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A GAMIFIED PLATFORM TO ENCOURAGE SUSTAINABLE BEHAVIOURS

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Abstract. The production, use, and disposal of goods and services require the use of natural resources, resulting in waste and environmental pollution. A growing number of people are embracing more sustainable lifestyles in alignment with the 3Rs (Reducing, Reusing, and Recycling) to counter these effects, but many remain uninformed of their options, or lack the motivation to adopt these practices. The work described in this paper addresses these issues through the development of the Sustainable App, a mobile application incorporating techniques of persuasion and gamification which offers its users eco-friendly alternatives to several types of daily activities, made available via an interactive map. The app employs diverse strategies to improve engagement, including a pet-nurturing game-like feature that responds to user actions related to sustainable transport choices, sustainable retail, and recycling. Additionally, the complete platform associated with the app also delivers Just-In-Time (JIT) messages concerning nearby sustainable choices based on location and time. Upon evaluation of the platform, positive user experience and overall good feedback were noted. Experts also weighed in on the application's evaluation, offering valuable insights to refine future iterations.

Keywords. Interactive Map, Persuasion, Sustainable Behaviour, Gamification, Virtual Pet, Just-In-Time Messaging

1 Introduction

In recent decades, our lifestyles have continuously improved with increased access to many products and services. However, this progress has led to increased consumption, resulting in environmental consequences such as resource depletion and greater waste production (Statista, 2023). The processes of production, utilization, and disposal of goods and services contribute to these environmental impacts. This exploitation of Earth's resources has severe consequences, including the collapse of ecosystems and pollution resulting from waste (Cronin and Pandya, 2009). These issues, in turn, contribute to more complex and global challenges, such as climate change (Connecticut Department of Energy & Environmental Protection, 2023).

While the environmental problem is vast and requires systemic changes from corporations and governments, individual actions are still crucial. By following the 3Rs — Reducing consumption and waste, Reusing products, and Recycling waste (Quercus, 2023; Conserve Energy Future, 2023) — individuals can play a part in addressing environmental challenges. This not only benefits the environment but may also foster trends that oppose those most responsible for its degradation.

In Portugal, there is a gap in the adoption of sustainable behaviours, particularly in waste management, diverging from the recycling and reusing goals set by the Portuguese government and the EU (Jornal de Notícias, 2023). It is crucial to guide people towards sustainable living, increasing awareness about the available sustainable choices (relative to the 3Rs), and ensuring that these choices are not perceived as time-consuming or uninteresting tasks.

This paper presents a platform developed to address the challenge of disseminating information and encouraging individuals to adopt eco-friendly behaviours beyond recycling. Leveraging the strong presence of smartphones (approximately 86% global ownership) (Turner, 2023), the platform builds on previous work, started by Santos's mobile app promoting recycling (dos Santos, 2021; dos Santos et al., 2022) and Barreiros's extension with gamification elements still targeting recycling (Barreiros, 2022). Unlike previous versions, this platform encompasses all 3Rs utilizing features like an interactive map, sustainable behaviour detection, a metric for evaluation of sustainable behaviours, a virtual pet plant that responds to these users'

behaviours, and JIT notifications to encourage some sustainable choices.

Since its beginning, this project has had the support of the Department of Environmental Sciences and Engineering (DCEA-NOVA), at NOVA School of Science and Technology, as well as the contribution of Amarsul[1], a company that operates in the market for the management of solid urban waste in the District of Setúbal. Amarsul provides access to the recycling spots database used in the project, which includes the geographic location of the collection spots, the supported recycling materials for each spot and the collection schedule. Amarsul updates this data daily, providing, almost in real time, updated information about its collection spots, through API access.

The rest of this paper is structured as follows. Section 2 recalls related works which have informed or otherwise influenced our work. Section 3 summarizes the design process and section 4 details the implementation. Section 5 presents the architeture of the developed platform, and Section 6 shows the evaluation performed on the mobile app, including users studies and experts' feedback. In section 7, there's an explanation on the current availability of the platform's source code for replication purposes, and finally, section 8 concludes the paper and outlines some future directions.

2 Related Work

As support for the development of the proposed platform, related work focuses on methods and technologies for motivating the use of the mobile app and enforcing sustainable behaviour, thus encompassing Gamification and Persuasive Technology.

Gamification is the application of game elements to non-game contexts to transform undesirable tasks into activities resembling games, thereby enhancing users' motivation and engagement in the tasks (Sailer et al., 2017; Khoshnoodifar et al., 2023). Examples of gamified applications that promote sustainability include JouleBug[2]. This is a gamified mobile app promoting sustainable behaviours and covering tasks such as turning off lights, recycling, and biking. Users manually "buzz" the app by pressing buttons for each action, earning points and bonuses that contribute to their overall score. The app includes social features, allowing users to follow others, be ranked, and create challenges.

