A Methodological Framework to Assess Individual Sustainable Behavior

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Abstract. Cities are privileged places in which the transition of society towards a sustainable future could be achieved. In this direction, individuals could have a preeminent impact in the attempt to meet such target.

To engage individuals in the more responsible use of resources, more sustainable behavior and environmental identity within citizens has to be promoted. To support the transition of citizens behavioral patterns toward a more sustainable use of resources, several tools have been proposed, especially in the Human-Computer Interaction field. Such tools are rarely used more than once by users, thus usually they fail in promoting a stable engagement of the user, and their efficacy in fostering a change in her environmental behavior is limited. In this paper a methodology to design a gamifyied environment is presented, taking into consideration the possibility to integrate different parameters to promote user's participation and to foster her perseverance in the engagement with the proposed serious game. A specific Sustainability Index is proposed, together with its calculation algorithm, in order to better communicate and compare the environmental performances of individuals, and ultimately to interact among each other through collaboration and competition in the framework of the proposed game itself.

Keywords: Sustainable behavior · Gamification · Environmental Impact

1 Introduction

Cities have a primary impact in the achievement of a more sustainable society [1]. Indeed, nowadays more than half of the world's population lives in urban areas, and their carbon emission related to the energy uses in cities account for more than half of the globally emitted greenhouse gases (GHG) [2]. A large number of initiatives target the city as the place in which to concentrate the actions towards a more sustainable future where to pursue an environmental sustainability and social inclusion [3]. The 2030 Agenda for Sustainable Development, for example, specifically addresses cities with its 11th Sustainable Development Goal (SDG), aiming at making "cities and human settlements inclusive, safe, resilient and sustainable" [3]. Furthermore, cities could also be particularly interested by the new paradigm of the Circular Economy [4] as it has

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been framed by the European Commission in its Circular Economy Action Plan (CEAP) adopted in the wider framework of the European Green Deal [5, 6]. The shift to this new paradigm will influence cities by limiting the loss of biodiversity, and create sustainable growth by generating new jobs [7–9].

The wished transition toward a more sustainable and circular city will inevitably have to consider the complexity of the urban system and the wider plethora of city users, stakeholders and actors, in order to ensure an equitable transition towards a human-centered circular model [10, 11]. In particular, considering the role of individuals in such transition, it has been extensively recognized the impact that they have in several fields related to the consumption of resources. In the building sector, for instance, it has been extensively demonstrated how the way in which the user operate a building has a great impact on its energy consumption [12], limiting the reliability of the assumptions made in the design phase and, thus, resulting in a mismatch between simulated and actual energy consumption [13–15].

Also in the general consumption of resources, the role of individuals is fundamental in achieving higher level of sustainability, as well as a potential shift to a more circular society. Several examples are presented in literature regarding recycling patterns [16, 17], water consumption [18], individual purchase decisions [19, 20].

Some studies have demonstrated that, even when structural barrier are removed, people tend to behave in a more sustainable manner only when they already have a pro-environmental attitude [17, 21], or environmental identity [22]. As such, to promote a better and more efficient use of resources, and thus, a more sustainable behaviour of individuals, the promotion of environmental identity within citizens has been stressed [21], as well as self-efficacy building education [23], and social interaction [24]. In engaging with sustainable behaviour, the amount of information possessed by the individual plays a significant role in this attempt [25], by affecting their perceived behavioural control and self-efficacy conceived, respectively, as the perceived amount of control people have on their actions [26], and their perceived level of control to implement these action regardless the events affecting their lives [27].

In regards to self-efficacy, for example, several are the studies suggesting that increasing the amount of information provided to individuals could reduce their use of energy [28–32], while the comparison to others could promote more sustainable behavioral patterns [17, 33].

Considering all the above, aim of this paper is to propose a methodology to evaluate the sustainability of individuals through self-reported virtuous actions to be implemented on an online application, and to foster their transition towards environmental conscious behaviour. In particular, the proposed methodology will exploit the possibilities of engaging the individual inside context specific virtual communities in gamified environments. These communities could be formed based on common interests or characteristics (employees of the same company, fan-bases of sport events, etc.) and defined in time (in the form of time defined challenges), in order to promote the effect that the push from peers could have in the achievement of higher level of individual sustainable behaviour.

The rest of the contribution is structured as follows: in Sect. 2 different sustainable evaluation protocols are presented with the focus both on the hardware component of the

urban infrastructure, and on the available tools to assess and foster individual citizens' sustainable behavioural patterns. In Sect. 3 the methodology to develop the gamified environment is delineated. Finally, in Sect. 4 conclusions and further avenue of the research are presented.

