Involving people in the building up of smart and sustainable cities: evidences from the changing of mobility habits of commuters, driven by a mobile app game

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Abstract

Mobility is recognized as a crucial issue in the aim to render urban contexts more inclusive, safe, resilient and sustainable. But, usually, mobility policies assessed by local governmental institutions tend to intervene on the side of the urban transport networks, by designing new and, usually, very expensive infrastructures, whereas only a few attention is paid to the possible positive effects induced by the mobility behavior of people.

Smartphone technologies and platforms, thanks to their rapid spreading among people, almost regardless cultural, economic and ethnic belonging, seem to easily becoming effective tools for involving citizens in this purpose. By means of an empirical application to a group of university students, that daily commute in order of reaching their departments, the effectiveness of a mobile app game in modifying the mobility behavior of this sample of citizens is here checked. The game, rewarding the most environmentally sustainable mobility habits, connects commuters with sponsors and companies operating in the urban context, in this way contributing to the growth of a network of virtuous categories of citizens. The interesting outcomes of this experimental application in a Mediterranean town encourage paying further attention to such behavioral tools for achieving the smartness of cities.

Keywords: Smart city; urban mobility; commuter’s behavior; mobile app.

1. Introduction

In modern times characterized by transient cities, the sustainability of the urban mobility other than by the actions for improving the performances of the traffic flows (Guerrieri et al., 2015; Corriere et al., 2013; Madlener and Sunak, 2011) can also be properly pursued by directly involving citizens, in order of suitably governing the changing features of such cities. This approach is part of the smart cities vision, in which the promotion of transportation means, which are alternative to the private ones, is a crucial point (Garau et al., 2016) for achieving sustainable urban contexts (Fenton, 2017). This is well recognized by the Sustainable Development Goal 11 that, starting from the consideration that half of humanity lives in cities (with a still ongoing urbanization trend), aims to render urban contexts more inclusive and, in the same time, safe, resilient and sustainable.

Designers suggest the necessity of a change of the citizens’ mentality towards mobility systems (Gaker et al., 2011) and claim that this change of mentality is made quicker and more productive by the new information technologies. Some USA for profit projects, such as Nuride (http://nuride.com/), Zimride (http://www.zimride.com/), Lyft (https://www.lyft.com/) and the equivalent European ones, such as Moovel (https://www.moovel.com/en/US/), Mo-bility (http://www.mo-bility.com/mo/home_.html), Covivo (http://www.covoiturage-dynamique.eu/), are strongly modifying the cities changing opportunities from the urban structure (the "hardware") to the citizens' and communities' habits (the "software"). Specifically, the above-cited projects aim to stimulate communities to change their bad habits, moving towards more environmentally responsible mobility behaviors via smartphone apps (Ben-Elia et al., 2008; Kamal et al., 2014). In fact, despite it is a common belief that mobility choices of people essentially depend upon prior commitments and available infrastructures (Urry, 2012), habits of people are also a key issue in transport patterns and performances. In light of this, the development of urban sustainable design models in the transportation domain often applies to the new communication technologies (Patier & Browne, 2010), due to their capability to intervene on the motivations that foster people to choose one or other urban transportation systems (Moore, 2011; Nasrudin & Nor, 2013). Starting from these considerations, solutions can be developed for the implementation and the rooting of more efficient and sustainable behaviors in urban transportation (Wasbrook et al., 2006). This implies that, other than by top-down policies positive effects can also be obtained by bottom-up actions driven by citizens (Gatersleben et al., 2013).

Using the 'Urban Metabolism' metaphor (Pincetl et al., 2012), in order of improving the "body" performance of towns we should operate upon their 'nervous system', i.e. people that too often 'use' the city improperly (Wamsler & Brink, 2014). The behavior of people, in fact, is as a key element for realizing an integrated urban sustainable mobility, with a high attention on the role of the multimodality. On the other hand, a suitable regulation of the commuters' mobility patterns could positively affect the productivity of urban and metropolitan businesses (Shomo & Blei, 2016) and may limit the burdens of the transportation infrastructures.

The issue of how individuals plan their daily activities has been addressed as key point for understanding new tendencies of the urban mobility. The influence of economic and psychological factors, along with the 'livability' needs, explain how transportation systems interact with societal needs, including opportunities for recreation and social interaction (Goldman and Gorham, 2006). On the other hand, the economic contribution of people to the suatainability of cities has been also investigated with a special focus on the new mobility habits (Bullock et al., 2017).

Beside the newly developed urban transport policies aimed at improving these actions, research works on the line “transport-values-communication-behaviors” are rapidly growing (Naess, 2013), while the increasing availability of large data sets and the use of suitable aggregated indicators have intensely enhanced the effectiveness of the analyses of the sustainability of urban transportation systems and their benchmarking (de Freitas et al., 2012; Ying et al., 2015).

In this domain, the use of new media-related technologies to modifying the citizens’ urban transports habits (Gal-Tzur et al., 2014) is getting increasing attention. Smartphones and other information management systems through personal mobile technologies show a great effectiveness due to the real time one-to-one dialogue with the citizens (Brazil & Caulfield, 2013; Iqbal et al., 2014). The Italian Ministry of Education and Research, for example, has directly supported the technology-driven social innovation tools with its 2012 call “Smart Cities and Communities and Social Innovation”, aimed at linking together research, innovation and immediately usable tools for the city services and requirements.

In this regard, an info-mobility Decision Support System, which tries to foster commuters toward more sustainable kinds of mobility by offering tangible incentives for more responsible choices, is introduced here. Starting from the current behavior of a group of University students in Palermo, which daily commute for reaching their campus-based departments, two different enhanced behavioral scenarios have been hypothesized where people is pushed toward more sustainable mobility habits by using emulative games.

