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# Nurturing Awareness and Responsible Practices in E-waste Management

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**Abstract:** Nowadays, people use electronic devices everywhere and all the time. Though they prove to improve our quality of everyday life, there also stands a challenge which is electronic waste (e-waste). The constantly expanding technology and unawareness among people about its severe effects remains a problem. Many harmful substances like mercury, barium and lead are found in e-waste and a huge amount of e-waste is generated consistently and if not urgently addressed it would show consequences by affecting our mother earth, our environment and health. Hence, our website "E-waste Facility locator" aims to contribute to proper e-waste management and responsible disposal. This issue demands attention and hence, we aim to develop a website that would increase the awareness among people of the e-waste and its effects. Our website focuses towards helping people find e-waste facilities and recycling centers nearby to their location which would increase the use of suitable e-waste disposal methods. We will also integrate an image identification model that would identify the e-waste item based on the image uploaded by the user and assist the user by suggesting a list of solutions on how to correctly dispose that off. Our website mainly focuses towards increasing awareness among people of the adverse effects of e-waste.

***Keywords:*** *Electronic Waste, Waste Management, E-Waste Facility Center, E Waste, Image Identification Model*

## 1. Introduction

In this digital world, there has been observed a huge increase in the usage of electronic devices affecting the way humans live and communicate with the environment. Undoubtedly, the use of smartphones, laptops and other gadgets have outstandingly contributed in helping us live a quality life. However, when not in the usable state and when it goes beyond repair, it is said to electronic waste or e-waste. The way it affects the health and environment is a topic of discussion and needs to be addressed. This is because it poses serious threats to the environment and the human health. It contains different harmful chemicals which cause various diseases and hence it is necessary to bring awareness among people related to e-waste and its effects.

India, a country in the midst of a technological revolution, has embraced digital innovations at an impressive pace. The affordability and functionality of electronic products have catalysed their widespread adoption, leading to an exponential increase in electronic device usage. This surge, however, has resulted in a proportional increase in E-waste generation as these devices reach their end-of-life or become obsolete with the advent of newer model’s. India ranks as one of the leading contributors to the worldwide e-waste flow, based on information from United Nations University, India generated an estimated 301 kilo-tonnes of electronic waste in 2016, marking an alarming 11% annual increase from the 266 kilo-tonnes produced in 2014 (2017, 2015). This upward trajectory can be attributed to two primary factors. First, the rapid adoption of technology and the ready availability of affordable electronic products have fuelled a surge in demand (2015). Second, economic disparities between developed and developing nations have created a lucrative opportunity for developed countries to export their E-waste to destinations like India (E-Waste contributions) [1].

The market for electrical and electronic equipment has grown exponentially at a global level over the last 20 years. As a result, waste management and corporate executives are dealing with a new challenge, and lawmakers are keeping a careful eye on waste electrical and electronic equipment, or "e-Waste." Microprocessors will certainly be found in an increasing number of common place objects and in an increase in the number of electrical devices in the world [2, 3]. Because of this, the quantity of WEEE grows annually at a rapid rate, and it's also believed to be one of the main issues with waste management in the twenty-first century. 20 to 50 tonnes of e-waste are produced annually worldwide, according to United Nations University, and it is important to develop an estimation method [4].

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Harmful substances are present in electronic devices. They include PCBs (polychlorinated biphenyls), BFRs (brominated flame retardants) and also heavy metals like lead, cadmium, chromium, etc. Hence, when these products are recycled, many harmful gases are released which can adversely affect the human health when they come in direct contact after polluting the air, soil or water. This condition has been observed to be consistent in many areas where the recycling process takes place and how the environment is affected negatively, from 2004 - 2014. [5]

The issue of e-waste is not confined to a single region or nation. it is a global challenge that demands our immediate attention. To address this problem effectively, it is essential to create a system that empowers individuals to dispose of their electronic waste responsibly. The e-waste management condition in India is a challenge. A huge amount of e-waste is generated every year in India contributing greatly to pollution and harmful effects of e-waste. This issue needs to be urgently addressed and needs a better understanding [6].

Different harmful substances are present in the e-waste like lead, mercury, cadmium etc. Old CRT monitors contain lead while mercury can be found in switches, batteries and lamps. When mercury is released, it can change into the extremely toxic form methylmercury, which can cause serious damage in human neurological function. The main way that this happens is through eating contaminated fish. Rechargeable batteries and semiconductors are common places to find cadmium, which is dangerous for both human health and ecological systems. It can cause kidney damage, lung and prostate cancer, and other conditions [7].

