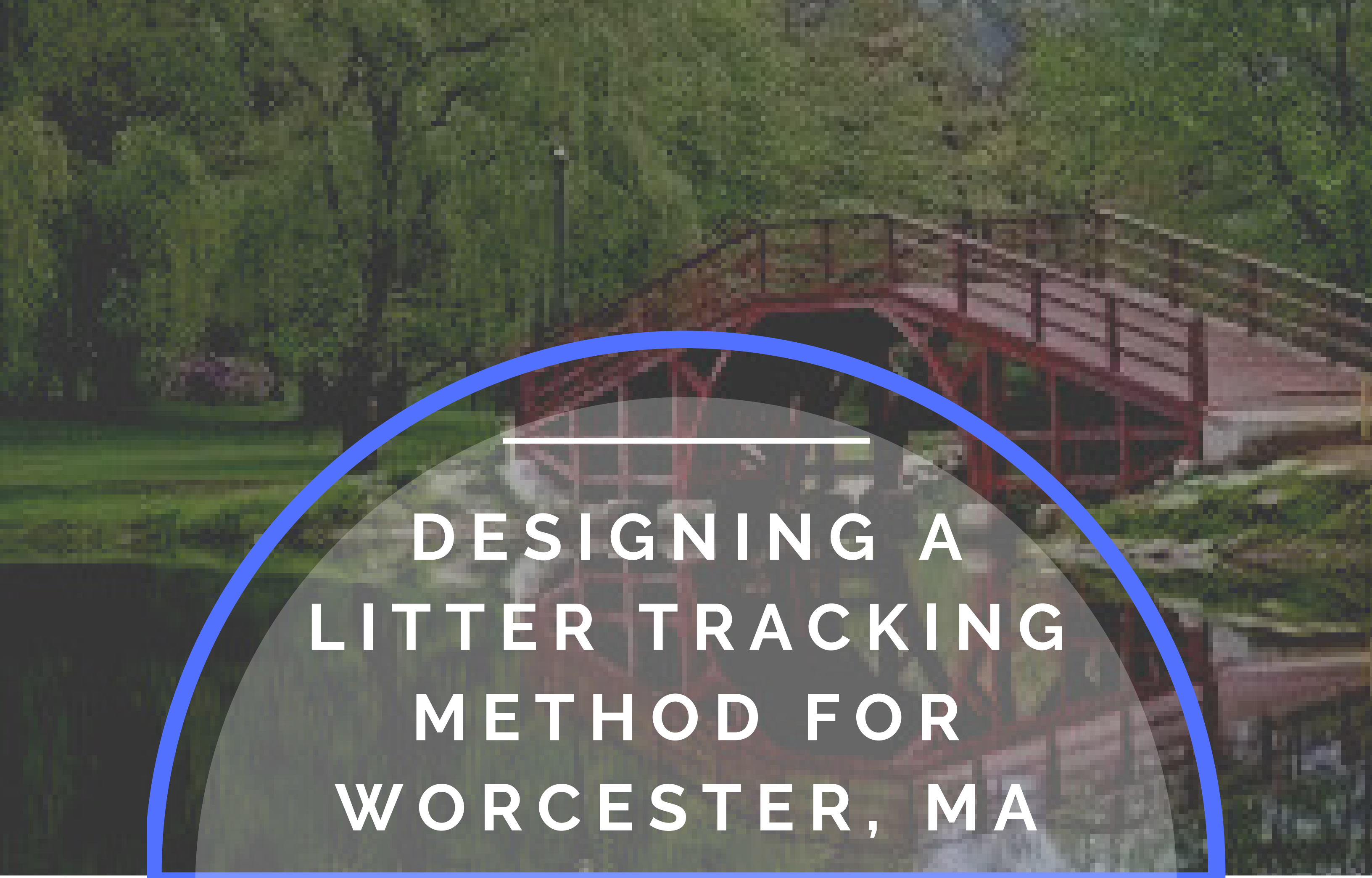

DESIGNING A LITTER TRACKING METHOD FOR WORCESTER, MA

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Date:
May 13, 2021

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ABSTRACT

In Worcester parks, litter is a growing problem. We worked in collaboration with Jacquelyn Burmeister, Senior Environmental Analyst with the Worcester Department of Public Works (DPW) to develop a litter tracking system that would help assess the amount of litter in parks to determine if litter mitigation efforts are effective. To do this we conducted interviews, field research, and a pilot study of different litter tracking methods. After analyzing our data, we developed both a mobile survey and an accompanying ranking table and guidelines. DPW employees will be able to rate parks using 5 different categories, catalogue litter types, and assess the impact of trash and the clean up effort over time. Finally, we developed numerous recommendations to reduce the amount of litter in Worcester.

ACKNOWLEDGEMENTS

The parks Interactive Qualifying Project (IQP) team would like to thank our project advisors Corey Dehner, Gillian Smith and Joseph Doiron for their support and guidance throughout this semester.

Furthermore we would like to thank our sponsor, Jacquelyn Burmeister, senior analyst of the Worcester Department of Public Works for sharing her knowledge and insight as we navigated this project. Her expertise helped us to create a thorough and efficient deliverable.

