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Sur le thème

designing a user-centric mobile app for promoting eco-friendly behavior

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Dedication

We humbly dedicate this work to our beloved parents, whose unwavering support and encouragement have been my foundation. They have our deepest love and respect.

To our sisters and brothers.

To my entire family and friends.

Billal Younes

Glossaire

— **HCD :** Human Centred Design .
— **Ai :** Artificial Intelligence .
— **IDE :** Integrated Development Environment .
— **JWT :** JSON Web Token
— **UI :** User Interface.
— **UX :** User eXperience.
— **TAM :** Technology Acceptance Model.
— **SUS :** System Usability Scale.
— **IOT :** Internet of things.
— **JSON :** JavaScript Object Notation.
— **BP :** Behavioral Pattern.
— **BI :**Bad Behavior.
— **TA :** Target Attitude.
— **PI :** Positive Impact.
— **NI :** Negative Impact.
— **B :** Behavior.
— **G :** Gamification.
— **E :** Event.
— **C :** Condition
— **A :** Action
— **MVC :** Model View Controller
— **API :** Application Programming Interface
— **RFID :** Radio Frequency Identification

Abstract

This master's thesis explores the design of a mobile application promoting environmentally friendly behavior among citizens. The research investigates existing user psychology, behavioral patterns, and motivational factors influencing eco-friendly actions. The user-centric application incorporates intuitive interfaces, gamification elements, and personalized feedback mechanisms to promote citizen engagement in activities like proper waste disposal, reporting overflowing bins, reducing single-use plastics, and waste segregation. This research contributes to building a sustainable society by leveraging mobile technology to encourage eco-friendly practices. The derived design principles and findings serve as a potential blueprint for future mobile applications aimed at driving positive environmental change..

Keywords : Mobile Application Design, Eco-Friendly Behavior, User Engagement, Gamification, Sustainable Development.

Résumé

Ce mémoire de maîtrise explore la conception d'une application mobile visant à promouvoir les comportements écologiques auprès des citoyens. La recherche s'intéresse à la psychologie de l'utilisateur, aux modèles de comportement existants et aux facteurs de motivation qui influencent les actions respectueuses de l'environnement. L'application centrée sur l'utilisateur intègre des interfaces intuitives, des éléments de gamification et des mécanismes de feedback personnalisés pour encourager la participation des citoyens à des activités telles que l'élimination correcte des déchets, le signalement des poubelles débordantes, la réduction du plastique à usage unique et le tri des déchets. Cette recherche contribue à la construction d'une société durable en exploitant la technologie mobile pour encourager les pratiques écologiques. Les principes de conception et les résultats obtenus peuvent servir de modèle pour de futures applications mobiles visant à impulser des changements environnementaux positifs.

Mots-clés : Conception d'applications mobiles, comportement écologique, engagement des utilisateurs, gamification, développement durable.

ملخص

تستكشف رسالة الماجستير هذه تصميم تطبيق للهاتف المحمول يعزز السلوك الصديق للبيئة بين المواطنين .يبحث البحث في سيكولوجية المستخدم الحالية، والأنماط السلوكية، والعوامل التحفيزية التي تؤثر على الإجراءات الصديقة للبيئة .يتضمن التطبيق الذي يركز على المستخدم واجهات بديهية، وعناصر التلعيب، وآليات ردود الفعل الشخصية لتعزيز مشاركة المواطنين في أنشطة مثل التخلص السليم من النفايات، والإبلاغ عن الصناديق الفائضة، والحد من المواد البلاستيكية ذات الاستخدام الواحد، وفصل النفايات .ويساهم هذا البحث في بناء مجتمع مستدام من خلال الاستفادة من تكنولوجيا الهاتف المحمول لتشجيع الممارسات الصديقة للبيئة .تعمل مبادئ ونتائج التصميم المشتقة كمخطط محتمل لتطبيقات الهاتف المحمول المستقبلية التي تهدف إلى إحداث تغيير بيئي إيجابي.

الكلمات المفتاحية :تصميم تطبيقات الهاتف المحمول، السلوك الصديق للبيئة، مشاركة المستخدم، التلعيب، التنمية المستدامة.

Table of Contents

List of Figures

List of Tables

Part I

General Introduction

Chapter

1 General Introduction

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Contents

1.1 Context and motivation

Public health is fundamental to a thriving society, directly influenced by our environmental conditions. Ensuring the well-being of the population in Algeria necessitates addressing the environmental challenges that impact health. One of the critical factors exacerbating environmental degradation is human behavior. Improper waste disposal, littering, and other irresponsible practices significantly contribute to pollution. These actions often stem from negative attitudes and habits, which, over time, become ingrained and widespread. Individual actions, when repeated, form habits that can collectively lead to substantial environmental harm. For instance, the casual disposal of waste can escalate into a broader societal issue of environmental neglect. These behaviors, driven by a lack of awareness or disregard for environmental consequences, create a cycle that is difficult to break. To mitigate the adverse effects of human behavior on the environment, it is essential to influence attitudes and encourage positive behaviors. Techniques such as gamification and persuasive design can be powerful tools in this endeavor. By incentivizing responsible actions and raising awareness, we can foster sustainable habits that benefit both the environment and public health. Addressing this issue requires a multifaceted approach that integrates technical solutions with behavioral change strategies.

1.2 Problem Statement

The environmental health of Tiaret is severely compromised due to improper waste management practices. Despite having infrastructural provisions and planning in place, the core issue lies within the behaviors of individuals that contribute to environmental degradation. This section explores the detrimental impact of human behavior on waste management and public health.

1.2.1 Human Behavior and Waste Management

Inadequate waste management is often a result of behaviors that neglect environmental considerations. Such behaviors include :

- **Littering :** Throwing garbage on the ground rather than using available trash bins, leading to widespread litter.
- **Improper Disposal :** Leaving unsealed garbage bags exposed, which results in waste being scattered by animals or weather conditions.
- **Bulk Waste Disposal :** Depositing large or bulky items on sidewalks or public areas instead of designated disposal sites.
- **Misuse of Public Bins :** Using public trash bins for unauthorized or hazardous waste, complicating waste management processes.
- **Lack of Recycling :** Failing to sort recyclable materials, contaminating regular waste streams and reducing recycling efficiency.

1.2.2 Impact on Environment and Public Health

These behaviors have significant repercussions :

- **Pollution :** Accumulated waste contributes to soil and water pollution, harming ecosystems and wildlife.
- **Health Risks :** Unmanaged waste can lead to the proliferation of disease vectors such as rodents and insects, increasing the risk of infectious diseases.
- **Aesthetic Degradation :** Visible litter and waste diminish the beauty of urban and natural landscapes, affecting the quality of life and potentially reducing property values.

1.2.3 Behavioral Patterns and Attitudes

Understanding the connection between behavior, attitudes, and environmental impact is crucial. Behaviors are often a result of established attitudes and habits :

- **Attitudinal Factors :** Attitudes towards waste management are shaped by cultural, social, and individual beliefs. A lack of environmental awareness or a perceived inconvenience in proper waste disposal contributes to negligent behaviors.
- **Habit Formation :** Repeated behaviors become habits, which are difficult to change without intervention. Poor waste disposal habits, once established, perpetuate a cycle of environmental degradation.

1.2.4 The Need for Behavioral Change

To mitigate the negative impact on the environment and public health, it is essential to foster a change in individual behaviors. This requires :

- **Education and Awareness :** Enhancing awareness about the environmental and health impacts of waste mismanagement.
- **Community Engagement :** Encouraging collective responsibility and community-led initiatives to promote proper waste management.
- **Policy and Enforcement :** Implementing and enforcing policies that incentivize responsible waste disposal and penalize non-compliance.

By addressing the behavioral aspects of waste management, it is possible to make significant strides towards a cleaner and healthier environment in Tiaret.

1.3 Overview of Our Solution

To participate in solving this problem, we have set the goal of designing and developing a mobile application with IOT devises dedicated to citizens. This application will help citizens locate nearby trash bins, raise awareness about city protection activities and initiatives,report issues, and educate citizens

through accessible tips and best practices via their smartphones,also helps waste collectors to be more efficient in their work additionally influence citizen to effect their attitudes and reverse the cycle.

1.4 Organization of Our Report

Our report is structured into five chapters. Chapter 1 provides a general introduction. Chapter 2 explores the relationship between technologies and behavior changes. Chapter 3 presents an analysis and diagnosis of the current situation. Chapter 4 focuses on designing a user-centric solution to promote eco-friendly behaviors. Chapter 5 discusses the proof of concept and tooling. Finally, we conclude with a general summary that addresses the limitations and potential extensions of the application.

Part II

Bibliographic Elements

Chapter

2 Technologies and behavior change

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Contents

2.1 Introduction

Human behavior is a very important aspect that must be considered by designers and developers in computer science. Recent research in software engineering has begun to introduce human aspects into software development, such as age, emotion, and education level. In this chapter, we will present the fundamental concepts of human behavior and the design process that must be followed to build solutions that consider human aspects. In addition, we will present some concepts about technology acceptance and testing.

2.2 Fundamental concepts

In this section, we present the fundamental concepts related to technologies and behavior change.

2.2.1 Behavior

Définition 1 (*Behavior*)

Behavior refers to your observable actions or how you conduct yourself in response to a situation or stimulus. It's the outward expression of your internal thoughts and feelings [14, 1].

Exemple 1. Example of Behavior

2.2.2 Attitude

Définition 2 (*attitude*)

An attitude refers to a collection of your beliefs, feelings, and evaluations towards a specific object, person, situation, or concept. It represents your internal perspective and influences how you think and feel about something [37].

Exemple 2. Example of Attitude

2.2.3 The Relationship between Attitude and Behavior

The relationship between attitude (A) and behavior (B) can be conceptualized as **a two-way influence** [22]. Here's a breakdown :

- A → B : A positive attitude (A) can influence a person to engage in a specific behavior (B).
- B → A : Engaging in a positive behavior (B) can reinforce a positive attitude (A).

$$\text{Behavior} \underset{\text{influence}}{\overset{\text{influence}}{\rightleftharpoons}} \text{Attitude}$$

Attitudes and behaviors are closely linked, but they don't always perfectly align [22]. Here's how they can influence each other :

- **Attitudes can influence behavior :** A positive attitude towards keeping your city clean (e.g., believing it's important and makes the city nicer) might lead you to participate in trash collection drives (behavior).
- **Behavior can influence attitudes :** Regularly participating in clean-up efforts (behavior) can strengthen your positive attitude towards city cleanliness (attitude) [31].

Exemple 3. Changing Citizen Behavior for Improved Trash Management *Imagine a city with a litter problem. Here's how attitudes and behaviors might play a role in changing citizen behavior regarding trash management :*

- ***Current Attitude :*** *Residents might have a negative attitude towards public cleanliness (e.g., believing it's someone else's responsibility, feeling the problem is too big to make a difference). Current Behavior : This attitude might lead to littering or not actively participating in trash collection efforts.*
- ***Changing Attitudes :*** *An awareness campaign could highlight the benefits of a clean city (improved health, aesthetics) and emphasize the impact of individual actions. This can shift resident attitudes towards valuing cleanliness.*
- ***Changing Behavior :*** *With a more positive attitude, residents might be more likely to :*
  - *Throw trash away properly.*
  - *Participate in clean-up initiatives.*
  - *Encourage others to do the same.*

By changing attitudes, the city can encourage positive behavior changes that lead to better trash management and a cleaner environment.

Remember : *While attitudes influence behavior, other factors can also play a role, such as :*

- ***Social norms :*** *What's considered acceptable behavior in the community ?*
- ***Convenience :*** *Are there enough trash bins readily available ?*
- ***Enforcement :*** *Are there penalties for littering ?*

By addressing both attitudes and practical concerns, a city can create a lasting positive change in citizen behavior regarding trash management.

The diagram illustrates the relationships between people, behavior (both good and bad), and attitudes, using arrows to denote different types of influences and changes.

2.3 Persuasive design

Persuasive design is a set of methods that seeks to influence a user's behavior by understanding the psychological forces that drive it **[fogg2009behavior?redstrom2006persuasive]**.

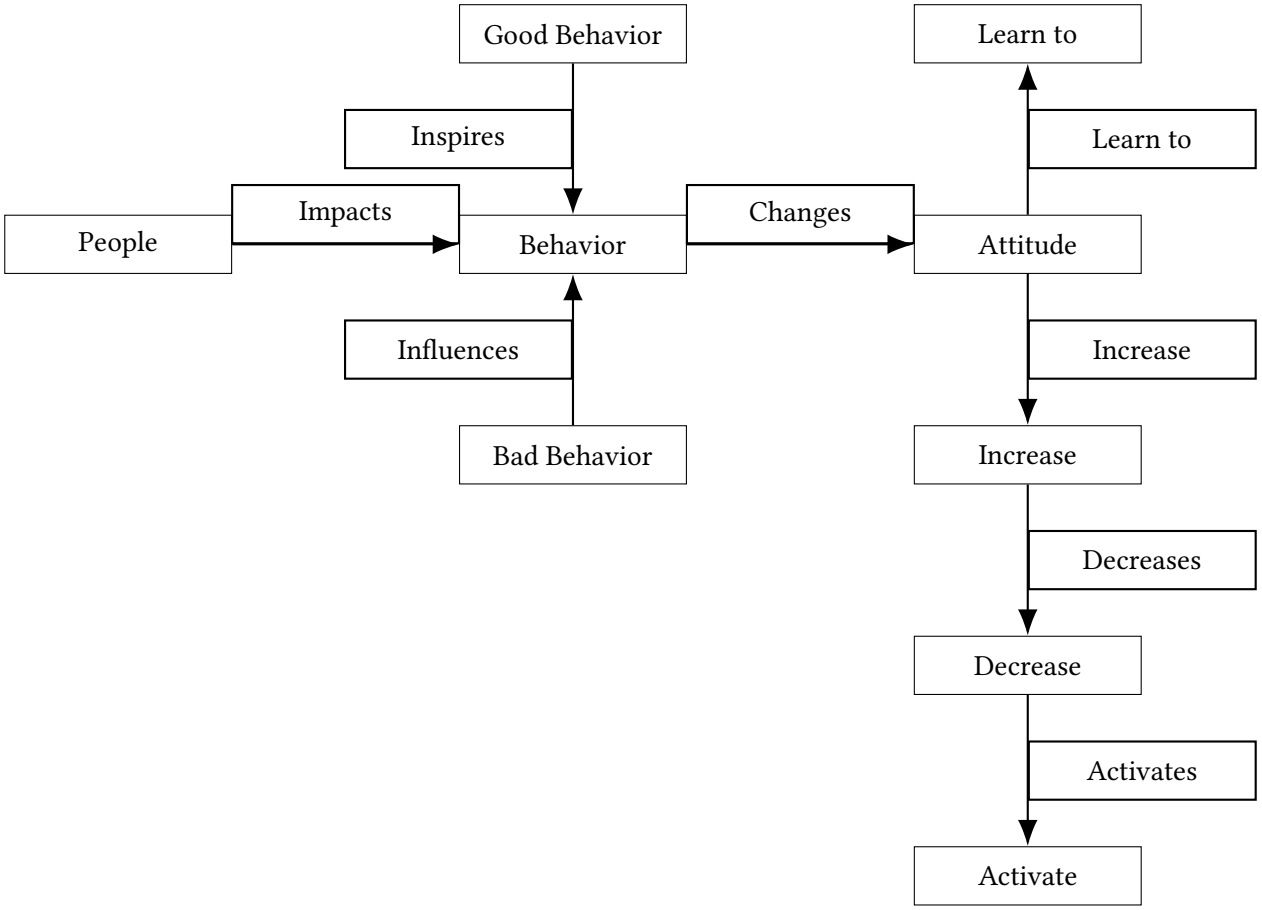


FIGURE 2.1 – Relationships between People, Behavior, and Attitude

2.3.1 Cognitive dissonance

Cognitive dissonance occurs when attitude and behavior are in contradiction, we act in a way that we do not consider good. The **??** illustrate the Cognitive dissonance [13, 7].

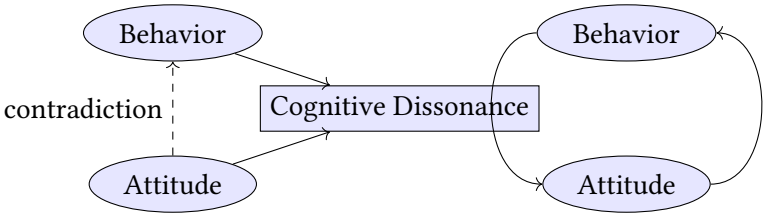


FIGURE 2.2 – Illustration of cognitive dissonance. [13].

For example, we can take the case of Michel, who has a strong ecological sensitivity and to whom his friends offer to join him for a plane trip to Romania.

— **Attitude :** he is not inclined to take the plane because he judges that going on vacation by plane does not justify the impact environmental

— **Behavior :** he accepts his friends' proposal and reserves his plane ticket

Behavior	The behavior is adjusted to be consistent with the attitude *Example of Michael : canceling his reservation*
Attitude	The attitude is adjusted to justify itself in relation to the behavior ; this is the process of rationalization *Example of Michael : telling himself that it's not that bad, that it's only for once, and that after all, he has the right to take a vacation with his friends*

Table 2.1 – Description of behavior and attitude adjustments

A persuasive interface can either

- Capitalize on an existing cognitive dissonance : the user wants to perform the behavior but is blocked,
- the interface will help him overcome this blockage
- Change the attitude so that the user realizes that he is not performing the right behavior, and readjusts by performing it from now on

2.3.2 Process of persuasive design

The table below a depiction of the Fogg Behavior Model created by BJ Fogg [15]. It outlines different ways people can change their behaviors. The table breaks down the model into three main categories : Do, Increase, Decrease, and Stop. Each category then has three subcategories : One Time, Span, and Path.

- **Do** : This section focuses on performing a behavior for the first time or in a single instance.
- **Increase** : This section focuses on gradually increasing the frequency of a desired behavior over time.
- **Decrease** : This section focuses on gradually reducing the frequency of an unwanted behavior over time.
- **Stop** : This section focuses on entirely eliminating a behavior.

2.3.2.1 Target the behavior to change

We must not be too ambitious or too broad in the choice of this behavior, since it must remain something that can be measured.

- **Good example :** 'take the bus instead of taking the car'
- **Bad example :** reduce the environmental impact of your daily activity'

The subcategories, One Time, Span, and Path, further define how long you perform the behavior for.

- **One Time** : This refers to performing a behavior just once.
- **Span** : This refers to performing a behavior for a set amount of time.

Target the behavior to change	Choose the behavior to modify ; it should be a simple behavior whose evolution can be monitored
Understand the users	Study the attitudes, motivations, capabilities, and sensitivity to triggers of the users
Identify behavior blockers	Identify the reasons why the behavior is not performed and categorize them in terms of motivation, capabilities, and triggers
Choose the appropriate technology	Select the best technology (website, mobile app, social network, etc.) on which to apply persuasive design
Find inspiring examples	Search the internet for examples of persuasive interfaces addressing a similar problem for inspiration
Prototype and test	Develop a prototype of the persuasive system and gather user feedback to improve it
Deployment and monitoring	Deploy the system in the users' environment and monitor the behavior evolution

TABLE 2.2 – Persuasive Design : Process [15].

— **Path** : This refers to continuously performing a behavior from now on.

The table uses color coding to represent different types of behaviors :

— **Green** : New behavior
— **Blue** : Familiar behavior
— **Purple** : Increase behavior intensity
— **Gray** : Decrease behavior intensity
— **Black** : Stop behavior

For example, a green dot in the "Do" section with a "One Time" subcategory indicates trying a new behavior once.

The Fogg Model suggests that the easiest way to change behavior is to start small and gradually increase the difficulty over time. This can help people to overcome inertia and build momentum towards their goals.

2.3.2.2 Know the users

Getting to know your users can't bring together wrong elements

— Technical skills
— Types of interfaces they are used to using
— Type of message they react to best (negative showing the disadvantages of not performing a behavior or positive showing the advantages of performing a behavior)

We learn about users by testing prototypes, so it's a step that gets richer as we go.

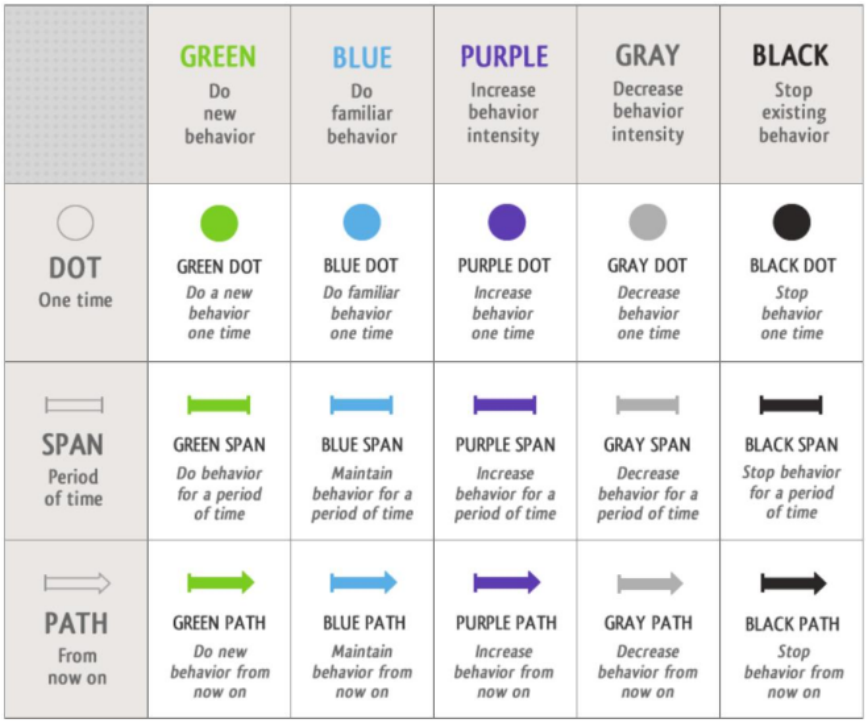


FIGURE 2.3 – Target the behavior to change [15].

2.3.2.3 Find What's Blocking the Behavior

The graph shows the connection between how motivated you are and your ability to achieve something (perceived ability).

