Digital Platform/Mobile App to Boost Cycling for the Promotion of Sustainable Mobility in Mid-Sized Starter Cycling Cities

Mário Meireles [1,*] and **Paulo J. G. Ribeiro** [2,*]

1 Centre of Environment, Territory and Construction—CTAC, School of Engineering, University of Minho, 4710-057 Braga, Portugal
2 Department of Civil Engineering, School of Engineering, University of Minho, 4710-057 Braga, Portugal
* Correspondence: id6920@alunos.uminho.pt (M.M.); pauloribeiro@civil.uminho.pt (P.J.G.R.)

check for updates

Abstract: According to the United Nations, cities will represent two-thirds of the world's population in 2050, which presents some challenges, especially to the transportation sector. To improve the population's quality of life and the sustainability of cities, mobility must be sustainable, and cycling will play an important role in achieving this. Literature shows that we can promote cycling with better infrastructures, through multimodality, and through behavioral changes. Promoting the use of bicycles through behavior can involve a number of aspects, but in this work, we explore what a digital platform should have in order to promote and increase bicycle usage, as well as to improve cycling conditions in a city. To evaluate what is needed, we conducted an analysis on different types of digital platforms that are available on the market in order to assess the main characteristics and outputs that they provide to cyclists, as well as the type of information that can and should be added to promote the use of bicycles in cities. Moreover, we also carried out a survey in a Portuguese mid-sized "starter cycling city", which showed, among other data, the relevance and type of information that a digital platform dedicated to cyclists should have in such types of cities.

Keywords: Cycling; Mid-sized Cities; Starter Cycling Cities; Digital Platform; Sustainable mobility

1. Introduction

In 2050, it is estimated that two-thirds of the world's population will live in cities and by 2030, this will already be around 60% [1]. This will represent challenges not only to the city, but also to transportation planners, especially in terms of reducing and mitigating potential problems and impacts related with this growth, such as accessibility/mobility, the use of public space, pollution, and many other issues.

Regarding urbanization and migration [2] as important city megatrends, it is relevant to point out that cities are rapidly growing in space and time, pressuring the urban transportation sector (mainly with environmental, social, and economic issues), as it was responsible for about 20% of all greenhouse gas emissions in the world and 27.55% in Europe alone in 2014 [3]. In addition, it is the main contributor to a decrease in safety in urban areas and inherent costs for societies. For example, road accidents in Portugal represent a cost of 2 billion euros yearly [4].

The current model of many European cities where the car remains the center of city planning and urbanism will not be feasible in the near future [5]. We need to have "true" smart cities and thus, we need smart mobility to achieve a sustainable city. The urban transportation system should be sustainable and efficient. To enhance that, it should not be necessary to own or use a car within a city and especially for commuting purposes. Travel within cities will have to be done on foot and by bicycle

or in conjunction with public transportation [6], using the most sustainable means of transport. Here, the bicycle plays an important role because in urban travels up to a maximum of 5–8 km, the bicycle is the fastest means of transport [7], does not pollute, improves the user's health [8], and occupies very little public space for circulation and parking. For the city, this represents a benefit of 0.18€ per km cycled (and if the person had traded their car for a bicycle, the benefit would be even higher because each kilometer driven by car incurs an external cost of 0.11€) in comparison to the usage of cars [9] and it can also increase by 10 times the range of a bus stop [10]. Thus, bicycles will be necessary to ensure that populations move in a sustainable, smart, efficient, and effective way within city areas.

"Smart velomobilities", policies, and potential innovation (to define cycling as an active, sustainable, inclusive, and networking mode of transport) are important to promote smart cities in the context of being an asset using the Internet of Things [11], mainly regarding mobility issues.

There are several ways to promote the use of a bicycle in a city. Several authors have concluded that good infrastructural conditions enhance the use of the bicycle as a regular mode of transport [12–15], showing that cycling infrastructure is an imperative condition to promote it. However, it is not always sufficient and there are other integrative measures to promote cycling that have to be adopted, are influential, and can speed up the process of adopting bicycles as a regular means of transport [16,17].

In some areas of knowledge, there is an expectation that people will start using bicycles to commute with little or even no infrastructure and few facilities. However, it is known that in the US, only 4% of people are considered "strong and fearless" for cycling, i.e., they will use the bicycle without any infrastructure. In the EU, the "strong and fearless" represent only 1%. The reasons for someone to use a bicycle can be different, since bicycle users may be categorized in different ways, e.g., as pioneers or followers [18–20]. On the other hand, the risk and its perception are directly related to the use of bicycles as a regular means of transport [21]. Implementing aspects that might influence people to use a bicycle more often as a regular means of transport takes time and needs political measures that support it.

Different cities present different levels of use, infrastructures, and political and cultural support for the use of bicycles as a regular means of transport. Therefore, they must be studied, analyzed, and planned to promote cycling in a customized way, i.e., more locally-oriented towards the respective specificities of a territory and its people.

Thus, cities with low cycling development or maturity are considered "starter cycling cities" [22]. These are cities with low cycling modal share (less than 10%) and that lack cycling infrastructures and/or support facilities. In these cases, the aim should be to implement a basic cycling network before any other measures that could stimulate cycling. In this regard, the city needs to communicate all the benefits of cycling and the advantages of implementing a cycling network.

However, there is insufficient data available on cycling in most cities to correctly assess how many people are using their bicycle as a regular means of transport, how many kilometers are cycled by each user, the profile of the cyclist, etc. Thus, in this context, research is even more necessary to collect the necessary and relevant information that will allow one to diagnose issues and define other solutions besides adequate infrastructure to promote cycling [23]. Transportation and urban planners usually have to use studies from other contexts, i.e., other cities that are in different stages of cycling evolution with more usage and infrastructures, to better target and develop the promotion materials to encourage new users for cycling, to determine new locations of bike-sharing stations, to help bike-sharing operators improve their systems [24], and even to help determine infrastructural problems and ascertain potential location risks [25]. In other words, the data gathered were mainly used to acknowledge where people are cycling so that the planners could prioritize interventions on those streets, making cycling easier, safer, and more comfortable [26,27]. As such, it is necessary to define a more suitable strategy and methodology to better promote cycling and, therefore, achieve a more sustainable mobility in starter cycling cities.

The strategy adopted to promote cycling [28] must be based on three fundamental guidelines: adequate infrastructure, complementarity with other public means of transport, and the support of digital tools.

The research of this study focused on the development of a digital tool that would support and increase the use of cycling in a starter cycling city since, according to the literature, the other two fields (infrastructure and multimodality) have been further studied and discussed already. In addition, digital technology is still growing strong and rapidly and could be a very important asset to promote cycling as a solution to establish mobility as a service (MaaS) in the future.

With this in mind, we conducted research on the Portuguese city of Braga since the local government assumed the need to improve both cycling and walking infrastructures in order to achieve sustainable mobility. For this purpose, 22 km of cycling routes were created and complemented with parking facilities in the city to promote multimodality. However, the local government has not yet shown interest nor concern on the development of digital platforms that promote sustainable mobility solutions, namely regarding cycling.

It was then possible to arrive at the conclusion that neither the city of Braga nor other medium-sized Portuguese cities have any type of digital support to promote cycling, which is a gap that this work intends to address by developing a methodology that can be replicated in any other of the 332 Portuguese municipalities with small and medium-sized cities or in other parts of the world.

Betting on the development of digital solutions to promote cycling is even more relevant in the Portuguese context since the current Portuguese Government adopted a National Strategy for Active Mobility—Cycling at the end of 2019, which defined the strategy to increase cycling in cities and to make starter cycling cities increase their bicycle modal share to 10%. The goal for the country is to achieve a 7.5% bicycle modal share, supported by a cycling network of 10,000 km until 2030 and other support measures [29].

Thus, this work aims to create proper digital cycling platforms and mobile applications that can influence non-regular cyclists to adopt bicycles as their daily main means of transport, especially for mid-sized starter cycling cities. We hope that this can be an example to replicate all around the world.

The study will focus on the city's existing cycling infrastructures, both digital and physical, and on an evaluation of the potential influence that the information of a mobile app for cycling can achieve based on a survey of the city's current cyclists.

It is important to restate that the survey was distributed to cyclists from the city of Braga in order to assess the local characteristics, as well as the relevance of using a mobile application to improve and boost cycling. The survey focused on cyclists who are familiar with the process of cycling in a context of low modal representation, especially with motorized traffic. This work did not include non-cyclists since they would not have the same perception about the reality of cycling in a starter cycling city, even if they could make relevant contributions to understand what the main issues are and obstacles for them to not use a bicycle. Beyond that, it is very unlikely that a non-cyclist will know the existing cycling apps and platforms and will be able to evaluate their suitability regarding that activity.

As such, the logic behind the choice of the survey's sample was to encourage occasional cyclists (the ones that cycle for sport or leisure) to use bicycles regularly, i.e., for commuting purposes, instead of focusing on non-cyclists.

The occasional cyclist group can represent up to almost 50% of the cyclists in starter cycling cities and them starting to use the bicycle regularly can also have a strong influence on others, especially the non-cyclist, therefore leading by example.

The results of this study will allow and guide mid-sized starter cycling cities to integrate and develop digital web/mobile platforms in the future, especially for promoting smart and sustainable mobility. The more people use bicycles on their daily trips, the more cities become sustainable. So, we will use the best features of every application and platform and conjugate them in one platform/app with wider capabilities that are not only focused on the cyclist, but also on the city user.

The remainder of this article is as follows: Section 2 is state of the art, concerning cycling apps and platforms; Section 3 describes the methodology that was used in this research; Section 4 is a results analysis, which is discussed in Section 4; finally, in Section 5, the main conclusions of the investigation are presented.

2. Theoretical Framework

2.1. Planning Cycling for a Sustainable Mobility

Some authors argue that the main factor to promote cycling is the existence of an adequate, safe, comfortable, and connected infrastructure [14,30–32] in order to guarantee that a city transforms itself and creates the necessary conditions to offer the possibility of making a modal shift from the car to other sustainable means of transport on people's daily trips, especially to the bicycle. Thus, it is necessary to create a cycling network that really allows people to move around the city without the need for polluting vehicles. In order to achieve this through the improvement of cycling infrastructures, the city must ensure five functional criteria, such as cohesion, directness, safety, comfort, and attractiveness [33,34]. Besides that, some effects need to be considered such as traffic evaporation [35], implementation of traffic calming measures [36,37], cycling streets increasing the number of users [38], defining a hierarchy decision regarding the type of cycling infrastructure that is most adequate to each street [37,39], and guaranteeing some other support facilities, like adequate bicycle parking for every need [40,41]. It is also important to mention that there is a need to define some guidelines regarding bicycle routes, such as unidirectional lanes and banning cycling on the sidewalk [33,34,39,42].

Literature shows that the lack of suitable infrastructure is not only an impediment to cycling, but it is also one of the biggest barriers identified, especially by non-cyclists [43]. All the studies that compared the barriers and constraints of cycling between cyclists and non-cyclists found significant differences amid them, while among cyclists, they found more similar results [20,43–45] since this group is usually treated as homogeneous. However, this can be considered an unsuitable approach since the literature also recognizes the existence of different types of cyclist according to several criteria, especially when it comes to the cycling experience. As such, different types of cyclists should have different perceptions of the pros and cons of cycling.

After the implementation of a cycling network, not only are there more people riding bicycles, but non-cyclists also started cycling after this change. Although the numbers vary from one city to another, it always shows an increase in cycling [46,47]. In addition, as was previously stated, the design of the infrastructure may encourage more people to ride a bicycle [48].

Why do we not have more commuters among bicycle users? Both cyclists and non-cyclists share the idea that more road safety would encourage bicycle commuting [49]. One of the biggest problems that non-cyclists point out for not using the bicycle is the danger that the city environment imposes—sharing the road with a car is automatically seen as a dangerous thing. This barrier does not exist when we talk about non-regular cyclists because they already have the experience of sharing the road, so the obstacle to become a commuter decreases [20,43–45,50]. Among cyclists, there is a multidimensional typology (dedicated cyclists, path-using cyclists, fair-weather utilitarian, leisure cyclists), with each reacting differently to how a city promotes the regular use of bicycles [51]. People who use a bicycle for sports or leisure should be more predisposed to commute by bicycle.

From the analysis of the existing literature on the subject, we were able to conclude that infrastructure is a necessary condition, although it is sometimes not sufficient to promote cycling. It is also necessary to educate the public and provide more support facilities, e.g., make cycling campaigns, add bike-sharing systems, give some financial incentives, and also implement some digital mobile applications that can influence people to use their bicycles more often [13,19,22,28,52].