Virtual pets have been used to encourage users towards certain behaviours, through the use of emotional cues (Byrne et al., 2012), and their owners have been shown to create emotional connections towards their pets (Lin et al., 2017; Tsai and Kaufman, 2014). In particular, virtual pets (and similar concepts) have also been used to promote sustainable behaviours. Energy Chickens, a serious game aimed at reducing plug-loads in offices through the use of virtual pets, involved players caring for virtual chickens to promote lower energy consumption, related with office devices' energy consumption data (Orland et al., 2014). In a study conducted in a real office environment, energy consumption decreased by 13%. Following the game, 69% of players noted heightened awareness of energy spending, impacting habits beyond the office.

Where it comes to persuasive technology, the Fogg Behaviour Model (FBM), outlines a framework for behaviour change, proposing that a behaviour occurs when a person's motivation (the desire to perform a behaviour) and ability (the capability to perform a behaviour) are both high, and a prompt (specific cues or triggers initiating a behaviour) is present to initiate the behaviour (Fogg, 2023). In this context, JIT (Sarker et al., 2017; Sporrel et al., 2022) messaging provides timely and opportune feedback (Sporrel et al., 2022) leading up to the needed prompt. Some projects, such as Close-The-Loop, have applied JIT messages to promote sustainability. Close-The-Loop was an app prototype utilizing iBeacons for JIT feedback in a university canteen (Casado-Mansilla et al., 2015). The app, leveraging Bluetooth technology, guided users in purchasing and recycling packaged food. iBeacons in vending machines and recycling spots would trigger notifications, prompting users to select packaging types and directing them to the appropriate recycling bins. A study of this project emphasized the significance of timely feedback, clear recycling information display, and incentives, like points, to maintain user engagement and promote recycling behaviours.

3 Solution design

To achieve its main goal of promoting sustainable behaviours in alignment with the 3Rs, the developed platform takes a two-fold approach. Firstly, it disseminates comprehensive information about sustainable choices, presenting them geographically and in more detail. Beyond mere information, the platform is strategically designed to actively promote these sustainable choices through the implementation of various gamification and persuasion techniques.

3.1 Solution features

The design of the solution centers around an integrated set of features, crafted to empower users in making informed and sustainable decisions. These encompass:

- **Interactive Map of Sustainable Services:** A map showcasing Points Of Interest (POIs) representing various sustainable services throughout Portugal. Users can filter POIs based on preferences and travel times from their current location, ensuring tailored information. This feature is meant to help users visualize different sustainable options, near or far from

[1] https://www.amarsul.pt/

[2] https://enterprise.joulebug.com/

them, helping to disseminate information about their alternatives.

- **Service Details:** Comprehensive information about each POI, aiding users in making informed decisions about sustainable choices.
- **Virtual Pet Plant:** A gamified feature responding dynamically to users' eco-friendly actions, and reflecting their efforts. The pet plant's health and mood are linked to Plant Score points, directly tied to the user's Sustainability Score. This virtual pet is meant to promote sustainability through conditioning and emotional cues, acting as a persuasive actor (Fogg, 2002).
- **Activity Detection:** Mechanisms for tracking sustainable choices, including modes of transportation, time spent at specific establishments (such as vegan restaurants and thrift shops), and active participation in recycling. The detection of activities will affect the pet plant's health and mood.
- **JIT Messaging:** Timely notifications about relevant POIs within a five-minute walking distance, enhancing user engagement. This follows the FBM, as previously mentioned, acting when the user supposedly has a greater ability and motivation to follow the prompts.
- **Sustainability Score Metric:** A metric designed to refine the application's point system, considering various components such as sustainable mobility (through the carbon emissions saved), sustainable retail (time spent at specific commercial establishments), and recycling participation. This scoring mechanism is dependent on the activity detection mechanism and is necessary for rating the wellness of the pet plant.
- **User Insights Dashboard:** A feature enabling users to track progress in sustainable practices, providing details on distances traveled, carbon emissions saved, time spent at sustainable spots, and total recycling contributions. This dashboard is meant to help users track and keep a record of their sustainable activities, acting as a self-monitoring persuasive tool (Fogg, 2002).
- **Ranking System:** Three categories of rankings - Sustainability Score, Plant Score, and Carbon Emissions - promoting healthy competition and social comparison, and encouraging continuous improvement in sustainable actions (Fogg, 2002; Oinas-Kukkonen and Harjumaa, 2009).

3.2 Game logic

The gamification logic of the app involves the detection of various user actions, including walking, biking, using the metro, frequenting vegan restaurants, visiting thrift shops, and engaging in recycling activities. These actions are identified through an activity detection API (Waga et al., 2012), which analyzes the user's trajectory collected from the app through the GPS signal and respective timestamps.

Although the activity detection is automatic, the confirmation of these activities needs to be made by the users, in the application. To remind users that they have available sustainable activities for confirmation, notifications are sent. These can be accessed inside the app's notification panel and in the smartphone's own notifications panel.

The Sustainability Metric provides support for evaluating sustainable actions, contributing to the computation of a Sustainability Score. Earned Sustainability Points also translate into Plant Score points. It is crucial to note that, while the Sustainability Score is unrestricted, the Plant Score has a defined maximum limit and undergoes gradual decay over time. This allows the pet plant's mood and health to be evaluated based on the Plant Score, and motivates the user's continued care for the plant.

Beyond the virtual pet plant, the system incorporates user rankings and dashboards. These are gamification techniques, providing a platform for users to compare themselves and monitor their sustainable activities.

