

ECOTrack: A Java-Based Desktop Application for Integrated Environmental Monitoring and Carbon Footprint Management

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Abstract - Climate change poses a significant threat to the environment due to increasing greenhouse gas emissions generated by everyday human activities. Many individuals are willing to contribute to sustainability but lack accessible tools to measure and understand their environmental impact. This paper presents EcoTrack, an innovative web application designed to help users monitor and reduce their carbon footprint by tracking daily activities such as travel, food consumption, and household appliance usage. The system includes a real-time carbon footprint calculator, visual analytics using dynamic charts, and an integrated AI-based chatbot that provides personalized sustainability suggestions and environmental guidance. EcoTrack also offers educational resources that promote awareness and encourage long-term eco friendly behavior. The architecture utilizes a web-based interface linked to a Java backend and Firebase cloud database, ensuring accessibility, scalability, and security. Preliminary testing indicates that EcoTrack effectively increases user engagement and awareness, enabling individuals to make more sustainable lifestyle decisions.

B.Motivation

The global challenge of reducing carbon emissions has reached a critical juncture. While transportation is often highlighted as a significant contributor to greenhouse gas emissions, it is crucial to acknowledge that carbon emissions stem from various sectors, including energy production, industrial activities, agriculture, and waste management. According to data from the U.S. Environmental Protection Agency (EPA) [15], these diverse sources collectively exacerbate the environmental impact, underscoring the need for a comprehensive approach to carbon reduction strategies.

Moreover, there is a significant gap in awareness regarding how individuals can effectively reduce their carbon footprint daily. Many people are unaware of the broader implications of their consumption patterns, waste management, and energy usage, leading to unintentional contributions to the carbon load. The disconnect between knowledge and action is a critical barrier that needs to be addressed through education and practical solutions.

By focusing on the wide range of carbon emission sources and highlighting practical, actionable steps that individuals and organizations can take, we aim to bridge the gap between awareness and action. Our objective is to develop and promote strategies that not only reduce carbon emissions across various sectors but also encourage a cultural shift towards more sustainable practices. This research is crucial in driving the necessary change toward a low-carbon future, where individual and collective actions align with long-term environmental sustainability.

EcoTrack is not just a web application but a step toward building a smarter and greener society. By integrating technology with environmental responsibility, the system ensures that every individual can actively contribute to sustainability with ease.

1. INTRODUCTION

A Problem Statement

Rapid urbanization and increased vehicle usage have significantly contributed to carbon emissions, leading to poor air quality and environmental degradation. Additionally, improper waste disposal and delays in addressing waste-related complaints continue to worsen sanitation conditions in many regions. Although awareness about sustainability is increasing, most individuals lack real-time guidance on reducing their carbon footprint and managing waste effectively. There is a strong need for a unified digital system that not only monitors environmental impact but also provides suggestions, encourages eco-friendly actions, and ensures accountability in waste management. This paper addresses the need for a user-friendly solution that empowers individuals to track and reduce their carbon footprints effectively...

2. OBJECTIVE

The primary objective of our initiative is to develop and implement effective strategies for reducing carbon footprints across several fields, such as transportation, appliance usage, and everyday human activities. We search for and support practical solutions to help individuals and companies reduce their carbon footprints. Additionally, our paper aims to encourage age people to adopt sustainable technologies and behaviors by emphasizing the long-term advantages and critical importance of such investments for the future of our world. By raising awareness of the different sources of carbon emissions and emphasizing the value of sustainability, we hope to cultivate a more informed and environmentally concerned community that is dedicated to the complete reduction of carbon emissions.

EcoTrack also includes a dedicated complaint registration and management feature that allows users to report waste-related issues such as improper garbage dumping or unclean public spaces. Once a complaint is submitted, the system tracks its status and provides regular updates until the problem is resolved. To enhance user awareness and environmental knowledge, the application offers an educational module containing informative articles, videos, and visual resources that teach users about recycling techniques, waste segregation, and sustainable lifestyle practices.

Integration of Google Maps enables users to easily locate nearby recycling centers and authorized waste disposal facilities, helping them take responsible actions and contribute actively to proper waste management. Through these combined features, EcoTrack not only solves environmental issues but also empowers users to become more informed and engaged citizens. environmental actions. By combining awareness, support, and motivation, EcoTrack Further the system aims to keep users enaged and motivated through interactive features such as chatbot that offers eco friendly tips and solutions , and a gamification module that rewards users for positive environmental actions. By combining awareness ,support and motivation, Eco Track encourages long terms behavioural change and contributes to building cleaner and healthier living environments.

