Research article

Pursuing softer urban mobility behaviors through game-based apps

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ABSTRACT

Cities are currently engaged through their urban policies in pushing people towards less environmentally impacting mobility modalities: therefore, cycling and walking are strongly promoted, especially by means of new and wider limited traffic and no-cars zones. In this paper, the effectiveness of the new smartphones and apps-based technologies in modifying the mobility behaviors of citizens towards more sustainable choices has been investigated. Specifically, the potential of a smartphone app, directly involving citizens by means of a game rewarding the most sustainable trips, has been tested on a university commuters' group. These latter, starting from their current mobility situation, were challenged by an enhanced scenario characterized by more restrictive and sustainable targets. Promising results have been obtained suggesting that game–based tools could be effectively used as urban policy interventions intended to obtain a more sustainable mobility.

1. Introduction

Sustainable Development Goal 11 [1], starting from the consideration that half of humanity lives in cities (with a still on-going urbanization trend), aims to render urban contexts more inclusive and, at the same time, safe, resilient and sustainable. Mobility is certainly one of the crucial issues where this complex challenge is played. However, policies assessed by local government institutions usually tend to intervene on the urban street networks by designing new and typically expensive infrastructures that, in addition, require long times to be realized. Such measures aim at enhancing the traditional mobility modalities of people through either private or public transport means, whereas only a few attention is paid to the mobility behavior of people. A change of these habits, instead, could achieve the double result of, on one hand, involving people in a shared building-up of smart cities' features and, on the other hand, enhancing the performances of the mobility characteristics without involving time and money-costing interventions on infrastructures.

Therefore, there is an increasing need for eco-efficient policy tools that could help local administrations in their challenging jobs of implementing more and more environmentally effective mobility policies. In this way, expensive infrastructural interventions, which heavily influence the urban layouts [2, 3], can be limited: the role of the different type of roundabouts in limiting the pollutant emissions has been deeply analyzed [2]. On the other hand, the causes of traffic delay that, on turn, result in a lowering of the air quality in urban contexts is also analyzed [3]. In the same time, the needs of different categories of movers, like bikers, can be properly taken into account [4].

Anyway, it is evident that, to improve the mobility configuration of a city, a suitable behavioral change of the people habits must be encouraged, due to evident pollution abatement implications related to mobility habits of citizens [5, 6]. Pushing people towards such better environmental mobility behavior can be usefully pursued by means of the so-called persuasive technologies [7] that underline the active role of citizens in this process. Commuters are certainly an important category of people moving from and toward cities, contributing with their different modes of mobility to the environmental performances of towns, and college students are certainly an important group of movers whose mobility habits need to be investigated [8].

Hence, local administrators should pay a careful attention to this relevant category of movers by promoting actions that could push them

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towards more sustainable mobility modes. The role of benefits in enhancing the mobility in urban contexts has been analyzed in the literature. One of the main findings of these studies is that free car parking is a tool that worsens the inclination to sweet mobility particularly to walking and cycling [9]; conversely, the access to bicycle storage and facilities for changing clothes would improve the level of bicycle commute modes [10]. Moreover, other instruments able to reduce CO_2 emissions in the transportation sector are examined [11] and compared, including carbon tax, energy tax, fuel tax, clean energy vehicle subsidy, and reduction on ticket price.

Clearly, suitable education campaigns along with proper integrated policies of public and private transportation would encourage people both to change their behaviors [12] and to select less impacting modalities among their mobility choices [13]. This is relevant since regulatory approaches alone do not seem to effectively improve the air quality of cities while people's travel choices play an important role for this aim instead [14]. Concerning the students that daily commute toward and from towns, the role of special parking tariffs and dedicated bus services has been also analyzed [15] along with the effects produced by toll payments, mileage reimbursement and free parking [16].

The significant penetration of new technologies such as smartphones and apps need a detailed study of the dynamic social networks [17] in order of singling out useful real life mapping of these behaviors. This would contribute to properly utilize smartphone applications for usefully engaging communities in environmentally conscious habits [18]. These technologies can be regarded nowadays as the key to developing more appropriate and comprehensive transport sustainability indicators [19]. The potential of mobile phones for the monitoring of the geography and mobility of the population [20] as well as for the investigation of the urban mobility in order to understand whether it follows a daily routine [21] has been studied. Nonetheless, the potentialities of the use of such new technologies in promoting attractive rewards for participants, which can be part of effective patterns involving citizens and administrations, have been less frequently investigated [22]. Furthermore, a growing number of cities, in the aim of moving their digital planning and policy-making from ad-hoc to an integrated and strategic approach, have developed urban digital strategies [23]. On purpose, ICT-enabled participatory planning frameworks have been established for guiding policy-making towards the planning of smart cities [24]. All this suggests that a debate between experts and non-experts aimed at understanding the manner in which new technologies can affect (and/or possibly be affected by) urban contexts should be pursued.

