# Introduction

This project proposes the implementation of a recycling solution to reduce waste. The project focuses on the collection and sorting of materials for reuse. The goal of the project is to design and develop a recycling solution that utilizes image recognition technology for the categorization of recyclable waste. This solution aims to improve the accuracy, efficiency, and sustainability of waste management practices by automating the sorting and categorization process. The recycling solution is intended to be a cost-effective, user-friendly tool that promotes sustainability which can aid individuals and organizations in their recycling efforts. This project involves a comprehensive analysis of the current state of waste management practices, the potential of image recognition technology, and the development and testing of a prototype recycling solution. This report highlights the objectives, methodology, results, and implication of the recycling solution with the results on this project will contribute to the advancement of sustainable waste management practices and promote the adoption of innovative technologies in the recycling industry.

# Objectives

The main objective of the project is to design and develop an efficient and effective recycling solution that utilizes image recognition technology to categorize recyclable waste. The purpose of this research is to explore the feasibility of utilizing image recognition technology in the recycling sector and to assess its effectiveness in facilitating application waste management protocols as well as educating users on proper disposal practices.

**Analyzing the current state of waste management practices:** This objective involves conducting an in-depth evaluation of the prevailing waste management procedures in Windsor ON, the assessment comprises an examination of the present collection, and recycling facilities, along with an identification of the challenges and prospects for enhancement. The analysis will be based on on-site assessments to acquire a comprehensive perception of the extant waste management approaches.

**Investigating the potential of image recognition technology:** This objective entails studying in-depth the analysis of the prospective utility of image recognition for the purpose of categorizing recyclable waste. The investigation will include an exhaustive review of the relevant literature on image recognition technology and its practical applications in the field of waste management. Furthermore, the investigation will involve identifying and evaluating various image recognition algorithms and models to determine the optimal approach for the proposed recycling solution.

**Designing and developing a recycling solution:** This objective involves the conception, design and construction of a prototype recycling solution that leverages image recognition technology for the purpose of categorization of recyclable waste. The solution will be founded based on the analysis, scrutiny of existing waste management practices and the inquiry of image recognition technology. This solution will comprise a software component which will have two prominent features image recognition and a knowledge base of recycling waste. The image recognition component will be predicated on the elected image recognition algorithm and model will be fine-tuned for precision, speed and expandability.

**Evaluating the effectiveness and efficiency of the developed recycling solution:** This objective involves validation of the accuracy, speed, and user-friendliness of the developed recycling solution. The validation will be predicated on a series of trials that involves the procession of diverse categories of recyclable waste through the developed solution. The evaluation will also encompass user feedback and usability testing to identify areas that require enhancement and additional development.

**Providing recommendations for further development and improvement:** This objective involves offering insights and recommendations for the further development and amelioration of the recycling solution. The recommendations will be based on the outcomes of the analytical, investigatory, and evaluating phases of the research project. The recommendations will focus on optimizing the performance of the recycling solution, enhancing its capabilities, and increasing its scalability.

The metrics used to gauge the effectiveness of this solution would be the % of recycle request the city of Windsor would receive.

# Related Works

**Scrap Uncle:** Scrap Uncle is a service that is currently being implemented in India. The service offers citizens the possibility to sell their recyclable trash by scheduling a pickup location. A company expert arrives at the location and gives the client a price estimation of their waste and gives a payment to the client. The service is implemented through a website and a mobile application. The user can schedule the pickup through the app or website, and the expert arrives at the scheduled time to evaluate and purchase the waste. The service is designed to promote the recycling of trash and reduce waste in landfills.

**iRecycle:** iRecycle is a mobile application that helps customers sort and bin their recyclable items. The app is implemented in various locations around the world, including the United States and Europe. The app allows users to browse for the materials they want to recycle and find the recyclers who will take them or inform them where they can drop their waste. The app provides information on recycling centers and other recycling-related information. The app is designed to promote recycling and make it easier for people to recycle their waste.

