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Smart Recycle – Development of a waste collection application

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Abstract:

Currently, the growing population demand for new technological resources, its housing growth and economic growth has brought to the fore a global discussion about how we should progress as a nation without affecting people's health and the planet's natural course in the coming years. Figures from 2019 indicate that each habitant produces 513.4 kilos of waste annually. The Portuguese environment agency has warned that these resources will be too destined for landfills, which will stop almost three out of five kilos (57.6%) of our urban waste.

The country's effective recycling rate is (23.7%), when compared to the targets set by the European Union for the year 2025 (55%) Portugal needs impulses and some actions to encourage smart and conscious recycling.

One of the factors addressed in this article is the uncontrolled advance of waste generated by individuals and companies, ways in which they are discarded in nature, actions that the government has taken and how the authors intend to help improve these numbers, bringing the country closer to the goals established by European Union.

Important facts about waste recycling are:

• Without some type of inspection / incentive / appropriate disposal site or help, many inhabitants choose to dispose of garbage in a simpler and easier way;
• There are not enough selective collection points in most countries/cities, or these cannot be easily found by the inhabitants;
• Access to public services for collection at home is very scarce and/or poorly managed;
• Material characteristics identification is ineffective and does not allow proper disposal;
• It is easier to use the "common trash" option if there is no incentive or any policy to raise awareness among the inhabitants;
• Correct recycling brings countless benefits not only to the inhabitants and the environment, but also to the economy and industries in general.

As a result of the study, tools in the form of mobile systems and applications with various control resources and intuitive assistants will be delivered in order to facilitate and make more pleasurable and exciting the way in which waste is characterized, disposed and reused by different organizational spheres to considerably reduce incorrect disposal and mitigate this impact on our planet thus making it healthier and less toxic for us and our future generations.

Keywords: *Applications, conscious recycling, economic growth, mobile systems, sustainability, waste collection.*

I. Introduction

The development of the prototype presented in this document was motivated by the exponential growth of waste generation by the

inhabitants and the lack of software tools for better targeting and control. The consequence most felt by the population is the overload of landfills and increased pollution of the ozone layer, however, there are many other tragic factors related to the topic.

Recycling and waste disposal are increasingly urgent issues for the preservation of the environment, our planet and the survival of future generations [1].

Data extracted from the website of the European Commission [2] indicate that in some countries more than 60% of the waste produced goes directly to landfills and that only 38% is recycled in some way.

Taking Portugal as an example, in 2019, 5.281 million tons (t) of Municipal Waste were produced, 1% more than in 2018, with a slight increase in production, when compared to previous years.

(millions of tons)

Region / Year	**2015**	**2016**	**2017**	**2018**	**2019**
Portugal Continental	4523	4640	4745	4945	5007
Madeira	110	119	124	126	129
Açores	132	132	137	142	146
TOTAL	**4765**	**4891**	**5006**	**5213**	**5281**
Variation from the previous year	↑ 1%	↑ 3%	↑ 2%	↑ 4%	↑ 1%

Table 1 - Waste Production

People living in cities are considered an essential part of the effective waste recycling process and even the smallest change in habits can strongly impact a city's ecological and economic sustainability. However, achieving virtuous behavior is not a trivial task, since people living in urban areas are heterogeneous, have different cultural, social and national origins.

Given these social and cultural differences compared to local recycling legislation, some of the recycling materials and categories may even have other classifications, which makes access to information and a globalized tool that meets current needs essential.

A considerable amount of research has been carried out on the factors influencing household waste recycling behaviors and a plethora of support tools have been created to try to aid the recycling task in recent years. Despite this, waste recycling is still perceived as a complicated task, and people around the world are often struggling to find efficient ways to recycle their waste.

Achieving active citizen engagement in this area is, therefore, the biggest challenge faced by studies, managers and tools such as the prototype presented in this document.

