Gurpreet Kaur , 2026, 14:4
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology
An Open Access Journal

AI Driven Scrap Classification and Price Prediction Using CNN and Random Forest Regression for Circular Economy Applications

Gurpreet Kaur, Firoz Ansari, Angad Gupta

Abstract- The increasing generation of household waste and the informal nature of scrap trading have created challenges related to price transparency, material classification, and efficient reuse of recyclable resources. This study proposed an artificial intelligence-driven digital platform that integrated scrap trading, second-hand product resale, automated scrap classification, price prediction, and dealer matching within a unified ecosystem. A Convolutional Neural Network was employed to classify scrap images into plastic, metal, paper, glass, and electronic waste categories. Random Forest Regression was applied to predict scrap prices using material type, weight, volume, market demand, and prevailing market rates. A location-based matching mechanism was also incorporated to connect users with suitable nearby scrap dealers. The experimental evaluation showed that the proposed classification model achieved an accuracy of 94.2 percent, while the price prediction model obtained a Mean Absolute Error of 2.1, a Root Mean Square Error of 3.4, and an R squared score of 0.91. The findings indicated that the integrated approach improved scrap identification, pricing transparency, and transaction efficiency. The proposed platform provides a scalable digital approach that supports material reuse, sustainable waste management, and circular economy practices.

Keywords: Artificial Intelligence, Scrap Classification, Price Prediction.

I. INTRODUCTION

The increasing generation of household waste has created significant challenges for sustainable waste management and resource utilization. Rapid urbanization, population growth, and changing consumption patterns have increased the quantity of recyclable and reusable materials generated by households. Effective collection, classification, recycling, and reuse of these materials are essential for reducing environmental pressure and supporting circular economy practices [1].

In India, the scrap management sector continues to depend substantially on informal collection and trading practices. Households often have limited access to transparent information regarding the market value of recyclable materials. As a result, scrap prices may vary between dealers, and users may experience difficulty in determining a fair selling price. Digital technologies and artificial intelligence are increasingly being explored to improve waste classification, recycling efficiency, and intelligent waste management [2], [7]. Previous studies investigated machine learning and deep learning techniques for waste classification and recycling management [3], [8], [10]. These approaches demonstrated the potential of image-based classification for identifying different categories of recyclable materials. Other studies explored recommender systems and intelligent digital technologies for improving waste management processes [5], [6]. However, existing research has generally focused on individual functions, such as waste classification, recycling, or recommendation systems, rather than integrating these capabilities within a unified scrap trading and resale platform.

A significant research gap therefore exists in combining automated scrap classification, fair price prediction, location-based dealer matching, and second-hand product resale within a single digital ecosystem. The informal nature of scrap trading, limited pricing transparency, and insufficient digital connectivity between households and scrap dealers remain important practical challenges. Existing approaches provide limited support for users who require both material identification and transparent price estimation before completing a scrap transaction.
This study proposed an artificial intelligence-driven digital platform that integrated scrap classification,

price prediction, dealer matching, and second-hand product resale. A Convolutional Neural Network was used for image-based scrap classification, while Random Forest Regression was applied for scrap price prediction. A location-based matching mechanism was incorporated to connect users with suitable nearby scrap dealers. The proposed system aimed to improve pricing transparency, transaction efficiency, material reuse, and sustainable waste management while supporting circular economy practices.

II. LITERATURE REVIEW

Previous research has explored the application of artificial intelligence, machine learning, and digital technologies in waste management and recycling systems [2], [7], [8]. Waste classification has emerged as an important research area because accurate identification of recyclable materials can improve sorting efficiency and reduce manual effort. Deep learning-based image classification approaches have demonstrated the ability to identify materials such as plastic, metal, paper, glass, and electronic waste from visual data [3], [10].
Convolutional Neural Networks have been widely investigated for image-based waste classification because of their ability to automatically extract relevant visual features [3], [10]. Existing classification approaches have primarily focused on identifying and separating waste categories. Although these systems improved material recognition, their functionality generally ended after classification and provided limited support for pricing, trading, or connecting users with scrap dealers.

Research on intelligent waste management has also examined machine learning, Internet of Things technologies, and recommendation mechanisms [2], [5], [6]. These approaches improved waste monitoring, collection, and resource management. However, many existing systems were designed for specific waste management functions and lacked integration with user-oriented digital marketplaces. Scrap price estimation and transparent valuation have received comparatively limited attention, particularly in informal scrap trading environments [9].

