



Campus Plate: Connecting Students on College Campuses to Reduce Food Waste and Food Insecurity

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ABSTRACT

Food waste and food insecurity are global challenges that are also prevalent on college campuses. Various studies show that between 30-40% of college students are food insecure while paradoxically, 30-40% of food is wasted in the United States. Food waste is also a contributor to global warming where methane has a 28-36 global warming potential compared to carbon dioxide. Various technical solutions have been offered to tackle both food waste and food insecurity throughout the lifecycle of food production to food consumption. However, more targeted approaches that specifically address these challenges on college campuses are limited. In this paper, we present Campus Plate, a targeted approach to addressing food waste and food insecurity on college campuses through the use of smartphones. With approximately 97% of college students having a smartphone, we are able to deliver a platform that a large majority of the student population can use. We focus on ease-of-use and best practices in user experience to allow users to quickly discover recoverable food and retrieve it directly. We share technical details of the platform as well as the collaborations that were created to support these efforts. In a pilot and general availability release, we demonstrate the effectiveness of Campus Plate with 1,693 food items recovered in a short period that continues to increase through continued active use. With Campus Plate, we are able to enhance community resilience by reducing both food waste and food insecurity that works towards building a more sustainable food system on college campuses.

CCS CONCEPTS

• **Social and professional topics** → **Sustainability**; • **Human-centered computing** → **Mobile computing**.

KEYWORDS

sustainability, food waste reduction, food insecurity reduction, smartphone applications

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1 INTRODUCTION

Food waste is a global issue where it is estimated that one third of the food that is produced, or 1.3 billion tons, is wasted [10]. Paradoxically, food insecurity is also a global issue where almost 770 million people were undernourished in 2020, an increase by 160 million from 2014 [11]. Focusing on the United States, food waste is the most common item found in landfills [24], where 40 million tons (between 30-40 percent of the food supply) is wasted every year [29]. Food waste can occur for a variety of reasons including food spoilage, issues in processing, over ordering, removal of extra food, and removal of food with imperfections. Food insecurity is also prevalent in the United States where approximately 11% of households reported being food insecure at some time during 2020 [23].

When focusing on college campuses in the United States, it is estimated that college campuses throw out 22 million pounds of food each year [13]. Additionally, food insecurity on college campuses is also a challenge where studies show between 15% of students [25] to 39% of students being food insecure [18]. Yet another study found that approximately one third of students face food insecurity [27]. At our home university, a study conducted in 2017 found that 53% of students had high food security, while 24% had marginal food security, and 20% had low or very low food security. Food insecurity has an adverse effect on students ability to succeed where one third of students said they experienced hardship and one fourth of students had to choose between food, education, and housing costs [13].

Food waste not only affects those that are food insecure, but also it contributes to global warming. As food waste collects in landfills, it breaks down anaerobically which results in methane gas being produced. While methane contributes an estimated 10% of the greenhouse emissions compared to carbon dioxide at 80% [8], methane has an estimated 28-36 global warming potential (GWP) compared to carbon dioxide [9]. One approach to reducing food waste from being sent to landfills is food composting. While this approach has its benefits, it is one of the least preferred methods by the US Environmental Protection Agency (EPA), which is one step above food going to landfills [7].

This paper describes Campus Plate, a system to address both food waste and food insecurity on college campuses using smartphones. We focus on the EPA's second most preferred option, to move surplus food to those in need, with the goals of reducing both food waste and food insecurity. We target college campuses where

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both food insecurity and food waste is prevalent. By focusing on college campuses, the solution is tailored to increase food recovery by removing intermediaries and allowing members of the campus community to directly retrieve food. Additionally, messaging targets reducing food waste instead of food insecurity, with the hope of alleviating stigma associated for those in need which can reduce those that are food insecure of utilizing the service [17]. This messaging also plays a role where a person participating in Campus Plate feels they are an active participant in addressing food waste, regardless of need. We also use terms such as "food stops" instead of "food pantries", as the latter implies only a person in need would utilize the resource. Participants are not tracked and do not need to show proof of need to recover food. They simply retrieve food on-demand or through a reservation they create in Campus Plate, where only a unique code is used to verify the reservation. The other novel approach to this solution is that the designated food stops as part of Campus Plate are strategically aligned with areas where food insecurity may be more prominent. Our contributions are as follows:

- (1) We present an approach to reduce food waste and food insecurity on college campuses by using smartphones.
- (2) We evaluate this approach and describe our findings through a three-week pilot and general availability release.
- (3) We describe important findings from this experience that may be beneficial to other researchers attempting to implement a similar approach.