The purpose of this paper is to verify in-field whether new technologies such as smartphones and apps can be used within the urban policies to modify the mobility behaviors of citizens towards more sustainable choices. To do this, a field checking of a smartphone app, in which benefits of the game are constituted by scores that can be exchanged with prizes at the local businesses taking part to the project, has been performed on a group of university commuters. These students (starting from their current mobility habits) were challenged by an enhancing scenario characterized by more restrictive and sustainable features. This hypothetical scenario represented the target benchmark to achieve trough the cited rewards-based game.

Moreover, the propensity of commuters towards better mobility habits, even without material rewards, has also been verified. In this case, the participants were pushed only by their environmental consciousness. The good result of this further check shows that suitable policies, aimed at changing mobility behaviors of people, can be usefully implemented in order of improving the effectiveness and sustainability of the urban transportation systems.

2. Materials and methods

It is worldwide recognized the need for a mentality's change of citizens in order of achieving a more sustainable mobility in urban contexts [25, 26, 27]. In fact, since cities are communities made by people, a modification of the urban conditions strongly depends on the way citizens live these contexts, including the fight to the urban traffic jam. In recent years, this effort has been facilitated by the new information technologies that enable the dialogue between citizens and administrations. Smartphone and apps-based technologies [28] are gaining a rising importance in this sense.

2.1. Description of the game tool based on an app for smartphones

TrafficO2 is an action-research project, co-founded in 2012 through the call "Smart Cities and Communities and Social Innovation" promoted by the Italian Education, University and Research Ministry. This action-research is mainly aimed at improving the urban traffic conditions without the recourse to policies imposed by the administrations of cities, but through the involvement of social networks supported by smartphone technologies. On this purpose, TrafficO2 is designed for addressing people towards an effective and environmentally conscious mobility by means of the logic sequence [29] "Move in a sustainable way, collect points, win prizes, save the world!" (Figure 1).

The proposal starts from the consideration that incentives seem to be feasible tools in order of bringing people towards the changing of their urban mobility habits [30, 31]. These incentives can be proposed and offered by the city's retail and services network [32], in order of fostering commuters to moving by softer modal splits, such as on foot or by bicycle. Besides, these "sweet" modalities of commuting, also including the local public transport, vehicle pooling and car sharing, can be encouraged by educational games [33] aimed to drop private traffic intensity and pollution by simply proposing awards in exchange for a more conscious environmental inclination.

Therefore, the mobile phone app selected here and further applied [34, 35] is an info-mobility Decision Support System that is specifically designed to fostering commuters toward more sustainable mobility behaviors by offering incentives for responsible choices. The tool is a platform where participants gain "environmental points" as a prize for their sustainable choices of mobility.

This app intends to put together the interests of two complementary subjects of the urban traffic, namely the communities' employees and the city's commerce and services network [32]. Consequently, all of the local businesses, which adhered to the project (as sponsors) have changed into the stations of a new type of transport system that assumes only the

Figure 1. The TrafficO2 logic sequence of the user experience.

following ways of movement: by foot, by bicycle, by local public transport, by vehicle pooling and by car sharing. The ultimate goal is the reduction of traffic and pollution simply using an educational game [33] that provides prizes in exchange for an environment friendly behavior.

As a decision support system [36] the first information given to each app user, after a survey and being logged in, consists in two personal improvement Scenarios obtained on the base of his/her daily mobility habit and his/her transport means preferred. In this manner, the commuter is aware promptly of what would be his/her total sustainable mobility improvement, and thus, will be more stimulated to fulfill it.

In other words, the user is brought by the User Experience (UX) to select the closest "Local Business Station" (LBS), as the starting or the arrival point. Afterwards, the path will be displayed based on the different kind of travel: walking, biking, public transportation or vehicle sharing. For each choice, the display will show time, environmental cost, economic cost and spent calories. Each preference will allow them gaining a given amount of O2 points (i.e. a virtual currency), by means of which users will get prizes; in this manner, the TrafficO2 platform is turned into a citizens' game [37] aimed at promoting sustainable and environmentally friendly journeys. In fact, in order of increasing their O2 points, users will be allowed to challenge, via both the website and the mobile app, their friends and to play with the information provided by the sponsors.

Clearly, recording and managing the length of the trips performed by users and the way they moved, requires the motion recognition operated by the smartphones technology [38]. Typical sensors, the phones are equipped with - and microprocessors -, overlap information of GPS location, while accelerometers detect the motion system with high accuracy. A software interface, with its dedicated algorithms, trained by means of a Fast Fourier Transform [39], is specifically aimed at this purpose.

Figure 2 reports the screenshots of the app, as it appears to users. For the selected layout trip and modality of mobility, the app presents the pertinent data in terms of time needed for reaching the destination, the burnt calories, the emitted and saved CO_2 along with the correspondent O2 points, and the cumulated score. In this way, the commuter is immediately aware of his/her possible improvement and will therefore be more motivated to achieve it.

The network of stores and businesses, which constitute the sponsors of the game, attributes the virtual currency that is the "O2 points", rewarding the soft ways of moving in a one-to-one dialogue. These greener behaviors will likely result in a reduction of the urban air pollution. Apart the "extrinsic reasons", such as rewards and challenges, the game encourages people to change their habits also through "intrinsic reasons" [40] providing information on burnt calories, costs, carbon footprint, etc. Moreover, the tool bring benefit for the urban network of businesses and sponsors, which actively participate to the project. In fact, local businesses can finance new and innovative advertisings, in this way becoming visible points of the system and getting detailed information about the customer's preferences.