**Recyclemap:** Recyclemap is a nonprofit project that is implemented in various locations around the world, including the United States, Canada, and Europe. The project helps in waste segregation and residential waste recycling in local communities by providing easy access to information about the closest recycling point in their living area. The project also educates citizens about waste segregation and recycling so they can improve ecological situations. Recyclemap is implemented through a website and a mobile application. Users can access the website or app to find recycling points in their area, and they can also contribute by adding new recycling points to the map.

Overall, these initiatives aim to promote recycling and reduce waste in landfills. They are implemented through websites and mobile applications and are designed to make recycling easier for people. By promoting ethical practices, these initiatives ensure that they do not contribute to any negative impact on the environment or society.

# Methods

The Exploratory Data Analysis (EDA) process for a recycling app that is aimed to recycle glass bottles, tin cans, cardboard, and plastic bottles using object detection algorithm involves several methods to ensure the app is effective and efficient in achieving its objectives.

The first method is data collection. The app will require a large amount of data to train its object detection algorithm to recognize recyclable items accurately. The app developers can collect data by taking pictures of the recyclable items or sourcing for existing datasets. The collected data should be comprehensive, diverse, and relevant to ensure the object detection algorithm can accurately identify the recyclable items. Then, The collected data will require preprocessing to clean it and prepare it for analysis. Data preprocessing involves tasks such as data cleaning, data normalization, data transformation, and data reduction. These tasks ensure that the data is in the right format, is accurate, and is ready for analysis.

Data visualization involves creating visual representations of the data to help the developers and users of the app understand the data better. The developers can use visualizations such as histograms, scatter plots, and bar charts to understand the distribution of the data, identify patterns, and detect outliers.

Feature engineering involves selecting the most important features from the data and creating new features to improve the accuracy of the object detection algorithm. The developers can use techniques such as principal component analysis (PCA), feature selection algorithms, and clustering algorithms to identify the most important features.

Model building involves developing a machine learning model that can accurately detect and classify the recyclable items. The developers can use algorithms such as Convolutional Neural Networks (CNNs), Support Vector Machines (SVMs), and Random Forests to build the model. The model should be trained using the preprocessed data, and the performance should be evaluated using metrics such as accuracy, precision, and recall.

Model deployment involves integrating the trained model into the app and making it available to users. The app should have a user-friendly interface that allows users to take pictures of the recyclable items and receive a recycling price suggestion based on the number of items detected. The app should also notify pickers in the near me area about the ad posted about the recycling item along with the suggested price so that they can pick up the recyclables and take them to the nearest recycling place to get the approximate payment.

In conclusion, the EDA process for a recycling app that is aimed to recycle glass bottles, tin cans, cardboard, and plastic bottles using object detection algorithm involves several methods, including data collection, data preprocessing, data visualization, feature engineering, model building, and model deployment. The developers must ensure that the app is accurate, efficient, and user-friendly to achieve its objectives effectively. With a well-executed EDA process, the app can help reduce waste and improve the ecological situation by encouraging recycling.

1. Dataset

Cleaning and processing data is a crucial step in any machine learning project, including the development of a recycling app that uses object detection algorithms to identify and price different recyclable items. The raw data collected from users' pictures can be messy and inconsistent, with a variety of errors and inaccuracies that can impact the accuracy of the model's predictions. Therefore, data cleaning and processing is necessary to ensure that the data is consistent, accurate, and ready for analysis and modeling. This bar plot represents the counts of objects that we are targeting:

Chart, bar chart

Description automatically generated

The first step in cleaning and processing the data is to ensure that the pictures are correctly identified and categorized based on the type of recyclable item they contain, such as glass bottles, tin cans, cardboard, or plastic bottles. This requires a combination of manual and automated processes, including image recognition algorithms that can analyze the pictures and identify the presence of different recyclable items. The manual processes involve trained personnel who can accurately identify and categorize the images and review them for any errors or inconsistencies. Here is images of the object that we are targeting in our project:

**Chart

Description automatically generated**

Once the images have been identified and categorized, the next step is to ensure that the data is consistent and accurate. This involves identifying and correcting any errors or inconsistencies in the data, such as missing values, duplicate entries, or incorrect labels. For example, if there are multiple entries for the same item with different labels or values, these must be corrected to ensure that the data is consistent and accurate.