To do this the use of a mobile app game that includes incentives is proposed. In this way, the mobility conditions are improved without the involvement of either heavy structural interventions or massive urban traffic policies

2. A new tool for a sustainable mobility based on a mobile app

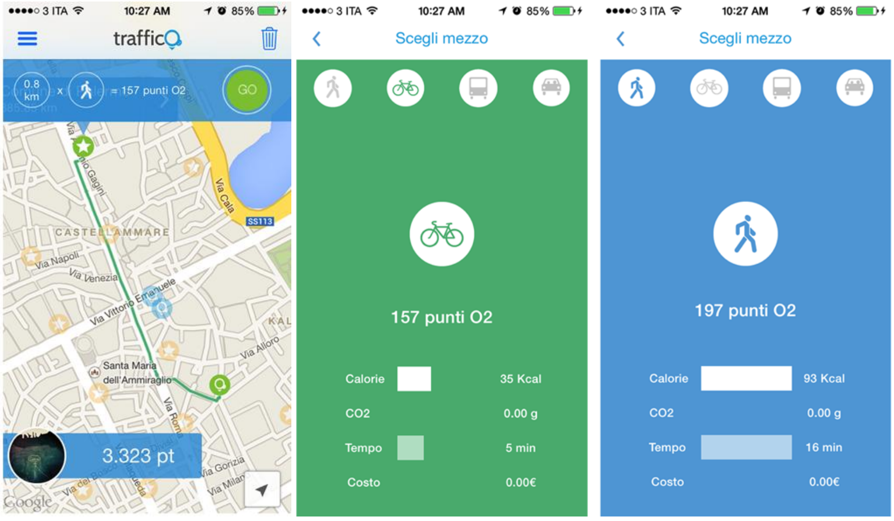
The proposed method relies on the idea of trigging a social and cultural change with the “dialogue tool” offered by the social media technology, possibly by creating a new service and a new market, as profit startups are currently doing (Herrador et al., 2015; Zhang et al., 2015).

The here proposed smartphone tool, the TrafficO_2 mobile app (Di Dio et al., 2015), is an info-mobility Decision Support System (DSS) that tries to foster people toward more sustainable mobility behaviors by offering tangible incentives for more responsible choices. Recently, TrafficO_2 has been selected by the EU campaign “Do the right mix” (http://www.dotherightmix.eu/) as a remarkable action for a future urban mobility and is currently under the testing process.

The attempt is to match the interests of two complementary actors of the city traffic scene: the community workers and the city retail and services network (Porta et al., 2009). Therefore, all of the local businesses that belong to the board (as sponsors) become stations of a new kind of mobility platform. In other words, TrafficO_2 mobile app connects together info-mobility, entertainment and engagement with local companies, so that urban commuters are informed of the array of possibilities that allow them both to circulate in a more sustainable way (on foot, by bike, by public transportation, by vehicle pooling, and by car sharing) and to be rewarded when they opt for more sustainable choices. The goal is to decrease traffic and its pollution simply through an educational game (Filsecker & Hickey, 2014), consisting in offering rewards for a respectful attitude towards the urban environment.

Apart the commuters, the other important categories involved in the project are sponsors and local business stations (LBS). By using the app, the commuter “knows” immediately (Vinci & Di Dio, 2014) what would be his/her total sustainable mobility improvement, and therefore will be more motivated to achieve it. Rewards are O_2 points, gained according to the chosen modality of transportation. The selected route is displayed on the smartphone according to the different types of the selected journey: walking, biking, public transportation or vehicle sharing. Each choice will be listed according to time, environmental cost, economic cost and spent calories. From left to right of Figure 1, an example of the screen shot appearing on the smartphone of the user is reported: the overview of the city map with local businesses (“bus” icons) and sponsors (“star” icons), along with the number of points collected by the *i-th* user at the time of login (3323, in this case). Information about the O_2 points that can be reached through the selected trip (by biking or walking, in this case) are also provided (157 O_2 points by biking and 197 O_2 points by walking). In other words, each choice will be worth a certain amount of the O_2 points (a virtual currency), which the users will earn and use to get prizes, transforming the TrafficO_2 method from a DSS for sustainable and environmentally friendly trips into a game for citizens.

The O_2 points are also be refined through suitable weather-related factors to award higher scores for the mobility means (walking, biking, public transport, for example) adopted on cloudy and rainy days. Winter mobility is moreover recognized by the score system.



157 punti O2

Calorie 35 Kcal
CO2 0.00 g
Tempo 5 min
Costo 0.00€

197 punti O2

Calorie 93 Kcal
CO2 0.00 g
Tempo 16 min
Costo 0.00€

Fig 1. The user interface

Obviously, more sustainable trips will award more points, as reported in Table 1 and, on the other hand, users will be able to increase their O_2 points by challenging, through the website or via mobile app, their friends and playing with the engagement contents made available by the sponsors. The system rewards walking trips more than biking trips because this modal gives the opportunity to check-out more local businesses, and therefore it helps to provide more advertising information and more revenues from the sponsors' networks. Points assigned to the other mobility modalities are less and decrease with the increasing of the pollutant emissions of the chosen urban mobility mean.

Table 1. Scheme of O_2 points attainable with the different mobility means.

	Basic O_2 points per kilometer	Cloudy weather multiplying factor	Rainy weather multiplying factor	Winter season multiplying factor
Walking	5	1.5	3	2
Biking	4	2	4	2.5
Public Transport	3.5	1.5	2	1.5
Car-pooling 2 seats	0.5	1	1	1.5
Car-pooling 3 seats	1.0	1	1	1.5
Car-pooling 4 seats	1.5	1	1	1.5
Car-pooling 5 seats	2.0	1	1	
Moto-pooling	0.5	1	1	
Car-sharing	1.5	1	1	

Basically, TrafficO_2 is a platform for value exchange: for every responsible choice there is a tangible market value, and every choice will advertise and communicate Local Business Stations. Indeed, many reasons could encourage people to change their habits: "extrinsic reasons" such as rewards and challenges, and "intrinsic reasons" (Pierce et al., 2003) such as the information on the burnt calories, the cost, the carbon footprint, etc. In other words, TrafficO_2, by combining information on mobility, advertising and the game, tries to provide commercial motivations and emotional input to push people to change their mobility habits. It is "not for profit business model" and its final aim is to guarantee a completely free service for the citizens and cover the administration costs by applying a business fee for the partners in exchange for the advertising content campaign and the specific market analysis that it develops.