In the proposed scheme, the system will recompense walking trips more than biking ones. In fact, moving on foot gives the opportunity to meet with several stores along the way, so enhancing the effectiveness of the advertising information and the rewards from the sponsors' networks. Despite commuters are reported to be less sensitive to weather conditions than non-commuters [41], the method considers the climate situation by means of proper adding factors to the basic O_2 points per km, particularly on the cloudy and rainy days.

Substantially, each trip selection corresponds to a certain amount of O_2 points (the virtual currency), which the users will get and spend in the participating commercial companies.

Despite the method is specifically aimed at pushing people towards soft mobility choices, the other modalities of travelling between home and the university campus that are actually used must be taken into account, that is: public transportation means, private cars and motorcycles, car-pooling, motor-pooling and car sharing. The central parameter of the tool is represented by the total unidirectional length, L_{trip}, travelled by commuters, which is given by the summation of each individual modality of moving adopted in their trip from home to work. It accounts for all the daily one-way distances, $D0i$, to get to the University by means of the above-cited modalities of moving. In turn, these distances define specific percentage rates of the different mobility systems, M_{0i}, as declared by commuters by means of a direct survey.

That is:

$$L_{i,\ trip} = D_{oi,w} + D_{oi,\ b} + D_{oi,pt} + D_{oi,\ c} + D_{oi,m} + D_{oi,\ cp} + D_{oi,mp} + D_{oi,\ cs} = (M_{0i,\ w} \times L_{i,\ trip}) + (M_{0i,\ b} \times L_{i,\ trip}) + (M_{0i,\ pt} \times L_{i,\ trip}) + (M_{0i,\ c} \times L_{i,\ trip}) + (M_{0i,\ m} \times L_{i,\ trip}) + (M_{0i,\ cp} \times L_{i,\ trip}) + (M_{0i,\ mp} \times L_{i,\ trip}) + (M_{0i,\ cs} \times L_{i,\ trip}) \quad (1)$$
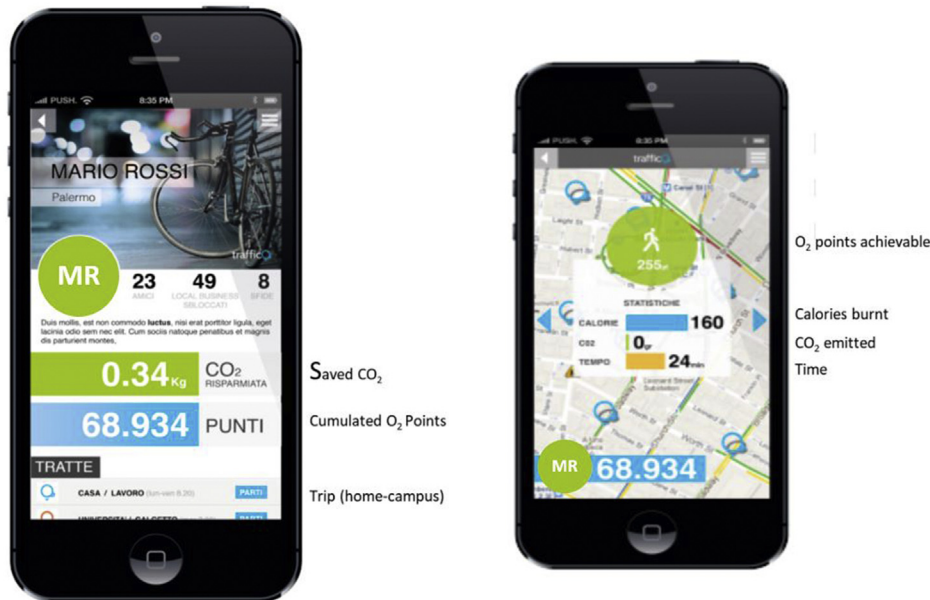

Figure 2. Mobile phone screenshots of the app for the applicant commuters.

where subscripts w, b, pt, c, m, cp, mp and cs indicate the modalities of walking, biking, public transport, car, motorcycle, car-pooling, moto-pooling and car sharing, respectively.

Each modal distribution, as defined in Eq. (1), will correspond to a certain environmental performance of the system. These performances are identified here with the total carbon dioxide emissions, E_0, that is calculated using the pertinent emissions of each mobility modality. That is:

$$E_0 = E_{0,\,pt} + E_{0,\,c}\,E_{0,\,m} + E_{0,\,cp} + E_{0,\,mp} + E_{0,\,cs} \tag{2}$$

where, for the ith commuter of the total number n of components of the sample, it is possible to write:

$$E_{0,pt} = \sum_{i=1}^{n} D_{0i,pt}\alpha_{pt} \tag{3}$$

$$E_{0,c} = \sum_{i=1}^{n} D_{0i,c}\alpha_{c} \tag{4}$$

$$E_{0,m} = \sum_{i=1}^{n} D_{0i,m}\alpha_{m} \tag{5}$$

$$E_{0cp} = \sum_{i=1}^{n} D_{0i,cp}\alpha_{cp} \tag{6}$$

$$E_{0,mp} = \sum_{i=1}^{n} D_{0i,mp}\alpha_{mp} \tag{7}$$

$$E_{0,cs} = \sum_{i=1}^{n} D_{0i,cs}\alpha_{cs} \tag{8}$$

being α (g/km) the CO_2 emission factors of each considered transportation modality [42].

