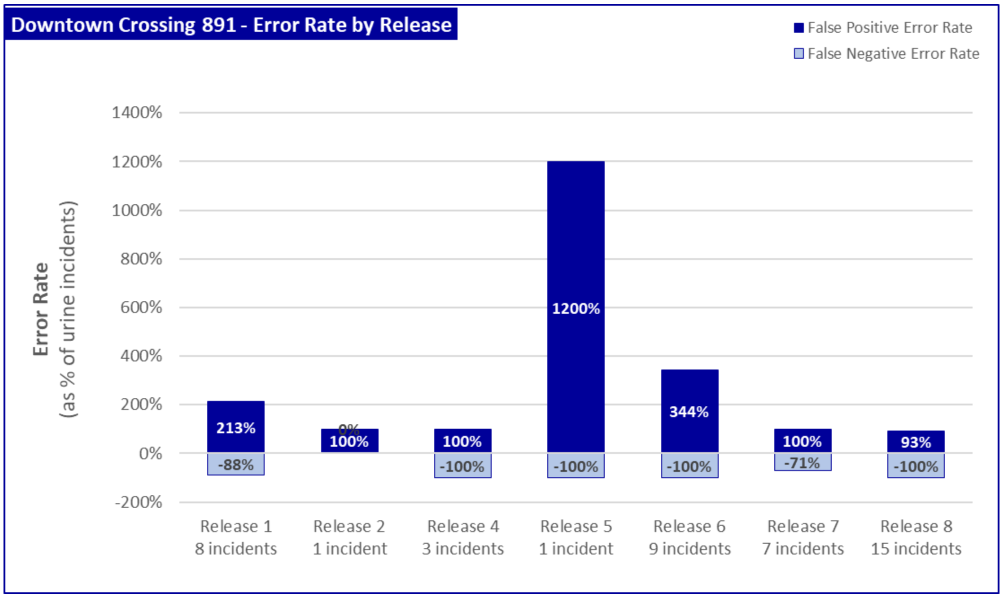
Cleaning agent form that was developed with the cleaning vendor and sensor vendor to cross-reference with cleaning agent detection alerts. The cleaning vendor was unable to incorporate this form into their operations during the pilot.

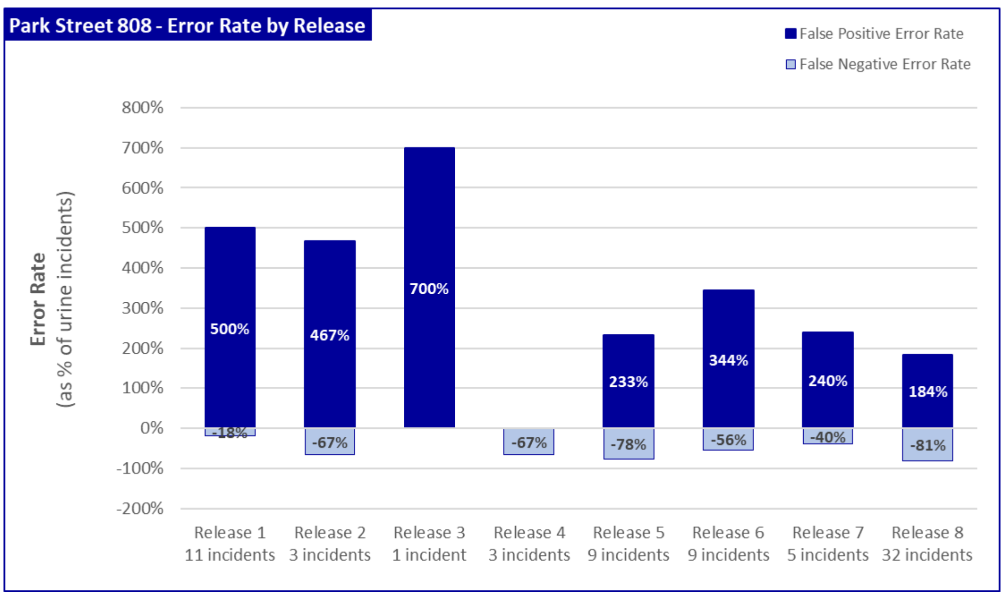


Appendix F – Pilot Elevator Chart – Error Rate by Software Release









Appendix G – Media

- Associated Press
- Boston Herald
- The Late Show with Stephen Colbert