Abstract—Facilitating and fostering positive changes in citizens’ behaviors is an important dimension in a Smart City, and one of the key issues for city sustainability. However, innovative and often costly city policies and advanced IT solutions are liable to fail, if not combined with initiatives aimed at increasing the awareness of citizens, and promoting their behavioural change. This paper explores the potential of gamification mechanisms to incentivize voluntary behavioural changes. We present a service-based gamification framework which can be used to develop long-running games on top of existing services and systems within a Smart City, and discuss some preliminary findings in an open-field experiment running in the city of Rovereto, Italy, to promote sustainable urban mobility.

I. INTRODUCTION

Smart Cities are complex conglomerates of people, information systems, services, sensors, smart objects, and many other ICT and cyber-physical systems, which innereve contemporary urban environments. Smart Cities present many new challenges and opportunities not only technology-wise – but also from the governance and societal points of view.

A principal challenge is how to leverage the advanced technological assets of a Smart City to foster and facilitate positive changes in the individual and collective behaviors of its citizenry, ideally in support to objectives and policies that are decided and agreed upon at the city-wide level. For example, Voluntary Travel Behavior Change (or VTBC) is a key issue for sustainable urban mobility [1], [2], which, in turn, is considered one of the main dimensions in a Smart City [3]. But VTBC can only happen when the definition of city-wide mobility initiatives and policies - and the deployment of advanced technological services that support those policies - go hand in hand with the convinced and continued embracement of those policies and services by a critical mass of citizens.

In recent years, gamification, i.e., the use of game design elements in non-game contexts [4], has been successfully applied to increase citizens engagement and participation in Smart City initiatives, for instance to promote sustainable mobility behaviors [5], [6], [7], [8].

To achieve the objective to promote and sustain behavioural change among smart citizens it is critical to recognize that using gamification as a persuasive technology [9], [10] in a Smart City is profoundly different, and way more challenging, than applying gamification to a single, well-known and self-contained information system or application, and for an objective that is decided a priori, as in many gamification projects that appear in the state of the art [5].

When we look at a Smart City, we look at a very complex, dynamic and open–bounded socio–technical system, in which objectives on behavioral change are dynamic, i.e., they may change often, or be manifested in varying ways over time. Furthermore, a Smart City is characterized by a great diversity of services, service providers, and technological affordances for the provision of those services. Those are also very dynamic and heterogeneous; any non–trivial city–wide gamified application must be able to interface with a variety of them. The socio-technical nature of a Smart City also implies that a multiplicity of different stakeholders must interact to fulfill city objectives, implement the corresponding policies, and foster and facilitate the desired behavioral changes by the citizenry.

Analogous granularity considerations have to do with the temporal dimension. To be truly effective, behavioral changes promoted by gamification must be sustained over time. That has two consequences: on the one hand, games must be designed to be long-running, that is, must promote citizenry engagement in the long term, and must ensure not only the engagement but also the retainment of players; on the other hand, those games must appeal to latecomers who enter the game at any point in time. That means that games must be designed to provide a variety of means to recognize performance of – and thus provide gratification to – the citizens/players, some of which must be effective independently from the accumulation of game status over time. Moreover, since in a city there may be (semi–)permanent initiatives to enact a policy, as well as campaigns that have narrower scope and shorter duration, the playful activities proposed by gamification should properly capture and emphasize those different scales; examples of such mechanics are mini-games and spot challenges embedded in games of wider scope and longer duration.

In this paper, we present a comprehensive software framework enabling the design and execution of gamification solutions for Smart Cities and supporting the following concerns:
1) dynamic and varying Smart City policies and objectives;
2) open-ended integration of heterogeneous services;
3) multi–stakeholder games;
4) games including playable units at various granularity levels and multiple temporal scales.

The proposed gamification framework has been evaluated through an on-the-field experiment in the city of Rovereto (Italy) with a long-running game in the domain of sustainable urban mobility, called Rovereto Play&Go.

In the rest of this paper, we discuss the overall design and implementation of our gamification framework (Section II), with a focus on provisions for long-term engagement and retainment of Smart Citizens in games, through the definition of personalized and contextualized challenges; we then present the on-going experiment carried out in the city of Rovereto (Section III) and discuss some preliminary results from the field; finally, we conclude presenting some related works (Section IV) and conclusions (Section V).

II. GAMIFICATION FRAMEWORK

Our framework for the specification and execution of gamified applications in a Smart City has learned from an early
design, which was outlined in [8], and greatly extends it with, among other things, provisions for multiple stakeholders, game analytics, and the capability of dynamically generating personalized units of playable content.