Finally, we would like to thank all of our interview participants for their time and contribution. Their assistance allowed the team to look closely into issues surrounding waste management in different locations. Their recommendations helped guide our team to explore new ideas and added depth to our research.

ADDRESSING LITTER IN WORCESTER PARKS

Plastic pollution from litter is a global problem. There is an estimated 12 megatons of plastic that makes it into the environment from falling off trucks or out of trash cans (Boucher, 2019). This is called leakage. Figure 1 shows that this amount of trash leaked into the environment is only 3% of the annual amount produced and mainly comes from coastal mismanaged waste. Plastic is everywhere and builds up in locations such as the Great Pacific Garbage Patch. The Great Pacific Garbage Patch is a place in the Pacific Ocean where litter builds up due to currents. It is an example of the extent of harm caused by plastic pollution that gets into oceans. Plastic pollution is particularly problematic because plastic does not break down, it just gets ground into smaller pieces. These smaller pieces then make it into the food chain. Litter is also a common problem in urban environments that continues to grow and cities across the nation are struggling to find a solution (Boucher, 2019).

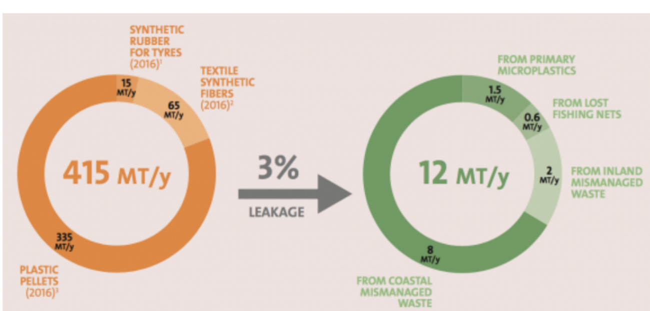


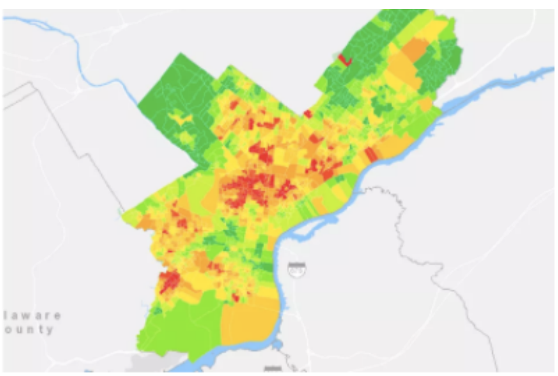
Figure 1: A breakdown of the most common types of plastics on the left, how much of those plastics leak into the environment, and a breakdown of where the leaked plastic comes from on the right .

Figure 2: An image of part of the Great Pacific Garbage Patch.

TRACKING AND MANAGEMENT RESOURCES

Current methods for cataloging locations of high litter density use manual data gathering and entry, which is slow and tedious. For example, the city of Salinas, California used an observation method where employees would visit sites around the city 3-6 times a year and log what they saw using the Onland Visual Trash Assessment field protocol and produce a heat map of litter in the city (Conley et al., 2019). A project conducted by Conley and his team improved on the existing method by introducing a system that continuously integrated the data gathered from the field resulting in faster identification of litter hot spots in the city to improve waste management. The resulting heat map showed the volume of pollution in specific geographical areas which provided easily identifiable places for city planners to start work on trash removal.

An example of a heat map from a similar program in Philadelphia, PA is shown below in figure 3. Heat maps are limited by the size of the region being observed. Regions are defined by the researchers and represent all of the land included in a single data entry. They can cover districts or neighborhoods depending on the resolution of the map. Therefore the ranking on a heat map is a guideline for the overall condition within a region. Rankings based on districts are more generalized than ones based on neighborhoods (Conley et al., 2019). Continuous integration of new data is part of many new technologies for tracking and managing litter around cities.



Screenshot via Litter Index Map

Figure 3: Map of litter density in Philadelphia, PA created by surveyors using a ranking matrix

Given the time commitment required to collect and log data manually, researchers have developed tools that simplify the cataloging of high density litter locations. Smart devices that utilize Artificial Intelligence (AI) and programming can help make common waste management devices like trash bins and street sweepers more efficient.

Smart bins, smart sweepers and netting systems are examples of the technology that can collect data over time. A smart bin can provide real time data about what kind of trash it is collecting and the quantity, allowing employees to work more efficiently. The company Big Belly offers an example of these smart devices shown in figure 5. These BigBelly bins are visible in many urban cities such as Boston and New York City. Boston has 543 BigBelly units all geotagged throughout the city and currently in use (Big Belly et al., 2021).

Companies have developed other technologies for mitigation of litter in waterways such as netting systems placed on the outflow pipes of waterways and sewer systems. These nets also can be used to record data on the volume at which they hold as well as how quickly they fill up. The quality of the litter may also be looked at to see what is filling up the majority of the nets and can then be used to look into ways to reduce the use and discarding of said materials. This data can be used to identify blue space "hotspots" or areas with the quickest volume fill up. Figure 7 shows a comparison of these methods.