- On the left side, it says "Motivation" (vertical axis) with "Weak" at the bottom and "Strong" at the top.
- On the bottom, it says "Perceived Capacity" (horizontal axis) with "Weak" on the left and "Strong" on the right.
- A diagonal line cuts across the graph from bottom left to top right, labeled "Increase in the probability of performing the desired behavior." This means the higher your motivation and perceived ability, the more likely you are to do what you set out to do.
- There are two boxes in the graph. The box on the left says "Strong Motivation" and "Strong Capacity" and the box on the right says "Weak Motivation" and "Weak Capacity."

plane ticket to go to Romania like Michel

- **Motivation** : the person simply does not want to go Romania
- **Capacity** : the person does not have the time or the means financial to go to Romania
- **Trigger** : the person wants to leave and thinks they have one abilities, but she doesn't particularly think about it and stays
- status quo, if she receives an email with an offer or someone asks him to leave, the behavior can be 'sets off'

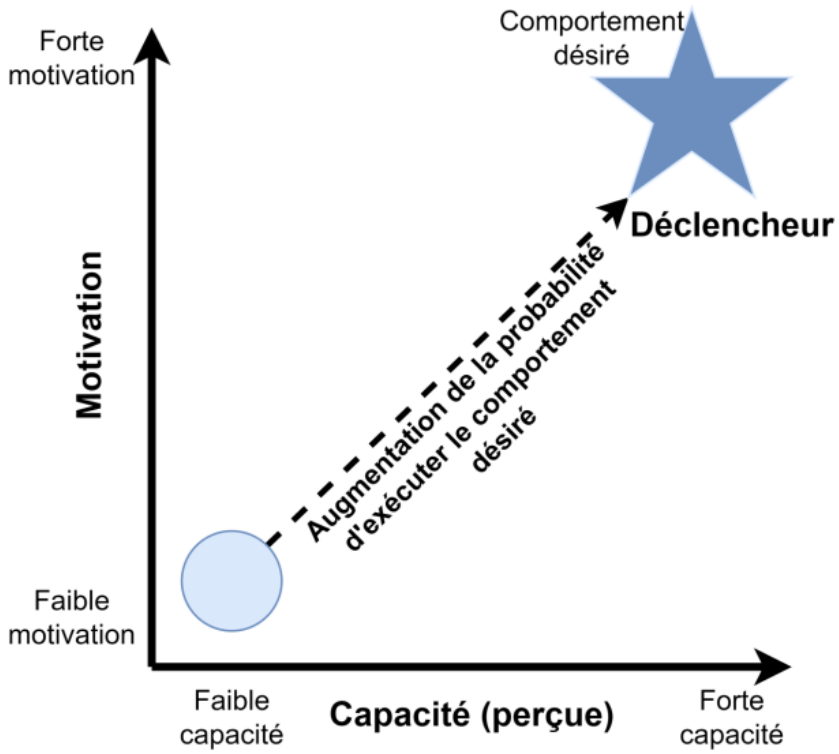


FIGURE 2.4 – Find what is blocking the behavior (Fogg Behavior Model) [15].

2.3.2.4 Choosing the Right Technology

There are many types of interface, for example a site web, a mobile application, a social network, etc. The right type should be chosen according to the users and what blocks the behavior

- If the users are already users of a smartphone, a application is a good type of interface
- If the problem comes from motivation, a social network in which users could encourage each other is a good type interface

2.3.2.5 Prototype and test

You must present the prototype to users and ask them questions about what is useful to measure, based on the design choices that have been made.

- If the interface is strong based on information, we can ask to the user if he found the information useful and credible
- If the interface seeks to simplify, we will rather ask questions about ease of use

2.3.2.6 Deployment and monitoring

Deployment and monitoring involve implementing the persuasive system in the users' environment. This stage ensures that the system is accessible and functions correctly in real-world settings. Continuous

Technique	Description
Simplification	Reduce complex behaviors to simplified actions
Tunneling	Guide the user through a process
Personalization	Adapt the persuasive message to the user's needs, interests, personality, context of use, or other relevant factors
Suggestion	Suggest a change in behavior at the most opportune moment
Self-Monitoring	Help users modify and monitor their behaviors to achieve a goal
Monitoring	Allow a user to compare their results to those of others to encourage them to achieve their goals
Reinforcement	Use positive reinforcement to turn existing behaviors into habits, or use negative reinforcement

Table 2.3 – Prototype and Test

monitoring is essential to track the effectiveness of the persuasive interventions. It allows for the collection of data to analyze behavior changes and make necessary adjustments for optimization.

2.4 Gamification

Gamification consists of using game mechanics in a non-game context. It also provides mechanisms for designing interfaces capable of changing user behavior.

There are many definitions of gamification in the literature, we extracted a definition from a recent paper survey.

Définition 3 (*Gamification*)

The use of game elements in non-gaming systems to improve user experience and user engagement, loyalty and fun." This definition emphasizes the use of game elements and their impact on user experience [12].

2.4.1 Flow theory

The Figure 2.6 depicts a graph illustrating the concept of Flow Theory, developed by Mihaly Csikszentmihalyi [4].

The graph reveals that individuals experience the highest levels of motivation and engagement when confronted with challenges of moderate difficulty. When the challenge is too simplistic, individuals become bored and disinterested. On the other hand, when the challenge is excessively demanding, individuals become stressed and disengaged.

2.4.2 Mechanisms

The Table 2.4 categorizes various gamification mechanics (e.g., points, badges, leaderboards) and provides brief explanations of their purposes.

TABLE 2.4 – Gamification Mechanisms [11]

Gamification Mechanic	**Description**
Points	Simple way to track progress and reward desired behaviors.
Badges	Virtual awards recognizing achievements and motivating completion of tasks.
Leaderboards	Allow users to compare their progress, fostering competition and improvement.
Levels	Provide a sense of progression and accomplishment as users move up.
Challenges	Encourage users to step outside their comfort zone and try new things.
Unlockables	New features or content that become available as users progress.
Progress Bars	Visual representation of progress towards a goal, keeping users motivated.
Virtual Goods	Items acquired within the experience, either cosmetic or functional.
Quests	Series of tasks users need to complete to achieve a goal.
Real-World Rewards	Tangible rewards earned for participation, like discounts or cash.

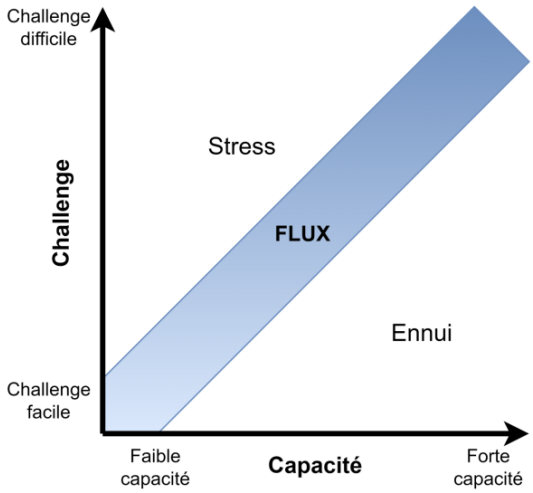


FIGURE 2.5 – Flow theory [4].

2.4.2.1 Points/scores

Earning points for completing tasks provides a sense of accomplishment and progress, fostering intrinsic motivation. [20].

Exemple 4. *users earn points for actions such as recycling, using public transportation, or participating in community clean-up events. These points can be tracked to monitor individual progress and environmental impact.*

2.4.2.2 Badges

Awarding badges for achieving milestones or demonstrating desired behaviors acts as a visual recognition system, increasing user engagement. [32].

Exemple 5. *Earn badges for achievements such as reducing their carbon footprint, planting trees, or completing a sustainability challenge. These badges can be displayed on their profile, encouraging further participation.*

2.4.2.3 Leaderboards

Public leaderboards introduce a competitive element, encouraging users to strive for better performance and improve their behaviors. [9].

Exemple 6. *Leaderboards can rank users based on their overall points, number of completed challenges, or amount of waste reduced. This creates a healthy competition that drives collective action towards sustainability goals.*

2.4.2.4 Levels

Level progression systems provide a clear path towards mastery, enhancing user motivation and satisfaction as they unlock new challenges. [23].

Exemple 7. *Users start at a beginner level and progress through levels like Eco-Warrior or Green Champion as they accumulate points and complete more challenging tasks. Each level unlocks new opportunities and rewards.*

2.4.2.5 Challenges

Time-bound or goal-oriented challenges create a sense of urgency and excitement, promoting active participation in desired behaviors. [34].

Exemple 8. *For example, platforms might issue challenges such as "Reduce your water usage by 10% this month" or "Bike to work every day for a week." Successfully completing these challenges can earn users additional points or badges.*

2.4.2.6 Unlockables

The opportunity to unlock new features, content, or functionalities within the platform incentivizes continued engagement and reinforces positive behaviors. [40].

Exemple 9. *Users can unlock new features such as advanced sustainability tips, exclusive access to eco-friendly product discounts, or entry into special events as they reach higher levels or complete certain challenges.*

2.4.2.7 Progress bars

Visualizing progress towards a goal through progress bars provides users with a sense of control and motivates them to persevere in their efforts. [3].

Exemple 10. *Progress bars might show how much waste a user has reduced over a month, how close they are to completing a challenge, or their progress towards a yearly carbon footprint reduction goal.*

2.4.2.8 Real-world rewards

Offering tangible rewards for achieving specific goals within the gamified system acts as a strong extrinsic motivator, further solidifying the desired behavior change. [28].

Exemple 11. *Users might earn real-world rewards such as discounts on eco-friendly products, vouchers for local sustainable businesses, or even cash rewards for significant contributions to community sustainability projects.*

2.4.3 Hazards

Gamification, if used incorrectly, can have counterproductive effects

- The game mechanics can be diverted (hunters of badges, awards)
- It's difficult to make a 'patch' on a gamified interface, and to modify or delete the points or badges system already in place without frustrating users
- Competition, if too keen, can lead to sabotage and return negative emotions which will have an adverse effect on motivation

2.4.4 Example

Coralog aims to encourage users not to let their computer run for nothing

- Mechanism used : personalization – user performance is represented by the state of health of a coral and fish – and self-monitoring
- An emotional attachment was observed, participants declared wanting to reduce their consumption to save the fish

Petkov's interface aims to encourage users to become aware of their energy consumption and its impact

- Mechanisms used : comparison with a group, comparison with a person, classification, conversion of consumption in terms of trees, perspective in relation to the limits of the planet, and finally the impact on habitat polar bears

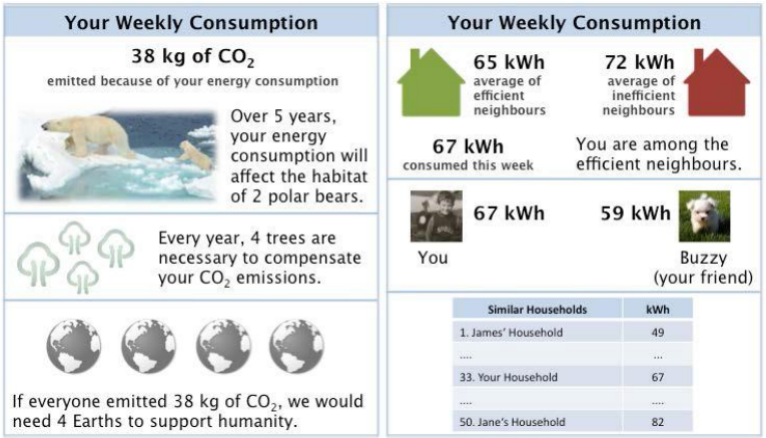


FIGURE 2.6 – Petkov's interface.

- The mechanisms preferred by participants are conversion in terms of number of planets can be effect seem quite distant because users feel more directly concerned by comparisons with the neighborhood or conversions into more meaningful units than kWh like trees or money
- Information on polar bears does not work well because it sends too negative a message for users

2.5 Impacts of technology on humans

Technology acceptance is a crucial factor in determining whether a new technology will be integrated into the lives of its intended users. It goes beyond simply acquiring the technology and delves into the human behavior of consistently using it.

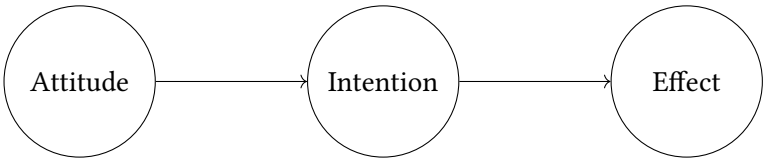
2.5.1 Acceptance of technologies

For several decades, researchers have been trying to understand what factors determine whether a technology will be adopted or not.

The best known works have taken psychology as starting point :

The theory of reasoned action suggests that behavior is determined by the intention to perform the behavior, which is determined by the subjective norm and attitude towards the behavior [18].

FIGURE 2.7 – The Relationship Between Attitude, Intention, and Effect



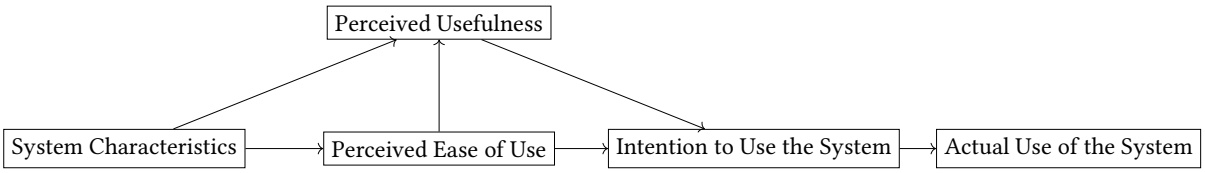


FIGURE 2.8 – Technology Acceptance Model (TAM)

Exemple 12. Description of the Revised Example Based on the Theory of Reasoned Action *In this example, we illustrate how attitudes and subjective norms influence intentions and behaviors regarding responsible trash disposal in the context of city protection.*

The Figure 2.9 illustrate a Behavioral Model for City Protection and Trash Management.

Components of the Model

Attitude towards the Behavior

Description : This refers to an individual's positive or negative evaluation of the behavior of properly disposing of trash.

Beliefs and Evaluations :

+ Positive Beliefs : "Keeping the city clean is good."
+ Negative Beliefs : "It's inconvenient to find a bin."

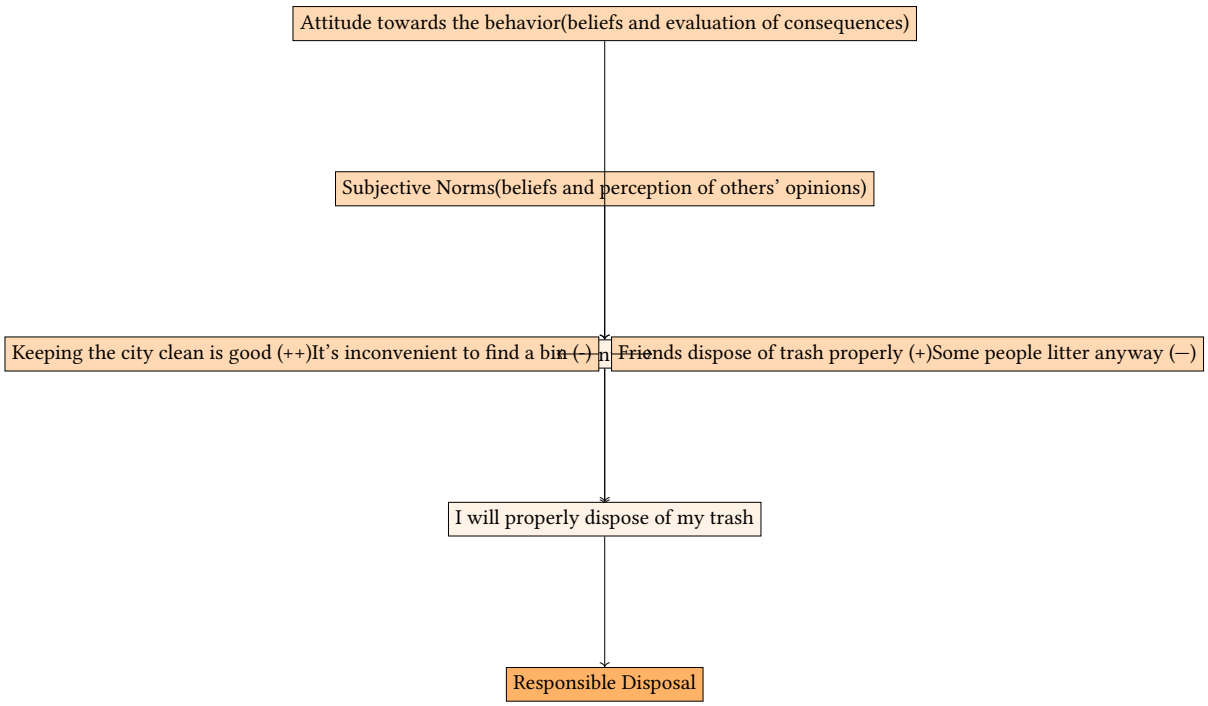


FIGURE 2.9 – Behavioral Model for City Protection and Trash Management

Overall Attitude : The individual weighs these beliefs, considering both the benefits of a clean city and the inconvenience of locating a trash bin.

Subjective Norms

Description : These are the perceived social pressures to perform or not perform the behavior of disposing of trash properly.

Beliefs and Evaluations :

+ Positive Social Pressure : "Friends dispose of trash properly."
+ Negative Social Pressure : "Some people litter anyway."

Overall Subjective Norms : The individual considers the social influences, such as the positive example set by friends and the negative behavior of others who litter.

Intention

Description : This is the motivational factor that indicates how much effort an individual is willing to exert to perform the behavior. It is shaped by both their attitudes towards the behavior and subjective norms.

Formed Intention : Based on the weighed attitudes and subjective norms, the individual forms the intention : "I will properly dispose of my trash."

Actual Behavior

Description : This is the behavior that is ultimately performed by the individual.

Behavior Exhibited : "Responsible Disposal." The intention to dispose of trash properly leads to the actual behavior of responsible trash disposal.

Pathways and Influence

Attitude to Intention : The belief that "Keeping the city clean is good" versus "It's inconvenient to find a bin" creates a balanced attitude towards trash disposal. If the positive aspects outweigh the negatives, the attitude will more likely be positive, leading to a stronger intention to dispose of trash properly.

Subjective Norms to Intention : The positive example set by friends versus the negative behavior of others forms the subjective norm. The individual considers these social influences and how much they care about each group's opinion.

Intention to Behavior : The intention to "properly dispose of my trash" directly influences the actual behavior of "responsible disposal." This shows a clear translation from intention to action.

David took the theory of reasoned action as a starting point and adapted it to the information systems context : Using a system is a behavior [8].

The result is **the Theory Acceptance Model (TAM)**, which is still today the best-known model for studying the factors that influence the adoption of a technology. – TAM was first proposed in 1985 but suffered several adaptations in the years that followed [35].

The central idea of TAM is that perceived ease of use and perceived usefulness are the two beliefs that influence (indirectly through intention) the actual performance of a behavior (using the system).

- **Perceived usefulness** is the extent to which an individual thinks that the use of a particular system will improve its professional performance
- **Perceived ease** of use is defined as the degree to which an individual believes that the use of a particular system would be free from physical and mental effort

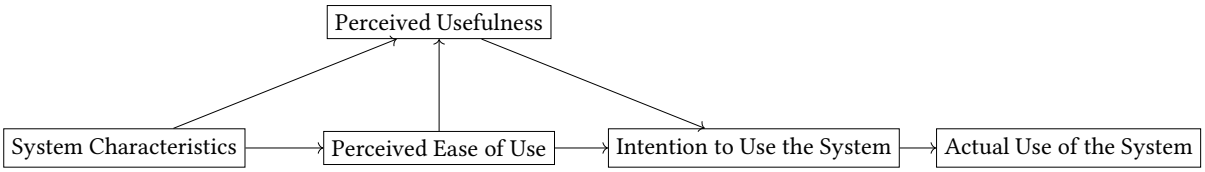


Figure 2.10 – Technology Acceptance Model (TAM)

The TAM is widely used but also criticized ;

- The TAM ignores essential aspects which have become very important with the evolution of technology, such as the trust in services and the influence of social norms
- The TAM has been subject to numerous marginal adjustments, which which has made the domain chaotic since we do not know what is the latest widely accepted version of the TAM

— TAM addresses perceived usefulness and perceived ease of use like black boxes and does not say what measures corrective measures can be taken concretely

2.5.2 User testing

Studies on TAM have shown several things

— There is a significant correlation between intention to use a system measured after one hour of use and usage effective
— Perceived ease of use is an important determinant of the intention to use a system

Therefore, it is important to ensure early enough that a system is easy to use for users.

The aim of user-centered system development is to ensure that the systems developed are easy to use for users.

Four iterative steps : analysis (understanding the requirements of users), design (how to answer it), implementation, and evaluation (did we answer it well)

In practice, the evaluation can be done in two main ways : by asking experts or by asking target users

— One of the most used techniques to ask target users is user testing
— User testing involves asking a target user to run specific single-objective scenarios on a system, without guidance on how to do so, and reporting the interaction through a mixture of qualitative (interviews) and quantitative (questionnaires) techniques

A technique often used in user testing is to administer a standard questionnaire to measure (i) Usability, and (ii) User Experience (UX).

Usability and user experience (UX) are two closely related concepts that are crucial for designing and developing successful products and systems.

2.5.3 Definition of Usability

Usability is the pragmatic component of UX, focusing on the practical aspects of a user's interaction with a system or product. It evaluates criteria such as :

— **Effectiveness :** The user's ability to achieve their goals quickly and easily.
— **Productivity :** The amount of work a user can accomplish using the system or product.
— **Ease of Use :** The ease with which a user can learn to use the system or product.
— **Learnability :** The speed at which a user can acquire the skills necessary to use the system or product.
— **Memorability :** The user's ability to remember the features and procedures of the system or product.

In summary, usability measures the extent to which users are able to perform their tasks in an effective, efficient, and enjoyable manner.

2.5.4 Definition of User Experience (UX)

UX encompasses a broader range of aspects than usability, including not only the practical but also the emotional and subjective elements of a user's interaction with a system or product. It considers factors such as :

— **Emotional Impact :** The feelings the user experiences when using the system or product, such as joy of use, aesthetic appreciation, amusement, novelty, and desirability.
— **Satisfaction :** The user's overall level of satisfaction with the system or product.
— **Engagement :** The level of involvement and motivation of the user in using the system or product.
— **Loyalty :** The user's propensity to continue using the system or product in the long term.

In summary, UX aims to create an overall positive and engaging experience for the user, going beyond mere functionality and encompassing all aspects of the interaction between the user and the system or product.

2.5.5 System Usability Scale (SUS)

The System Usability Scale (SUS) is a widely used questionnaire for measuring usability. Developed in 1996, it consists of 10 statements that users rate on a 5-point Likert scale from strongly disagree to strongly agree. The total score ranges from 0 to 100, with higher scores indicating better usability.

Table 2.5 – SUS Scale

Item	1	2	3	4	5
1. I think I would like to use this system frequently.	○	○	○	○	○
2. I found this system to be unnecessarily complex.	○	○	○	○	○
3. I found this system easy to use.	○	○	○	○	○
4. I think I would need a lot of technical support to be able to use this system.	○	○	○	○	○
5. I found the various functions in this system were well integrated.	○	○	○	○	○
6. I found there were too many inconsistencies in this system.	○	○	○	○	○
7. I imagine that most people would learn to use this system very quickly.	○	○	○	○	○
8. I found this system very awkward to use.	○	○	○	○	○
9. I felt very confident using this system.	○	○	○	○	○
10. I needed to learn a lot of things before I could get going with this system.	○	○	○	○	○

2.5.6 Factors Influencing the Intention to Use Technology

The intention to use a technology is influenced by a combination of individual and external factors. These factors can be broadly categorized into two main groups :

1. Individual Factors Individual factors are those that relate to the characteristics and beliefs of the individual user. These factors include :

— **Performance Expectancy :** The extent to which users believe that using a particular technology will improve their job performance or make their lives easier.