2 Evaluation Methods and Engagement Strategies

2.1 Urban Sustainability Protocols and Methods

The attempt to evaluate sustainability at the urban level is a complex task that comprise several dimensions: from environmental, economic, and social ones, and it is not just a purely technical/scientific evaluation [34]. In the context of urban regeneration projects, the literature presents a variety of methods to assess decision-makers in selecting the most suitable alternative to achieve higher level of sustainability against a wide variety of criteria [35]. Several international and regional protocols originally proposed with the goal of assessing the performance of buildings [36] are now expanding their view in order to provide evaluation tools more balanced toward the assessment of environmental, social and economic dimensions" [37]. Among these, BREEAM Communities, CASBEE-UD, GBI Township, LEED-ND, IGBC Green Township and GRIHA-LD could be named to provide an example of the wide variety of protocol used both internationally and in specific national frameworks. Compared to their "building-focused" counterparts, tailored for the site specific evaluation of aspects of building performance related to its site [38–40] these large scale tools aim to transcend building components or buildings separately [41, 42], in order to take in consideration, at the same time, also the built environment, landscape, infrastructure in their evaluation [43]. The previously mentioned protocols are based on evaluations performed by third party organizations. Other frameworks measure individual assets or portfolio grounding on self-reported data [36]. Tools like the Global ESG Benchmark for Real Assets (GRESB) [44] or European Public Real Estate (EPRA) [45] aim to collect data on environmental, social, and governance performance of buildings in order to provide recommendations on optimization options, and to provide a framework to track their performance over the years.

All these methods assess the urban environment as static assets or in specific moment of time, lacking an integration of the dynamic component represented by the users of spaces. In these sense, a method to engage people in the "on going" sustainability of a city/district/neighborhood is still lacking. Therefore, an assessment tool that could engage the community at different moment (as it could be the case of specific windows of time) could integrate these aspects in the assessment of the sustainability of the urban areas. Nonetheless, these methods allow the comparison between achieved performance (or design option) against benchmark ones, thus guiding towards areas of possible improvements of the former.

2.2 Environmental Footprint as Individual Sustainability Assessment Tool

The evaluation of individuals' behavior in term of sustainability is usually demanded to Ecological footprint calculators. Similar to self-assessment methods [36], these tools

are based on self-reported data about user's consumption pattern in order to evaluate her impact on the environment. The results of the calculation are usually presented in kilograms of equivalent CO_2 yearly emitted (thus usually referred to as "carbon footprint calculator"), accompanied by advices and suggestions on how to reduce this figure through behavioral change [25]. Also in this field, a variety of calculators are available in literature [25], both internationally and national specific [46].

The capability of certain calculators of providing continuous information about environmental impact through monitoring and feedbacks aim to influence individual perception of self-efficacy [47], allowing them to be considered behaviour change interventions [25], with proven effects on individual environmental footprint reduction [48–50].

Despite these potentialities, the use of environmental footprint calculator is not so widespread among individuals [51]; furthermore, the majority of these tools are used few times by the same user [46, 52].

This aspect, in particular, has a peculiar hindering effect on the desirable outcomes of the use of environmental footprint calculator [25]. In the household domain, for instance, it is recognized that the efficacy of feedbacks is related on their frequency and continuity [28, 31, 53, 54]. One of the major obstacle in this regard resides in the design itself of the commonly used calculators, structured to provide feedback on a yearly base [55], reducing the likelihood of a repeated use of the tool [25].

Another aspect that has been recognized as culprit for the reduced impact of these calculators is their too narrow focus in solely providing information about carbon footprint, without providing actionable feedbacks [46]. An avenue of improvement in that sense as been proposed in the introduction of gamification aspects in these tools.

2.3 Gamification and Serious Games to Foster Behavioral Change

The promotion of behavioral change toward a more pro-environmental one is a common goal for initiatives in the realm of serious games and gamification in the Human-Computer Interaction (HCI) field [46, 56]. These two concepts refer to the inclusion of game design elements in real-world contexts, to combine entertainment purposes, with other motivations such as learning ones [57–59]. These elements take the form of points, levels, badges to name few, and absorb the player in non-game activities, motivating her to engage in the activity for which the gamified environment has been designed [60]. In this sense then, gamification has been recognized as promising in promoting a shift toward more sustainable behavioral pattern in users and, in general, among members of society [46, 60].

Regarding some of the limitation of the aforementioned environmental footprint calculator, and in particular the issue related to their one-off use by users, gamification specifically address this matter by motivating users (also referred as players in this framework) to repeatedly engage with sustainable actions [60], and, by doing so, promoting habit formation and, consequently, the long-term maintenance of a certain behavior [61].