Bike-sharing systems are turning the bicycle into a public transportation service as they are able to increase the bicycle mode share by 1% to 1.5% in a city that has just implemented their cycling

network [53]. However, the city must have a structured and continuous cycling network and the entire system (e.g., the location of the stations) needs to be well designed and correctly implemented [53,54].

On the other hand, multimodality between the bicycle and public transport, with the introduction of bicycle parking and bike-sharing stations near bus stops, can increase the influence of a bus station by 10 times [10].

The literature also shows that there must be an effort to change people's behavior, mainly through marketing and educative campaigns promoting the use of sustainable means of transport in the city [55]. There are campaigns to promote cycling to school and to work, like Bike to School Day or Bike2Work [56,57], public campaigns to raise car drivers' awareness to the presence of cyclists that teach them some techniques, like opening the door with the right hand when exiting a car, and also to raise awareness to the benefits of cycling in a city [27,58]; iii) debates, meetings, congresses, and forums about cycling and mobility are important to put the bicycle on the Agenda of cities [59]; iv) laws, street laws, and regulations must be revised in order to better protect the unarmed and more vulnerable road users and to make the people who are using vehicles with a higher probability of causing injury and death more accountable [60–63].

All of these planning strategies and measures should be a part of a Sustainable Mobility Plan, with actions, deadlines, budgets, and objectives promoting an efficient and sustainable city mobility [28,64].

2.2. Promoting Cycling with Digital Solutions for Sustainability

As was stated in the introduction, this work will explore the growth of the bicycle as a main means of transport through a behavioral change, through digital platforms, and smartphone applications. Furthermore, this paper is going to present a methodology to help understand what kind of information a digital app for cycling should have in order to simultaneously fill the gap of existing apps and fit the local cyclists' needs and expectations in order to change non-regular cyclists into regular ones and also help non-cyclists to overcome some barriers related to the lack of information on cycling. Thus, in this subsection, we will present brief state of the art information on the existing mobile apps that can be used by cyclists, even if they have been developed with different means of transport in mind.

Usually, when asking cyclists what triggers them, digital platforms or smartphone applications are rarely mentioned, and when asking non-cyclists the same thing, digital platforms or smartphone applications are never mentioned as something that could lead people to cycle more often, making them irrelevant [21,44,46]. However, Portuguese studies show that when cyclists are questioned about the potential that digital apps have to promote an increased frequency of cycling, these are scarcely mentioned, still having a low impact [20,65].

Navarro et al. [52] show that all the answers given to the survey regarding smartphones applications or web-based platforms indicate that they are potential tools to promote as they engage and encourage the residents of Sydney to cycle regularly.

Schwanen [66] states that a mobile application can be a contributor to a transition towards sustainable mobility, including urban cycling, but is not very clear on how smartphone applications impact these innovations and trends. So, this is a question that needs to be explored in starter cycling cities.

A mobile cycling app can influence route choice and motivate cyclists to cycle more frequently and with greater intensity, especially when the application has a gamification mode [67,68]. These cycling applications are tools that are useful to understand how changes in infrastructure can improve the use of the bicycle [69] and also support transportation planning and Smart Mobility [70,71].

When talking about intelligent platforms or smartphone apps that motivate more people to cycle, we are talking about "smart mobility", which is an upgrade of the "Intelligent Transport", which focuses on geospatial technologies. Smart Mobility is concerned about the same technologies but in a more critical perspective about the use, experience, and the politics that result from them [11,72,73].

Furthermore, cycling and cycling apps are important in the context of Smart Cities [74]. Cities can take advantage of the bicycle user to scan the city, i.e., being mobile sensors with their smartphones or by

turning bicycles into beacons in order to provide a lot of data and relevant mobility information [11,75]. This is part of the IoT (Internet of Things) and with all this information, cycling would be a mass contributor to the Smart Mobility and consequently, to the Smart City [11].

More than Smart Cities, we need *Sefficiency* cities to face the future [76]. However, we can also use it to classify cities that are efficient and incorporate the three dimensions of sustainability: environment, economics, and society. It is necessary to discuss in detail the essential features that are needed for achieving sustainability [77]. For that reason, we should have some tools that are able to measure the performance of a city through the development of different potential techniques in the planning and development of sustainable cities, but also some suggestions on how to reach a green economy and to make some urban changes that lead to sustainable cities, especially in the mobility and transportation system, so that politics and planners may adjust their policies.

The data produced by cycling mobile applications are being used to perform mobility analyses in cities. Analyzing the most commonly used routes as well as the origins and destinations will allow policymakers to map out mobility strategies and make decisions based on real data [78,79]. However, self-monitoring bike riding activities are related to a specific context or intent, such as sports and health monitoring [80], which lack some accuracy in data acquisition. Using data from different monitoring systems on cycling, like those that are used in Big Data systems, can be analyzed with multiple purposes. It is important to discuss the use of mobile apps in order to highlight the health benefits of cycling for users [81], as well as for Smart Cities [74].

There are some cycling tools that can be found in the CIVITAS initiative, which is a program that is co-financed by the European Union, like "Bike Citizens App", "BIKLIO", "ByCycling", "TRACE—Walking and Cycling Tracking Services", and "Bicycle Citizens", which track cyclists' routes and gather information about stores and parking locations. The tracking made by these applications represents a lot of data that can be used to help decision-making about cycling and allow city planners to do so, taking into account cycling from a user's perspective [78,82].

Some cities use data to better target promotion materials so that new users can be encouraged to use bicycles, to suggest the location of bike-sharing stations, or even to help the bike-sharing operators to improve [24]. Cities also use these data to help determine problems in the infrastructure and to calculate the risk of cycling [25]. The data gathered were used to determine where people are cycling. That way, the planners were able to define a hierarchy on the streets that need interventions to make cycling comfortable or, in some cases, possible [26,27].

There are a lot of applications that provide information to end-users, but the information is not always available or is expensive to planners. Bike Citizens is a digital platform that allows the end-user to access its information and also planners to obtain data that can help them make informed and data-sustained decisions. However, there are no cycling applications that allow users to report problems [83].

CEiiA has developed a game-changing platform that rewards the user when he or she makes choices that reduce CO_2 emissions. The reward is AYR credits that can later be exchanged for services provided by other applications. For example, you can change AYR credits for time in CIRC, an e-scooter sharing app [84].

We have at our disposal different applications that sometimes do almost the same thing. We also have several different applications that could work better if absorbed into only one app. For example, we have some applications, like BSB's "Minha Freguesia", that allow us to report problems, check the public transport lines and schedules, deal with local and municipal bureaucracy, register our pets, and read local news. That kind of application could be upgraded to an integrated application that helps the city to become a smart city, so we could also get some bicycle tracking and some data related to those who use bicycles in cities.

However, cycling-related mobile apps cannot be seen by the city and transport management authorities as the only data providers, but must instead be taken into account as efficient tools to improve cycling in cities, especially from a user perspective. In this context, there are numerous cycling

mobile applications available at Google and Apple online stores, such as Strava, Endomondo, BIKLIO, among others. Most of the applications are designed to treat cycling as a sport, allowing users to map and enrich the route with information about slopes, accumulated altitude, speeds, calories burned, and distance travelled. For that reason, the majority of the existing platforms and applications do not attend to the needs of common bicycle users due to not providing information about several issues such as (i) tips on how to use a bike; (ii) the location of bike stores or bike-friendly stores; (iii) potential benefits in said stores; information about lighting rules; (iv) how to ride on the road in the rain or in the sun. In other words, existing digital platforms and apps are not providing a lot of useful information for the non-cyclist who might even consider being a user or to those who use the bicycle as a regular means of transport.

Regarding bicycle-related applications/platforms, it is important to highlight Strava and Endomondo apps as the two most widely used cycling apps found in Apple and Google online stores. Furthermore, Strava claims that it is "the #1 app for runners and cyclists" [85,86]. These applications make it possible to map a particular route that a user takes and track the live and average pace achieved. It is also possible to analyze users' physical activity, namely, calories burned, average and maximum speed, distance covered, and heart rate by using wearables like smartwatches [87]. On the other hand, the application Garmin Connect needs a specific Garmin device to analyze and record any kind of data collected during the trip [88].

Map My Ride is a cycling tracking app, from the same company as Endomondo, but with fewer functionalities and less accuracy [89].

Komoot is an application that allows cyclists to plan routes or create new ones. These routes could work as tour maps. When planning routes, users are given information about the best one according to the type of bicycle they have, altitude, and estimated travel time. The experience is considered very similar to Google Maps [90].

Relive is an app that can import data from other applications, such as Endomondo, Strava, Map My Ride, Garmin, and more. At the same time, it also allows users to track their routes and to make the corresponding video [91].

Biklio is an application that recognizes that bicycle users are making the city a better place, so it rewards them with benefits offered by local establishments. It is an application that is already available in 11 European cities, 4 of which are Portuguese. The application is available only in some cities because they have to really embrace the concept so that the "spots" can promote their offers and discounts that are available to cyclists using the app [92].

The MoveX app tracks users' daily routine as long as they have their phone with them. This app acknowledges the routes travelled, the time spent on each activity, steps taken, and the distance travelled on foot, jogging, cycling, or being transported by other means [93].

Concerning all applications that can be used for cycling purposes, Table 1 summarizes the main features that each offers its users as well as its level of use.

Table 1. Comparison of the characteristics of the analyzed cycling mobile applications (Source: Own Work).

App Name	Apple Store Rank	Nb. of Users on Google Store	Travelled Distance	Time of Activity	Calories Burned	Login with Social Network	Elevation Gain	Average Speed	Instantaneous Velocity	Map	Comparison with Other Modes of Transport (Tracking of the Use of the Car, Walking, Cycling)
Endomondo	87 *	661,765	o	o	o	o	o	o	o	o	
Strava	23 *	461,877	o	o	o	o	o	o	o	o	
Garmin Connect	72 *	392,049	o	o			o	o	o	o	
Map My Ride	N.P.	121,589	o	o		o				o	
Komoot	N.P.	92,533	o	o		o		o	o	o	
Relive	176 *	58,588	o	o		o	o			o	
Biklio	N.P.	36								o	
Moves (Move X)	N.P.	-	o	o		o				o	o

N.P.—No Position; * Health and Fitness

One of the problems associated with these applications is battery drain on smartphones, along with a lack of GPS accuracy. One solution is to introduce beacons on bikes and even in some parts of the city to communicate with the smartphone app using Bluetooth Low Energy (BLE) technology. However, this requires that beacons are installed on people's vehicles, which is not always possible [78,82].

All analyzed apps are designed to consider cycling as a sport. Nevertheless, it is possible to identify some design problems and inconsistencies [94]. There is no app that is suitable to the use of the bicycle as a commuter that considers other relevant information and the particulars of a city. Thus, it becomes necessary to use multiple apps to interact, experience, and to learn how to behave in a city, rendering the existing apps somewhat inefficient.

The use of digital platforms that track cyclists, such as Strava, is not only useful to gain background information on existing bicycle usage, but also to influence more people to trade other means of transportation for the bicycle. However, the data collected by Strava is expensive, i.e., cyclists need to pay in order to access their own data collected by the app and it is not available to everyone [83], which can be considered the main constraint to the use and dissemination of these tools to promote cycling in a city.

3. Materials and Methods

3.1. Case study of Braga, PT. Characterization of Physical and Digital Cycling Infrastructures of the City

Braga is located in the North of Portugal and it is the country's oldest city. In the past 50 years, it has rapidly grown and sprawled to the surrounding areas on car-oriented urban planning. Nowadays, only the historical city center can be considered a pedestrian and cycling-friendly area. With 181,484 residents, Braga is the 7th biggest city of the country population-wise and in a broader context, e.g. European cities, it can be considered a medium-sized city [95]. It is located in a valley and 55% of its population live in a relatively flat area.

Concerning weather, Braga is a South European city with a moderate average temperature (annual maximum average is 17 °C and the annual minimum average is 10 °C) and during the year, it rains about 45% of the time (average per year is 1822 mm), so it is rain-free about 195 days a year [16].

In the 2011 censuses, Braga presented a very low cycling mode share of 0.1%. In 2013, a mobility study showed that the use of a bicycle in Braga increased to 0.4%. After that, there was no further survey of the modal split in this territory and there is currently no reliable information about the real number of people who use bikes on a regular basis. According to these values of cycling mode share, Braga can be classified as a medium-sized starter cycling city.