The paper is organized as follows: Section 2 describes related work to address food waste reduction and food insecurity. Section 3 describes our methodology including both the technical details of Campus Plate and the people and partnerships to implement a solution on a college campus. Section 4 describes the findings from a three-week pilot and general available release of Campus Plate. Finally, Section 5 summarizes our conclusions of the study and provides discussion for future work and other considerations.

2 RELATED WORK

Previous work has focused on multiple facets of food waste and food insecurity and how computing can address these challenges. Starting from food production and distribution, studies have focused on how to reduce food waste and promote more sustainable food production. Studies investigated on how trust and accountability can exist in tracking food using RFID and blockchain, although these solutions have their limits [22]. Post food production, research has also looked at how food is distributed from food recovery sites to food distribution sites for those that are food insecure. With crowdsourcing becoming a more popular approach to solving complex problems where scalability has been a challenge, one approach investigated if a crowd-shipping model can be employed that is primarily volunteer based [21]. The research primarily focuses on restaurants and in their model they propose that a financial incentive to restaurants slightly lessens participation while a financial incentive can encourage sufficient participation of crowd-shippers. Other approaches investigated how machine learning could be used to improve volunteer engagement with having volunteers retrieve and deliver food [28]. Their proposed recommendation system attempts to identify the most probable volunteer to perform a food

rescue and sends them a push notification to perform the retrieval. Based on the study, the volunteer hit ratio could be improved by almost 30% .

Another approach to addressing food waste and food insecurity is to introduce novel solutions that combine both hardware and software. One solution combined cameras with a publicly available refrigerator where food could be placed and retrieved using a companion mobile application [3]. Through the mobile application, food can also be reserved, similar to Campus Plate. The idea stems from community book donation stations. Another solution that was proposed is the use of drones to deliver food from those that have unused food to those in need [4]. In this peer-to-peer solution, those with extra food are able to have it be retrieved directly and delivered to those in need. The approach included the ability for the recipient to send a "thank you" message to the person that shared the meal. Another approach looked at having a bin that is in a communal setting, such as a college dormitory, that shows its mood depending on detected food waste [1]. As more food waste is detected, the mood state of the bin becomes more negative.

There are an increasing number of services and platforms that also focus on reducing food waste and food insecurity that utilize mobile applications and websites. One of these is *Olio* which allows users to contribute surplus food directly to those in need [5]. *412 Food Rescue* is a program based in Pittsburgh that partners with community volunteers, food retailers, and nonprofit organizations to recover unused food and delivering them to nonprofit organizations that then distribute the food. They utilize a mobile application to mobilize volunteers, rescue food, and then deliver it to nonprofits [26]. Other solutions look at connecting food at food producing businesses that would go to waste and sell at a discount to consumers through an application. Example of these include *Too Good to Go* [14], *Food for All* [12], and *Your Local* [20]. However, what these solutions lack compared to Campus Plate is they do not provide a tailored solution where college students can directly and easily recover available food. Many of these solutions require transportation to a specific location or additional funds, which are both challenges for college students. Campus Plate removes these barriers and provides the convenience to students to retrieve food where they are at no additional cost or require additional transportation.

3 METHODOLOGY

While food insecurity is a challenge on college campuses [13], smartphone adoption among students is high where an estimated 97% of students own a smartphone [6]. Given the high adoption of smartphones, the main interface for the campus community to interact with Campus Plate is through a mobile application. The mobile application communicates through a shared set of web services that are also utilized by a web dashboard that is accessible by food stop managers and administrators to manage the application and view current statistics. We describe these components in more detail in the sections below.