Before initiating the implementation, prototypes of the graphical interfaces were created using the Figma[3] design tool. These prototypes simulated the user experience and allowed clickable interactions. Creating prototypes was a crucial step in the design process, providing a visual representation, identifying potential changes, and allowing tests that permitted the gathering of valuable user feedback before actual development.

4 Sustainable App: Implementation details

This section presents implementation details for each key feature of the Sustainable App, following design and prototype results.

4.1 Interactive map

The interactive map is a key feature, which displays relevant categorized POIs like metro entrances, bike-sharing stations, vegan restaurants, thrift shops, and recycling points. POIs are clustered for clarity when they are too close to each other, enhancing visibility. A small card in the top right corner serves as an unobtrusive visual reminder of the user's plant state while exploring (Figure 1).

The application allows users to filter the POIs based on categories such as metro entrances, bike-sharing stations, vegan restaurants, and thrift shops. Additionally, users can filter services based on foot-walking travel time, enhanc-

[3] https://www.figma.com/

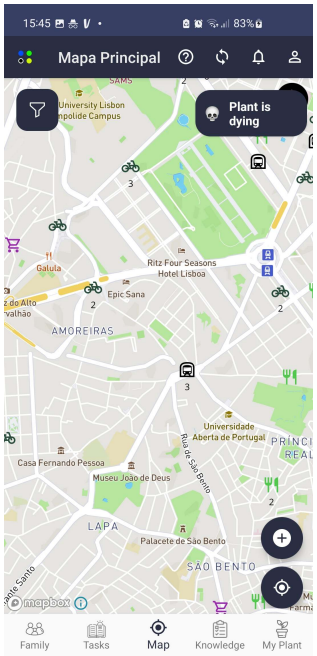

Figure 1. Application interactive map.

ing the map's usability by focusing on practical accessibility (filter's slider visible in Figure 2).

Figure 2. Storyboard representing the filtering by categories.

4.2 Details page

When users select a POI on the map, a preview displaying essential information is shown. This preview can be clicked to access a full details page. In the case of metro station entrances, for instance, users gain in-depth insights, including precise entrance address, wheelchair accessibility, escalator confirmation, and real-time metro arrival information (Figure 3). The page also features a visual representation of the metro line, presenting stations, intersections, and network connectivity. While similar details pages exist for other services (for example, see bike-sharing station details in Figure 4), we specifically delve into the practicality of the metro entrance details for a comprehensive exploration.

Figure 3. Storyboard representing the metro details.

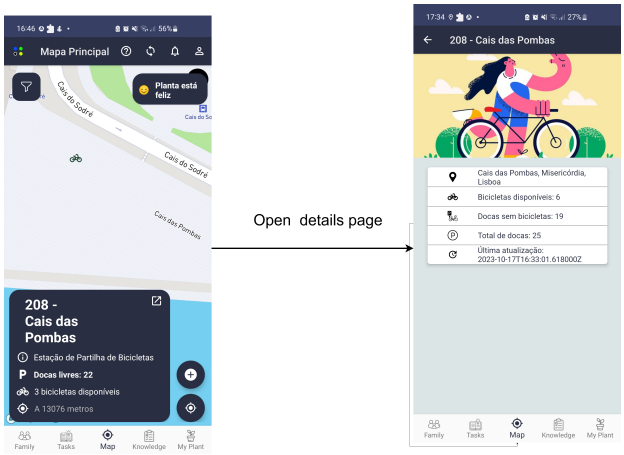

Figure 4. Storyboard representing the bike-sharing station details.

4.3 Virtual Pet Plant

In the Sustainable App, a key gamification feature is the virtual pet plant, accessible through the bottom navigation bar (Figure 5). This interface allows users to observe the well-being of their virtual pet. The plant's well-being is indicated by four states: "Happy," "OK," "Sad," and "Dying," each visually distinctive. Below the plant, a textual

indicator communicates its current state, accompanied by the Plant Score, assessing overall health and happiness.

The plant score operates within a capped range. This cap allows for a graded evaluation of the plant's condition, providing users with a clear scale for measuring progress. Wellness states are defined based on the percentage of the plant score relative to its maximum value: "Happy" (75% or more), "OK" (between 50% and 75%), "Sad" (between 25% and 50%), and "Dying" (below 25%).

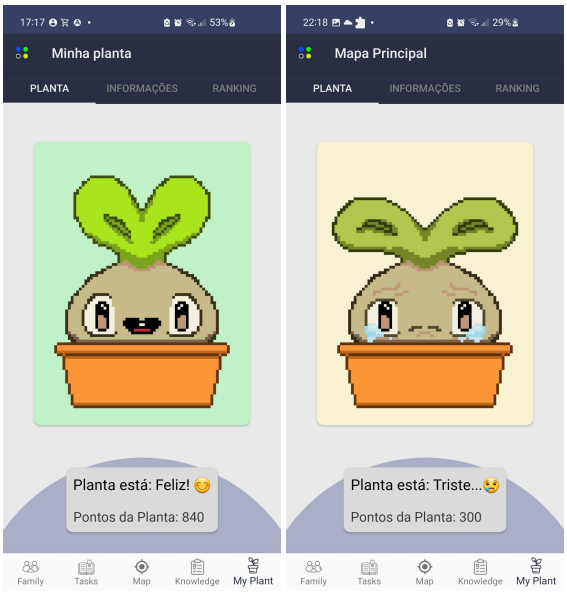

Figure 5. Examples of plant when happy and sad.