Our website intents on enabling the use of suitable practices for the handling of e-waste and its disposal practices and increase awareness among people. For ease of access, the website will be kept updated and user-friendly. Our website can be used by all kinds of public, general public and also companies and organizations. It will assist all users in finding the e-waste facility and recycling centers based on the location that they will enter in our website's ‘Facility locator' tab. All nearby centers will be displayed. Google Maps provides the API which is reliable and hence we have used that API to find nearby centers.

E-waste is generated almost everywhere and hence needs to be addressed immediately. Recycling and proper disposal is vital. Hence, this website is developed with the intention of helping different groups of people to locate the nearby e-waste facility locators and identifying the e-waste they possess. People need to know what actions are to be taken on different devices that are not working or are at their "end of life" stage. Knowing different types of e-waste like computers, mobile phones, fridges, cameras, TVs, circuits etc. is vital. The actions to be taken on these products that are not working and nearing or at the end of their “useful” life is crucial. Hence, this e-waste facility locator will also provide information on what steps can be taken against the e-waste an individual or organization has. The list of suggestions will be displayed after identification of the photo of the e-waste that the person uploads. The system identifies the image using CNN (Convolutional Neural Network). CNNs are significant as they require fewer training examples than traditional machine learning algorithms. They are also capable of transfer learning. They are scalable due to their ability to add or remove layers [8]. Hence, they are a class of neural networks that are a huge breakthrough in image recognition. Thus, the approach presented here is a fundamental one, commensurate with the issue.

## 2. Literature Survey

Ammar Karkar and Shamim Haider [9], offers a comprehensive insight into electronic waste (e-waste) management practices, emphasizing the critical importance of appropriate disposal methods. E-waste management and disposal have become critical in an era of rapid technological advancement and widespread electronic device use. The report signifies how there is an urgently user-friendly tools are needed so that the nearby facility centers are located easily. The authors understand how important this issue is and so it aims to helps users to quickly locate approved disposal locations, which will promote responsible disposal of e-waste.

Neeraj Sachan and Shalini Agarwal, "Leveraging Information Technology for E-Waste Management, examines how information technology may be used to manage e-waste and the creation of digital tools for locating e-waste facilities. These findings highlight the difficulties that are currently facing e-waste management, as do related studies. It highlights how important digital tools and platforms can be in solving this urgent problem. These realisations combined provide the groundwork for appreciating the necessity of an e-waste facility locator website, which could have a big influence on appropriate e-waste disposal methods [10].

“Smart Garbage Collection Using GPS & Shortest Path Algorithm”. In order to solve the problem of collecting kitchen waste in urban areas, this paper suggests a method that can combine GPS technology with shortest path algorithm of garbage collection system. The suggested system has a number of benefits. By using a smartphone application, consumers can track garbage collection trucks in real-time, doing away with the need to wait by the side of the road. The application can direct a user to another nearby truck in case they miss the collection truck. This system offers an effective way to manage waste in urban areas while also saving the public money and time [11].

The study by Dharam Singh and Vikash Kumar (2023) talks about the various programmes that brings awareness among people about home electronic waste, issues related to the environment and improper electronic waste disposal. It also shows that the government conducts an effective e-waste programme and offers various recommendations for educating people and increasing awareness of e-waste among them. This study urges policymakers in India and other developing nations to create public awareness campaigns and citizen accountability for e-waste management.[12].

A CNN model review is given by Kumar et al. (2022) to construct an image prediction model for categorization of random images into predetermined classes. It talks about the independent API Keras which is used commonly [13]. Their model uses the Keras SGD optimizer. We are to use the Adam optimizer as it converges faster. The Convolutional layers, their suggested CNN infrastructure, and their benefits were examined by S. Yu et al. (2017)[14].

## 3. Methodology

The Major objectives of the E-waste facility Locator are 1) find nearest E-waste facility centers 2) Identify the E-waste type using image of e-waste based on that suggest suitable disposable way.

a) To provide users with the nearest E-waste facility centers, we will employ geolocation and mapping techniques. these include the integration of mapping service i.e., Google Map API to display nearest facility centers. This provides correct information of the locations which enables appropriate locating and disposing of e-waste.

b) For e-waste identification, we have employed a (CNN Convolutional Neural Network) model. This model plays a central role in identifying e-waste objects like mouse, keyboard, laptops etc.