3.1 System

3.1.1 Mobile Applications. Both iOS and Android dominate the smartphone market where they comprise approximately 100% of the market [19]. Given this, a mobile application for both Android

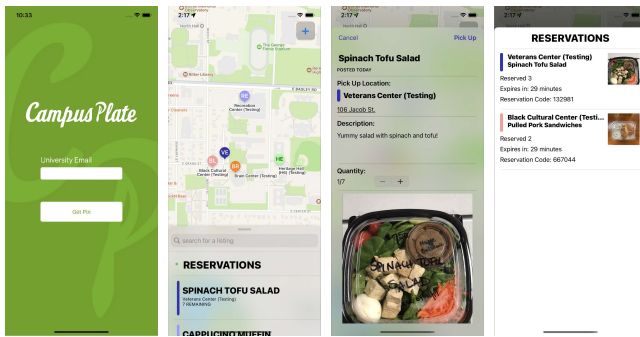


Figure 1: Screenshots of iOS application depicting registration, viewing food items, reserving food, and reservation code.

and iOS were developed. We considered creating a progressive web application (PWA) that could be used on both platforms, where doing so could reduce the cost in developing both applications. However, native mobile application capabilities such as using Apple's Keychain and Android Keystore are key requirements of the application that allow us to simplify the registration and authentication process. Additionally, we considered the impact of usability and that an application that consisted of a native "look and feel" could improve usability which can increase user adoption and retention.

Both iOS and Android applications are developed using native preferred languages, Swift and Java. Both applications contain similar workflows for core functionality including registering the user, confirming the registration, viewing listings, reserving listings, and viewing reservations. However, the user interface for each application is designed to ensure both follow preferred guidelines where with Android we followed Google's Material Design Guidelines [15] and with iOS we followed Apple's Human Interface Guidelines [2]. Screenshots of the iOS application are shown in Figure 1. The Android application contains very similar screens, however with Android components and design elements that would be more familiar to an owner of an Android smartphone.

To authenticate devices to Campus Plate, a user enters their university associated email where a random six digit pin is sent. The user confirms their account with their pin where a globally unique identifier (GUID) is generated and stored on the device. The GUID is protected on iOS using Keychain and on Android using Keystore Services [16].

The main feature within the application is the ability to reserve food. A user is able to reserve multiple food listings for up to thirty minutes for each reservation. Once food is reserved, it is removed from the quantity that is available to be reserved or retrieved on demand. A reservation is fulfilled by a food stop manager when the food is retrieved, or a reservation can expire in which the quantity that was reserved is then made available again to be either reserved or retrieved on demand. A reservation can be cancelled where it is then also returned back to the pool of reservable items. As users are interacting with the application, new food listings are updated automatically on the main screen along with updated quantities. If a food listing does not have any more items that are reservable, it

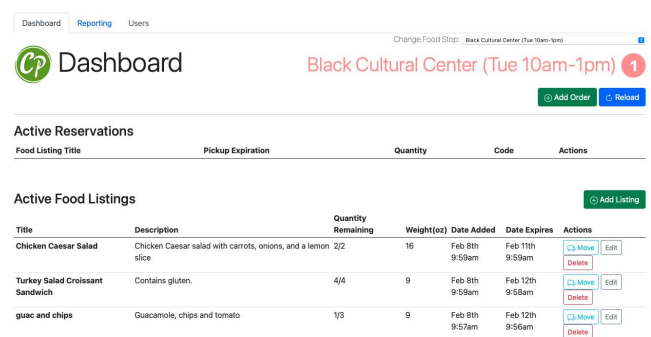


Figure 2: Web Dashboard that allows food stop managers and administrators to manage core components of Campus Plate including food listings and reservations.

is no longer listed within the application. This ensures that users are only viewing food that is available to be recovered.

If a user is a food stop manager or an administrator, a + icon will be displayed on the map that allows them to add a listing. This capability allows the administrator or food stop manager to utilize the camera on the device to take a picture of the food. Administrators can add listings to any food stop, but a food stop manager can only add a listing to food stops they manage. Food stops can have multiple managers as well as managers can manage multiple food stops.

