

**A SMART APPLICATION FOR MUNICIPAL SOLID WASTE
RECYCLING**

**ODETOLA, AZEEZ OPEYEMI
(21PCG02290)**

B.Sc. Computer science, Tai Solarin University of Education, Ogun state

AUGUST, 2023

**A SMART APPLICATION FOR MUNICIPAL SOLID WASTE
RECYCLING**

BY

**ODETOLA, AZEEZ OPEYEMI
(21PCG02290)**

B.Sc. Computer science, Tai Solarin University of Education, Ogun state

**A DISSERTATION SUBMITTED TO THE SCHOOL OF
POSTGRADUATE STUDIES IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE
(M.SC) DEGREE IN COMPUTER SCIENCE IN THE DEPARTMENT
OF COMPUTER AND INFORMATION SCIENCES, COLLEGE OF
SCIENCE AND TECHNOLOGY, COVENANT UNIVERSITY, OTA,
OGUN STATE, NIGERIA.**

AUGUST, 2023

ACCEPTANCE

This is to attest that this dissertation is accepted in partial fulfilment of the requirements for the award of the degree of Master of Science in Computer Science in the Department of Computer and Information Sciences, College of Science and Technology, Covenant University, Ota, Nigeria.

Miss Adefunke F. Oyinloye

(Secretary, School of Postgraduate Studies)

Signature and Date

Prof. Akan B. Williams

(Dean, School of Postgraduate Studies)

Signature and Date

DECLARATION

I, ODETOLA, AZEEZ OPEYEMI (21PCG02290), declare that this research was carried out by me under the supervision of Dr. Olamma U. Iheanetu of the Department of Computer and Information Sciences, College of Science and Technology, Covenant University, Ota, Ogun State, Nigeria. I attest that the dissertation has not been presented either wholly or partially for the award of any degree elsewhere. All sources of data and scholarly information used in this dissertation are duly acknowledged.

ODETOLA, AZEEZ OPEYEMI

Signature and Date

CERTIFICATION

We certify that this dissertation titled “**A SMART APPLICATION FOR MUNICIPAL SOLID WASTE RECYCLING**” is an original research work carried out by **ODETOLA, AZEEZ OPEYEMI (21PCG02290)** in the Department of Computer and Information Sciences, College of Science and Technology, Covenant University, Ota, Ogun State, Nigeria under the supervision of Dr. Iheanetu O.U. We have examined and found this work acceptable as part of the requirements for the award of Master of Science (M.Sc.) in Computer Science.

Dr. Olamma U. Iheanetu
(Supervisor)

Signature and Date

Prof. Olufunke O. Oladipupo
(Head of Department)

Signature and Date

Prof. Adebukola S. Onoshoga
(External Examiner)

Signature and Date

Prof. Akan B. Williams
(Dean, School of Postgraduate Studies)

Signature and Date

DEDICATION

I dedicate this work to the Almighty God, for His infinite grace over my life.

ACKNOWLEDGEMENTS

First and foremost, I want express my gratitude to the Divine Creator for bestowing upon me the mercy and resilience that facilitated the successful and efficient completion of this research endeavor. I extend heartfelt appreciation to my parents and siblings for their unwavering affection and assistance.

Secondly, I want to specially thank my supervisor Dr. Iheanetu O. whose dedication significantly contributed to the triumph of this research study., thank you so much ma, May God continue to bless and protect you.

I also want to appreciate my postgraduate colleagues and friends for their support and encouragement in times when things were tough, I celebrate you all.