In the beginning, the plant starts with 50% of the maximum plant score, ensuring an "OK" initial state, while the sustainability score begins at zero. Design modifications for the plant were also implemented based on user feedback during prototype tests. Users' feedback suggested emphasizing neotenic attributes [4] (Shaffer, 2013) to increase the plant's "cuteness", which according to literature can be beneficial (Steinnes et al., 2019; Weeks, 2018).

These features are meant to foster a connection and encourage sustainable actions to improve its well-being.

4.4 User insights dashboard

The user insights dashboard acts as a centralized information hub. It offers users a comprehensive overview of their sustainable actions and achievements, enabling users to monitor their activity.

Key sustainability insights include tracking distances covered on foot, by bicycle, and via the metro to promote eco-friendly transportation choices. Users can also monitor the time spent on sustainable services, emphasizing consumption in vegan restaurants and thrift shops. The dashboard

[4] More juvenile characteristics associated with early development stages in a living being, which may include a larger forehead, lower eyes, a smaller chin, etc.

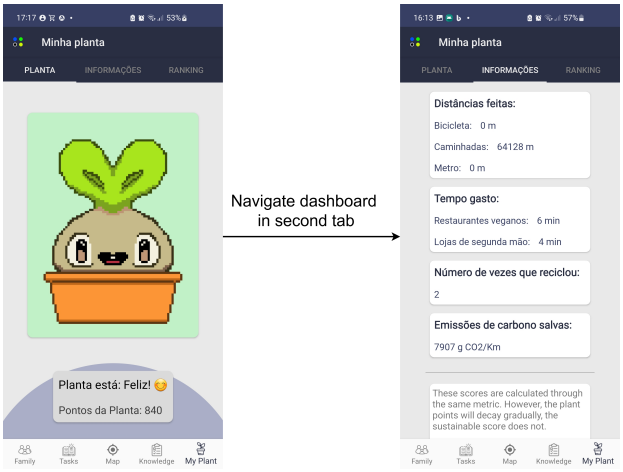

Figure 6. Storyboard representing the user insights dashboard.

also highlights recycling activity and calculates the saved carbon emissions of the sustainable transportation choices (Figure 6).

Additionally, users can easily check their current Sustainability Score and Plant Score on the dashboard.

4.5 User Rankings

The user rankings (Figure 7) offer users insights into their standing within the Sustainable App community, recognizing their efforts to sustainability. Users can easily switch between different ranking categories through a drop-down menu, including Sustainability Score, Plant Score, and Carbon Emissions Saved, catering to different interests and motivations.

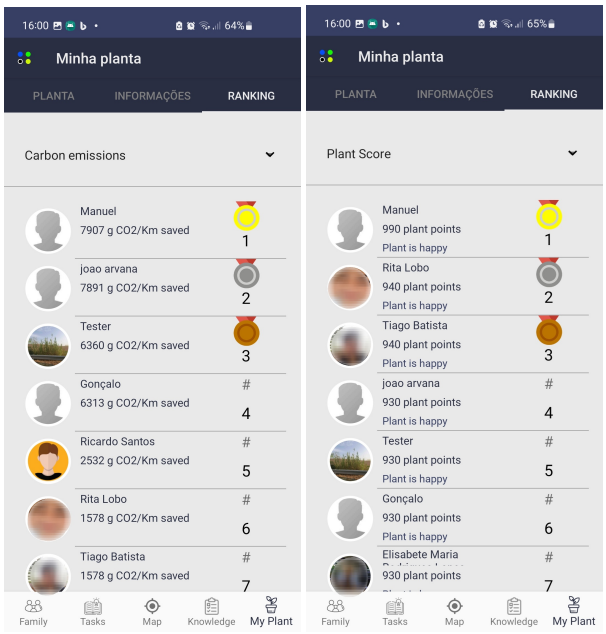

Figure 7. Screen of user ranks based on carbon emissions and Plant Score.

4.6 Activity synchronization and confirmation

The application features a function to synchronize and confirm sustainable activities, allowing users to confirm their actions at their convenience. Initiated by a dedicated button, the synchronization retrieves, and presents the available sustainable activities for user confirmation. The confirmation pages display tabs for various activities, enabling users to visualize and confirm each. In the confirmation pages, users can check information about the activities and see the whole route made during the day. The application notifies users of pending confirmations through smartphone and in-app notifications.

4.7 JIT notifications

The JIT notifications in the app are designed to inform users about nearby sustainable services at strategic times. Notifications are tailored based on specific times and services, considering lunch and dinner for vegan restaurants (12:00-14:00 and 19:00-22:00) and weekends for thrift shops (10:00-19:00). The app considers the user's location, proximity to services within a 5-minute walk, and service availability. It utilizes server-side isochrone services and checks the opening status of detected services. CoroutineWorkers manage JIT notifications, running in the background when the map interface is inactive.