To distribute the application, Android allows applications to be "side-loaded". However, Apple's App Store is the only mechanism to install general available applications. To deploy the application on iOS, we used Apple's TestFlight service which allows us to publish a URL for the campus community to install the application. To ensure that only members of the campus community can register an account with Campus Plate, the registration process only permits users with an email address that is associated with our campus.

3.1.2 Web Services. Web services support key features within the application including the ability to create, update, and delete listings, register and verify users, retrieve all listings, retrieve listings for a particular food stop, and create, get, and delete reservations. Users are defined in three different roles: user, food stop manager, and administrator. Any user that registers and verifies their account within Campus Plate is a user. A food stop manager is a user where a relationship exists that they are able to manage a food stop.

3.1.3 Web Dashboard. The web dashboard is the main interface for food stop managers and administrators to manage food listings and fulfill reservations. Through the dashboard, a manager can also add an on-demand retrieval (order), where a food listing can be retrieved without a reservation. Listings can also be added through the dashboard, similar to the mobile application. They can also be edited or deleted. If a food item expires, it will be listed below the active food listings under a category of recently expired food items in the past 72 hours. Food items that are past their set expiration date are also no longer viewable by users to reserve or retrieve on-demand. Through the dashboard, a food stop manager also has the ability to move a listing from one food stop to another. The food

stop manager can specify the quantity that is moved and if it is part of the total quantity, a copy of the listing is created. Figure 2 shows the main screen of the web dashboard that a food stop manager or administrator could see for a particular food stop.

The dashboard also includes reporting features which show total items recovered since inception, items recovered in the last week, total weight of items recovered, and total items that are not recovered. User statistics are also reported in the dashboard where the total number of active users in the past week and the total number of new credentials that were created are included. It is important to note that the total number of active users only takes into account users of the mobile application and does not take into account on-demand food retrievals.

3.2 People and Partnerships

The people that support Campus Plate are critical to its success. Without the collaborative efforts of various departments and organizations within the university, a technical solution would exist, but it would lack the support needed to manage food recovery and food transportation. To support Campus Plate, four primary programs and organizations were engaged: Computer Science, Sustainability, The Brain Center (community engagement), and Dining Services. The Computer Science team is primarily responsible for developing the technical solution including the mobile applications, web services, and web dashboard. They also provided continued support for the application and performed bug fixes as well as incorporated new features. The Sustainability team is primarily responsible for identifying key partners within the university and coordinating efforts among them. Additionally, they volunteered to assist with coordinating efforts and retrieving and delivering food. The Brain Center team was responsible for coordinating efforts between the various food stops and recruiting students to manage food stops. They also coordinated with Dining Services, which was responsible for packing food that was remaining from dining halls and events to be distributed to food stops.

To ensure proper food handling, each student volunteer completed food safety training. The training ensures the proper handling of food to prevent food spoilage and delivering food that would be unsafe. Dining Services had a large role in this areas as well where they labeled food with potential allergens and with expiration dates, which would then be used in the Campus Plate system to determine when food was expired.

It is important to highlight some of the shared perspectives from students from the various teams. Through their work and discussions, they clearly understood the problem that Campus Plate is trying to solve and recognized that food waste and food insecurity is a prevalent issue within the campus community. As one student become more aware of food insecurity on campus, they said: "I was completely unaware that the number of food-insecure students was that large" and "It hit me really hard in class you know when I'm looking around at my fellow students". Another said: "There's students that need that food or may need that food and may not tell anyone". Students also realized their efforts could make a difference: "I am very passionate about minimizing food waste, and this seems like a great outlet for that". In addition, one of the students researchers acknowledged that they are food insecure and



Figure 3: Left to Right: Food stop coordination with Brain Center and Dining Services, fulfilling a food reservation, and delivery being completed at a designated food stop.

thus utilized Campus Plate for their own support. Students also realized the tough decisions that students have to make between food insecurity and other expenses: "We wanted to make sure that students didn't have to decide between a meal and paying a bill that might keep them in their house at the time ... A meal shouldn't be what keeps you from success".