— **Effort Expectancy :** The extent to which users believe that using a particular technology will be easy and require minimal effort.

— **Social Influence :** The extent to which users are influenced by the opinions of others, such as peers or colleagues, to adopt a new technology.

2. External Factors External factors are those that relate to the environment in which the technology is used. These factors include :

— **Facilitating Conditions :** The extent to which users have the resources and support they need to use a particular technology, such as access to training or technical assistance.

In addition to the factors influencing the intention to use technology, it is important to consider control variables in research studies. Control variables are used to ensure that the observed effects are not due to other unaccounted-for factors. Here are some examples of commonly used control variables :

— **Gender** : The gender of participants can influence their intention to use certain technologies.

— **Age** : The age of participants can also influence their intention to use certain technologies, with younger individuals generally tending to be more open to new technologies than older individuals.

— **Experience** : Participants' experience with a similar technology can influence their intention to use a new technology.

— **Voluntariness** : Whether the use of the technology is perceived as mandatory or a choice for participants can influence their intention to use it.

Understanding the factors that influence the intention to use technology can be helpful for designers, developers, and marketers who are trying to promote the adoption of new technologies.

The Figure 2.11 shows the Factors Influencing the Intention to Use a Technology (UTAUT Model).

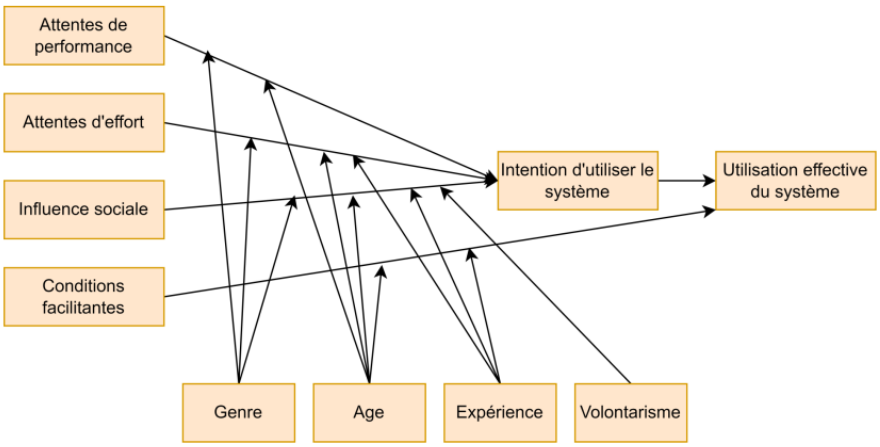


Figure 2.11 – Factors Influencing the Intention to Use a Technology (UTAUT Model)

2.5.7 Technology and inclusiveness

Systems must be evaluated with users

— However, one user is not the other, people have differences

— Some master technologies better than others, some suffer from more or less serious disabilities

It is important to design technologies in an inclusive way so that everyone can benefit from them, at the risk of further widening inequalities (e.g. digital divide).

Two perspectives on the inclusiveness of technologies

— Design of specific technologies to make them autonomous people with disabilities and include them as best as possible in society and the professional world (enabling techs)

— Consideration for people suffering from disabilities in designing systems for use by everyone

2.6 Conclusion

Persuasive design and gamification provide mechanisms to influence behavior." (Persuasive design and gamification offer mechanisms to act on behavior.) The absence of sustainable behavior can be explained by things other than attitude, for example a question of lack of abilities. Persuasive design and gamification offer mechanisms to influence behavior (for example, breaking down a behavior, offering virtual rewards)."

In the following chapter, we present an analysis and diagnosis of the current situation regarding the impact of human behavior on environmental conservation, urban protection, and waste management.

Chapter

3 Analysis and Diagnosis of the Existing Situation

Understanding the Impact of Human Behavior on Environmental Conservation, Urban Protection, and Waste Management

—

Contents

3.1 Introduction

In the previous chapter we introduced human behavior and technologies, because in this chapter we were interested in the problem of citizens' behavior towards the protection of their cities and in the problem of waste.

Before embarking on the phase of collecting needs and reflecting on a possible solution to the issues raised, it is necessary to first study the existing system. This will allow for a better understanding and identification of its limitations, as well as motivations. Therefore, we have chosen to structure this chapter as follows : we begin by presenting the organization of the Tiaret Wilaya Park in Algeria. Next, we will explain the current overall approach used in this service. Finally, we will conduct a diagnosis of the current system before concluding on the tasks with which we are entrusted through this project.

3.2 The organization of the study system :

The park of the Wilaya of Tiaret responsible for managing waste bins in the city is composed of several bodies : a finance and accounting service and the Storage Service. In this organization, the park is managed by an administrator who is assisted by personnel responsible for managing waste bins in the city.

Figure 3.1 – Overall architecture of the existing system.

It should be noted that these bodies also include material equipment, human resources, traditional methods, as well as good practices.

3.2.1 Evolution of the number of neighborhoods and population

The number of neighborhoods and citizens has continued to increase in the Wilaya of Tiaret. However, for the first time since 1991, the proportion of the population has also increased. Although the

means of waste collection resources are well provided everywhere, an official succession plan is also required detailing how the operation will be transferred to the next generation in waste management.

Given this increase in the number of neighborhoods and population, some difficulties have been identified :

- Increase in the number of neighborhoods,
- Lack of means to assess quantitatively / qualitatively the cleaning work and the necessary human resources,
- Absence of park data tracking tools,
- Difficulty in searching for and retrieving documents,
- Absence of detailed data traceability.

3.3 Study of the Existing System

After presenting the mission of the production service, which interests us, we will now begin the study of its current system. During our study, we observed that the Tiaret Wilaya Park service mainly interacts with the management of the directorate and tries to respond to their requests as quickly as possible. We summarized the steps of the existing system process in the figure below.

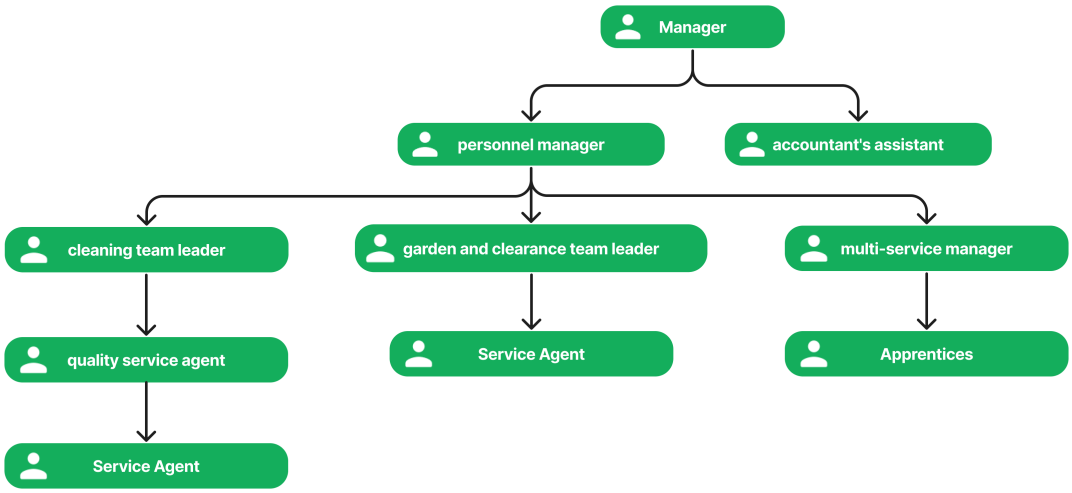


Figure 3.2 – Overall architecture of the existing system.

The previous figure illustrates the following steps :

- The trigger point is the request from decision-makers; they send a request to the logistics service manager specifying the type of report they wish to receive (Statistics).
- The logistics service checks the request and verifies if they have the data stipulated in the report to be provided. In the absence of this data, they request it from the teachers.

— The teachers prepare the data (Excel file, paper report).

— The management handles the interventions of the cleaning agents as much as possible.

— The Tiaret park service prepares and modifies the files in Excel format.

— Then, they transmit them to the deputy manager, who begins preparing the requested schedule by performing the necessary data processing.

— Residents of these streets are asked to take out their trash on Friday mornings rather than the day before.

— The manager receives the report and asks if all the bins will be collected tomorrow.

3.3.1 Actors of the current system :

The table below presents the actors involved in the processes of the current system.

Actors	Roles
Director	- Establish statistics requests to the Wilaya Park. - Receives statistics.
Park Manager	- Make requests to the logistics service. - Receives reports.
Logistics Service (Administration)	- Request data from agents. - Acquire data from the database. - Prepare reports. - Send reports.
Agents	- Prepare data. - Respond to requests from the Logistics Service.

Table 3.1 – Actors of the current system.

3.3.2 Study of cleaning intervention management procedures :

The cleaning process is triggered when there is a cleaning request from the park manager. This request can come from the logistics management service, other park services, or decision-makers. Requests from other logistics services and those from decision-makers pass through the general means management service. The general means management service then forwards the report requests to the intervention management service. The latter verifies the availability and feasibility of the report before submitting the requested reports to the logistics management service. Once the reports are received, the logistics management service consolidates and transmits them to decision-makers and other services that have made a request. Here is a figure that presents the garbage collection process.

FIGURE 3.3 – The garbage collection process.

3.3.3 The current process of garbage collection

The responsible persons in the garbage collection department of the Wilaya Park of Tiaret use in their particular contexts generally adopt an approach composed of the following four phases (Figure) :

3.3.4 The current process of garbage collection

Managers in the garbage collection sector of Parc de la Wilaya de Tiaret typically adopt an approach consisting of the following four phases in their specific contexts (Figure) :

- **Neighborhood survey phase :** The manager queries data sources such as existing Excel files. However, these sources only provide non-detailed data on neighborhood characteristics such as population numbers, notes, events, etc. The manager is thus forced to move on to the next phase.
- **Processing phase :** Among the data returned during the previous phase, several are duplicates. The researcher needs to read the summary, which does not provide detailed neighborhood data. Reading the entire paper will verify whether the paper is relevant or not.
- **Planning phase :** The final phase of the systematic review involves analyzing the data. Planning cleaning agent interventions is a crucial step in any current garbage collection process. It provides administrators with a clearer and more understandable view of the data, statistical results, and reports.

3.4 Current System Diagnosis :

After studying the processes of the current "park management service" system, we have reached the following observations :

3.4.1 Remarks on storage :

We remind that the garbage collection management service does not have direct access to a database. To obtain data, it must send a request to various services. These services then send the requested data in formats such as docx, xls, etc.

We have noticed at this level that :

— The data transmitted from the services are not standardized and therefore difficult and sometimes impossible to process.

3.4.2 Remarks on data quality :

We have observed that the data transmitted by the general means service are raw data and therefore require a cleaning phase before they can be used for analysis purposes.

3.4.3 Remarks on data analysis :

Once the data is processed, an administrator from the management service can then exploit them for analysis purposes.

In the context of this project, we are interested in managing resource data such as agents, trucks, etc. After studying this aspect, we have reached the following observations :

— The analysis of the number of citizens is the only analysis performed within the statistical management service that focuses on analyzing the activities of the Wilaya.

— This analysis is done manually and sometimes becomes difficult to perform.

— There is a lack of methodology based on the analysis of cleaning intervention data.

3.4.4 Remarks on visualization :

After conducting data analyses related to cleaning activities, the statistical management service must visualize the analysis results using a visualization tool. These results are intended for decision-makers and serve as a basis for decision-making.

We observed in this aspect that :

— The service only uses Excel as a visualization tool.

— Sometimes it presents limitations in terms of graphical representations despite the availability of dedicated visualization modules in MS Excel.

3.5 System Diagnostics

3.5.1 Identification and evaluation of anomalies

A careful examination of our system allowed us to understand its operation and identify the reasons for the problems as well as the potential consequences in case of malfunction. Although it is not possible to list in detail all the challenges and problems encountered, we will try to document those identified during our research. We will mention in particular :

3.5.1.1 Anomaly 01 : Data Accuracy

Causes	Consequences
- Inaccuracy of data collection techniques. - Incorrect allocation of resources.	- Suboptimal waste collection routes. - Making unfavorable decisions based on inaccurate data.

Table 3.2 – Data Accuracy

Specific Information : "Inaccurate data on waste production, bin locations, and collection routes. [Oxfam Report (2023)] As a contributing factor to inefficiencies in waste management in Algeria."

3.5.1.2 Anomaly 02 : Obsolete Geographical Information

Causes	Consequences
- Lack of regular updates to geographical databases. - Inaccurate resource allocation.	- Ineffective route planning. - Longer travel times due to obsolete information.

Table 3.3 – Obsolete Geographical Information

3.5.1.3 Anomaly 03 : Inaccurate Waste Production Forecasts

Causes	Consequences
- Inadequate models for predicting waste production. - Insufficient coverage of waste collection.	- Misallocated resources. - Inadequate planning for variable waste volumes.

Table 3.4 – Inaccurate Waste Production Forecasts

3.5.1.4 Anomaly 04 : Incompatible Population Density Data

Causes	Consequences
- Lack of accurate demographic information. - Ineffective planning of routes.	- Uneven distribution of waste collection resources. - Missed collections in densely populated areas.

Table 3.5 – Incompatible Population Density Data

3.5.1.5 Anomaly 05 : Unexpected Events

Causes	Consequences
- Lack of emergency planning for unforeseen events. - Ineffective response to unexpected challenges.	- Disruptions in waste collection schedules. - Increased operational challenges during events.

Table 3.6 – Unexpected Events

3.6 Areas of Improvement :

Based on the anomalies identified previously, we were able to suggest improvements in organizational, informational, and technical aspects.

3.6.1 Informational

1. Public education campaigns on the importance of waste sorting and correct methods.
2. Informing the population about new systems and environmental benefits.
3. Media campaigns and educational workshops to raise awareness among the population about the impacts of waste on the environment.
4. Sensitizing urban planners to the environmental implications of development plans.
5. Transparent communication about training opportunities and career prospects in waste management.
6. Awareness campaigns on legislative changes and their implications for the community.

3.6.2 Organizational

1. Establishment of monitoring and surveillance bodies to ensure compliance with regulations.
2. Continuous training programs for waste collection and processing personnel.
3. Integration of waste management specialists into urban planning teams.
4. Promotion of community participation through events and projects.

5. Planning for the modernization of waste treatment facilities.
6. Strengthening surveillance and patrols to detect and penalize offenders.
7. Implementation of selective collection programs with separate containers.
8. Reorganization of collection routes for better efficiency.

3.6.3 Technical

1. Use of real-time tracking technologies to optimize route planning.
2. Installation of automated sorting stations to facilitate separation of recyclable materials.
3. Installation of surveillance cameras in sensitive areas.
4. Upgrading treatment facilities for increased capacity and more efficient methods.
5. Use of social media and online platforms to disseminate information about waste management.
6. Use of modeling software to assess the impact of urban plans on waste management.
7. Automation of repetitive tasks to optimize human resource utilization.

3.7 Our Mission :

After studying the processes of the current system and conducting the diagnosis, we have deduced that the main limitation of this system is the lack of a data exploitation methodology in the existing process.

Our mission, therefore, involves the development of an *Information System for Waste Management in the City*. This application communicates with various stakeholders, including park managers, workers, and citizens. We have focused on the management aspect at the park manager level.

The realization of this project must involve :

1. A thorough understanding of the data related to the city park.
2. Associated methods.
3. And finally, capturing the needs of end users.

Once these aspects are established, the selection of the right implementation approach will be necessary to avoid any discrepancies between the results and expectations.

3.8 Conclusion :

Understanding the existing system not only reveals its shortcomings but also inspires the definition of a new solution. At the end of this phase, we have immersed ourselves in the project context in terms of understanding the limitations of the current system, as well as the framework of our final project. We will now deepen our knowledge of concepts related to data analysis to consider the methodology to adopt for the implementation of our solution.

Part III

Contribution

Chapter

4

Designing a User-Centric Solution for Promoting Eco-Friendly Behavior

Contents

4.1 Introduction

Environmental degradation is an urgent global issue that significantly impacts both natural ecosystems and human health. Urban areas, in particular, face a myriad of environmental challenges due to dense populations and industrial activities. This thesis aims to investigate the causes of environmentally harmful behaviors and propose strategies to promote sustainable practices and enhance environmental awareness. The importance of addressing environmental degradation cannot be overstated. Pollutants released into the air and water by industrial activities, as well as improper waste disposal practices, contribute to a host of adverse effects. These include increased pollution levels, health hazards for the population, and a general decline in the quality of life. By understanding the root causes of these behaviors, we can develop effective interventions to mitigate their impact and foster a healthier, more sustainable environment

4.2 Motivating Example

We use motivating examples to capture the reader's attention and make the concepts of environmental awareness more relatable. By highlighting the real-world impact of environmentally harmful behaviors, we can encourage a sense of responsibility and inspire individuals to adopt more sustainable practices.

4.2.1 Scenarios

In our environment, we can observe many behaviors that contribute to an unhealthy and unclean environment. For instance, numerous factories in downtown areas release pollutants into the air and water, contributing to environmental degradation. Additionally, trash is often discarded indiscriminately in public spaces while bins remain empty and underutilized. These actions lead to a host of negative consequences, including increased pollution, health hazards, and a decrease in the overall quality of life. If left unaddressed, these behaviors can result in long-term damage to the ecosystem, making it imperative to adopt sustainable practices and promote environmental awareness.

4.2.2 Domain Analysis

In this section, we will identify and cite challenges related to environmental degradation as reported by the general population, including individual behaviors and waste collectors

4.2.2.1 Challenges Related to Individual Behaviors

Individual behaviors play a crucial role in environmental degradation. We mention the main challenges

- **Take out trash** : The widespread habit of discarding trash in public spaces instead of using designated bins.
- **Lack of Awareness** : Insufficient knowledge about the environmental impact of personal actions.

4.2.2.2 Challenges Faced by Waste Collectors

Waste collectors encounter several issues that hinder effective waste management :

- **Inconsistent Collection Schedules** : Irregular waste collection leading to overflow of trash in public areas.
- **Insufficient Resources** : Insufficient information about the location and fill level of the trash bins .

4.2.2.3 Challenges Faced by the General Population

The general population also faces challenges that impact environmental health :

- **Health Hazards** : Exposure to polluted air and water resulting in various health issues.
- **Decreased Quality of Life** : The presence of pollution and unclean environments reducing the overall living standards.

4.2.2.4 Anomaly Identification

In this section, we will identify anomalies in current environmental practices and behaviors, highlighting areas that require improvement. These anomalies often contribute to environmental degradation and hinder efforts to create a sustainable and clean environment.

Behavioral Anomalies :

- **Inconsistent Recycling Habits** : Many individuals do not consistently engage in recycling, often mixing recyclable and non-recyclable waste.
- **Negligence in Waste Disposal** : A large number of people neglect proper waste disposal practices, which leads to waste and pollution.

Educational Anomalies :

- **Lack of Environmental Awareness** : There is a general lack of awareness regarding the impact of individual actions on the environment.
- **Insufficient Environmental Education** : Educational systems often do not emphasize the importance of environmental sustainability and the role individuals play in it.

Collaborative Anomalies :

- **Poor collaboration Among Stakeholders** : There is often a lack of collaboration between various stakeholders, such as government bodies, private companies, and the community, in addressing environmental issues.
- **Inefficient Waste Management Practices** : Disjointed and uncoordinated waste management efforts lead to inefficiencies and increased pollution.

Motivational Anomalies

- **Lack of Incentives for Sustainable Practices** : There are often insufficient incentives for individuals and organizations to adopt and maintain sustainable practices.
- **Low Engagement in Environmental Initiatives** : Many people show low levels of engagement and participation in environmental protection initiatives.

4.2.3 Avenues for Improvement

To address the identified anomalies, we propose several avenues for improvement focusing on behavior change, education, collaboration, and motivation.

Behavior Change

- **Promote Consistent Recycling Practices** : Implementing Eco events,public awareness campaigns and providing convenient recycling facilities can encourage consistent recycling habits.
- **Encourage Proper Waste Disposal** : Educational initiatives and stricter enforcement of waste disposal regulations can reduce negligence in waste disposal.

Education

- **Increase Environmental Awareness** : Launching comprehensive awareness campaigns can educate the public about the environmental impact of their actions. Additionally, informed individuals can help raise awareness among those who are less aware.
- **Enhance Environmental Education** : As we all know, children are the seeds of society. Therefore, integrating environmental sustainability into educational curricula is essential to instill the importance of sustainable practices from a young age.

Collaboration

- **Improve Stakeholder collaboration** : Establishing frameworks for better collaboration among government bodies, private companies, and the community can enhance environmental efforts.
- **Optimize Waste Management Practices** : Streamlining waste management processes through collaborative efforts can improve efficiency and reduce pollution.

Motivation

- **Provide Incentives for Sustainability** : Offering incentives, such as rewards and gifts , can motivate individuals and organizations to adopt sustainable practices.
- **Increase Engagement in Environmental Initiatives** : Creating engaging and accessible environmental programs can boost public participation and commitment to sustainability.

4.2.4 Motivation and Research Question

Despite numerous technological advancements aimed at promoting environmental sustainability, changing human behavior remains a significant challenge. Through extensive research and analysis of human behaviors and anomalies, it has become evident that technology alone is insufficient to motivate people to adopt environmentally friendly practices.

The primary motivation for this research stems from the need to bridge the gap between technological solutions and human behavior. The goal is to leverage technology not just as a tool, but as a means to inspire and facilitate positive behavioral changes.

How can we utilize technology to effectively encourage and enable individuals to adopt sustainable and environmentally friendly behaviors ?

To address this question, we will explore the following sub-questions :

- What psychological and social factors influence people's environmental behaviors ?

— How can technology be designed to align with these factors to promote positive changes ?
— What are the best practices for integrating technology into everyday life to make sustainable behaviors more convenient and appealing ?
— How can we measure the effectiveness of technological interventions in changing behavior ?

4.3 Our Proposal

Our system is composed of three main components : (i) IoT part, (ii) Data feed part, and (iii) user part. Figure 4.1 shows the overview of our system. In this section, we present the details of each component.