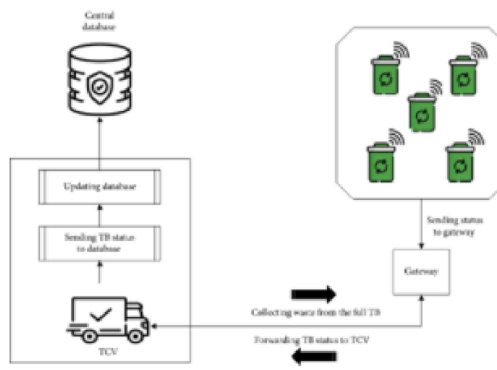


Figure 4: Diagram depicting the stages the stages of waste transport and how it is improved with the smart bins (Image Credit: Aniqa et al., 2020)

Figure 5: An Image of a Big Belly Receptacle (Image credit: Big Belly et al., 2021)

Figure 6: StormX Netting Trash Trap in use (Image Credit: StormX, 2020)

Like these technologies, another method that can be used to collect data when there are limited employees is citizen science. Citizen science is data collection or data monitoring performed by nonprofessional volunteers. Teams conducting research projects have collaborated with inspired volunteers to produce meaningful data especially in the environmental sciences (Kosmala 2016). The data collected by citizen scientists is then given to professional scientists to analyze. This data comes in many forms. Subjective tasks such as numeric estimations or broad categorization, are not well suited for citizen science. Additionally tasks that require more background knowledge such as identifying uncommon species may present challenges for citizen scientists and affect the data quality. Collecting metadata from the volunteers is one way to overcome some of the variability. Metadata includes information about the conditions which may influence the volunteer such as the weather, temperature, and environment when the sample was collected, the time of capture, and the tool or device used. The metadata can be used to statistically decrease bias and to calibrate the results. Methods for calibrating data may include targeted replication such as mixing professionally categorized samples into the volunteers data pool to assess volunteer performance or comparing the classification results between researchers and volunteers on fixed characteristics (Kosmala, 2016).

Physical data such as photographs or sample specimens can be easily reviewed by multiple people. Therefore, data that can be collected by volunteers, using tools such as their smartphone and then verified by others, have the potential for fewer data anomalies (Kosmala 2016). Photographs of litter can be used to easily demonstrate various degrees of litter density in different environments and litter guides can improve communication about classification. These photos provide a concrete way to quantify the conditions that are preserved in the snapshot

Technology	Cost	Efficiency	Uses
LidBot-Smart Bin (Big Belly)	$120 + $3/mo. subscription fee	• Low cost • Easy installation	• Notifications when full • Automated reports
Smart Street Sweeper	built into budget	• Reduced litter accumulation on streets • Efficient route creation in high litter areas	• Litter classification • Automated reports
StormX Netting Trash Trap	12" net = $467.88/ unit	• Collects waste as small as 5 mm • Nets can range in sizes for different outlets	• Collects stormwater runoff litter • Collects organic matter to improve water quality

Figure 7: Comparison of trash management technologies.

and provide a powerful message to raise awareness (Earll et al., 2000). The rising popularity of smartphones and their high quality cameras have yielded a surge in citizen science applications. These apps allow citizens to play a role in up-and-coming research by submitting data through images or data entry. Smartphones with location services can also record the date, time, and coordinates of each submission which makes it an efficient and organized way to sort large volumes of data. Figure 8 below illustrates the variety and utility of citizen science smartphone or web-based applications (Citizen Pothole Reporting, 2014).

STATE OF LITTER MANAGEMENT IN WORCESTER

Worcester is the second largest city in Massachusetts and has been working hard to remove litter from city streets. To keep the city clean, the Worcester Department of Public Works (DPW) provides weekly trash and recycling collection as well as park maintenance. The park maintenance is a massive issue since Worcester contains close to 500 acres of designated recreational parks marked on the City of Worcester city parks map (Discover Central Mass, 2020). To monitor and manage this large amount of land would take many work hours, which DPW employees do not have the resources for. The Worcester DPW has

Type	User base	Expertise Required	Method	Impact
Residential app for reporting local problems	-Limited to residents of corresponding location Ex: -Portland, Oregon -Boston, MA -San Antonio, TX	-Must have smartphone that can support the app	-Taking pictures -Submitting forms -Mobile access	-Report problems to city government in an efficiently -Improves communication between government and citizens
Organization based apps Ex: Debris Tracker	Nationally Used	-Must have smartphone with data to connect to the app	-Taking pictures -Logging categorized data	-Generates public information - Single platform for multiple studies
Website Ex: Zooniverse	Internationally used	-Must be able to follow procedures outlined for the project may include: -Sorting -Transcribing -Counting	-Researchers upload data and create a public project -Provides training to volunteers -Volunteers manually categorize data	-Delegates tasks to volunteers -Has a system of data verification -Updates volunteers on their impact and project milestones
Mapping Example: Picture Post	Nationally Used	-Portable camera that can upload images to the website such as a smartphone	-A wooden post is placed in an area of interest -Anyone is allowed to take pictures using the post and submit them to the map -Photos are viewable through an interactive map	-Organizes data submissions from different research goals geographically -Uniform method for all locations