2.2. Description of the game tool based on an app for smartphones

The rates of the various mobility modalities, M_{0j}, along with the corresponding pollutant emissions, E_0, are the parameters by means of which different scenarios of mobility for commuters can be compared and ranked. Hence, the definition of a benchmark scenario, against which commuters are challenged, needs the definition of a suitable modal split and pollutant emissions. This scenario is obtained here using the algorithm described in Eq. (9).

$$B_j \longrightarrow I_N \longrightarrow I'_N \longrightarrow I_{Nj} \longrightarrow M_{Nj} \tag{9}$$

where (in percentages) B_j is the benchmark of each modality of mobility, I_N is the potential total improvement of the new scenario, I'N is the best improvement of each single modality, I_{Nj} is the actual reachable improvement of each modality j and M_{Nj} is the modal split rate for each modality of the new scenario.

The procedure starts with the establishment of the benchmarks (best results) of each modality of trips, B_j, being j the subscript indicating the modality of moving. For instance, if at least one component of the sample declares to cover, let's say, the 75% of the trip length by walking, and he/she holds the best performer of the group, the relative benchmark will be $B_w = 0.75$. Likewise all the benchmarks referring to the other modalities are defined. Further, the total potential improvement of the new scenario, I_N, is computed by simply subtracting from the total the percentage rates of the modalities of travelling that must be discouraged. For example, if the new scenario tends to avoid the use of private cars and motorcycles, its potential improvement will be given by the following formula:

$$I_N = M_c + M_m = 1\text{-}(M_w + M_b + M_t + M_{cp} + M_{mp} + M_{cs}) \tag{10}$$

Then, the best improvement percentage of the new scenario, I'Nj, for each transportation modality, and related to the Bj benchmarks, may be evaluated as the difference between the benchmark and the rate of the same modality in the actual scenario. That is, for the i-th member of the sample of commuters:

$$I'_{Ni,w} = (B_w - M_{0i,w})\,K_{i,w} \tag{11}$$

$$I'_{Ni,b} = (B_b - M_{0i,b})\,K_{i,b} \tag{12}$$

$$I'_{Ni,t} = (B_t - M_{0i,pt})\,K_{i,pt} \tag{13}$$

$$I'_{Ni,cp} = (B_{cp} - M_{0i,cp})\,K_{i,cp} \tag{14}$$

$$I'_{Ni,mp} = (B_{mp} - M_{0i,mp})\,K_{i,mp} \tag{15}$$

$$I'_{Ni,cs} = (B_{cs} - M_{0i,cs})\,K_{i,cs} \tag{16}$$

In the previous equations, K_{ij} is a Boolean variable, indicating the presence (1) or not (0) of the considered modality of travelling.

The reachable improvement (the target) of the j-th modality, I_{Nj}, is obtained using an if-then-else algorithm that explores, in a given hierarchical order, the actual possibilities to reach the total potential target, by saturating all the modal split improvements. The hierarchical order of the improvements adopted here is: walking, biking, public transport, car-pooling, motorcycle pooling and car sharing. Finally, the achieved modal split rate, M_{Nj}, in the new scenario, for each modality j of commuting, is expressed as the sum of the corresponding split rate in the old scenario, M_{0j}, plus the reachable improvement rate of the same modality in the new scenario, I_{Nj}. That is:

$$M_{1i,w} = M_{0i,w} + I_{1i,w} \tag{17}$$

$$M_{1i,b} = M_{0i,b} + I_{1i,b} \tag{18}$$

$$M_{1i,pt} = M_{0i,pt} + I_{1i,t} \tag{19}$$

$$M_{1i,cp} = M_{0i,cp} + I_{1i,cp} \tag{20}$$

$$M_{1i,mp} = M_{0i,mp} + I_{1i,mp} \tag{21}$$

$$M_{1i,cs} = M_{0i,cs} + I_{1i,cs} \tag{22}$$

It must be observed that, if the saturation procedure does not reach the improvement's target, it means that there is stillroom for car and motorcycle trips.

As previously stated, the suitability of the game-based tool has been checked on a group of students of the University of Palermo that daily commute from their homes to the university campus. Since students are curious and young people, they represent a promising social community to which addressing behavioral changing projects driven by social media technologies [43]. The answer of this category of citizens to such kind of tools represents a useful check on the actual feasibility of such tools. In order of checking the feasibility of the game-based tool and the response of people regarding a change of mobility behavior, we have challenged a group of commuter students of the University of Palermo against the performances of a benchmark scenario that remarkably improves the status quo situation.