The primary objective of EcoTrack is to empower individuals and communities to reduce their environmental impact through smart digital tools. The system focuses on

3. LITERATURE REVIEW

The scientific community is examining recycling and scrap classification globally on various issues and has a large number of publications reflecting issues in waste management practices and the public, people's attitudes, technological development, and policy implications. Min and other colleagues (2019) studied consumers' intentions to separate theirwaste in China bringing an Extended Theory of Planned Behaviour into practice to pinpoint individual engagement in waste management activities (Min et al. 2019). According to this case study reported by Wang and Tan (Wang & Tan, 2022) researchers in Wusheng County, Sichuan, China, exploring farmers' views and attitudes towards domestic waste classification using multi-channel propaganda and community engagement as key determinants to change waste management behaviours and

Pires & Chang (2011) reviewed the solid waste disposal systems in Europe and emphasized the optimization of waste disposal processes via systems analysis, which provides efficiency (Pires & Chang, 2011). Jin et al., (2019) adopted a science mapping approach to assess the trends in construction and demolition waste management by scrutinizing the widespread conclusions and the scope of the research applied in the field (Jin et al., 2019). The study by Hannan et al., 2015) demonstrated the state of solid waste monitoring and management systems regarding environmental monitoring as well as information and communications technology, which have their challenges and opportunities associated with them .

Tang et al. (2022) looked at motivation factors of urban areas' household waste sorting behaviour and also proposed the role of reward and punishment mechanisms in enhancing the practice of classification of wastes (Tang et al. 2022). Lu & Yuan (2010) made an in-depth study about success factors for waste management in the Chinese construction and demolition field, to show that the problem is becoming more critical due to the growing amount of construction waste (Lu & Yuan, 2010; Gala et al., 2020) carried out a comprehensive survey on post-consumer plastic film waste in Spain in the aim of targeting the optimal way of waste management specific to the waste sources.

Researchers have explored various aspects of waste management to improve environmental practices across different regions. Tang et al. (2022) investigated motivational factors influencing household waste sorting behavior in urban areas and highlighted that reward and punishment mechanisms

learning methods are used to escalate the waste sorting processes (Chu et al., 2018). Moreover, the improvement of waste classification methodologies, including deep learning-based methods presented by Altikat et al. (2021), showed that AI could be used to optimize waste management practices.

(Cerchecci et al., 2018) introduce a multi-sensor node architecture for waste management in the context of a Smart City with special attention to the role of IoT in reducing waste (Cerchecci et al., 2018). In addition, Pardini et al. (2019) worked on a survey on IoT-based solid waste management solutions, emphasizing the role of urbanization and cloud computing in facing the problem of waste in urban areas. In Aarif et al., 2022, a smart waste segregation system by deep learning and IoT technologies to distinguish waste items as biodegradable or non-biodegradable was presented, which demonstrated such technologies' applicability in waste management (Aarif et al., 2022).

Adding on that, automated waste separation using image processing and machine learning, as done by 's (2018) study, portrays the necessity of automation in waste management processes for proper waste segregation and disposal (Dev, 2018). In parallel, Mapari et al. discuss a waste separation and monitoring system that stresses the waste hierarchy as a critical component of waste management design. (Mapari et al., 2020;). Chitale (2023) developed a smart waste segregation system with the support of the Internet of Things emphasizing the significance of using effective segregation mechanisms to deal with waste management issues (Chitale, 2023).

Accumulation of knowledge in the field of research foreshadows smart waste systems that emit IoT devices (Sairam et al., 2021) strengthening the need not only for environmentally friendly habits but also for the reduction of waste pollution using the technology. Lundin et al., in 2017, conducted research to operationalize sensor-based solutions that help monitor service and collection of waste in public trash bins. The study gave a real-life example of how sensors are used to improve waste management operations (Lundin et al., 2017). An IoT-based lead route system for the recommendation was proposed by Ghahramani et al, 2022. In that realm, smart waste management consists of the role of IoT in devising efficient waste collection routes given that storage is confined (Ghahramani et al., 2022)

Concerning waste classifying and controlling the field, the recent research work found us with some viable ways of controlling waste. Residents' mechanisms of decision-making have been studied by Meng et al. (2019) which depict how residents

4. RELATED WORK

Many carbon footprint tracking tools today include features like emission calculators, progress trackers, etc. However, they often fall short in several important ways. The Pawprint app [10] is a sustainability-focused platform designed to help users track, and reduce their carbon footprint. It was launched by Christian Arno in 2020. The Earth Hero: Climate Change [11] app is a mobile platform designed to reduce emissions and encourage community engagement through collective climate action. The Earth Hero app was launched in 2019. These apps typically don't offer personalized recommendations. While they may provide general advice on reducing emissions, they usually don't give personalized suggestions based on individual behaviors or preferences. This makes it challenging for users to make the right choices that would reduce their carbon footprints. Additionally, many of these tools don't promote or raise awareness about sustainability. Apps like Pawprint [10] and Earth Hero [11] might offer data and metrics but often lack integrating features that encourage users to adopt sustainable practices and eco-friendly options. Without such elements, users might not fully understand the impact of their actions or be inspired to choose more sustainable alternatives. EcoTrack overcomes these shortcomings by combining everything on one platform. Its diagnostic branch provides personalized insights based on each user's input. An AI-powered chatbot will increase this, providing timely recommendations and answering specific questions about sustainable practices. What makes EcoTrack different is the payment system. It not only tracks progress but encourages environmental behavior by offering rewards such as sustainable product donations. By combining these features, EcoTrack helps users understand and reduce their carbon footprint and promotes a sustainable and healthy lifestyle.