The dataset of e-waste images was downloaded from *Roboflow* that consists of a total of 1493 images of Camera, Keyboard, Laptop, Microwave, Mobile, Monitor and Mouse. The images were resized to 100x100. The images in the dataset had the following preprocessing and augmentations:

- Auto-orient: applied
- The images are 90 degrees rotated both clockwise and counter-clockwise
- Saturation is applied to images
- Images of different brightness are included.
- Exposure is applied to images.

## 4. Proposed System

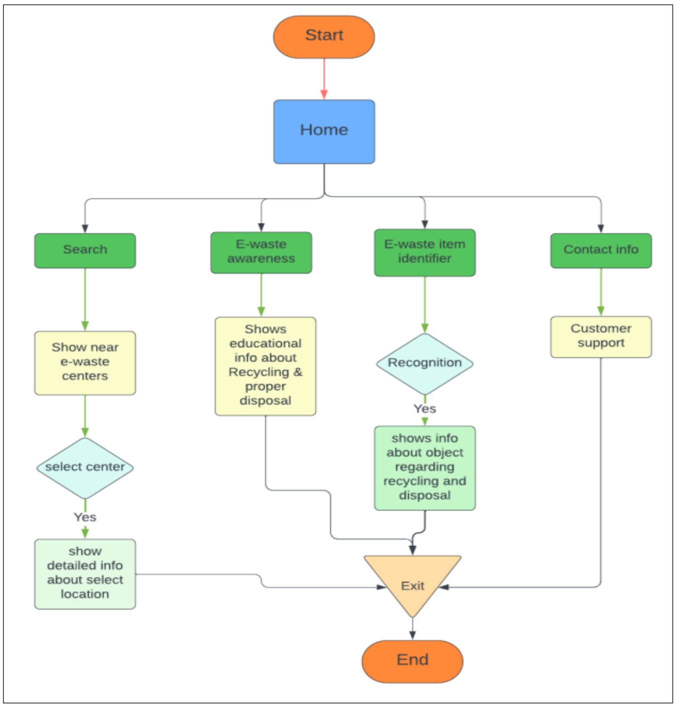



**Fig.1** Flowchart of our system

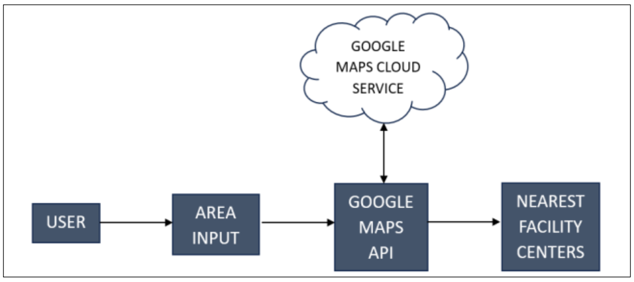



**Fig.2** Displaying nearest facility centers.

1)Figure 2 shows how the nearest facility centers are located. You need to first search the place where you want to find the centers and based on the search results, we will display the nearest centers. For this purpose, we used Google Map API, we used API key to use the Google map services. Along with that we also made use of Haversine formula [15] to find nearest centers.

Haversine Formula:

The formula is as follows: -

Inputs:

Latitude (φ1) of the first location (user's location).

Longitude (λ1) of the first location.

Latitude (φ2) of the second location (e-waste center).

Longitude (λ2) of the second location.

$$\Delta latitude = \varphi 2 - \varphi 1 \quad \dots (1)$$

$$\Delta longitude = \lambda 2 - \lambda 1 \quad \dots (2)$$

$$\frac{a\sin^2(\Delta latitude)}{2} + \cos(\varphi 1) * \cos(\varphi 2) * \frac{\sin^2(\Delta longitude)}{2} \quad \ldots (3)$$

$$c = 2.\,atan2\left(\sqrt{a}\sqrt{1-a}\right) \quad \ldots (4)$$

$$distance = R * c \quad \ldots (5)$$

Where,

A is the chord length between the points divided by two.

The angle measured in radians is denoted by c.

The Earth's radius, R is 6,371 km on average.

The difference or magnitude of changes in latitude (1) and longitude (2) is used in haversine formula calculations. Using the formula in (3), (4), and (5), we can determine the distance between two points based on (1) and (2).

