# PROJECT TITLE: Smart Trash Sorting for Zero Waste in Minnesota

1. **PROJECT STATEMENT**

The proposed project aims at enhancing recycling in Minnesota to achieve ‘zero waste’ with our citizens’ efforts. Towards this end, this project will leverage modern technology to provide a *smart* and *precise* public trash sorting tool. The major goal of this tool is to increase recycling rates in Minnesota, by reducing recyclables to landfill, as well as recyclables contaminated by landfill garbage. **This project has immediate and long-term impact on the education of Minnesotans, especially our next generation, in recycling practices.**

The proposed tool consists of: (i) a smartphone application for real-time trash recognition, sorting, and education, and (ii) a mesh/network of connected trash bins with information about the bin location, bin type and fill-level for busy areas such as the University of Minnesota, the Minneapolis-Saint Paul airport, and the Mall of America.

The importance of the proposed project stems from the fact that in Minnesota, waste management systems have not received as much attention in the city planning process as other sectors, such as water and energy. However, waste materials have value and recycling can save the state money, hence providing economic benefits. In 2010, Minnesota wasted recyclable materials worth $285 million and spent an additional $200 million to throw them away into landfills. These numbers suggest that several things can be done in Minnesota to improve recycling.

Various waste categorizations exist in public spaces in Minnesota, such as recyclable/landfill, organic/paper/bottles/landfill and compost/plastic/landfill. With limited education in waste disposal practice, such kind of categorizations usually cause confusion and lead to wrong trashing decisions. If materials go to the wrong bins, it will cost extra time and money to remove them at a sorting facility. In many cases, the mistake is not recoverable because recyclables can be easily contaminated if tossed in the landfill bin. To make the situation even worse, non-recyclable items tossed in the recycling bin will contaminate other recyclables, which results in a further waste of resources. For instance, soiled papers from food packaging can cause the whole paper bin to landfill. In the worst-case scenario, improper trash sorting poses a threat to public health and the environment.

We propose to enhance trash sorting at its source, which is to help people accurately sort trash onsite in public areas. Towards this end, the smartphone application represents an ideal tool to educate Minnesotans to properly recycle resources and protect our environment. Thus, the proposed project has the broad impact of guiding our citizens, especially the next generation, in trash sorting and achieving ‘zero waste’ in Minnesota.

# PROJECT ACTIVITIES AND OUTCOMES

**Activity 1: Developing real-time and precise trash sorting algorithms on mobile platforms.**

We will leverage the latest evolution of machine learning, i.e., deep neural networks, for developing algorithms to help users make a *real-time* and *precise* decision on where to toss a particular trash item. Our trash sorting is expected to be implemented on embedded platforms with limited computing capabilities. Thus, our neural network model has to be deployed using efficient structures targeted for mobile applications, e.g., MobileNets. Towards this end, we will first select a high-performing model based on detailed analysis of the state-of-the-art achievements in deep learning, and then adapt it to our needs through transfer learning. We plan to capture around 2000 training images for each category as our systematic dataset and label them according to expert suggestions. Once the data is ready, we will train our model using the collected data for efficient trash sorting. During this process, we may also need to adapt the model structure for optimal performance. Finally, we will deploy the trained model in mobile platforms and further improve its performance upon feedback analysis.

# ENRTF BUDGET: $ 125,594

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| **Outcome** | **Completion Date** |
| *1. Collect a systematic image dataset for training and testing* | *June 2021* |
| *2. Create an efficient deep learning network model tailored for mobile platforms* | *November 2021* |
| *3. Repetitively tune the model to get improved results on the mobile platforms* | *June 2022* |

**Activity 2: Building a public trash bin network aware of the bin type and level of filling.**

This activity aims at creating an Internet of Things (IoT) network of bins to assist users in locating the *nearest non-full* bin. In this project, we will focus on *indoor* spaces covered by Wi-Fi, with a special focus on busy areas at the University of Minnesota, Malls of America, and the MSP airport, where 200 trash bins will be selected and used. We will leverage the existing Wi-Fi infrastructure to *locate* and connect the trash bins to the network. In particular, a group of bins (for different types of materials) will be located close to an access point and paired with it. When a user’s phone connects to an access point, it will be directed to the group of bins connected to that access point given the bins are not full. We will use ultrasonic sensors to detect the fullness of the bins. If a bin is full, a signal will be sent to a central server to mark the bin as *not available* on the map and the user will be directed to the next closest bins. This study and its outcomes will provide useful insights to analyze other scenarios such as: (i) a trash/recycle bin positioning system across the city area, (ii) facility staff being notified on the fill-level of the bins for timely management, and (iii) outdoor solar powered bin networks.

# ENRTF BUDGET: $ 138,378

**Activity 3: Developing a smartphone application with real-time trash sorter, bin finder and a recycling game**

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| **Outcome** | **Completion Date** |
| *1. Mark the trash/recycle bins in study on the bin map and install fill-level sensors* | *August 2021* |
| *2. Pair the bins with the WiFi access points and create the IoT network* | *January 2022* |
| *3. Enable communication between bin networks and the smartphone application* | *February 2023* |

We will develop a smartphone application that integrates the precise trash sorting algorithm developed from activity 1. App users will be asked to take several photos of their trash in hand, so that the deep neural model can provide sorting suggestions based on these images. We will also integrate the bin networks from activity 2 into the application so that, after the recognition and sorting, app users can be guided to find the closest non-full bin for tossing their trash in hand. To achieve a long-term educational goal, we will design an interactive recycling game for kids to learn while playing. We will leverage the opportunity of undergraduate design project advisory for the smartphone app development. In particular, each semester during *the funding period*, we will provide a project aimed at developing/improving the app to a group of undergraduate students*.*

# ENRTF BUDGET: $ 130,737

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| **Outcome** | **Completion Date** |
| *1. A smartphone application with image acquisition and trash sorting abilities* | *November 2021* |
| *2. The above app with an educational recycling game* | *June 2022* |
| *3. The above app with communication with the public trash bin network* | *June 2023* |

1. **PROJECT PARTNERS AND COLLABORATORS:**

*Dr. Ce Yang oversees the project. Dr. Martina Cardone* from the Department of Electrical and Computer Engineering will be responsible of building the IoT trash bin networks, and of the supervision of the undergraduate student groups for the development of the smartphone application. *Dr. Youbing Wang* from the College of Science and Engineering will advise and work on the trash recognition and sorting algorithms.

# LONG-TERM IMPLEMENTATION AND FUNDING:

This project is foreseen to have a significant positive impact on the education of Minnesotans, especially younger citizens, in recycling practices. The education on recycling will take effect immediately and last a life- long time for our citizens. The project will pave the way to improve the overall recycling of Minnesota and embraces the ambitious goal of expanding the bin network to all public areas and redefining household recycling goals. Upon completion, the project team will continue to secure funding from the United States Department of Agriculture (USDA) and the Environmental Research & Education Foundation (EREF).