A. Gamification Framework at a Glance

Our gamification framework 1 caters to three principal stakeholders: i) officials and decision-makers of the Smart City, who want to promote their policies by making sure that the logic of the game, and the corresponding incentives and game mechanics, meet the corresponding objectives and constraints; ii) gamification experts, who design and develop appropriate games in line with the policies of the city and the community; iii) the Smart Citizens, who collectively participate in games that promote those policies, by interacting with the Smart City IT environment (services, sensors, apps etc.).

The architecture of the gamification framework is organized in three main layers: Gamification Enablers, Gamification Services and Gamification Front-end (see Figure 1).

The Gamification Enablers support for the basic functionality related to the design, deployment (the Game Definition component), and execution (the Gamification Engine component) of games, and its integration with Smart Cities ICT systems; it also supports advanced functionalities for the automatic generation of challenges (the Challenge Generator component), which are personalized playable units that are synthesized taking into account a player’s profile, game state and game history (i.e. game results and actions, respectively).

The Gamification Services expose the functionality implemented by the enablers as services, which can be easily used to build new gamification components and applications that exploit the core components of the framework (e.g., services supporting the definition and deployment of games, services for accessing information about the game and player state, services supporting the configuration of notifications for communicating game results to the players).

The Gamification Front-end layer contains end-user applications for the three stakeholders. In particular, it provides applications supporting the definition and deployment of games (for game experts), the presentation of game state (for smart citizens), and the analysis of game results and impact vis-a-vis to the city objectives (for officials and decision makers).

B. Openness, Generality and Extensibility

Our framework aims to be open, general and extensible, with respect both to the ICT affordances (applications, sensors, services, etc.) that it can integrate, and the types of game mechanics and games that it supports. In order to achieve those objectives, from the technical point of view we have designed our gamification framework in accord with the architectural principles of service orientation.

Adherence to service orientation offers a number of major advantages, including: i) the ability to integrate with open, heterogeneous and multi–ownership systems (including legacy) that are operating in a Smart City and that expose their functionality in terms of standard services (or, at least, in a way that makes possible to wrap them as services); ii) the standardisation of interactions that occur between our gamification framework and players game presentation, independently of the medium and device delivering that presentation; iii) the extensibility of the set of game concepts that can be used in specific gamification applications.

The first two advantages regard the integration between the framework, the surrounding ICT fabric of a Smart City, and its Smart Citizens. They are critical to enable the gamified applications to run and be experienced in an open-ended and heterogeneous ICT landscape. The latter advantage impacts the ability to design flexible games that can use and swap in a modular way a variety of game mechanics and related incentives, depending on the objectives and policies of the city or community being gamified.

About the open-ended integration of heterogeneous Smart City ICT affordances, we use a uniform layer of service wrapping, which issues notifications to the framework, whenever game-relevant actions, are taken by the player. We call those notifications gamifiable actions. The gamification designer designates what gamifiable actions are relevant for the game at hand, and decides on their data payload.

Gamifiable actions are thus the entry point to the system, and, specifically to our Gamification Engine (GE). The GE is in charge of launching games and executing their game logic, advancing the game state for all players in all executing games, and persisting that game state. The GE adopts a reactive computing model, as advocated int [11]: the logic of a game is expressed as a set of rules that predicate on players current state, and are triggered and fired in response to the incoming events, i.e., the gamifiable actions. Rules can modify the game state, and also fire additional events that may trigger chains of further game rules. To that end, the GE encapsulates state-of-the-art rule engine technology (i.e., the Open Source DROOLS rule engine – http://www.drools.org).

The GE is also in charge of providing access to the game state. By again leveraging service orientation, the GE can present a uniform service interface to retrieve the various elements composing the game state of players. A game presentation front-end can access those game state elements through the service interface, and deliver them to the player according to the desired user experience, medium and/or device (e.g. Web-based, or mobile App, messaging systems, etc.). Similarly, a subscription service interface allows to register such a front-end to receive notifications about events that occur within the game, such as, for example, updates to one players game state. The way incoming notifications are presented to the player is again a issue for the front-end.