***Algorithm for Haversine formula*:**

i) Firstly "EarthRadius" is to be declared and initialized with its value i.e., 6371. and the longitude, latitude, Haversine and distance are to be declared as integer variables additionally. Declare the following as Integer- longitude, latitude, Haversine, distance as integer.

ii) Now EarthRadius, longitude and latitude are read.

iii) Initialize longitude with (λ2 – λ1) in radians. Conversion from degrees to radian will be required.

iv) Similarly, Initialize latitude with (φ2 – φ1) in radians. Convert from degrees to radian.

v) Apply the formula Haversine formula (3)

vii) Calculate distance as EarthRadius * Haversine

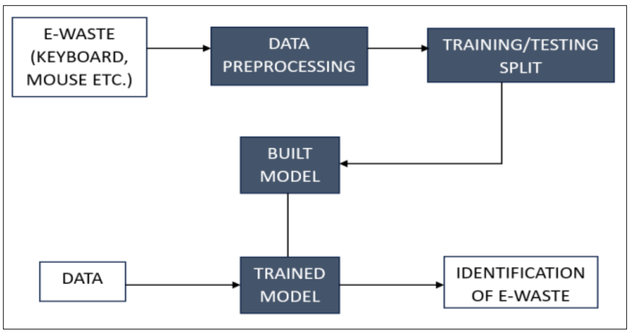



**Fig.3** Image identification model

2. For e-waste image identification, we built a CNN model. Block diagram is shown in Figure 3.

A basic description of how we built the CNN model step by step:

- Convolutional layers: Convolutional layers consist of filters that move across the input image performing mathematical operations to detect patterns. It captures features like edges and textures.

- Then we made use of the Rectified Linear Unit ReLu activation function.

- We compiled the model using adam optimizer (since we have multiclass identification) specifying the metrics as accuracy since we are using accuracy as our measure of performance of our model.

- Once compiling was done, we training of the model on the dataset of e-wate images was done. After training, the model identified e-waste images after the user uploaded an image of the waste item.

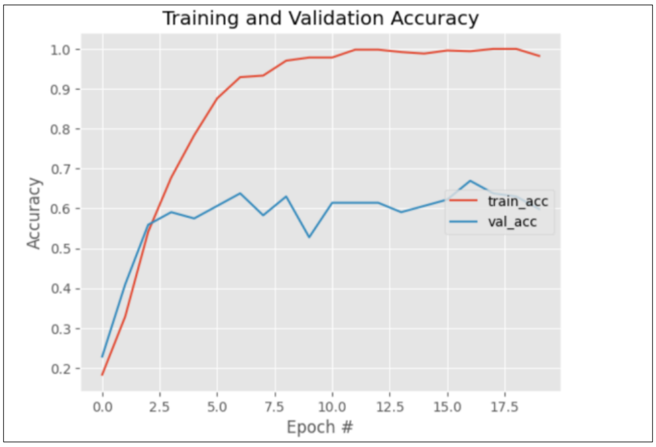



**Fig. 4** Training and Validation accuracy for 20 epochs

## V. TABLES OF ANALYSIS

**TABLE 1:** Qualitative comparison of various mapping APIs and location services (on a scale of 10)

| | Mapping Services | | | | |
|---|---|---|---|---|---|
| Parameter | Google Maps API | Open Street Map (OSM) | Mapbox | MapQuest API | Bing Maps API |
| Geocoding precision | 9 | 7 | 8 | 6 | 7 |
| Routing Efficiency | 9 | 7 | 8 | 6 | 7 |
| POI Data | 8 | 6 | 7 | 5 | 6 |
| Real-Time Data Quality | 9 | 6 | 8 | 6 | 7 |

