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Design and Development of Sustainable Food Waste Management Kiosk for Restaurants & Catering Services

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Abstract: Food waste is a major problem in India that if solved can lead to solutions for many other issues like poverty and hunger. A food storage kiosk along with an app was developed to reduce food waste among multiple end users. The kiosk, which doubles as food storage and awareness spreader can be placed outside restaurants and event halls, and excess food can be stored in them and picked up by NGOs. The app works in connection with the kiosk, and also offers relevant features based on the user profile selected. For restaurant owners and event hall managers, the app allows them to connect with NGOs to manage their excess food. NGOs can use the platform to link with other organizations and receive alerts for food pickup. Individuals who download the app will receive updates on food related news and use the app to receive reports, recipes and tips to reduce food waste. They can also use the app as social media, to spread information on food solutions. Together, a system is created, wherein food waste can be potentially reduced through collaboration.

Index Terms **- Food waste awareness, Food loss, Food storage kiosk, Excess Food, Restaurants, Caterers, NGOs, Food waste management app**

I. INTRODUCTION

Food waste is a major problem on a worldwide scale. As per the UNEP Food Waste Index Report (2021), approximately 1.3 billion tons of food are lost or wasted every year globally. This is roughly 1/3rd of the edible portions of food produced for human use. With 68.8 million tons wasted per year, India accounts for 7% of the world's food waste (UNEP Food Waste Index Report, 2021). According to the Ministry of Consumer Affairs in Parliament, (March 2022) an Indian household, on average, wastes 50 kg of food per annum. This was much less than most developed countries, the Ministry said. Nonetheless, 25% of the world's malnourished people live in India (Dubey 2022). Generally speaking, a 1% reduction in food waste corresponds to a 0.28% rise in GDP growth. GDP per person rises by 0.16% for every 1% decrease in poverty. Food waste and poverty have a favorable correlation. A one percent decrease in food waste is correlated with an eighty-seven percent reduction in poverty. Therefore, lowering food waste can increase GDP growth and decrease poverty (Jayadevan, 2022). Despite much progress in food grain production and a decline in malnutrition rates over the past two decades, India remains highly vulnerable to food and nutrition insecurity, with a position of 107 out of 121 nations on the 2022 Global Hunger Index. Although there have been improvements, malnutrition still affects more children than is ideal; of all children under five, 35% are too short for their age and 19% are underweight. Anemia is quite frequent, especially in children between the ages of 6 and 59 months (67%), and in women of reproductive age (57%). (Agarwal, 2021)

Food waste has broader effects than is commonly understood. Hunger and poverty are directly impacted by food waste, and reducing food waste gives us access to more resources. We fail individuals who could have satisfied their hunger with food when it goes to waste that is safe to eat. Food waste is an international issue that requires additional work to be resolved. It's critical to comprehend how we characterize the issue in order to comprehend it more fully. The majority of definitions frequently vary depending on the organization that created them and its own areas of emphasis. While some definitions of food waste exclusively take into account food meant for human consumption, others also include the inedible portions of food. The definition employed can vary depending on the point at which food is rejected (production, processing, consumption, etc.). The Food and Agricultural Organization (FAO), which is a specialized United Nations agency, defines food loss and food waste thus:

> Food losses refer to the decrease in edible food mass throughout the part of the supply chain that specifically leads to edible food for human consumption. Food losses take place at production, postharvest and processing stages in the food supply chain …. Food losses occurring at the end of the food chain (retail and final consumption) are rather called “food waste”, which relates to retailers’ and consumers’ behavior. (Parfitt et al., 2010)

When food is not used for its intended purpose, the US Environmental Protection Agency refers to it as "wasted food" rather than "food waste" since the former phrase implies that the food has lost value and must be managed as waste, while the latter term emphasizes that a valuable resource is being wasted. (US EPA, 2024) WRAP UK, a climate action NGO defines 'food surplus' as any food and uneatable parts that are sent to the following:

a. Bio-based materials (e.g. materials for other industrial products).
b. Redistributing the food to people (e.g. via NGOs or businesses)
c. Food for animals (livestock)