Figure 8: Table summarizing different methods for collecting citizen science data

implemented volunteer based annual clean ups, environmental citizen science, and has a mapping feature for citizens to report litter around the city through the Keep Worcester Clean Program. Currently these efforts have been done as individual projects and there is no overarching method to assess the extent of Worcester's litter problem. Integrating different sources of information would provide the Worcester DPW with diverse data points on the amount and type of litter in Worcester's blue and green spaces. This information needs to be organized to inform further litter mitigation plans. Therefore, developing a procedure to categorize and quantify types of trash in an area would provide a solid metric to judge the efficacy of litter prevention practices. The goal for this project was to work with the Worcester DPW to design a method of tracking and monitoring litter that can be easily implemented to enable staff and volunteers to begin restoring the blue and green spaces in Worcester.

METHODOLOGY: DESIGNING A LITTER TRACKING PROGRAM

The main goal of this project was to devise an easily implemented method of monitoring and tracking litter to restore blue and green spaces in Worcester, Massachusetts. Blue and green spaces refer to public natural areas that have waterways (blue) or trees, grass, flowers, etc. (green). Research has shown that education alone is not enough to curb littering behavior (Soares et al., 2021). Furthermore, modifications in the environment, such as placement of trash cans and community feedback, have been influential in preventing littering behavior (Portman, Schultz, 2020, 1999). Accordingly, Jacquelyn Burmeister, senior environmental analyst for the Worcester Department of Public Works and Parks, Lakes, and Ponds Program, wants to track the amount of litter within the city as a first step toward decreasing it and improving the ecological condition of Worcester's parks.

Objective 1: Assessment: Identified current Worcester litter tracking and clean up programs

To begin the project, our first step was to learn what methods and tools were being used within Worcester. We started by interviewing our sponsor Ms. Burmeister to get a better understanding of what she wanted from this project and if she had any recommendations for people to interview. From there we used snowball interviews to talk with seven city officials and two representatives from the Regional Environmental Council (REC) Worcester. We interviewed a variety of people to identify the current work addressing litter and different opinions on what still needed to be done to mitigate the issue.

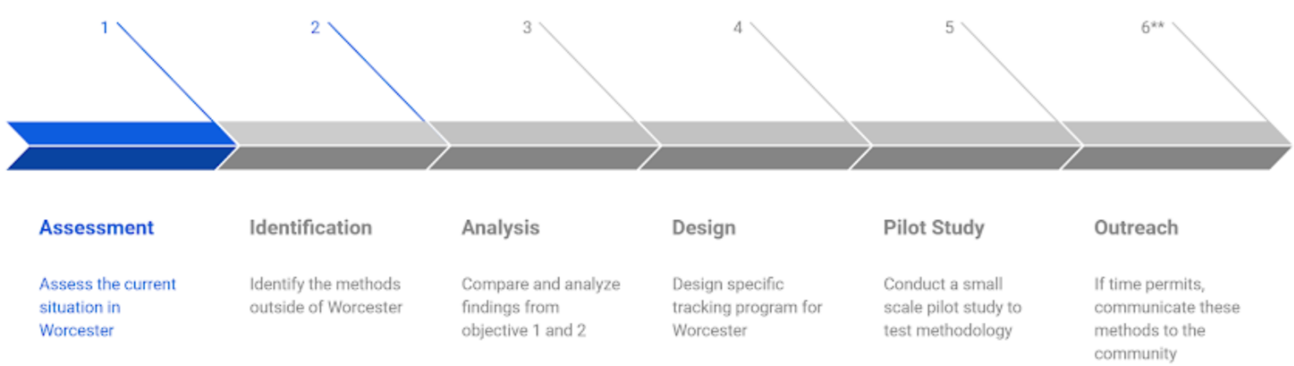


Figure 9: Flowchart of objectives

Objective 2: Identification: Identified methods of litter tracking from places outside Worcester

We looked outside of Worcester for examples of litter tracking because we wanted to have a variety of tracking methods to look at and be able to compare the methods used and places implemented with Worcester. We interviewed people charged with implementing the litter tracking programs in order to gain their insight on the effectiveness of the program.

Objective 3: Analysis: Comparatively analyzed tracking methods

We organized findings from the Assessment and Identification steps using common themes that appeared in our assessment. For example, we recorded information such as the resources they had available, the area covered, and the volume of litter collected. For the entire analysis, see the Parks and City Data Table in Appendix J of our supplemental material. We analyzed this information using a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis. We used a SWOT analysis because it organized the data in four distinct categories that made comparative analysis straightforward. Internal attributes of the method's data collection system were organized under strengths and weaknesses while the method's implementation or external attributes were categorized under opportunities and threats. We put together a presentation of the analysis for Ms. Burmeister in an attribute table.