According to the goals of the Portuguese National Strategy for Active Cycling Mobility, cities like Braga have to reach 10% in bicycle mode share by 2030 [29]. In this context, Braga mobility goals are aligned with the National Cycling Strategy since the city wants to have 10% of the population riding a bicycle by 2025 [96]. Furthermore, the municipality of Braga has the intention to build a 76 km cycling network during the next few years, starting with a 22 km network that includes the city of Braga [96], as can be seen in Figure 1.

In general, the streets of Braga are car-oriented and not cycling-friendly. In fact, they are deterrents for cycling and other active means of transportation, especially the primary and secondary distributors. Braga has a large road network, with more than 1000 km of roadways. However, there are only 7.5 km of bicycle lanes (3800 m segregated, 700 m BUS + Bicycle, and 3030 m in coexistence with pedestrians) [96], which do not form a complete cycling network. When observing the map of Figure 1, one may see that there are several cycling infrastructures that are not interconnected and continuous and also do not cover the center of the city, nor the majority of the most important facilities and equipment of Braga. These factors represent the main barrier to what is intended, which is using bicycles as a regular means of transport. Besides that, the city lacks bicycle support facilities like parking places and maintenance spots.
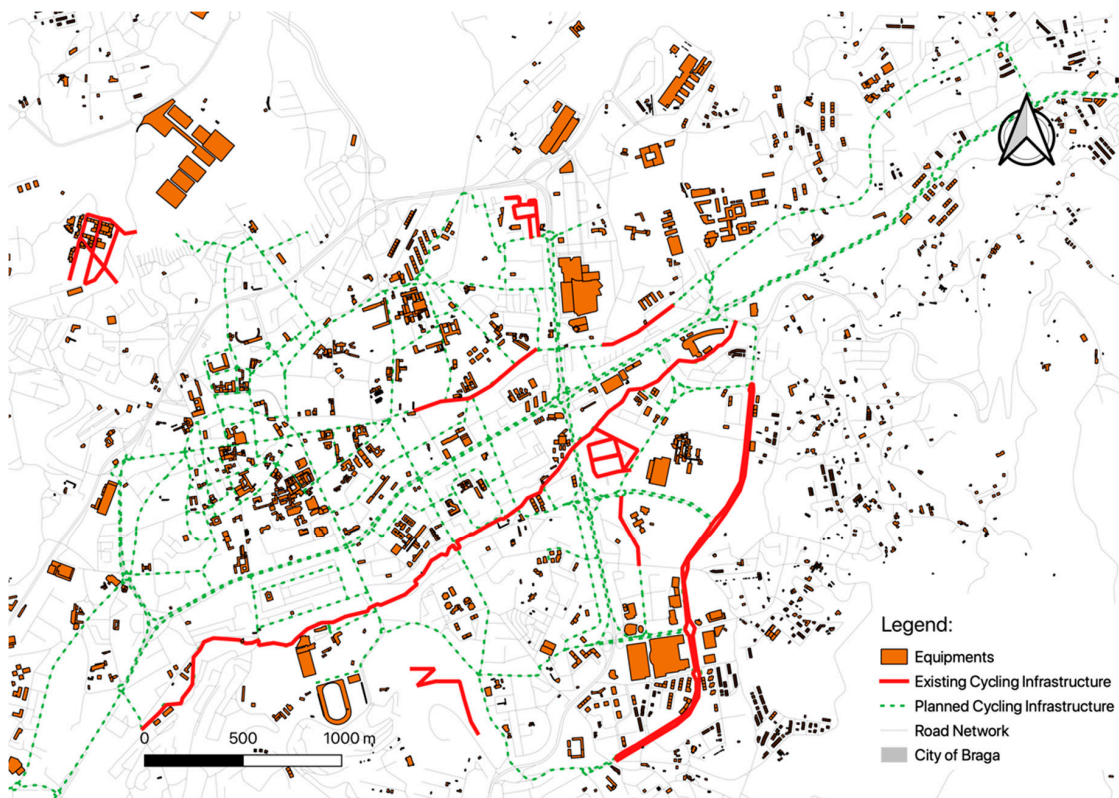
Figure 1. Map of Existing and planned cycling networks in the city of Braga (Source: Own Work).

In terms of digital cycling infrastructures, it is possible to verify that Braga does not present digital solutions to support cycling mobility. In fact, not even Google Maps allows obtaining itineraries for bicycle trips, demonstrating that there is a gap in this matter and that there is room for improvement, both in quantity and in quality. However, it is important to highlight the role of associations that promote the use of bicycles, like the Cycling Braga Association (*Braga Ciclável*), which developed and made available on its website a map that shows the available bicycle lanes, as well as the desired routes and parking spots for the city's bicycle users [97].

3.2. Model to Promote Cycling Mobility in Mid-Sized Starter Cycling Cities

As the diagram in Figure 2 shows, we have two ways to start promoting cycling mobility in cities. A Bottom-Up Strategy can be forced by society, making politicians and leaders adjust their politics to match people's interests. Conversely, a Top-Down Strategy can be imposed or started by leaders and politics by their own initiative. Both ways should lead politics and leaders to create a Strategic Council for Mobility, with territorial authorities, operating capacity, and a dedicated budget. After that, there is a need to create a Sustainable Urban Mobility Plan with the necessary policies and measures to ensure cycling in the city. These would be based on three main areas: (i) infrastructure, (ii) multimodality, and (iii) behavior, including the development of digital support solutions.
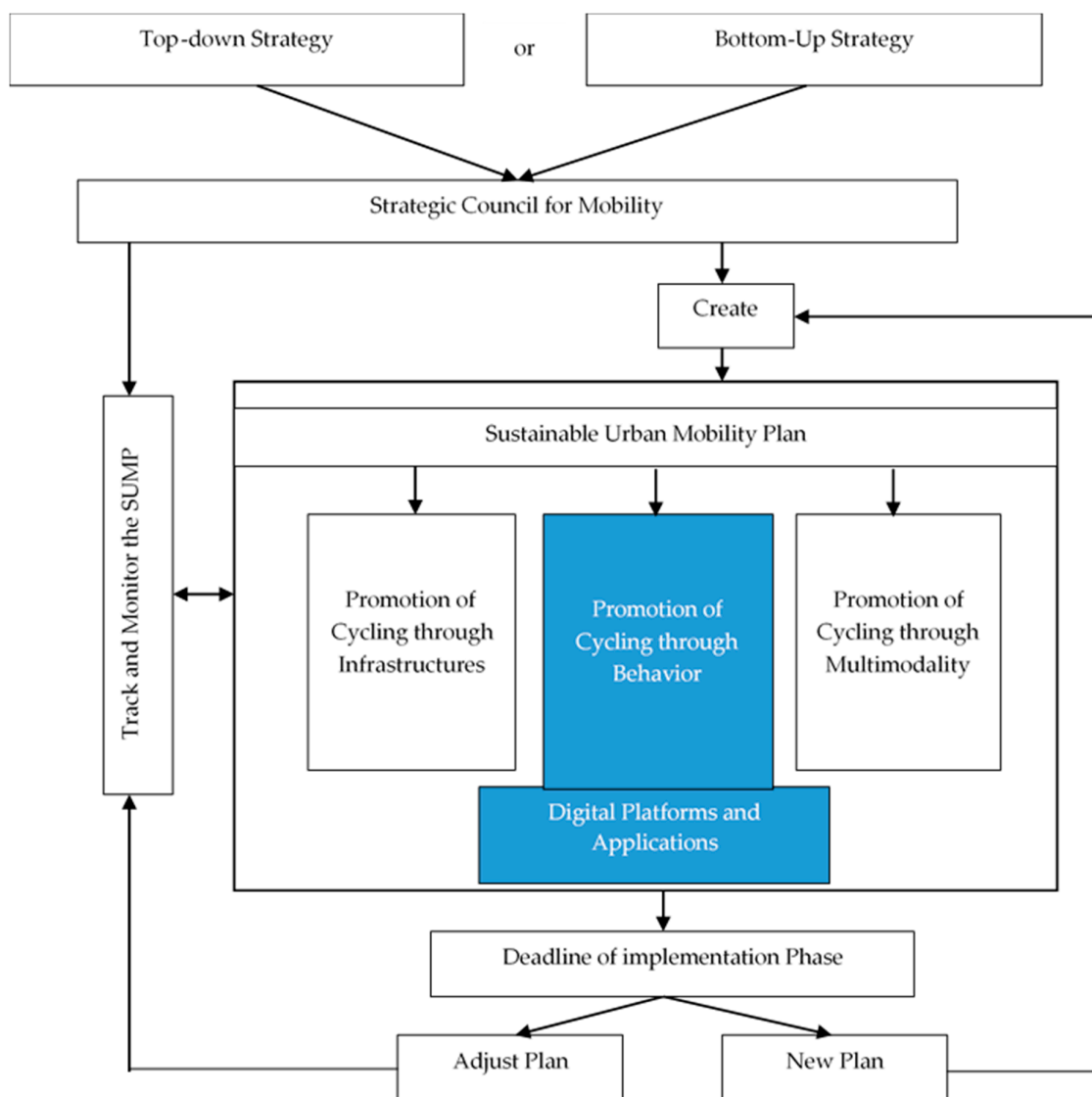
Figure 2. Model to promote Cycling mobility in Cities [adapted from 15].

When the implementation phase of the plan reaches a deadline, the Strategic Council for Mobility can adjust the plan by tracking and monitoring it or, if it reached the last deadline, they should create a new plan and implement it. This strategy then continues with the logic of PDCA (Plan, Do, Check, Act).

As stated in the introduction, the objective of this work focuses on triggering a change of behavior, which can be achieved through education, marketing, and also through the usage of digital platforms and applications, among others.

It is known that digital platforms can help people to adopt the bicycle as a main means of transport in their multiple daily trips and could also increase its sporadic use, especially in cities where the level of usage and dedicated infrastructures are low, as it happens in starter cycling cities. Digital solutions can prepare the city's population to better know the specificities of cycling and give them the support needed so that the expected growth of the city's cycling network is achieved. Such is the case of Braga where over the next 5 to 10 years, 22 km of cycling lanes will be built.

3.2.1. Methodology for the Development of a Digital Solution (App) for a Starter Cycling City

To inspire non-regular cyclists to ride a bicycle as commuters or to improve the conditions for all bicycle using citizens, it is useful to have a platform/mobile application that will help them by providing relevant information about cycling and app features that this type of user really needs and

wants. Thus, Figure 3 presents a diagram of a methodology to develop a mobile app based on two information sources: (1) existing apps and digital platforms, and (2) a survey on existing users of a starter cycling city.
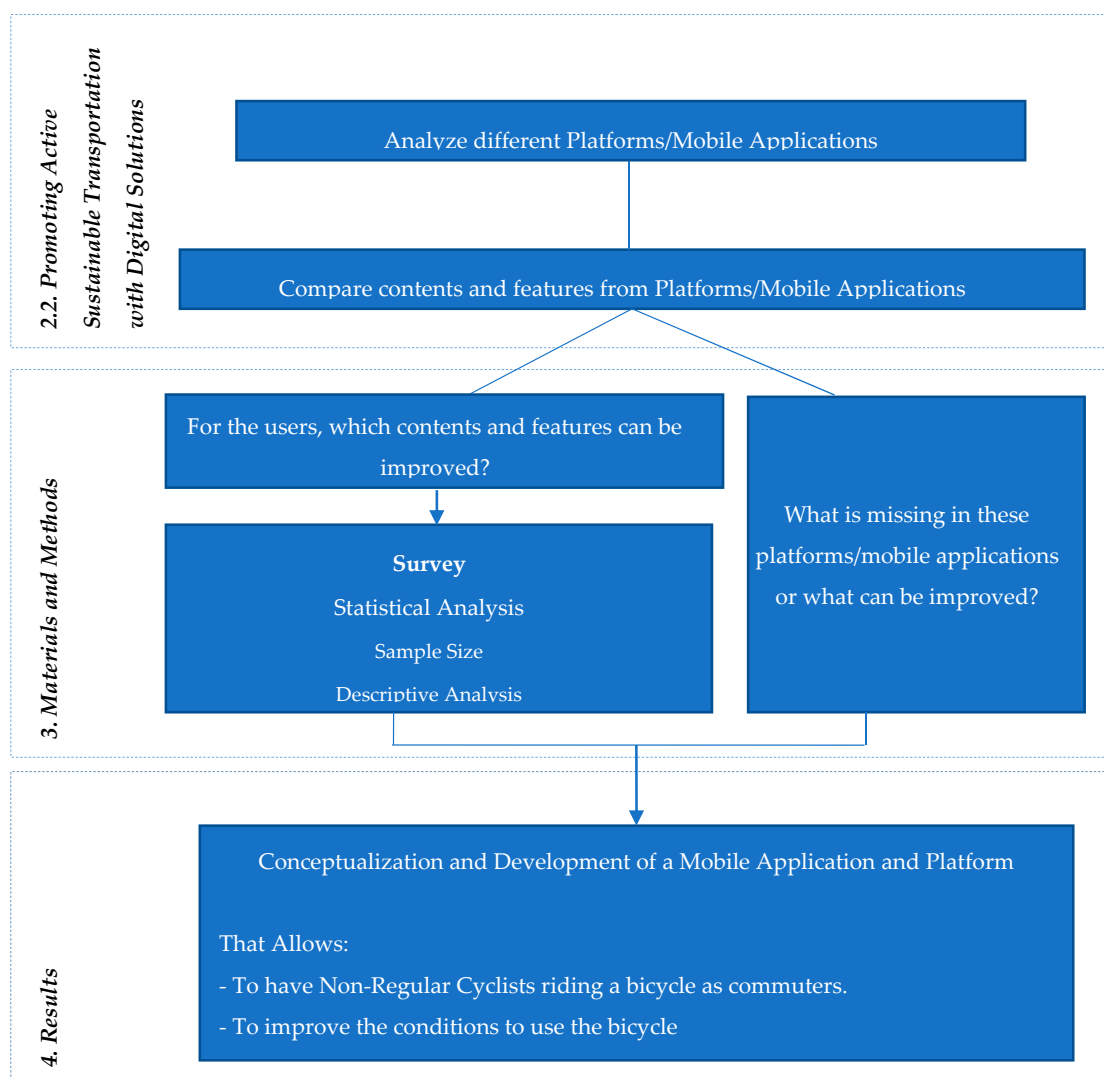

Figure 3. Methodology Diagram (Source: Own Work).

