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Sustainable Smart Parking Solution in a Campus Environment

Elsa Remelhe[1], Marcelo Cerqueira[1], Pedro Miguel Faria[1] and Sara Paiva[1,*]

[1]ADiT-LAB, Instituto Politécnico de Viana do Castelo, Rua Escola Industrial e Comercial Nun'Álvares, 4900-347 Viana do Castelo, Portugal. Email: {elsaremelhe@ipvc.pt, jmarcelocerqueira@ipvc.pt, pfaria@estg.ipvc.pt, sara.paiva@estg.ipvc.pt}

Abstract

INTRODUCTION: With the continuous growth of cities and its demography, the number of vehicles has also increased in the cities which contributes to a greater difficulty in finding parking spaces. The time it takes for a citizen to find a free space in a car park can be tiring and contributes negatively to the level of air pollution. Smart Parking solutions intend to address this issue by proposing systems that, in many cases, include sensors and/or cameras with the purpose of facilitating the search for available parking spots.

OBJECTIVES: In this paper, a crowdsourcing-based approach that makes use of a mobile app for facilitating the search for a parking space in the Instituto Politécnico de Viana do Castelo is presented.

METHODS: The solutions intend to lower the time to park and, therefore, the amount of CO2 produced by vehicles of the academic community. Some gamification techniques were used to motivate users to be engaged with the mobile app.

RESULTS: A survey was used to evaluate the solution and the app usability. It showed that the use of the app can contribute to reduce the time spent to find a parking space in approximately 50.75%, and consequently reducing the CO2 by the same amount, and it was also verified that the users enjoyed using the mobile app.

CONCLUSION: The developed solution shows the efficient use of mobile applications, crowdsourcing and gamification approaches and their role to contribute to a more sustainable mobility.

Keywords: Smart Parking, Sustainability, Ecological Footprint, Campus, Mobility, Gamification, App Usability

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1. Introduction

Since the half of the last century until now, it was possible to notice a huge increase in the number of vehicles in public roads. For example, in Lisbon, in 1996, 300 thousand vehicles entered the city per day, which is 6.5% more than in 1980, and the number of cars globally is rising two times faster than the world's population [1]. It is predicted that by 2030, there will be around 2 billion cars all around the globe. In a census made in the U.S last year, it was discovered that only 8.7% of households do not have access to a vehicle of any kind [2][3]. This rising number of vehicles significantly affects the air pollution levels and contributes to the current climate change problem the planet is facing. One litre of petrol weighs 0.9kg and, when burned, produces an average of 2,33kg of CO2 [4], an amount that is deemed alarming when multiplied by all the cars currently in use. Many plans have been discussed to

*Corresponding author. Email: sara.paiva@estg.ipvc.pt

reduce the amount of greenhouse gases produced on the roads, such as ways to foster citizens to use public transportation or bicycles in their everyday lives. In Lisbon, if 10% of people that drive a car started to use the bus for their day-to-day activities for a year, the production of CO2 would reduce by 7301 tons, NOx by 120 tons, and CO2 by 45913 tons [1]. Lisbon can be considered a small city, with only 504.718 people, so these values show the potential impact larger cities could have if this hypothetical situation was implemented. More cars on the road means more traffic and more parking spots being sought after. Currently, the search for parking spots can be tiring and occupy a significant part of our time. It can also have other consequences like congestion, obstruction of fire-fighting systems, as well as pollution. In the U.S, motorists spend an average of 17 hours per year on the search for parking spaces. This hunt also translates into a total average spending of $345 per year per driver, considering wasted time, fuel, and emissions. These are conservative numbers when compared to big U.S cities: in New York City, a driver can spend around 107 hours per year looking for parking spaces, with an average spending of about $2,243 [5]. All this time and resources spent hunting for parking spaces translate into more pollution produced, and there's a critical necessity to lower the global ecological footprint. A solution to this can be using smart parking applications: a vehicle parking system that helps people find an available parking spot, with the use of cameras and/or sensors. Using this method, air pollution and noise levels can be highly reduced. If the biggest cities around the globe adopt these systems, along with other methods to reduce traffic pollution (encouraging citizens to use bicycles or public transportation, paid parking, incentives to buy electric vehicles, etc), it may significantly reduce the amount of CO2 produced in public roads. The relevancy of such solutions is evident. In 2011, San Francisco's SFPark smart parking solution showed that people reduced time taken to park their car by 43% and the distance taken to it by 30%. Consequently, polluting gases emissions dropped by 30% and traffic volume by 8%.