The defining and redefining of food waste leads to changes in the way it gets managed. During the course of this research and design, we defined food waste as excess food which is eatable but needs to be consumed soon (e.g., within the day) and/or requires proper storage. Food waste which cannot be consumed falls under these categories:

a. Excess food which is not eatable (i.e., the remains of someone's meal or spoilt food, parts of food typically left uneaten)
b. Vegetable and fruit waste, typically used to make compost

Food waste is directly related to many other social and environmental issues like hunger, loss of biodiversity, wastage of natural resources and many others. When food is wasted, it takes away nutrition and health from those who could otherwise have accessed it. The resources which went into growing and transporting the food also go down the drain, which further burdens the agricultural sector to produce more to make up for what was lost. This project aims to convert food waste to food surplus, thus preventing edible food from ending up in dustbins and landfills.

II. RELATED WORK

To learn about the existing methods of food waste management and research conducted in this regard, we reviewed research papers and articles to gain more insight. We also collected information on some of the existing products and organizations which attempt to solve this issue.

2.1 Literature Survey

In India, there is a quite a lack of research on food waste. The majority of the data comes from a few wedding based case studies. Food waste statistics at the national level are nonexistent. Only 22 of the 106 publications examined in WRI India's working paper were specifically related to food loss in the country, and only 10 produced original data. Restaurants, big social gatherings, and weddings are major causes of food loss. A few academics looked into Indian households' experiences with food waste. According to their report, the majority of Indians believed that returning to ancient beliefs and practices—like honoring farmers' labors, sharing meals with family, and feeding livestock with food waste—would help address food waste (Priya, et al. 2023).

In Bharucha's (2018) study, 63 restaurant owners from Mumbai and its suburbs participated. 75 percent of these eateries have an additional 10–20% of preparation. Expensive fine-dining establishments take waste management far more seriously and make even more extra preparations. A few of the restaurant owners assert that they are able to predict the needs for particular days of the week. Overall, 18% of the businesses questioned said they had a thorough process for disposing of leftover food. (Bharucha, 2018). With regard to apps, a study examines the background of overordering behavior on Food Delivery Apps (FDAs) (Talwar, 2023). The authors' results confirm that most people do not consider the negatives of excess food remaining while ordering on such apps, and they intend to consume the leftover food later.

Penalver (2022) studied the Food Bank of Navarra (FBN) in order to quantify the water-related advantages connected with food loss and waste reduction. A comparison study was conducted between the FBN-assisted scenario and a fictitious situation in which the FBN did not intervene. In addition to saving 2.7 thousand tons of edible food waste in 2018, the FBN also prevented the waste of over 3.2 million m^3 of freshwater (Penalver, 2022).

A sizable amount of cooked food is kept in Japan's municipal government storage facilities, where it is wasted while not in use. (Sato, et al. 2018) This study analyzed the nutritional content of stored food and the attitudes of the Japanese people and supermarket assistants towards giving food bank customers access to it.

Three smartphone apps—Fridge Pal, LeftoverSwap, and EatChaFood—that aim to lower home food waste were compared by Farr-Wharton et al. (2014). The study looks at how each app is affected by users' location, literacy, and understanding of the food production chain. With features to help users manage their food, EatChaFood, their own prototype, encourages users to eat their food before it expires. An additional study looks at the quality perception and development process of MySusCof, an app designed to help users waste less food. Based on the findings, it appears that a hybrid mobile app with both gamification and utilitarian components could be the most successful combination to persuade users to adopt a more sustainable eating pattern. (Haas, 2022).

2.2 Existing Solutions

Solutions that currently exist include those that are based on technology and those which depend on collaboration and community effort. A British company, Winnow has developed technology which allows commercial kitchens to track their food waste using AI. Many companies provide biogas services which convert food waste into energy. There are apps like Copia which picks up extra food from restaurants and delivers it to people in need. Too Good to Go, is an app which lets consumers pick up surplus food in surprise bags from establishments for a third of the price is helping solve the food waste problem across 12 cities in the US. Just Dabao is a similar platform in Singapore, where users can buy food surplus from eateries at discounted rates. OzHarvest, an Australian company, collects and redirects food surplus, saving it from the landfill and providing meals to those suffering from hunger.