II. Related Work

In the scope of waste recycling, several scattered efforts are already exploring mobile apps as a way to engage users in better waste recycling [3]. Municipalities are releasing apps that provide up-to-date garbage collection calendars and garbage recycling guides. However, the fact that they mostly only provide static information often leads to poor adoption.
A quick search on Google Play Market, for example, can easily report over fifty (50) apps destined for waste recycling. However, when analyzing the existing solutions, the lack of a practical user-centered approach together with the absence of a chain of mutual benefits between those involved in the process, seem to be the relevant factors for the applications to fall into disuse.
Some studies report the recent use of IOT devices (smart bins, for example), which help agencies in monitoring and better collecting materials, however, they do not help in the way citizens dispose of their waste, nor are the applications integrated today. existing and made available to users.
Several factors are actually influencing an individual's willingness to properly recycle waste. According to the literature, the most prominent behavioral intentions arising from the theory of rational action [4], and integrated by Chu and Chiu [5] for the domain of residues, include: personal attitude, subjective norms, perceived behavioral control and perceived moral

obligation. Among the 4 intentions, the first and the last 2 are the most targeted when addressing recycling support. Personal attitude can be successfully changed through gamification approaches [6], [7], often exploring social networks [8], [9]. In the latter case, that is, for approaches based on social reputation, the PMO factor is also targeted. PBC is an ideal candidate for mobile apps.
For example, past and recent studies [10], [11] have consistently found that a person's knowledge of how to recycle and the types of materials eligible for recycling is an important factor influencing participation in recycling.

Investigation of Existing Applications

In a study carried out and published in the article "WasteApp: Smarter Waste Recycling for Smart Citizens" [1] the authors researched several typical design choices adopted by mobile devices and application developers to engage users and try to bring about a behavioral change in the recycling task.

An inventory was carried out on 37 different apps, drawn mainly from the Android Market and Apple Store.
Among the apps surveyed, 5 refer to Italy, 16 to the United States, 8 to Australian users and 8 to Canadian users. Interestingly, most apps are designed for specific municipalities, this is especially true for the US, CA and AU market, while in Italy most apps are offered by garbage collection companies.

Among the US, CA and UA applications, there is a clear trend towards outsourcing, as the majority (32) waste applications are developed by just two software companies.
For each county-specific app, the number of user reviews and downloads is very low relative to the city's population. For example, Toronto Waste, the waste app for the City of Toronto (CA), has just a few hundred facilities and 12 assessments, while the total city population is around 2.6 million people. Likewise, the Surrey Waste facility, the recycling app for Kingston (CA) ranges between 1000 and 5000, with 214 reviews, while the city has around 117,000 residents. This situation is common to almost all apps surveyed, meaning that even when municipalities try to deliver recycling improvements through apps, the percentage of the population engaged is still far from the critical mass needed to trigger sensible changes in recycling behavior.

Many similarities emerged between the solutions adopted in the applications. Almost all waste applications provide a dictionary of recycling materials, reporting a description of the different types and a list of examples of products included in each of them.

In most cases, the basic waste dictionary is complemented by some recycling guideline (how to) and in some cases (almost 50%) by a keyword search function for quick identification of waste types. However, in all cases, the information is static and the search is very basic.

Almost all apps provide a static and often out-of-date waste collection schedule. The location of nearby recycling points is another important information that seems to be missing from the apps searched. Most apps don't actually support this function, and the ones that provide the maps only offer information about delivery locations.

While this lack can be justified by door-to-door collection, sidewalk collection is part of almost all waste system management throughout the world. So having a quick way to identify boxes close to the user's position can be a help.

No application supports or supports waste monitoring systems in order to provide, for example, the current level of filling of collection boxes near the citizen's house or location.

Based on the research carried out, it was decided to create a more comprehensive and fully integrated system to help everyone involved in the recycling chain with mutual benefits and features that will encourage the use of the proposed applications.

The survey based on [1] has 37 applications for mobile phones and their comments and reviews, the survey is divided into:

Country	Amount	Provider (>90%)
Italy	5	Local recycling companies
USA	16	Counties
Canada	8	Counties
Australia	8	Counties

Table 2 - Application Inventory - Countries

Below are the numbers of the two main applications analyzed.

County	Installs.	Population	Reviews	App. Name
Toronto	200	2.6 millions	12	Toronto Waste
Kingston	10000	117.000	214	Surrey waste

Table 3 - Application Inventory - Cities

In total, 37 applications were researched, 32 were developed by only 2 software companies and for this reason they have basically the same features and therefore very similar ratings and installation percentages.

Analyzing the reviews considered negative, the main ones were:
• Difficulties in use due to the interface;
• Outdated information;
• Few useful features;
• Lack of encouragement to continue using the application;
• Basically static iteration between user and application.

Among the suggestions and based on other applications, the following needs were identified:
• Dynamic map with location of recycling points and GPS for assistance;
• Intuitive and dynamic interface;
• Smart search for materials and a direct chat with a government agent to clear doubts with the possibility of sending photos;
• Greater integration between those involved to generate a feeling of responsibility and duty fulfilled in users;
• "Recycle points" incentive system that encourages those involved;
• Possibility of integration with smart devices and adaptation to "Smart Cities";
• Integrated management with indicators for government entities;

III. Smart Recycle

Since the creation of programmable computers, humanity has had a strong ally in making more accurate and reliable strategic decisions.