Finally, to support the work of the game designer, we have introduced service-based game modules, which we call game plugins. Each game plugin represents a game concept: we have game plugins for fundamental building blocks such as Points, Badges, Badge Collections, Challenges, Leaderboards, and so on. A game plugin has two major purposes: i) it makes available the data structures that describe the portion of the game state for the corresponding game concept and rules of the game shall refer to and manipulate those data structures, and they are persisted by the GE; ii) it exposes a service interface with operations that the game rules can use to interact with the game concept, and implements those operations with a logic that is consistent with the semantics of the concept.

By using game plugins we encapsulate and enforce specific game mechanics in a modular way, and we create a repertoire of game mechanics with precise semantics and well-defined means of interaction in the game, which a game designer can choose from. Each new game mechanic can be captured by

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1See https://github.com/smartcommunitylab/smartcampus.gamification
a plugin with the proper data structures, a suitable service interface, and an internal implementation of the logic of that mechanic. Each game plugin may have multiple instantiations in the same game; for example, you may have multiple sets and specializations of the Points concept (such as, green points, health points, participation points etc.), with the corresponding rules, competitions and leaderboards.

The gamification services also support the deployment and set-up of game instances in the Gamification Engine.

C. Automatic and Personalized Generation of Challenges

The Challenge Generator component of Figure 1 provides our framework with the capability of producing in a (semi–) automatic way new units of playable content for players, called challenges. A challenge consists in proposing to a given player to reach a specific goal, whose achievement requires a prolonged individual commitment, typically within a limited period that is significantly shorter than the game as a whole. If the player manages to fulfill a challenge within the allotted time, she receives a prize, either in-game, or possibly even material. Challenge goals may have to do with either in-game performance targets, e.g., gaining a certain number of points, reaching a game level, completing a badge collection etc., or directly with achieving specific behaviors promoted by the game, or breaking one’s habits (e.g., in the case of a urban mobility game, trying a new way of commuting, or increasing one's usage of sustainable transportation means).

Challenges represent a valuable game mechanics for engagement and retention in a long-running game, since they can be diverse and – with their specific scope and fine time granularity – they offer to players the possibility of success, progress and reward with a focused and limited effort. Challenge goals may have to do with either in-game performance targets, e.g., gaining a certain number of points, reaching a game level, completing a badge collection etc., or directly with achieving specific behaviors promoted by the game, or breaking one’s habits (e.g., in the case of a urban mobility game, trying a new way of commuting, or increasing one's usage of sustainable transportation means).

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We represent challenges as a tuple: 
\( (P, G, C, Pz) : (\text{Player}) (\text{Goal}) (\text{Constraints}) (\text{Prize}) \).

A typical example of constraint is a deadline for satisfying the goal and obtaining the corresponding prize.

The Challenge Generator is based on templates for different challenge types. For instance, a template can be used to define in a urban mobility game all challenges related to improving the sustainable mobility behavior of players: for example a challenge like “Player P, try to double your trips using Public Transport next week and win 100 bonus Green Leaves” can be generated from a template in which the Goal G is improve by X% user state variable V in mode Y, the Constraint C is within time interval TI and Prize Pz is a quantity Q of game concept GC. In the template, X, V, Y, TI, Q and GC are all parameters; the game designer only needs to decide what values she wants for the parameters, and those choices are automatically compiled in a set of game rules that check the player’s progression and fulfillment of the instantiated challenge.

The other design decision that the Challenge Generator component requires from the game designer is to provide the selection criteria for assignment of a given challenge to (subsets of) participating players. Selection criteria are boolean expressions predicing over data belonging to the player’s state. For instance, the game designer may decide to assign the “double your public transport trips” challenge above only to those players who - from the historical information contained in their game state - do use public transport already, but only sporadically. Other players, who are shown to already use public transport a lot, but mostly for short trips, might be asked to take up a different challenge instead, say, increase the amount of Km they walk weekly. Although this second challenge seems quite different from the first, it can in fact be derived from the same template.

The Challenge Generator thus enables right now a semi–automatic production of challenges; it still requires from the designer a certain amount of expert knowledge, for example to calibrate prizes vs. goals, or to elaborate selection criteria for challenge assignment.

\[ \text{See } \text{https://github.com/das-fbk/game-engine.challenge-gen} \]
We are envisioning, as the next step, a more automated approach for challenge generation, which starts from the templates and a set of valid values for the templates’ parameters, and, via their permutation, generates a wide variety of possible challenges for a given player. Then, an additional valuator module will be in charge of estimating the difficulty of each generated challenge for that player, based on historical considerations and user preferences, and to synthesize an appropriate prize to reward the player’s effort. Finally, a recommender system will be used to rank the set of challenges and propose to the player the best options, based on two perspectives: i) from the player’s perspective, those challenges that would offer the best potential for game advancement, that is, the most desirable prizes given the player’s game state and goals, while requiring incremental (as opposed to drastic) effort; and ii) from the Smart City perspective, those challenges that promote behavioral improvements and goals that are especially valuable given the city policies currently in place.