An interesting aspect related to gamification is the possibility to connect members in a community [46] by sharing experiences and best practices [62] and to foster the engagement of players through competition among them.

Ro et al. [60] highlights how this latter aspect could be related to behavioral change theory, and, especially, on the aspect of group norms. Users playing in groups (teams)

are motivated to engage with behavior that would fit with others in seek for a sense of acceptance, further conforming to the group norm [46, 60, 63]. Another positive advantage in the introduction of competitive aspects in the system is also represented by the possibility of pushing slaking members to engage by reminding them of the contribution that they could provide [60].

This role of providing information about other users and, especially, who leads the group in terms of commitment, is fulfilled by leaderboards providing information about individual or group/team achievements [46], thus providing extrinsic rewards [62, 64], and, ultimately, spread the adoption of desirable behaviour through social diffusion [60, 65].

3 Gamified Methodology to Assess Individuals and Collective Sustainability

In light of the considerations above, the present paper aims at presenting an ongoing research about the construction of a platform-based gamified environment (a serious game) with the target of boosting the adoption of sustainable behaviors among users. Such goal will be fostered by the mechanics of the game aiming at promoting the interaction of the user with the platform and with other users.

The game is based on the calculation of a Sustainability Index (SI) proposed as a metric to establish the level of sustainability of the user's behavior. The SI will be calculated as a player's total score, based on three main components that will grant her points: (i) the actual behavior of the player, (ii) the fruition of educational contents provided by the platform, (iii) and the continuity of interaction with the platform itself. The SI will be then normalized in a scale from 0 to 1, representing the percentage of achievement of a fully desirable sustainable behavior, being 0% an unsustainable behavior of the user, and 100% a fully sustainable and desirable behavior.

Considering the first aspect, the actual behavior of the user will be evaluated by means of the self-reported environmental responsible actions that she accomplishes during a day. In particular, on the platform, a set of environmental conscious behaviors (actions) will be proposed; examples of such actions might be, for instance, "increase the set-point of your cooling system", "switch to a plant based diet" and so on. Each day, the player will state which action she has performed, and she will score a number of points according to the number of action she accomplished. The higher the score, the higher the level of commitment of the user with an environmental conscious behaviour. The second aspect (fruition of educational contents) will aim at sensitise the user toward the possible changes in her behaviour in order to reduce her environmental footprint, and also regarding the impact that the actions described above could have in this direction. The mechanics of the game will grant extra points to the player due to her interaction with these educational contents, thus increasing her final SI score. The last way in which the player could score points is by means of a repeated interaction with the platform: the longer the player self-reports actions and make use of the educational contents, the more extra points are granted, and her SI will increase, thus rewarding the continuity of the player's engagement.

The ultimate goal of the integration of these two last additional ways for scoring points in the mechanics of the game (i.e. the fruition of educational content, and the perseverance in interacting with the platform) is to increase the awareness of the user toward the possible impacts that her daily actions and choices could have in terms of environmental sustainability, and to promote a change in her behaviour and the maintenance of the latter in time.

The mechanics presented above will result in the calculation of the individual player's SI. A second step to further boost the engagement of the individual player will be by means of the interaction among users [46, 60]. In this regard, the players could decide to join together forming teams and compete among each other during defined time-windows, so called "challenges". These challenge could be tailored on specific community of users, and promoted during particular events in partnership with different types of promoters, such as sport or cultural events, corporate team-building activities, and so on. During a challenge, a player could voluntary join a team and participate to the construction of the team's SI (SI_{tm}) that will be calculated as an average of each team member's individual SI.

Depending on the type of event for which the challenge is promoted, possible extrinsic rewards could be envisioned such as specific benefits in case of corporate team-building, or intrinsic ones in case of operations such as community building attempts [62]. While the single-mode mechanics (the possibility for the user to calculate her SI) is not time-limited, the competition in teams will be necessarily constrained within specific time-spans in order to act on two temporal levels (continuous and punctual), using the challenge mechanism as singularities to boost users' participation.

The present mechanics share some similarities with several other proposed ones regarding the interaction among different users, but differentiate itself particularly in the way in which the environmental performance of the users are calculated and used to compete against each other, or in teams (See in particular [66]). In particular, the proposed methodology is bases on the calculation of a tailored index (the SI) capable to easily communicate to the users the impacts that individual actions could have on the environment. At the same time, such index will be used in the competition among users and teams to establish the most sustainable one. An aspect of novelty of the proposed methodology reside specifically in the calculation of such index, in analogy with the sustainability assessment protocols presented in Sect. 2.1. Such procedure allows to perform benchmarking evaluations against an optimum common sustainability target independently from other users (differently, for example, from mechanics used in other projects such as [66]), thus providing feedbacks regarding the distance of each user from a desirable goal.