Over the years, intelligent computer systems or specialist systems have helped companies and their users in different fields of activity and in different specific ways.

However, with thousands of these systems already in operation and with their specific tasks, very common problems generated by pertinent questions come to light:

Is there something already created that meets my specific needs?

Is there anything I can use like that that I can add to my requests without too much effort?

If I decide to create something from scratch, will the time vs investment vs effort be compensated at the end of the project?

An intelligent computer system must provide its users with reliable information through user-friendly interfaces and without much complexity involved.

In the case of an intelligent system like the one proposed, built to assist, above all, the impact generated by humanity on the planet, which are basically the environmental impacts linked to the theme, some items characterized as essential in the chain come to light.
• Engagement of people involved in the process (Citizens, Companies and government agencies;
• Mutual benefits of using the system in the best way;
• Social responsibility and income statement;
• Concern about how to do it correctly;

As we can see, the listed items are not specifically part of an intelligent system, but they are certainly essential when we talk about issues related to any existing systems.

We know from the start that even if a system is considered to be easy to use, it must have very intuitive mechanisms that provide users with forms of help and technical support quickly and reliably.

The “Smart Recycle” will have mechanisms that help the user to catalog their waste correctly before submitting it to a government agency for approval. It will also have a specific chat area, where the user, when faced with something not catalogued, can send photos and quickly get answers to their questions.

A big problem that we have today is the insufficiency of waste collection points available to the population, or even the distance it is from the person who wants to carry out recycling in a correct way. With "Smart Recycle" the user will be fed with information about all collection points near their residence and how to get there, through a simple interface on their mobile phone and with the option of GPS navigation to the chosen point.

Another problem identified by the authors is the lack of mobility and difficulties in transporting large amounts of waste produced. For this theme, the authors proposed an integrated cycle that works in a simple and effective way described in the subsequent paragraphs.

The citizen or company responsible for the waste accesses the system, asks their government agency for a prior assessment (by uploading photos through the application), the agency approves it and makes it available in the system as available material. From then on, two paths are opened, the first one is that a company that uses the material involved offers to carry out the collection with its own resources, which helps all involved and relieves the resources of government agencies destined for such service and avoids the material to proceed to the landfills that are already overloaded. The second way is for the governmental agency to provide assistance to remove the material and dispose of it in the best possible way. In both ways the citizen or company made the collection in the ideal way and the bonuses will be credited to his profile.

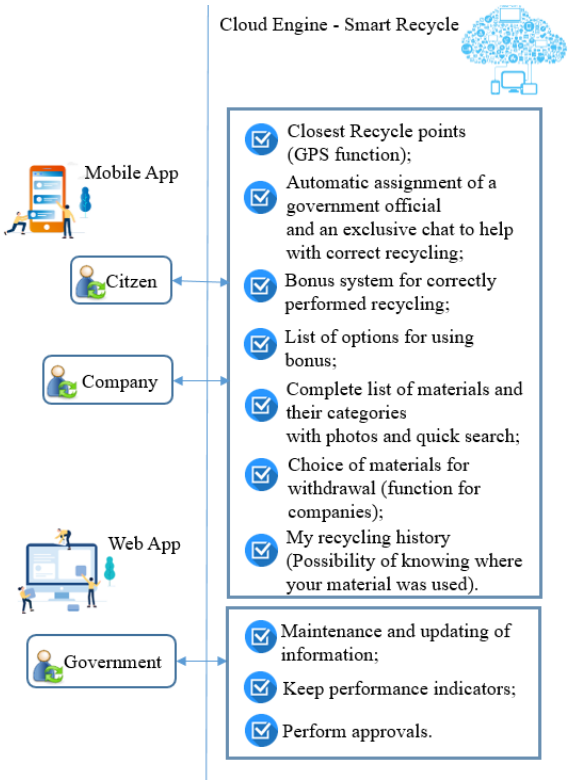
Above all, the authors propose the creation of a customizable points program according to the needs of government agencies, which encourages users to participate and use the system to carry out recycling in a correct manner. Bonuses (recycle points) are credited to companies and citizens (system user profiles) when recycling is carried out via the system and approved by the responsible government agency (system user profile). After this approval, the user will receive on his/her registered mobile phone/email confirmation that the action was carried out as it should be and that the waste was made available for proper use or final disposal.