5. METHODOLOGY

The Eco Track system uses a modular and technology-driven approach to promote environmental sustainability through active user participation. The methodology begins with user registration and profile creation, where basic information related to the user and their environmental activities is securely stored in the database. Once logged in, the user can access multiple eco-related features designed to reduce carbon emissions and improve waste handling practices.

To estimate vehicle-based pollution, the system provides a carbon footprint calculator where users input details such as vehicle type, distance traveled, and fuel usage. The system then generates the estimated carbon emission using standard calculation formulas and returns results in an easily understandable format. This enables users to track their environmental impact and adopt greener transportation options to reduce emissions over time.

For waste management, EcoTrack includes a complaint

registration module that allows users to report unclean areas, littering issues, or overflowing garbage bins. The complaint is geo-tagged using GPS and forwarded to concerned authorities for action. Users can track the status of their complaint in real time until the issue is resolved. Additionally, a waste advisory service provides tips for proper waste segregation and disposal based on user input, helping people manage household waste more responsibly.

To further support behavior change, EcoTrack integrates an AI-based chatbot that offers instant guidance, environmentally friendly suggestions, and answers common questions related to pollution control and recycling practices. The system also implements a gamification mechanism where users earn points or rewards for completing eco-friendly tasks, such as reducing carbon emissions or filing valid waste reports. Google Maps integration assists in locating nearby recycling centers and waste disposal facilities, encouraging correct waste handling. Using these combined methodologies, EcoTrack delivers a comprehensive and engaging platform that encourages sustainable living and contributes to environmental protection.

To ensure seamless data processing and secure storage, EcoTrack follows a cloud-based architecture using a real-time database. All user interactions, such as complaint submission, carbon emission data, and chatbot queries, are stored and retrieved through backend services for fast performance and reliability. The system also uses role-based access control, where authorities can log in to view, update, and resolve complaints submitted by the users. This ensures transparency, accountability, and faster response from municipal organizations for cleanliness and waste-related concerns.

The system methodology of EcoTrack is primarily designed around three essential aspects of environmental improvement — awareness, action, and motivation. By educating users about the impact of carbon emissions and improper waste disposal, the system builds awareness and encourages them to take responsibility for their surroundings.

Overall, the system methodology focuses on awareness, action, and motivation — the three key aspects needed to improve environmental responsibility within communities. By combining IoT-inspired features, machine learning-based guidance, mobile application convenience, and social responsibility tools, EcoTrack creates a complete digital ecosystem for environmental protection. This systematic approach ensures that users are not only informed but also actively involved in reducing carbon emissions and maintaining cleaner surroundings.

6. SYSTEM ARCHITECTURE

As the time post-deployment passes continue to track the application's performance and collect user feedback. Use this knowledge to prioritize and set in motion bug correction, addition of new features, and modifications.

Eco Track's Carbon Footprint Calculator is an essential tool for users to understand the environmental impact of their everyday actions. It provides a comprehensive view of carbon emissions by examining various aspects of their lifestyle, such as travel, diet, and household appliance use. This tool offers clear insights into their carbon footprint, making it easier to make informed choices that contribute to sustainability. • **Transportation Choices:** The carbon calculator estimates emissions from different modes of transportation by considering factors such as vehicle type (e.g., electric, hybrid, gasoline, diesel), distance traveled, and the frequency of trips. The emissions for each journey are calculated using the following formula [12]: $\text{CO}_2 \text{ Emissions} = \text{Distance} \times \text{Emission Factor}$ (kg) (km) (kg CO₂ per km) The emission factor varies based on the mode of transport. Below are the emission factors used:

- Gasoline Car: 0.23 kg CO₂/km
- Electric Car: 0.05 kg CO₂/km
- Diesel Car: 0.29 kg CO₂/km
- Hybrid Car: 0.15 kg CO₂/km
- Bike: 0.05 kg CO₂/km
- Bicycle: 0.02 kg CO₂/km
- Walking: 0.0 kg CO₂/km
- Bus: 0.08 kg CO₂/km

To enhance accuracy, the calculator also considers real-time factors like traffic conditions and vehicle fuel efficiency. This allows users to compare the environmental impact of different travel options, such as driving a gasoline-powered car versus using public transport or cycling. By better understanding the carbon footprint of their transportation choices, users are motivated to adopt more environmentally friendly travel habits, helping to support a more sustainable future.