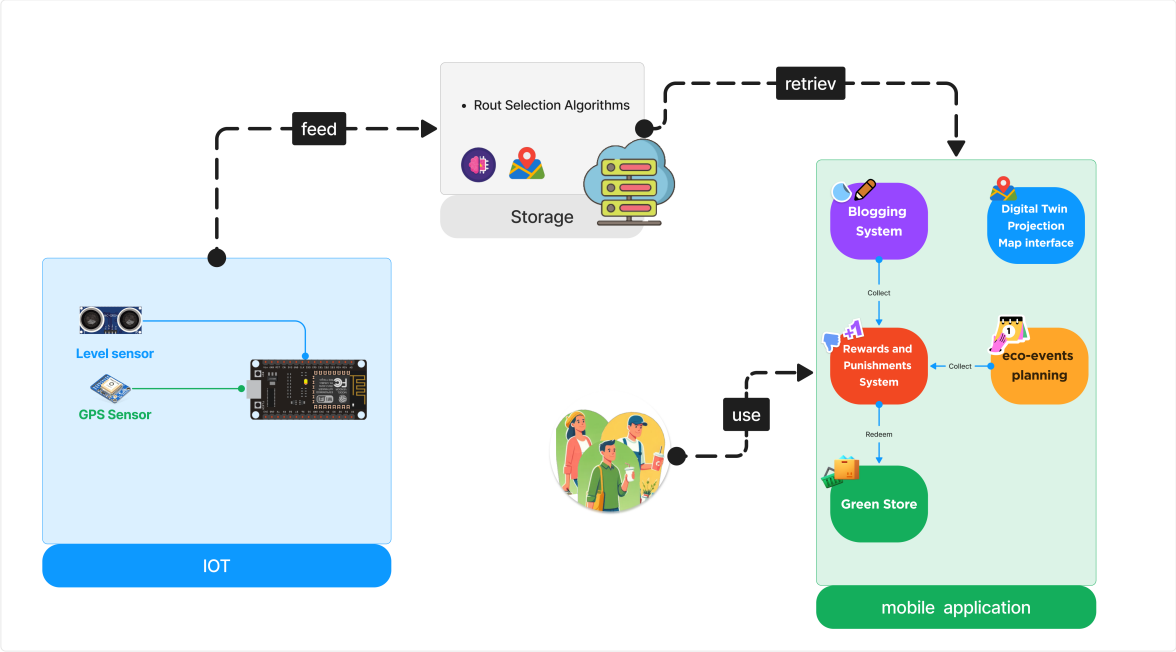


FIGURE 4.1 – Our system

4.3.1 Internet of Things

The Internet of Things (IoT) is a rapidly advancing paradigm in modern wireless communication. The basic idea is the presence of various objects (such as radio frequency identifiers (RFID), sensors, actuators, mobile phones, etc.) that, through unique addressing systems, can interact with each other and cooperate to achieve common goals [25].

We utilize this paradigm to design two types of bins to address specific problems :

4.3.1.1 Sorting Bins

Sorting bins are intelligent bins connected to the internet, containing two essential parts :

— **Artificial Intelligence** : The primary function of these bins is to identify and sort various types of waste such as plastics, cans, and cartons.
— **Level Sensor** : This sensor indicates how full the bin is and sends the data to be displayed on a map.
— **Servo Motors** : These motors is responsible for directing the trash in his right place

These bins can be found in downtown areas, public places, and other high-traffic locations.

4.3.1.2 Neighborhood Bins

Neighborhood bins are also connected to the internet for data transfer and contain three parts :

— **Level Sensor** : Similar to the sorting bins, this sensor indicates the bin's fill level and sends the data to be displayed on a map.
— **GPS** : This component locates each bin, allowing citizens and waste collectors to easily access them.

4.3.2 Storage

Our system employs two types of databases to efficiently manage and store data : MongoDB and Firebase Realtime Database. Each serves a distinct purpose in our architecture.

4.3.2.1 MongoDB

MongoDB is utilized to store user data. It is a NoSQL database that offers flexibility, scalability, and high performance, making it well-suited for handling diverse and dynamic data structures. Key features include :

— **Document-Oriented Storage** : MongoDB stores data in JSON-like documents, which allows for rich data structures and nested fields.
— **Scalability** : MongoDB can handle large volumes of data and scale horizontally by distributing data across multiple servers.
— **Flexible Schema** : Unlike traditional relational databases, MongoDB does not require a fixed schema, enabling easier updates and modifications to the data structure as user requirements evolve.
— **High Performance** : It provides fast read and write operations, ensuring quick access to user data.

4.3.2.2 Firebase Realtime Database

Firebase Realtime Database is used to store and manage the data related to the bins. It is a cloud-hosted NoSQL database that enables real-time data synchronization and updates. Key features include :

- **Real-Time Synchronization** : Firebase ensures that data is synchronized in real-time across all clients connected to the database. This feature is crucial for our application as it allows for instantaneous updates on bin status and locations.
- **Offline Capabilities** : Firebase Realtime Database supports offline usage, enabling the application to function seamlessly even when there is no internet connection. Data changes are synchronized once connectivity is restored.
- **Scalability** : Firebase can handle a large number of concurrent users and data updates, making it ideal for applications with high usage.
- **Security** : Firebase provides robust security rules that ensure data integrity and secure access controls.

By utilizing MongoDB for user data and Firebase Realtime Database for bin data, our system leverages the strengths of both databases to provide a robust, scalable, and efficient storage solution. This architecture ensures that user information is handled with flexibility and speed, while bin data is managed in real-time, facilitating timely updates and accurate monitoring.

4.3.3 User Part

GreenTopia is an innovative platform designed to engage users in environmentally friendly practices and promote sustainability within communities. It leverages technology to provide users with tools and incentives to participate actively in waste management and environmental conservation efforts. The platform serves three main types of users : citizens, waste collectors, and administrators. Each type of user has access to specific features tailored to their needs.

4.3.3.1 Features

GreenTopia offers a range of features designed to support its users :

4.3.3.1.1 Login System

GreenTopia features a robust login system that ensures secure access for all users. The login system includes :

- **User Authentication** : Secure authentication mechanisms to verify user identities.
- **User Profiles** : Each user has a profile where they can track their activities, achievements, and contributions to eco-friendly practices.

4.3.3.1.2 Route Algorithm System

The route algorithm system helps waste collectors find the full bins efficiently. Key features include :

- **Optimal Routing** : Algorithms that calculate the shortest or most energy-efficient paths based on real-time data.
- **Dynamic Updates** : Real-time updates on route changes due to traffic and bin status.

4.3.3.1.3 Digital Twin Projection (Map Interface)

GreenTopia includes a digital twin projection, providing a real-time map interface that mirrors the physical environment. This interface offers :

- **Real-Time Bin Status** : Users can view the fill levels of nearby bins and their locations.
- **Interactive Map** : An interactive map that allows users to find bins, plan routes, and access additional information about waste management facilities.

4.3.3.1.4 Eco-Event Planning

To foster community engagement, GreenTopia offers eco-event planning tools. These tools allow users to :

- **Organize Events** : Create and manage events such as community clean-ups, recycling drives, tree planting, and environmental workshops.
- **Event Participation** : Sign up for events and track participation history.

4.3.3.1.5 Green Store

The Green Store is an online marketplace integrated into GreenTopia where users can purchase eco-friendly products. Key features include :

- **Eco-Friendly Products** : A curated selection of products that promote sustainability, such as reusable bags, eco-friendly cleaning supplies, and energy-efficient gadgets.
- **Point Redemption** : Users can use points accumulated through various activities, such as recycling and participating in eco-events, to purchase items from the store.
- **Secure Transactions** : The store ensures secure payment processing for all transactions, whether users are purchasing items directly or redeeming points.
- **User Rewards** : Special discounts and exclusive products are available as rewards for users who consistently engage in sustainable behaviors.

4.3.3.1.6 Reward System

GreenTopia incorporates a reward system to motivate users through gamification. Features include :

- **Points and Badges** : Users earn points and badges for eco-friendly actions such as recycling, participating in events, and proper waste disposal.
- **Leaderboards** : A competitive element where users can see their rankings compared to others, encouraging more sustainable behaviors.
- **Redeemable Rewards** : Points can be redeemed for various rewards, such as discounts, eco-friendly products, or recognition in the community.

By integrating these features, GreenTopia aims to create an engaging and interactive platform that encourages users to adopt and maintain sustainable behaviors. The combination of secure access, efficient routing, real-time data visualization, community event planning, and rewarding eco-friendly actions helps to foster a culture of environmental responsibility.

4.3.3.2 Users

GreenTopia serves three main types of users, each with specific roles and access :

4.3.3.2.1 Citizens

Citizens use GreenTopia to raise awareness about environmental issues and actively participate in eco-friendly activities. The features available to citizens include :

- **Blogging** : Users can write and share blog posts to raise awareness about environmental issues and share tips on sustainable practices.
- **Eco-Event Planning** : Citizens can create and manage eco-events such as community clean-ups, recycling drives, and environmental workshops. They can also join existing events to contribute to collective efforts.

4.3.3.2.2 Waste Collectors

Waste collectors use GreenTopia to efficiently manage waste collection processes and interact with the community. The features available to waste collectors include :

- **Route Algorithm System** : Helps waste collectors find the most efficient routes to access filled bins, optimizing their collection efforts.
- **Real-Time Bin Status** : Allows collectors to view the fill levels of bins in real-time, ensuring timely waste collection.
- **Neighborhood Rating** : Waste collectors can rate neighborhoods based on cleanliness and waste management practices, providing feedback to the community.

4.3.3.2.3 Administrators

Administrators manage the overall system and user roles within GreenTopia. The features available to administrators include :

- **User Role Management** : Administrators can change user roles, such as upgrading a citizen to a waste collector, ensuring appropriate access and functionality.
- **System Monitoring** : Administrators oversee the system's performance and address any issues that arise.

4.4 Theoretical foundation of our system

We now describe the problem and our framework more formally.

4.4.1 Core element description

As we said before in the chapter 2 :

- $A \rightarrow B$: A positive attitude (A) can influence a person to engage in a specific behavior (B).
- $B \rightarrow A$: Engaging in a positive behavior (B) can reinforce a positive attitude (A).
- $Bi \rightarrow A^{-}$: Bad behavior (Bi) can negatively impact attitudes (A).

Our **Framework (F)** <A, B, BP, G>
Our framework is formalized as F $< \mathcal{B} = \{A_1, A_2, ..., A_n\}, B_i \subseteq \mathcal{B} = \{A_1, A_2, ..., A_n\}$, BP, $\mathcal{G} >$. It represents the following :

- $\mathcal{B} = \{A_1, A_2, ..., A_n\}$: Set of all possible actions (A).
- $B_i \subseteq \mathcal{B} = \{A_1, A_2, ..., A_n\}$: Subset of actions representing bad behaviors.
- BP : Collection of behavioral patterns. Each pattern describes a recurring behavior type with properties like category, application conditions, and target attitude.
- $\mathcal{G}$: Set of gamification elements that can be applied to modify bad behaviors.

4.4.2 Behavior

Behavior (B)
A set of actions denoted by $\mathcal{B} = \{A_1, A_2, ..., A_n\}$.

4.4.3 Bad Behavior

Bad Behavior (Bi)
A subset of behaviors considered undesirable or negative, denoted by $B_i \subseteq \mathcal{B} = \{A_1, A_2, ..., A_n\} \subseteq \mathcal{B} = \{A_1, A_2, ..., A_n\}$.

4.4.4 Behavioral Pattern

Behavioral Pattern (BP)
A general class that describes a recurring pattern of behavior across various contexts, potentially influenced by a person's attitude (A).

A general class that describes a recurring pattern of behavior across various contexts, potentially influenced by a person's attitude (A). Each BP is represented using the ECA paradigm and additional properties :

- * **ECA Paradigm :**
  - * **Event (E) :** The triggering event or situation that leads to the behavior pattern (e.g., feeling overwhelmed, social pressure). This can be a bad behavior (Bi) itself.
  - * **Condition (C) :** The specific circumstances or internal state that make the behavior more likely (e.g., lack of planning, low self-confidence).
  - * **Action (A) :** The specific bad behavior (Bi) exhibited within the pattern (e.g., procrastination, impulsive decision-making).

- **Category of BP :** Classifications for BP based on aspects like Risk Level, Challenges, Social interaction, or Emotion (represented by C(BP)).
- Properties :
  - **Summary :** A concise description of the BP.
  - **Application Conditions :** Situations where the BP is likely to occur, denoted by AC(BP).
  - **Target Attitude (TA) :** The specific attitude that the BP is associated with or aims to influence (e.g., Motivation, Confidence, Risk Aversion).
  - Impact : Potential consequences of the BP :
    - **Positive Impact (PI(BP)) :** Beneficial outcomes of the BP when addressed.
    - **Negative Impact (NI(BP)) :** Detrimental consequences of the BP if not addressed.
  - **Related Patterns :** Other BPs that are connected to the current pattern, denoted by RP(BP).

4.4.5 Gamification

Gamification (G)
The application of game-like elements (Gi1, ..., Gin) to a non-game context with the goal of increasing engagement and motivation.

4.4.6 Problem Formalization

In summary, the behavior change problem is formalized by input-output as described below :

Input :
- * **A set of bad behaviors (Bi)** identified within a specific domain (e.g., educational setting, workplace).
- * **Behavioral patterns (BPs)** associated with these bad behaviors, represented using the ECA (Event-Condition-Action) paradigm :
  - * **Event (E) :** The triggering event or situation that leads to the behavior pattern.
  - * **Condition (C) :** The specific circumstances or internal state that make the behavior more likely.
  - * **Action (A) :** The specific bad behavior (Bi) exhibited within the pattern.
- * **User data (optional) :** This information can include user demographics, attitudes, preferences, or past behavior data (U_d) that can be leveraged to personalize gamification interventions.

Output :
- * **A set of gamification interventions (G)** designed to target the identified bad behaviors (Bi) within their corresponding behavioral patterns (BPs). These interventions aim to positively influence the target attitudes (TA) associated with the BPs.

Goal :
- To reduce the occurrence of bad behaviors (Bi) by modifying the associated behavioral patterns (BPs) through gamification interventions (G). This, in turn, aims to positively impact user attitudes (TA) and promote better overall behavior.

Relationship between A, B, BP, and G
* A positive attitude (A) can influence a person to engage in a positive behavior (B). * Engaging in a positive behavior (B) can reinforce a positive attitude (A). * Bad behaviors (Bi) can negatively impact

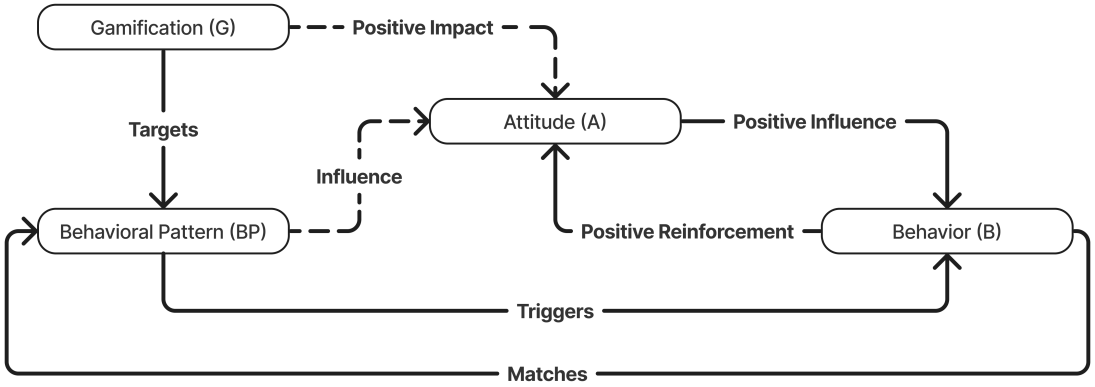


FIGURE 4.2 – Relationship between A, B, BP, and G

attitudes (A) (e.g., procrastination can decrease motivation). * Gamification (G) can be designed to target bad behaviors (Bi) and their associated behavioral patterns (BPi) with the goal of influencing attitudes (A) in a positive way.

The core of our theory is that "Bad behaviors create attitudes." This relationship forms the nucleus of our conceptual framework.

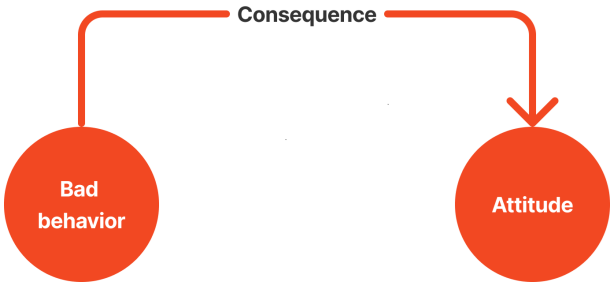


FIGURE 4.3 – relation between bad behavior and attitude

Exemple 1.

— ***Bad behavior :*** *Not respecting the designated time to take out the trash.*
This behavior inherently creates a corresponding attitude.

— ***Attitude :*** *Disregarding the appropriate time for trash disposal, showing a lack of concern for regulations.*

By addressing these attitudes directly, we can influence and change the underlying behaviors.

After introduce some approaches to attitudes lead to promote positive behavioral changes.

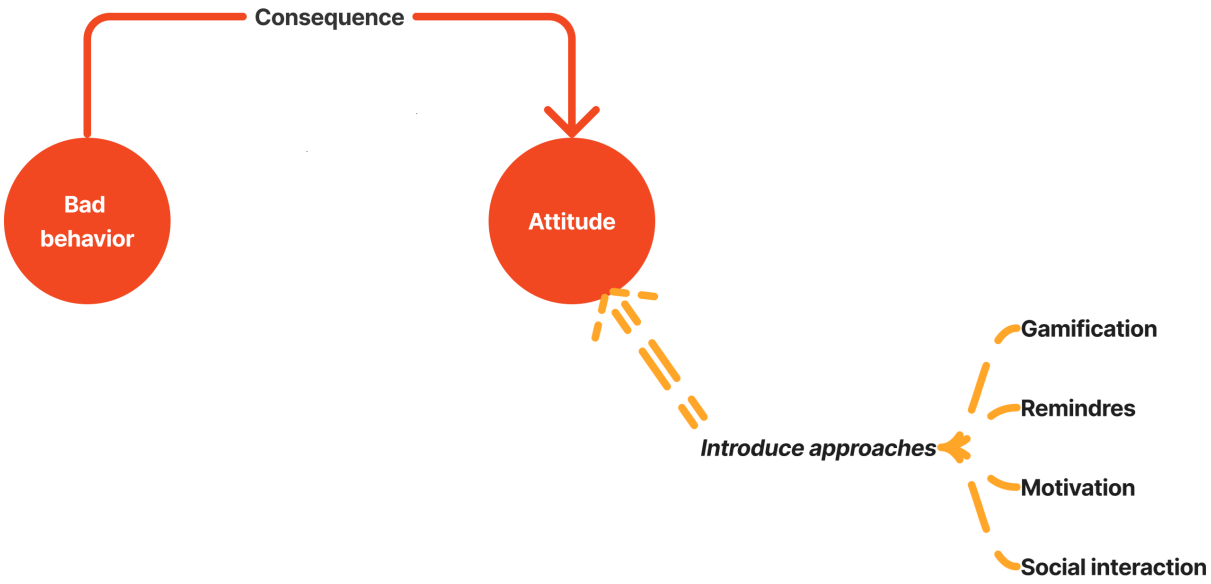


FIGURE 4.4 – introduce approaches to attitude

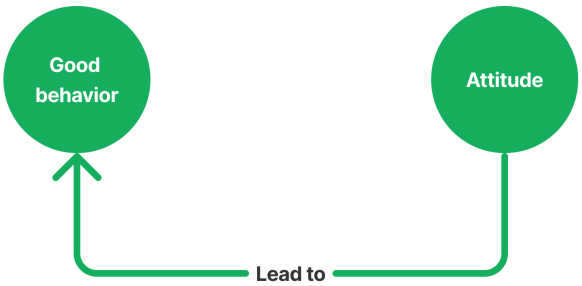


FIGURE 4.5 – change behavior

4.5 Conceptual organisation of our system

In encouraging people to be more active participants in city protection efforts, we can employ a strategy inspired by gamification principles. This approach taps into psychological and motivational factors to drive behavioral change effectively.

Gamification involves integrating elements of games into non-game contexts to motivate and engage people. To implement this strategy effectively, we need to consider both intrinsic and extrinsic stimuli. Intrinsic stimuli, such as challenges and social interaction, appeal to individuals' inherent motivations. Meanwhile, extrinsic stimuli, like badges, rewards, feedback, and notifications, offer additional incentives to reinforce desired behaviors.

By striking the right balance between these stimuli, we can create an engaging experience that encourages people to actively participate in city protection initiatives. However, it's essential to tailor the gamified elements to the specific goals and preferences of the target audience. This ensures that the gamification strategy effectively promotes the desired level of engagement and participation.

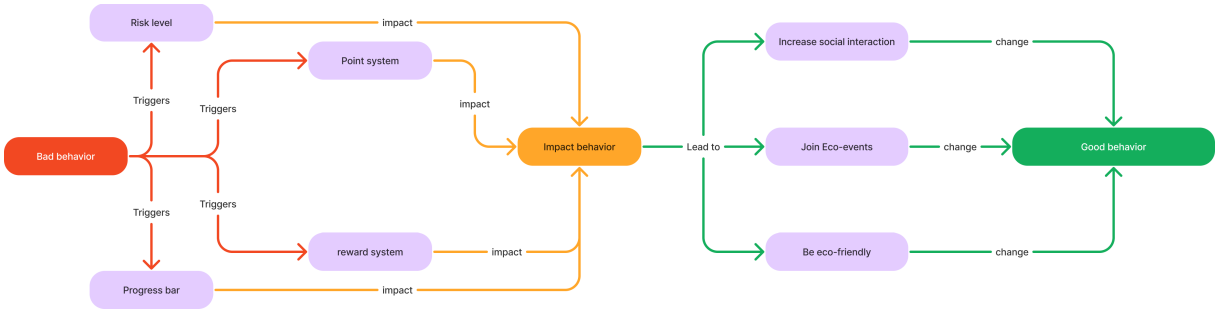


FIGURE 4.6 – Conceptual organisation of our system

4.6 User Centered Approach

Human-Centered Design (HCD) is a framework that creates solutions by focusing on human needs throughout the design process. This involves understanding the problem in context, brainstorming, developing, and implementing solutions. HCD prioritizes the needs and desires of the end-users, ensuring the design addresses real-life problems.

HCD is iterative, meaning the design is repeatedly refined based on feedback at each stage. Users and stakeholders are involved throughout, from defining requirements to testing and evaluation. This iterative process helps ensure the design remains aligned with user needs. Typically, HCD progresses from simple prototypes to more refined versions, with some industries using agile cycles for rapid development. [6]

4.6.1 Human-centered design process

The Human-Centered Design (HCD) process involves several key stages to ensure the creation of solutions that truly meet user needs :

1. **Observation :** Understanding the problem in its real-world context by observing and engaging with users.
2. **Ideation :**Brainstorming and generating a wide range of ideas to address the observed problems.
3. **Prototyping :** Developing initial versions of solutions, ranging from low fidelity to high fidelity prototypes.
4. **User Feedback :** Collecting feedback from users to understand their experiences and identify areas for improvement.
5. **Iteration :**Refining the design based on user feedback and repeating the process to enhance the solution.
6. **Implementation :** Finalizing the design and deploying the solution in the real world.