In this paper, the process and development of an android prototype for smart parking in a campus is described [6]. The solution proposed does not use cameras or sensors; instead, it uses the community feedback to feed data to the app, therefore using a crowdsourcing-based approach. The contribution of the users is fundamental in this type of approach, so gamification methods are used to reward users for their contribution. Badges and *XP* points and rankings are the gamification aspects used in this app.

The rest of this paper is organized as follows. In Section 2, related works are presented and discussed further. In Section 3, the proposed solution is presented, namely its general overview, the technological architecture, gamification techniques and the prototype implementation. In Section 4, the evaluation of the system is presented regarding the contribution to ecological footprint reduction and the usability of the mobile app. Finally, conclusions are presented in Section 5.

2. Related Work

In this section, a literature review is presented on smart parking systems and, more specifically, on mobile solutions being used on campus environments.

2.1. Smart Parking Systems

Smart parking systems implementation can effectively reduce traffic congestion in urban areas. That congestion usually leads to a higher waste of time and fuel, which leads to higher noise and CO2 levels. Driver App [7] was developed using a vacancy system detection using mobile devices to improve parking space searching experience providing the users the location and occupancy of parking spaces. The system is composed by an image recognition algorithm named Convolutional Neural Networks (CNN) running in a Raspberry Pi that identifies vacant parking spaces from a parking lot camera retrieved in real time with an IP camera.

An evolution of this system is presented in [8] where the administrator can check the parking space and vehicle information at any time, which leads to a workload reduction. On the other hand, the driver can, not only check the parking information of the parking lot, but also book the parking space. Authors also analyse the complexity of various path finding algorithms, considering the different real-time requirements of the map in the parking lot and off-site path guidance, also using Dijkstra and Floyd algorithms to analyse the parking space navigation, which leads to reduction of the time that driver takes to find a parking space.

To minimize the problem between parking supply and demand, shared parking has been attracting various researchers, policymakers, and entrepreneurs. Shared parking [9] consists in sharing private parking spaces with public users but, for that, it is necessary that owners of private parking have their park spot free whenever they return to it. To fix this problem, firstly, the authors introduced a management framework of shared parking space in terms of space and time. Under that framework, to control the access to parking spaces from public users, four phases were divided in time dimension (preparatory phase, open phase, releasing phase and reconstructive phase), and in two types (pre-stored and shared parking spaces) divided in spatial dimension. Then, based on the proposed management framework, an intelligent parking management system (IPMS) was developed to simulate the operation of shared parking having in consideration the uncertainties from public users and owners. The results showed that the IPMS can't only realize that there will be enough available parking spaces for owners, but also brings improvements in both utilization and turnover rate of parking spaces, comparing with the non-shared management strategy.

2.2. Mobile apps for Campus Environment

The East Tennessee State University (ETSU) [10] has implemented a mobile application that helps students with their every-day academic life. In 2014, they added a new feature that helps students find a parking spot more efficiently by using 3 different pieces of integrated software: *CASE Parking*, *Streetline* and *Blackboard*. *CASE Parking* is responsible for the sensors that detect the entry and exit of vehicles and return that information in real-time, while *Streetline* informs students about free parking spaces depending on their geographical location. The application is built on *Blackboard Mosaic*, a mobile platform built to help schools and universities offer useful features to their students via mobile applications.

UC San Diego [11] also has a mobile application that offers a plethora of useful features to its' students and has implemented a smart parking feature in 2019. The application shows students how many spaces are available, by percentage, in each section of the university parking lot, translating those percentages into the approximate number of free spaces. Currently this feature is only available to be used in one of the campus parking lots, but it’s planned to be expanded to cover the other lots as well. The functioning of the application depends on cameras that use artificial intelligence to determine the number and place of free parking spaces.

War Eagle Parking [12] is a mobile application created in 2018 that helps students check the occupation of Auburn University's parking lot spaces in real-time. To achieve that, a service named *FoPark* was used for its' advanced technology and proven accuracy in the use of cameras and incorporated artificial intelligence software to detect when vehicles stop at a certain spot.

The Spots app [13] is a mobile application designed and created by a group of students from the Polytechnic of Leiria with the objective of minimizing the time taken to find an available parking spot and reduce the emission of pollutants derived from vehicles. The application was made to be used alongside sensors, however there are no sensors currently installed on the campus' parking lots, therefor the application was only tested using systems that mimic the response and behaviour of real sensors.