3. Results

From May 2013 to June 2015, a total sample of 311 university students was involved in the test. By means of a survey campaign and using a simple ©Google map analysis, we assessed the daily one-way trip's length for getting the University campus of each component of the sample. The distance distribution of the sample was the following: 67.4% within 3 km from the campus, 21.4% between 3 and 5 km and 11.2% between 5 and 10 km.

Despite the original number of students registering for the app was 664, only 46.8% of them have actively taken part to the test (that is commuters utilizing the app at least four times in home-to-work trips

during the test). Clearly, this percentage represents a first interesting information about the actual suitability of the method: in other words, it must be analyzed whether a percentage of redemption less than 50% of participants can be assumed as an indication of the real propensity of citizens to be involved in sustainable mobility policies.

The first step of the procedure consisted in the determination of the actual modal split of the sample of students. The current distribution (Scenario 0) of the trip modalities, indicated in the left side of Table 1, has resulted from a survey enquiry. As it is possible to see, 62% of the distance is covered on foot by commuters living at a distance less than 3 km from campus, the 12% by biking, while these percentages become respectively 32% and 20% for commuters living at distances comprised between 3 and 5 km from the campus.

Obviously, the percentages of walking and biking rapidly decrease with distance, while it is evident the preference for walking and biking for people starting from sites close to the campus. On the other hand, a part of the sample (11.2%, between 5 and 10 km) lives at distances for which moving daily by walking is almost impossible and maybe biking is not compatible with the reasonable times needed for reaching the university.

Starting from the status quo (Scenario 0) and using the above-described procedure, a new scenario (Scenario 1) has been designed that represents an improvement of the actual one in terms of both modality distribution and environmental performances. This enhanced scenario constitutes the target that challenges commuters when trying to improve their mobility habits. It enables people to judge the effectiveness of their preferred modality of trip, even not excluding the use of private cars and motorcycles; higher scores will however be obtained by selecting the most sustainable modalities of trip. The modal split of the Scenario 1 is obtained by applying to the considered sample of commuters the "saturating" procedure described in the previous sections and, particularly, the computing sequence of the algorithm (9) and Eqs. (17), (18), (19), (20), (21) and (22).

The resulting distribution of the new modalities is reported on the right side of Table 1.

Clearly, this new scenario is characterized by a better performance, since the percentages of walking and biking show an increasing (along with the public transportation means), while those referred to the less sustainable modalities, such as cars and motorcycles, correspondently decrease. Another important feature of the benchmark scenario is that people living in the most distant zones are required to significantly increase their habits in order of achieving the targets established by the Scenario 1. In fact, the walking modality should increase from 32% to 55% in the zone "B", while the biking modality should grow from 4% to 17% in the zone "C".

As mentioned earlier, a field-test on the selected sample of commuters was carried out in order of verifying whether these citizens, pushed by monetary rewards and challenged by a smartphone-based game, were able to ameliorate their mobility behaviors and, possibly, to improve the performances indicated by the benchmark scenario.

During this field-test, totally 166 local businesses have taken part to the test with an average reward of 58.11 € each.

The modal split distribution reported in Table 2 summarizes the results of this field check provided by the commuters.

It is noteworthy (see Tables 1 and 2) the performance attained by walking in the areas closest to the campus that, from a percentage of 62% in the Scenario 0, reaches a value of 80.3%, overpassing the benchmark figures of the enhancing Scenario 1 (67%). In the intermediate areas (between 3 and 5 km), the results of walking are good (45.1%), but not enough to reach those of the Scenario 1 (55%), although improving the values of the status quo (32%). In the most distant zones, on the contrary, the field-test shows an interesting percentage (13%) of trips covered by walking, despite the distance would not seem so attractive.

On the other hand, the biking trends show a different behavior. In fact, for the closest distances, there is a decrease, from 12% to 7.5%, of people using bikes. Anyway, in the intermediate and most distant zones, there is a remarkable increase of this modality, reaching 42.4% and 57.5%, respectively. The decrease registered in the closest zones may be attributable to the fact that people preferred to walk, in order of getting higher scores and rewards, and this clearly reduces the percentage of people using bikes.

A collateral positive outcome of this modality distribution is that, correspondingly, the shares of trips covered by private cars and motorcycles decrease (compare Tables 1 and 2), in this way leading to a mobility system that is generally more sustainable than the starting one.

In general, the group of students demonstrated a high interest to the app and changed their trip habits remarkably. This is evident in Table 3, where the weighted average modal splits of all the transportation means, realized by the commuters, are reported. These data can be considered as synthetic indicators of the changes among the Scenarios: they clearly signal the improvements achieved in the field test. In fact, the walking and biking modalities account for a total percentage of 76.0, while in the scenario 0 and in the benchmark scenario these percentages were 26.8 and 41.7, respectively.

As regards the environmental performances of this mobility study, we have calculated the emissions of carbon dioxide of the three scenarios by using the Equations from 2 to 8. Pertinent emission factors have been adopted for evaluating the pollutant releases of each modality of transportation, as suggested in the software ©Copert, 4.10 release [42, 44]. Buses data were scaled for the average number of passengers typically present in vehicles; the car-pooling data were defined by the car emission values divided by 2.5, which is the average number of passengers using the service in the same time; the motorcycle-pooling data were defined by the motorcycles emission data, divided by the two hypothesized number of passengers.