In Fig. 1 a schematization of the architecture of the proposed environment is provided. Starting from self-reporting the accomplishment of virtuous actions {A.1, A.2, A.3…A.n} selected from the set of available options (a) (such as "increase the set-point of your cooling system", "switch to a plant based diet" and so on), and the other forms of engagement with the game such as: access to App-embedded online content (q), repetitive use of the platform during several days (c), each user will score a specific amount of points. Furthermore, the SI individually achieved by each of the users will be averaged

on the number of users to return the overall SI_{tm} that will be used as the metrics to compete with the other teams in the time-defined challenge.

Similar to the building and neighborhood evaluation protocols described above (such as BREEAM, LEEDS, and so on), 5 labels are associated with predefined thresholds. These labels are defined in the form of medals (platinum, gold, silver, bronze, wood), in order to provide the user with an easy to understand metrics to evaluate her own level of sustainability.

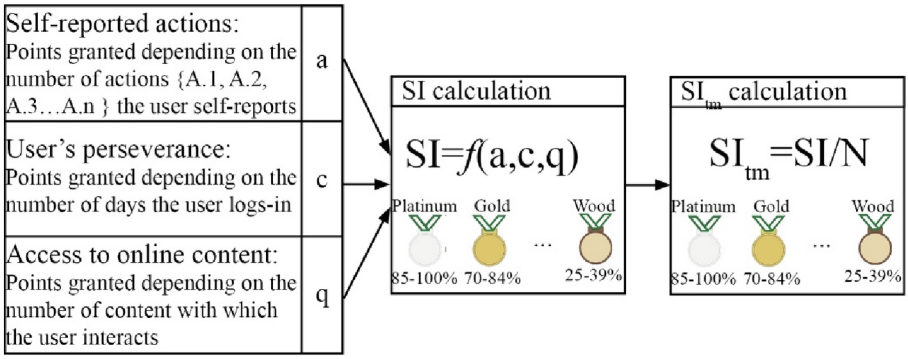


Fig. 1. Architecture of the proposed serious game.

In the next sections, a mathematical description of the game mechanics used to calculate the SI is presented.

3.1 Sustainability Index Calculation

Following the proposed mechanics, each user's individual SI will be calculated daily following Eq. (1):

$$SI = log((a + c + q) * \frac{9}{k} + 1) \tag{1}$$

where a is the total amount of points scored by the user by self-reporting the accomplishment of the virtuous actions, c and q are a number of possible bonus points to account for the interaction of the user with the App, and k is the total amount of points worth of achieving the highest SI. For consistency reasons, the latter parameter must be constrained according to Eq. (2):

$$k \geq (a + c + q) \tag{2}$$

and, furthermore, the value of k should be equal to the maximum points achievable by accomplishing all the actions proposed by the set of predetermined ones in the App:

$$k = a_{max} \tag{3}$$

being a_{max} the sum of all the points granted by self-registering all the actions of the proposed set. In line with the attempt of the proposed mechanics to promote user's participation and to challenge them to achieve higher level of sustainability in their behaviour, the logarithmic function (1) has been proposed against a possible linear one in the normalization of the SI. In Fig. 2 a graphical comparison among the two normalization strategies are displayed.

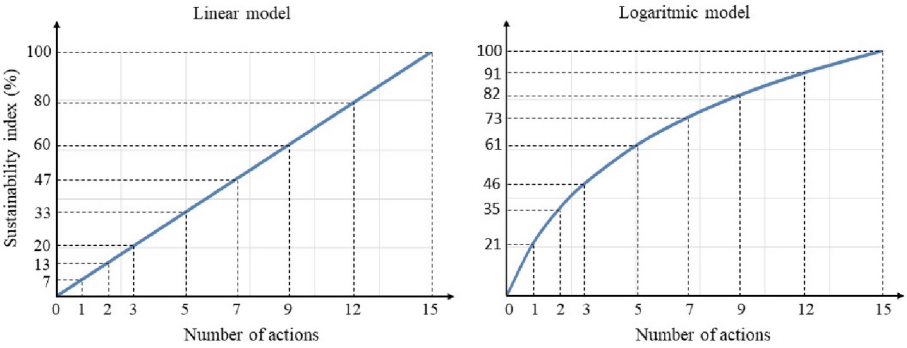


Fig. 2. Comparison between linear and logaritmic model

As it appears clear, the non-linear function (the logarithmic one) grant higher level of SI even to users that score low amounts of points while becoming more and more challenging for users that already achieve higher scores. This could have a double-fold advantage on the linear model: on the one hand, it lessens the punitive results of slacking individuals, while keeping the already virtuous users challenged. The latter aspect might respond to a common issue reported by few Authors highlighting how already pro-environment users report lower interest toward not challenging environmental calculators [46].