A group of engineering students from Chulalongkorn University developed a mobile and web application called Park King [14] after a study that revealed that students and workers of the university took an average of 15 minutes to find an available parking spot in campus. Besides this, the university requires that each vehicle has a ticket that needs to be manually verified by campus security personnel. The app is an IoT-based prototype that allows its' users to book parking spots, based on solutions like Aida Engineering, a self-service parking system, and Daimler AG, developers of a parking reservation application for subscribers of Mercedes. The tickets previously used were replaced by a QR code system. According to the authors, this application was made to be a generic smart parking app, suitable to be used at any university campus.

As seen by the examples presented, none of the applications have implemented gamification methods into their features. This is likely because they rely on sensors and/or cameras to gather information.

However, the prototype we built doesn't rely on any outside technology and needs the participation of its' users to do a good and accurate job. For this reason, implementing gamification methods is crucial to the proper functioning of the application.

3. SmartPark Solution

SmartPark is a mobile application prototype made for android devices that allows its' users to collaborate and provide information about the occupancy of Escola Superior de Tecnologia e Gestão (ESTG) of the Instituto Politécnico de Viana do Castelo (IPVC), which corresponds to the test scenario used for the work described in this paper.

For this project, a crowdsourcing approach was used, as opposed to other solutions that use sensors and/or cameras. Because of this, the features of the application change somewhat when compared to examples of related work. Instead of managing individual parking spots, the application manages whole parking rows, and it relies on its' user’s information to function with precision. Because of the crowdsourcing approach, there was a need to implement gamification methods to encourage participation from the academic community.

Figure 1 presents the general overview of the architecture of the designed solution. The solution is composed by a user that interacts with a mobile app that allows him to obtain information about the availability of parking spaces in the parking lot and to provide his feedback to the system, as it uses a crowdsourcing-based approach. The system stores all necessary information using Firebase Services.

3.1. Technological architecture

As shown in Figure 2, the technological architecture was developed using the React Native framework that also uses three main components: Firebase Realtime Database, Firebase Storage and Firebase Authentication. The app is React Native based, which is built with JavaScript, Node and NPM packages. For the Database, Firebase Realtime

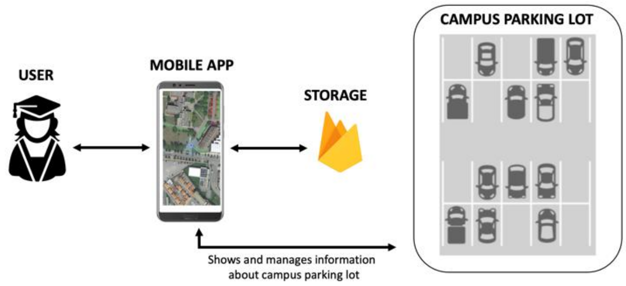


Figure 1. General Overview with the main components: User, Mobile App, Storage and Parking Lot.

Database was chosen. It offers real time changes listeners, something that allows to keep the information displayed by the app always updated. It was also used it to store user data, such as levels, *XP* and awarded medals. All the app user management, such as login and registration, is made under Firebase Authentication, which is an easy way to store users and manage login credentials. Firebase Storage was also used to store all images required by the app.