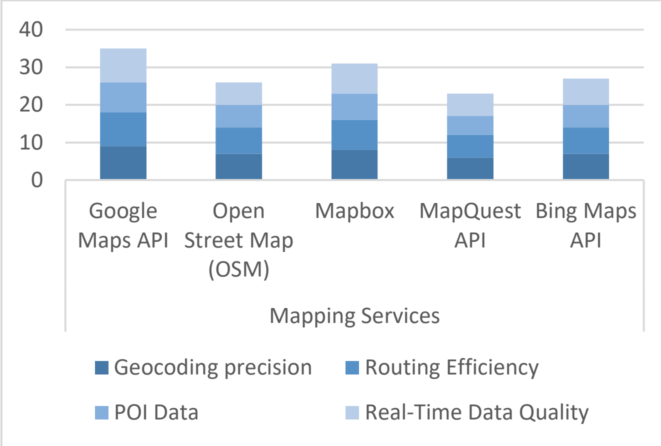



**Fig. 5:** Comparison of various mapping APIs

**TABLE 2**: Validation accuracy per epoch

| Epoch | Accuracy | Epoch | Accuracy |
|---|---|---|---|
| 1 | 0.351 | 11 | 0.662 |
| 2 | 0.450 | 12 | 0.668 |
| 3 | 0.568 | 13 | 0.656 |
| 4 | 0.543 | 14 | 0.668 |
| 5 | 0.625 | 15 | 0.687 |
| 6 | 0.581 | 16 | 0.687 |
| 7 | 0.650 | 17 | 0.693 |
| 8 | 0.662 | 18 | 0.687 |
| 9 | 0.668 | 19 | 0.706 |
| 10 | 0.662 | 20 | 0.698 |

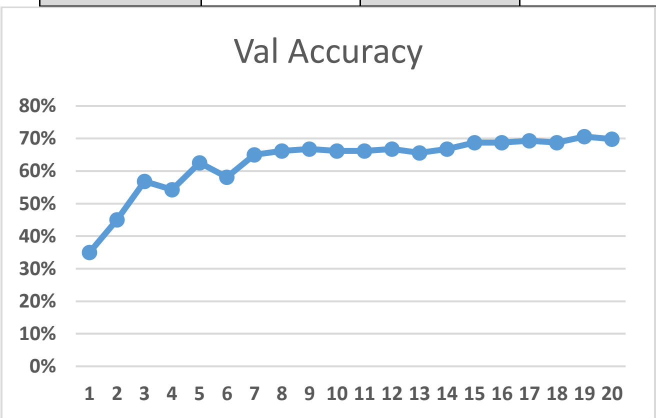



**Fig. 6:** Validation accuracy of model per epochs

The graph above shows how the validation accuracy increases with epochs.

The values below show the performance of the model based on different measures:

**TABLE 3:** Different measures of performance of the CNN model

| CNN Model for E-waste identification | |
|---|---|
| Accuracy | 70% |
| Precision | 67.7% |
| Recall | 66% |
| F1 score | 66.8% |

While accuracy indicates the incidence of how the model is correct overall, the precision of the model indicates the accuracy of its predictions for the target class. Recall reveals if an ML model can identify every object in the target class. F1 is the harmonic mean of the two values- precision and recall.

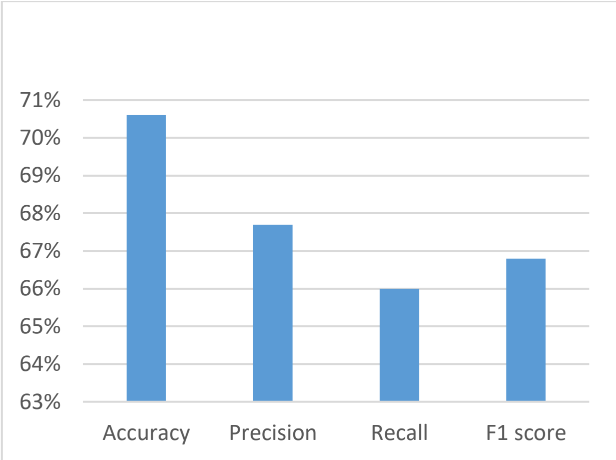



**Fig. 7:** Performance measures of the model

We also compared different algorithms and methods for image classification model. Below is the comparison-

**TABLE 4:** Comparison of classification algorithms

| Algorithm | Performance on small datasets | Performance on large datasets | Ability to capture spatial dependencies |
|---|---|---|---|
| CNN | Moderate | High | Yes |
| SVM | Moderate | Moderate | No |
| KNN | Low | Moderate | No |
| Logistic Regression | Moderate | Moderate | No |
| Decision Trees | High | Moderate | No |