The data must also be processed to ensure that it is in a format that can be easily analyzed and modeled. This includes converting the raw data into a structured format, such as a table or spreadsheet, with columns and rows that can be easily analyzed and manipulated. The data must also be transformed and cleaned to remove any outliers or anomalies that could skew the analysis or modeling.

During the cleaning and processing of the data, it is important to ensure that the privacy and security of users' data are protected. This includes ensuring that the data is stored securely and that access is restricted to authorized personnel only. The app must also comply with all relevant data protection and privacy regulations, such as GDPR or CCPA.

In conclusion, cleaning and processing data is an essential step in the development of a recycling app that uses object detection algorithms to identify and price different recyclable items. It involves a combination of manual and automated processes, including image recognition algorithms, manual categorization, and data processing and transformation. The aim is to ensure that the data is consistent, accurate, and in a format that can be easily analyzed and modeled while also maintaining the privacy and security of users' data. By taking these steps, the app can be developed with a high level of accuracy and reliability, making it a valuable tool in promoting recycling and environmental sustainability.

1. Exploratory Data Analysis

**Data Collection and Pre-processing:** The first step in any data analysis project is to collect and clean the data. In the context of the recycling app, this would involve collecting images of the recyclable objects such as glass bottles, tin cans, cardboard, and plastic bottles. These images can be obtained from various sources such as the internet, social media platforms, or crowdsourcing. The data should be pre-processed to ensure that it is in a format that is suitable for analysis. This could involve resizing, normalizing, and cropping the images.

**Data Visualization:** Data visualization is a powerful tool for understanding the data and identifying patterns. Histograms and box plots can be used to visualize the distribution of the variables, while scatter plots can be used to visualize the relationship between variables. In the context of the recycling app, histograms and box plots can be used to visualize the distribution of the number of objects detected in each image, while scatter plots can be used to visualize the relationship between the type of object detected and the location where it was detected.

**Statistical Analysis:** Statistical analysis can provide insights into the dataset and help identify trends and patterns. Measures such as mean, median, mode, standard deviation, and variance can be used to describe the dataset. In the context of the recycling app, statistical analysis can be used to determine the average number of objects detected in each image and the distribution of the types of objects detected.

**Machine Learning Techniques:** Machine learning techniques such as clustering, dimensionality reduction, and classification can be used to identify patterns and relationships in the data. In the context of the recycling app, clustering can be used to group images with similar types and numbers of objects, while classification can be used to categorize images based on the type of object detected.

**Data Augmentation:** Data augmentation is the process of generating additional data from the existing dataset. This can be done by adding noise to the data, rotating the images, or flipping them horizontally or vertically. In the context of the recycling app, data augmentation can be used to generate additional images of the same objects from different angles and perspectives.

In summary, the EDA process for a recycling app that uses object detection algorithms involves collecting and pre-processing the data, visualizing the data using histograms, box plots, and scatter plots, conducting statistical analysis to describe the dataset, using machine learning techniques such as clustering and classification to identify patterns and relationships in the data, and using data augmentation to generate additional data. By conducting a thorough EDA process, we can gain a deeper understanding of the dataset and make informed decisions about the machine learning models that we develop for the recycling app.

# Application of the Five Ethics Principles

**Consent:** The application will obtain informed consent from users before collecting and using their personal data. This means that the application will provide clear and transparent information about the types of data that will be collected, how it will be used, and who will have access to it. Users will have the option to opt-in or opt-out of data collection, and they should be able to revoke their consent at any time.

**Control:** The application will give users a high degree of control over their data. This means that users should be able to control what data is collected, how it is used, and who has access to it. The application will have clear and easy-to-use privacy settings that allow users to manage their data preferences and make informed decisions about how their data is used.

**Clarity:** The application will be designed to be clear and easy to understand for users. This means that it will provide clear instructions on how to use it, what it does, and what data it collects. The application will also use plain language and avoid technical jargon, so that users of all backgrounds can understand it. Additionally, the application will have a clear and easy-to-access privacy policy that provides detailed information about data collection, usage, and sharing.

**Consistency:** The application will be designed to operate consistently and reliably. This means that the application will be thoroughly tested before release to ensure that it functions as intended. Additionally, the application will be regularly updated and maintained to ensure that it remains compatible with current operating systems and technologies. It will be designed to minimize errors and reduce the risk of incorrect detections, and users will be notified in the event of an error or malfunction.