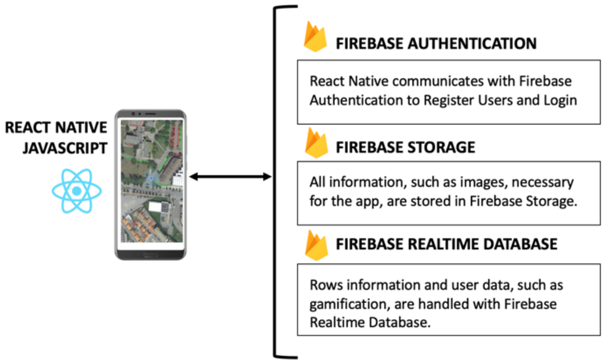


Figure 2. Technological Architecture Diagram

3.2. App gamification

Eco-feedback technologies are important in human-computer interaction (HCI) research. In HCI the focus is mainly on people's interaction with computer systems. Thus, to seek to leverage the use of the developed mobile app, research was done on gamification methods, including frameworks, level progression, and the use of medals and rankings. Octalysis is a framework created by Yu-Kai Chou after more than 17 years of research in the area of gamification and behavioral design. This framework aims to guide the organization of ideas within a project where gamification techniques will be applied. It's represented by an octagon where each side, known as a *core drive*, has individual characteristics and specifications, as shown in Figure 3. Furthermore, the octagon can be divided horizontally and vertically. By dividing it vertically, we separate *cores* that represent creativity on the right, and *cores* that represent logic thinking on the left. If on the other hand we divide it horizontally, the upper half represents *cores* connected to *white-hat* gamification, meaning they motivate the user with positive methods, while the bottom half represents *black-hat* gamification, *cores* that negatively motivate users to engage with the application.

Chou defends that, if there is no *core drive* present in an application that wants to include gamification as a main feature, there will be no motivation and, consequently, no behaviour on the part of users. This is based on the premise that almost all applications that have gamification appeal to certain *core drives* within users and motivate them to make a variety of decisions and actions. This was the framework chosen to be used as a guide to what should and should not be implemented because it is a generic one and approaches a big number of *cores*. In terms of *core drives*, the methods will focus on *white-hat* gamification, which means we will use the *core drives* represented in the top half of the octagon, discussed further below.

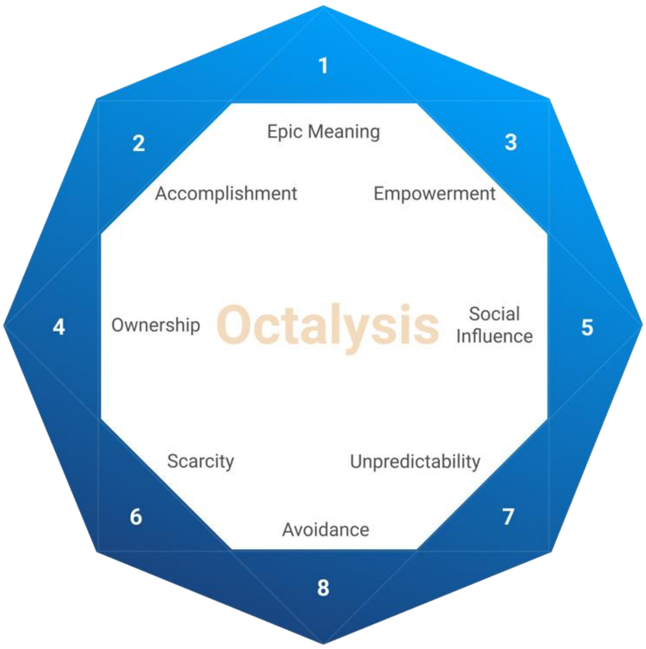


Figure 3. Core Drives

Implemented *Core Drives*

- *Core Drive 1* - Epic Meaning & Calling: This *core* is present when users feel they are doing something of significant importance to the community. In the developed application, users' actions directly help the community by providing information about the current state of the parking zone, giving these actions a sense of importance.

- *Core Drive 2* - Development & Accomplishment: The nature of this *core* stems from the user's need to succeed and overcome obstacles. In the case of the application, levels, medals, and a ranking list will be implemented.

- *Core Drive 5* - Relationships and Social Influence: This *core* embodies the human need for social relationships. Although we don't address this core in depth, it's present with the use of ranking lists, encouraging users to compete. We also incorporate an invitation system, in which the user is encouraged to invite people to use the application. Both the user and the invited person will receive a considerable amount of *exp*, therefor this action is also encouraged by *core drive 2*.

Level Progression

Each user starts at level 0 and can progress to further levels by completing actions in the application. The level progression is done by utilizing a polynomial progression metho [16], in which each level will be reached by gaining $100*n^2$ *exp*, as shown in Table 1.

Table 1. Polynomial Method for Level Progression

Level	*Exp* Needed
1	100
2	400
3	900
4	1600
5	2500
…	…
N	$100*n^2$ *exp*

At this moment, the levels aren't limited, and because of the level progression system each level gets harder and harder to achieve. For that reason, it's necessary to consider an *exp* limit at a given level, moving from the polynomial progression system to an arithmetic progression [16] (in which the precise *exp* range for each level is the same). A user earns 50 *exp* whenever they receive a confirmation and receives 100 *exp* whenever their invite code is used by someone else at registration. At the moment, these are the only ways to consistently receive *exp*. However, a user will also gain *exp* for receiving medals, and the amount of *exp* gained depends on the medal acquired.