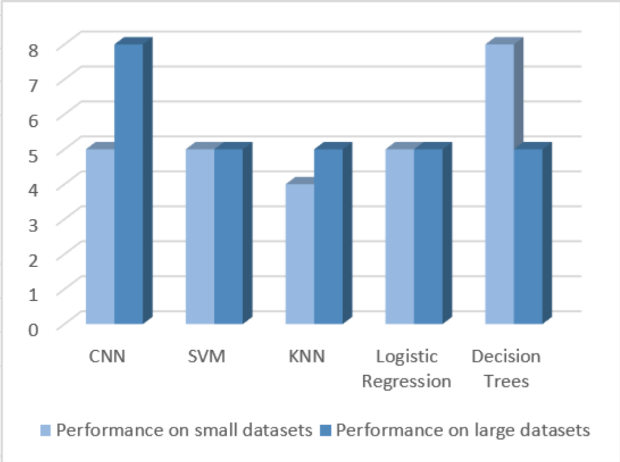



**Fig. 8:** Performance of algorithms based on dataset size

As a result, this e-waste facility locator can be used by different groups of people by increasing awareness about efficient e-waste disposal.

A qualitative summary of the possible usage levels across various user categories is given in Table 5.

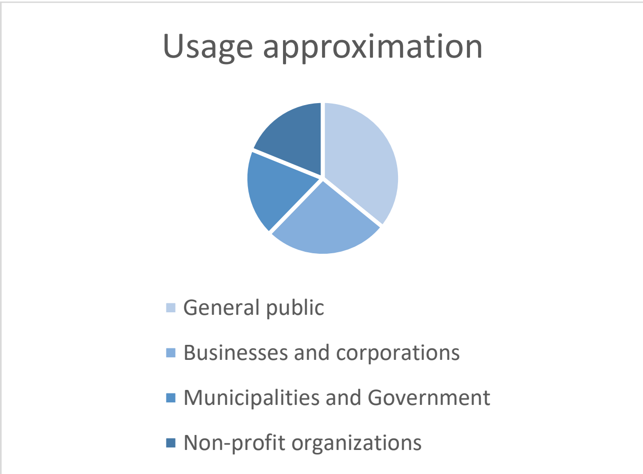



**Fig. 9:** Rough usage approximation of e-waste facility locator

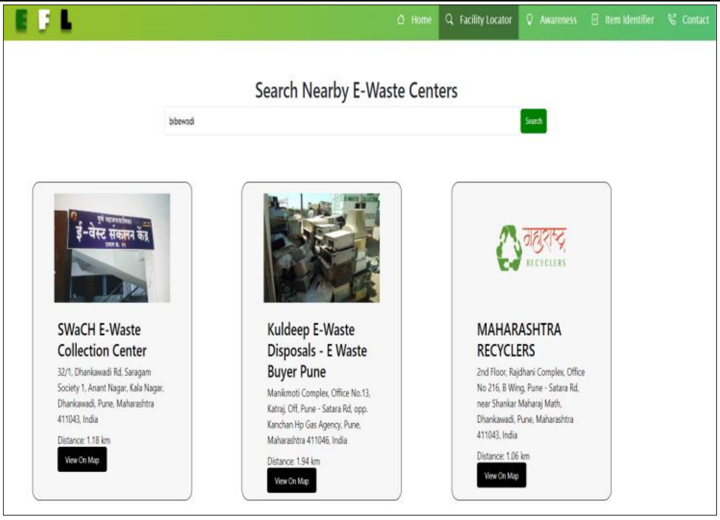
**TABLE 5:** Usage of e-waste facility locator by different groups

| Users | Usage approximation |
|---|---|
| General public | High usage because of increased awareness and convenient disposal. |
| Businesses and corporations | Moderate to heavy usage in the technology sector motivated by regulatory compliance policies and responsibility initiatives by the corporate. |
| Municipalities and Government | Moderate usage as they could make this a part of their various waste management initiatives. |
| Non-profit organizations | Moderate use in support of environmental and community outreach projects. |

The result of our system is shown below:

## 5. Results

| OUTPUT | DESCRIPTION |
|---|---|
| | In the Facility locator tab, after entering the location, the nearby facility centers are displayed. A view map option is also displayed that shows location and information in detail. |