Food waste solutions in India range from community level systems to low-cost products made to solve specific problems. The Indian food landscape poses a very particular set of problems, and innovation is at the forefront of many of these solutions. S4S technologies won the BBC's Earthshot prize in 2023 for their solar powered dryer, a low cost, no-energy method which is used to preserve fruits and vegetables which would have remained unsold in the market and thus, ended up in landfills. They work closely with female entrepreneurs and farmers and have helped add significantly to their income. Wastelink, Noida is a company that

repurposes leftover packaged/processed food into animal feed mix, thus recovering economic benefit from excess food and saving it from the landfill.

Greenpod Labs, a Chennai-based startup, produces eco-friendly sachets that can prevent fruits and vegetables from degrading quickly in places where cold storage is expensive. Skrap, Mumbai is an NGO which provides waste management services at events. This includes food waste management, where they partner with local NGOs to ensure that all edible food is redistributed to people in need. The No Food Waste NGO crowdsources data on hunger spots and takes requests for donation of excess food. They began in Coimbatore and have spread to 10 cities across India. They collect food with their own vehicles and donate to slums, hospitals, old age homes, orphanages, etc.

Having analyzed research papers and existing products, we understood that many organizations across the globe are trying to address the issue of food waste management, albeit with varying levels of technology. Food waste management has guaranteed benefits which mainly include saving resources and economic recovery. However, to bring restaurants, event halls and individuals together, it would require a larger model or a combination of mechanisms to effectively manage and attend to each stakeholder's needs.

III. DESIGN AND DEVELOPMENT OF PROPOSED SOLUTION

The design of the food storage kiosk along with the app was done through a methodical process which involved analyzing current practices, developing a set of design requirements and creating a solution tailored to tackle the problem of food waste from various fronts.

3.1 Primary Research

To understand how restaurants dealt with their food waste, we interviewed restaurants and food stall owners in the New BEL Road area of Bangalore. It was observed that there is no particular method of disposal used by restaurant owners, but that all food waste and excess food is collected by waste collection trucks to further process it for animal food. Thus, it was made clear that though food was consumable, there was little or no attempt to make use of it in the most ideal way, i.e., redistribution for consumption.

Conducting an online survey among around 50 individual consumers revealed that while most of them were educated about food waste, they had no idea about the scale at which it was happening. 57% of the respondents revealed that they encounter food waste the most while throwing away leftovers. Thus, while many of today's consumers are educated about the issue of food waste, many of them are not as proactive in doing their bit to better the state of the problem. A professor in Hospitality and Catering Technology (RUAS) opined that ensuring the quality of the food after it had been out in the open for the majority of the day may be a hindrance in redistribution of leftover food by caterers and restaurant owners. In case of indigestion or sickness occurring among those who eat the food, the person/persons responsible for the cooking would be held accountable. Thus, it was key to ensure that the quality of food could be answered for at every stage of the process.

3.2 Concept Generation

To tackle this issue, we designed a system in which a food storage kiosk and an app work in sync. The design process involved setting requirements for the functioning of the kiosk (Fig 1), as well as creating an Information Architecture (IA) for the app to function. We went through different designs for the kiosk and explored UI theme options for the app.

The kiosk would be used by larger establishments so that they could make better use of their resources. Multiple rounds of ideation were conducted (Fig 2) before the design of the storage kiosk was finalized. Some of the main criteria were sufficient storage space, placement of advertising panels and how the kiosk could be situated in a public space. The kiosk would have the following functionalities:

- Storage space for event hall/ restaurant excess food
- Refrigeration system to ensure quality of food
- Touchscreen for restaurant staff and NGO persons to operate the device
- Connection to app to update about usage of the storage
- LED panels to feature art/posters on food waste and responsible consumer behavior

The requirements for the app include the following:

- Different user profiles for easy usability
- Engaging content for individual users
- Easy-to-use interface for restaurant owners and event hall managers
- Provision of a platform providing help and visibility to local NGOs