Since the identifying of a particular mobility mean represents the fundamental guarantee for users and sponsors of the effectiveness of the game's rules, the smartphone technology, beyond the software interface, provides the needed detecting of motion connected with the trips, by differentiating, with a high accuracy level, whether the user is walking, biking or driving. This is possible due to the sensors present in the smartphone devices and to the microprocessors that, through specifically devoted algorithms, overlap information of GPS location and accelerometer, and detect the motion system (Manzoni et al., 2010).

3. The app in action: *status quo* conditions and possible improving scenarios

The features of the app model are described in more detail below, particularly referring to its application to a group of commuters of the town of Palermo (Italy). Specifically, after the definition of the *status quo* of this sample, two possible enhancing behavioral scenarios are defined. The first one is characterized by the implementation of more environmentally performing mixes of yet existing modalities of mobility; the second one is essentially based on a less use of the private (fuel fed) transportation means. These scenarios are specifically designed for showing the effectiveness of fixing benchmarks in the aim of fostering people to abandon their traditional mobility habits. Both scenarios are compared with the *status quo* case, in terms of improved modal split changes and saved pollutant releases.

3.1 The status quo of the mobility situation: the Scenario 0

The group of 77 commuters participating in the experimental application was selected by means of a casting workshop, in which three different departments (Computer Science, Design and Marketing Communication) of the University of Palermo were involved. This group of voluntary students was required to check in the field the user interaction with the model and its survey structure devoted to suitably catch the individual modal split. They were provided with a questionnaire to evaluating the length of their daily one-way trip, needed to get the University from their homes, along with the pertinent distances, checked by means of a simple ©Google map analysis. Commuters were also asked to declare their usual modality of mobility for getting the university. The resulted distribution represents the Scenario 0 (*status quo*). By crossing such information with the availability or ownership of mobility systems (bicycle, car, motorcycle) and with local transportation opportunities, five subclasses of the commuters have been singled out, depending on the daily one-way length needed for getting to the University sites. Figure 2 reports the availability or ownership of private means of transportation - that is bicycles, motorcycles and cars – for people living at increasing distances from the target of the commuting trips. The availability of bicycles decreases for distances greater than 5 km; the availability of motorcycles remain almost the same for distances greater than 3 km; the availability of private cars increases with the distance, reaching rapidly the 100%, according with the Italian distribution.

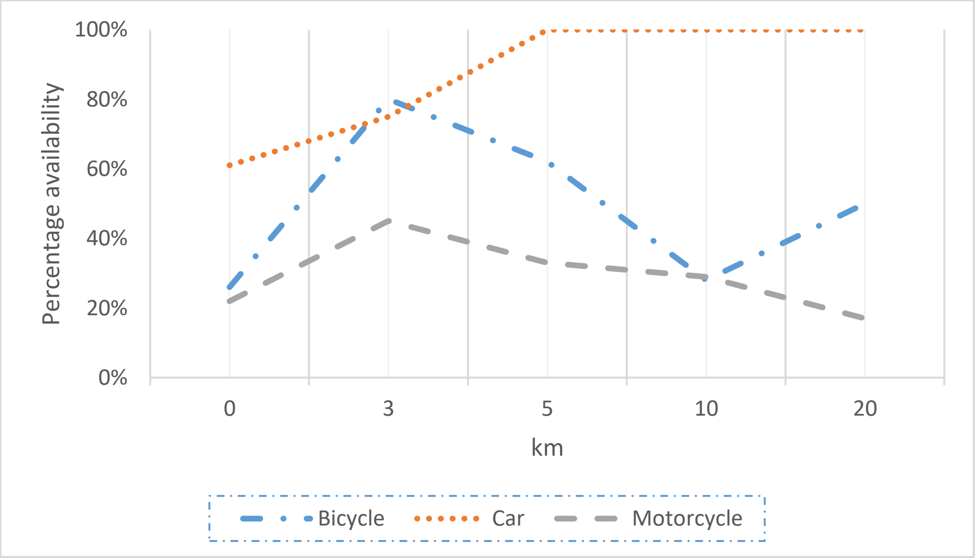


Fig. 2. Availability of private means of transportation of the selected sample of commuters at increasing distances from the university campus.

We have also asked people to declare their usual modal split of transportation for getting the university. As reported in Figure 3, there is a substantial correspondence between the availability of transportation means at increasing distances from the university and the preferred modality of mobility.