3.2 Point Scoring Mechanics

Aa seen before, the user might score points accomplishing certain actions from a set of predefined ones (parameter a), by fruition of contents embedded in the App (parameter q), or logging in the App for more days in a row, thus engaging recurrently with the App and the team (parameter c).

In particular, regarding parameter a, the set of possible virtuous actions {A.1, A.2, A.3…A.n} are individuated. Each action grants a number of points related to its possible environmental impact reduction that a user would achieve by acting according to that behaviour instead of a usual one.

Therefore, the value of parameter a will be calculated as (4):

$$a = \sum V_{A.n,acc} \tag{4}$$

where $V_{A.n,acc}$ is the value $V_{A.n}$ of the actions that user accomplishes and self-register.

Regarding parameter c, it considers the perseverance of the user in interacting with the challenge (the time-defined period of time in which the user joins a team and compete against other teams), granting points depending on the amount of days she log-in the App. The calculation of c is performed according to Eq. (5):

$$c = \left(t * \frac{\sqrt{c_{max}}}{T} \right)^2 \tag{5}$$

where t is the number of days the user logs-in during the challenge, T is total duration of the challenge in days, and c_{max} is the total amount of points grantable by the variable c. The mechanics rewarding the user with more points the longer she interacts with the challenge is quite evident from the shape of the curve that grants points with a quadratic relation to the number of days of log-in (5). The points granted by the parameter c will increase each day of participation of a user to a challenge, motivating her to be perseverant in her engagement.

Finally, parameter q is intended to promote the interaction of the user with educational content regarded sustainability targets that could be achieved by engaging in more pro-environment actions and behaviors: each day the App will provide the user with educational contents the fruition of which will grant her a predefined amount of points to increase her SI level (avoiding the necessity to accomplish each and every one of the possible action defined in the set of actions {A.1, A.2, A.3…A.n}, thus reducing the possible disappointment of the user not capable of doing all the actions every day). One of the main advantages of the presented model is the possibility to specify all the parameter at stake (from the number of actions, to their specific value through the number of possible impacts, to the maximum amount of points granted by parameters c and q). The final step to be performed to calculate the SI at the team level (SI_{tm}) would then be to average the individual SI of the team members and to average them with the number of team members (N_{tm}). The SI_{tm} will then be:

$$SI_{tm} = \frac{SI}{N_{tm}} \tag{6}$$

4 Conclusion and Future Perspectives

In this paper a serious game has been proposed in order to support individual's transition towards a more environmental conscious behaviour. The proposed mechanics make use of a specifically designed index able to easily communicate to the player her degree of sustainability compared to a fully desirable one. Such index could be used to foster user's engagement by means of interaction and competition with other users, and, thus, building on the concept of group norm.

The proposed methodology for the calculation of such index specifically targets the issues that such serious games usually have to face, such as the lack of users' participation or the low number of times that the player interacts with it, by means of the introduction of different parameters in the calculation process.

Regarding the calculation process itself, the aggregated Sustainability Index at the team level could have a counter-productive effect: due to the fact that the former is calculated by averaging the individual member's Sustainability Index, the virtuous behaviour of a single user could be lost in a not so performing one at the team level, thus depressing the individual user's motivation to challenge herself in performing more environmental conscious actions. In this regards, the communication of the performance of each user should not be presented as subordinate to the aggregated communication of the performance of the team as a whole, in order to promote social diffusion and the engagement starting from the individual level.

The present paper is methodological in nature, therefore, both the range of actions to be considered in the point scoring mechanism, and the possible duration of the team challenging mechanism have to be further defined, and the potential to adapt their case by case selection depending on the specific events should be further investigated.

As a future development of the research, the different amount of points granted by the actions should be defined based on the reduction potential that such action could have on the overall footprint of an individual, against different sets of criteria (such as reduction in the use of energy or resources, or the reduction of behaviour induced carbon emissions). Such impact should be adequately evaluated and scientifically sound, in order to further be informative on the potential reduction of one's environmental impacts. Finally, the methodology will be implemented on a web-app, and it will be tested in different context (urban communities, corporate team building events, sport or cultural events) in order to test its capability to foster individuals' engagement, and to evaluate possible context-specific modification to the methodology itself (in terms, for example, of bonus point allocation).

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