When completed, the extended Challenge Generation component, which is currently under development, will represent a novel example of automated Procedural Content Generation (PCG), a concept that is increasingly employed to augment variability and variety in video games [12] thus providing a more engaging user experience, but to the best of our knowledge has not been yet applied to gamification. In this case, there is an additional purpose for such PCG, i.e., to find – out of the universe of possible challenges – of those that represent a “sweet spot” between the player’s and Smart City perspectives outlined above.

III. CASE STUDY: A LONG-RUNNING MOBILITY GAME

Within the STREETLIFE EU Project (www.streetlife-project.eu), which aims at evaluating the contribution of advanced IT technologies in the domain of sustainable urban mobility, we conducted an open-field experiment to measure the impact of gamification techniques and incentives on the mobility behavior of citizens in the city of Rovereto and the surrounding area.

Rovereto is a small city of about 40K inhabitants situated in the North-East of Italy. Despite its small size, the city is exposed to a significant traffic pressure especially in the city centre. On average, each two inhabitants, one owns a car, and if we consider the modal split, the percentage of trips traveled by private vehicles is 59%. Moreover, the occupancy rate of parking areas in central zones reaches 90%, and this generates additional traffic related to vehicles looking for parking.

The city has thus invested considerable effort and resources in improving the mobility situation. For instance, Rovereto has more than 30 km. of bicycle lanes and in the future the total length of the bicycle network is foreseen to be almost 75 km. In addition, in September 2014, Rovereto launched a new bike sharing system with more than 10 stations.

A. Rovereto Play&Go

Rovereto Play&Go is a long-running open-field game (April 16 - June 18, 2016) targeting all Rovereto citizens willing to take part in the game; it is organized on 9 weeks, and experiments with the different game concepts supported by our Gamification Framework.

The game is structured in two phases. During Phase 1: Basic Game (2 weeks) the game consists in collecting Green Leaves points, which are assigned according to the Km. travelled with sustainable transportation means, and with bonuses associated to zero-impact trips (no CO2 emissions). The game also supports weekly and global leader boards for Green Leaves, as well as a variety of badges and badge collections assigned when reaching certain amounts of Green Leaves, or taking specific kind of trips (e.g., the bike aficionado collection assigns badges every 5–10 trips by bike), or exploring some mobility alternatives (e.g. when using a designated Park&Ride facilities for the first time, trying the Bike Sharing service for the first time, or exploring different Bike Sharing stations).

In Phase 2: Challenges (7 weeks - April 30 to June 19, 2016), on top of the basic game we introduce weekly themes (e.g., a bike week, a zero-impact week, a public transport week, etc.) as well as weekly challenges targeting the specific theme, and personalized with respect to the player profile and game results. These challenges award Green Leaves bonuses upon completion. For instance, during the bike week, we have different types of challenges promoting the usage of bicycle transport, targeted to different kind of players and personalized to their profile: from challenges pushing players to try the bike / bike sharing mode (for those who never tried it before) to challenges requiring a small (or significant) improvement in terms of Km. and trips traveled by bike or bike sharing (for players who are already accustomed to use bicycles for their transportation needs). To take part in the game, a player needs to install the App ViaggiaRovereto Play&Go App (available on Android Play Store and Apple Store), register to the game, and use the App for journey planning and tracking sustainable itinerary choices.

The player can use the App also to check her status in the game (e.g., points and badges earned, active challenges, weekly and global leader boards rank), share her results on social networks (i.e. Facebook or Twitter), inspect the rules of the game and the weekly prizes. Figure 2 presents selected screenshots of the functionality offered by ViaggiaRovereto Play&Go App.

The Play&Go game also awarded weekly material prizes (varying from tickets for cultural events in the city, to subscriptions to mobility services such as bike and car sharing) as well as final grand prizes (including a bicycle, long-term gym subscriptions etc.) for players who reach the top positions in the Green Leaves leader board. Weekly and final leader boards, prizes and personalized challenges are elements that encourage user engagement and retention, in order to sustain the impact of the game and the promoted mobility behaviors throughout its duration.