For bonus credits, the system will provide a table with materials, quantities and respective bonuses for collections. The responsibility for keeping the information up to date rests with the responsible government agency.

In the prototype there will also be a table available on how the citizen or company can use their approved bonuses, the maintenance of this data is the responsibility of the responsible government agency.

Thus, the authors believe that an intelligent system with these characteristics can engage everyone involved in the generation and capture of waste to make the best decision with benefits for everyone and with a very explicit definition of the responsibilities assigned to each individual.

The final prototype has an architecture entirely based on "cloud computing" with application versions for Android and IOS and a WEB system based on the Angular programming language, as well as a "RestFul API" responsible for the algorithms, supply and collection of information between the applications, which totally meets the theme of the Masters and the future of technology in the world.



Picture 1 - Smart Recycle Architecture

The main screen of the system concentrates essential information for users, right at the top, the amount of accumulated bonuses and their respective value in euros are highlighted (the material/equivalent ratio in euros is defined by the person in charge of the government). In the center of the screen the options available to users based on their profile.

Picture 2 - Smart Recycle Main Screen

IV. Prototype Tests

For the purpose of finding and researching the usability and usage experience of the Smart Recycle prototype, version for mobile phones, 7 users with heterogeneous experience levels were selected and a document in the form of a sequenced guide was delivered containing all the features available in the application, step for access in the correct way and the possible output results.

Task	Step
Create new subscription	Register for the Smart Recycle app
Do Login	Access the application after registering.
Recover Password	Recover your password.
Search Materials, Categories and Perform Recycling	Find the material “Tetrapack Packaging” and make a new recycling of 10 items.

My Responsible in Government	Find your government official.
Use bonus	Use your bonuses in a wash for your vehicle.
My Recycling History and Bonus Usage	Check your bonus recycling and usage history.
My Profile and Change Password	View your profile and change your password.
Recycling Points	Find the recycling point closest to your home.
Messages	Send a text message and a photo of a product to your government official.
Collection Calendar	Access the door-to-door collection calendar and the recycling bins near your address.
Available Materials	Check, choose a material available for collection and make the request for its removal.
Do Logout	Quit using the application.

Table 4 - Task guide for tests

After the experience of using the prototype, users were submitted to a questionnaire survey in order to know their satisfaction and the level of usability of the application, in order to collect evaluations, improvements and identify possible malfunctions of the application during the period of tests. The research and evaluation of results resorted to statements, using the Likert scale [14], one of the most popular methodologies in questionnaire surveys and, consequently, more suitable for conducting opinion polls as they allow obtaining more comprehensive information than, for example, binary answer questions. Among the response options, and considering the original 5-point scale here, we would have: (1) totally disagree, (2) disagree, (3) indifferent (or neutral), (4) agree and (5) totally agree.

The analysis below refers to the questions pertaining to the research aimed at the experience of using the Smart Recycle application for mobile phones.

Question / Answer	4 (agree)	5 (totally agree)
Overall, the Smart Recycle app for mobile phones is easy to use	**3 (42,86%)**	**4 (57,14%)**
The colors used facilitate the usability of the platform.	**2 (28,57%)**	**5 (71,43%)**
The graphical layout (location of each element on the screen) is adequate	**2 (28,57%)**	**5 (71,43%)**
The response time is fast (when clicking on a link).	**2 (33,33%)**	**4 (66,67%)**
Information appears clearly (titles, texts, images).	**2 (28,57%)**	**5 (71,43%)**

Table 5 - Data Analysis - Application Usage

The analysis below refers to the main questions pertaining to research directed to the features of the Smart Recycle application for mobile phones.

Question / Answer	2 (disagree)	4 (agree)	5 (totally agree)
The ability to register in the application using multiple forms is essential in this type of application.	**0**	**2 (28,57%)**	**5 (71,43%)**
The functionality “search for materials” by category or part of the name provides the necessary facility to effectively recycle a material.	**0**	**1 (14,29%)**	**6 (85,71%)**
In a context of life in society, the user's connection directly to his/her local government official through an application is essential in this type of application.	**0**	**2 (28,57%)**	**5 (71,43%)**
The functionality that awards a bonus for each recycling performed should be mandatory in encouraging waste recycling.	**1 (14,29%)**	**4 (57,14%)**	**2 (28,57%)**