In fact, the survey could also consider non-cyclists. However, in a city where the bicycle does not have much use, the rationale was that the existing apps and digital solutions are being developed for other types of users and thus, do not meet the real needs of cyclists from a starter cycling city.

For a starter cycling city, we argue that the first level of intervention (policy goal) should be focused on non-regular cyclists, i.e., those who do not use bicycles daily or frequently, inspiring them to become regular users—cycling commuters—since this group is already aware of the majority of pros and cons of cycling in this type of city. A comparison between the two groups of cyclists will allow one to identify if there is a barrier and if so, whether it can be minimized through a digital solution.

In the future, non-cyclists will also be studied to try to come up with a solution that encourages them to join the cycling community or to revise and improve the ones we arrived at during this stage of the project.

3.2.2. Survey Framework

As such, we applied a survey to bicycle users of a starter cycling city in order to help us understand their real needs and either realize the type of information they lack or improve the existing one, so later we could develop an appropriate mobile application, considering the already existing digital solutions and the characteristics of this type of city. With this in mind, we concluded that the survey had to be based on a questionnaire with four different parts:

i. Profile of the cyclist (regular or non-regular users);
ii. Characterization of cycling in Braga;
iii. Evaluation of the main features we should use in promoting cycling, based on the three domains presented in the model: (i) infrastructure, (ii) multimodality, (iii) behavior.
iv. Cycling digital platforms and applications (understanding the contents, features, and information existing in apps that are available on the market).

The questionnaire was designed to learn and raise the profile of people who are using the bicycle in Braga to understand to what ends these people use bicycles, if they are commuting by bike in an intermodal way, to know the time and distance of their journeys, how they are experiencing the infrastructure (or the lack of it), how they see and classify the factors that can influence them to use bicycles, some open questions regarding said usage, and what they think about the weight that a digital platform can have in influencing more people to cycle.

In this work, we focused on part iv) of the questionnaire, starting by analyzing and comparing the existing cycling digital platforms and mobile applications in order to understand what features each one of them offers and which ones are missing. Thus, at the same time of the survey, we also acknowledged the features that are missing from the existing software that could be added to a new platform designed to improve cycling in a mid-sized starter cycling city.

Applying this methodology to the case study of Braga will provide relevant information to guide other mid-sized starter cycling cities to develop web platforms and apps in the future, especially to make them realize that cycling is a way to achieve smart and sustainable levels of urban mobility.

3.3. Sample

While there is a lot of data and research about the use of the bicycle as a means of transport in some European countries like the Netherlands [98], Germany [99], Denmark [100], France [101], or Great Britain [102], this is not the case in Portugal, and especially in the city of Braga. Knowing the approximate number of people using bicycles in Braga i.e., to define the population of this case study analysis, was hard and required a lot of effort.

It would be easier if the analysis focused only on non-cyclists since we could consider them to be almost the entire population of the city of Braga, considering that the mode share for cycling is around 0.4%. Beyond that, to get 400 or 1000 non-cyclists to answer the questionnaire would be much easier since the number of cyclists is very small, with Braga being a starter cycling city.

Furthermore, the major barriers and other information identified in the other studies mentioned in the theoretical framework [20,21,44,46] regarding non-cyclists would probably be similar to the non-cyclists of Braga. After analyzing the literature, we were able to conclude that building a safe and well-designed infrastructure is the main way to get more people cycling, ideally also converting non-cyclists into cyclists. However, in the case of cyclists, we have different types of users and reasons for cycling, or not, on a regular basis. Thus, knowing the profile, needs, and expectations of the different types of cyclists in Braga will allow one to develop a digital solution that can be designed to increase cycling frequency and somehow influence people in becoming commuters.

Additionally, developing a digital solution based only on non-cyclists' contributions would probably lead to a digital solution that is already present in the market since this group would be much more focused on infrastructure, safety, and multimodality issues that would not be directly solved with an app. Beyond that, the probable unfamiliarity with this type of cycling app would not allow

them to draw reliable conclusions in accordance to the specific needs of cyclists, even in the case of a starter cycling city.

In this context, the target audience for this questionnaire was the bicycle users, i.e., cyclists who travel by bicycle in Braga, for different purposes like sport, leisure, and commuting, among others. To define the current number of cyclists in Braga, we analyzed several sources of information and data.

Thus, in 2011, the Portuguese Census indicated that in Braga, 196 people used bicycles as their main means of transport (the preferred) for commuting [103]. However, this question could limit the accounting of people who cycle in the city since an affirmative answer from those who use bicycles as a means of transport but not as their preferred mode were automatically excluded. More recently, a mobility study for the Region of Braga named "Quadrilateral Integrated Mobility Study (*Estudo de mobilidade integrada do Quadrilátero*)" indicated that 725 people used bicycles (0.4% of the population), regardless of whether they used it for commuting (as a main means of transport), exercising, or leisure purposes [104]. This originated a discrepancy in the numbers because censuses counting was limited to cyclists that travel by bicycle as their main means of transport for daily commuting.

As such, with the collective effort of Cycling Braga Association (*Braga Ciclável*), Minho Bicycle Tourism Association (*Associação de Cicloturismo do Minho*), and Cycling Club of Braga (*Clube de Ciclismo de Braga*), it was also possible to identify 722 people who used bicycles in 2019, regardless of the purpose. That number was then accepted as valid and was presented in the "integrated mobility study for four main municipalities of Minho Region" and was considered the population for statistical analyses.

Once the statistical population was set on 725 cyclists, the questionnaire was applied to a random sample for significant convenience for a confidence interval of 95% and an error margin of 5%, resulting in a sample size of at least 252 respondents.

Since the structure or the stratification of data was not available for the cycling population, the statistical analysis had to be based on nonparametric assumptions and tests.

For this article, we analyzed the different questionnaire parts concerning the characterization of cycling and also the platforms and mobile applications for cyclists.

3.4. Survey

According to the proposed methodology, we prepared a questionnaire with 30 questions using the online platform *SurveyMonkey*. This was available on the platform from 19 December 2018 to 29 March 2019 in order to reach more bicycle users and also to allow people to manage the time they had available to answer.

The questionnaire was firstly applied, in a pre-test, to 30 cyclists through an online survey and was later disseminated by web and e-mail and also near bicycles parked through the city. We collected 338 responses, but only 275 were considered complete and valid answers.

The pre-test allowed us to adjust some issues related to the features and user interaction with the questionnaire, which required answering follow-up questions that should only present themselves if there was a previous specific answer, e.g., "Did the respondent use the bike in a complementary way to another means of transport?" and then another question would arise, prompting them to indicate which complementary means of transport, even if the answer was "No".

Once the questionnaire was adjusted, it was then disseminated on social networks, either through personal messaging or by sharing in groups related to bicycle mobility in the city of Braga. It was also sent via email to members of local cycling associations, such as Braga Cyclable Association (*Braga Ciclável*), Minho Bicycle Tourism Association (*Associação de Cicloturismo do Minho*), Braga Cycling Club (*Clube de Ciclismo de Braga*), all the students from the University of Minho, Braga's school groups, and to Go By Bike and Bike Zone's customers. At the same time, small flyers were distributed with a small text and a QRcode, making the questionnaire accessible to more bicycle users from Braga. These pamphlets were left on the handlebars of the bicycles found in the city.

3.5. Statistical Data Analysis

To properly analyze the data collected, we used SPS—Statistical Package for the Social Science, executing a descriptive analysis of the results and using the Mann-Whitney U test in order to compare the results about the main cycling issues for regular and non-regular cyclists in Braga.

In short, the Mann-Whitney test (Non-parametric test) compares the outputs between two independent groups (Cyclists—Regular and Non-Regular). The null hypothesis for the nonparametric test is H0: The two populations are equal. An underlying assumption for appropriate use of the U test was that the continuous outcome was approximately normally distributed or that the samples were sufficiently large to justify their use, based on the Central Limit Theorem (with more than 50 elements), which was verified.

The test statistic for the Mann Whitney U Test is U, and which is the smaller of U1 and U2 is defined by the following equations:

$$U_1 = n_1 n_2 + \frac{n_1(n_1 + 1)}{2} - R_1 \tag{1}$$

$$U_1 = n_1 n_2 + \frac{n_2(n_2 + 1)}{2} - R_2 \tag{2}$$

R_1 is the sum of the ranks for group 1
R_2 is the sum of the ranks for group 2.

The U test is a nonparametric test of the null hypothesis, which is designed to test differences between groups using ordinal data. A hypothesis is rejected when the p-value (significance) is lower than 0.05, indicating that there was a significant difference in the evaluation made (Soria-Lara et al., 2017). Thus, the U test can be used for rejecting or not rejecting options according to the statistical significance of the answers obtained.

4. Results

4.1. Main Results about Cycling in the City of Braga

The implementation of the questionnaire resulted in 275 responses, which was sufficient to yield results with statistical significance considering the population of 725 cyclists, with a confidence interval of 95% and an error margin of 5%.

These survey results allowed us to build the main profile of the people who use bicycles in Braga. Of all the respondents, 73.1% were men and 26.9% were women. More than half (52%) were married or in a civil union, 39.6% were single, and 8.4% divorced.

In terms of literacy, 0.7% were illiterate, 6.2% had a basic education, 21.5% had secondary education, and 70.8% had a superior degree (30.5% had graduated, 35.6% had a masters degree, and 4.7% had a PhD).

Regarding their professional activity, 68.7% were employed, 13.8% were self-employed, 8.4% were students, 6.2% were unemployed, and 2.9% were retired.

In Braga, about half of the cyclists use bicycles on a regular basis, i.e., for commuting purposes, and the other half use them more sporadically (non-regular), i.e., for leisure and sport purposes (Table 2).

Table 2. Types of Cyclists in Braga (Source: Own work)

Type of Cyclist	Frequency	Percentage (%)
Regular (Commuter)	143	51.7
Non-Regular (Sport Cyclist/Leisure)	132	48.3

Most of the people who answered use a bicycle combined with another means of transport, i.e., in a multimodal way, and it was said that the car (diesel) was the other vehicle. Furthermore, only 29.8% of the cyclists combined the bicycle with public transportation (mainly the bus and the train).

Table 3 shows the relevance that the two groups of cyclists (regular and non-regular) give to the main cycling issues in the city of Braga, concerning network criteria, physical characteristics (infrastructures), support facilities, safety measures, and environmental and health features.