Objective 4: Design: Devised a custom litter tracking program for Worcester

We presented our SWOT analysis findings and attribute table to Ms. Burmeister and shared our thoughts on how the project could move forward. We discussed ways of adapting the methods from the Analysis step to fit Worcester. The goal of the presentation was to leave with initial ideas for the project such as aspects chosen by our sponsor to incorporate into a new method. We took these ideas and filled them out with details such as how litter was logged, who did the data gathering, etc. While the initial ideas were being filled out into full methods, interviews with DPW employees were conducted in order to help identify implementation strategies, or means of effective operation, that would be effective in Worcester. We took the Worcester specific litter tracking methods and the implementation strategies learned from the DPW employees to make litter tracking programs. We followed an iterative design process to devise a custom program for Worcester while incorporating feedback from Ms. Burmeister and volunteers that helped test the program.

Objective 5: Pilot Study: Effectiveness of litter tracking program determined from a small scale pilot study

Once the methods identified in previous steps were adapted, the methods were tested to determine their effectiveness. Over the course of a week, the team tried out the method at Coes Pond to gain first hand experience using the methods for litter tracking. We used that experience to revise the procedure. Next, we conducted a pilot study in order to evaluate the clarity and accessibility of the directions, tools, and expectations for new users.

The pilot study group consisted of our team attempting to use the method under participant observation at various parks around Worcester including Bell Pond, Elm Park, East Park, Indian Lake, and Coes Pond. The findings of the pilot study were analyzed and compared with the results the IQP team gathered from our initial trial. From these results, the data collection methodology was tweaked to improve the user experience and quality of data collected. These adjustments led to more effective cleanup and trash tracking in Worcester. This objective was limited by the small sample of size of volunteers which may not have been representative of the wider Worcester community.

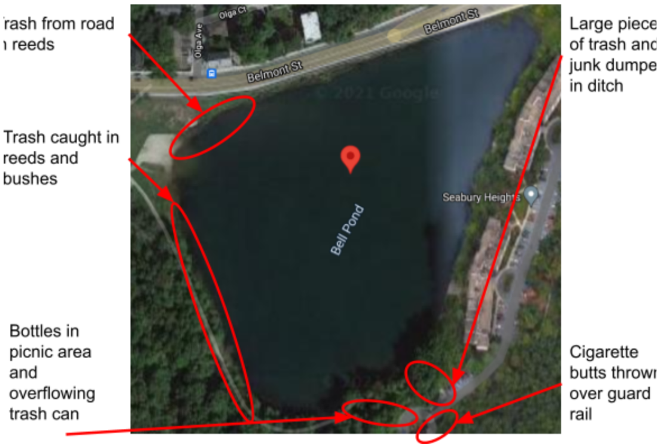


Figure 10: Aerial view of Bell Pond displaying field observations (Image credit:google maps)

WORCESTER, MA PUBLIC PARKS: OBSERVATIONS AND FINDINGS

Worcester has 61 parks which are managed by the Worcester Department of Public Works (DPW). These parks consist of 1300 acres of green and blue spaces throughout Worcester. The DPW manages the city's trash and recycling programs, water quality, and parks but has a limited staff and available resources to properly control and track litter in these spaces. As Worcester currently lacks a litter tracking program, the goal of this project was to create a methodology and implementation plan for tracking litter in the blue and green spaces of Worcester. Our sponsor, senior environmental analyst, Jacquelyn Burmeister works closely with public parks in Worcester to provide high quality green and blue spaces for city residents. She envisioned a tool to track the amount of litter in parks to assess if mitigation techniques are successful. We learned from interviewing Ms. Burmeister, that the ideal tool needed to: (i) be able to depict change over time to determine if litter mitigation efforts are successful, (ii) be able to be carried out by her small team to provide quantitative data, (iii) be straightforward, efficient and able to be incorporated into their routine park visits, and (iv) be used for public outreach to raise awareness. Through interviews, field observations, and online research we developed and recommended a method involving trained DPW employees for monitoring and tracking litter. The deliverables include a mobile survey with a ranking table customized for Worcester public parks, guidelines for filling out the survey, a recorded presentation that walks through rating 4 parks in Worcester, and recommendations for implementing the tracking methods. We discuss our specific findings in conjunction with the associated deliverables and recommendations in the sections below.

COMPONENTS OF WORCESTER PARKS LITTER TRACKING METHOD

We created a litter tracking method that can be applied effectively within Worcester parks. The method consists of a two part mobile survey. The first part uses a ranking system that will be used for park assessments and the second part consists of picture submissions, short response notes and multiple choice questions. In this section, we describe how we determined the best method for park evaluation and its implementation through research and a pilot study.

NUMERIC RANKING SYSTEM

We found that a numerical ranking system is an efficient method to measure changes in park conditions. During our background research, we found that Bamberg County, SC and Philadelphia, PA use a litter tracking index to track litter around their county and city respectively. These ranking scores make it easy for residents to understand how clean their parks are. The ranking system is also efficient for Worcester surveyors, because they can make one pass of a park and jot down a handful of numbers with short additional descriptions for greater clarity in a short time. The numbers can then be compiled into a single score that quickly and coherently conveys the state of litter in a park to DPW employees. These scores are calculated with the formula ((∑Ranks)/25)*10. The total score is converted to a number between 1 and 10 for easier conceptualization. Parks with lower scores are cleaner than parks with higher scores. All scores for each park at a given time are averaged to create the overall park ranking. It should be noted that because the minimum total score is a 5 out of 25, the lowest possible ranking is a 2 out of 10. The DPW can use these rankings to track the changes in a given park over time to monitor the success of mitigation efforts.