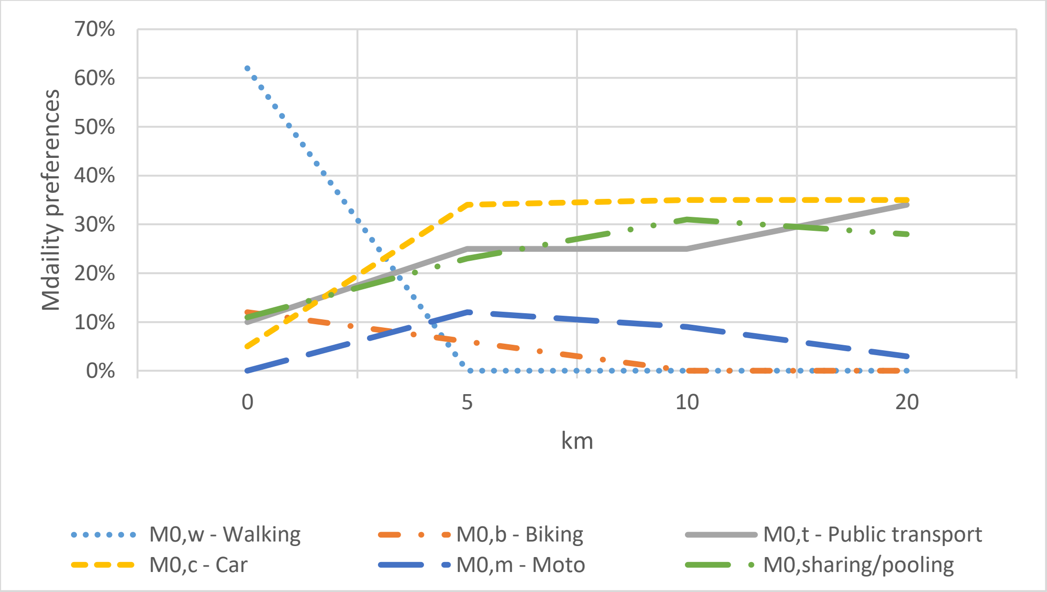


Fig. 3. Usual modality of mobility of the selected sample of commuters at increasing distances from the university campus.

It must be noted that this modal split is quite representative of the present mobility habits of people in the Sicilian towns and not only of the selected commuters (http://www.un.org/sustainabledevelopment/sustainable-development-goals/). Indeed, as it can be observed, a large use of private cars was registered for distances higher than 10 km along with the recourse to the public transport system; the practice of sharing private cars (and motorcycles) among different commuters has also emerged. On the other hand, biking is not a common habit, especially for distances higher than 5 km. Relevant changes were detected for distances less than 3 km, between 3 and 5 km, between 5 and 10 km, between 10 and 20 km, and higher than 20 km.

As a result, the sample of commuters was divided into five subclasses, characterized by the daily one-way length needed for getting the university sites.

Table 2. Scenario 0 - The five subclasses of University commuters.

Sample subclass	A	B	C	D	E	TOT
Trip length, L	L < 3 km	3 km<L<5 km	5 km<L<10 km	10 km<L<20 km	L>20 km	($L_{0,\ trip}$)
$\sum L_{i,trip}$	34.7	75.8	156.1	89.7	164.7	521
Sample percentage (%)	30%	26%	27%	9%	8%	

In Table 2, $L_{0},_{trip}$ represents the total unidirectional length, obtained by summing up all the lengths, $L_{i,trip}$, realized by the users with the different mobility modalities in all subclasses. That is, for each subclass:

$$\begin{aligned} L_{i,trip} &= D_{0i,w} + D_{0i,b} + D_{0i,t} + D_{0i,c} + D_{0i,m} + D_{0i,cp} + D_{0i,mp} + D_{0i,cs} = \\ &= \left(M_{0i,w} \cdot L_{i,trip}\right) + \left(M_{0i,b} \cdot L_{i,trip}\right) + \left(M_{0i,t} \cdot L_{i,trip}\right) + \left(M_{0i,c} \cdot L_{i,trip}\right) + \\ &+ \left(M_{0i,m} \cdot L_{i,trip}\right) + \left(M_{0i,cp} \cdot L_{i,trip}\right) + \left(M_{0i,mp} \cdot L_{i,trip}\right) + \left(M_{0i,cs} \cdot L_{i,trip}\right) \end{aligned} \tag{1}$$

where D_{0i} are the daily one-way distances (km) for getting the university campus with a given moving modality, and subscripts *w*, *b*, *t*, *c*, *m*, *cp*, *mp* and *cs* indicate the different modalities (that is walking, biking, public transport, car, motorcycle, car-pooling, moto-pooling and car sharing, respectively); M_{0i}, are the percentages of use of the different mobility systems declared in the survey by the single user; subscript *i* refers to the *i-th* commuter.

Obviously, for the *j-th* modality of mobility it is possible to write:

$$D_{0i,j} = \left(M_{0i,j} \cdot L_{i,trip}\right) \tag{2}$$

As regards the environmental performances of the Scenario 0, the total carbon dioxide emissions (E_0) have been computed using the following equation:

$$E_0 = E_{0,t} + E_{0,c} + E_{0,m} + E_{0,cp} + E_{0,mp} + E_{0,cs} \tag{3}$$

where,

$E_{0,t}$ = emissions of public transportation = $\sum_{i=1}^{n} D_{0i,t}\alpha_t$ (4)

$E_{0,c}$ = emissions of cars = $\sum_{i=1}^{n} D_{0i,c}\alpha_c$ (5)

$E_{0,m}$ = emissions of motorcycles = $\sum_{i=1}^{n} D_{0i,m}\alpha_m$ (6)

$$E_{0,cp} = \text{emissions of carpooling} = \sum_{i=1}^{n} D_{0i,cp}\alpha_{cp} \tag{7}$$

$$E_{0,mp} = \text{emissions of motor pooling} = \sum_{i=1}^{n} D_{0i,mp}\alpha_{mp} \tag{8}$$

$$E_{0,cs} = \text{emissions of car sharing} = \sum_{i=1}^{n} D_{0i,cs}\alpha_{cs} \tag{9}$$

In these algorithms, i is the *i-th* commuter, n is the total number of the commuters (belonging to each of the five mobility classes), and α_j (g/km) are the CO_2 emission factors of the j –th transportation modality.

The α_j emission factors (indicated in the algorithms but also in Table 3 below) were calculated using the software ©Copert 4.10 (Kioutsioukis et al., 2010; http://www.emisia.com/copert/); the public transportation data were scaled for the average number of passengers hosted in a bus (80, typically, for the rush hours when commuter students move); the car-pooling values were defined by dividing the mean car occupancy by 2.5 (that is the typical average number of commuters per car).