5 Architecture of the Platform

The application architecture (Figure 8) comprises six components: client (front-end), Spring server (back-end logic and data), PostgreSQL database, image storage (Firebase Cloud Storage), and external servers. The Android front-end, developed in Android Studio, interacts with the Mapbox SDK for the use of the interactive map. The Spring server, using the MVC model, communicates with the PostgreSQL database via Hibernate and facilitates RESTful APIs for direct communication with the client and external servers. Firebase Cloud Storage handles image storage for performance purposes, and external servers provide APIs (e.g., Amarsul, Overpass, Metropolitano de Lisboa). Nominatim service is the only external server connected to the client, facilitating geocoding.

6 Evaluation

This section presents the Sustainable App evaluation procedures, which encompass users studies and expert analysis providing feedback on the app and sustainability metric.

6.1 User Tests

User tests were conducted in controlled environments to collect feedback and identify issues for improving the application.

These tests included 16 participants, with a gender distribution of 9 males and 7 females. The average age was 25.81 (and a standard deviation of 5.80), with most participants being 23. Participants came from diverse educational backgrounds, including high school, computer science and engineering, biomedical engineering, and early childhood education. Most participants had extensive experience with mobile devices and daily use of mobile applications. While many emphasized the importance of sustainability, only a portion reported having common sustainable practices. A majority claimed moderate awareness of sustainable alternative services near them. Three participants had prior experience with a sustainability-related mobile application, specifically "Vinted," a second-hand clothing platform.

The user tests methodology involved a test script guiding participants through various tasks, such as map functionalities, activity synchronization, JIT notifications, interaction with the virtual pet plant, and exploration of user rankings and insights dashboard. Tests were performed outdoors along a predefined path, incorporating points of interest. Participants then filled out questionnaires assessing demographics, system usability (SUS), system's functionalities and overall experience (UEQ).

The results of the users tests are presented below, following the described methodology.

6.1.1 The System Usability Scale (SUS)

The System Usability Scale (SUS) is employed to evaluate the usability of a system (Brooke, 1996). The average SUS score of the app was approximately 86.72, well above the global average of 68. Individual SUS scores were also consistently above the global average, indicating participants found the application easy to use and with good usability. Learnability, with an average score of 96.09, suggests users found it easy to learn. The usability component, with an average score of 84.38, also indicates positive perceptions, though with greater variability and a lower minimum value (as perceptible in Figure 9). Participant classifications of the application mostly aligned with their scores, generally reflecting positive feedback.

6.1.2 Users feedback on functionalities

In this section, some important participant responses to questions about specific functionalities tested during user trials are highlighted. The questions used a Likert scale ranging from 1 to 5, where 1 represents complete disagreement and 5 indicates complete agreement. Middle values are interpreted as "disagree," "undecided," or "agree."

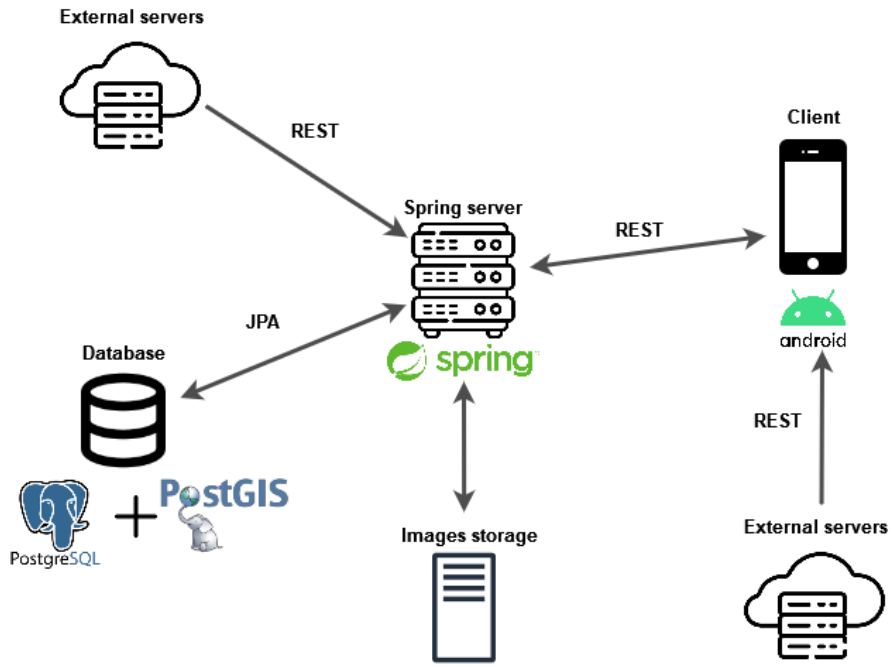

Figure 8. System's architecture.