IMAGE SUBMISSION

We found that adding image submissions to the tracking form allows surveyors to collect more objective data points that can be reviewed by other DPW employees for accuracy. During interviews with City Councilors and department heads within Worcester government such as the DPW commissioner, Jay Fink. Many of them brought up the idea of photo submissions when asked what they thought should be included in a litter tracking app. Councilor Wally noted he takes pictures of litter on corporate property and posts it on Twitter. The corporation tagged usually takes swift action to remove the litter. The director of the office of urban innovation, Eric Batista suggested before and after images of an area when doing a clean up. These types of comparison pictures demonstrate the abrupt reduction in litter. In the case of having picture submissions in the tracking form, they can be used to demonstrate the reduction of litter in a location over time. Additionally, a surveyor that is having trouble ranking a specific site can get the input of other surveyors without them having to come to the park by taking a picture.

Overall Conditions	Negligible	Mild	Moderate	Severe	Critical
Clean Up Effort	No clean up required or litter can be removed easily during assessment	Litter can be collected by a single person during a short routine visit	Litter could be cleaned up by a small team of 1 or 2 people in around 1 hour	Litter could be cleaned up by a team of 2 or 3 people in a few hours	Litter clean up would require a large team of 4 or more people and/or heavy machinery
At a glance	Litter is not noticeable upon park entry	Litter is somewhat noticeable upon park entry	Litter is noticeable upon park entry	Litter is very noticeable upon park entry	Litter is very noticeable from outside park
Safety	The site has no potentially dangerous litter and it can be removed without any safety concerns	The site contains a few items that can be removed with caution such as unbroken glass objects	The site contains some potentially dangerous items such as large glass shards or cans with sharp edges and requires gloves for safe handling and removal	The site contains many items that can be dangerous to clean up crews and require gloves for safe handling such as small glass shards	The site contains dangerous items such as, needles and other biohazardous items that require safety equipment for safe handling and removal
Litter density/ Distribution	None	Small clusters and/or lightly scattered	Medium clusters throughout and/or moderately scattered	Large clusters and/or heavily scattered throughout	High volume of litter throughout entire area
Impact/ Functionality	No impact/effect	Affects aesthetics but not functionality	Majorly affects aesthetics and mildly affects functionality	Impedes walkways and/or use of space	Prevents access to certain areas

Table 1: Ranking system table used to assign rankings to parks in various categories

ADDITIONAL NOTES AND OBSERVATIONS

We found that adding notes for specific site conditions and observations allowed surveyors to record important features that may not have been covered by the ranking table or image submissions. The ranking table only covers the presence and distribution of litter itself and pictures take time to analyze for information other than the main subject. Additionally, to cover all the conditions at each site would take numerous pictures. To combat this problem, we added a section with short answers and checkboxes. There is a checkbox table for classification of the types of litter, another table to rank the major environmental hazards that clean up crews would come across, and short answers for presence of litter in reeds/water and extra site notes not specified.

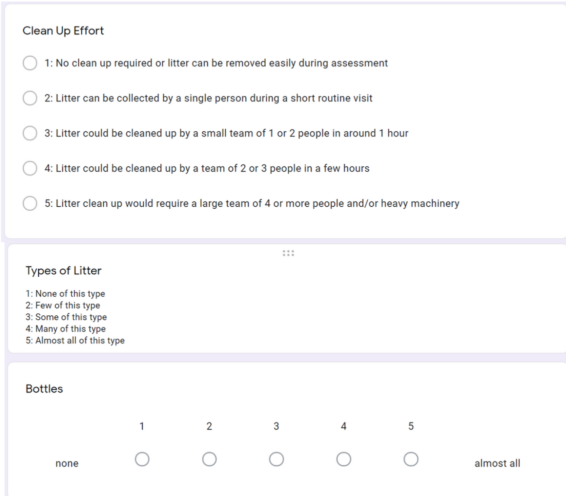
MOBILE SURVEY PLATFORM

We found that using a mobile survey platform makes the survey easily accessible to employees. The most common type of phone around is a smartphone. Therefore, having the survey accessible by a smartphone would require no extra equipment to be brought to the site being surveyed. As shown in figure 11 below, Google forms has user friendly question answer entry systems and is compatible with mobile devices, making it a great candidate for this survey. The results of the survey can also automatically be sent to a Google sheet that can be setup to reduce the amount of time spent analysing each entry. Many of the Worcester representatives we interviewed said ease of use would be important for a litter tracking method using mobile phones. We found through testing different versions of the form that having around five multiple choice options was ideal to get enough data while minimizing scrolling.