TABLE OF CONTENTS

CONTENTS	PAGES
COVER PAGE	i
TITLE PAGE	ii
ACCEPTANCE	iii
DECLARATION	iv
CERTIFICATION	v
DEDICATION	vi
ACKNOWLEDGEMENTS	vii
TABLE OF CONTENTS	viii
LIST OF FIGURES	xii
LIST OF TABLES	xiv
ABSTRACT	xv
CHAPTER ONE: INTRODUCTION	1
1.1 Background to the study	1
1.2 Statement of the problem	3
1.3 Aim and Objectives of the study	3
1.4 Significance of the study	4
1.5 Scope of the study	4
CHAPTER TWO: LITERATURE REVIEW	5
2.1 Preamble	5
2.2 Municipal Solid Waste Management Practices	5
2.2.1 Key Municipal Solid Waste Management Challenges in Nigeria	8
2.2.2 Potential of Source Separation for Enhancing Recycling in Nigeria	9
2.3 Overview of Internet of Things	10
2.3.1 Application of IoT to Waste Management Systems	10
2.3.2 IoT Architecture	13
2.4.1 Solid waste management as a decision-making problem	16
2.4.2 MCDM Methods	18
2.4.3 Analytic Hierarchy Process	19
2.5 The proposed system	21
2.5.1 The proposed smart-bin monitoring architecture (IOT)	22
2.5.2 Machine Learning-Based Waste Forecasting	24

CHAPTER THREE: RESEARCH METHODOLOGY	26
3.1 Preamble	26
3.2 Random Forest Regression	27
3.2.1 Data Retrieval	27
3.3 System Architecture	28
3.3.1 Proposed System Architecture	29
3.4 Software architecture	29
3.4.1 Requirement analysis	32
3.4.2 Functional requirements of the proposed system	34
3.4.3 Non-functional requirements of the proposed system	35
3.5 Problem definition for ranking with AHP	36
3.5.1 Problem Criteria	37
3.5.2 Criteria weight assignment	38
3.5.3 Alternatives	39
3.5.4 Justification for using AHP	39
3.6 System modeling	40
3.6.1 Unified Modelling Language	41
3.7 Logical designs	42
3.7.1 Use case diagrams	42
3.7.2 Activity Diagram	52
3.7.3 Sequence Diagram	53
3.8 Conceptual Design	55
CHAPTER FOUR: RESULTS AND DISCUSSION	57
4.1 Preamble	57
4.2 Implementation environment	57
4.2.1 Software Prerequisites	57
4.2.2 Hardware Requirements	58
4.2.3 Waste Bin Model Requirements	58
4.3 API design	58
4.3.1 User Authentication and Onboarding	59
4.3.2 Authorization and Authentication	59
4.3.3 User Onboarding	60
4.3.4 Onboarding and authentication flow for households and recyclers	60

4.3.5	Register (As a household)	60
4.3.6	Register as a recycler	61
4.4	Smart bin integration	62
4.4.1	Weight module calibration	62
4.4.2	Hardware Integration and Testing	63
4.4.3	Data Logging and Dashboard Update	64
4.5	User's Dashboard	64
4.5.1	Pickup requests	65
4.6	Schedule pickup	68
4.6.1	Ranking pickup requests using AHP	68
4.6.2	Assigning weight to recycler preferences	68
4.6.3	Evaluating the accuracy of AHP: Ranking pickup requests	69
4.6.4	Pairwise comparison matrix	70
4.6.5	Normalizing the features and creating the criteria matrix	72
4.6.6	Ranking scores of pickup requests	74
4.6.7	Recycler ranking output	75
4.6.8	Accepting/Rejecting pickup requests	75
4.7	Predicting future waste generation	76
4.7.1	Data Collection and Pre-processing	76
4.7.2	Train-Test data split	77
4.7.3	Developing of prediction model	77
4.7.4	Making prediction	78
4.7.5	Model Evaluation	78
4.7.6	Export the model as JSON	80
4.8	Usability Evaluation	81
4.8.1	Usability Evaluation Attributes	81
4.8.2	Participants	82
4.8.3	Data Analysis	82
4.8.4	Discussion	83
CHAPTER FIVE: CONCLUSION AND RECOMMENDATION		86
5.1	Summary	86
5.2	Contribution to Knowledge	86
5.3	Recommendations	86