• **Dietary Habits:** This feature evaluates the carbon footprint of users' diets by analyzing the types of foods consumed, including meat, dairy, and plant-based products. It considers the environmental impact of various food production methods and calculates the associated carbon emissions weekly. The carbon emissions can be determined using the following formula [13]:

$\text{CO}_2 \text{ Emissions} = \text{Quantity} \times \text{Emission Factor}$ (kg) (kg) (kg CO₂ per kg)

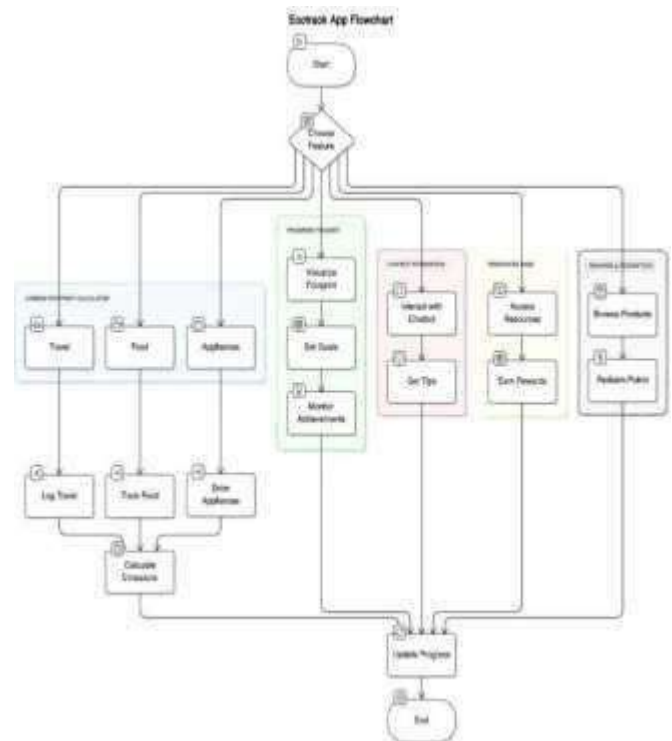
- Meat (e.g., beef, lamb): 27 kg CO₂ per kg
- Dairy: 6 kg CO₂ per kg
- Poultry: 6 kg CO₂ per kg
- Plant-Based Foods: 0.5 kg CO₂ per kg

By emphasizing the effects of dietary selections on total carbon emissions, this feature encourages users to adopt more sustainable food practices and modify their eating habits, ultimately promoting a more environmentally friendly lifestyle. • **Household Appliances:** The calculator also assesses the energy usage of various household appliances, such as refrigerators, washing machines, and air conditioners. It factors in the energy efficiency of each appliance, how long it is used, and the source of electricity (renewable or non-renewable). Many users are unaware of how appliance usage impacts their carbon footprint.

By providing detailed information on the emissions from everyday household activities, this feature helps users understand their energy use better and encourages them to adopt more energy-efficient practices. The carbon emission for various household appliances can be calculated using the following formula [15][16]: $CO_2 \text{ Emissions} = \text{Power} \times \text{Usage Time} \times \text{Emission Factor (kg CO}_2\text{) (kW) (h) (kg CO}_2\text{/kWh)}$ The Power usage varies based on the appliance used. Below is a list of the power usage range for some appliances. It may further differ based on the model:

- Refrigerator: 0.2 - 0.8 kW
- Washing Machine: 0.5 - 2.5 kW
- Dishwasher: 2.0 - 5.0 kW
- Air Conditioner: 1.0 - 2.5 kW
- Microwave Oven: 1.0 - 1.5 kW
- Television (LCD/LED): 0.05 - 0.15 kW
- Laptop: 0.05 - 0.1 kW

The Carbon Footprint Calculator combines these various data points into a cohesive analysis, offering real-time feedback that guides users in making impactful decisions to reduce their carbon footprint. This empowers individuals to take charge of their environmental impact, positioning Eco Track as a crucial resource in the battle against climate change.



7. System Requirement

A. Hardware Requirements

- **Processor:** Minimum Dual-Core / Recommended Quad-Core
- **RAM:** Minimum 2 GB / Recommended 4 GB or above
- **Storage:** At least 200 MB free space for installation and data storage
- **Device:** Android Smartphone/Desktop/Laptop with standard display
- **Internet Connectivity:** Required for database access, chatbot communication, and complaint tracking

B. Software Requirements

- **Operating System:** Windows / Linux / Android
- **Programming Language:** Java
- **Frontend Framework:** JavaFX for user interface design
- **Backend & Database:** Firebase (for real-time data management and authentication)
- **AI Integration:** NLP-based chatbot to provide suggestions
- **Development Tools:** Android Studio / IntelliJ IDEA / Eclipse (based on deployment platform)

- 8. TECHNOLOGIES USED

The EcoTrack system will be developed using **Java** as the primary programming language due to its strong performance, platform independence, and wider industry usage. The user interface of the application will be built using **JavaFX**, which provides modern UI components, responsiveness, and a smooth user experience. For backend data storage and authentication, **Firebase** will be utilized, allowing real-time database operations, secure login, and easy scalability for handling multiple users and complaints.