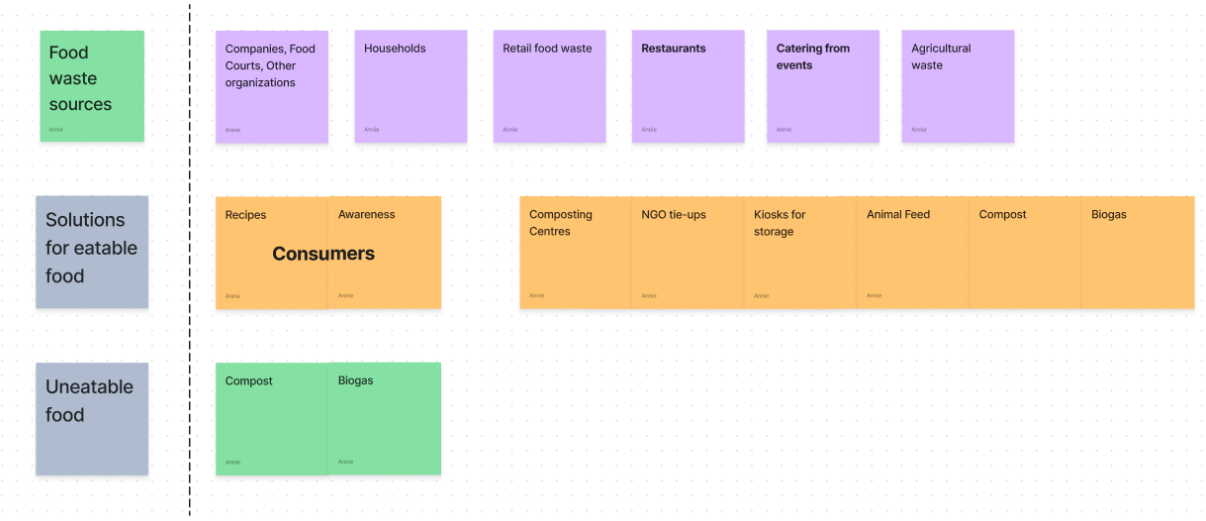

Figure 1: Brainstorming

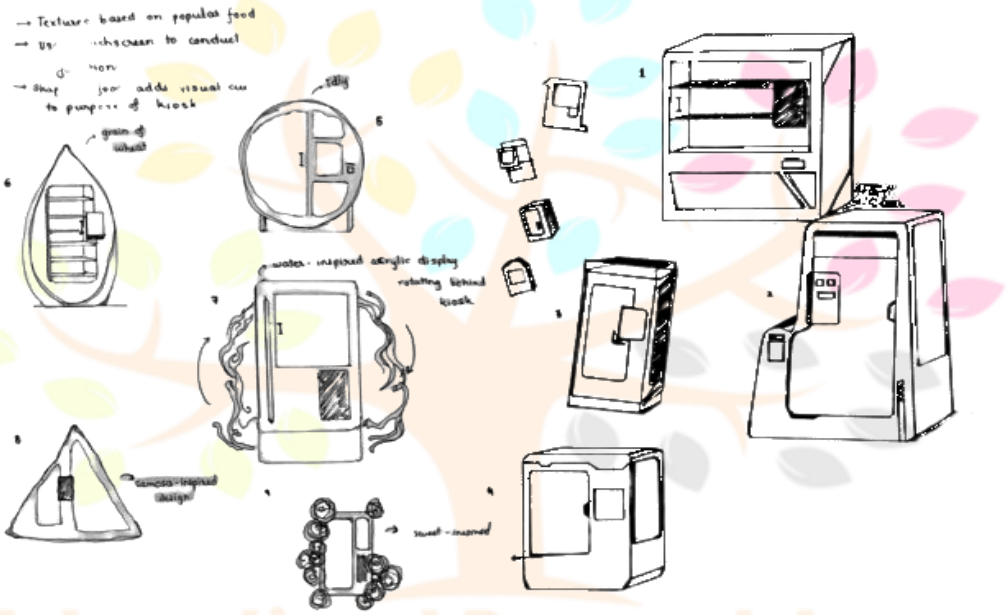

Figure 2: Concept sketches for Kiosk

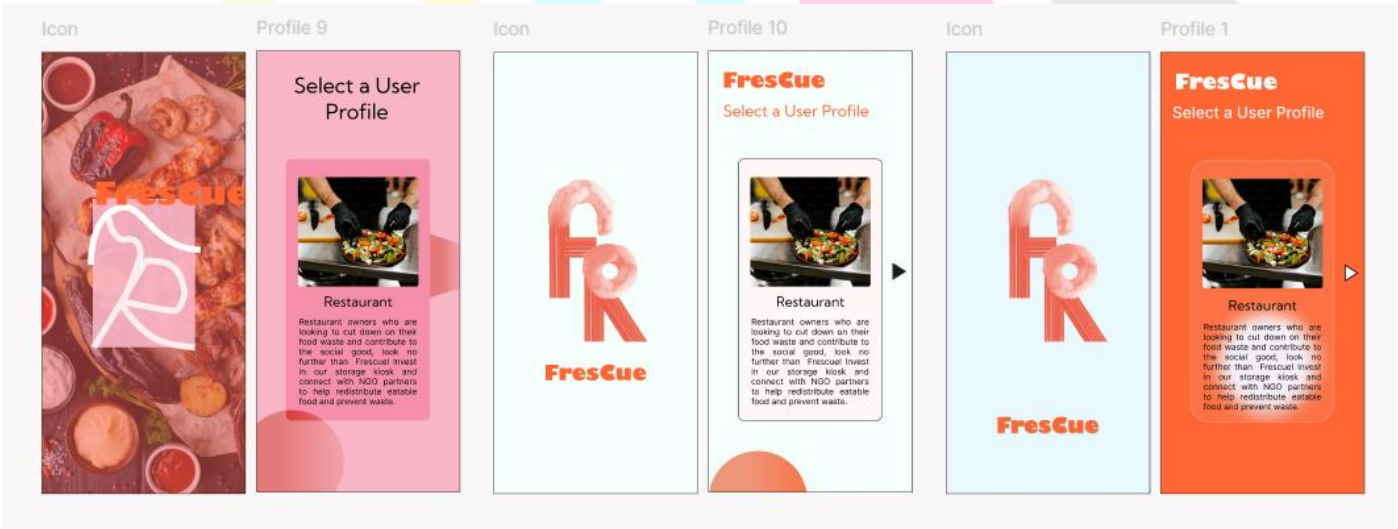

Figure 3: (From left to right) (a) Theme 1 (b)Theme 2 (c) Theme 3 Themes for App

3.3 Selection of Concept

For the chosen concepts, 3D models were developed and rendered, as shown in Fig. 4. The final concept for the kiosk was selected using a Pugh Matrix. The following criteria were taken into consideration: Ease of use (ease of finishing main tasks like

keeping food inside and picking up the food), ease of maintenance (cleaning, electrical maintenance), aesthetics (ability to appear visually pleasing at restaurants and other locations of placement), volume (amount of food which can be stored in the kiosk), ease of prototyping (ease with which a working model can be created to showcase functioning), advertising value (number of advertising panels and their visibility). Prototyping ease was taken as the determining factor for the final selection. Based on these concepts, Fig 4 c was the final concept selected for which a physical prototype was developed.

The main features of the kiosk would be the following:

- The device has a touchscreen to be operated by restaurant/event hall staff and NGOs people.
- The door unlocks on receiving staff ID code or OTP in case of food pickup
- The LED panels on the side display awareness posters or art which supports the cause of food waste.
- The device can be operated by a single person and they can clean the kiosk at the end or beginning of the day as needed.
- There is an option which provides a slip to the pickup person in case of extra food which does not fit into the kiosk.