B. Experimental Results

During the game, about 300 citizens downloaded and registered for the Play&Go game on their mobile terminals; of those, 110 actively played and accumulated points in the game, recording almost 3,000 valid itineraries, plus a number of ancillary game actions, like recommending the game to friends and completing surveys on their mobility and playing experience. Active players succeeded in 212 individual challenges, and worked towards 83 more challenges, without managing to complete them in time.

We analyzed the logs of the gamification framework to shed light on the following research questions:

- **RQ1**: did the game concepts encompassed by the experiment (challenges, weekly themes and prizes) encourage engagement and retention in the long-term?
RQ2: did the introduction of thematic challenges encourage players to select prevalently those sustainable mobility alternatives that were promoted by the challenges and - in general - by our system?

RQ3: if RQ2 is verified, how much did that form of voluntary behavioral change impact the mode choices of the players towards more sustainable transport modes?

For all RQs, since our focus is to sustain the behavioral changes of gamification in the long term, we analyzed the dynamics of the temporal series of the collected data, which cover the whole duration of our long-running game.

To investigate RQ1, we looked at the distribution of trips per player across the nine weeks of the game. Figure 3 shows boxplot charts visualizing those distributions. Our framework records as gamifiable actions all trips which the players want to contribute to their game performance, and which are considered valid by a component that matches tracked vs. nominal itineraries; the number of valid trips recorded over time hence indicate propensity to keep playing. The boxplots show a tendency to either maintain or increase the median number of gamifiable actions played by participants, over time as well as in comparison with the distribution over the whole game (in green in the Figure). There is an exception in weeks 4 and 5 (light blue in the Figure); during those two weeks, the weather in Rovereto was quite unfavorable, with many rainy days, and temperatures several degrees below the season average. That may explain less trips recorded in those weeks; in fact, we also observed in the same weeks a sharp decrease in Km. traveled by bicycle or on foot, as visible in Figure 4. The median decreased also in the last week of the game, while variance was maximal. This is the consequence of a bi-modal behavior: the overall player population played less, while those players who were still in competition for the grand prizes redoubled their effort to climb positions in the final leaderboard.

Overall, the data in Figure 3 suggest a positive response to RQ1, that is, our design was successful in supporting the sustained engagement and retainment in our long–running urban mobility game.

To investigate RQ2, we looked at the modal split in Km. of recorded players’ trips across the game weeks. In Figure 4, the bars on the left show the results for Phase 1 of the game (without challenges), while the others represent Phase 2, i.e. weeks 3 to 9, in which challenges were active. Looking at the weekly themes, we can make several observations:

- in week #3 we activated challenges for the first time; although there was no specific mobility–related theme for that week, the proposed challenges were personalized to encourage each player to improve her own game performance or the sustainability of her transport choices. We can see that usage of sustainable transportation is increasing, and that 0-impact modes (i.e., modes that do not produce CO$_2$ like walking, bicycle, bike sharing) amount to more than 50% of the recorded Km;
- in both week #4 and #5, possibly due to the unfavor-
able weather conditions discussed above, 0-impact modes were penalized, while car usage increased;

- in particular, week #4 was "bicycle week", but bike and bike sharing Km. recorded were at a minimum;
- in week #5 - "public transport week" - we were anyhow able to record the highest percentage of public transport Km. (41% by train, plus 29% by bus);

- in week #6 - "0-impact week" - challenges pushed only 0-impact transport modes, and we see those modes gaining ground, with an increase to 38% (from 28% of week #5);
- in week #7 - "leave the car at home week" - specific challenges were proposed to push that behavior; however, the car mode percentage increased slightly;
- week #8 was "health and well being week", and promoted those modes – like walking and biking – that require physical exercise (hence challenge targets were similar to week #6); in week #8, we recorded the highest combined percentage of Km. for the target modes, with 62%.

- in week #9, personalized challenges were administered to players (including one requiring to fill an exit survey), but no specific mobility-related theme was active;

Overall, the data in Figure 4 suggest a positive response to RQ2, that is, the challenges generated for Phase 2 of the game were useful to induce in players specific VTBC choices that varied, mostly, in accord with the theme of the week.