5.4 Conclusion 87

REFERENCES 88

LIST OF FIGURES

FIGURES	TITLE OF FIGURES	PAGES
2.1	Municipal solid waste management hierarchy	6
2.2	MSW composition in sub-Saharan Africa and globally	7
2.3	Three-layer architecture	13
2.4	A generic decision-making process	15
2.5	The hierarchical structure of MCDM methods	18
2.6	Circuit connection of weight monitor (Arduino Forum, 2019)	22
2.7	Arduino UNO R3 microprocessor	23
2.8	Four-wired load cell and HX711 amplifier	23
2.9	Circuit diagram of the smart bin weight monitor	24
3.1	Snapshot of the dataset	28
3.2	Illustration of the proposed system architecture	29
3.3	The adopted three-tier architecture	30
3.4	Use case diagram of the proposed system	43
3.5	Class Diagram for the proposed system	51
3.6	Activity diagram for the proposed system	53
3.7	Authentication sequence diagram	54
3.8	Pickup request sequence diagram	55
4.1	Household registration	61
4.2	Recycler's registration	62
4.3	Calibration of HX711 amplifier and load sensor	63
4.4	The firebase real-time with waste data and userId	64
4.5	Dashboard for households and recyclers	65
4.6	Requesting a pickup	66
4.7	Recycler "X" assigned to the pickup	67
4.8	A recycler receiving email notification on threshold	67
4.9	Scale of relative importance (Saaty, 1980)	69
4.10	Profile of Recycler A, B and C with their preferences	70
4.11	Criteria matrix	71
4.12	Random index scale (Saaty, 1980)	71

4.13	Pairwise matrix for the criteria (Distance)	73
4.14	Pairwise matrix for the criteria (Quantity)	73
4.15	Pairwise matrix for the criteria (Price)	74
4.16	Overall ranking scores for each request for recyclers	74
4.17	Pickup requests sorted by score for the recyclers	75
4.18	Importing dataset and preprocessing	76
4.19	Split dataset into training and test	77
4.20	The regressor model	77
4.21	Calculating the MSE and MAE for the model	79
4.22	Calculating the MAPE for the model	80
4.23	Export the model in JSON	80
4.24	User-friendliness chart	83
4.25	Navigation & Efficiency chart	83
4.26	Error rate chart	84
4.27	Clarity & Responsiveness chart	84
4.28	Overall Satisfaction chart	85

LIST OF TABLES

TABLE	TITLE OF TABLE	PAGES
3.1	Registration (Recyclers & Households)	44
3.2	Smart Bin Monitoring	45
3.3	Pickup Request	46
3.4	Recycler Pickup Offer	47
3.5	Ratings and Feedback	48
3.6	Recycler Pickup Preference Setup	49
3.7	Role-based Access Control	50
4.1	Criteria weighted sum value	71
4.2	Statistical Analysis of Usability test	82

ABSTRACT

Sustainable municipal solid waste (MSW) management is a critical challenge faced by rapidly urbanizing regions, such as Lagos, Nigeria. The negative impacts of unchecked waste generation and poor waste disposal practices have become increasingly evident, necessitating innovative solutions to harmonize economic growth with environmental sustainability. This thesis proposes an IoT-based system to optimize MSW management in Lagos, Nigeria, by leveraging smart bins and the Analytic Hierarchy Process (AHP) for waste ranking. To address these challenges, the proposed IoT-based system incorporates smart bins equipped with weight sensor, microprocessor, and IoT connectivity. The system empowers households to create pickup requests and enables recyclers to set preferences for waste collection, optimizing resource allocation and efficiency. Additionally, the system uses AHP to systematically rank available recyclable waste, guiding recyclers' decision-making process. The system represents a transformative approach to municipal solid waste management in Lagos, Nigeria. Successful implementation of the system will require collaboration with local stakeholders (recyclers and households) and continuous improvement based on stakeholders' feedback. This research lays the groundwork for future advancements in end-user sorting as a waste management practice and serves as a model for other urban areas facing similar challenges.

Keywords: Municipal solid waste, Recycling, Analytical hierarchy process Machine learning, Forecasting, Smart cities.