Data storage, management, and retrieval within the application will be done by ** Firebase Storage and Firebase Database which will make the data interaction as smooth as possible for the users and the effective operation of different manipulations with the data (Dahunsi et al., 2021, para. 5).

Through Google Maps API, the website users will be able to locate appropriate recycling centres and waste disposal facilities (Miller, 2006).

Such technologies will help the waste management mobile app to fill in the available gap of simple methods for categorizing waste, raising complaints, providing resourceful information, and location-based services as a way to ensure that unfamiliar waste management practices and environmental sustainability are promoted.

To support environmental guidance features, the system will incorporate an AI-based **Chatbot** that delivers eco-friendly recommendations and answers frequently asked queries. The **Google Maps API** will assist in locating nearby recycling centers and in geo-tagging complaint locations for accurate waste reporting. Additionally, mathematical models and APIs will be used to calculate the carbon footprint based on vehicle type, distance traveled, and fuel consumption. This combination of technologies ensures that EcoTrack will be efficient, reliable, and capable of supporting environmental sustainability initiatives effectively.

Furthermore, the integration of these technologies enhances user engagement by providing accurate, real-time insights that support informed decision-making. As the platform evolves, advanced features such as personalized recommendations, data analytics dashboards, and predictive insights can be introduced to help users visualize their long-term environmental impact. With strong scalability and the ability to adapt to emerging eco-technologies, EcoTrack ensures continuous performance improvement while promoting a culture of environmental responsibility.

9. FUTURE SCOPE

EcoTrack has strong potential for expansion with advanced technologies that can enhance its effectiveness and user engagement. In the future, additional AI capabilities can be integrated to provide more accurate and highly personalized environmental recommendations. Machine learning models can also analyze long-term user behavior to predict carbon patterns and suggest smarter lifestyle alternatives.

Another major future enhancement includes the introduction of **regional customization**, where emission factors, waste disposal rules, and environmental policies are updated automatically based on the user's location. Multilingual support can also be added to reach a wider audience, especially in rural and non-English-speaking communities.

The waste management module can be extended to support real-time IoT-based smart bins, automated complaint assignment to municipal authorities, and live tracking of garbage collection vehicles. EcoTrack can also establish collaboration with government organizations, NGOs, and sustainable businesses to provide exclusive rewards, product discounts, and volunteering opportunities that motivate users to adopt greener habits.

In future, a carbon tracking device or integration with smart wearables and EV dashboards can help automatically log travel emissions without manual input. By partnering with environmental agencies, EcoTrack could assist in generating official sustainability reports for communities and smart cities. With these advancements, EcoTrack can evolve into a powerful smart-environment assistant that significantly contributes to global climate action and promotes a greener future.

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In the future, EcoTrack can be enhanced with carbon tracking devices or integration with smart wearables and electric vehicle dashboards to automatically record travel emissions without requiring manual input. By collaborating with environmental organizations and government agencies, the system could further support the generation of official sustainability reports for communities and smart cities. these advancements would transform.

10. SYSTEM FLOW:

The first thing they see upon entering the application is a choice either to log in or register. When having a successful authentication, users will be directed straight to the Home Screen. In this case, if the user is not logged in, the login or registration screen is presented. The Home Screen presents various icons representing distinct functionalities: Home, Education, Direction, Sense of Place, and Summary. Under these functionalities, users can access specific features: the home part can be used for registration of complaints in their preferred category, in the Learning part there are educational videos or articles to be accessed, in the map section they can mark the service centre locations on a map, under Status one can observe the progress of the problem resolution, and there is a Profile section to edit the user profile. This makes it easy for users to have seamless navigation and access to all those features, which makes the app much more friendly to use and efficient.