Table 3. Level of importance of the main cycling issues for cyclists in Braga (Source: Own Work)

Group	Issues	Type	1	2	3	4	5	Mean	Median
Network Criteria	Cohesion	R.	39.2%	30.8%	18.9%	9.1%	2.1%	2.04	2.00
		N.R.	39.4%	27.3%	24.2%	7.6%	1.5%	2.05	2.00
	Directness	R.	11.2%	26.6%	29.4%	22.4%	10.5%	2.94	3.00
		N.R.	12.1%	26.5%	40.2%	12.9%	8.3%	2.79	3.00
	Safety	R.	30.8%	27.3%	23.8%	14.0%	4.2%	2.34	2.00
		N.R.	29.5%	34.8%	26.5%	6.8%	2.3%	2.17	2.00
	Comfort	R.	19.6%	29.4%	34.3%	14.7%	2.1%	2.50	3.00
		N.R.	18.2%	33.3%	37.9%	7.6%	3.0%	2.44	2.00
	Attractiveness	R.	10.5%	30.1%	28.7%	21.0%	9.8%	2.90	3.00
		N.R.	17.4%	28.8%	31.8%	17.4%	4.5%	2.63	3.00
Physical Characteristics	Segregated Cycling Network	R.	0.7%	2.1%	10.5%	25.9%	60.8%	4.44	5.00
		N.R.	2.3%	1.5%	18.9%	29.5%	47.7%	4.19	4.00
	Direct Way (Shortest way)	R.	2.8%	4.9%	19.6%	44.8%	28.0%	3.90	4.00
		N.R.	0%	10.6%	26.5%	31.1%	31.8%	3.84	4.00
	Cycle path where the pavement is not cobblestone or damaged	R.	2.8%	2.1%	13.3%	26.6%	55.2%	4.29	5.00
		N.R.	0.8%	4.5%	22.0%	31.8%	40.9%	4.08	4.00
	Street Slope	R.	7.7%	11.2%	24.5%	31.5%	25.2%	3.55	4.00
		N.R.	9.1%	12.9%	25.8%	25.9%	27.3%	3.48	4.00
Support Facilities	Bicycle parking	R.	1.4%	4.2%	14.7%	25.2%	54.5%	4.27	5.00
		N.R.	3.8%	8.3%	15.2%	28.8%	43.9%	4.01	4.00
	Maintenance and washing points for bicycle	R.	14.7%	22.4%	28.0%	20.3%	14.7%	2.98	3.00
		N.R.	7.6%	18.2%	37.1%	18.9%	18.2%	3.22	3.00
	Bike-sharing system	R.	9.8%	20.3%	25.2%	23.1%	21.7%	3.27	3.00
		N.R.	7.6%	17.4%	26.5%	25.8%	22.7%	3.39	3.00
Safety Measures	Reduced Speed of cars	R.	2.8%	5.6%	13.3%	24.5%	53.8%	4.21	5.00
		N.R.	3.8%	3.8%	16.7%	28.8%	47.0%	4.11	4.00
	Pedestrian zones transformed into coexistence zones	R.	2.8%	1.4%	14.0%	25.2%	56.6%	4.31	5.00
		N.R.	3.8%	3.0%	18.2%	38.6%	36.4%	4.01	4.00
Environmental and Health Features	Heat	R.	11.9%	18.9%	28.0%	24.5%	16.8%	3.15	3.00
		N.R.	6.1%	18.2%	36.4%	25.0%	14.4%	3.23	3.00
	Rain	R.	8.4%	10.5%	15.4%	29.4%	36.4%	3.75	4.00
		N.R.	3.0%	7.6%	28.8%	25.8%	34.8%	3.82	4.00
	Benefits for Health	R.	0.7%	2.1%	11.2%	19.6%	66.4%	4.49	5.00
		N.R.	0%	0%	9.1%	18.2%	72.7%	4.64	5.00
	Reduction of Pollution	R.	0%	4.9%	8.4%	18.2%	68.5%	4.50	5.00
		N.R.	2.3%	0.8%	5.3%	18.2%	73.5%	4.60	5.00

Scale of the level of Importance 1—Low importance, 2—Slightly important, 3—Neutral, 4—Moderately important, 5—Very important. R—Regular; N.R.—Non-Regular.

Regarding network criteria, it was possible to conclude that attractiveness, comfort, and directness of cycling infrastructure are the three most important factors for both groups of cyclists. This means that these are, from the respondents' point of view, the three most important functional requirements that must be ensured in cycling network planning.

At the same time, cyclists said that the existence of segregated cycling infrastructures, the existence of safe cycling parking places, and smooth pavements not made of cobblestone and without damage are the three most important aspects concerning the physical characteristics of cycling infrastructures.

Other important features for both groups relate to safety aspects, such as forcing cars to circulate at lower speeds on city streets and transforming pedestrian zones into coexistence zones that include cycling.

Health benefits and the reduction of pollution are the two most relevant reasons that regular and non-regular cyclists use bicycles. On the other hand, weather aspects, such as rain or heat, do not represent significant barriers to the use of bicycles.

The Mann-Whitney test was used to check if both regular and non-regular cyclists from Braga give the same importance to the issues identified.

The null hypothesis tested was "Are the main cycling issues for cyclists in Braga equally important for regular and non-regular cyclists?" We may see the results below in Table 4.

Table 4. Mann-Whitney test for the level of importance of the main cycling issues for cyclists in Braga.

Main Issues	Mann-Whitney U Test	Asymp. Sig. (2-tailed)	H0
Cohesion	9362.000	0.903	Not Rejected
Directness	8722.500	0.261	Not Rejected
Safety	8842.000	0.347	Not Rejected
Comfort	9078.000	0.568	Not Rejected
Attractiveness	8294.500	0.073	Not Rejected
Existence of a Segregated Cycling Network	8025.000	0.017	Rejected
Existence of a Direct Way (Shortest way)	9057.000	0.543	Not Rejected
Cycle path where the pavement is not cobblestone or damaged	7992.500	0.018	Rejected
Bicycle parking	8248.000	0.051	Rejected
Bike-sharing systems	8943.500	0.441	Not Rejected
Maintenance and washing points for bicycle	8438.500	0.119	Not Rejected
Reduced Speed of cars	8845.000	0.329	Not Rejected
Pedestrian zones transformed into coexistence zones	7578.000	0.002	Rejected
Street Slope	9190.500	0.699	Not Rejected
Heat	9165.500	0.670	Not Rejected
Rain	9425.000	0.984	Not Rejected
Benefits for Health	8748.000	0.196	Not Rejected
Reduction of Pollution	8895.500	0.302	Not Rejected

As we can see, there is one statistically significant difference ($p = 0.05$) between the two types of cyclists about the Existence of bicycle Parking ($p = 0.051$), with Regular Cyclists being more relevant (mean 4.27 versus 4.01 when comparing to Non-Regular Cyclists).

The main issues with statistical differences were the existence of a segregated cycling network, the existence of a path not made of cobblestone or damaged, and transforming pedestrian zones in coexistence zones. As shown in Table 4, we can see that all of these main issues were rated higher by regular cyclists than by non-cyclists.

4.2. Evaluation of the Potential Influence and Information of a Mobile App for Cycling

When analyzing the answers given to the question "Evaluate on a scale of 1 to 5 (where 1 means low importance and 5 very important) the relevance you give to a mobile app for cyclists", we can see that from all the reasons given (transport, exercise, leisure [39]), cycling users consider the existence of a mobile app to be important (Table 5) and both groups (regular and non-regular cyclists) consider it very important when using the bicycle as a means of transport, with a median value of 4.0.

Table 5. Answers to the question "Evaluate the importance you give to a mobile app for cyclists" (Source: Own Work).

Type of Bicycle Use	Type of Cyclists	1	2	3	4	5	Mean	Median
as a transport mode	R.	12.6%	18.2%	18.9%	23.8%	26.6%	3.34	4.00
	N.R	6.1%	13.6%	25.0%	22.7%	32.6%	3.62	4.00
as sport	R	10.5%	12.6%	26.6%	25.2%	24.5%	3.41	3.50
	N.R	3.0%	9.1%	16.7%	27.3%	43.2%	3.99	4.00
as leisure	R	11.9%	14.7%	25.9%	27.3%	19.6%	3.28	3.00
	N.R.	3.8%	15.9%	23.5%	21.2%	34.8%	3.68	4.00

Scale of the level of Importance: 1—Low importance, 2—Slightly important, 3—Neutral, 4—Moderately important, 5—Very important. R—Regular; N.R.—Non-Regular.

As Table 6 indicates, non-regular cyclists consider an application as more important to further influence using bicycles as a main means of transport than regular cyclists, reinforcing the logic that was behind the selection of the sample.

Table 6. Answers to the question "Can a bicycle app influence the use of the bicycle as a means of transport?" by type of cyclist (Source: own work).

Type of Bicycle User	Yes		No	
	Frequency	Percentage	Frequency	Percentage
Regular (Commuter)	73	51.0	70	49.0
Non-Regular (Sport Cyclist/Leisure)	80	60.6	52	39.4

In general, cyclists consider that the most important feature in a mobile app is the distance travelled, followed by travel time, the existence of a map, and the CO_2 saved when comparing to a car. However, when we separately analyze the answers given by the type of cyclists, we can see that for regular cyclists, the map is the second most important feature and for non-regulars, it is the travelled time (see Table 7).

Table 7. Answers to the question "When using a cycling app, what content/feature do you consider most important?" (Source: own work).

Type of Bicycle User	Travelled Distance	Time of Trip	Burned Calories	CO₂ Saved Compared to a Car	Elevation Gain	Average Speed	Instantaneous Speed	Map	Comparative to Other Modes of Transport
Total	183	168	102	109	65	107	62	166	103
Regular	97	87	50	61	34	55	30	91	60
Non-Regular	86	81	52	48	31	52	32	75	43

The most used app by the respondents (Table 8) is Google Maps, followed by Strava and then, much less used, Garmin Connect, Endomondo, and Relieve. However, 63 people indicated that they do not use any of the mentioned apps.

Table 8. Answers to the question: "Which of the following apps do you use?" (Source: own work).

Type of Bicycle User	Strava	Relive	Cycle Maps	Map My Ride	Endomondo	Garmin Connect	Biklio	Moves	Google Maps	None
Total	107	15	3	5	17	38	3	3	140	63
Regular	41	4	1	3	4	9	2	1	73	41
Non-Regular	66	11	2	2	13	29	1	2	67	22

As for missing features (Figure 4), respondents indicated as being the most important or necessary in an app when using a bike the following: route calculation, street sorting by type of bicycle infrastructure, points of interest (workshops, support, maintenance), a comparison with other means of transport, benefits, and discount offers and parking spots.
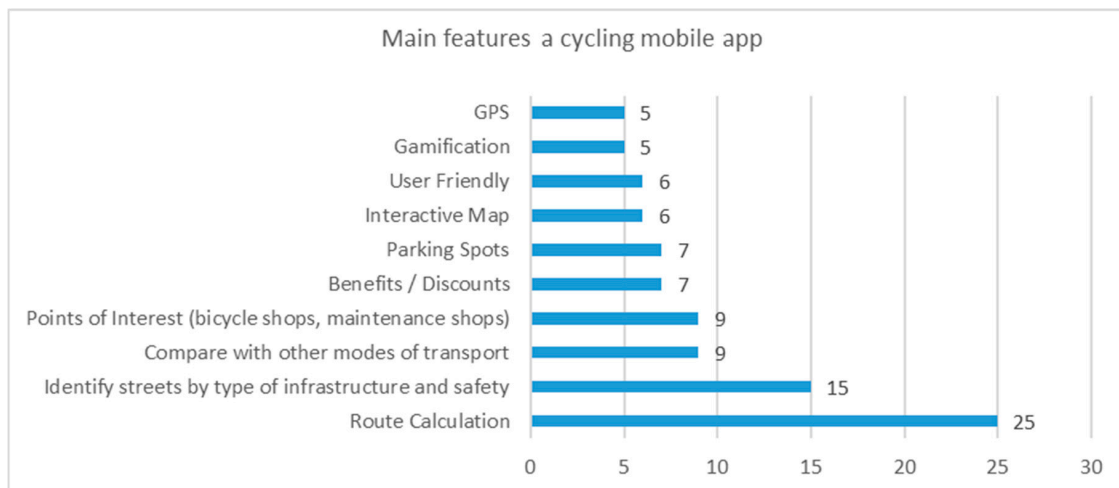

Figure 4. Top 10 answers to the question: "what features should an app have compared to existing ones?" (source: own work).

4.3. Conceptualization and Development of the Mobile Application and Platform

According to the proposed methodology, Table 9 shows the main features that a cycling app should have, based on the relevance that both groups of cyclists have regarding the main features provided by the existing apps analyzed in this work. Cyclists consider that the three most important features, which are covered by the existing apps, are the travelled distance, a map, and the time of activity. As we can see in the same Table 8, the map is present in all of the mentioned applications, but the travel distance and the time of activity were present only in 87.75% of them.

Table 9. Application Features on Existing Applications and percentage of cyclists answers as important features.