This iterative process ensures that the design remains focused on user needs and effectively solves real-life problems.

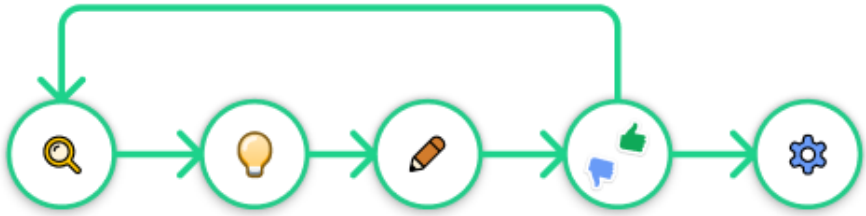


FIGURE 4.7 – Human-centered design process

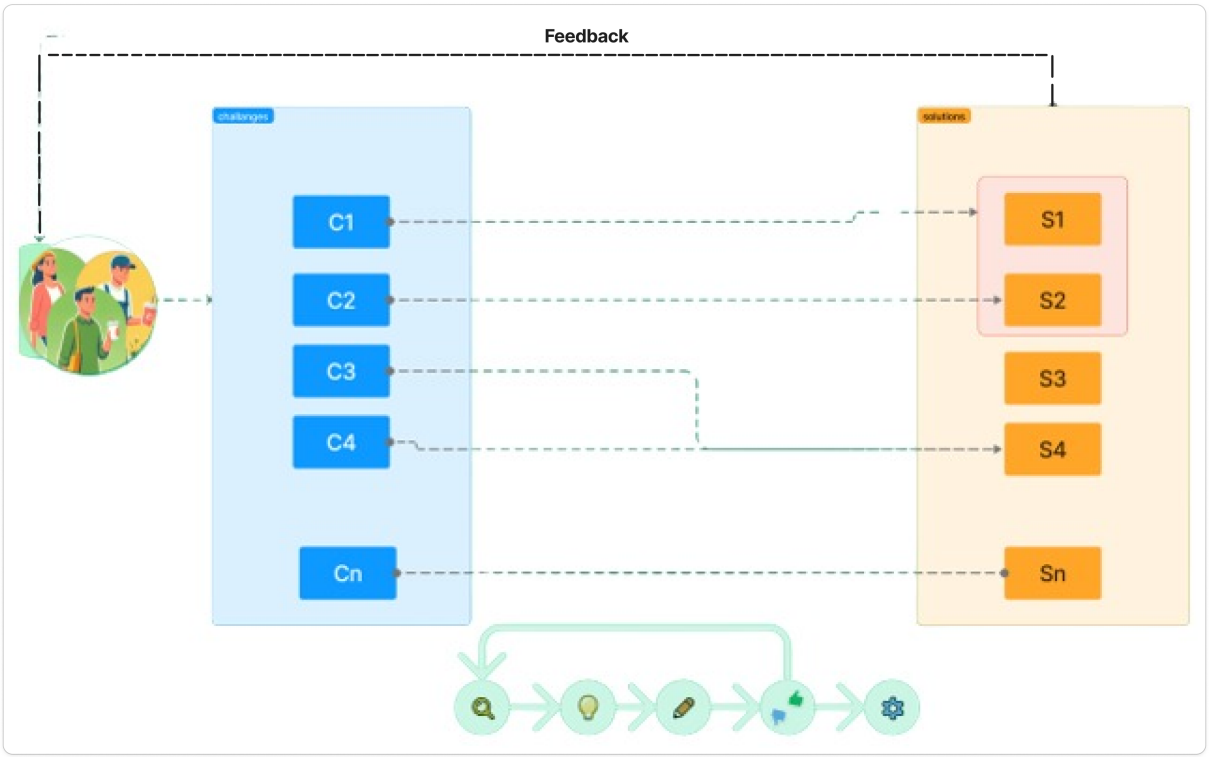


FIGURE 4.8 – HCD structure

4.6.2 Evaluation

Evaluation is a critical component of the user-centered design approach, ensuring that the system meets the needs and expectations of its users. Here, we outline the methods used to evaluate the user experience (UX) and gather user feedback.

4.6.2.1 User experience Design

The UX design evaluation focuses on assessing the usability, accessibility, and overall experience of users interacting with the GreenTopia platform. Key elements include :

- **Usability Testing** : Conducting sessions with users to perform specific tasks on the platform to identify any usability issues and gather feedback on the ease of use.
- **Heuristic Evaluation** : Experts review the interface based on established usability principles (heuristics) to find potential usability problems.
- **User Surveys and Questionnaires** : Collecting quantitative and qualitative data from users about their experiences, satisfaction levels, and any challenges faced while using the platform.

4.6.2.2 Thinking Aloud

The "Thinking Aloud" method is a valuable qualitative research technique used to understand the user's thought process while interacting with the platform. During this evaluation :

- **Methodology** : Users are asked to verbalize their thoughts, feelings, and actions while performing tasks on the GreenTopia platform. This provides insights into their decision-making processes and identifies any difficulties they encounter.
- **Data Collection** : Sessions are recorded and transcribed to analyze user feedback and identify common themes or issues.
- **Analysis** : The verbal data is analyzed to understand user expectations, frustrations, and areas where the platform meets or fails to meet their needs. This information is crucial for iterative design improvements.
- **Iterative Improvements** : Based on the findings from the Thinking Aloud sessions, the design and functionality of the platform are refined to enhance usability and user satisfaction.

By employing these user-centered evaluation methods, we ensure that GreenTopia is not only functional but also intuitive and enjoyable for all its users.

4.7 Conclusion

GreenTopia is designed to encourage eco-friendly behavior through a user-friendly mobile app that leverages IoT technology, data management, and engaging features. By focusing on behavior change, education, collaboration, and motivation, the app aims to promote sustainable practices effectively. Using human-centered design principles and robust user evaluation methods ensures that GreenTopia is both effective and easy to use. The goal is to inspire and support individuals in adopting environmentally friendly habits for a healthier planet.

Chapter

5

Proof of Concept & Tooling

« The true method of knowledge is experiment. »

— William Blake

Contents

5.1 Introduction

Our project aims to revolutionize waste management and change behavior[5] through intelligent technology, while also assisting waste collectors. By integrating advanced machine learning models, real-time data processing, and seamless communication between hardware and software components, the project demonstrates a cutting-edge solution for automated waste classification and bin level detection. This proof of concept (PoC) highlights the feasibility and effectiveness of the system, showcasing its potential to improve waste sorting efficiency, monitor bin levels, and reduce environmental impact. Our approach involves three interconnected components : binAI, binVision, and GreenTopia the mobile application.

5.2 Software and hardware Components

In order to implement our system, various software and hardware components were utilized. This section details the key technologies and tools employed.

5.2.1 Software Components

we leveraged several software tools and frameworks, each playing a crucial role in different aspects of the project :

— **Arduino IDE :**

Description : The Arduino Integrated Development Environment (IDE) provides an easy-to-use interface for writing, compiling, and uploading code to microcontroller boards. It supports various libraries essential for handling Wi-Fi connectivity and sensor data collection.[2]

Purpose : Used for programming the ESP Wemos D1 Mini microcontrollers.

FIGURE 5.1 – arduino IDE logo.

— **Visual Studio Code (VSCode) :**

Description : Visual Studio Code, developed by Microsoft, is a powerful, lightweight source code editor that supports various programming languages and frameworks. It offers built-in support for Git, debugging tools, and extensions for Python, JavaScript, and more. VSCode was used extensively for developing and managing the project's codebase, including the backend, frontend, and AI components. Its features like IntelliSense, integrated terminal, and extensions for Docker and Kubernetes were particularly useful for enhancing productivity and maintaining code quality.[24]

Purpose : ntegrated development environment for coding, debugging, and version control.

FIGURE 5.2 – VScode logo.

— **TensorFlow :**

Description : TensorFlow is a powerful open-source machine learning framework developed by Google. It allows for the creation of complex neural networks that can be trained on large datasets to perform tasks such as image recognition and classification.[36] TensorFlow's flexibility and comprehensive ecosystem make it ideal for implementing our AI model.

Purpose : Utilized for developing and training the AI model(image clasification)

FIGURE 5.3 – Tensorflow logo.

— **Firebase : Description :** Firebase, a platform developed by Google, offers a real-time NoSQL cloud database and authentication services. It allows for real-time data synchronization across all clients, ensuring that the mobile application displays up-to-date bin statuses. Firebase also provides secure user authentication, making it easy to manage user access and data privacy.[21]

Purpose : Provides real-time database for storing IoT data sent by the sensors

FIGURE 5.4 – firebase logo.

— **MongoDB :**

Description : MongoDB is a NoSQL database known for its flexibility and scalability. It stores user credentials, profiles, and other related data. Using MongoDB allows for efficient management of user authentication, ensuring secure access to the mobile application and backend services. MongoDB's document-oriented storage model is particularly well-suited for handling diverse user data and supporting complex queries.[33]

Purpose : Used for authentication and user data storage.

— **React Native :**

FIGURE 5.5 – mongodb logo.

Description : React Native is a JavaScript framework for building natively rendering mobile applications for iOS and Android. It uses the same design principles as React, allowing developers to create a rich mobile UI using declarative components. React Native enables us to maintain a single codebase for both platforms, ensuring consistency and reducing development time.[30]

Purpose : Employed for developing the cross-platform mobile application

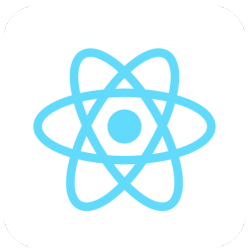


FIGURE 5.6 – ReactNative logo.

— **Node.js and Express :**

Description : Node.js is a JavaScript runtime built on Chrome's V8 JavaScript engine, and Express is a minimal and flexible Node.js web application framework. Together, they provide a robust backend solution for managing client-server communication, data processing, and storage. The server handles API requests from the mobile application[26]

Purpose : Backend server for handling API requests and managing data.

(a) (b)

FIGURE 5.7 – Node.js and Express logos

5.2.2 Hardware Components :

In addition to software tools and frameworks, our system relies on various hardware components for data collection, processing, and communication

— **ESP Wemos D1 Mini :**

Description : The ESP Wemos D1 Mini is a compact microcontroller board based on the ESP8266 Wi-Fi chip. It features digital and analog input/output pins, making it suitable for interfacing with sensors and transmitting data wirelessly to the server.[17]

Purpose : Microcontroller board for connecting sensors and enabling Wi-Fi communication.

FIGURE 5.8 – ESP Wemos D1 Mini .

— **Ultrasonic Sensor (HC-SR04) :**

Description : The HC-SR04 ultrasonic sensor calculates distance by sending out high-frequency sound waves and measuring the time taken for the echo to return. The speed of sound in air is approximately 343 meters per second (at room temperature).[27] Using this information, the distance (D) can be calculated using the formula :

$$D = \frac{1}{2} \times \text{speed of sound} \times \text{time taken for the echo}$$

Purpose : Measures the fill level of the garbage bin.

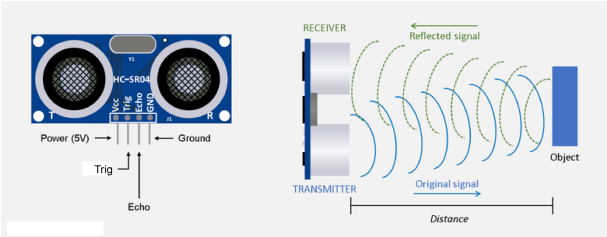


FIGURE 5.9 – Ultrasonic Sensor (HC-SR04)

— **Servo Motors :**

Description : Servo motors are used to control the movement of specific parts of the garbage bin,They provide precise angular control, allowing for automated placement of the garbage[39]

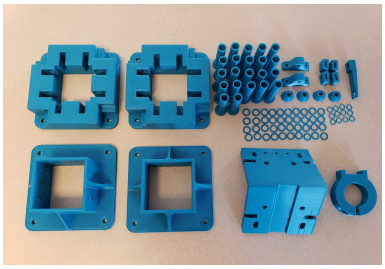
Purpose : Actuates mechanisms for positioning the garbage in the correct place within the garbage bin.

FIGURE 5.10 – Servo Motor.

— **Enclosure (3D Printed Box) :**

Description : A 3D printed box serves as the enclosure for the hardware components. It shields the sensitive electronics from dust, moisture, and physical damage, ensuring the durability and longevity of the system deployed in outdoor environments. The 3D printed enclosure also allows for customization and rapid prototyping during the development phase.[16]

Purpose : Protects the hardware components from environmental factors.



(a) 3d printed parts

(b) 3d printer

5.3 Technical implementation

5.3.1 Firebase Realtime Database Configuration

5.3.1.1 Create a Database

The first step is creating a Realtime Database for our project.by folowing this steps :

1. On the left sidebar click on Realtime Database and then, click on Create Database.

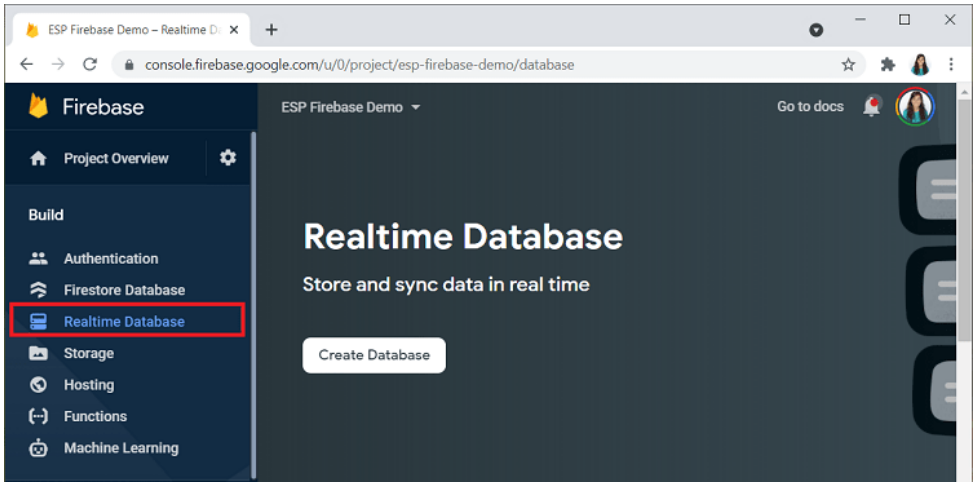


FIGURE 5.11 – Create-Realtime-Databas

2. next setup the security rules.For testing purposes, select Start in test mode

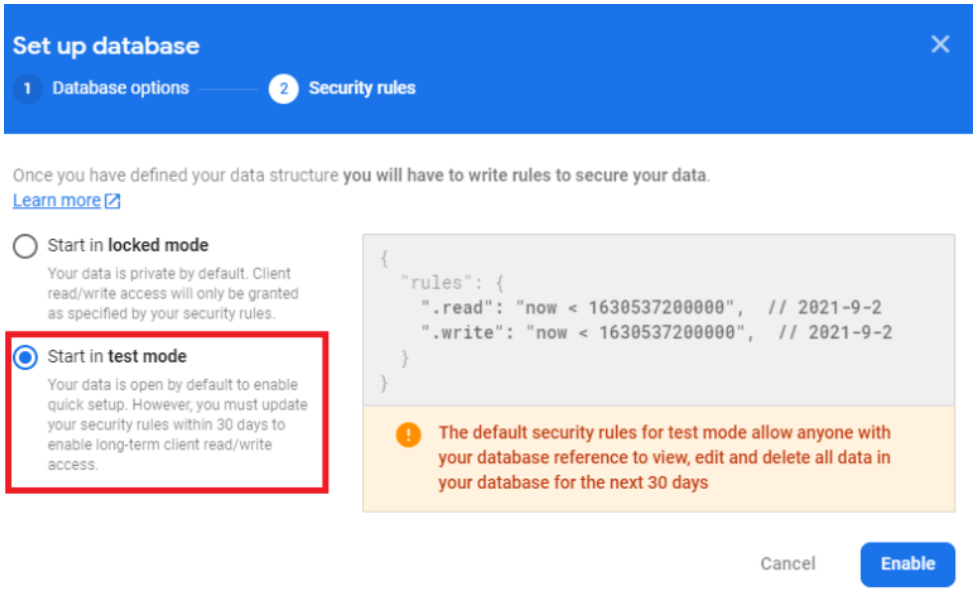


FIGURE 5.12 – Set-Up-Firebase-database

3. our database is now created. we need to copy and save the database URL—highlighted in the following image—because we'll need it later in our Wemos code.

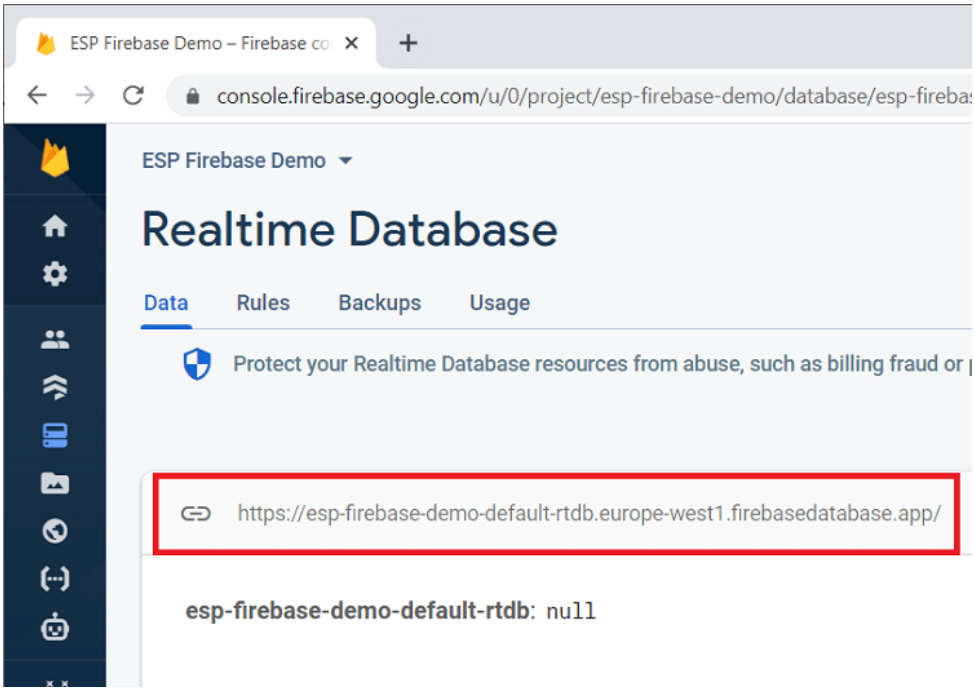


Figure 5.13 – Firebase-project-database-URL

4. get the project's API key, located on the Project Settings.

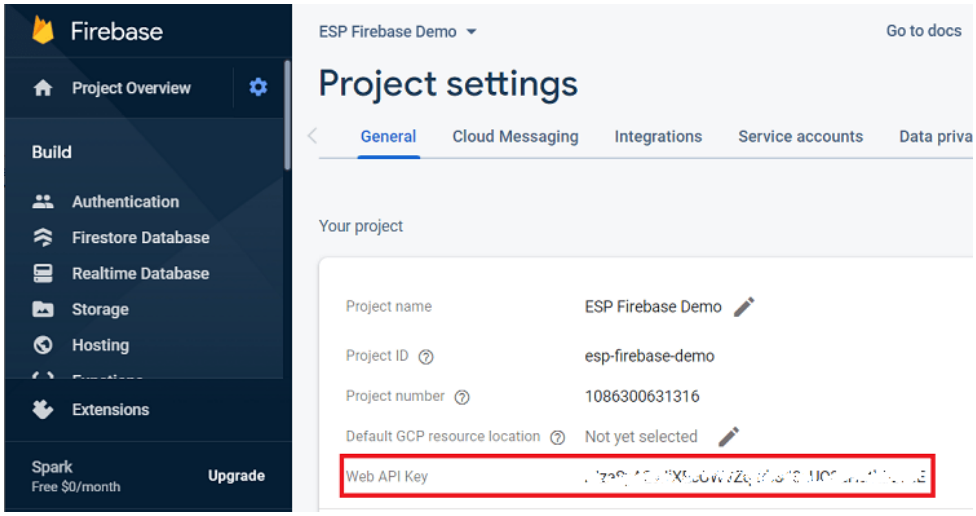


FIGURE 5.14 – Firebase-Project-Settings-Web-API-Key

5.3.1.2 RealTime database structure

The given figure represents information about a set of garbage bins. Each bin has specific attributes such as its ID, location, type, and the number of bins available.

FIGURE 5.15 – database Structure

5.3.2 Integration of AI Component

5.3.2.1 Data Collection and processing :

Image data collection for AI/ML training involves gathering and preparing images to be added to datasets that will train AI/ML algorithms.[38] This include images of plastic bottles, soda cans,etc.