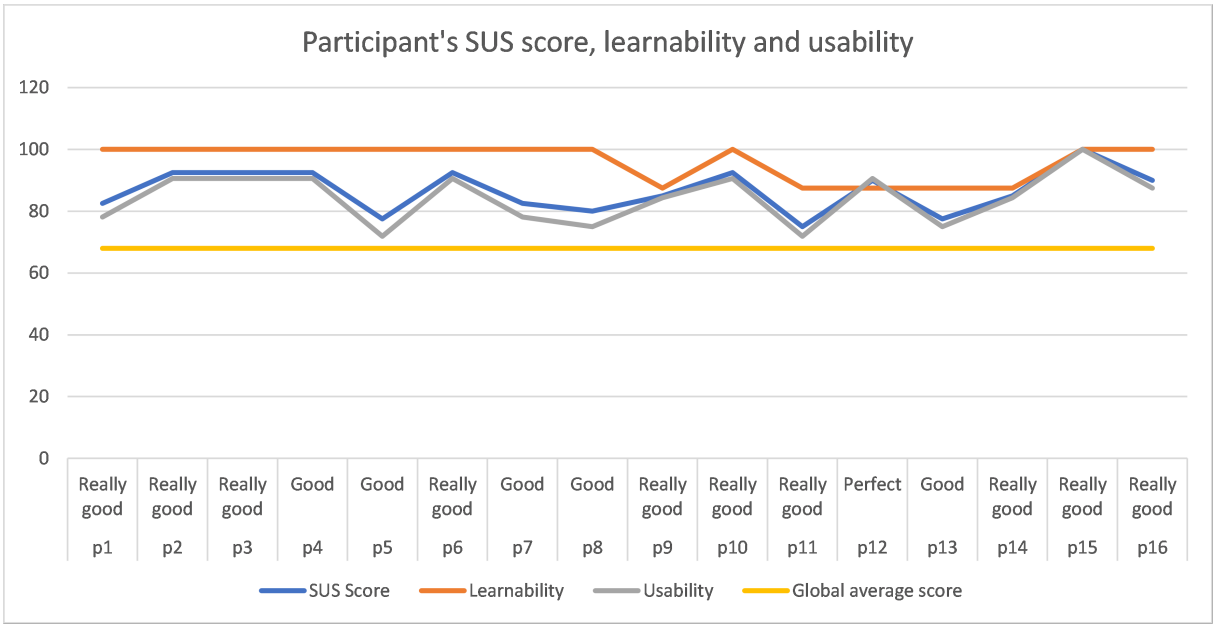

Figure 9. Participants' scores compared to their own ratings.

Interactive map and filters

In the evaluation of map interaction functionalities, participants generally found the interactive map and clustering to be intuitive (Figure 10), with a majority (50%) giving it a top rating of 5, and 43.8% rating it a 4. However, issues arose with the filtering of the map interface by categories, where the default pre-selection of categories confused some participants. Suggestions for improvement included adding a more noticeable signal for selected category buttons.

Regarding map filtering by travel times, there was a higher level of agreement among users compared to the filters by categories, with 50% selecting the top rating of 5 and 37.5% choosing 4. Some users suggested enhancements for the travel times slide bar, such as making it larger for easier interaction.

Overall, opinions on the usefulness of filtering through travel times were positive, with a mode and median value

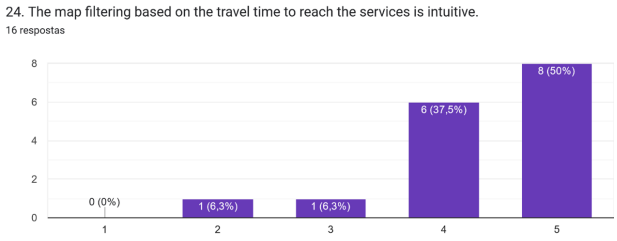

Figure 10. Intuitiveness of the map filtering based on time travel.

of 5, indicating unanimous agreement among users on its efficacy.

Activity synchronization

The synchronization of activities faced usability challenges during user tests, with users struggling to quickly grasp the process or locate the synchronization button. Survey results reflected mixed opinions on its intuitiveness (Figure 11), indicating room for improvement. While the confirmation pages for synchronized activities received positive feedback, users proposed enhancements, such as automatic confirmation, eliminating the need for manually confirming activities. Despite challenges, participants acknowledged the usefulness of the synchronization feature for tracking sustainable actions, appreciating its value in locating businesses and reviewing transport routes.

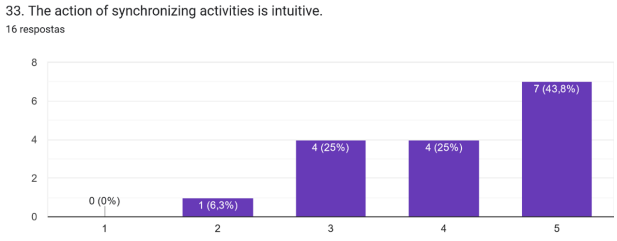

Figure 11. Intuitiveness of the synchronization of activities.

Virtual pet plant

Users easily accessed the virtual pet plant feature during tests, as concurred by survey results, where 87.5% chose a 5 and 12.5% a 4. The interest in the virtual pet plant was also high, with all participants showing great interest. Although users appreciated the existing concept, there was unanimous agreement (81.3% choosing 5 and 18.8% choosing 4) that extending the plant concept, such as introducing a growth system or a marketplace for plant-related items, would enhance user engagement. Participants also strongly agreed (93.8% rating 5) that the plant feature could have an important contribution in engaging users and others (Figure 12), indicating a very positive sentiment.