In Figure 3 the comparison among the CO_2 emissions of the status quo, the benchmark scenario and the field test is shown. This last performs remarkably better than the actual situation, despite its total emissions are greater than those of the benchmark scenario. In fact (Table 3), in the field check of the method, people still selected private

Table 1. Modal split of the commuters in the actual (0) and enhanced (1) Scenarios.
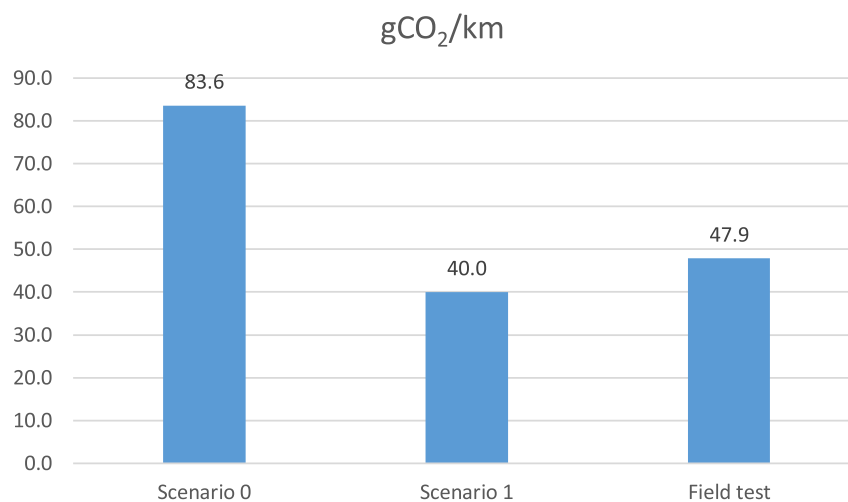
	SCENARIO 0			SCENARIO 1		
	"A"<3 km	3km<"B"<5 km	5km<"C"<10km	"A"< 3km	3km<"B"<5km	5km<"C"<10km
$M_{0,w}$ - Walking	62%	32%	0%	67%	55%	0%
$M_{0,b}$ - Biking	12%	20%	4%	12%	20%	17%
$M_{0,pt}$ - Public transport	10%	13%	25%	10%	13%	32%
$M_{0,c}$ - Car	5%	9%	34%	0%	0%	6%
$M_{0,m}$ - Moto	0%	14%	12%	0%	0%	0%
$M_{0,cp}$ - Car-pooling	6%	9%	17%	6%	9%	36%
$M_{0,mp}$ - Moto-pooling	5%	4%	8%	5%	4%	9%
$M_{0,cs}$ - Car-sharing	0%	0%	0%	0%	0%	0%

Table 2. Modal split of the university commuters in the field test.

Field test	"A" less than 3 km	3 km<"B"<5 km	5 km<"C"<10 km
$M_{0,w}$ - Walking	80.3%	45.1%	13.0%
$M_{0,b}$ - Biking	7.5%	42.4%	57.5%
$M_{0,pt}$ - Public transport	8.2%	5.7%	3.8%
$M_{0,c}$ - Cars	2.0%	1.5%	9.3%
$M_{0,m}$ - Motorcycles	0%	0.6%	0%
$M_{0,cp}$ - Car-pooling	2.0%	2.9%	16.4%
$M_{0,mp}$ - Moto-pooling	0%	1.8%	0%
$M_{0,cs}$ - Car-sharing	0%	0%	0%

Table 3. Average modal split through the three scenarios (%).

Transportation modality	Scenario 0	Scenario 1	Field-Test
Walking	17.2	24.4	31.0
Biking	9.6	17.2	45.0
Walking + biking	*26.8*	*41.7*	*76.0*
Public transportation	19.7	23.8	4.9
Cars	22.3	3.5	6.1
Motorcycles	11.3	0.0	1.7
Car pooling	13.3	24.2	10.7
Moto-pooling	6.5	6.8	0.05
Car sharing	0.0	0.0	0.0

Figure 3. Environmental performances of the scenarios.

cars (6.1%) and motorcycles (1,7%) for their trips, while the values of the benchmark scenario were respectively 3.5% and 0%.

Figure 3. As previously pointed out, an important driver of the game is constituted by the rewards offered by the town's retails, along with the emulation among players that challenges people against their fellows, in order of getting higher and higher scores with their mobility choices.

Since the final aim of this game among citizens is to achieve a more sustainable urban mobility system - and not the game itself -, one could be interested in understanding the level of influence that the offered prizes have on the effectiveness of the results. In other word, it would be very stimulating to establish whether people could be pushed only by environmental motivations and not by material rewards.