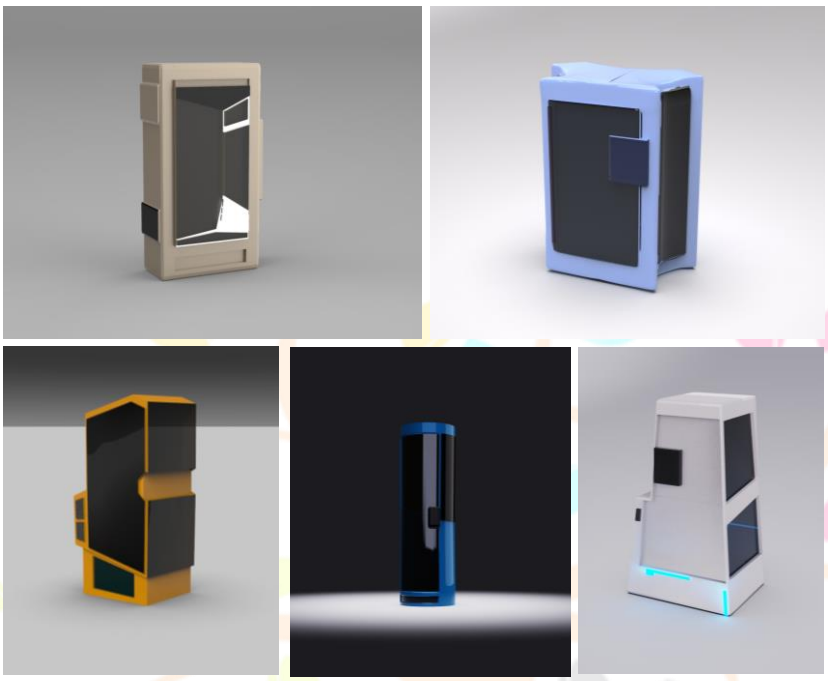

Figure 4: (clockwise from top left) (a) Concept 1 (b) Concept 2 (c) Concept 3 (d) Concept 4 (e) Concept 5

A clean, bright yet minimalist look (Fig 3 c) was chosen for the app to reinforce the idea of avoiding wastage. This concept was chosen based on the minimal colors and the simple and functional layout. The colors chosen also convey the desire to avoid wastage and make better choices. By choosing this theme, we were able to convey the purpose of the app. The hi-fidelity prototype screens for individual users is shown in Figure 5.

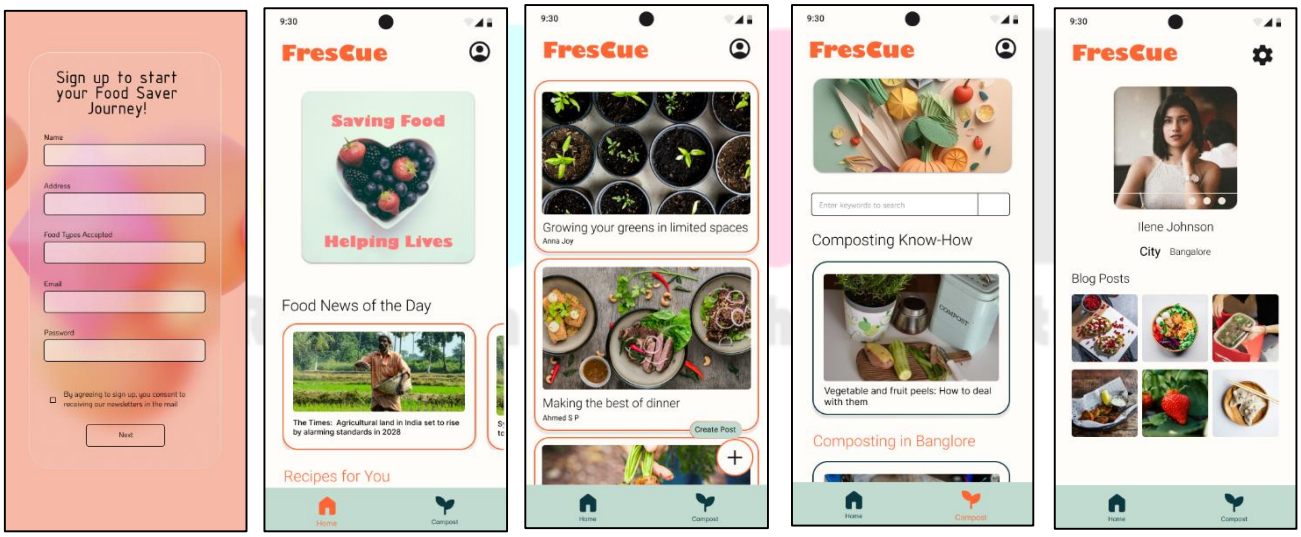

Figure 5: App Main screens for Individual Users

3.4 Prototype Development

The prototype was created according to the 3D model (Fig 6 a) built. For prototyping purposes, the model was built at a 1:3 scale to the original. The model was mainly built from MDF wood, acrylic sheets and sunboard. The assembly of the main body as well as the putty and paint application were done at the college workshop. As of now, the prototype developed showcases the