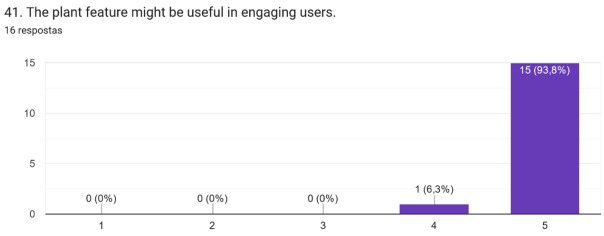

Figure 12. Perceived usefulness of the virtual pet plant feature.

User insights dashboard and Rankings

Participants generally found the dashboard's information useful, with 62.5% choosing 5 and 31.3% choosing 4. The predominant pattern suggests users are interested in the information presented on the dashboard. Concerning user rankings, the feature's intuitiveness received great agreement, with nearly all participants selecting either 5 or 4, affirming its user-friendly nature. Additionally, participants expressed confidence in the rankings fostering friendly competition, as the majority fully agreed (81.3%) with the statement. The diverse ranking scores available were also deemed interesting, with 81.3% choosing 5 and the remainder opting for 4.

JIT notifications

Participants generally favored weekend afternoons (12h00-18h00) for shopping, aligning with the platform's thrift shopping JIT notifications time frame (10h00 to 19h00). However, diverse responses highlighted the challenge of pinpointing specific shopping time frames since a lot of people seemed to have diverging preferences. The majority showed varying degrees of openness to trying a thrift shop located nearby during their typical shopping times.

Survey results indicated widespread agreement among participants regarding the effectiveness of JIT notifications in promoting sustainability. While most participants agreed, a minority expressed concerns related to general notification usage preferences and suggested improvements. The findings highlight the importance of considering individual preferences and customization in optimizing notification timing for sustainability promotion.

6.1.3 User Experience Questionnaire (UEQ)

The User Experience Questionnaire (UEQ) is a questionnaire that evaluates the user experience of platforms across six dimensions: Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation, and Novelty (Schrepp,

2023). Despite some areas for improvement, the results were generally positive. The dimensions with lower averages were Efficiency and Dependability (Figure 13), which coincidentally had bigger standard deviations as well. Upon analysis of the items of these dimensions, we can see that while the perceptions were mostly positive, some people thought the application was unorganized and slow (Efficiency) (Figure 14), and not secure and unpredictable (Dependability) (Figure 15).

Scale	Mean	Std. Dev.	Median	Confidence
Attractiveness	2,44	0,55	2,58	0,27
Perspicuity	2,11	0,75	2,13	0,37
Efficiency	1,81	0,86	2,13	0,42
Dependability	1,89	0,81	2,13	0,39
Stimulation	2,20	0,47	2,25	0,23
Novelty	1,95	0,56	2,13	0,28

Figure 13. UEQ mean, standard deviation, and the margin of confidence

Data analysis revealed minor inconsistencies in four participants' responses (each having just one per dimension), but their responses were still considered reliable. These factors, along with the use of heuristics to detect inconsistencies, supported the overall reliability of the responses, indicating diverse user experiences and opinions about the app's Efficiency and Dependability. Nevertheless, all dimensions were rated highly, specially Attractiveness, Perspicuity and Stimulation, the most relevant when considering the app's goal.

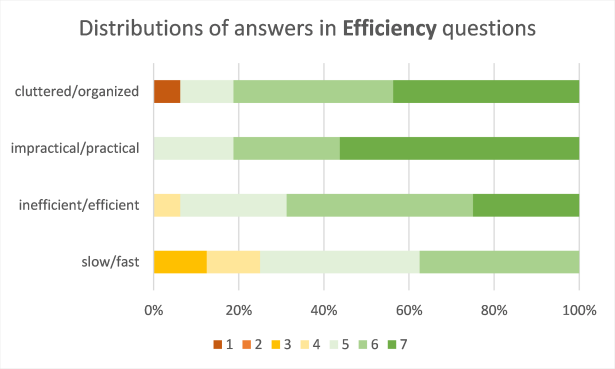

Figure 14. Distribution of answers per item in the Efficiency scale.

6.2 Expert's analysis

Besides the evaluations done through the user tests, the metric and application were also subject to analysis by experts in the areas of environmental engineering who provided valuable insights on enhancing the application.

6.2.1 Metric analysis

Expert feedback led to adjustments in terminology and metric components. For recycling, precise language was emphasized, leading to changes in terminology. Regarding sustainable mobility, the focus was simplified to operational carbon emissions, excluding biogenic emissions. Carbon emissions values for walking and biking were updated to zero, meaning the emissions saved by using these mobility methods are now equal to the emissions saved by not using a car, making that value more sensible.