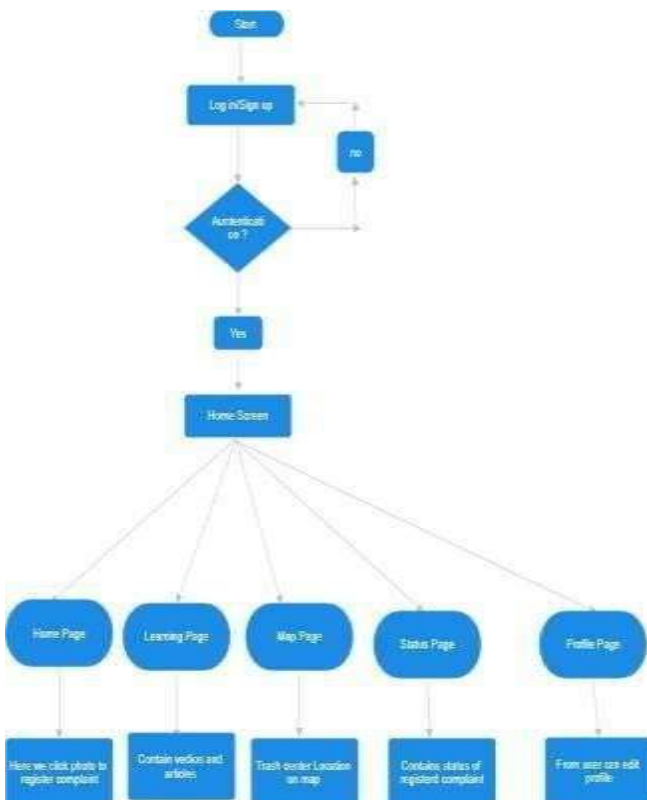


Figure 11 System Flow

platform-cross compatibility that will boost the availability of the application (Kasteren et al., 2020). The integration of the location services allows users to identify the nearest waste places thereby filtering their choice of information site using GPS or location coordinates. (Jacobs et al., 2020). The Firebase Storage and Database for making the data easily storable in the application and to ensure the smooth interaction with data in the application are used (Bono et al., 2004). The provision of Google Maps integration ensures location-based services provision where people can easily find recycling centres near and waste disposal facilities for well-developed sustainable waste management practices (Sundram et al., 2022). The research paper shows that a specialized solution, which includes the next generation of technologies aimed at the waste management problem, can be created and, consequently, can allow an environmentally friendly approach to waste management and moral disposal practices.

11. CONCLUSION:

Eventually, EcoTrack exemplifies the transformative potential of mobile applications in combating climate change by offering a comprehensive and user-friendly platform for reducing individual carbon footprints. The app not only empowers users to make informed, sustainable choices but also incorporates gamification and rewards systems, incentivizing eco-friendly behavior. By allowing users to redeem rewards for purchasing eco-friendly products, EcoTrack not only encourages sustainable practices but also promotes the integration of sustainability into everyday life, underscoring the broader impact of mobile technology in fostering global environmental responsibility.

Moreover, EcoTrack goes beyond traditional environmental applications by combining awareness, action, and motivation into a single integrated ecosystem. The system's ability to provide real-time guidance, track sustainability progress, and support community-driven waste management makes it a valuable tool for both individuals and society. By promoting responsible behavior through education and rewards, EcoTrack encourages users to develop habits that positively impact the environment. As environmental challenges continue to grow, platforms like EcoTrack play a crucial role in supporting a greener future and inspiring a collective shift toward sustainable living.