design but not all the functionalities. For the app, wireframes and the hi-fidelity prototypes were created in Figma. The overall functioning of this system is based on the app and kiosk working in sync. There are 4 user profiles and each user can choose their profile, create an account and log in. After this, the usage differs according to the user.

Individuals: Individuals who download the app can access easy leftover recipes, post about food waste, donation drives and anything else which supports the cause of reducing food waste. They can also receive the latest food news, reports and papers, information about NGOs in their locality and tips on composting and composting facilities.

Restaurants, Event Halls/Caterers: Restaurants, Event Halls and Caterers can have the storage kiosk placed outside or within their establishments. Once they have a certain amount of food which they feel will not get sold out during the course of the day, or within closing time, they can place that food in the kiosk and set an alert on the app. The alerts are sent to the NGOs and societies registered on the app, and the first one to respond can come to pick up the food. Other than this, the app can be used to monitor the amount of food in the kiosk, check on spoilt food and how to compost it well. They can also view statistics on the amount of food being saved.

NGOs: NGOs use the app to connect with other NGOs and restaurants in their locality. They will receive alerts from restaurants/event halls with excess food in their kiosk.

Figure 6: (from left to right) (a) 3D Model of Final Concept for Kiosk, (b) Exploded view of Kiosk, (c) Finished 1:3 prototype of Kiosk

IV. RESULTS AND DISCUSSION

User validation for individual consumers was conducted in-person with a test sample of four. They viewed the app prototype and were given a detailed explanation regarding the overall functioning of the system. For validation from restaurant-based users, a professional chef, a member of restaurant staff and a restaurant manager were interviewed. The concept was explained to them and questions were posed on how they would utilize it.

The individual profile testers described the app UI as "simple" with no complications. Test users were able to view all the features without issue. Some opined that a fully functioning version would provide a better understanding of the app. The system as a whole was deemed useful for restaurants and NGOs. 50% of the test users were of the opinion that individuals who weren't passionate or actively involved with food waste would have little or no reason to download the app. Users suggested adding a personal tracker to the app so that it would provide more interaction as well as an opportunity to better their food habits. They wanted to know if they could interact with other users on the app and approved when they were informed that they could do so. Some suggested that the recipes section should include recipes not just for leftovers but normal food also, and that special food recommendations could be made for weekends.

The feedback gathered from the professionals suggests that apart from the existing features, addition of a bacteria/contaminant monitoring mechanism would ensure the quality of the food while in storage. Providing different options in storage volume would be helpful for restaurant owners to have a kiosk as per their requirements.

V. CONCLUSION AND FUTURE WORK

A food storage kiosk with advertisement capabilities and an app aimed at four different user bases were designed. Through this combination, a system was achieved which provided a multi-faceted solution to tackle food waste in urban and semi-urban areas. The solution will provide a platform for restaurants, event halls and NGOs to connect and work together. The kiosk acts as both a functional device and an object to pique public interest. As the app has provisions for various users, even individuals who do not have personal or work connections to the food and hospitality sector can educate themselves and act to challenge the matter of food waste.

The future of this concept appears promising and many avenues for expansion present themselves. Adding bacteria and foreign component detection system to the kiosk to ensure quality of food is maintained, customizing the kiosk exterior to match with branding or décor of restaurants/event halls, getting input from chefs, dieticians and nutritionists to create better recipes and grocery plans, are some ways in which we can better the kiosk for commercial use. Providing artists and graphic designers a platform to showcase their work on awareness for food waste is a way to allow the general community to connect with the core of our design. Adding a personal habit tracker to the app for individual users, to provide motivation on their food saving journey will make the app appealing to individual users.

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