Table 3. Emission factors α_j used in the application (Copert 4.10).

α emission factors	α_c - Car	α_t - Bus Transport	α_m - Motorcycle	α_{cp} - Carpooling	α_{mp} - Motopooling	α_{cs} - Car sharing
CO_2 g/km	238,9	22,5	80,8	95,5	40,4	238,9

Using these specific emissions, pertinent to each modality of mobility, and based on the modal splits of Figure 3, the overall environmental performances of the Scenario 0 were obtained (Table 4).

Table 4. Scenario 0: CO_2 emissions of the five university commuter subclasses.

Sample subclass	A	B	C	D	E	
Distance, L	L < 3 km	3 km<L<5 km	5 km<L<10 km	10 km<L<20 km	L>20 km	TOT

Σ $E_{0\,i}$ (g CO_2)	760	3,514	17,996	11,092	19,052	52,416
E_0/km (g/km)	21.9	46.4	115.3	123.7	115.7	100.6
% E_0	1.50	6.70	34.30	21.20	36.30	100

As it was expected, the most impacting classes of commuters are related to the last three distance categories (C, D, and E) that show a specific impact greater than 100 g/km. Moreover, despite only 44% of the sample lives in these areas, its impact accounts for more than 91% of the E_0 global emissions.

In order to improve the mobility (and, in turn, the environmental) performances of the Scenario 0 by means of the app game, two possible behavioral improvements are proposed to the commuters by the TrafficO_2 app, corresponding to two further scenarios.

3.2 The enhancing Scenario 1: "Do your right mix".

This scenario implies an easy modal split improvement that doesn't exclude *a priori* car and motorcycle trips (as does the Scenario 2), but fosters to move either on foot, by bike, by public transportation, or by vehicle-pooling. For these reasons, it is defined the "*Do your right mix*" scenario. In synthesis, the mission of Scenario 1 is to foster toward better environmental mobility choices using an emulation principle based on the slogan: "your fellows do it, why don't you?".

Starting from Equation 1, the assumptions behind this scenario can be synthetically expressed by Equation (10), for each subclass.

$$I_{1,i} = M_{i,c} + M_{i,m} = 1 - \left(M_{i,w} + M_{i,b} + M_{i,t} + M_{i,cp} + M_{i,mp} + M_{i,cs}\right) \tag{10}$$

where $I_{1,i}$ is the percentage target of improvement that the i^{th} user can reach by using various more sustainable mobility systems. In other words, this percentage of improvement is given by summing up the rates of the mobility modalities that should be reduced and that, in the case of the

Scenario 1, are supposed to be cars and motorcycles ($M_{i,c}$ and $M_{i,m}$). Parameters $M_{i,j}$ are computed using an if-then-else algorithm that explores in a subsequent order all the *j-th* mobility modalities, by saturating, at each step, the improvement percentage of each considered modality. The hypothesized order of priority in the algorithm is the following: walking, biking, public transportation, carpooling, motor pooling, and car sharing. Table 5 reports these improvement targets for each class of distances.

Table 5. Target improvements for the Scenario 1 assumptions.

SCENARIO 1	"A" less than 3 km	3 km<"B"<5 km	5 km<"C"<10 km	10 km<"D"<20 km	"E">20 km
Improvement 1	30%	60%	81%	71%	67%

In Table 6 the new percentages of the modal split, computed using this recursive algorithm for the Scenario 1, are reported.

Compared to the results of the Scenario 0 (Figure 3), these ones show a general improvement of the performances. In fact, the percentages associated to the less sustainable transportation means (cars and motorcycles) are reduced: for example, the use of cars related to the E subclass decreases from 35% to 13% in the Scenario 1, and the use of motorcycle decreases in all classes. However, it is evident that this scenario still allows partial improvements that can be achieved by reducing cars and motorcycles uses in the subclasses C, D and E.

Table 6. Scenario 1: commuter classes modal split.

Mobility mode	A	B	C	D	E
	L < 3 km	3 km<L<5 km	5 km<L<10 km	10 km<L<20 km	L>20 km
M1,w - Walking	67%	55%	0%	0%	0%
M1,b - Biking	12%	20%	17%	0%	0%
M1,t - Public transport	10%	13%	32%	22%	48%
M1,c - Car	0%	0%	6%	21%	13%
M1,m - Moto	0%	0%	0%	2%	0%
M1,cp - Car-pooling	6%	9%	36%	42%	37%

M1,mp - Moto-pooling	5%	4%	9%	12%	3%
M1,cs - Car-sharing	0%	0%	0%	0%	0%

The environmental performances of the “Do your right mix” scenario in terms of CO_2 emissions are reported in Table 7.

Table 7. Scenario 1: cumulated values of the emissions for the five University commuter classes.

Sample	A	B	C	D	E	
Trip length, L	L < 3 km	3 km<L<5 km	5 km<L<10 km	10 km<L<20 km	L>20 km	TOT
ΣE_1 (g CO_2)	357	969	9,321	9,145	13,190	32,984
E_1/km (g/km)	10.3	12.8	59.7	102	80.1	63.3
% E_1	1.10%	2.90%	28.30%	27.70%	40.00%	100

As shown, the Scenario 1 allows reducing the total CO_2 specific emissions from 100.6 (registered in the status quo Scenario) to 63.3 g CO_2/km.

3.3 The enhancing Scenario 2: “Do your best mix”

The second enhanced scenario (Scenario 2) represents a remarkable behavioral change that does exclude *a priori* car and motorcycle trips having an occupancy coefficient equal to one (pass/veh) and, depending on the distance of the subclasses, excludes also other mobility systems. In this Scenario, in fact, people of class A, the closest ones to the university, shall do journeys only on foot or by bicycle; users of classes B and C should go to the university only on foot, by bicycle and by public transport; and finally, users of D and E groups will be allowed to use car or motor-pooling and car sharing. For these reasons, it is defined the “*Do your best mix*” scenario.