**Consequences:** The application will be designed to minimize negative consequences for users and the environment. This means that the application will be designed to ensure that users are not misled or given inaccurate information about recyclable materials. Additionally, the application will be designed to minimize the risk of false detections or incorrect categorizations, which could lead to waste contamination or damage to recycling facilities. It will also be designed to protect user privacy, by ensuring that user data is stored securely and is not shared with third parties without user consent.

# Performance metrics

**Precision:** This measures the accuracy of the model's predictions. It is calculated by dividing the number of correctly identified recyclable items by the total number of identified items. A high precision value indicates that the model has few false positives, or items that were identified as recyclable but are not.

**Recall:** This measures the model's ability to identify all the relevant recyclable items in the dataset. It is calculated by dividing the number of correctly identified items by the total number of recyclable items in the dataset. A high recall value indicates that the model has few false negatives, or items that were not identified as recyclable but are.

**F1 Score:** This is the harmonic mean of precision and recall. It is used to give equal weight to both precision and recall. A high F1 score indicates that the model is both precise and has a high recall rate.

**Mean Average Precision (MAP):** This is used to evaluate the accuracy of the model at different thresholds. It is calculated by taking the average of the precision values at different recall levels.

To ensure that the model is performing well, it is important to evaluate it on a diverse range of data that includes different types of recyclable items, different lighting conditions, and different backgrounds. The model's performance should be evaluated periodically and adjusted as needed to maintain its accuracy.

It is also important to consider the computational resources required to run the object detection algorithm. The size of the dataset and the complexity of the model can greatly impact the computational resources required to run the algorithm. It is important to strike a balance between accuracy and computational efficiency to ensure that the model can run in real-time on mobile devices.

Another important factor to consider is the impact of false positives and false negatives. False positives can result in non-recyclable items being identified as recyclable, which can result in contamination of the recycling stream. False negatives, on the other hand, can result in recyclable items being missed, which can reduce the effectiveness of the recycling program. It is important to minimize both false positives and false negatives to ensure that the model is effective in identifying recyclable items. Here is a Confusion matrix representing false positives and false negatives of the base model:

Chart

Description automatically generated

In conclusion, evaluating the performance of a recycling app that uses object detection algorithms is essential to ensure that the app is accurate and effective. Performance metrics such as precision, recall, F1 score and mAP can be used to evaluate the model's accuracy, and it is important to consider the impact of false positives and false negatives. The computational resources required to run the algorithm should also be considered, and the model's performance should be evaluated periodically to maintain its accuracy.

1. Limitations

More images to train the neural network model as they require a lot of pictures to really get high accuracy.

While the recycling app described has numerous benefits, there are also some limitations to consider. One of the biggest limitations is the accuracy of the object detection algorithm. While it has been shown to be effective in identifying and categorizing items, there is still room for error. For example, the algorithm may have difficulty differentiating between two similar-looking items, such as a plastic water bottle and a sports drink bottle. This could result in inaccurate pricing suggestions or misclassification of recyclables.Another limitation of the app is the reliance on user-generated content. While this is a key feature that allows users to post ads for their recyclables, it also means that the quality and accuracy of the information provided can vary. Users may not always provide accurate descriptions or pricing suggestions for their recyclables, which could impact the effectiveness of the app in connecting pickers with recyclers.

Another potential limitation is the need for a reliable internet connection. Without a stable and fast internet connection, users may have difficulty accessing the app, uploading photos, or receiving notifications about new ads. This could limit the app's effectiveness, particularly in areas with poor internet connectivity or in regions where access to mobile data is limited.The app may also face challenges in terms of user adoption and engagement. While there is a growing interest in sustainability and recycling, not all users may be willing or able to use the app. Some users may prefer to recycle through more traditional means, such as taking their recyclables directly to a recycling center. Others may be hesitant to use the app due to concerns about privacy or security.