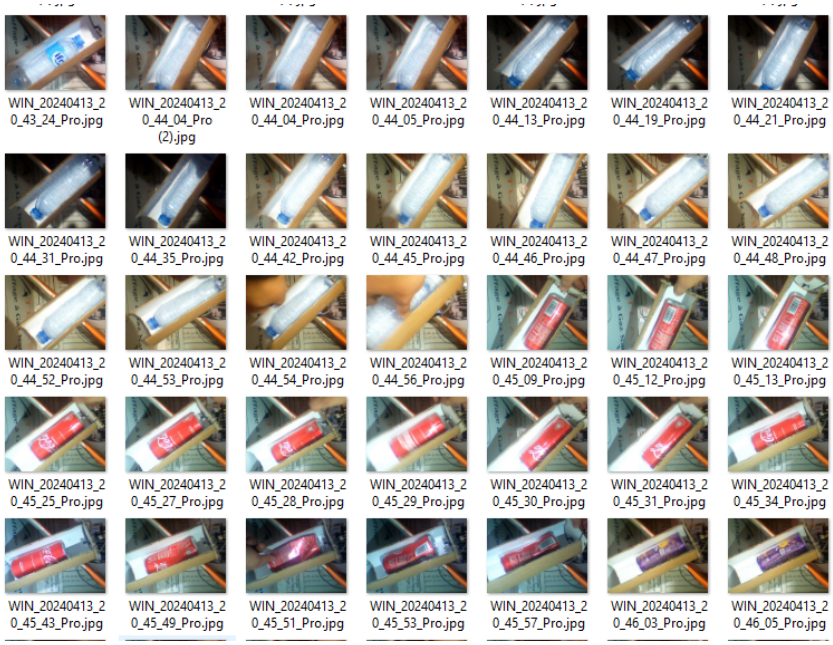


FIGURE 5.16 – dataset for image classication model

After that we put each set of images in labeled folder

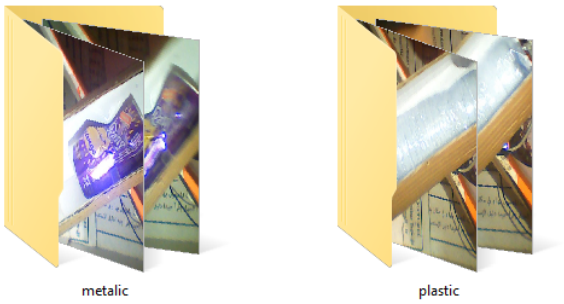


FIGURE 5.17 – labeled dataset

Cleaning and Load the data

the cleaning process is removing any dodgy images[19] and those that are corrupted, improperly labeled.this part of code shows the data cleaning process :

```
DATA_PATH= 'data' //the dataset path
IMAGE_EXTS=['jpeg','jpg','png','bmp'] // the valid file extensions
  for folder in os.listdir(DATA_PATH) :
      for image in os.listdir(os.path.join(DATA_PATH,folder)) :
          image_path =os.path.join(DATA_PATH,folder,image)
          try :
              img = cv2.imread(image_path)
              tip = imghdr.what(image_path)
              if tip not in IMAGE_EXTS :
```

```
                print("Image not in extension list {}".format(image_path))
                os.remove(image_path)
            except Exception as e :
                print("Issue with image {}".format(image_path))
```

Listing 5.1 – Remove dodgy images

tensorFlow provides utilities to efficiently load and preprocess data, especially for image datasets.Use $tf.keras.utils.image_dataset_from_directory to load images from directories$

```
data = tf.keras.utils.image_dataset_from_directory('data')
```

Preprocess Data :

1. **Data Scaling :** Data scaling is the process of transforming the features of a dataset to a similar scale. This is often necessary when the features have different units or scales, as it can help improve the performance and convergence of machine learning algorithms.[29]

```
# originally the images data are bettween 0.0 -255.0, we convert it  0-1.0 (scaled it)
data =data.map(lambda x,y :(x/255,y))
```

Listing 5.2 – Data Scaling

2. **Data Splitting :** Data splitting involves dividing a dataset into two or more subsets for different purposes, such as training, validation, and testing. The most common split is into training and testing sets, where the training set is used to train the model and the testing set is used to evaluate its performance.

```
trian_size = int(len(data)*.7) #12 bachtes
val_size = int(len(data)*.2)+1#validation  4 bachtes
test_size = int(len(data)*.1)+1 #2 bachtes
trian = data.take(trian_size)
val = data.skip(trian_size).take(val_size)
test = data.skip(trian_size+val_size).take(test_size)
```

Listing 5.3 – Data spliting

5.3.2.2 Training the AI Model

Model Selection :

Model selection is the process of choosing the right architecture and configuration for your neural network. This choice depends on several factors(Nature of the Task, Data Complexity, Resource Availability)

Sequential Model in TensorFlow :

The Sequential model in TensorFlow is a linear stack of layers(dense layers) where you define the model layer by layer from the input to the output. It is particularly useful for simpler tasks where a straightforward stack of layers is sufficient.[10]

Using a Sequential Model for BinAi :

In a Sequential model, you add layers one by one in a linear fashion. Each layer has a specific role, such as convolution for feature extraction or dense layers for classification.

Build Deep Learning Model : after the process of selecting the suitable AI model, the next step is implementing the model

```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten, Dense
model = Sequential()

model.add(Conv2D(16, (3,3), strides=1, activation="relu", input_shape=(256,256,3)))
model.add(MaxPooling2D())
model.add(Conv2D(32, (3,3), strides=1, activation="relu"))
model.add(MaxPooling2D())
model.add(Conv2D(16, (3,3), strides=1, activation="relu"))
model.add(MaxPooling2D())
model.add(Flatten())
model.add(Dense(256, activation="relu"))
model.add(Dense(1, activation="sigmoid"))
```

Listing 5.4 – Deep Model

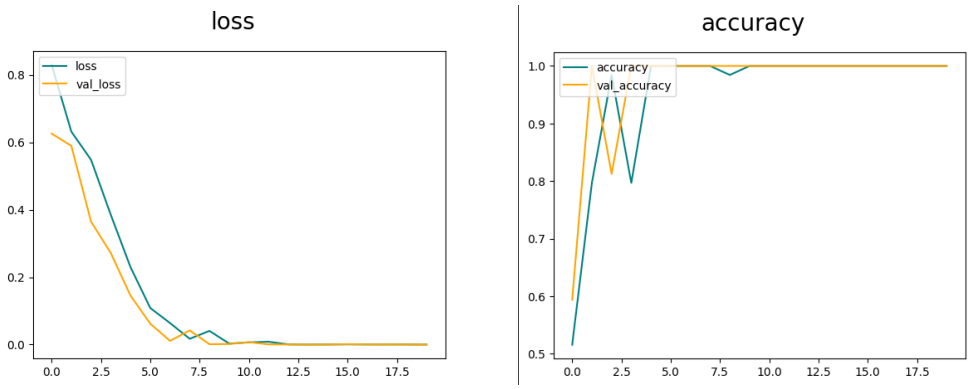
— **Conv2D Layers :** Extract features from the input images.
— **MaxPooling2D Layers :** Reduce the spatial dimensions and help in generalizing the features.
— **Flatten Layer :** Converts the 2D feature maps into a 1D vector.
— Dense Layers : Perform the classification based on the extracted features.

Training process :

To train the defined model, we need to compile it with an appropriate loss function, optimizer, and optionally metrics. Then, we can fit the model to our training data using the fit method.

```
LOG_DIR ='losgs'
tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=LOG_DIR)
history=model.fit(trian,epochs=20, validation_data=val, callbacks=[tensorboard_callback])
history.history
#loss ploting
fig = plt.figure()
plt.plot(history.history['loss'], color='teal', label='loss')
plt.plot(history.history['val_loss'], color='orange', label='val_loss')
fig.suptitle('loss',fontsize=20)
plt.legend(loc="upper left")
plt.show()
#accuracy ploting
fig = plt.figure()
plt.plot(history.history['accuracy'], color='teal', label='accuracy')
plt.plot(history.history['val_accuracy'], color='orange', label='val_accuracy')
fig.suptitle('accuracy',fontsize=20)
plt.legend(loc="upper left")
plt.show()
```

Listing 5.5 – loss and accuracy ploting



(a) (b)

FIGURE 5.18 – loss and accuracy plotting

5.3.2.3 Evaluate the model Performance

```
from tensorflow.keras.metrics import Precision, Recall, BinaryAccuracy
prec = Precision()
recall = Recall()
BinAcc = BinaryAccuracy()
for batch in test.as_numpy_iterator() :
    X,y = batch
    yhat = model.predict(X)
    prec.update_state(y,yhat)
    recall.update_state(y,yhat)
    BinAcc.update_state(y,yhat)
print(f'precision={prec.result()}, recall={recall.result()}, binary accuracy={BinAcc.result()}')
```

Listing 5.6 – Model Evaluation

This code will calculate the loss and accuracy of our model on the test dataset.

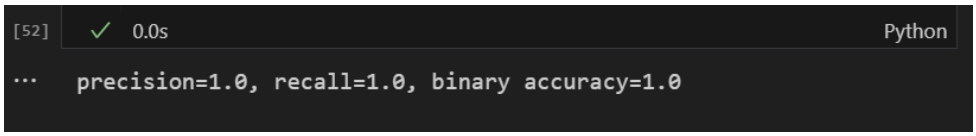


FIGURE 5.19 – The calculated precision

5.3.2.4 Saving the Model

Saving a trained model in TensorFlow is crucial for future use, deployment, or further experimentation. You can save the entire model, including its architecture, weights, and training configuration, in the Hierarchical Data Format (HDF5) format

```
from tensorflow.keras.models import load_model
MODELS_PATH='models'
```

```
model.save(os.path.join(MODELS_PATH,'GarbageModel_v3.h5'))
```

Listing 5.7 – model serialization

5.3.3 Backend Development

5.3.3.1 GreenTopia Bakend :

The GreenTopia backend is responsible for handling all server-side logic, including API endpoints, data storage, and authentication. It ensures secure and efficient communication between the client (frontend) and the server

1. **Overview of MVC Design Pattern :**

   The MVC design pattern divides the application into three interconnected components :

   (a) **Model :** Model represents the structure of data, the format and the constraints with which it is stored. It maintains the data of the application. Essentially, it is the database part of the application.

   (b) **View :** View is what is presented to the user. Views utilize the Model and present data in a form in which the user wants. A user can also be allowed to make changes to the data presented to the user. They consist of static and dynamic pages which are rendered or sent to the user when the user requests them.

   (c) **Controller :** Controller controls the requests of the user and then generates appropriate response which is fed to the viewer. Typically, the user interacts with the View, which in turn generates the appropriate request, this request will be handled by a controller., to sum it up :

   – **Model** is data part.
   – **View** is User Interface part.
   – **Controller** is request-response handler.

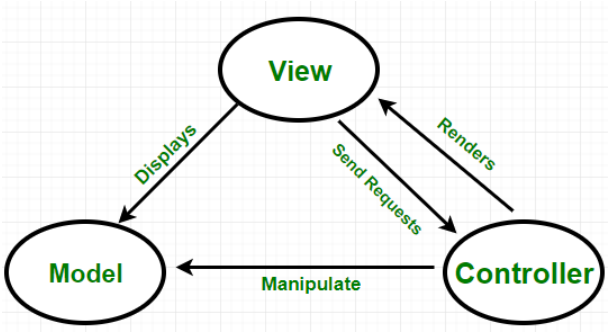


FIGURE 5.20 – mvc-block-diagram.

2. **Key Components :**

   Project Structure : The GreenTopia backend is organized as follows :

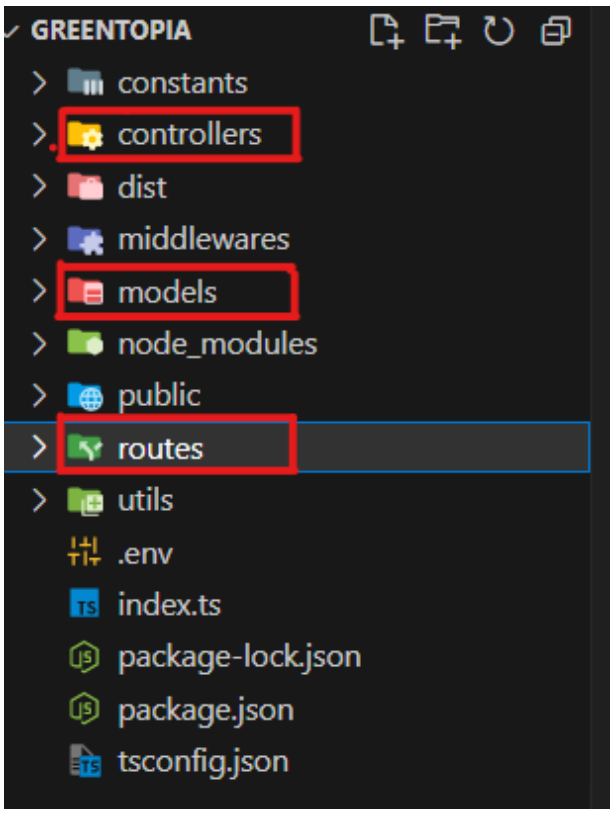


FIGURE 5.21 – mvc-project-stucture.

As the name suggests, there are three folders, called models, views(in our case the views are represented with the route folder), controllers which will help in the mvc architecture implementation.

Models : Models define the schema for the MongoDB collections and provide methods to interact with the database.we represent it with the following class diagram

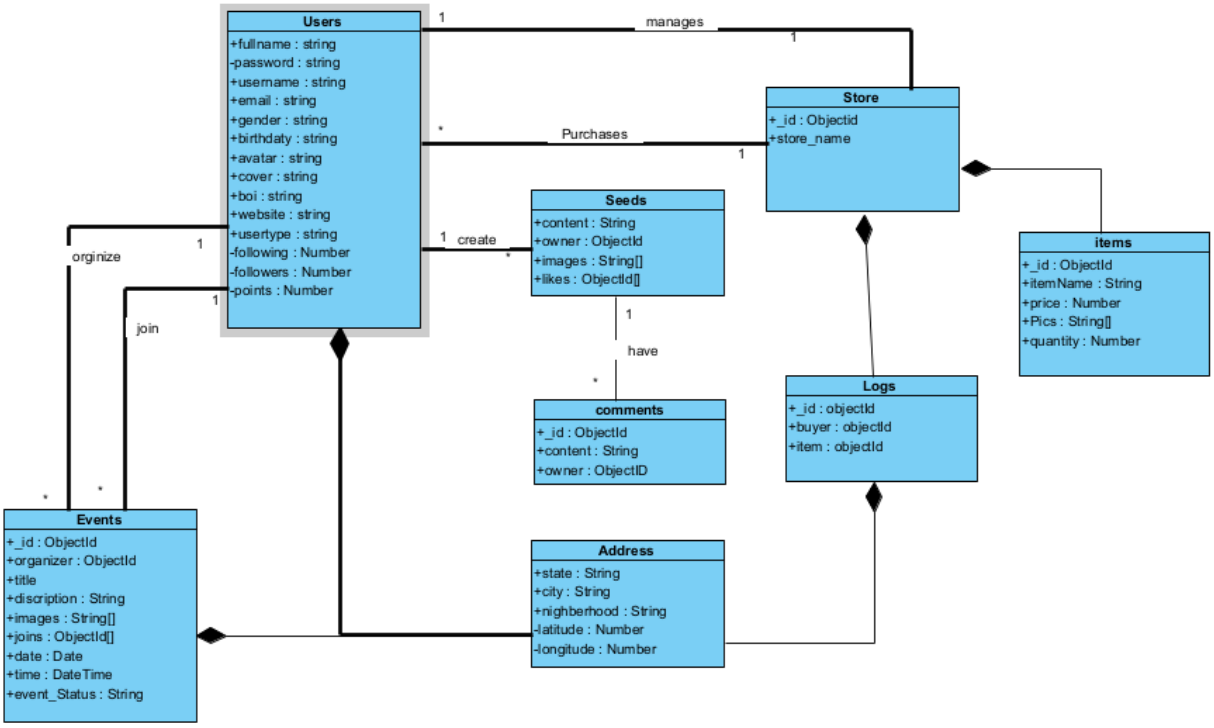


FIGURE 5.22 – class diagram

```
        import mongoose, { Schema } from "mongoose";
import mongodb, { ObjectId } from "mongodb";
import isEmail from "validator/lib/isEmail";
const AddressSchema = new mongoose.Schema({
    country : String,
    postalCode : Number,
    state : String,
    city : String,
});
const UserSchema = new mongoose.Schema({
    fullname : {
        type : String,
        required : true,
    },
    username : {
        type : String,
        required : [true, "pleas Enter a userName"],
        unique : true,
        minlength : [4, "minimum username length is 4"],
    },
    email : {
        type : String,
        required : [true, "pleas Enter an email"],
```

```
        unique : true,
        lowercase : true,
        validate : [isEmail, "pleas Enter a valid email"],
    },
    password : {
        type : String,
        required : [true, "pleas Enter a password"],
        minlength : [8, "minimum password length is 8"],
    },
    gender : {
        type : String,
        default : "",
        enum : ["male", "female"],
    },
    birthday : {
        type : Date,
    },
    .
    .
    .
    .
    .
    .
const User = mongoose.model("User", UserSchema);
export default User;
```

Listing 5.8 – User Model

Controllers : Controllers handle the request and response logic, interacting with the Models to perform CRUD operations.

```
    export const login = async (req : Request, res : Response) => {
    try {
        const { login, password } = req.body;
        const login_res : Error | null = loginChecklist(req.body);
        if (login_res) throw login_res;

        const user = await User.findOne(
            isEmail(login) ? { email : login }  : { username : login }
        );
        if ( !user)
            throw new Error("query error :greenTopia.users :user not found");
        const isMatch = await bycrypt.compare(password, user.password);
        if ( !isMatch)
            throw new Error(
                "query error :greenTopia.users :password not matched"
            );
        let token;
        if (process.env.JWt_SECRET) {
            token = jwt.sign(
                { id : user.id, role : user.usertype },
                process.env.JWt_SECRET
            );
```

```
        } else
            throw new Error(
                "server error :authentication errror  :internal server error"
            );
        user.password = "";
        res.status(200).json({ user, token });
    } catch (error : Error | any) {
        errorHandller(error, res);
    }
};

export const register = async (req : Request, res : Response) => {
    try {
const{fullname,username,email,password,gender,birthday,avatar,
        } = req.body;
        console.log(req.body);
        console.log(password.length);

        const imagePath = `/pictures/users/${avatar}` ;
        const salt = await bycrypt.genSalt(10);
        const hashPassword = await bycrypt.hash(password, salt);
        let query = {};
        if (avatar)
            query = {
                username,
                email,
                fullname,
                password : hashPassword,
                gender,
                birthday,
                avatar : imagePath,
            };
        else
            query = {
                username,
                email,
                fullname,
                password : hashPassword,
                gender,
                birthday,
            };

        const newUser = new User(query);
        if (password.length < 8) {
            const err = new Error.ValidationError();
            err.message =
                "validation error :greenTopia.users :password must be at least 8 characters";
            throw err;
        }
        const savedUser = await newUser.save();
        addPoints(savedUser._id, POINTS.newAcount);
        res.status(201).json(savedUser);
    } catch (error : any) {
```

```
        errorHandller(error, res);
    }
};
```

Listing 5.9 – authentication controller

Routes Routes define the endpoints and map them to the corresponding controller methods.the following tree represent the current routes that our app can access forest

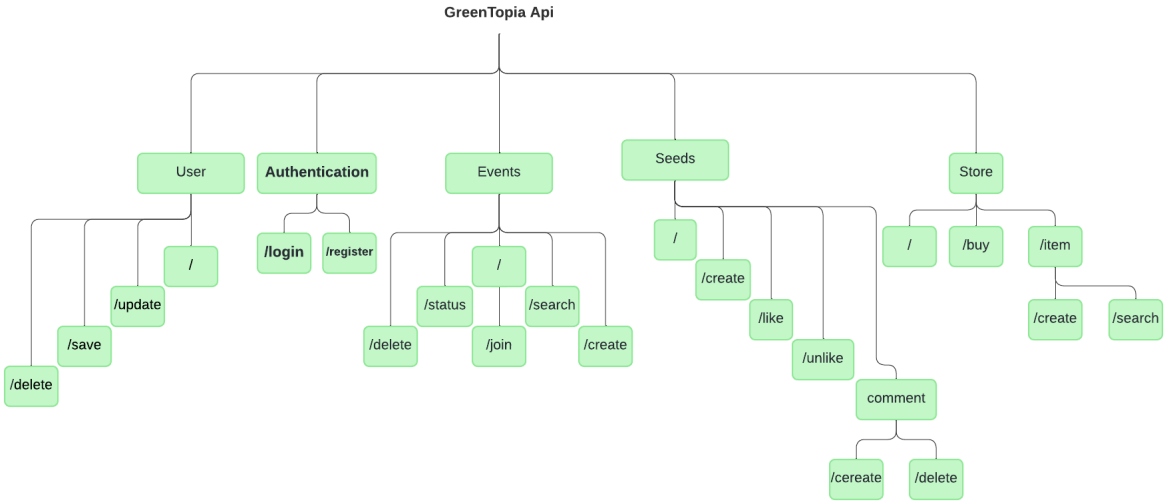


FIGURE 5.23 – Routes and endpoints Tree

this following code is a simple of one of the mentioned routes

```
    import express from "express";
import { login, register } from "../controllers/auth";
import { userUpload } from "../utils/Upload";

const router = express.Router();

router.post("/login", login);
router.post("/register", register);

export default router;
```

Listing 5.10 – authentication Route

JWT (JSON Web Token) : JSON Web Tokens, or JWT for its abbreviation, are RFC Open Standard (RFC 7519) for passing information securely, known as claims between two parties, usually a server and a client. Data and information can be transported securely and verified using digital

signature and encryption algorithms. JTWs follow a structured approach by following JSON Standards and are encoded for transportation over the internet using base64 algorithms

JWT token structure :

(a) Header
(b) Payload
(c) Signature

the Structure of JWT can be represented at the following format

header.payload.signature

The header part of the JWT, seen in the Figure consists of information regarding the hashing and encrypting algorithms that are being used along with the payload and signature.

```
{
  "alg": "HS256",
  "typ": "JWT"
}
```

FIGURE 5.24 – JWT header example

The payload Contains the claims or assertions that represent the user or any additional data

```
{
  "sub": "1234567890",
  "name": "John Doe",
  "admin": true
}
```

FIGURE 5.25 – JWT Payload example

The last part of a JWT token structure is the signature. A signature is a computed part of a JWT token that consists of :

1. A base64Url encoded header and payload ;
2. A given secret ;
3. Algorithm of signing.

```
HMACSHA256(
  base64UrlEncode(header) + "." +
  base64UrlEncode(payload),
  secret)
```

Figure 5.26 – JWT Signature example

If we now put all of the parts together (header, payload, and signature), we get the full structure of the JWT, presented in the Figure

```
eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.
eyJzdWIiOiIxMjM0NTY3ODkwIiwibmFtZSI6IkpvaG4
gRG9lIiwiaXNTb2NpYWwiOnRydWV9.
4pcPyMD09olPSyXnrXCjTwXyr4BsezdI1AVTmud2fU4
```

Figure 5.27 – JWT compact Structure example

in order to apply JWT to our backend server will use Token Verification Middleware.This middleware function checks for the presence of a JWT token in the request headers. It verifies the token and attaches the user ID to the request object, allowing protected routes to access the authenticated user's information.

```
export const verifyToken = (token : any) => {
    let decodedToken : String | JwtPayload = "";
    let verifiedToken;
    if (process.env.JWt_SECRET)
        decodedToken = jwt.verify(token, process.env.JWt_SECRET);
    console.log(decodedToken);
    return decodedToken;
};
export const isAuthenticated = async (req : Request,res : Response,next : NextFunction) => {
    const bearerHeader = req.headers["authorization"];
    console.log(bearerHeader);
    if (typeof bearerHeader == "undefined") {
        res.status(401).json({ code : 13, message : "user not loged in" });
        return;
    }
    const bearerToken = bearerHeader.split(" ")[1];
    const decodedToken : any = verifyToken(bearerToken);

    if (!decodedToken) {
        res.status(401).json({ code : 24, message : "not authorized" });
        return;
    }
    const user = await verifyUser(decodedToken.id);
    if (!user) {
```

```
        res.status(401).json({ code : 24, message : "not authorized" });
        return;
    }
    res.app.locals.userId = decodedToken.id;
    next();
};
```

Listing 5.11 – Token Verification Middleware

Server Configuration :

The main server file initializes the Express application, connects to the MongoDB database, and sets up routes and middleware.

```
    import express from "express";
import { getIp } from "./utils/NetworkIp";
import dotenv from "dotenv";
import cors from "cors";
import bodyParser from "body-parser";
import authRouter from "./routes/auth";
import mongoose from "mongoose";
import userRouter from "./routes/user";
import seedRouter from "./routes/seed";
import uploadRouter from "./routes/upload";
import DevRouter from "./routes/dev";
import storeRouter from "./routes/store";
import { isAuthenticated, isDev } from "./middlewares/authMiddleWare";
import { fileURLToPath } from "url";
import path from "path";
import { getImage } from "./controllers/images";
dotenv.config();
const Host ="192.168.132.219"
const Port : number = Number(process.env.PORT) || 3000;
// h;
console.log(Host)
const app = express();
app.use(cors());
app.use(express.json());

app.use(bodyParser.json({ limit : "30mb" }));
app.use(bodyParser.urlencoded({ limit : "30mb", extended : true }));

// routes
app.get("/", (req, res) => {
    res.send("Hello ");
});
app.use("/auth", authRouter);
app.use("/user", isAuthenticated, userRouter);
app.use("/dev", isAuthenticated, isDev, DevRouter);
app.use("/seed", isAuthenticated, seedRouter);
app.use("/upload", isAuthenticated, uploadRouter);
```

```
app.use("/store", isAuthenticated, isDev, storeRouter);
app.get("/pictures/ :folder/ :path", isAuthenticated, getImage);
const uri = process.env.MONGO_URL;
if (uri)
    mongoose
        .connect(uri)
        .then(() => {
            console.log("connected to mongo db");
            console.log("connecting to server ....");

            app.listen(Port, Host, () => {
                console.log(‘Server started on ${Host} :${Port} ‘);
            });
        })
        .catch((error) => console.log(error.message));
```

Listing 5.12 – server configiration file

5.3.4 Embedded Systems Integration

5.3.4.1 BinVision device

1. **Circuit :**

   – **Wiring :**

Wemos	HC-SR04P
5v	vcc
D1(GPIO5)	Trig
D2(GPIO4)	Echo
GND	GND

TABLE 5.1 – wiring table.