Again referring to Equation 1, the assumptions behind this scenario are synthesized by equations 11, 12 and 13. In these algorithms, $I_{2A,i}$ represents the target of improvement that the *i-th* user of subclass A can realize with more sustainable mobility systems; $I_{2BC,i}$ represents the target of improvement that the *i-th* user belonging to subclasses B and C can realize with more sustainable mobility systems; finally, $I_{2DE,i}$ represents the target of improvement that the *i-th* user belonging to classes D and E can realize with more sustainable mobility systems.

$$I_{2A,i} = M_{Ai,c} + M_{Ai,m} + M_{Ai,t} + M_{Ai,cp} + M_{Ai,mp} + M_{Ai,cs} = 1 - \left(M_{Ai,w} + M_{Ai,b}\right) \tag{11}$$

$$I_{2BC,i} = M_{BCi,c} + M_{BCi,m} + M_{BCi,cp} + M_{BCi,mp} + M_{BCi,cs} = 1 - \left(M_{BCi,w} + M_{BCi,b} + M_{BCi,t}\right) \tag{12}$$

$$I_{2DE,i} = M_{DEi,c} + M_{DEi,m} = 1 - \left(M_{DEi,w} + M_{DEi,b} + M_{DEi,t} + M_{DEi,cp} + M_{DEi,mp} + M_{DEi,cs}\right) \tag{13}$$

In the same way than for the Scenario 1, the percentages of utilization of the different mobility modalities, $M_{i,j}$, are here computed using a recursive if-then-else algorithm. Table 8 reports the percentages of improvement referring to the limits to the mobility means established within the Scenario 2.

Table 8. Target improvements for the Scenario 2 assumptions.

SCENARIO 2	"A" less than 3 km	3 km<"B"<5 km	5 km<"C"<10 km	10 km<"D"<20 km	"E">20 km
Improvement 2	65%	75%	100%	71%	67%

As it is possible to observe and compared with Table 5, 100% of C class users can improve their mobility habits. The A class users could improve the sustainability performances of their mobility by more than two times referring to the Scenario 1, and also the number of B class users that can increase their behavior can rise consistently (from 60% of Scenario 1 to 75% of Scenario 2). For D and E classes, the hypotheses are the same of the Scenario 1.

In Table 9, the modal splits for the Scenario 2, as computed using the recursive algorithm previously described, are shown. Evidently, there is no room for car and motorcycle trips in this scenario.

Table 9. Scenario 2: commuter classes modal split.

Mobility mode	A	B	C	D	E

	L < 3 km	3 km<L<5 km	5 km<L<10 km	10 km<L<20 km	L>20 km
M2,w - Walking	86%	53%	0%	0%	0%
M2,b - Biking	14%	27%	14%	0%	0%
M2,t - Public transport	0%	20%	86%	34%	58%
M2,c - Car	0%	0%	0%	0%	0%
M2,m - Moto	0%	0%	0%	0%	0%
M2,cp - Car-pooling	0%	0%	0%	47%	38%
M2,mp - Moto-pooling	0%	0%	0%	20%	4%
M2,cs - Car-sharing	0%	0%	0%	0%	0%

Compared with the results of the Scenario 0 (Figure 3), these ones show a consistent improvement in uses of the more sustainable transportation means, and no longer uses of cars and motorcycles. For instance, the use of the public transport systems associated to the C class of the considered university commuters increases from 25% (status quo scenario) to 86% in the Scenario 2.

By applying again the Equation 3 to evaluate the environmental performances related to this scenario, the emissions of Carbon Dioxide are computed (Table 10).

Table 10. Scenario 2: cumulated values of emissions for the five university commuter classes.

Sample Trip length,	A L < 3 km	B 3 km<L<5 km	C 5 km<L<10 km	D 10 km<L<20 km	E L>20 km	TOT
Σ E_2 (g CO_2)	0.0	316	2,889	5,397	9,614	18,218
E_2/km (g/km)	0.0	4.2	18.5	60.2	58.4	35.0
% E_2	0.0%	1.7%	15.9%	29.6%	52.8%	

As it is possible to note, this last scenario allows reducing the CO_2 emissions from 100.6 (registered in the status quo Scenario) to 35.0 g CO_2/km.

4. A field application

From 28th of May to 28th of June 2014, which is a period typically full of academic activities (lectures, examinations, degree theses), we conducted a first field test of the method with the aim of verifying its feasibility, particularly its capability to push student commuters toward more sustainable mobility habits using emulative games. During the test, walking and biking were the only hypothesized means of mobility to get O_2 points.

The 77 testers were invited to download and install the mobile app to start the challenge (http://www.traffico2.com/suv). Due to the selected modalities of transportation (i.e. walking or biking), only classes A, B and C of commuters were involved, being the starting points of classes D and E too far (trips longer than 10 km) from the campus to use these mobility means. Of the 77 participants, the 45,56 % belonged to class A, while 39,66% and 16,70% belonged to classes B and C respectively. The total number of kilometers attributable to scenarios and subclasses was computed as the product of the daily lengths declared by participants by the number of trips recorded through the app for each tester.

The analysis of the gathered data shows that the actual daily user habits improved consistently from the initial Scenario 0 for both mobility means, and that even some C users made a few trips by walking.

In general, the field application shows the tendency of the selected commuters to move toward the walking modality when participating to the proposed challenge: all the sample subclasses, in fact, show to enhance the targets established for Scenarios 1 and 2, as shown in Table 11.

Table 11 Walking mobility: comparison of the field application with the base scenario and the two hypothetical ones.