In addition, the app may face challenges in terms of scaling and sustainability. As the app becomes more popular and attracts a larger user base, there may be increased demands on the server infrastructure and technical support. This could require significant investments in technology and personnel to maintain and scale the app. Furthermore, the app's effectiveness may be limited by regulatory or policy factors. For example, some areas may have restrictions on the types of recyclables that can be collected or the prices that can be offered for recycling. These regulations may vary by region or country, which could impact the app's ability to function effectively in certain areas.

Finally, the app may face challenges in terms of financial sustainability. While the app's revenue model is based on a percentage of the transaction fees between the pickers and recyclers, it may take time for the app to attract a large enough user base to generate significant revenue. In the meantime, the app may require ongoing investments in marketing, technology, and personnel to continue operating.

In conclusion, while the recycling app has the potential to revolutionize the way we recycle, it is important to consider the potential limitations and challenges. By understanding and addressing these limitations, we can work towards building a more effective and sustainable recycling app that benefits both individuals and the environment.

1. Conclusion

With the increasing population and consumerism, it is important to develop sustainable ways of handling waste, and this app provides a convenient way for people to recycle and earn some money in the process.

The development process of the app involves data collection, cleaning, processing, and analysis. The data collection process involves obtaining images of the recyclable materials that will be used to train the object detection algorithm. The images are collected from different sources and labeled accordingly to ensure the algorithm learns to recognize the objects accurately.

Cleaning and processing the data involve removing any noise or irrelevant information that may hinder the algorithm's accuracy. This process also involves resizing the images to a standard size and converting them to the appropriate format for training. The cleaned and processed data is then used to train the object detection algorithm, which is an essential step in ensuring that the app can accurately recognize the recyclable materials.

The app's user interface is designed to be user-friendly, making it easy for users to take pictures of the recyclable materials and post them on the app. The app's backend processes the images using the object detection algorithm and provides users with an estimated recycling price based on the number of items in the picture. Pickers, who are another type of user, are notified of the ad posted about the recycling item along with the price in their near me locations, which enables them to collect the recyclables and take them to the nearest recycling place to earn money.

The performance metrics of the app are evaluated based on various factors such as accuracy, speed, and ease of use. The accuracy of the app's object detection algorithm is crucial in ensuring that the recyclable materials are recognized correctly. The speed of the app is also essential, as users want a fast and efficient experience when using the app. The app's ease of use is another important performance metric, as users want a simple and straightforward app that is easy to navigate.

The app's limitations include the accuracy of the object detection algorithm, which may be affected by various factors such as lighting, angle, and distance. The app's performance may also be limited by the quality of the images posted by users. Additionally, the app's effectiveness may be limited by the availability of pickers to collect the recyclables.

In conclusion, the development of a recycling app that uses object detection algorithms to recognize recyclable materials provides a convenient and sustainable solution to the growing waste problem. The app's user interface is designed to be user-friendly, making it easy for users to recycle and earn some money in the process. The app's performance metrics are evaluated based on accuracy, speed, and ease of use, and its limitations include the accuracy of the object detection algorithm, the quality of the images posted, and the availability of pickers.

Overall, the development of the recycling app provides a great opportunity to contribute to the reduction of waste and the promotion of sustainable living. With further improvements in the app's performance and increased awareness, it has the potential to revolutionize waste management and promote a cleaner and healthier environment.

1. Apendices

* **Github link:** [**https://github.com/DhyeyPatel074/RecycleMates.git**](https://github.com/DhyeyPatel074/RecycleMates.git)
* **Datasets links :** [**https://github.com/DhyeyPatel074/RecycleMates.git**](https://github.com/DhyeyPatel074/RecycleMates.git)

### Work done

|  |  |
| --- | --- |
| Weekly Schedule | Plan of Action |
| Week 1-3 |  |
| Week 4-6 |  |
| Week 6-8 |  |
| Week 8-10 |  |
| Week 10-12 |  |

### Upcoming Plan

|  |  |
| --- | --- |
| Weekly Schedule | Plan of Action |
| Week 1-3 |  |
| Week 4-6 |  |
| Week 6-8 |  |
| Week 8-10 |  |
| Week 10-12 |  |

# References/Articles

<https://www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/reduce-plastic-waste.html>

<http://web.cecs.pdx.edu/~singh/rcyc-web/index.html>

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