Table Legend	
Color	Meaning
✓	Meets criteria
X	Does not meet criteria
🔍	Requires further research

Method	Time Efficient	Photo Submissions	Ranking System	Citizen science friendly	Quantitative	Mapping feature	Needs a platform
Philadelphia Litter Index: Interactive map	✓	🔍	✓	X	X	✓	✓
Pothole.info: App	✓	✓	X	✓	🔍	🔍	✓
Debris Tracker: App	X	X	X	✓	✓	X	✓
Picture Post: Photo submission	🔍	✓	X	✓	✓	✓	X
Rubbish.love: app	X	✓	X	✓	✓	✓	✓
Bamberg County Litter Index	X	X	✓	X	✓	✓	X
Lafayette, LA: app	X	✓	X	✓	✓	✓	✓

Table 2: Tracking Method Attribute Table summarizing the SWOT analysis used for comparison of methods. (green indicates presence of a quality, red indicates lack of a quality, blue indicates a quality that could be looked into being added to our method)


Clean Up Effort

- 1: No clean up required or litter can be removed easily during assessment
- 2: Litter can be collected by a single person during a short routine visit
- 3: Litter could be cleaned up by a small team of 1 or 2 people in around 1 hour
- 4: Litter could be cleaned up by a team of 2 or 3 people in a few hours
- 5: Litter clean up would require a large team of 4 or more people and/or heavy machinery

Types of Litter

1: None of this type
2: Few of this type
3: Some of this type
4: Many of this type
5: Almost all of this type

Bottles

	1	2	3	4	5	
none	○	○	○	○	○	almost all

Figure 11: An excerpt from the google form displaying the format used to apply the ranking table and the format used to record information about the type of litter present

MULTIPLE CHOICE AND SHORT ANSWER RESPONSES

We found that multiple choice and short answer responses were the easiest question format to use in mobile surveys. Through testing different versions of the survey on our phones while visiting parks around Worcester, we found questions with 5 multiple choice options to be ideal for constrained questions and short responses for more open ended questions to get the most data without confusing the user. Having too many options on multiple choices would require scroll and could confuse users. There are two options on google forms for multiple choice questions, a checkbox matrix and a select one checkbox. The matrix was nice because it was condensed, but sometimes the user would accidentally select multiple options in the same row with scrolling. Shown in table 2 below are the multiple choice options we settled with. The short answer questions are primarily for the surveyor to record notes about the location and did not need to be long.

CATEGORIES FOR ASSESSING PARK CONDITIONS

The ranking table consists of five categories that each focus on aspects which contribute to park use and function. The findings in this section show that using multiple descriptive categories for park condition allows employees to: (i) evaluate the effects of litter on the green and blue space, (ii) more effectively respond to issues, and (iii) help the DPW better track improvement over time.

IMPACT/FUNCTIONALITY AND AT A GLANCE

The categories “impact/functionality” and “at a glance” evaluate the effects of litter in green and blue spaces. The “at a glance” category looks at how the park looks while passing by. While interviewing Commissioner Fink, he mentioned that visitors to Worcester first see the roads and the visitors may get a negative first impression of Worcester if the roads are dirty. That also can apply to parks. If the park looks dirty while driving by, that can deter visitors. A park that scores high in this category can signal to clean up crews that there is a lot of litter or that the litter is of a type that is significantly visible.

The “impact/functionality” category describes how the litter affects the park visitors. Most litter such as food wrappers just affects aesthetics but litter such as shards of glass can impact functionality. At Indian Lake park we found glass shards in the sand during our visit. We concluded that visitors would not want to walk around that park barefoot and therefore the litter was limiting the use of the beach. Scoring high in this category can signal to clean up crews that this park either has litter physically blocking portions of it or hazardous litter such as glass otherwise affecting its use.

SAFETY AND CLEAN UP EFFORT

The categories of "safety and "clean up effort" provide information for effective responses to issues. "Safety" looks at how dangerous the litter is to clean up crews and park visitors. The DPW does not want park visitors or DPW employees to be injured while in the parks. The safety category ranges from no danger to biohazard. While talking with Worcester representatives, we learned that Worcester has a significant drug problem and needles are often left in parks. This proved true when we visited Indian Lake park and found a used needle on the edge of the beach near the bushes. Since needles are biohazards, we concluded that biohazards should indicate a critical level cleanup. From there, small glass shards are avoidable, but still can injure clean up crews and visitors.

"Clean up effort" is an important category because it gives an estimate for how many man hours it would take to remove the litter observed in the surveyed park. The DPW can use this information to figure out which parks can be improved the fastest so they can manage their time efficiently. This category also gives the analyst a basic understanding of how much litter is at a certain location. This category does have a downside where size of the park could affect clean up time, skewing the results. We recommend breaking down parks into zones to avoid this issue.

LITTER DENSITY/DISTRIBUTION

The category of "litter density/distribution" can be used to monitor changes in the amount of litter in parks. "Litter density/distribution" pertains to a visual observation while patrolling the park to determine the distribution of litter. This observation can lead to an overall estimate of how much litter is actually at the park which can affect clean up effort. If the litter density/distribution score goes down after numerous clean ups, that can support the idea that people are littering less at a cleaner park and indicate mitigation methods are working. We noticed a correlation that there was more litter in areas farther away from trash cans. We recommend that more research is done to look into solutions to combat litter on a site specific level such as trash cans, recycling bins, and anti-litter signage.