Medal System

Medals are the main source of *exp* and they can provide users with a sense of pride and accomplishment, so their correct implementation is imperative. Table 2 shows the medals implemented, as well as the *exp* gained by receiving each one of them.

Table 2. Currently Implemented Medals and Their Rewarded *Exp*

Medal	*Exp* Gained	Values of N
n confirmations	(n+(n-5)*2	5, 20, 50
n invites sent	n*10	1, 5, 10
level n achieved	n+n	5, 20, 50
used invite	50	N/A
1st time in ranking	50	N/A
3rd place in ranking	100	N/A
2nd place in ranking	200	N/A
1st place in ranking	300	N/A

Currently, there are a total of 14 medals implemented. Many more were discussed while planning this project, but since it's still a prototype, these medals have been chosen specifically to test out the efficiency of this system and how the users react to it.

Ranking

The application has a ranking section that classifies users by level, showing a maximum of 25 users. During the planning, there was discussions about implementing a second ranking that would rely on users' received confirmations, and it would reset every week. We feel like this would encourage a repeated engagement with the application, as well as include new users who haven't achieved superior levels.

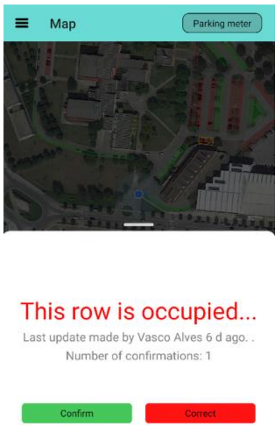
As shown in the section above, users will be able to gain medals by achieving certain placements on the ranking. These medals can only be earned once, therefor if a user falls from the ranking and earns their place back, they won't gain further medals or *exp* points.

3.3. Main features

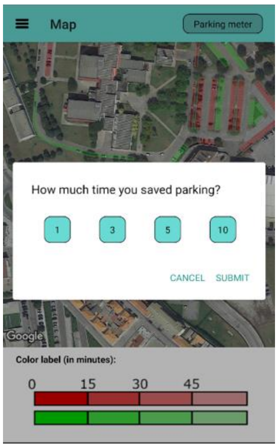
As explained previously, *SmartPark* lets its user gather information about the campus' parking lot, as well as inform other users about its' occupancy. The main features are as follows:

Map's information: As depicted in Figure 4a, users have access to a map with the information about all the rows available for parking. Right away, the user can see each row has a different color to differentiate between rows with free parking spots (in green) and rows that are completely full (in red). The stronger the color, the more recent the information presented is, as shown by the label below the map.

(a)



(b)



(c)

Figure 4. Map's Main Features: (a) Map Page; (b) Modal; (c) Pop-up for Data Purposes

The user can also select a row and a modal will appear, as depicted in Figure 4b. That modal shows the user more details about the row, such as the last person that updated the information presented and how many people agreed with the information in the form of confirmations. Here is where the user can confirm the state of the row or correct it.

The button on the top right corner toggles a pop-up, depicted in Figure 4c and it is used to gather information about how long it took for the user to find a suitable parking spot. This information is vital to gather data for the app's evaluation.

Profile: Each user will have access to a profile that features their username, *exp* points gained, level, the list of obtained medals, and their invitation code. The user is the only one with access to their own profile.

Rank: All users will have access to the rank and be able to participate in it. As explained before, the rank is based on level, and only 25 users will show up on it. Their names and level will be displayed alongside their placement in the ranking.

Invite System: Users can invite people to use the application. This will award medals and *exp* points if the person invited uses the code provided by the original user to sign up. This code can be found in the user's profile, as shown before. The person invited must use this code in the sign-up process and will also receive a medal and *exp* points.

The application provides other small features (such as a login system and password management); however, these are the ones we found most important to both implement and test rigorously.

4. Results Evaluation

In this section, the results of the tests and surveys done are presented, namely regarding the reduction of CO2 such a solution can contribute for and regarding the usability of the system.

4.1. Contribution to ecological footprint reduction

The topic of climate change gets more pressing with each passing day and reducing the carbon print is vital. Although CO2 is a natural occurring gas in nature, man-made CO2 emissions have created a severe overabundance of greenhouse gases that trap heat and result in an increase of global temperature [17].