Mobility classes	Scenario 0 (km/trip)	Scenario 1 (km/trip)	Scenario 2 (km/trip)	Field application (km/trip)
A	1.85	2.16	4.90	6.23
B	2.39	2.81	3.14	4.13

C	0	0	0	3.03
Total	4.24	4.97	8.04	13.40

The field application shows the same tendency to enhance the targets evidenced by Scenarios 1 and 2 also in the case of the biking modality, at least for the subclasses A and B. On the contrary, the result of the subclass C (4.04 km/trip) is between those of Scenarios 1 (2.38 km/trip) and 2 (7.8 km/trip), as shown in Table 12. In other words, commuters beginning from the most distant starting points are still inclined to use private (mainly, cars) or public means of transportation (when available).

Table 12 Biking mobility: comparison of the field application with the base scenario and the two hypothetical

Mobility classes	Scenario 0 (km/trip)	Scenario 1 (km/trip)	Scenario 2 (km/trip)	Field application (km/trip)
A	0.84	0.84	0.84	2.50
B	3.69	3.69	4.20	10.72
C	1.30	2.38	7.80	4.04
Total	5.83	6.91	12.84	17.26

In Figure 4 the three different mobility scenarios, for cumulated biking and walking modalities, along with the TrafficO$_2$ field application are reported. It is interesting to observe that results of the field application seem to be in the middle of the two enhanced scenarios (i.e. Scenario 1 and Scenario 2).

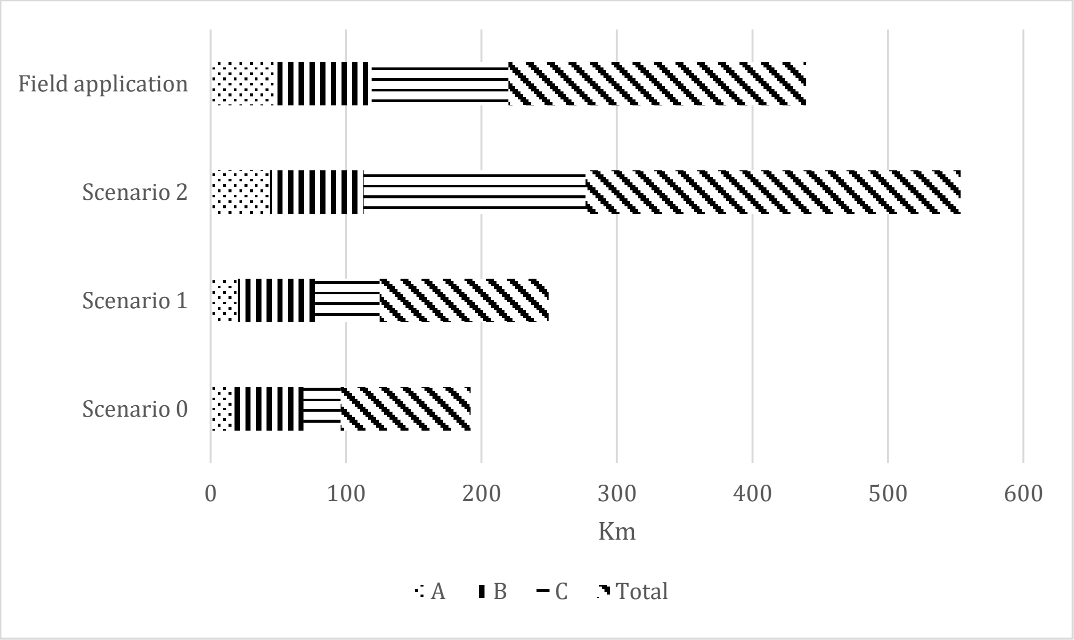


Fig. 4. Changes (km) of walking + biking modalities among the three scenarios compared with the field application of the method. Distribution by the distance subclasses.

Figure 4, that refers to the biking and walking modalities, shows that it is possible to attain really sustainable behaviors through a social innovative tool driven by emulative motivations without recurring to infrastructural interventions on the urban transportation grid. In fact, the three subclasses of commuters participating to the field application have reached results close to the hypothetical Scenario 2, which is the "*Do your best mix*" one, representing a sort of behavioral benchmark of the method.

Lastly, it is worth observing that, with respect to data referring to the Scenario 0, the modal split proposed by the field application of the TrafficO_2 method significantly reduces the carbon dioxide emissions up to almost 40%: in fact, emissions of Scenario 0 account for 40.8 tons of CO_2, while the field application indicates a release in the atmosphere of only 23.2 tons of CO_2.

5. Discussion

As stated above, the proposed model aims to fostering people to abandon bad mobility habits. The field application has shown the feasibility of this social technology-driven tool that is based on incentives and structured as a game. Table 13 compares Scenarios 0, 1 and 2 in terms of modal split rates by indicating, for each considered modality of mobility, the percentages of improvement provided by the enhancing scenarios.

Table 13. Modal split distribution of the commuting modalities for the three scenarios.

Scenario 0 (*Status quo*)		Scenario 1 ("Do your right mix")		Scenario 2 ("Do your best mix")	
Commuting modality	Percentage rate (%)	Percentage rate (%)	Improvement percentage (%)	Percentage rate (%)	Improvement percentage
Walking	9	14	56	15	67
Biking	5	9	80	9	80
Public Transport	22	30	36	51	132
Car	27	9	-67	0	-100
Moto	8	0	-100	0	-100
Car-pooling	23	31	35	20	-13
Moto-pooling	6	7	17	5	-17
Car-sharing	0	0	0	0	0

It is interesting to see how the "Do your right mix" (Scenario 1) assumptions distribute almost all car (27%) and motorcycle (8%) habits of the starting situation among the other mobility modalities, in this way signaling a general improvement of the overall performance of the system. In addition, the analysis of the single modal split components indicates that the initial biking (5%) and walking (9%) modalities are affected by the higher improvements (80% and 56% respectively) in the Scenario 1, followed by public transport and carpooling (36% and 35 % respectively). Cars and motorcycles have a dramatic decrease, registering 67% and 100% of diminution respectively, in this way indicating the higher sustainable performances of the Scenario 1 compared to those of the Scenario 0. As for “Do your best mix” hypotheses (Scenario 2), since car and motorcycle trips were excluded from its assumptions, the model reallocates a cumulated 35% percentage of car (27%) and motorcycle (8%) habits prevalently to public transports modality (with a whole improvement of almost 130%), conversely reducing them respectively by 13% (car) and 17% (motorcycles). On the other hand, walking and biking modalities in the Scenario 2 maintain almost the same values of Scenario 1.