<table>
<tr>
<td>


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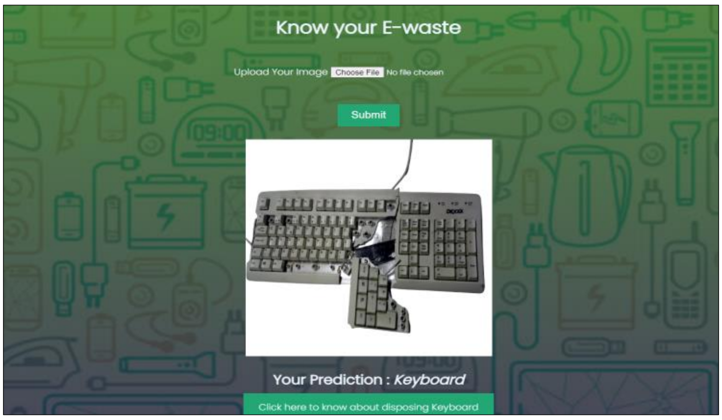
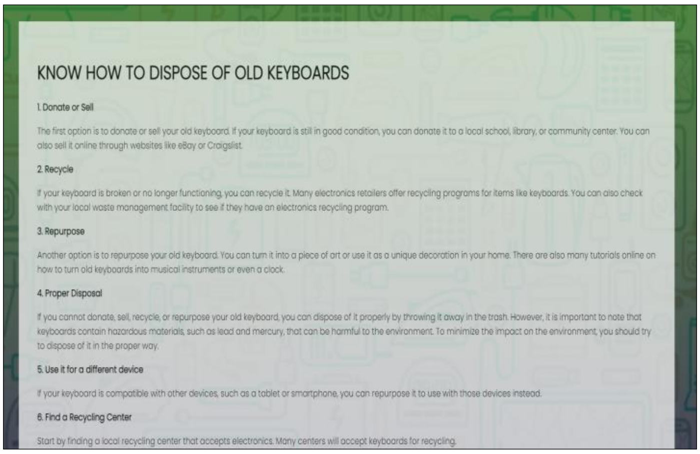


</td>
<td>In the item identifier tab, the users can upload pictures of their e-waste and the image identification model gives the prediction. A link is also displayed that provides suggestions on how to dispose the identified e-waste.</td>
</tr>
<tr>
<td>


</td>
<td>Clicking on the link redirects to the page where suggestions on how to dispose the e-waste are provided.</td>
</tr>
</table>

## 6. Discussion

The e-waste facility locator aptly locates the nearest centers depending on the area entered by the user as input. The CNN based image identification model integrated with this facility locator also identifies the e-waste image uploaded by the user with an accuracy of up to 70%. The dataset used to train the model was limited and covered only a few items and hence there is limited generalizability. The main goal however, as discussed is to reduce the environmental impact of e-waste by creating awareness among people [12]. Hence, this website can be used by any kind of users to contact their nearest e-waste recycling centers and identifying the waste to be recycled.

## 7. Scope of Research

Having an efficient system for sustainable e-waste management is necessary and hence this research can be explored under environmental science and pollution research.

The data necessary for e-waste image identification can be collected from various e-waste recycling centers, environmental organizations and disposal facilities for a wider range and better accuracy. The locator can be used to evaluate the energy efficiency, waste reduction strategies, and carbon footprint of E-waste facilities with respect to the environment. It could be utilized to identify only those centers that adhere to environmental laws and E-waste management standards. To keep up with evolving technology and rising E-waste management demands, the locator can be scaled and upgraded. Thus, the scope of research on an e-waste facility locator can encompass a broad range of environmental, social, and technical subjects

## 8. Future Scope

The e-waste facility locator system proposed by us is only the beginning. There is so much more to add to it to extend its capabilities. In the future, it could support a great range of features and a dataset larger than we have used for our system. It would include various kinds of e-waste items. We would also like to extend our partnerships with e-waste companies. Our platform would be kept updated after thoroughly studying the feedback from our users. We would put our efforts in making the overall user experience great by an even better user interface of our platform. Our objective will be to contribute in the betterment of the environmental health and the e-waste industry by addressing this very vital issue. This platform could also be taken at a global level to have an even higher impact on the environment positively.

## 9. Conclusion

Hence we suggested a solution by making a website that locates nearby e-waste facilities depending on the location entered by the user and also by integrating an image identification model to identify e-waste items. As discussed before, the e-waste management issue needs immediate action to be taken on. Lack of knowledge on electronic waste and its effects would damage the environment and deteriorate human health as well. In India, even though the government has taken different initiatives for proper e-waste management like 'Gandhian E-waste management system', it still remains a tough challenge since all citizens do not act responsibly. Being responsible citizens, awareness regarding this issue is necessary. Thus, we aimed to address this problem and provide an efficient solution.

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