4 EVALUATION

4.1 Pilot Phase

Much of the development of the mobile applications, web services, and web dashboard occurred during the Fall 2020 and Spring 2021 semesters at our university. While the initial plan was to use a full academic year to develop the components for Campus Plate, the research team made significant progress and with continued work planned over the Summer semester, we strived to have a three-week pilot release at the end of the Spring semester. The main goal of the pilot release was to run Campus Plate in a limited window where lessons could be learned. From this pilot, technical issues and improvements to processes could then be addressed over a larger timespan (Summer) so that a general available release could be more successful in the following academic year.

In the pilot, one hundred members of the campus community were invited to install the application through using Apple's TestFlight service. These members received the invitation through an email that was sent directly from the TestFlight that prompted them to install the TestFlight iOS application, which would then allow them to install Campus Plate. In the pilot, only the iOS application was made available for testing as development started early for iOS with a group of students that developed a proof of concept application. The Android application was on schedule, but would not be ready until the following Fall semester. During the pilot release, an initial group of members were invited to install the application but any member of the campus could use the service.

During the pilot, there were small software defects identified in the mobile application, web dashboard, and web services that were quickly addressed. An example is that a user could only register a single device with Campus Plate, so if they then attempted to register another device, for example a tablet, the tablet's credential would override the smartphone credential. While this is an uncommon use case, it was able to be quickly identified and fixed. Throughout the pilot and development of the application, by using Apple's TestFlight service and a continuous integration development environment, we were able to quickly identify software defects and deploy fixes and new features to users in the pilot.

In the three-week pilot, 314 food items were recovered from 4 food stops. The initial food stops included our Black Cultural Center, Veterans Center, Commuter Student Lounge, and our Recreation Center. The team viewed the three-week pilot as surpassing expectations. It is important to note the dedication of students and staff as well as the coordination that was done with the Brain Center as instrumental to the success of the pilot. While the development of the Campus Plate platform was ahead of schedule, the tenacity of the supporting groups was the key contributor to a successful pilot where training, recruitment, and staffing occurred. Figure 3 shows from left to right the coordination efforts of the team, fulfilling an order, and a food stop refrigerator being fulfilled after a delivery from Dining Services. It is important to note that during this time, events were limited and limits were placed on gatherings due to the COVID-19 pandemic. However, classes were in-person and the campus was active, which helped the campus community discover Campus Plate and recover food using the service.

4.2 General Availability

During the Summer 2021 semester, development continued with the Android application and adding new features in both the iOS application and the web dashboard. Examples of features were the ability to cancel reservations, view a list of the food manager that exist per food stop, and view open hours for a food stop. Planning also continued over the summer to coordinate food stop staffing and open hours along with delivery from Dining Services.

At the start of the Fall 2021 semester, staffing shortages that affected the restaurant industry across the United States also had an impact on our Dining Services. Due to this staffing shortage, Dining Services did not have the capacity to start packaging surplus food. We worked closely with Dining Services to ease the burden of retrieving food where students volunteered to retrieve food directly from dining halls and deliver it the dedicated food stops. With this additional effort, food deliveries started in week 8 of the semester. Before the first delivery, the Android application was also released and available for users to install directly from the homepage of Campus Plate. To simplify the installation process, we used QR codes on the homepage and on signage for users to quickly scan to download and install the iOS or Android application.

During the general availability release, we promoted Campus Plate through digital ad signage throughout campus, paper signage, and also through a dedicated social media account. We also showcased the project during our Computing, Engineering, and Mathematics Showcase (CEMS) event where attendees could download the application, install it, and retrieve food that was available at the event. We additionally presented a poster on the work at a faculty research event and had several local media outlets interview the project team which helped raise visibility. With this additional awareness, an additional 546 food items were recovered for a total of 887 food items between the pilot phase and general availability phase which included 7 weeks in the Fall semester. Figure 4 shows the distribution of food by food stop for both the pilot and general availability phase. Understanding the breakdown of distribution by food stop allows us to identify potential areas of opportunity to increase food recovery by modifying open hours, the quantity of food delivered, and advertising the availability of the service. We