Second-hand digital marketplaces have supported product reuse by allowing users to buy and sell previously owned products. These platforms contribute to circular economy practices by extending product life cycles [11]. However, conventional resale platforms generally depend on manual product listing and valuation and do not integrate automated scrap classification, intelligent price prediction, or location-based scrap dealer matching.

The analysis of previous studies revealed a gap in the integration of automated scrap classification, price prediction, dealer matching, and second-hand product resale within a unified digital platform. Existing research has generally addressed these functions independently. The present study addressed this gap by proposing an artificial intelligence-driven ecosystem that combined Convolutional Neural Network-based scrap classification, Random Forest Regression-based price prediction, location-based dealer matching, and second-hand product resale to improve transparency, efficiency, and sustainable material reuse.

A comparative analysis of existing waste classification, second-hand marketplace, traditional scrap dealer, and smart recycling approaches is presented in Table I. The comparison highlights the functional differences between existing approaches and the proposed integrated system.

TABLE I Comparison of Existing Systems

Existing System	Method Used	Key Features	Limitations
Waste classification systems	CNN-based image recognition	Automatic waste identification	No resale or dealer connection; classification only

Existing System	Method Used	Key Features	Limitations
Second-hand marketplaces	Product listing platforms	Product reuse and resale	No AI price prediction; manual valuation only
Traditional scrap dealer systems	Manual valuation	Direct scrap collection	No transparency; no digital platform; prone to bias
Smart recycling platforms	IoT and basic machine learning	Waste monitoring and collection	Limited user interaction; weak price forecasting
Proposed system (this work)	CNN and Random Forest Regression with digital marketplace integration	Scrap classification, price prediction, dealer matching, and second-hand product resale	Requires diverse training data, regional price adaptation, and practical deployment evaluation

As shown in Table I, existing approaches generally focus on individual functions such as waste classification, resale, manual scrap valuation, or waste monitoring. The proposed system integrates scrap classification, price prediction, dealer matching, and second-hand product resale within a unified platform. However, further evaluation using diverse regional datasets and practical deployment environments is required.

III. PROBLEM STATEMENT

The existing scrap management process faces significant challenges related to pricing transparency, material identification, and communication between households and scrap dealers. Many users have limited information regarding the market value of recyclable materials, which may result in inconsistent pricing and difficulty in determining a fair selling price. The absence of reliable price estimation mechanisms can also reduce trust between users and scrap dealers.

Reusable products and recyclable materials may be discarded because users have limited access to integrated digital platforms for resale and scrap trading. Scrap dealers also experience difficulties in identifying potential customers and managing collection requests efficiently. Existing digital solutions generally address waste classification, recycling, or second-hand resale as separate functions and provide limited integration between these services.

Therefore, there is a need for an intelligent and integrated digital platform that can support automated scrap classification, transparent price prediction, efficient dealer connectivity, and second-hand product resale. Such a system can improve transaction efficiency, increase pricing transparency, encourage material reuse, and support sustainable waste management practices.

IV. PROPOSED SYSTEM

The proposed system was designed as an artificial intelligence-driven digital marketplace that integrated households, scrap dealers, and second-hand product buyers within a unified platform. The system consisted of user, dealer, and artificial intelligence modules that supported scrap trading, material classification, price prediction, dealer connectivity, and product resale.

The user module enabled users to register on the platform, upload scrap images, list recyclable materials and second-hand products, and obtain an estimated price for scrap materials. The dealer module enabled registered scrap dealers to access relevant scrap listings, connect with users, and manage collection requests. These modules were designed to improve communication and transaction efficiency between users and scrap dealers.

The artificial intelligence module integrated scrap image classification and price prediction. A Convolutional Neural Network was used to identify the category of scrap material from uploaded images. The classification process considered plastic, metal, paper, glass, and electronic waste categories. Random Forest Regression was used to estimate scrap prices based on material type, weight, quantity, market demand, and prevailing market rates.

The proposed system also incorporated a location-based dealer matching mechanism that connected users with suitable nearby registered scrap dealers. Dealer availability, distance, and collection capability were considered during the matching process. The platform additionally supported second-hand product resale to encourage product reuse and reduce unnecessary waste generation.