According to a survey conducted on 10 students from IPVC, most spend between 1 to 3 minutes searching for a parking space without the use of the app.

These results are shown in Table 3, where the first column represents the interval in minutes that each participant took searching for and finding a parking space, and the second column shows the number of answers on the survey relating to each interval. The third column represents the middle-point to each interval, and the fourth column is the result of the multiplication between the second and the third column, a total that will be used to calculate the average time taken to find a parking spot.

Table 3. Results of the Survey and Sub-sequential Calculations without the app

Interval(min)	Frequency (F)	Mid-Point (X)	F * X
0-1	2	0,5	1
1-3	4	2	8
3-5	3	4	12
5-10	1	7,5	7,5

To calculate the average, we need to use the following mathematical equation:

$$\sum(F * X) \;/\; \sum F$$

In this case, $\sum F = 10$ and $\sum(F * X) = 28.5$ so the result will be 2,85. This translates into 171 seconds, therefore based on the survey the average student spends around 2 minutes and 51 seconds to find a parking spot.

The students also volunteered to test the application in the field, so that we can compare the time saved when using the application. According to a survey done afterwards, and using the same method described above, participants spent an average of 1,4 minutes (translates to 1 minute and 24 seconds) less than they previously spent while looking for a suitable parking spot.

Table 4. Results of the Survey and Sub-sequential Calculations with the app

Interval(min)	Frequency (F)	Mid-Point (X)	F * X
0-1	4	0,5	2
1-3	6	2	12

An average car can produce around 2,33kg of CO_2 per litre of gasoline burned [4], and an idling car can spend around 0,6 litres per minute, based on a conservative estimate of 0,11 gallons per hour [18]. Taking that information into account and using the averages calculated before, we can conclude the participants produced an average of 3,98kg of CO_2 each in the time it takes them to find a parking spot. By saving 1,4 minutes using the app, this amount was reduced to 2,02kg, a reduction of almost 50.75%.

If we use this data to extrapolate over 1000 students (that use a diesel run car), that means during a regular school year (180 days) over 716 thousand Kg of CO_2 is produced by those students. This application could potentially reduce this number to about 363 thousand, a significant reduction that corresponds to the 50.75% value discussed above.
These results should be taken with a pinch of salt, as this was a pilot survey conducted on a very small number of students and some assumptions had to be made to arrive to a prediction.

4.2. Mobile App Usability

The mobile application was also evaluated regarding its usability. The participants mentioned in the above section answered a second survey related to how easy and practical they felt the application was, using the System Usability Scale [19] to measure that. The 10 questions are shown in the Table 5. The users have 5 answer options: 'Strongly Agree', 'Agree', 'Neutral', 'Disagree' and 'Strongly Disagree', that correspond from 1 to 5 respectively. The final score is measured using the methodology described in [19], presented below:

- Add all the scores for the odd numbered questions (1, 3, 5, 7, 9) together and subtract 5 from this.
- Add all the scores for the even numbered questions together (2, 4, 6, 8, 10) and subtract this number from 25.
- Add the scores calculated in steps 1 and 2 together and multiply by 2.5.
- Round the number calculated in step 3 to nearest whole number to get the final SUS score.

Table 5. SUS Questions

Question	Description
Question 1	I would like to use the system frequently.
Question 2	The system was unnecessary complex.
Question 3	The system is easy to use.
Question 4	The support of a technical person was needed to use the system.
Question 5	The various functions of the system were well integrated.
Question 6	There was too much inconsistency in the system.
Question 7	People would learn to use the system very quickly.
Question 8	The system was very cumbersome to use.
Question 9	I am very confident using the system.
Question 10	I needed to learn a lot of things before I could get on with the system.

With the results presented in Table 6, we achieved an average score of 75, which is above the average score of 68. This indicates that our app has a good usability result, and we can confirm it by the fact that all our tester’s results were above 68 individually.