Application Features	Existing Apps	Cyclists Answers	
		Regular	Non-Regular
Travelled Distance	87.75%	67.83%	65.15%
Time of Activity	87.75%	60.84%	61.36%
Calories Burned	25.00%	34.97%	39.39%
Login with social network	75.00%	42.66%	36.36%
Elevation Gain	50.00%	23.78%	23.49%
Average Speed	50.00%	38.46%	39.39%
Instantaneous velocity	50.00%	20.98%	24.24%
Map	100.00%	63.64%	56.82%
Comparison with other modes of transport	12.50%	41.96%	32.58%

Thus, by matching the existing features in cycling apps and the opinion of the inquired cyclists from Braga, we are now able to identify the basic level of information/features that a cycling mobile app should have. Furthermore, this information could be relevant and used by other similar cities.

According to the cyclists' answers that were previously analyzed on topic 4.2 and the information provided in Table 9, we can say that a mobile application must, at least, have the following features:

- Travelled distance;

- Map;
- Time of activity;
- Login using social networks;
- Average Speed;
- Calories Burned;
- Route Calculation;
- Streets identification by type of infrastructure and safety;
- Comparison with other means of transport;
- Points of Interest;
- Benefits/Discounts;
- Parking Spots.

Based on these results and on behalf of this research project, we developed a prototype of a cycling application and a digital platform. Its layout is shown Figures 5 and 6. This digital solution mobile application is now in a pre-test phase, i.e., in the experimentation phase, and it has been used by 29 people in order to solve some problems that could be detected when using the app.
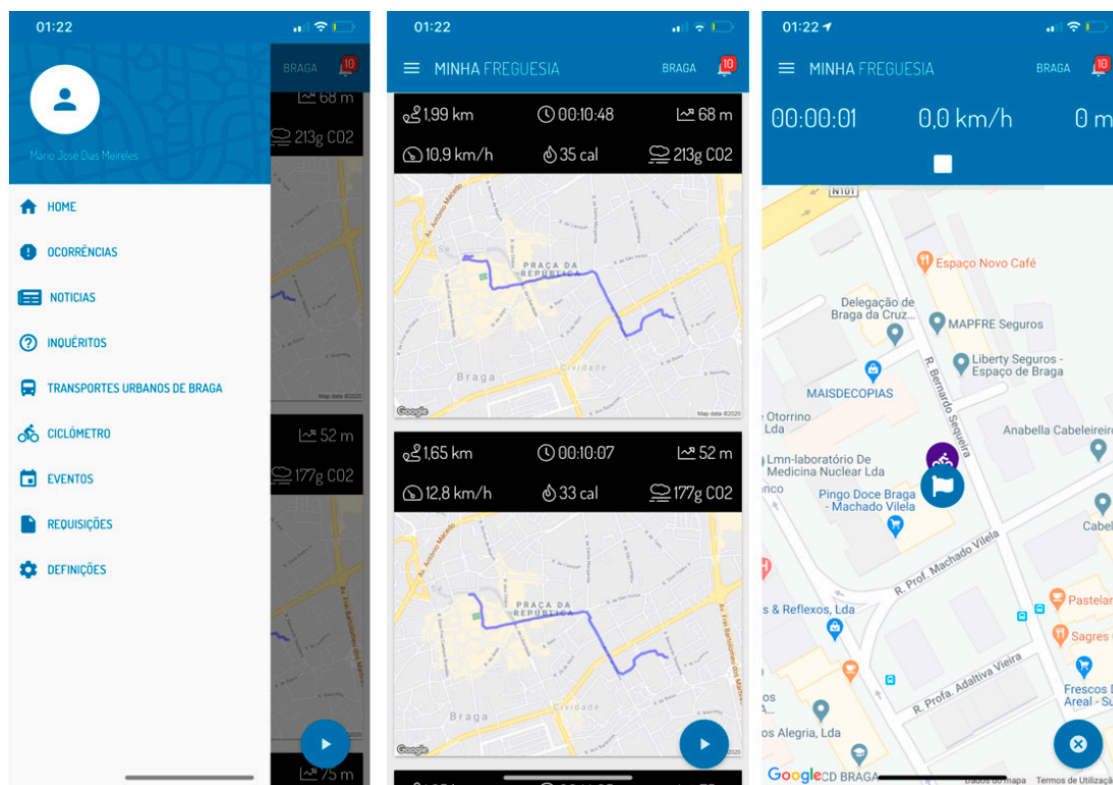
Figure 5. Application Prototype with the Bicycle Module developed to the inherent research project (Source: own).
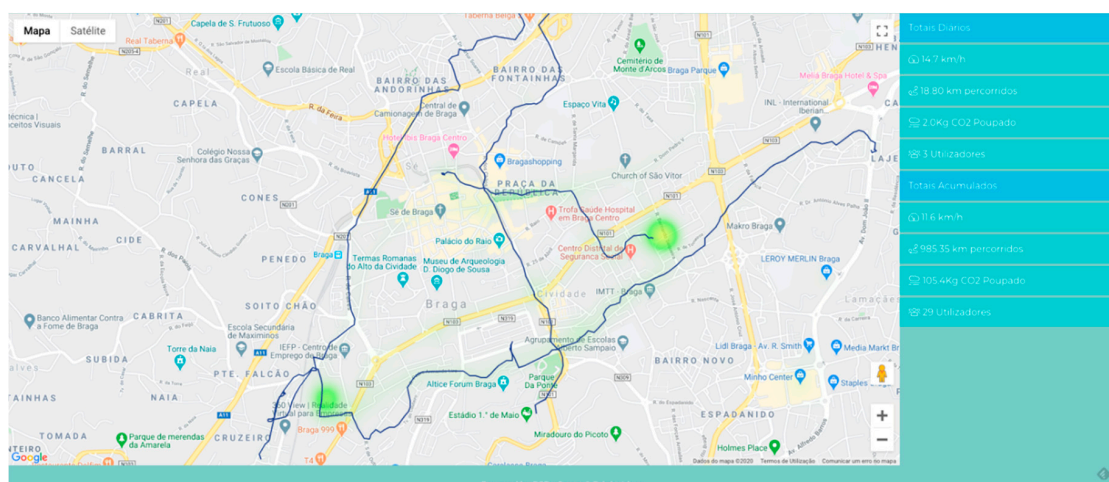
Figure 6. Digital Platform with users tracking information by day and time (Source: own work).

The application will be tested during the next year to gather robust (quantity and quality) results that should allow us to confirm whether a digital solution based on a cycling mobile platform and app can or cannot influence a non-regular cyclist to become a regular cyclist and a non-cyclist to become a non-regular or even a regular cyclist since he or she could be more easily accustomed to cycling in the starter cycling city of Braga.

The Digital Platform (layout presented in Figure 6) is one of the ways to see the routes that cyclists using the application are effectively taking, and this will be useful for the local transport and planning authorities to analyze cyclists' behaviors, needs, and expectations to better adequate their policies and strategies to promote cycling in Braga.

5. Conclusions

This research focused on the development of a digital tool to support and increase cycling in a starter cycling city. According to the literature, cycling can be mostly promoted through adequate infrastructures, by connecting them with other means of transport in a multimodality approach, and through changes in cycling behavior, namely by using digital solutions that can be integrated into future mobility as a service (MaaS) solutions for cities.

With this in mind, we developed a case study on the Portuguese city of Braga, since the local government had assumed the need to improve cycling for the promotion of more sustainable mobility, by creating, in a first phase, 22 km of cycling paths in the city (76 km are planned). However, they have not yet made any effort to develop digital solutions to increase cycling, despite having already demonstrated, as a local transport authority, that this will be their next step.

In this context, it was concluded that neither the city of Braga nor any other medium-sized Portuguese city have any type of digital solution to promote cycling. This is a gap that this work addressed by developing a methodology that can be replicated in any other mid-sized starter cycling city in Portugal and around the world.

It is also important to highlight that Portugal has recently adopted an active position in promoting cycling all over the country, but especially in cities, by creating a National Strategy to Active Mobility—Cycling, which sets the goal of increasing bicycle mode share to 10% in Portuguese cities [29]. In this particular context, this work presented a methodology to create a digital cycling platform and mobile application that would lead non-regular cyclists to adopt the bicycle as the main means of transport on a daily basis, especially in mid-sized starter cycling cities.

The case study was the starter cycling city of Braga, consisting of a characterization of the city's cycling system in terms of the existing physical and digital infrastructures and on the evaluation of the potential influence that a proper mobile app for cycling could have, based on a survey of the city's

cyclists. Therefore, it is important to emphasize that it is not easy to work in a territory where the data related to mobility is outdated. Everything becomes even more complicated when the numbers from the existing studies do not match because the survey questions were different. Without mobility and mode share numbers, it is necessary to put a lot of effort into knowing the case study's "population", i.e., the number of cyclists in Braga.

Thus, one of the weaknesses that can be pointed out in this work is the need to compare cyclists and non-cyclists. However, there are a lot of studies about non-cyclists and even in Portugal, a recent study from the city of Lisbon made this comparison between cyclists and non-cyclists to increase cycling in the city [20]. According to this study, the barriers identified by non-cyclists to engage in the activity are related to the idea that riding a bicycle with traffic is not safe, the distances they have to travel require too much effort, the city being too hilly, and the lack of a safe, secure and suitable bicycle network. These barriers could also be perceived as default by non-cyclists from all the Portuguese cities.

Therefore, this work did not include non-cyclists since even if they could make relevant contributions to understand the main issues and obstacles for them not using a bicycle, they would not have the same perception about the reality of cycling in a starter cycling city. Besides, there is a high probability that a non-cyclist will not know what the existing cycling applications and platforms are and will evaluate their suitability to the type of cycling they practice.

Thus, the aim of the methodology was to develop a digital solution that could lead to an increase in cycling in the starter cycling city of Braga. Also, this was based on the survey applied to people that already use bicycles in the city of Braga in order to assess the local characteristics of cyclists and cycling, as well as the relevance of using a mobile application in the promotion and increase of bicycle usage in urban travels. The survey focused on cyclists who are more familiar with cycling in the context of low modal representation, especially in relation to motorized traffic. Beyond that, the reasoning behind the choice of the survey's sample was to encourage non-regular cyclists, namely the ones that cycle for sport or leisure purposes, to use the bicycle more regularly. The group of cyclists represent around 50% of all types of cyclists in the starter cycling city of Braga, and their shift to a more regular use can also have a strong influence on others, especially non-cyclists, to use bicycles, therefore leading by example.

In this sense, this work will contribute to the literature in terms of characterizing the Portuguese reality of mid-sized city cyclists, as an example of cyclists from a South European city, and also to define what an application designed to boost the regular bicycle usage should have, since Braga is a medium-sized starter cycling city that could be seen as a model to many other cities in Portugal.

In terms of the digital cycling infrastructures of Braga, the survey respondents gave more relevance to an app when they were using the bicycle as a way of exercise (3.69 points in 5) and gave the same score when they were using the bicycle as a means of transport or for leisure (3.47 points in 5).

The existence of a map, the travelled distance, the time travelled, the reduction in CO_2 emissions compared to that of an automobile, the average speed, the comparison between means of transport, and the calories burned are the most important characteristics for the respondents, in this order. Most respondents use Strava (38.55%) to track their daily bicycle trips. Google Maps was used by 50.55% of the respondents, but this app does not offer a tracking feature. Only 22.91% did not use any application.

As mentioned in this state of the art research, we find that Strava is, in fact, the most widely used mobile app, but we also have Bike Citizens as a wider platform, which allows not only users to track their activities, but also allows planners to use real information to make more informed decisions. Interestingly, no respondents mentioned things like improved application battery performance as a need to take into account when developing new applications.

Although respondents felt that a digital platform was useful for all trips, respondents were divided when they answered whether a platform could lead to more people using bicycles as their main means of transport. In other research, we have seen authors who indicate this possibility. We know that the existing infrastructure in cities is a decisive factor in attracting and increasing bicycle users. In the case of Braga, the lack of adequate bicycle infrastructure and being a car-centric city makes the population afraid of walking and cycling in the city. This may be one of the factors for the difference in

answers: a digital platform may not be enough in Braga. However, we know that more than half of the cyclists (55.64%) said that a cycling application could be a way to influence the adoption of the bicycle as a means of transport. But when we break down the answers by the type of cyclists, 60.6% of the non-regular cyclists from Braga considered that an application could lead to more people using bicycles as a means of transport.