   – **schematic :**

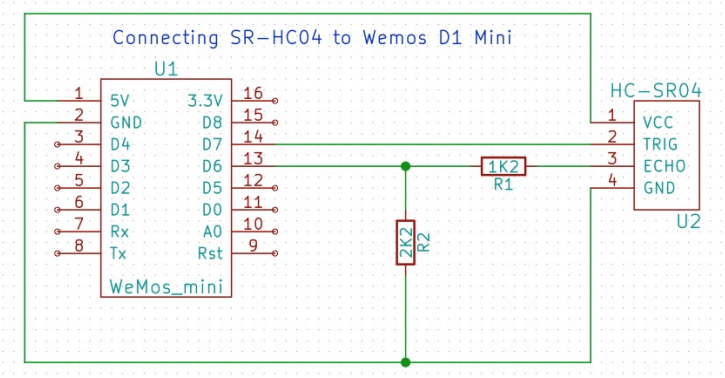


FIGURE 5.28 – Servo Motor.

2. **Code :**

— The following code is a simple example of how we can get the distance between the sensor and an object,and convert it to a percentage,using the Wemos board

```
const int trigPin = 12;
const int echoPin = 14;

//define sound velocity in cm/uS
#define SOUND_VELOCITY 0.034
#define CM_TO_INCH 0.393701

long duration;
float distanceCm;
float distanceInch;

void setup() {
  Serial.begin(115200); // Starts the serial communication
  pinMode(trigPin, OUTPUT); // Sets the trigPin as an Output
  pinMode(echoPin, INPUT); // Sets the echoPin as an Input
}

void loop() {
  // Clears the trigPin
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  // Sets the trigPin on HIGH state for 10 micro seconds
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
  // Reads the echoPin, returns the sound wave travel time in microseconds
  duration = pulseIn(echoPin, HIGH);
  // Calculate the distance
  distanceCm = duration * SOUND_VELOCITY/2;

  // Prints the distance on the Serial Monitor
  Serial.print("Distance (cm): ");
  int prec = 100-(dis*100/max_length);
  Serial.println(prec);
```

```
  delay(1000);
}
```

Listing 5.13 – Ultrasonic Sensor C code

— The next following code snippets connect the esp8266(Wemos) to the real-time Database we create earlier

```
#define API_KEY "AIzaSyA0UKoS1ENS94ds1VXsAXf0iSH5yO2DDso"
/* 3. Define the RTDB URL */
#define DATABASE_URL "https ://green-topia-default-rtdb.firebaseio.com/"
#define USER_EMAIL "younesbenzaama011@gmail.com"
#define USER_PASSWORD "younesben054090"
// Define Firebase Data object
FirebaseData fbdo;
FirebaseAuth auth;
FirebaseConfig config;
unsigned long sendDataPrevMillis = 0;
unsigned long count = 0;
void setup(){
  Serial.begin(115200);

  WiFi.begin(WIFI_SSID, WIFI_PASSWORD);
  Serial.print("Connecting to Wi-Fi");
  unsigned long ms = millis();
  while (WiFi.status() != WL_CONNECTED)
  {
    Serial.print(".");
    delay(300);
  }
    Serial.print("Connected with IP : ");
  Serial.println(WiFi.localIP());
  Serial.println();

  Serial.printf("Firebase Client v%s\n\n", FIREBASE_CLIENT_VERSION);
  config.api_key = API_KEY;
  auth.user.email = USER_EMAIL;
  auth.user.password = USER_PASSWORD;
  config.database_url = DATABASE_URL;
  config.token_status_callback = tokenStatusCallback; // see addons/TokenHelper.h
#if defined(ESP8266)
  fbdo.setBSSLBufferSize(2048 /* Rx buffer size in bytes from 512 - 16384 */, 2048 /* Tx buffer
     size in bytes from 512 - 16384 */);
#endif
  fbdo.setResponseSize(2048);
  Firebase.begin(&config, &auth);
  Firebase.reconnectWiFi(true);
  Firebase.setDoubleDigits(5);
  config.timeout.serverResponse = 10 * 1000;
  }
```

Listing 5.14 – firebase conection with essp8366(wemos)

— Lastly this code snippets sends the bin level to the database periodically

```
    int prev_dis;
dis = sonar.ping_cm();
// Serial.println()
if(prev_dis!=dis){
  int prec = 100-(dis*100/max_length);
  Serial.println(dis);
Serial.printf("Set int... %s\n", Firebase.RTDB.setInt(&fbdo, "/bins/"+String(bin_id)+"/level",
    prec) ? "ok" : fbdo.errorReason().c_str());
}
delay(100);
```

Listing 5.15 – bin level updating

5.3.4.2 BinAi device

The BinAi device is an intelligent system designed to classify garbage into two categories : soda cans and plastic bottles. This classification is achieved using the previously developed AI model and a web camera installed on the garbage bin. The system utilizes several Python scripts runs in a computer to perform different tasks, from capturing images to communicating with the WEMOS and the classification script.

1. **Computer Side :**

   Here's a brief explanation of the key components :

   serial Communication

   This script manages the serial communication channel, enabling the Wemos to send data, such as the presence of an item, to the computer.

```
import serial
import time

class serialComm():
    com = "COM3"
    baud = 9600
    serialTimeout = 1.0
    serial_Comm = None
    def __init__(self, com="COM3", baud=9600):
        self.com = com
        self.baud = baud
        self.serial_Comm = serial.Serial(self.com, self.baud)

    def reciveData(self):
        recived_data = self.serial_Comm.readline().decode('utf-8')
        print(recived_data.strip())
        # int_data = int(recived_data)
        return recived_data.strip()
    def ReadData(self):
        recived_data = str(self.serial_Comm.readline())
        # int_data = int(recived_data)
```

```
            return recived_data.strip()
        def sendData(self, data) :
            # data += "\n"
            # self.serial_Comm.write(b'0')
            self.serial_Comm.write(data.encode(encoding="utf-8"))
            time.sleep(0.5)
        def sendInt(self, data) :
            self.serial_Comm.write(data)
            time.sleep(0.5)
        def serialDisconnect(self) :
            self.serial_Comm.close()
```

Listing 5.16 – serial comunication between the esp8266(wemo) and the computer

Image capturing

Captures images using a web camera and handles image classification requests.

```
import cv2
from matplotlib import pyplot as plt
from smartBin import decode_image
import base64
from EspSerialConnection import serialComm
import time

def take_photo(camera_number) :
    cap = cv2.VideoCapture(camera_number)
    ret, frame = cap.read()
    cap.release()
    ret, buffer = cv2.imencode('.jpg', frame)
    return base64.b64encode(buffer)

serial = None
coms = ["COM3", "COM4", "COM5", "COM6"]
print("connecting", end="")
while (not serial) :
    print(".", end="")
    for com in coms :
        try :
            serial = serialComm(com=com,baud=115200)
        except :
            pass
    time.sleep(0.5)
print("")
print("connected")

while (True) :
    recived_data = serial.reciveData()
    # print("recived_data",recived_data)
    if (recived_data == "waste in") :
        print("taking a picture...")
```

```
                pic = take_photo(0)
                (waste_type, res) = decode_image(pic)
                print(res)
                print(res)
                serial.sendData(str(res))
                pass
            time.sleep(1)
```

Listing 5.17 – main.py

Image classification

This script loads the pre-trained AI model stored in the "models" directory. It processes the input image, resizes it to the required dimensions, and normalizes the pixel values.Uses the loaded model to predict the category of the garbage (soda can or plastic bottle) based on the image.Returns the classification result, which can be either "soda can" or "plastic bottle."

```
         import base64
from PIL import Image
from io import BytesIO
import matplotlib.pyplot as plt
import numpy as np
from tensorflow.keras.models import load_model
from os import path
import tensorflow as tf
import uvicorn
from pathlib import Path
DIRNAME = path.dirname(path.abspath(__file__))
MODLE_PATH = path.join(DIRNAME, "models")
MODLE_NAME = "GarbageModel_v2.h5"
model = None
def classify(y) :
    if (y < 0.5) :
        return 0
    return 1
def classifyImage(image) :
    global model
    if (not model) :
        model = load_model(path.join(MODLE_PATH, MODLE_NAME))
    resized_image = tf.image.resize(image, (256, 256))
    y_predicted = model.predict(np.expand_dims(resized_image/255, 0))
    return classify(y_predicted)
def decode_image(img) :
    try :
        # Decode base64 string to bytes
        #decoded_image = base64.b64decode(img)
        # open image
        #image = Image.open(BytesIO(img))
        classify_res = classifyImage(img)
        res = "plastic bottle" if classify_res else "soda can"
        print("python", res, classify_res)
        return (res, classify_res)
```

```
            except Exception as e :
                print("error")
```

Listing 5.18 – smartBin.py

2. MicroController Side :

(a) **Circuit :**

— **Wiring :**

Wemos	X Servo	Y Servo	Proximity Sensor
5V	VCC	VCC	VCC
GND	GND	GND	GND
D5(GPIO12)	Signal	/	/
D6(GPIO14)	/	Signal	/
D3(GPIO0)	/	/	OUT

— **schematic :**

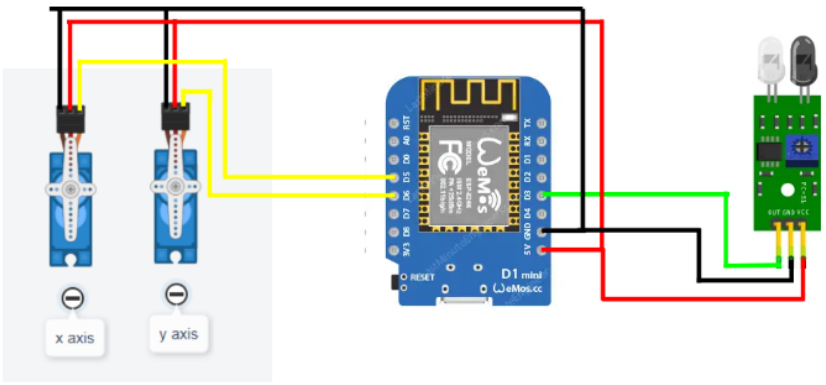


FIGURE 5.29 – BinAi schematic.

(b) **Code :** The following code sending signal to the computer when the item is present and control the servos movement to place the item in the correct spot based on the computer response

```
    from machine import UART,PWM,Pin
import time
import sys
from servo import Servo

uart = UART(0,115200)
servos=[]
servo_pins=[14,12]
for pin in servo_pins :
```

```
    servo = Servo(pin)
    servos.append(servo)
servos[0].spin(180,2)
servos[1].spin(90,2)
def throw_bottle() :

    servos[1].spin(40,2)
    time.sleep(1)
    servos[1].spin(90,2)
    pass
def throw_can() :
    servos[0].spin(0,2)
    time.sleep(1)
    servos[1].spin(160,2)
    time.sleep(1)
    servos[1].spin(90,2)
    time.sleep(1)
    servos[0].spin(180,2)
    pass
WASTE_IN_PIN= 0
waste_in=Pin(WASTE_IN_PIN,Pin.IN)
while True :
    if(not waste_in.value()) :
        print("waste in")
        data=sys.stdin.read(1)
        if(data=="1") :
            print("bottle")
            throw_bottle()
            data=None
        elif(data=="0") :
            print("can")
            throw_can()
            data=None
        else :
            print("no data")
    time.sleep(1)
```

Listing 5.19 – garbageBin control

5.4 UI/UX of our assistant Tool

5.4.1 Mobile app design process

Creating an intuitive and engaging mobile app involves several critical steps in the design process. Here we outline the primary phases we followed to ensure our assistant tool provides a user-friendly experience.

5.4.1.1 Sketching

Sketching is the initial phase of the design process where we translate our ideas into rough visuals. This stage involves :

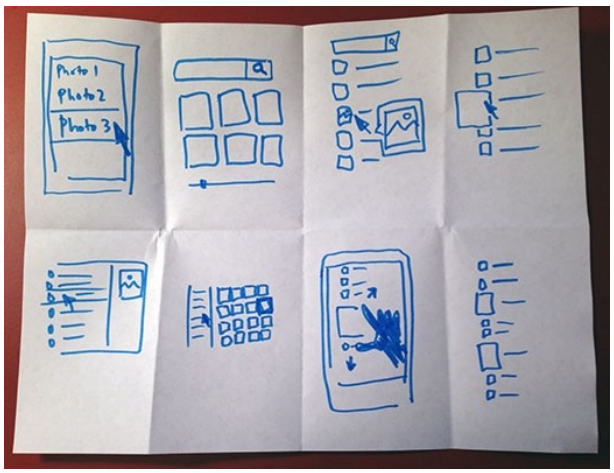


FIGURE 5.30 – skeching

- **Brainstorming sessions :** Generating concepts and defining user needs.
- **Rough sketches :** Creating hand-drawn representations of key interfaces and user flows to explore different layout options.
- **Feedback gathering :** Sharing sketches with stakeholders to refine ideas based on initial feedback.

5.4.1.2 Wireframing

Wireframing converts sketches into more detailed and structured layouts. This step focuses on :

- **Detailed outlines :** Developing wireframes that depict the app's structure and layout without color or graphics.
- **User flow :** Ensuring seamless navigation by mapping out the user journey across various screens.
- **Usability testing :** Conducting early tests to identify potential usability issues and iterating based on findings.

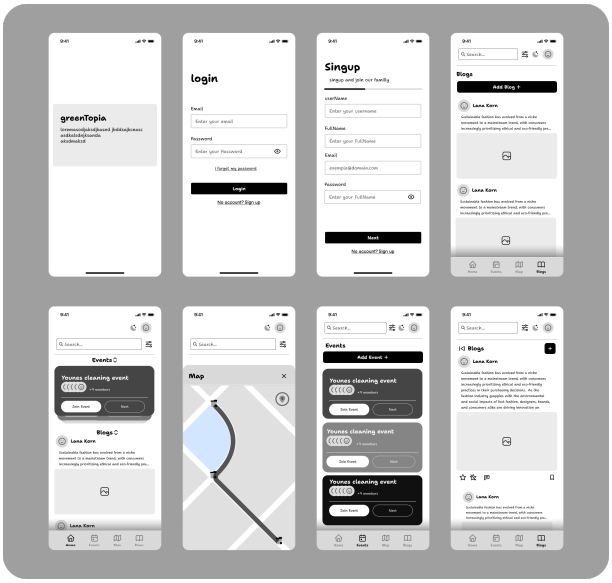


FIGURE 5.31 – wireframing

5.4.1.3 Storyboards

Storyboards help visualize the app's functionality through a sequence of screens, providing a narrative of user interactions :

- **User scenarios :** Creating scenarios that depict how users will interact with the app in real-world situations.
- **Screen sequences :** Designing sequences that illustrate key interactions and transitions between screens.
- **Experience mapping :** Mapping out the emotional journey of users to ensure the app delivers a positive and engaging experience.

5.4.2 Mobile app demonstration

To showcase the effectiveness of our design process, we provide a demonstration of key interfaces within the mobile app. This demonstration highlights the app's capabilities and user experience.

5.4.2.1 splashScreen

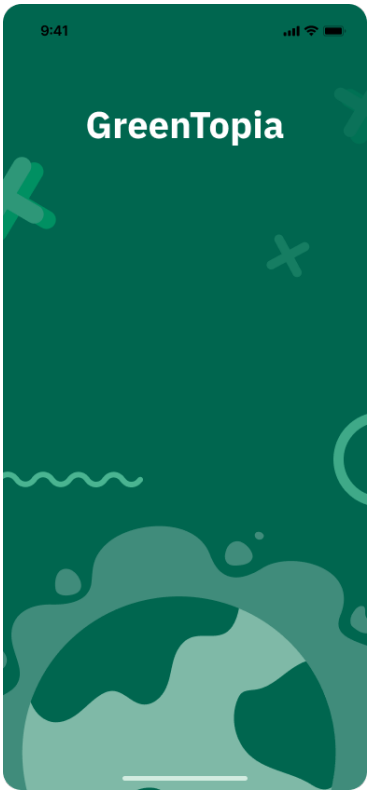


FIGURE 5.32 – SplashScreen

5.4.2.2 Login interface

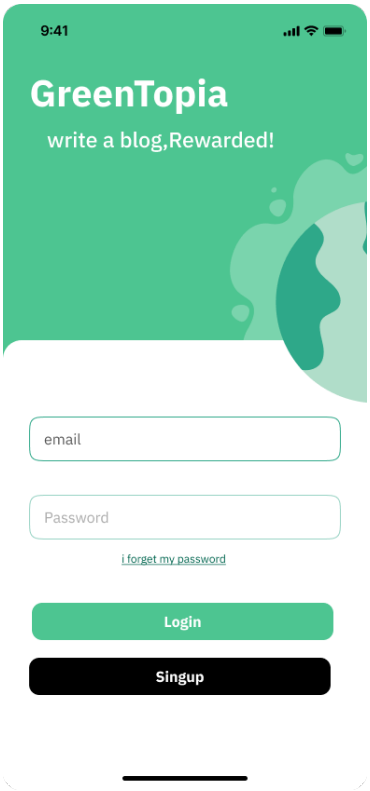


FIGURE 5.33 – Login

5.4.2.3 Signup interface

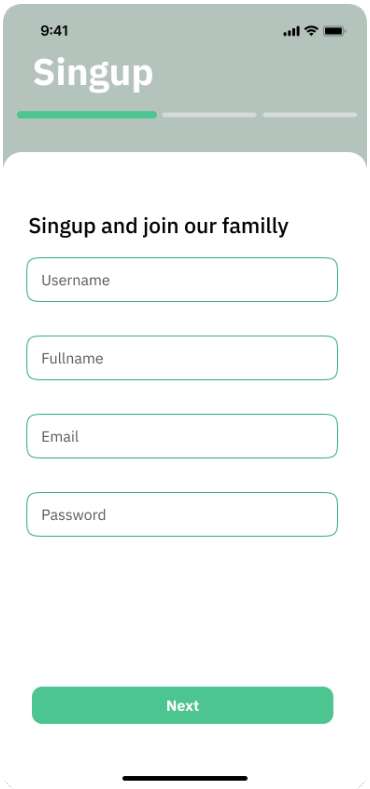


FIGURE 5.34 – signup interface

5.4.2.4 interface of location

This interface allows users to view and manage the locations of different bins. It provides a map view, showing the geographical placement of each bin, along with detailed information about the bin's status, type, and fill level. The design ensures easy navigation and quick access to essential information.

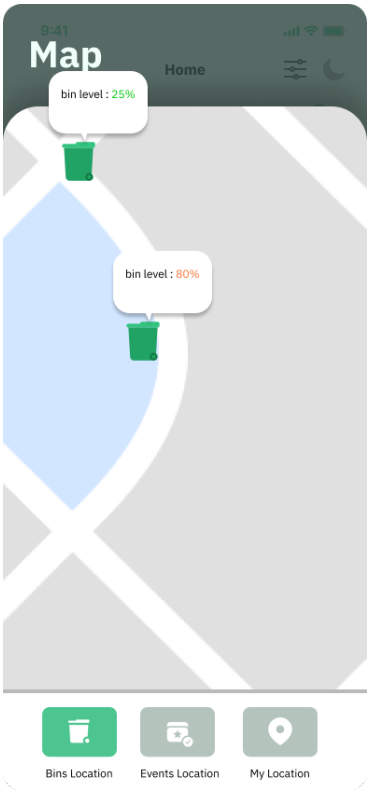
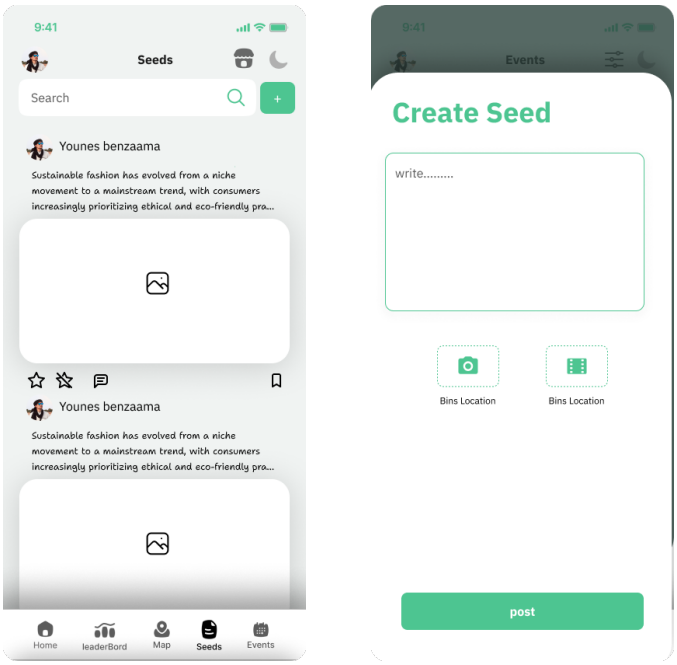


FIGURE 5.35 – map interface

5.4.2.5 interface of Blogs

The blogging interface serves as a platform for users to read and post articles (Seeds) related to waste management, recycling tips, and environmental conservation. It includes features such as article categories, search functionality, and user comments, all designed to foster a community around sustainable practices.