SIZE ISSUE RECOMMENDATIONS

We recommend that parks be broken into zones of set size to further account for the variability in ranking results that is caused from the difference in size of the parks. The primary reason to break parks into zones is to have a consistent land area being observed when marking down litter density/distribution and clean up effort. Larger parks could have the same amount of litter by weight, but the bigger park may be rated as lightly scattered instead of moderately scattered. Larger parks would also inherently have longer clean up times because travel to the littered parts of the site is increased. When we visited larger parks, there was an uneven distribution of litter, particularly in Coes Park where more secluded areas had significantly more litter. Breaking parks down into zones could help clean up crews focus their work to heavily littered sections of the park.

Figure 12: An image of Coes Pond Beach. Litter was highly concentrated in sections A. Source: Google maps

LITTER CLASSIFICATION AND EXCLUSION FROM OVERALL PARK SCORE

The parks accumulate different types of litter based on how the visitors use them. The second section of our form requires surveyors to provide information describing what kind of litter is present. These findings explore why this data is important and justify why the numbers generated from the litter classification do not affect the overall park score. Litter classification can also be helpful in targeting cleanup efforts.

We found that classifying litter based on how the land is being used in each park provides insight on how to manage the litter left behind. Litter classification is where the observer records what type of litter makes up the litter at this location. In the google form we have ten categories, some of which are shown in table 4, each with a 1-5 checkbox to rank how much of the litter is this material. This is additional information not counted towards the final score or ranking that DPW workers can look at when deciding how to mitigate litter in a specific park. We noticed that at parks with playgrounds, the number of glass bottles dropped drastically, while parks with more secluded areas had significantly more glass bottles. This is because the glass bottles were primarily for alcohol and therefore less kid friendly.

However, while useful, we found that excluding the litter classification ratings improves accuracy of the overall park score. After our first round of surveying, when calculating the final scores, we initially included the litter classification ratings. We decided against including these ratings in future final scores and rankings because they added too much variation and made it much more difficult to compare the states of different parks. Instead, we decided to treat the classification ratings as additional information to be used primarily for identifying what types of litter are present, thereby assisting the DPW in narrowing down options for potential mitigation efforts they could use.

We found that parks can contain environmental hazards that can impede cleanup efforts. Many of the parks visited had litter that would be difficult to reach without equipment, which could delay the cleanup's progress. Collecting this data would allow for a more effective clean up in the future by ensuring the clean up crew is prepared to handle the challenges on site when they arrive.

RESOURCES REQUIRED TO EXECUTE A LITTER TRACKING PROGRAM

The findings in this section led the team to conclude that a small team of surveyors consisting of DPW employees would be: (i) appropriate to meet the needs of our sponsor and (ii) maximize the data quality of the survey results.

SMALL TEAM OF SURVEYORS

We found that a small team of surveyors would increase the reliability and consistency of the survey results. We found that citizen science is most reliable for objective data collection that does not require estimations, judgement, or opinions. Limiting the surveyors to the same people every time can also improve their consistency with the form as they become more familiar with it. **Therefore, we recommend that the survey is implemented by trained DPW employees while conducting their regular site assessments to maximize efficiency.** We learned from our interview with Jacquelyn Burmeister that a group of DPW employees travel to Worcester ponds monthly taking water samples to keep track of water quality throughout the city.. Due to the survey being easily accessible on mobile devices, DPW employees can fill it out on their phones during their visit.

RECOMMENDED TRAINING

We recommend that surveyors are trained using the Tracking Form Guidelines document and training slideshow created by our team. The guidelines include detailed descriptions of all of the categories in the ranking table. Example images for each tier within the categories are provided, such as those shown in figures 3 and 4. The training slideshow goes into more depth by explaining the process of ranking four Worcester parks. The slideshow discusses how factors such as park size affected overall park scores as well as other observations that influenced our judgement.

CONCLUSION:

Litter is a growing problem that has detrimental effects on the environment. Worcester is one of many cities that is struggling to solve this global problem. Due to the prevalence, more management and prevention strategies will need to be developed. In order to determine if a strategy is effective, there needs to be a method that can measure the change in the amount of litter over time.

While our team has developed a tool for litter tracking, it is important that in the future prevention strategies are implemented in order to address the issue before land use in parks is affected. The best way to reduce litter is to address the source of the problem. Further research will need to be done in order to determine the root cause behind littering behavior as well as infrastructure design that encourages environmentally conscious actions.

Category	Examples
Bottles	Water bottles, gatorade bottles
Plastic cups	Dunkin cups, red solo cups,
Glass	Glass shards, liquor bottles
Bags	Disposable plastic bags
Food packaging and containers	Plastic Utensils, take out containers, sauce packets, food wrappers
Tobacco products	Empty cigarette boxes, lighters, cigar packages

Table 3: This table shows 4 of the 10 categories of litter that we decided best showed what we saw at parks and examples of each category.


Moderate Cluster ^


Moderately Scattered ^

Figures 13 and 14: These figures show a snapshot of the tracking form guidelines, specifically the section going into further detail about what is meant by moderate litter density.

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