For this aim, another small test was launched, where no local businesses were involved, while the game maintained its points-based structure. A new sample of 65 commuter students was therefore invited to take part to another field test. Of these, 46 participants represented the active users, which is those that used the app at least four

times for home-to-work trips during the test. The decision of inviting a different group of commuters depended on the fact that players already involved in the previous test could have been influenced by the former game; in fact, the previous group was specifically selected among commuters that intended to take part to a rewards-based test. As done for the former one, this group of commuters was also requested to declare the current mobility habits, which constituted their Scenario 0. Again, a specific benchmark scenario has been designed for these commuters, using the same criteria and methodology adopted for modelling the Scenario 1 in the rewards-based test.

Since these commuters were mainly guided by environmental motivations, it is important to report the results of this new test in terms of the environmental performances achieved during the field checking. Figure 4 reports the pertinent specific emissions (gCO$_2$/km) of this no-rewards driven test.

Figure 4. First, it must be observed that the specific emissions of this status quo situation were considerably less (65.5 gCO$_2$/km) than those of
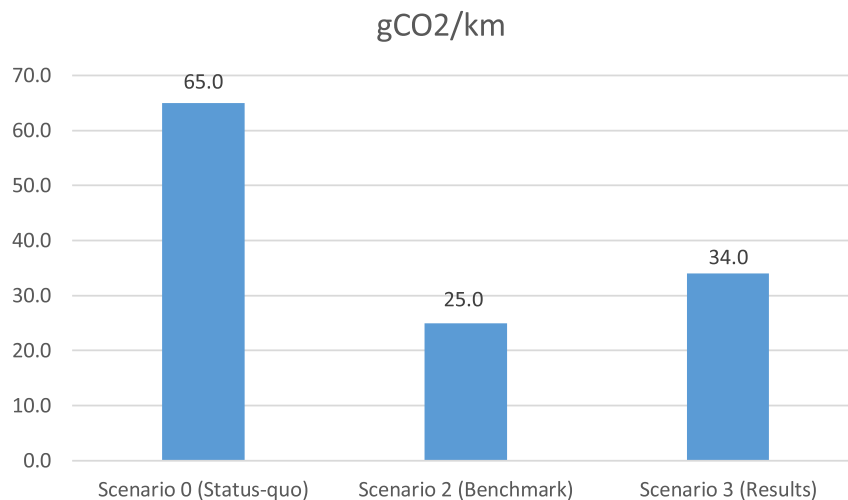
gCO2/km

Figure 4. Environmental performances of the no-rewards scenarios.

the reward-based group (83.6 gCO_2/km, in Figure 3). This is not surprising, since the new group of commuters is certainly characterized by a higher environmental consciousness, demonstrated by the fact that they voluntarily took part to the game, being mainly guided by environmental reasons and not aspiring to monetary prizes.

Moreover, the results of this field-test show better performances compared with those of the previous one. In fact, its average specific emissions of 34.0 gCO_2/km constitutes a decrease of 47.6% of the status quo value (65.0 gCO_2/km), while the correspondent reduction of the reward-based test (47.9 gCO_2/km) is only the 42.7% of the starting situation (83.6% gCO_2/km).

In Table 4, a comparison between the two tests is reported on the base of some relevant comprehensive indicators. The different percentages of active users (46.8 and 70.7, respectively) suggest that the reward-based scheme, although certainly worth for the success of the game based app, cannot be considered the only effective one for involving people in more sustainable paths of mobility. Conversely, the environmental consciousness seems to be effective enough for pushing citizens towards sustainable behaviours, despite the smallness of the last sample certainly suggests some caution in drawing definitive conclusions in this sense.

Table 4 also signals that the average length per active user realized by the no-rewards guided commuters (83.3 km) is higher compared to that of the rewards guided ones (59.2 km). In addition, the average percentage of reduction of pollutant emissions indicates a prevailing trend for the participants to the second test. This is particularly significant when considering that the mean specific emissions of the second test were very low already in the status quo condition and, therefore, a further decrease was not easily achievable.

4. Discussion

Results of the above described analyses, although stimulating, likely could depend on the relatively small dimension of the involved groups of participants, particularly the no-reward based one. Moreover, the interpretation of these data could be affected by the fact that a certain lapse of time has passed and, therefore, people could have been modified their preferences.

In order of confirming or refuting these outcomes, we have assessed another test involving a wider group of participants, taking also into account different kind of trips that commutes may realize in their daily movements [45]. The experiment started in September 2018 [46] and, although still ongoing, is providing interesting food of discussion, in order of better understanding what actually drives the propensity of people toward more sustainable mobility habits, including the possible role plaid by incentives (monetary or not). This new test has been created

through the involvement of different citizens and stakeholders in six European neighbourhoods [46]. The work is performed within MUV H2020 research and innovation action.

The test is involving 4268 registered users, with 649 active users (15.2% of registered users), that account for a double number than that of the first test. It is remarkable to note that the main modality with which the test is run contemplates only symbolic rewards (such as badges and medals). Anyway, in the same time some specific challenges are activated (lasting from a week to three months) that are characterized by monetary rewards and involve as far as 35 city's retails with an average of about 180 € each.