12. REFERENCES:

- [1] (2021). A practical solution for pollution management and waste disposal issue in urban environments. *Journal of Machine and Computing*, 48-56.
<https://doi.org/10.53759/7669/jmc202101006>
- [2] (2021). Untitled. *World Journal of Environmental Research*, 10(2). <https://doi.org/10.18844/wjer.v10i2>
- [3] (2023). Interaction between waste management and energy generation systems in terms of material properties and environmental impact in the European Union. *International Journal of Progressive Research in Engineering Management and Science*.
<https://doi.org/10.58257/ijprems30525>
- [4] (2023). Speedy ship- intracity logistic app. *International Research Journal of Modernization in Engineering Technology and Science*.
<https://doi.org/10.56726/irjmets37539>
- [5] Aarif, K., Yousuff, C., Hashim, B., Hashim, C., & Poruran, S. (2022). Smart bin: waste segregation system using deep learning-internet of things for sustainable smart cities. *Concurrency and Computation Practice and Experience*, 34(28).
<https://doi.org/10.1002/cpe.7378>
- [6] Addo, H., Dun-Dery, E., Afoakwa, E., Elizabeth, A., Ellen, A., & Rebecca, M. (2017). Correlates of domestic waste management and related health outcomes in Sunyani, ghana: a protocol towards enhancing policy. *BMC Public Health*, 17(1).
<https://doi.org/10.1186/s12889-017-4537-8>
- [7] Afrianto, I., Irfan, M., & Atin, S. (2019). Aplikasi chatbot speak english media pembelajaran bahasa inggris berbasis android. *Komputika Jurnal Sistem Komputer*, 8(2), 99-109.
<https://doi.org/10.34010/komputika.v8i2.2273>
- [8] Allesch, A. and Brunner, P. (2015). Material flow analysis as a decision support tool for waste management: a literature review. *Journal of Industrial Ecology*, 19(5), 753-764.
<https://doi.org/10.1111/jiec.12354>
- [9] Alqahtani, A. (2019). Usability testing of Google Cloud applications: students' perspective. *Journal of Technology and Science Education*, 9(3), 326.
<https://doi.org/10.3926/jotse.585>
- [10] Altikat, A., Gülbe, A., & Altikat, S. (2021). Intelligent solid waste classification using deep convolutional neural networks. *International Journal of Environmental Science and Technology*, 19(3), 1285-1292. <https://doi.org/10.1007/s13762-021-03179-4>
- [11] Anagnostopoulos, T., Zaslavsky, A., Ntalianis, K., Anagnostopoulos, C., Ramson, S., Shah, P., ... & Salmon, I. (2021). Iot-enabled tip and swap waste management models for smart cities. *International Journal of Environment and Waste Management*, 28(4), 521.
<https://doi.org/10.1504/ijewm.2021.10042472>
- [12] Aparcana, S. (2017). Approaches to formalization of the informal waste sector into municipal solid waste management systems in low- and middle-income countries: review of barriers and success factors. *Waste Management*, 61, 593-607.
<https://doi.org/10.1016/j.wasman.2016.12.028>
- [13] Bingimlas, K. (2009). Barriers to the successful integration of ICT in teaching and learning environments: a review of the literature. *Eurasia Journal of Mathematics Science and Technology Education*, 5(3).
<https://doi.org/10.12973/ejmste/75275>
- [14] Bono, P., Krause, A., Mehren, M., Heinrich, M., Blanke, C., Dimitrijević, S., ... & Joensuu, H. (2004). Serum kit and kit ligand levels in patients with gastrointestinal stromal tumours treated with imatinib. *Blood*, 103(8), 2929-2935. <https://doi.org/10.1182/blood-2003-10-3443>
- [15] Brown, C., Milke, M., & Seville, E. (2011). Disaster waste management: a review article. *Waste Management*, 31(6), 1085-1098.
<https://doi.org/10.1016/j.wasman.2011.01.027>
- [16] Brusentseva, T. (2023). Main aspects of the implementation of the law on waste management in European legislation. *Bulletin of the National Technical University Khpi Series Innovation Researches in Students' Scientific Work*, (2), 3-10.
<https://doi.org/10.20998/2220-4784.2023.02.01>
- [17] Cerchecci, M., Luti, F., Mecocci, A., Parrino, S., Peruzzi, G., & Pozzebon, A. (2018). A low-power IoT sensor node architecture for waste management within smart cities context. *Sensors*, 18(4), 1282.
<https://doi.org/10.3390/s18041282>
- [18] Chadwick, R. (2016). Embodied methodologies: challenges, reflections and strategies. *Qualitative Research*, 17(1), 54-74.
<https://doi.org/10.1177/1468794116656035>
- [19] Chen, S., Huang, J., Xiao, T., Gao, J., Bai, J., Luo, W., ... & Dong, B. (2020). Carbon emissions under different domestic waste treatment modes induced by garbage classification: a case study in pilot communities in Shanghai, China. *The Science of the Total Environment*, 717, 137193.
<https://doi.org/10.1016/j.scitotenv.2020.137193>
- [20] Chin, W. and Mees, H. (2021). The rising stars of social innovations: how do local governments facilitate citizen initiatives to thrive? the case of waste management in Brussels and Hong Kong. *Environmental Policy and Governance*, 31(5), 533-545. <https://doi.org/10.1002/eet.1953>
- [21] Chitale, M. (2023). Automated smart waste segregation system using IoT technology. *Journal of Physics Conference Series*, 2601(1), 012015.