The comparison of these scenarios in terms not only of effectiveness of the realized mobility, but also in terms of environmental performances is furthermore interesting.

Table 14 shows that Scenario 1 (Σ E_1) cuts off remarkably the greenhouse releases for all the considered subclasses of distance. These reductions are clearly confirmed by the intensive values (E_1/km) of the emissions (g CO_2/km). In the Scenario 2, the decrease in the CO_2 emissions (absolute as well specific) is very impressive for all subclasses of commuters compared to those featured in both Scenario 0 and Scenario 1.

Table 14. CO_2 emission of the commuting modalities in the three scenarios.

Sample subclass	A	B	C	D	E	TOT
Trip length, L	L < 3	3 km<L<5 km	5 km<L<10 km	10 km<L<20 km	L>20 km	
Σ E_0 (g CO_2)	761	3.514	17.997	11.092	19.053	52.417
Σ E_1 (g CO_2)	358	969	9.322	9.145	13.190	32.984
Σ E_2 (g CO_2)	0	317	2.890	5.397	9.614	18.218
E_0/km (g/km)	22	46	115	124	116	101*
E_1/km (g/km)	10	13	60	102	80	63*
E_2/km (g/km)	0	4	19	60	58	35*

* Average values

This comparison further singles out that CO_2 emissions decrease from Scenario 0 to Scenario 1 by 37% and from Scenario 0 to Scenario 2 by 65%; additionally, there is an improvement from Scenario 1 to Scenario 2 with a total cut of the emissions of 45%.

As regards the actual feasibility of this method, essentially based on the principle of emulation of correct habits, it must be remarked that the Scenario 1 could easily be implemented in a given community by a local government, being basically funded on the enhancement of walking and biking modalities of commuting for people that start from not so far distances (up to 5 km). Instead, the Scenario 2 definitely needs quite radical behavioral changes because it requires that people almost totally abandon cars and motorcycles.

Moreover, in sight of their possible implementation in a given context, it is interesting to note that each of these two improvement scenarios are not alternative, since Scenario 1 might be regarded as a partial target that leads towards the most efficient goals defined by Scenario 2.

Clearly, once the suitability of the method is proven, it could easily be applied by changing the nature of the game and its prizes: for instance, different award systems could be based on scores represented by economic discounts of the costs of the public services offered by the Public Administrations for citizens that change their mobility habits toward more sustainable ones.

Clearly, further analyses are needed to better understand what pushes people to greener habits (Dickinson et al., 2013) including the role that can be played by gaming and social network features (Bartolo & Mariani, 2014) and to better singling out what individually drives each single user, or each single category, to choose whether to be greener (Gatautis & Vitkauskaite, 2014).

6. Conclusions

In this paper, we presented the TrafficO$_2$ model, which is a tool that intends to improve traffic conditions and reduce air pollution through a social network by fostering directly citizens toward greener behaviors in a one-to-one dialogue. This tool is meant to facilitate the interaction between pre-defined categories of users, companies, and potential sponsors in order to reach an agreement that is fair to all of them, providing for a reward in exchange for sustainable modes of mobility.

Specifically, we have analyzed a particular category of commuters and argued whether and to which extent the social innovation project TrafficO_2 could effectively face the challenge of reducing their related traffic flows and environmental pollution, without involving the urban structure or infrastructure modifications. No classical mobility policies such as road pricing, public transport network management, traffic-limited areas were applied in this research. The strategy adopted consisted in encouraging - through a suitable structure of information and appealing rewards - daily commuters to select more sustainable mobility means instead of private cars and motorcycles. We have studied the behaviors of a sample (a group of students of the University of Palermo) and have simulated their resulting CO_2 emissions. In order of assessing credible user-tailored targets, we have defined two different improvement scenarios: the “Do your right mix” (Scenario 1) and the “Do your best mix” (Scenario 2). These are suitable models that take into account the different commuter distances from their University departments, their mobility means and their current behaviors (that is the Scenario 0).

Certainly, since the results of the presented application strongly depend on the specific town under analysis, its mobility system, and its vehicular running fleet (apart the selected sample itself), the reliability of TrafficO_2, specifically in of different user communities and city contexts, needs to be verified. Nevertheless, since the presented model is explicitly based on the user experience instead of the context’s features, it should ensure a good scalability in different contexts. Another strength point of the presented model is in that it is based on smartphones that are getting cheaper and more popular, while Internet connections are rapidly improving.

Furthermore, the system, apart generating benefits for citizens, will produce profits for the urban network of businesses and sponsors that actively participate to the project. In fact, local businesses willing to invest in innovative advertising and targeting geo-referred marketing analysis will receive visibility by becoming stations of the system and by getting detailed information about their customers and their products.

Once the suitability of the method is proven, it could easily be applied by changing the present nature of the game and its prizes: for example, different award systems could be based on scores represented by economic discounts of the costs of the public services offered by the Public Administration for citizens that change their mobility habits toward more sustainable ones.

In our opinion, an important lesson of this application is that effective results can be achieved through the involvement of people, almost comparable to those obtained by implementing deep mobility policies and structural modifications of the transportation system.

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