The most important difference of this new test resides on the circumstance that, apart the usual home-university trips, routinary movements are now encountered. A total number of 15,625 routinary tracks are registered, with a cumulated length of the trips of 191,309 km, which means an average trip length per active user of 294.77 km. Moreover, a percentage of 27.4% of routinary tracks is now found, with a sensible difference with the percentages of the two previous tests (13.3% and 9.1%, respectively) that considered only home-work-home tracks.

These two different features with which the test is conducted originated from a twofold reason. On one hand, the main modality of involvement of the participants is a no-rewards one: in fact, the propensity of people of applying to sustainable mobility behaviours should not depend on a monetary reward. On the other hand, the availability of city's commercial retails in taking part to environmental-wise policies is in this way checked. This different modality is aimed at developing a citizens-side approach that would enable to meet needs and new services, by means of policies based on digital tools and gameplay potentialities.

Due to the particular structure of this new test, a direct comparison with results provided by the previous ones is not possible. Anyway, some important considerations do arise from the preliminary outcomes.

First of all, people seem to demonstrate that incentives (at least the monetary ones) cannot be considered as the unique tools for addressing towards more sustainable habits in their urban mobility, as shown by the fact that, a significant percentage of active users is still observed, despite a less homogeneous composition of the participants. Moreover, the typology of the trips seems not affecting the propensity of people in being involved in sustainable mobility behaviours. In fact, unlike the previous tests, where only home-work paths were considered, in this case the habitual commuting mobility are also contemplated. Finally the new sample of people involved in the app-game realize, with their modified mobility behaviour, a relevant saving of the CO_2 emissions: the registered value of this reduction accounts for 32.4%. This percentage is less than that of the previous tests (42.7% and 47.6%, respectively); anyway it must be considered that in this new field experiment the car-pooling was

Table 4. Comparison of the rewards-based and no-rewards based tests.

	Rewards-based test	No rewards-based test
Total involved sample	664	65
Active users[1]	311	46
Percentage of active users (%)	46.8	70.7
Local businesses involved	166	-
Monetary rewards (€/business)	58.11	-
Total tracks recorded	10,357	1,487
Tracks home-work-home	1,381	136
Percentage of "home-work-home" tracks (%)	13.3	9.1
Total length of the tracked trips (km)	18,409	3,926
Average length per active user (km)	59.2	83.3
Average CO_2 emission reductions in the test (%)	42.7	47.6

[1] Commuters utilizing the app at least four times in home-to-work trips during the test.

not included, due to the less homogeneity of the sample – with different needs of mobility - that does not foresees an easy pooling of people for sharing a car.

But the most relevant characteristic of this last field experiment is the preliminary verification of the acceptability of the app-based tools by different categories of commuters, apart from the university students that constituted the previous tests. In fact, university students represent a very particular group of citizens that, thanks to their open minds, are naturally inclined to welcome urban policies that would modify their mobility habits.

Clearly, the suitability of the game provided by apps to different urban contexts, that is the evaluation of the extent to which the study may, or may not, be appreciable to large and medium-sized cities in other part of the world, should be checked.

All these investigations are important in order to define what individually drives each single user, or each single category, to choose whether to be greener and to better understand what really pushes people to greener mobility habits.

5. Conclusions

A technology-driven tool has been checked in field for the direct involvement of citizens towards more sustainable choices concerning their urban mobility. It is based on a competitive game among participants and is performed by means of a specific app that can be installed on the smartphones commonly utilized by people. The game can be founded on rewards for more sustainable mobility choices: in this version, the participants can obtain prizes in exchange for their achieved scores at the local businesses involved in the scheme. On the other hand, a game without monetary rewards can be also assessed by means of the tool.

The suitability of the tool was verified by means of a field check involving a group of commuter students of the University of Palermo (Sicily). This specific category of commuters has been intentionally selected, since university scholars certainly represent group of citizens usually open to innovations and that, therefore, can be easily involved for checking new tools. The method, in its first application, has shown to be effective in addressing people towards more sustainable preferences concerning their home-work-home trips. A benchmark scenario, built up on purpose, challenged the group of commuters.

In addition, another field-test involving a different group of student commuters, demonstrated that people could be addressed towards sustainable mobility habits, even driven only by the environmental consciousness, without any monetary reward.

A further important feature of this tool is that it can likely implement effective measures for improving the livability of cities without modifying the existing mobility infrastructures. The motivation of people, in fact, seems to be strong enough to drive citizens towards mobility behaviors that could exert a less pressure on the urban environment.

Obviously, the game-based method needs to be verified in different urban areas, including towns belonging to other geographic contexts and for wider samples of participants. This check is still ongoing by means of a new test whose preliminary results are reported in the paper.

Anyway, on the base of these first outcomes, the proposed method candidates itself like a promising tool for involving citizens in the policies aimed at the building up of smarter and environmentally sustainable cities.

Declarations

Author contribution statement

Contributed reagents, materials, analysis tools or data; Wrote the paper.

Salvatore Di Dio, Francesco Massa, Domenico Schillaci: Conceived and designed the experiments; Performed the experiments; Giorgia Peri, Antonino Nucara: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Gianfranco Rizzo: Analyzed and interpreted the data; Wrote the paper.

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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