The novel contribution of the proposed system was the integration of automated scrap classification, intelligent price prediction, location-based dealer matching, and second-hand product resale within a single digital ecosystem. Unlike existing approaches that generally focused on individual waste management functions, the proposed system combined these capabilities to improve pricing transparency, transaction efficiency, material reuse, and circular economy practices.

The overall workflow of the proposed AI-driven scrap and resale marketplace is presented in Figure 1. The system architecture and interaction between the major platform components are illustrated in Figure 2. The scrap price prediction process using the selected input features and regression model is presented in Figure 3.

A CNN-Based Scrap Classification

The proposed framework employed a Convolutional Neural Network for the automated classification of scrap materials based on images uploaded by users. The classification model was designed to identify five major scrap categories, including plastic, metal, paper, glass, and electronic waste. An uploaded scrap image was processed by the classification model, and the corresponding material category was predicted automatically.

The image dataset was preprocessed before model training to improve classification consistency. Input images were resized to a uniform dimension and prepared for the training process. The dataset was divided into training and testing subsets using an 80:20 ratio. The classification model was trained to learn visual characteristics associated with each scrap category.

The CNN architecture consisted of an input layer, convolutional layers, ReLU activation functions, max pooling layers, a flattening layer, fully connected layers, and a softmax output layer. The convolutional layers extracted relevant visual features from the scrap images, while the pooling layers reduced feature dimensions and computational complexity. The fully connected layers processed the extracted features, and the softmax output layer generated the predicted scrap category.

The performance of the classification model was evaluated using accuracy, precision, recall, and F1 score. These evaluation metrics were used to assess the ability of the model to correctly classify different scrap materials and analyze the overall reliability of the image classification process.

B Random Forest Regression for Price Prediction

The proposed system employed Random Forest Regression to predict the market price of scrap materials. The model was selected because of its ability to handle nonlinear relationships among multiple input variables and provide reliable predictions for complex datasets. The price prediction process was designed to improve pricing transparency and assist users in estimating the expected value of their scrap materials.

The prediction model considered several input features, including scrap type, weight, quantity, geographical location, prevailing market rate, and market demand. These features were used to estimate the expected price of the scrap material.

User input and available pricing data were processed before being supplied to the regression model. The collected data were pre-processed to identify missing values, remove inconsistent records, and prepare the input features for model training. Categorical attributes were converted into a suitable numerical representation, and relevant features were selected for the prediction process. The dataset was divided into training and testing subsets using an 80:20 ratio.

The Random Forest Regression model was trained using the prepared training dataset and was evaluated on the testing dataset. Model performance was assessed using Mean Absolute Error, Root Mean Square Error, and the coefficient of determination. These evaluation metrics were used to measure prediction error and determine the ability of the model to estimate scrap prices.

C Dealer Matching Algorithm

The proposed platform incorporated a location-based dealer matching mechanism to improve connectivity between users and registered scrap dealers. The matching process was designed to reduce communication delays and improve the efficiency of scrap collection and transactions. After a user uploaded the scrap details and received the predicted price, the system obtained the user's location through location services. Based on the available location information, the platform identified registered scrap dealers operating within the nearby service area.

The matching mechanism considered dealer availability, collection capacity, and distance from the user's location. These parameters were evaluated to identify and recommend a suitable nearby scrap dealer. The location-based matching process was intended to reduce unnecessary travel and improve the efficiency of scrap collection.

After a dealer was selected, the platform enabled pickup scheduling and transaction confirmation. This process improved convenience for users and dealers by providing a structured communication and collection mechanism.