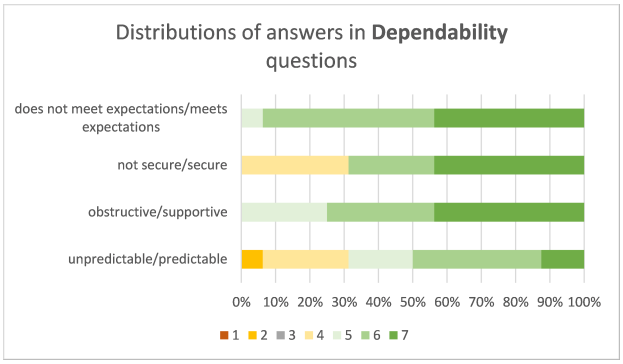

Figure 15. Distribution of answers per item in the Dependability scale.

The challenge of obtaining more precise car carbon emissions values for Portugal was addressed by determining a median value for car models of the most common brand. This value, approximately 120 g CO2/km, doesn't fully capture the entire carbon emissions profile of an average car in Portugal, acknowledging the challenge and ongoing efforts needed for precision.

Expert suggestions also prompted consideration of a Points-Per-Visit strategy for the Vegan Restaurants and Thrift Shops component instead of a Points-Per-Minute strategy, with specific point values yet to be determined.

6.2.2 Application analysis

Expert recommendations for the application include refining transportation activity detection, emphasizing sustainable mobility, and adding organic and municipal markets to sustainable food options. Experts also suggested considering vegetarian alternatives in addition to vegan ones, extending the audience for sustainable retail. Additionally, they suggested recognizing electric cars and carpooling in the metric and sustainable activities, and implementing JIT notifications for recommending recycling after one month without recycling. Caution was advised to prevent notification fatigue.

Finally, an expert recommended resetting user ranks monthly to enhance engagement. Overall, experts praised the app and expressed positive interest in its potential.

7 Data and Software Availability

The software developed as part of the Sustainable App platform is not publicly available . This decision is primarily due to the following reasons:

- Use of Non-Public APIs and Data: Parts of the application rely on data and an API that are not publicly available. Sharing the source code without proper authorization or without censoring these parts could compromise the confidentiality of the data.
- API Keys and Sensitive Information: The application's source code contains API keys and other sensitive information. Disclosing the source code would require removing or censoring these sections, which would impact the overall functionality of the application for review or replication purposes.

While this platform aims to contribute to the community by promoting sustainable behaviors, protecting the integrity and confidentiality of the data and the information sources is also important.

The data used from public datasets and APIs can, however, be accessed. Such is the case with the Open Street Map (OSM) data, accessed through the Overpass API. Overpass API queries used to gather data from the OSM for various POIs relevant to the Sustainable App. These queries can be executed using the Overpass API service, allowing access to up-to-date geospatial data from OSM.

To retrieve data on metro entrances in Lisbon, the following query was used:

```
[out:json];
area["ISO3166-1"="PT"][admin_level=2];
(node["railway"="subway_entrance"]
(area);
way["railway"="subway"](area);
rel["railway"="subway"](area););
out center;
```

For retrieving information on metro routes, this query was used:

```
[out:json]
[timeout:250];
area["ISO3166-1"="PT"];
(relation["type"="route"]
["route"="subway"]
["network"="Metropolitano de Lisboa"];
);
out body;
>;
out skel qt;
```

To identify vegan restaurants, the following query was applied:

```
[out:json][timeout:29];
area["ISO3166-1"="PT"];->.searchArea;
(node["amenity"="restaurant"]
["cuisine"="vegan"]
["diet:meat"!="yes"]
(area.searchArea);
node["amenity"="restaurant"]
["diet:vegan"="only"]
["diet:meat"!="yes"]
(area.searchArea););
out body;
>;
out skel qt;
```

For locating thrift shops, this query was used:

```
[out:json];
area["ISO3166-1"="PT"]->.boundaryarea;
node["shop"~
"^(second_hand|thrift_shop|vintage|
charity)$"]
(area.boundaryarea);
out center;
```

Besides OSM data mentioned, the app also uses the Metropolitano de Lisboa API[5], the Proximo Metro API[6], the CityBikes API[7], and also the Transport Mode Detection API[8].

8 Conclusion

This project aimed to develop a platform promoting sustainable choices aligned with the 3Rs (Reduce, Reuse, Recycle). The application features an interactive map, virtual pet plant, user rankings, dashboard, and JIT notifications, integrating them to engage users in sustainable practices. The application utilizes GPS-based location tracking to detect user activities, impacting the sustainability metric and virtual pet plant well-being. User studies in session 6 show positive user reception, genuine interest, and expert feedback for improvements. The prototype introduces new combined approaches to sustainability promotion not present in the market and related work found during research.

The knowledge obtained will allow us to focus on overcoming specific challenges in order to achieve a truly comfortable and satisfying interface which users want to

[5] https://api.metrolisboa.pt/store/apis/info?name=EstadoServicoML&version=1.0.1&provider=admin

[6] https://proximometro.pt/

[7] https://rapidapi.com/eskerda/api/citybikes

[8] http://cs.uef.fi/mopsi/routes/transportationModeApi/api_doc.html

use. Future work also comprises including additional categories of POIs, refining the sustainable metric, and performing longitudinal user studies.

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