- Management, 43, 509-523.
<https://doi.org/10.1016/j.wasman.2015.05.033>
- [22] Harman, G. and Yenikalayci, N. (2022). Determination of science students' awareness of waste management. *Journal of Science Learning*, 5(2), 301-320.
<https://doi.org/10.17509/jsl.v5i2.39376>
- [23] Hassan, M., Dilawar, S., & Akbar, M. (2021). Industrial waste management in Pakistan: problems and prospects. *Global Management Sciences Review*, VI(I), 39-53.
[https://doi.org/10.31703/gmsr.2021\(vii\).04](https://doi.org/10.31703/gmsr.2021(vii).04)
- [24] Håkansson, H. and Waluszewski, A. (2016). "methodomania"? on the methodological and theoretical challenges of imp business research. *Imp Journal*, 10(3), 443-463.
<https://doi.org/10.1108/imp-01-2016-0001>
- [25] Imparato, G., Urciuolo, F., & Netti, P. (2022). Organ-on-chip technology to model cancer growth and metastasis. *Bioengineering*, 9(1), 28.
<https://doi.org/10.3390/bioengineering9010028>
- [26] Inckle, K. (2010). Telling tales? using ethnographic fiction to speak embodied 'truth'. *Qualitative Research*, 10(1), 27-47.
<https://doi.org/10.1177/1468794109348681>
- [27] Jacobs, R., Mayeshiba, T., Afflerbach, B., Miles, L., Williams, M., Turner, M., ... & Morgan, D. (2020). The materials simulation toolkit for machine learning (mast-ml): an automated open-source toolkit to accelerate data-driven materials research. *Computational Materials Science*, 176, 109544.
<https://doi.org/10.1016/j.commatsci.2020.109544>
- [28] James, P. and Griffiths, D. (2014). A secure portable execution environment to support teleworking. *Information Management & Computer Security*, 22(3), 309-330. <https://doi.org/10.1108/imcs-07-2013-0052>
- [29] Jasim, A., Qasim, H., Jasem, E., & Saihood, R. (2021). An Internet of Things-based smart waste system. *International Journal of Electrical and Computer Engineering (Ijece)*, 11(3), 2577.
<https://doi.org/10.11591/ijece.v11i3.pp2577-2585>
- [30] Jin, R., Yuan, H., & Chang, Q. (2019). Science mapping approach to assisting the review of construction and demolition waste management research published between 2009 and 2018. *Resources Conservation and Recycling*, 140, 175-188.
<https://doi.org/10.1016/j.resconrec.2018.09.029>
- [31] Kanwar, V., Sharma, A., Kanwar, M., Srivastav, A., & Soni, D. (2022). An overview of biomedical waste management during a pandemic like COVID-19. *International Journal of Environmental Science and Technology*, 20(7), 8025-8040.
<https://doi.org/10.1007/s13762-022-04287-5>
- [32] Kasteren, P., Veer, B., Brink, S., Wijsman, L., Jonge, J., Brandt, A., ... & Meijer, A. (2020). Comparison of commercial rt-pcr diagnostic kits for COVID-19.
<https://doi.org/10.1101/2020.04.22.056747>
- [33] Kim, D., Kumar, V., & Murphy, S. (2010). European foundation for quality management business excellence model. *International Journal of Quality & Reliability Management*, 27(6), 684-701.
<https://doi.org/10.1108/02656711011054551>
- [34] Kim, J. (2021). Construction and demolition waste management in Korea: recycled aggregate and its application. *Clean Technologies and Environmental Policy*, 23(8), 2223-2234.
<https://doi.org/10.1007/s10098-021-02177-x>
- [35] Kraus, P., Stokes, P., Moore, N., Ashta, A., & Britzelmaier, B. (2023). An elite perspective on interviewing entrepreneurs – methodological considerations for the entrepreneurship field. *Journal of Small Business and Enterprise Development*, 30(5), 857-879.
<https://doi.org/10.1108/jsbed-12-2022-0492>
- [36] Kulkarni, B. and Anantharama, V. (2020). Repercussions of COVID-19 pandemic on municipal solid waste management: challenges and opportunities. *The Science of the Total Environment*, 743, 140693.
<https://doi.org/10.1016/j.scitotenv.2020.140693>
- [37] Kumar, M., Kumar, K., Surender, R., Melingi, S., & Tamizhselvan, C. (2023). An IoT-aware nature-inspired multilayer hybrid dropout deep-learning paradigm for waste image classification and management. *International Review of Applied Sciences and Engineering*, 14(1), 25-34.
<https://doi.org/10.1556/1848.2022.00390>
- [38] Li, N., Wang, P., Wang, X., Geng, C., Chen, J., & Gong, Y. (2020). Molecular diagnosis of covid 19: current situation and trend in China (review). *Experimental and Therapeutic Medicine*, 20(5), 1-1.
<https://doi.org/10.3892/etm.2020.9142>
- [39] Liang, R. and Sun, Y. (2022). An intelligent sensor mobile phone assisting system using AI and machine learning. <https://doi.org/10.5121/csit.2022.121004>
- [40] Liu, A., Osewe, M., Wang, H., & Xiong, H. (2020). Rural residents' awareness of environmental protection and waste classification behaviour in Jiangsu, china: an empirical analysis. *International Journal of Environmental Research and Public Health*, 17(23), 8928. <https://doi.org/10.3390/ijerph17238928>
- [41] Liu, X., Wang, Z., Wei, L., Li, G., & Zhang, Y. (2019). Mechanisms of public education influencing waste classification willingness of urban residents. *Resources Conservation and Recycling*, 149, 381-390.
<https://doi.org/10.1016/j.resconrec.2019.06.001>
- [42] Lu, W. and Yuan, H. (2010). Exploring critical success factors for waste management in construction projects of China. *Resources Conservation and Recycling*, 55(2), 201-208.
<https://doi.org/10.1016/j.resconrec.2010.09.010>