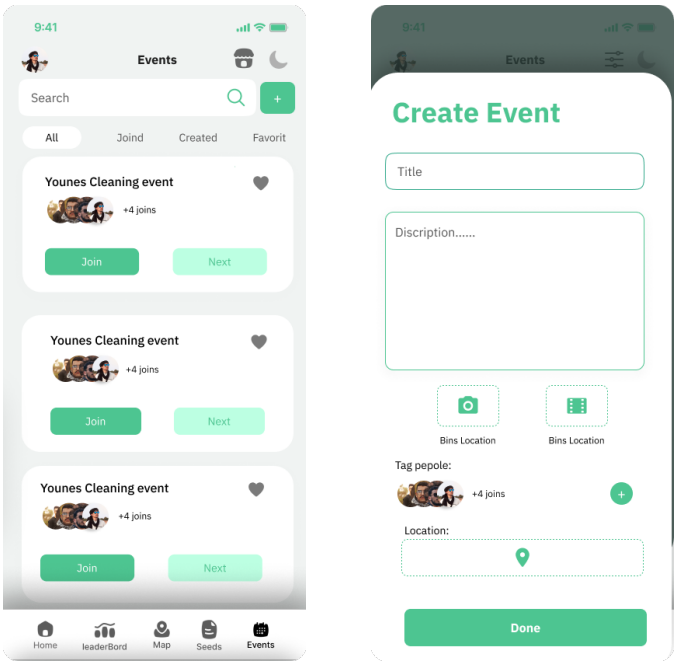


(a) (b)

FIGURE 5.36 – blog interface

5.4.2.6 interface of of Events

The events interface keeps users informed about upcoming events related to recycling drives, environmental workshops, and community clean-up activities. Users can view event details, register for events, and receive notifications, making it easier to participate in local initiatives.



(a) (b)

FIGURE 5.37 – event interface

5.4.2.7 interface of Store

The store interface allows users to purchase products related to recycling and waste management, such as recycling bins, composting kits, and educational materials. The design focuses on a smooth shopping experience with features like product categories, detailed product descriptions, and a secure checkout process. Additionally, users can redeem coupons based on their earned points to get discounts or free items, incentivizing consistent and correct recycling behavior.

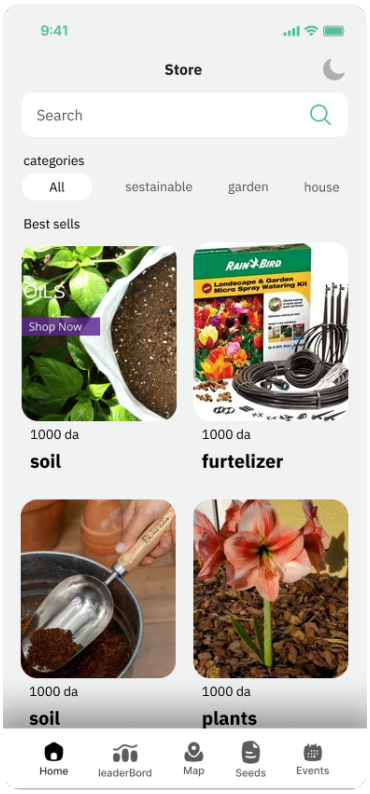


FIGURE 5.38 – store interface

5.4.2.8 interface of leaderbord

The leaderbord interface is designed to engage users through gamification and a points system. Users can view their recycling statistics, achievements, and current point balance.

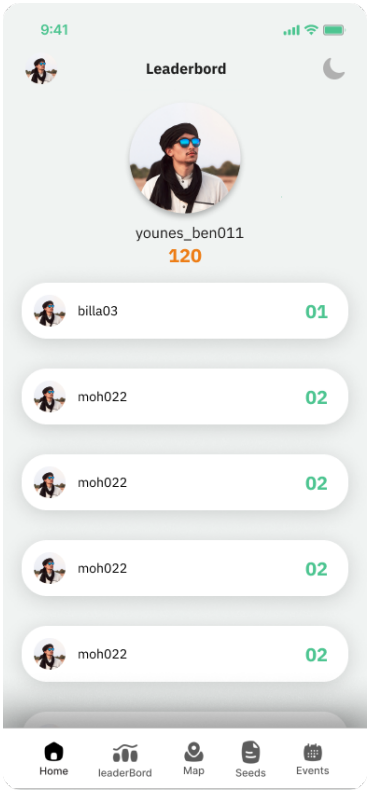


FIGURE 5.39 – leaderBoard interface

5.5 Conclusion

Our project successfully demonstrates the potential of integrating AI technology with mobile applications to enhance waste management practices and change user behavior. The binAI system proves that real-time waste identification using AI is not only feasible but also highly effective in improving the accuracy and efficiency of recycling processes. By accurately categorizing waste at the point of disposal, binAI helps reduce contamination and streamline recycling operations.

Part IV

Conclusion and perspectives

Chapter

6 General Conclusion and Perspective

« To accomplish great things, you must not only act, but also dream ; not only plan, but also believe. »
— Anatole France (1844-1924)

Contents

6.1 Conclusion and Perspective

This chapter presents an assessment of our work as well as a set of openings and perspectives.

6.1.1 Conclusion

This final year project focused on the critical issue of waste management in the Tiaret region of Algeria. Recognizing that public health is strongly influenced by the state of the environment, our approach aimed to design an innovative solution to address organizational, technical, and informational dysfunctions in waste management.

Analyzing citizen behaviors and the challenges faced by civil protection services revealed non-eco-friendly habits, such as improper waste disposal and a lack of selective sorting. In response to these issues, we developed a mobile application called "Greentopia," which aims to engage and empower citizens. This application offers key features such as two types of intelligent bins :"BinAi and BinVision", raising awareness about ecological initiatives, reporting issues, and accessing practical tips, routing algorithm designed to waste collectors to be efficient in their work additionally they have influence to raise awareness for better environmental behavior.

In conclusion, our "Greentopia" project makes a significant contribution to waste management in Tiaret by combining technical and educational solutions. We hope this initiative will serve as a catalyst for positive and sustainable changes in waste management while raising awareness among citizens about the importance of their role in environmental protection.

6.1.2 Future Perspectives

In terms of future extensions, several avenues can be explored, such as adding RFID, locking mechanism and reporting system.

Part V

Annexes

البطاقة التقنية للمشروع

الاسم و اللقب Votre prénom et nom Your first and last Name	Bensaadi Billal Abdelkarim Benzaama Abdellah Younes
الاسم التجاري للمشروع Intitulé de votre projet Title of your Project	GreenTopia
الصفة القانونية للمشروع Votre statut juridique Your legal status	
رقم الهاتف Votre numéro de téléphone Your phone Numbers	Billal: 0542629596 Younes: 0558496714
البريد الالكتروني Votre adresse e-mail Your email address	Bnsabdou087@gmail.com younesbenzaama011@gmail.com
مقر مزاولة النشاط (الولاية– البلدية) Votre ville ou commune d'activité Your city or municipality of activity	Tiaret,Tiaret

طبيعة المشروع

GreenTopia is a mobile application aimed at changing human behavior to be more environmentally friendly and sustainable, while incentivizing active participation in waste management and environmental conservation efforts	Citizens: use GreenTopia to raise awareness about environmental issues and actively participate in eco-friendly activities Waste collectors: use GreenTopia to efficiently manage waste collection processes and interact with the community Administrators: manage the overall system and user roles within GreenTopia.

Value Proposition **القيمة المقترحة أو العرض المقدّم**

تحديد المشكل الذي يواجهه الزبون

1. Lack of Awareness and Education on Environmental Issues 2. Inefficient Waste Management 3. Lack of Motivation for Sustainable Practices Raise the recyclable 4. there is not the culture of recycling	ما هي المشكلة التي تريد حلها؟
There is no data, but our environment has already the data that we see it every time	ما هي البيانات المتوفرة لديك التي تدل على وجود المشكلة المحددة؟
there are no projects that aimed to solve this problem	ما هي المشاريع الأخرى التي استهدفت نفس المشكلة والتي جرى تنفيذها؟
Mobile application: 1. Enhance Environmental Awareness and Education	ماهي أهداف مشروعك و/أو نتائجه المتوقعة؟

2. Promote Sustainable Behaviors 3. Improve Waste Management Practices 4. Distribute all our smart bins in all neighborhoods and city centers throughout the country.	

القيمة المقترحة وفق المعايير التالية

Change behavior by introducing approaches to human attitudes BinAi: Smart sorting bins to recognize type of waste and sorted BinVision: Smart bin that indicate the fill level of the bin using twin digital projection Help waste collectors to find the full bins	القيمة المبتكرة أو الجديدة

	القيمة بالتخصيص
	القيمة بالسعر
– Design a simple and intuitive user interface to ensure a smooth experience for all ages. – Use attractive design and pleasant colors to improve user experience.	القيمة بالتصميم
–Develop a stable, bug–free application to ensure a smooth user experience without technical problems. – Ensure a rapid response to user requests.	القيمة بالأداء العالي
–Provide technical support available 24/7 to help in emergencies. – Provide excellent, responsive and efficient customer service to resolve all issues and	القيمة بالخدمة الشاملة
	قيم أخرى

شرائح العملاء أو الزبائن Customer Segments

Géographique الجغرافية	Démographique (B2C) **citizens**	Démographique (B2B) **contracts with recycling companys and municipalities**	Psychographique العوامل النفسية و الشخصية	Comportemental السلوكيات
Continent القارة Afriqua	Age العمر +18years old	Secteur القطاع	Classe sociale لطبقة الاجتماعية All classes	Usage استخدام People and waste collectors
Pays الدولة Algeria	Sexe الجنس Male Female	Nombre d'employés عدد العمال في القطاع	Niveau de vie المستوى المعيشي	Loyauté الوفاء
Région الجهة Algerian territory	Revenus annuel متوسط الدخل avrage	Maturité de l'entreprise نضج المؤسسة	Valeurs القيم	Intérêt اهتمام Change human behavior Make our environment

				cleaner greener more sustainable
Département الولاية Tiaret	Etat matrimonial الحالة الاجتماعية	Situation financière الحالة المالية للمؤسسة	Personnalité الشخصية	Passion الهواية وشغف
Ville الدائرة او البلدية Tiaret	Niveau d'étude المستوى الدراسي	Détention/ actionnariat الملكية/المساهمة	Convictions المعتقدات	Sensibilité حساسيات
Quartier الحي	Profession المهنة	Valorisation/ capitalisation boursière التقييم / القيمة السوقية	Présence digitale et sur les réseaux sociaux استعمال التكنولوجيا في التواصل	Habitude de consommation عادة الاستهلاك
Climat المناخ	Culture الثقافة	Business model نموذج الأعمال	Centres d'intérêts	Mode de paiement

طرق الدفع	مراكز الاهتمام			
Connaissance المعرفة		Secteur servi القطاع الذي يخدمه	Religion الدين	
Nature de la demande طبيعة الطلب		Technologie utilisée التكنولوجيا المستعملة	Langue اللغة	
Fréquence d'achat عدد مرات الطلب على السلعة		Format du produit ou packaging شكل المنتج أو التعبئة والتغليف		

قنوات التوزيع Channels

المبيعات المباشرة	Goods traded via the application Contracting with recycling companies and municipalities
تجار الجملة	/
الموزعون	/
توزيع التجزئة	/

العلاقة مع العملاء Customer Relationship

Customer Service: Collect information about customers. Analyze the data. Provide a personalized customer experience.	كيف تدير علاقاتك مع العملاء؟
Monday CRM Microsoft Dynamics Zoho CRM IoT Manufacturers Waste Management Companies municipalities Wholesalers	ماهية أهم البرامج التي ستعتمد عليها في ادارة العلاقة مع الزبون Microsoft Dynamics Monday CRM Zoho CRM الخ.....

الشركاء الأساسيون Key Partners

الشركاء	معلومات حول الشركاء	طبيعة الشراكة
PCBWAY(electronic devices manufacture)	PCBWay offers high-quality PCBs with direct manufacturer pricing, fast turnarounds as quick as 24 hours, no minimum order requirements, excellent customer service, and a 99% on-time delivery rate, making them a top choice for reliable and efficient PCB production	In essence, PCBWay supports GreenTopia's mission by providing the essential hardware components needed for the app to operate effectively, thus enabling GreenTopia to focus on encouraging sustainable practices among its users.
AGENCE NATIONALE DES DÉCHETS	The AND was created by Executive Decree No. 02 – 175 of May 20, 2002. Placed under the supervision of the Ministry of the Environment and Renewable Energy, it is responsible, within the framework of a mission of subjection of service public to inform and popularize the techniques of sorting, collection, transport, treatment, recovery and elimination of waste. It	Statutory missions - are: Provide assistance to local authorities in the field of waste management, Process data and information on waste, Establish and update a national data bank on waste -

	must capitalize and constitute a documentary base on waste management and ensure its dissemination to local communities and the sector of activity.	
Municipalities are essential to the effective governance and service delivery at the local level. Their collaboration with innovative solutions like GreenTopia can significantly enhance their capacity to manage waste and promote sustainable practices, ultimately leading to greener and more sustainable communities.	Municipalities are administrative entities composed of a defined territory and its population. They are the most local level of government, responsible for providing essential services and governance to their communities	**municipalities**

قم بكتابة قائمة الشركاء الرئيسيون لمشروعك بالتفصيل مع ذكر الإسم، الهاتف، العنوان...إلخ

structure Costs هيكل التكاليف

From 100,000 da –Marketing on social networks (Facebook, Instagram). –Content marketing (creation of videos). –flyers	تكاليف التعريف بالمنتج أو المؤسسة Frais d'établissement
Our project depends only on electricity From 30.000DA	تكاليف الحصول على العدادات (الماء– الكهرباء (..... Frais d'ouverture de compteurs (eaux–gaz–....)
From 100.000Da Google Map API Forming in mobile development	تكاليف (التكوين– برامج الاعلام الالي المختصة) Logiciels, formations
From 20.000 da	Dépôt marque, brevet, modèle تكاليف براءة الاختراع و الحماية الصناعية و التجارية
From 300.000 da	Droits d'entrée تكاليف الحصول على تكنولوجيا او ترخيص استعمالها
	Achat fonds de commerce ou parts شراء الأصول التجارية أو الأسهم
From 300.000da	Droit au bail الحق في الإيجار
	Caution ou dépôt de garantie وديعة أو وديعة تأمين
	Frais de dossier رسوم إيداع الملفات
From 50.000da	Frais de notaire ou d'avocat تكاليف الموثق–المحامي–.....
From 250.000da	Enseigne et éléments de

	communication تكاليف التعريف بالعلامة و تكاليف قنوات الاتصال
	Achat immobilier شراء العقارات
	Travaux et aménagements الأعمال والتحسينات الاماكن
From 1.250.000da Hosting server Computers 3D printer	Matériel الآلات– المركبات– الاجهزة
From 300.000da Tables, chairs, printers	Matériel de bureau تجهيزات المكتب
	Stock de matières et produits تكاليف التخزين
From 1.000.000da	Trésorerie de départ التدفق النقدي(الصندوق) الذي تحتاجه في بداية المشروع.

المجموع =3.700.000

نفقاتك أو التكاليف الثابتة الخاصة بمشروعك

From 50.000da	Assurances التأمينات
Internet pack 1GB/s 4000da/month	Téléphone, internet الهاتف و الانترنت
	Autres abonnements اشتراكات أخرى
	Carburant, transports

	الوقود و تكاليف النقل
from 500.000da	Frais de déplacement et hébergement تكاليف التنقل و المبيت
from 10.000da	Eau, électricité, gaz فواتير الماء – الكهرباء– الغاز
	Mutuelle التعاضدية الاجتماعية
From 25.000da	Fournitures diverses لوازم متنوعة
	Entretien matériel et vêtements صيانة المعدات والملابس
from 30.000da	Nettoyage des locaux تنظيف المباني
from 50.000da	Budget publicité et communication ميزانية الإعلان والاتصالات

المجموع =690.000da

مصادر الإيرادات Revenue Stream

	Apport personnel ou familial المساهمة الشخصية أو العائلية
	Apports en nature (en valeur) التبرعات العينية
	Prêt n°1 (nom de la banque) قرض رقم 1 اسم البنك
	Prêt n°2 (nom de la banque)

قرض رقم 2 اسم البنك	
Prêt n°3 (nom de la banque) قرض رقم3 اسم البنك	
Subvention n°1 (libellé) منحة 1	
Subvention n°2 (libellé) منحة 2	
Autre financement (libellé) تمويل آخر	

المجموع =

رقم الأعمال

Votre chiffre d'affaires de la première année بيع المنتج في السنة الأولى

بيع المنتج في السنة الأولى	متوسط أيام العمل في الشهر
1Mois الشهر	20
2Mois الشهر	20
3Mois الشهر	20
4Mois الشهر	20
5Mois الشهر	20
6Mois الشهر	20
7Mois الشهر	20
8Mois الشهر	20
9Mois الشهر	20
10Mois الشهر	20
11Mois الشهر	20

12Mois الشهر	20

المجموع =

النسبة المئوية للزيادة في حجم الأعمال بين كل شهر لسنة الأولى؟

بيع المنتج في السنة الثانية Votre chiffre d'affaires de la deuxième année

بيع المنتج في السنة الثانية	متوسط أيام العمل في الشهر
1Mois الشهر	20
2Mois الشهر	20
3Mois الشهر	20
4Mois الشهر	20
5Mois الشهر	20
6Mois الشهر	20
7Mois الشهر	20
8Mois الشهر	20
9Mois الشهر	20
10Mois الشهر	20
11Mois الشهر	20
12Mois الشهر	20

المجموع =

النسبة المئوية للزيادة في حجم الأعمال بين كل شهر لسنة الثانية؟

بيع المنتج في السنة الثالثة Votre chiffre d'affaires de la troisième année

بيع المنتج في السنة الثالثة	متوسط أيام العمل في الشهر
1Mois الشهر	20
2Mois الشهر	20

3Mois الشهر	20
4Mois الشهر	20
5Mois الشهر	20
6Mois الشهر	20
7Mois الشهر	20
8Mois الشهر	20
9Mois الشهر	20
10Mois الشهر	20
11Mois الشهر	20
12Mois الشهر	20

المجموع =

النسبة المئوية للزيادة في حجم الأعمال بين كل شهر لسنة الثالثة ؟

تطور حجم رقم الأعمال في السنة

- النسبة المئوية للزيادة في حجم الأعمال بين السنة 1 والسنة 2؟
- النسبة المئوية للزيادة في حجم الأعمال بين السنة 2 والسنة 3 ؟

حاجتك لرأس المال العامل

متوسط مدة الاعتمادات الممنوحة للعملاء بالأيام Durée moyenne des crédits accordés aux clients en jours	30 يوم
متوسط مدة ديون الموردين بالأيام Durée moyenne des dettes fournisseurs en jours	30 يوم

رواتب الموظفين و مسؤولين الشركة

52.000da/ month	رواتب الموظفين Salaires employés
90.000da/month	صافي أجور المسؤولين Rémunération nette dirigeant

Business Model Canvas

Designed for:

Designed by:

Date:

Version:

Key Partners

Who are our Key Partners? Who a
key suppliers? Which Key Resour
we acquiring from partners? Whicl
Activities do partners perform?

MOTIVATIONS FOR PARTNERS
Optimization and economy, Reduc
risk and uncertainty, Acquisition of
particular resources and activities

Key Activities

What Key Activities do our Value
Propositions require? Our Distribu
Channels? Customer Relationship
Revenue streams?

CATEGORIES:
Production, Problem Solving,
Platform/Network

Key Resources

What Key Resources do our Value
Propositions require? Our Distribu
Channels? Customer Relationship
Revenue Streams?

TYPES OF RESOURCES: Physic
Intellectual (brand patents, copyrig
data), Human, Financial

Value Propositions

What value do we deliver to the cu
Which one of our customer's prob
we helping to solve? What bundle
products and services are we offe
each Customer Segment? Which
needs are we satisfying?

CHARACTERISTICS: Newness,
Performance, Customization, "Ge
Job Done", Design, Brand/Status,
Cost Reduction, Risk Reduction,
Accessibility, Convenience/Usabil

Customer Relationships

What type of relationship does eac
Customer Segments expect us to
and maintain with them? Which or
we established? How are they inte
with the rest of our business mode
costly are they?

Channels

Through which Channels do our C
Segments want to be reached? H
we reaching them now? How are
Channels integrated? Which ones
best? Which ones are most cost-e
How are we integrating them with
routines?

Customer Segments

For whom are we creating value?
our most important customers? Is
customer base a Mass Market, Ni
Market, Segmented, Diversified, M
sided Platform

Cost Structure

What are the most important costs inherent in our business model? Which Key Resour
most expensive? Which Key Activities are most expensive?

IS

BUSINESS MORE: Cost Driven (leanest cost structure, low price value proposition, ma
automation, extensive outsourcing), Value Driven (focused on value creation, premium
proposition).

SAMPLE

CHARACTERISTICS: Fixed Costs (salaries, rents, utilities), Variable costs, Economies
scale, Economies of scope

Revenue Streams

For what value are our customers really willing to pay? For what do they currently pay?
they currently paying? How would they prefer to pay? How much does each Revenue S
contribute to overall revenues?

TYPES:

sale, Usage fee, Subscription Fees, Lending/Renting/Leasing, Licensing, Brokerage fee
Advertising

FIXED PRICING: List Price, Product feature dependent, Customer segment dependent
dependent

DYNAMIC PRICING: Negotiation (bargaining), Yield Management, Real-time-Market

Business Model Canvas

Designed for:	*Designed by:*	*Date:*	*Version:*
B-tech	Billal Younes	06/09/2024	2.0.1

Key Partners

- IoT Manufacturers
- Waste Management Companies
- Municipalities Wholesalers

Key Activities

- App Development and Maintenance
- User Engagement IoT Integration
- AI components integration

Key Resources

- App Development Team
- IoT Device Partnerships
- Marketing and Outreach

Value Propositions

For the People:

- Connects users with like-minded individuals.
- Personalized eco-friendly tips to reduce impact.

Smart Living with IoT Devices

For the Waste Collectors :

- Provides an Efficient Waste Management
- Cleaner neighborhoods and reduced efforts and work houres

Customer Relationships

- Engagement
- Feedback Loop
- Rewards

Channels

- Mobile App Stores
- Online Platforms
- Collaboration with waste collectors
- Wholesalers

Customer Segments

Citizens:

These are everyday individuals who want to adopt eco-friendly practices.

Waste Collectors :

Professionals involved in waste management and recycling.

Cost Structure

- Development Costs
- Electronic components
- Marketing Expenses
- 3D printing & mold injection .Data hosting
- Support and Operations
- Giveaways

Revenue Streams

Contracts: Signing contracts with various recycling companies and municipalities

Partnerships: Collaborate with IoT device manufacturers for revenue sharing.

Greenstore: Selling sustainable, maintainable items

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