If 60.6% of the non-regular cyclists start using a smartphone application that "converts" them into regular-cyclists, the number of people using bicycles regularly will increase. Thus, the applications is not enough to influence a relevant number of people to use the bicycle just by itself, but it can increase the regular use of bicycles among cyclists. Moreover, in cities with very low levels of bicycle use as a regular means of transport, apps can have a big impact and create new dynamics in the city's mobility, creating a more eco-friendly social environment, boosting the local economy, and forcing political decisions that favor the use of bicycles.

In terms of existing and new features that an application should have, the non-cyclists will never give the same contribution that the cyclists gave for this work because the cyclists are familiarized with some applications and with the problems and opportunities that they might face on the city's streets. Besides that, the barriers that non-cyclists have to pass until they use a bicycle regularly are bigger than the barriers that a non-regular cyclist has to pass to use a bicycle to commute regularly in the city.

Regarding what can be added to a cycling application or platform, the answer turned out to be a compilation of the work already produced, and their integration into a single platform. The platform/tool "Bike Citizens" does not allow people to report problems, and this was something that was noticed as an issue. It seems that BSB's "Minha Freguesia" platform could be a good alternative engine that suppresses this flaw, encourages cycling, and integrates various aspects of the city, with mobility being one of them. That way, we received contributions to develop the platform and application "Minha Freguesia" so that it can contribute to the population adopting the bicycle as a means of transport. This mobile (smartphone) application is already integrated with other mobility services, so we defend that cycling can also be integrated in order to make the application even more efficient. It is not yet a MaaS—Mobility as a Service because the systems are not yet integrated, but the path that the city is currently taking is towards the integration of mobility systems.

Among cyclists, there are more who think that a smartphone application can encourage the use of bicycle among those who use it for sport or leisure (60.6%) than among those who are using it to commute (51%). It is probable that a smartphone application can lead to having more people riding a bicycle frequently. This can be true not only for Braga, but for all the places where people are using the bicycle only for sport/leisure.

If cyclists seem to think that an application can result in more people riding bicycles on a daily basis, and here we can assume that more cyclists turn into commuters, then it is also important to know if non-cyclists in Braga think that an app can change their behavior and make them use bicycles on a daily basis. This is work that could and should be done in the future.

Here resides the originality of this work because from the theoretical framework, we know that in the studies that approach cyclists and non-cyclists' barriers, the relevance given to smartphone applications is either null or irrelevant, even in Lisbon, which is also a Starter Cycling City. However, in our survey, conducted in another Portuguese Starter Cycling City, Braga, we can see that the application has relevance for cyclists in terms of enlarging the regular use of bicycles.

These results are only part of a larger discussion because in Portugal, the increment of bicycle usage is considered a national purpose. The National Strategy to Active Mobility—Cycling has the goal to increment bicycle use to the European average numbers: 7.5%. To achieve that, there are plans to finance infrastructure, but also plans to finance other programs that can expand the use of bicycles. Thus, cycling can be scaled on a national level and, regarding these results, a smartphone application can play an important role in achieving these goals.

For now, it is necessary to continue improving and testing the platform to see whether or not it raises awareness in cyclists to use bicyles as a means of transport. Considering the critical period

of climate changes that we are experiencing, we need to take a step back and observe the way that we move within cities. It is not surprising that there are some concerns from the local and national governments towards promoting the use of bicycle in cities. Thus, new policies need to be implemented in order to increase the number of cyclists. A city mobility application that considers cycling can help revise some policies, not only with the implementation of the app, but in its complementarity with other measures.

References

1. UN. *World Urbanization Prospects: The 2014 Revision, Highlights*; Department of Economic and Social Affairs: New York, NY, USA, 2014.
2. Mendes, J.F.G. *O Futuro Das Cidades*; Minerva: Coimbra, Portugal, 2011.
3. Ritchie, H.; Roser, M. CO_2 and Greenhouse Gas Emissions. *Our World Data* **2017**.
4. Donário, A.A.; dos Santos, R.B. Custo Económico e Social Dos Acidentes de Viação Em Portugal. *Economica* **2012**, *500*, 6.
5. Newman, P.; Kenworthy, J. The End of Automobile Dependence. In *The End of Automobile Dependence*; Springer: Berlin/Heidelberg, Germany, 2015; pp. 201–226.
6. Nieuwenhuijsen, M.J.; Khreis, H. Car Free Cities: Pathway to Healthy Urban Living. *Environ. Int.* **2016**, *94*, 251–262. [CrossRef] [PubMed]
7. CE. *Cidades Para Bicicletas, Cidades de Futuro*; Serviço das Publicações Oficiais das Comunidades Europeias: Luxemburgo, 2000.
8. Lindsay, G.; Macmillan, A.; Woodward, A. Moving Urban Trips from Cars to Bicycles: Impact on Health and Emissions. *Aust. N. Z. J. Public Health* **2011**, *35*, 54–60. [CrossRef] [PubMed]
9. Gössling, S.; Choi, A.; Dekker, K.; Metzler, D. The Social Cost of Automobility, Cycling and Walking in the European Union. *Ecol. Econ.* **2019**, *158*, 65–74. [CrossRef]
10. Herrador, V.H.; Salazar, C.; Peña, M.L.; Herrera, J. *Metodología Para El Desarrollo Intermodal Bicicleta-transporte Público*; Área Metropolitana de Sevilla: Sevilla, Spain, 2014.
11. Behrendt, F. Why Cycling Matters for Smart Cities. Internet of Bicycles for Intelligent Transport. *J. Transp. Geogr.* **2016**, *56*, 157–164. [CrossRef]
12. Nelson, A.C.; Allen, D. If You Build Them, Commuters Will Use Them: Association between Bicycle Facilities and Bicycle Commuting. *Transp. Res. Rec.* **1997**, *1578*, 79–83. [CrossRef]
13. Garrard, J.; Rose, G.; Lo, S.K. Promoting Transportation Cycling for Women: The Role of Bicycle Infrastructure. *Prev. Med.* **2008**, *46*, 55–59. [CrossRef]
14. Zahabi, S.A.H.; Chang, A.; Miranda-Moreno, L.F.; Patterson, Z. Exploring the Link between the Neighborhood Typologies, Bicycle Infrastructure and Commuting Cycling over Time and the Potential Impact on Commuter GHG Emissions. *Transp. Res. Part D Transp. Environ.* **2016**, *47*, 89–103. [CrossRef]
15. Grudgings, N.; Hagen-Zanker, A.; Hughes, S.; Gatersleben, B.; Woodall, M.; Bryans, W. Why Don't More Women Cycle? An Analysis of Female and Male Commuter Cycling Mode-Share in England and Wales. *J. Transp. Heal.* **2018**, *10*, 272–283. [CrossRef]
16. Meireles, M. Como Promover a Mobilidade Ciclável Em Portugal. O Caso Da Cidade de Braga. Master's Thesis, Universidade do Minho, Braga, Portugal, 2017.
17. Savan, B.; Cohlmeyer, E.; Ledsham, T. Integrated Strategies to Accelerate the Adoption of Cycling for Transportation. *Transp. Res. Part F Traffic Psychol. Behav.* **2017**, *46*, 236–249. [CrossRef]

18. Dill, J.; McNeil, N. Four Types of Cyclists? Examination of Typology for Better Understanding of Bicycling Behavior and Potential. *Transp. Res. Rec.* **2013**, *2387*, 129–138. [CrossRef]

19. ECF. What Would Happen If We Prioritised Cycling? Available online: https://ecf.com/news-and-events/news/what-would-happen-if-we-prioritised-cycling (accessed on 26 December 2019).

20. Félix, R.; Moura, F.; Clifton, K.J. Maturing Urban Cycling: Comparing Barriers and Motivators to Bicycle of Cyclists and Non-Cyclists in Lisbon, Portugal. *J. Transp. Heal.* **2019**, *15*, 100628. [CrossRef]

21. Ul-Abdin, Z.; De Winne, P.; De Backer, H. Risk-Perception Formation Considering Tangible and Non-Tangible Aspects of Cycling: A Flemish Case Study. *Sustainability* **2019**, *11*, 6474. [CrossRef]

22. Asperges, T.; Vanmaele, L. BYPAD (BicYcle Policy AuDit): Cycling, the European Approach Total Quality Management in Cycling Policy. Results and Lessons of the BYPAD-Project., s.l.: s.n. **2008**.

23. Handy, S.; Van Wee, B.; Kroesen, M. Promoting Cycling for Transport: Research Needs and Challenges. *Transp. Rev.* **2014**, *34*, 4–24. [CrossRef]

24. O'brien, O.; Cheshire, J.; Batty, M. Mining Bicycle Sharing Data for Generating Insights into Sustainable Transport Systems. *J. Transp. Geogr.* **2014**, *34*, 262–273. [CrossRef]

25. Strauss, J.; Miranda-Moreno, L.F.; Morency, P. Mapping Cyclist Activity and Injury Risk in a Network Combining Smartphone GPS Data and Bicycle Counts. *Accid. Anal. Prev.* **2015**, *83*, 132–142. [CrossRef]

26. Romanillos, G.; Zaltz Austwick, M. Madrid Cycle Track: Visualizing the Cyclable City. *J. Maps* **2016**, *12*, 1218–1226. [CrossRef]

27. Meireles, M.; Ribeiro, P. O Papel de Uma Associação Não-Governamental Na Promoção Do Uso Da Bicicleta Em Braga. *II Encontro Nac. Sobre Reabil. Urbana e Construção Sustentável do Edifício Para a Escala Urbana* **2017**, 299–306.

28. Meireles, M.; Ribeiro, P. Como Promover a Mobilidade Ciclável Em Portugal. *CECS-Publicações/eBooks* **2018**, 131–145.

29. Secretaria de Estado Adjunta e da Mobilidade. *Estratégia Nacional Para a Mobilidade Ativa—ENMA 2020–2030*; Governo de Portugal: Lisboa, Portugal, 2019.

30. Wallström, M. Reclaiming City Streets for People: Chaos or Quality of Life. Luxembourg: Directorate-General for the Environment, European Commission, downloaded May 2007. Available online: https://op.europa.eu/en/publication-detail/-/publication/94a8a003-be86-467a-9a85-63a5d52bf7ae (accessed on 20 January 2020).

31. Sadik-Khan, J.; Solomonow, S. *Streetfight: Handbook for an Urban Revolution*; Penguin Books: New York, NY, USA, 2017.

32. van Goeverden, K.; Nielsen, T.S.; Harder, H.; van Nes, R. Interventions in Bicycle Infrastructure, Lessons from Dutch and Danish Cases. In Proceedings of the 18th Euro Working Group Transportation EWGT 2015, Delft, The Netherlands, 14–16 July 2015.

33. CROW. *Design Manual for Bicycle Infrastructure*; CROW: Delft, The Netherlands, 2007.

34. DfT. *Cycle Infrastructure Design*; TSO: Norwich, UK, 2008.

35. Cairns, S.; Atkins, S.; Goodwin, P. *Disappearing Traffic? The Story so Far*; The Institution of Civil Engineers-Municipal Engineer: London, UK, 2002; Volume 151, pp. 13–22.

36. Alves, M.J. Encorajar o Uso Da Bicicleta: Que Opções? Available online: https://sites.google.com/site/mariojalves/encorajarousodabicicletav1.pdf (accessed on 20 January 2020).

37. IMTT. *COLECÇÃO DE BROCHURAS TÉCNICAS/TEMÁTICAS Acalmia de Tráfego*; IMTT: Lisbon, Portugal, 2011.

38. Blitz, A.; Busch-Geertsema, A.; Lanzendorf, M. More Cycling, Less Driving? Findings of a Cycle Street Intervention Study in the Rhine-Main Metropolitan Region, Germany. *Sustainability* **2020**, *12*, 805. [CrossRef]

39. IMTT. *COLECÇÃO DE BROCHURAS TÉCNICAS/TEMÁTICAS Rede Ciclável—Princípios de Planeamento e Desenho*; IMTT: Lisbon, Portugal, 2011.

40. Celis, P.; Bølling-Ladegaard, E. *Bicycle Parking Manual*; The Danish Cyclists Federation: Copenhagen, Denmark, 2008.