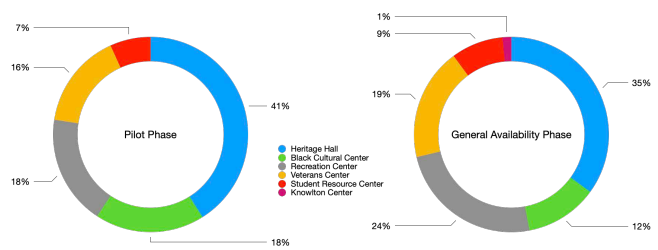


Figure 4: Distribution of food by food stop in both the Pilot phase and the General Availability phase.

continued with Campus Plate in the Spring 2022 semester where at the end of the semester, a total of 1,693 items were recovered. The food stops have also expanded to 6 food stops which included a food stop in our Student Resource Center and a temporary food stop in our STEM building.

4.3 Usability Study

A usability study was conducted by a UX lab in our university which included the user performing simple tasks such as finding a food listing, finding open hours for a food stop, creating a reservation, and cancelling a reservation. To understand how well each participant completed the task, eye tracking software was used, sessions were recorded, and participants were interviewed. From the study, the team provided several findings. One is that when a user opens the application, they are greeted with a view of the map which users found confusing. Most users could quickly identify the task they were trying to complete, but some were left unsure how they should interact with the map. Therefore, the map was shown to have less value than we initially thought, and we received feedback on how we could change the landing page to best suit the user's needs. The study also found opportunities for including more buttons when performing tasks. For example, if somebody is an Android user using an iPad, they may not know about specific iOS gestures. For example, swipe-to-delete is a popular gesture on iOS applications. Simple changes like adding a delete button for removing reservations can efficiently resolve such issues and prevent the app from being too foreign across operating systems. Lastly, the usability study showed that there should be a sort and filter option when showing the types of food available for reservation.

5 CONCLUSION AND DISCUSSION

Campus Plate thus far has exceeded initial expectations, but the full potential has not yet been realized. While our campus has returned close to a pre-pandemic state, the number of events on campus have not yet returned to their pre-pandemic state and there are still active health protocols that require masking in indoor spaces. We anticipate that once events return to a pre-pandemic state, food recovery from events will increase the amount of food that may be recovered and distributed to the campus community. Additionally, a more active campus will increase the awareness of Campus Plate and some of the staffing challenges with Dining Services will be addressed during this time.

While Campus Plate so far has recovered over one thousand food items in a short timespan, we do track the number of food items that end up expiring and are not recovered, which is currently 224 food items compared to 1,055 items recovered, which is 79% success rate of preventing food from going to waste. Fortunately, our campus has a food composting system that is able to convert food waste to a soil additive and trap the methane gas produced as food breaks down. However, additional training and awareness may increase our success rate. Additionally, planned features in the application can also increase the success rate of food recovery. This includes notifications which would increase awareness of the availability of food items as well as a self-service model incorporating geofencing or Bluetooth Low Energy (BLE) to ensure a user is in close proximity of a food stop location to recover food.

In the future, we aim to partner with other universities to offer Campus Plate as a service on their campus. The web services could be hosted onsite or we could host the service at our university where small changes would be needed to support additional universities. As part of this effort, it is important to also provide best practices and support to help establish the necessary collaborations to locally support food retrieval and delivery efforts. We also believe there are ways to integrate external partners into the Campus Plate system including local restaurants and other food providers.

In conclusion, Campus Plate exceeded our expectations with over one thousand food items recovered so far. It continues to be actively used and we anticipate the amount of food recovery to steadily increase in the future. By communicating food waste as the primary goal, we reduce stigma associated with food recovery with an aim to increase participation. We also focus on ease-of-use and building a platform that is built natively for each major smartphone operating system so that users can quickly reserve and recover food. These efforts would not be possible without the collaboration of various organizations on campus that supported this effort. It is also worth noting the impact of student participation as they managed food stops, delivered food, and showed a genuine passion towards their work and the goals of the project. We expect Campus Plate to continue to grow in the future not only on our college campus, but through partnerships with other college campuses and the potential for external partners to integrate into the platform.

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