The use of the application is stimulating even without financial rewards, incentive features such as leaderboards towards other users or displays of progress or experience are enough.	**1 (14,29%)**	**0**	**6 (85,71%)**
The functionality "Recycling Points near my home" with the possibility of using the GPS, is very important in the matter of waste recycling, because with this I will know the distance from the closest point to my home and will also be able to have additional information about the collection calendar.	**0**	**2 (28,57%)**	**5 (71,43%)**
If the region I live in provided a similar application I would find it useful.	**0**	**2 (28,57%)**	**5 (71,43%)**

Table 6 - Data Analysis - Application Features

V. Conclusion

This study began with a problem identified by the researcher, which consisted of a need or even non-existence of an application that encompassed easily accessible mechanisms and tools to assist and guide users regarding the recycling of waste in their place of residence. One possible solution, it was thought, would be to develop an application that could be interactive and stimulating for users in different contexts.

In addition to this problem, at the time of the beginning of the study, political and social issues were identified, mainly in Portugal, which indicated the need to improve recycling rates compared to other countries in the European Union. It was believed, therefore, that this application could also respond to this government intention and be an essential application not only in Portugal, but in the various countries that are concerned in some way with the main issue involved.

Therefore, we believe that this study brings several contributions to the area of waste recycling and has a substantial evolution potential if we evaluate the possible integrations and expansions described in the section (Future Works). The results achieved also allow us to serve the academic and scientific community, and may be promoters of new developments in the themes addressed.

In another aspect, other than education, this work may also contribute to other contexts related to public administration and companies. Since this is a study of prototyping and evaluation of a technological platform, with recognized potential, in these sectors, identified by its users, it could be an opportunity to expand the platform from educational spaces to other spaces that serve the general public.

Suggestion for Improvements

Some notes considered important were made by the evaluators, as they were not considered construction or functioning errors, it was decided to categorize them as suggestions for improvement or future work. Thus, all relevant comments were included in Suggestions, which did not impede the performance of the requested tasks. Below is a list of the changes and improvements proposed by the evaluators:
(1) Question 1 – Questionnaire Application contents and functionalities: The possibility of registering in the application through the use of multiple forms is essential in this type of application.
Comment - "I miss the login with the Face ID option"

(2) Question 6 – Questionnaire Contents and features of the application: The functionality “Recycling Points near my home” with the possibility of using the GPS, is very important in the matter of waste recycling, because with this I will know the distance from point closest to my home and I can still have additional information about the collection schedule and, in cases proposed as future work, the levels of the dumps in the ecopoint in question.
Comment - "Great functionality, would it be possible to include an option to search from the current point and not from the home address (using the mobile phone's GPS)?"

(3) Question 1 – General Platform Usage Quiz: Overall, the Smart Recycle app for mobile phones is easy to use.
Comment - “Suggestion: Adding a filter on some screens (example: My Recycle Bins) would make the search easier.”

(4) Question 4 – General Platform Usage Questionnaire: The response time is fast (when clicking on a link).
Comment - "I missed a little loading on the screens."

Study Limitations

A very perceptive limitation was the lack of a sponsor to collect information and apply the prototype in a practical and face-to-face manner, which became a widespread problem with the emergence of the pandemic and the defined time window for completing the work.

Other points identified by the researcher as improvements and that should exist in applications that propose to be integrated in the field of smart cities, which were not considered due to lack of time, are the integrations with smart devices and gamification techniques.

Future Works

During the prototype implementation, the investigator identified possible new features that could be integrated into the project, add value and enhance the commercialization of a commercialized version. Such features are based on gamification techniques and IOT devices.

In the article “Smart Recycling Bin for Waste Classification” [12], the authors propose the creation of a smart waste bin that classifies materials through image recognition algorithms and sensors and segregates them in the correct way. What if we had something like this, for example, at Eco Points or large recycling centers? We would undoubtedly avoid misclassifications and save labor that could be committed to other tasks.

In another article “Smart Waste Management System for Crowded Area” [13], the authors discuss how to optimize waste management in the context of smart cities using the realization of the Internet of Things (IOT), and suggest installing sensors with microcontrollers, a sensor capable of measuring the filling level of dumpsters using ultrasound and an internet data transmission module. The architecture was analyzed with a focus on energy savings, technologies and policies, with the purpose of extending the battery life, reducing energy consumption, through the optimization of hardware and software. We could for example implement such technology at our collection points and provide information through the mobile or government application and thus avoid embarrassment for users who can choose which recycling point to turn to for their filling level.

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