41. FPCUB. *Manual de Estacionamentos Para Bicicletas*; FPCUB: Lisbon, Portugal, 2015.

42. Summala, H.; Pasanen, E.; Räsänen, M.; Sievänen, J. Bicycle Accidents and Drivers' Visual Search at Left and Right Turns. *Accid. Anal. Prev.* **1996**, *28*, 147–153. [CrossRef]

43. van Bekkum, J.E.; Williams, J.M.; Morris, P.G. Cycle Commuting and Perceptions of Barriers: Stages of Change, Gender and Occupation. *Health Educ.* **2011**, *111*, 476–497. [CrossRef]

44. Iwińska, K.; Blicharska, M.; Pierotti, L.; Tainio, M.; de Nazelle, A. Cycling in Warsaw, Poland–Perceived Enablers and Barriers According to Cyclists and Non-Cyclists. *Transp. Res. Part A Policy Pract.* **2018**, *113*, 291–301. [CrossRef]

45. Gatersleben, B.; Haddad, H. Who Is the Typical Bicyclist? *Transp. Res. Part F Traffic Psychol. Behav.* **2010**, *13*, 41–48. [CrossRef]

46. Chowdhury, S.; Costello, S.B. An Examination of Cyclists' and Non-Cyclists' Mode Choice under a New Cycle Network. *Road Transp. Res. A J. Aust. New Zeal. Res. Pract.* **2016**, *25*, 50.

47. Cervero, R.; Caldwell, B.; Cuellar, J. Bike-and-Ride: Build It and They Will Come. *J. Public Transp.* **2013**, *16*, 5. [CrossRef]

48. Hull, A.; O'Holleran, C. Bicycle Infrastructure: Can Good Design Encourage Cycling? *Urban Plan. Transp. Res.* **2014**, *2*, 369–406. [CrossRef]

49. Biernat, E.; Buchholtz, S.; Bartkiewicz, P. Motivations and Barriers to Bicycle Commuting: Lessons from Poland. *Transp. Res. Part F Traffic Psychol. Behav.* **2018**, *55*, 492–502. [CrossRef]

50. Daley, M.; Rissel, C. Perspectives and Images of Cycling as a Barrier or Facilitator of Cycling. *Transp. Policy* **2011**, *18*, 211–216. [CrossRef]

51. Damant-Sirois, G.; Grimsrud, M.; El-Geneidy, A.M. What's Your Type: A Multidimensional Cyclist Typology. *Transportation (Amst.)* **2014**, *41*, 1153–1169. [CrossRef]

52. Navarro, K.F.; Gay, V.; Golliard, L.; Johnston, B.; Leijdekkers, P.; Vaughan, E.; Wang, X.; Williams, M.-A. SocialCycle What Can a Mobile App Do to Encourage Cycling. In Proceedings of the 38th Annual IEEE Conference on Local Computer Networks-Workshops, Sydney, Australia, 21–24 October 2013; 2013; pp. 24–30.

53. ITDP. *The Bike-Share Planning Guide*; ITDP: New York, NY, USA, 2013.

54. DeMaio, P. Bike-Sharing: History, Impacts, Models of Provision, and Future. *J. Public Transp.* **2009**, *12*, 3. [CrossRef]

55. Risser, R.; Sucha, M. Start Walking! How to Boost Sustainable Mode Choice—Psychological Measures to Support a Shift from Individual Car Use to More Sustainable Traffic Modes. *Sustainability* **2020**, *12*, 554. [CrossRef]

56. ECF. Bike2Work. 2014. Available online: https://ecf.com/projects/past-projects/bike2work (accessed on 21 January 2020).

57. MUBi. Bike to School Day. 2014. Available online: https://mubi.pt/2014/03/18/projeto-bike-to-school-day/ (accessed on 22 January 2020).

58. Annear, S. To Avoid "Doorings", Cyclist Wants Drivers to Do the "Dutch Reach". 2016. Available online: http://epaper.bostonglobe.com/infinity/article_popover_share.aspx?guid=e08a2101-7a23-42a8-a111-a5750dab1f3a (accessed on 23 January 2020).

59. ECF. Scientists for Cycling. 2016. Available online: https://ecf.com/community/scientists-cycling (accessed on 19 January 2020).

60. MAI. Decreto-Lei n.º 114/94, de 3 de Maio, Alterado Pela Lei n.º 40/2016, de 29 de Julho Do Ministério Da Administração Interna. *Portugal NV—Diário da República: I série, Nº 169* **2016**.

61. Maker, C. Strict Liability in Cycling Laws to Ready the Roads for Environmentally Friendly Commuting. *BC Envtl. Aff. L. Rev.* **2015**, *42*, 473.

62. Share, R. *The Case for Presumed Liability on Scotland's Roads*; Road Share: London, UK, 2015.

63. Schäfer, H.-B.; Müller-Langer, F. Strict Liability versus Negligence. In *Tort Law and Economics*; Faure, M., Ed.; Edward Elgar Publishing: Cheltenham, UK, 2008; Part I, Chapter I.

64. Roughton, C.; van Hengel, D.; Duncan, A.; Weigand, L.; Birk, M. Creating Walkable and Bikeable Communities: A User Guide to Developing Pedestrian and Bicycle Master Plans. 2012. Available online: https://ppms.trec.pdx.edu/media/project_files/IBPI%20Master%20Plan%20Handbook%20FINAL.pdf (accessed on 18 January 2020).

65. da F.Léchaud, C. The Role of Innovation on Bicycle Commuting in Portugal. Master' Thesis, Universidade Europeia, Lisboa, Portugal, 2016.

66. Schwanen, T. Beyond Instrument: Smartphone App and Sustainable Mobility. *Eur. J. Transp. Infrastruct. Res.* **2015**, *15*, 675–690.

67. Barratt, P. Healthy Competition: A Qualitative Study Investigating Persuasive Technologies and the Gamification of Cycling. *Health Place* **2017**, *46*, 328–336. [CrossRef]

68. Pritchard, R. Revealed Preference Methods for Studying Bicycle Route Choice—A Systematic Review. *Int. J. Environ. Res. Public Health* **2018**, *15*, 470. [CrossRef]

69. Heesch, K.C.; Langdon, M. The Usefulness of GPS Bicycle Tracking Data for Evaluating the Impact of Infrastructure Change on Cycling Behaviour. *Heal. Promot. J. Aust.* **2017**, *27*, 222–229. [CrossRef] [PubMed]

70. Musakwa, W.; Selala, K.M. Mapping Cycling Patterns and Trends Using Strava Metro Data in the City of Johannesburg, South Africa. *Data Br.* **2016**, *9*, 898–905. [CrossRef] [PubMed]

71. Jestico, B.; Nelson, T.; Winters, M. Mapping Ridership Using Crowdsourced Cycling Data. *J. Transp. Geogr.* **2016**, *52*, 90–97. [CrossRef]

72. Mangiaracina, R.; Perego, A.; Salvadori, G.; Tumino, A. A Comprehensive View of Intelligent Transport Systems for Urban Smart Mobility. *Int. J. Logist. Res. Appl.* **2017**, *20*, 39–52. [CrossRef]

73. Benevolo, C.; Dameri, R.P.; D'Auria, B. Smart Mobility in Smart City. In *Empowering Organizations*; Springer: Berlin, Germany, 2016; pp. 13–28.

74. Mone, G. The New Smart Cities. *Commun. ACM* **2015**, *58*, 20–21. [CrossRef]

75. Oliveira, D.S.; Afonso, J.A. Mobile Sensing System for Georeferenced Performance Monitoring in Cycling. In Proceedings of the World Congress on Engineering 2015, London, UK, 1–3 July 2015; Volume 2217, pp. 269–273.

76. Haie, N. Sustainable Efficiency (Sefficiency) of Water Use Systems amidst Environmental Impacts. In Proceedings of the International Conference of Recent Trends in Environmental Science and Engineering (RTESE'17), Toronto, ON, Canada, 23–25 August 2017; Paper no 11. pp. 111–115.

77. Addanki, S.C.; Venkataraman, H. Greening the Economy: A Review of Urban Sustainability Measures for Developing New Cities. *Sustain. Cities Soc.* **2017**, *32*, 1–8. [CrossRef]

78. Romanillos, G.; Zaltz Austwick, M.; Ettema, D.; De Kruijf, J. Big Data and Cycling. *Transp. Rev.* **2016**, *36*, 114–133. [CrossRef]

79. Griffin, G.P.; Jiao, J. Crowdsourcing Bicycle Volumes: Exploring the Role of Volunteered Geographic Information and Established Monitoring Methods. *URISA J.* **2019**, *27*, 57–67.

80. Piwek, L.; Joinson, A.; Morvan, J. The Use of Self-Monitoring Solutions amongst Cyclists: An Online Survey and Empirical Study. *Transp. Res. Part A Policy Pract.* **2015**, *77*, 126–136. [CrossRef]

81. Griffin, G.P.; Jiao, J. Where Does Bicycling for Health Happen? Analysing Volunteered Geographic Information through Place and Plexus. *J. Transp. Heal.* **2015**, *2*, 238–247. [CrossRef]

82. Strava. Strava. 2019. Available online: www.strava.com (accessed on 10 February 2020).

83. Under Armour. Endomondo. 2019. Available online: www.endomondo.com (accessed on 10 February 2020).

84. West, L.R. Strava: Challenge Yourself to Greater Heights in Physical Activity/Cycling and Running. *Br. J. Sport. Med.* **2015**, *49*, 1024. [CrossRef] [PubMed]

85. Garmin Ltd. Garmin Connect. 2019. Available online: https://connect.garmin.com/ (accessed on 10 February 2020).

86. Under Armour. Map My Ride. 2019. Available online: https://www.mapmyride.com/ (accessed on 10 February 2020).

87. Komoot GmbH. Komoot. 2019. Available online: https://www.komoot.com/ (accessed on 10 February 2020).

88. Relive, B.V. Relive. 2019. Available online: https://www.relive.cc/ (accessed on 10 February 2020).

89. Biklio. Biklio. 2019. Available online: https://www.biklio.com/ (accessed on 10 February 2020).

90. CloudSport. MoveX. 2019. Available online: https://movex.me/en-us/index.html (accessed on 10 February 2020).

91. Ferreira, P.; Zabolotny, A.; Barreto, J. Bicycle Mode Activity Detection with Bluetooth Low Energy Beacons. In Proceedings of the 2019 IEEE 18th International Symposium on Network Computing and Applications (NCA), Cambridge, MA, USA, 26–28 September 2019; 2019; pp. 1–4.

92. Van Schaik, F. Designing a Mobile User Interface for Road Cyclists. Master's Thesis, TU Delft, Delft, The Netherands, 2013.

93. Khodambashi, S.; Liodden Sandes, R.; Gulla, J.A.; Abrahamson, P. Design and Implementation of Mobile App and Web-Based Software for Management and Monitoring of Bicyle Routes. In Proceedings of the European, Mediterrianean & Middle Eastern Conference on Information Systems, Krakow, Poland, 23–24 June 2016.

94. CEiiA. AYR—Are You Ready. Available online: https://www.ceiia.com/ayr (accessed on 21 December 2019).

95. Dijkstra, L.; Poelman, H. Cities in Europe: The New OECD-EC Definition. *Reg. Focus* **2012**, *1*, 1–13.

96. Município de Braga. Relatório de Revisão Do Plano Diretor Municipal de Braga. 2015. Available online: http://pdmbraga.cm-braga.pt/index.php/relatorio (accessed on 24 January 2020).

97. Braga Ciclável. Mapa Braga Ciclável. Available online: www.bragaciclavel.pt/mapa (accessed on 25 January 2020).

98. Ministerie van Infrastructuur en Waterstaat. Kennisinstituut voor Mobiliteitsbeleid (KiM). Available online: https://www.kimnet.nl/ (accessed on 30 January 2020).

99. Federal Ministry of Transport and Digital Infrastructure. Fahrradportal. Available online: https://nationaler-radverkehrsplan.de/en/themenfelder/statistics (accessed on 1 February 2020).

100. DTU Management - Center for Transport Analytics. The Danish National Travel Survey. Available online: https://www.cta.man.dtu.dk/english/national-travel-survey (accessed on 2 February 2020).

101. CEREMA. Enquêtes Déplacement. Available online: https://www.cerema.fr/fr/mots-cles/enquete-deplacements (accessed on 20 February 2020).

102. Department for Transport. National Travel Survey. Available online: https://www.gov.uk/government/collections/national-travel-survey-statistics (accessed on 3 February 2020).

103. INE—Instituto Nacional de Estatística. Meio de Transporte Mais Utilizado Nos Movimentos Pendulares (N.o) Por Local de Residência (à Data Dos Censos 2011) e Principal Meio de Transporte. Available online: https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&indOcorrCod=0007093&contexto=bd&selTab=tab2 (accessed on 4 February 2020).

104. ATKINS; WAY2GO. Estudo de Mobilidade Integrada da Associação de Municípios de fins específicos - Quadrilátero Urbano (Maio 2014). Available online: http://81.90.61.41/revisaopdm/index_doc_referencia/dref_mobil.html (accessed on 5 February 2020).