To investigate RQ3, we looked further at 0-impact trips, i.e., trips that include only legs in the walk, bicycle or bike sharing modes. Such trips do not cause any CO2 emissions, therefore are most sustainable ecologically speaking, and were among the itinerary types that were most promoted via game rules, challenges etc. Figure 5 shows the weekly progression of the number of 0-impact trips compared with the number of active players in the same weeks. From the trend lines in the

C. Feedback from the players

In addition to the data recorded in the logs of our gamification framework, we have also collected feedback from our players, by means of in–App entry and exit surveys. The entry survey was filled by all the players who registered, whereas the exit survey was itself cast as a challenge to be completed in week #9; 36 out of the 110 active players took that challenge. Below, we look at some of that feedback, which can provide additional insights into the effects of our sustainable mobility game, as well as the perception players have of gamification as a persuasive technology.

For instance, one question in the exit questionnaire asked the players "To what extent the game induced a change in your mobility habits?" (i.e., VTBC): more than half (55%) of the 36 respondents answered considerably and 8% answered a lot, whereas 16% answered not at all and 21% a little. To those who recognized some VTBC due to their game participation, we then asked: "Would you keep your new mobility behaviors also after the end of the game?": we collected positive responses form 81% of respondents (26% answered yes and 55% probably yes).

Another question asked the players what elements in the game they found effective in persuading them to keep playing and changing their mobility habits: personalized challenges were a lot effective for 10 of the 36 respondents, and considerably for 17; in contrast, 5 players were not influenced by challenges at all, and 4 only a little. The principal game mechanics of Green Leaves points was a lot effective for 8 players, and considerably for 20; material weekly and final prizes were mentioned as a lot effective by only 10 players and considerably for 13. Finally, badges were considered as a lot effective by only 3 players, but considerably so by 18.

IV. RELATED WORK

Gamification has demonstrated potential in a variety of domains [5], and there is a growing body of work on applying gamification as one means to persuade citizens to embrace socially beneficial collective action [13]. One area of application is environmental sustainability, with multiple examples on energy savings [14], [15], and sustainable mobility [6], [7], [8], as well as on other salient Smart City concerns, such as tourism [16], or participatory governance of urban neighborhoods [17]. Most of the current works regard empirical studies (like the ones mentioned above), or methodological aspects (like for instance [18], [19]). A novel contribution of this paper is the architecture of our framework (see Section II). While platforms designs exist for the gamification of well–delimited and self–contained systems and applications (e.g., Enterprise Information Systems [20]), our Gamification Framework offers – with its underlying service–based design principles – an open and extensible technological platform that specifically addresses the multifold complexity we have identified for gamification in Smart City environments. In fact, the framework has already proven its flexibility beyond the Rovereto Play&Go application, by being adopted for an ongoing "city
explorer” game in the city of Tampere, Finland within the STREETLIFE project, and by enabling a team-based game for schools, pupils and their families, which promotes independent children mobility to and from school [21].

Our second major contribution is represented by the provisions we have built for supporting the long-term engagement and retention of smart citizens as players, since maintaining the benefits of gamified participation over time requires internalizing behavioral changes into new habits, which is a well-known problematic issue [6], [22]. For that purpose, we have introduced in long-running games the game mechanics of challenges. Challenges, like missions and analogous mechanisms, provide games with variety and a dynamic system of incentives; as such, they have been explored also in Smart City gamification applications, including e.g. TRIPZOOM [7], and YWYM [23]. What stands apart in our case is the Challenge Generator component, which can produce a large number of challenges as fine-grained units of playable content, and taps into the player’s profile (her preferences, usage history and game state), in order to make those challenges meaningful and engaging for each individual player, through personalization and contextualization of goals and prizes.

V. CONCLUSION

We presented a gamification framework for long-term engagement of smart citizens. The framework enables the design and execution of gamification solutions for Smart Cities and supports i) open-ended integration of heterogeneous technologies and services in multi-stakeholder games, ii) games including playable units at various granularity levels and multiple temporal scales, and iii) dynamic, semi-automatic generation of personalized challenges. The framework was evaluated in a 9-weeks long open-field experiment in the city of Rovereto, Italy, through a game that promoted Volunteer Travel Behavioral Change and sustainable urban mobility.

From a technological point of view, our ongoing work includes an extension of our challenge generator to generate a wide variety of challenges, and automatically assign them a player-specific difficulty level and a corresponding prize. A recommender system will then be developed to propose to each player the most suitable challenges in terms of i) player gain in the game, ii) effort required, and ii) benefit with respect to the Smart City objectives and policies.

From an applicative point of view, we are going to launch a revised version of the sustainable mobility game on a larger scale in the Fall of 2016, involving the city of Trento (Italy) and the surrounding territory. We are also exploring the application of our framework to other Smart City domains, like energy efficiency and participatory e-government.

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REFERENCES