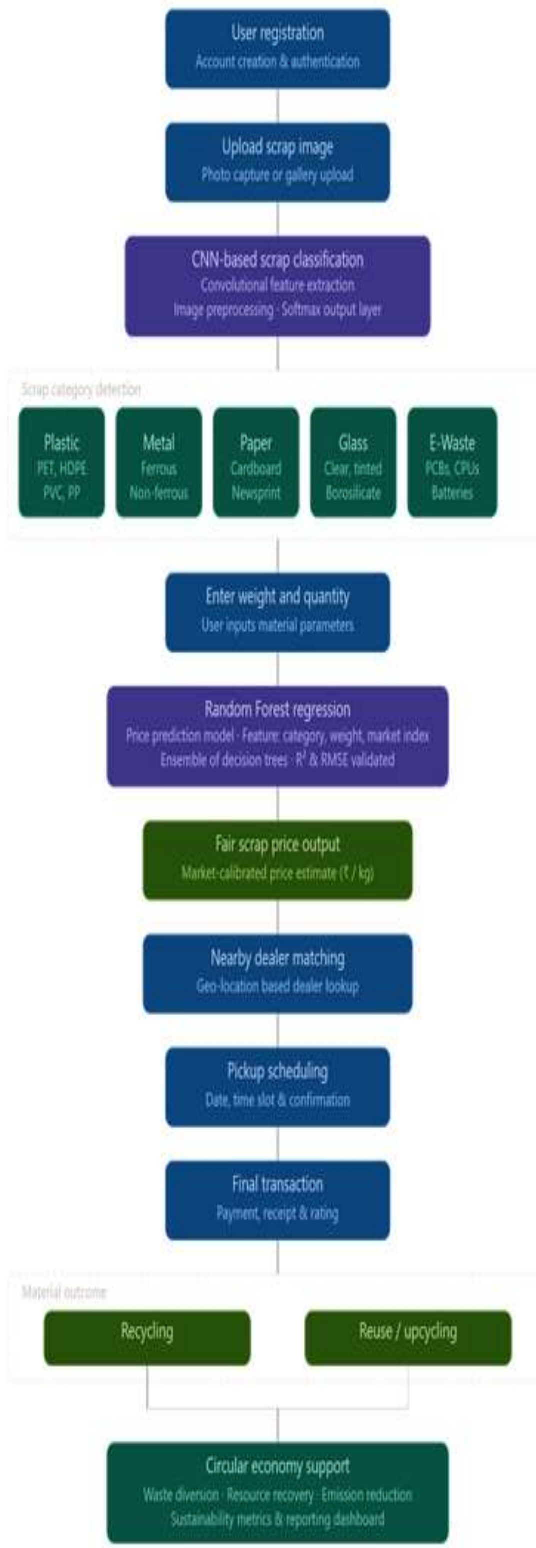

Figure 1. Workflow of the AI-Driven Scrap and Resale Marketplace System

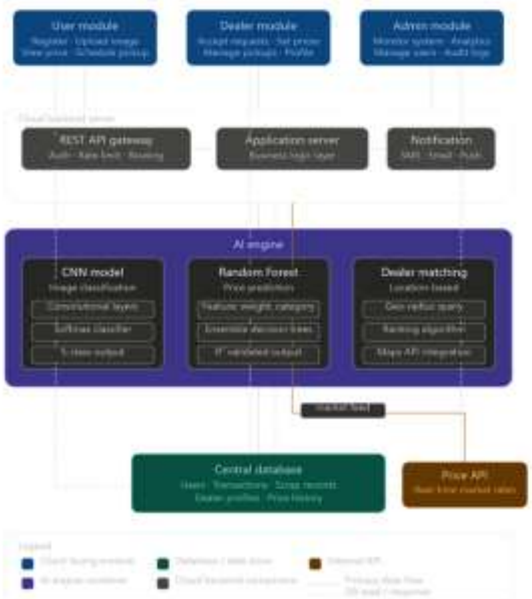

Figure 2. System Architecture of the Proposed Platform

Figure 3. Scrap Price Prediction Model Workflow

V. EXPERIMENTAL RESULTS AND DISCUSSION

The experimental evaluation of the proposed system was conducted for scrap image classification and scrap price prediction. The classification model was evaluated using a dataset containing five scrap categories, namely plastic, metal, paper, glass, and electronic waste. The dataset was divided into training and testing subsets using an 80:20 ratio.

The CNN model was evaluated using accuracy, precision, recall, and F1 score. The model achieved an overall classification accuracy of 94.2 percent, a precision of 92.8 percent, a recall of 91.6 percent, and an F1 score of 92.1 percent. These results indicated that the model effectively identified visual characteristics associated with different scrap categories and achieved consistent classification performance.

The Random Forest Regression model was evaluated using Mean Absolute Error, Root Mean Square Error, and the coefficient of determination. The model achieved a Mean Absolute Error of 2.1 per kilogram, a Root Mean Square Error of 3.4 per kilogram, and an R squared score of 0.91. The R squared value indicated that the regression model explained a substantial proportion of the variation in scrap prices. The relatively low prediction errors demonstrated the potential of the model to support scrap price estimation.