Table 6. SUS Scores for the ten Testers

Tester	1	2	3	4	5	6	7	8	9	10	Avg
Quest.1	3	4	2	4	3	5	4	4	5	4	3.8
Quest.2	1	2	2	1	1	2	2	2	3	1	1.7
Quest.3	5	5	4	4	4	5	5	4	5	4	4.5
Quest.4	1	2	1	1	1	1	1	3	1	1	1.3
Quest.5	5	4	4	4	3	4	5	3	5	4	4.1
Quest.6	1	2	3	1	3	2	1	3	5	4	2.5
Quest.7	5	5	4	4	3	5	5	5	5	5	4.6
Quest.8	2	2	3	1	2	1	1	3	1	1	1.7
Quest.9	4	5	3	4	4	5	5	3	4	5	4.2
Quest.10	1	2	1	1	1	1	1	1	1	1	1.1
Score	90	83	68	88	73	93	95	68	83	85	75

Despite this good result, there's always room for improvement. As we can see in Table 6, the testers 3 and 8 had a score of 68, which is the average score. Analysing their answers, we can see that the testers thought that the system was a little inconsistent, the tester 8 would need the support of a technical person to use the system and the tester 3 would not like to use the system frequently. With that we can conclude that the app needs some changes in its functionalities, as well as some look adjustments.

To receive some more feedback from the tester, some more questions were presented in the survey, shown in Table 7.

Table 7. Survey other questions

No.	Question
1	What's your opinion about the app's design?
2	What do you think that could be changed in the app's design?
3	On average, how long do you take to find a parking space at ESTG?
4	On average, with the use of the app, how much time you think you would save to find a parking space at ESTG?
5	One of the ways to earn XP in the app is by obtaining medals, which range from being present in the rank for the first time, being on the podium of the rank, inviting people to join the app, reaching certain levels, registering with an invite code and confirmations received. What other actions do you think could give the user XP?
6	Did you find bugs in the app?
7	If so, what bugs did you find?

With the first two questions in Table 7, we wanted to receive feedback from the users about the app's design. The first one had a scale from 1 (too bad) to 5 (too good) and had an average score of 3,7. Thus, the users overall, liked the app's design. For the second one (it was an optional question), the answers received are the ones presented in Table 8.

Table 8. Answers to question 2

Received answer
The colors chosen to the app's design
Compatibility with different screen sizes
Different colors for the superior bar. The pop-up that opens when a row is clicked it's not nice to see
Some UI features

The 3rd and 4th questions aimed to calculate how much time people took to park the car with and without the use of the mobile app. The results were used then to the calculations made in section 4.1.

The 5th question was made to verify what testers thought that would be pertinent to give them XP, which had the answers (optional question) shown in Table 9.

Table 9. Answers to question 5

Received answer
Users' feedback by the app rating in the PlayStore.
XP per day of use.

The last 2 questions (6th and 7th) aimed to bug reporting. Four out of the 10 testers did not find bugs in the app, the other 6 did. The bugs found are indicated below (Table 10).

Table 10. Answers to question 7

Received answer
It is possible to click multiple times in the "Confirm" button, in the modal, which opens more than one dialog. Sometimes the modal takes a lot to close.
Sometimes the app gets slow.
When I confirm, something slows down the app. I can interact with the map, but nothing else. The problem disappears some seconds later.

With the answers indicated in table 10 it is possible to conclude that testers did find some bugs in the app, bugs that affect the app's performance and will be considered in future updates.

Thus, we can claim, through the experience that users have expressed, by using of the mobile application, that the results obtained are very satisfactory. Thus, the decision to include gamification elements in the application may increase the use of the mobile app, and thus contribute to reduce the time to find a parking space and consequently reduce air pollution.

5. Conclusions

This paper describes a mobile app developed with the objective to contribute to reduce the time that an academic community takes to park their car, inside the campus of Escola Superior de Tecnologia e Gestão of Instituto Politécnico de Viana do Castelo. An initial study showed that most of the people generally struggle to find a parking spot, which means more time spent with the engine of the car running. This causes a higher level of air pollution, due to CO2 and other greenhouse gases produced by the engine.

The main objective of the mobile app developed is to reduce ecological footprint caused by cars, by helping people to find a parking spot quicker and, therefore, reducing the number of pollutants produced by everyone. The app allows the academic community to have information about spots in the park where parking spaces are available. This information is possible to provide, given a crowd-sourcing-based approach, which combines gamification elements to promote the usage of the app.

The developed prototype was submitted to assessment by 10 different users. The adopted surveys allowed to conclude that, with the use of the mobile app, it is possible to reduce both, time, and gas emissions by 50.75%. The potential users considered the app to be easy and practical to use. Even considering the good results obtained, the app still has room for some improvements, namely on some design features that could be changed, such as the colors of the app. Also, it will be important to add other ways to provide people with XP, rather than just the medals. That will benefit the user of the app represents future work to be done.

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