The classification and regression results demonstrated the potential benefits of integrating artificial intelligence techniques into a digital scrap management platform. Automated image classification reduced the dependence on manual material identification, while price prediction provided users with an estimated market value for scrap materials. The integration of these functions can improve pricing transparency and assist users during scrap transactions.

The proposed system also combined location-based dealer matching and second-hand product resale with the artificial intelligence modules. This integration extended the system beyond standalone waste classification and price prediction approaches. Overall, the experimental findings demonstrated that the proposed framework has the potential to improve material identification, price estimation, transaction efficiency, and sustainable material reuse within a circular economy-oriented scrap management ecosystem.

TABLE II CNN Model Performance for Scrap Classification

Performance Metric	Value (%)
Accuracy	94.2
Precision	92.8
Recall	91.6
F1-Score	92.1

Table II presents the performance of the CNN-based scrap classification model on the testing dataset. The model was evaluated using accuracy, precision, recall, and F1 score. The classification model achieved an accuracy of 94.2 percent, a precision of 92.8 percent, a recall of 91.6 percent, and an F1 score of 92.1 percent. The obtained results indicated consistent performance across the selected classification evaluation metrics.

TABLE III Random Forest Regression Performance for Scrap Price Prediction

Evaluation Metric	**Value**
MAE (Mean Absolute Error)	₹2.1 per kg
RMSE (Root Mean Square Error)	₹3.4 per kg
R^2 Score (Coefficient of Determination)	0.91

Table III presents the performance of the Random Forest Regression model for scrap price prediction. The model was evaluated using Mean Absolute Error, Root Mean Square Error, and the coefficient of determination. The model obtained a Mean Absolute Error of 2.1 rupees per kilogram and a Root Mean Square Error of 3.4 rupees per kilogram. The R^2 score of 0.91 indicated that the model explained a substantial proportion of the variation in scrap prices. These results demonstrated the potential of the regression model to support scrap price estimation.

VI. CONCLUSION

This study proposed an artificial intelligence-driven digital platform for scrap classification, price prediction, dealer matching, and second-hand product resale to improve transparency, efficiency, and sustainable waste management. The proposed framework employed a Convolutional Neural Network for the automated classification of plastic, metal, paper, glass, and electronic waste and used Random Forest Regression to estimate scrap prices based on relevant material and market features. The classification model achieved an accuracy of 94.2 percent, while the price prediction model obtained a Mean Absolute Error of 2.1 per kilogram, a Root Mean Square Error of 3.4 per kilogram, and an R squared score of 0.91. The main novelty of the proposed system was the integration of scrap image classification, intelligent price prediction, location-based dealer matching, and second-hand product resale within a unified digital ecosystem.

This integration provided a broader approach than standalone waste classification or resale systems and supported pricing transparency, material reuse, and circular economy practices. However, the proposed system was limited by its dependence on the quality and diversity of the available training data, variations in regional scrap prices, and the requirement for reliable location information for dealer matching. Future improvements can include larger region-specific datasets, real-time market price integration, and broader practical deployment. The proposed framework demonstrates the potential of artificial intelligence to support transparent and efficient scrap management while promoting sustainable resource utilization.

VII. FUTURE SCOPE

Although the proposed system addressed major challenges in scrap management, several improvements can be considered in future work to enhance its practical usability and scalability. A dedicated mobile application can be developed for android and Ios platforms to allow users to upload scrap images, obtain estimated prices, list second-hand products, and schedule scrap pickups through mobile devices. The integration of real-time scrap price data can further improve price prediction by updating market rates according to changing demand and regional market conditions. Future versions of the platform can also explore secure digital transaction mechanisms to improve transparency and maintain reliable transaction records between users and scrap dealers.

The proposed system can be extended beyond household scrap management to industrial waste environments where large quantities of recyclable materials require efficient classification and collection. Internet of Things-Enabled smart containers can also be integrated for automated waste monitoring and collection planning. Multilingual interfaces and voice-based assistance can improve accessibility for users with limited technical knowledge. These improvements can enhance the scalability, accessibility, and practical applicability of the proposed platform for smart city waste management and broader circular economy applications.

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