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# Greencoin: prototype of a mobile application facilitating and evidencing pro-environmental behavior of citizens

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**Abstract**

Among many global challenges, climate change is one of the biggest challenges of our times. While it is one of the most devastating problems humanity has ever faced, one question naturally arises: can individuals make a difference? We believe that everyone can contribute and make a difference to the community and lives of others. However, there is still a lack of effective strategies to promote and facilitate pro-environmental behavior of individuals. To fill this gap, in this paper, we introduce and discuss the Greencoin mobile application prototype. The app is built on existing intelligent data-driven technologies, including supervised and unsupervised learning techniques. Since its end-users will mostly concern the city dwellers, the project falls into the scope of the ongoing research in the area of smart city applications. Nevertheless, the application is still in the design phase, we believe it is a good starting point to spark discussion on its further directions of development, as well as to draw the attention of both national and international audiences to the issues raised.



*Keywords:* Digital Innovation; Mobile Prototype; Smart City

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## 1. Introduction

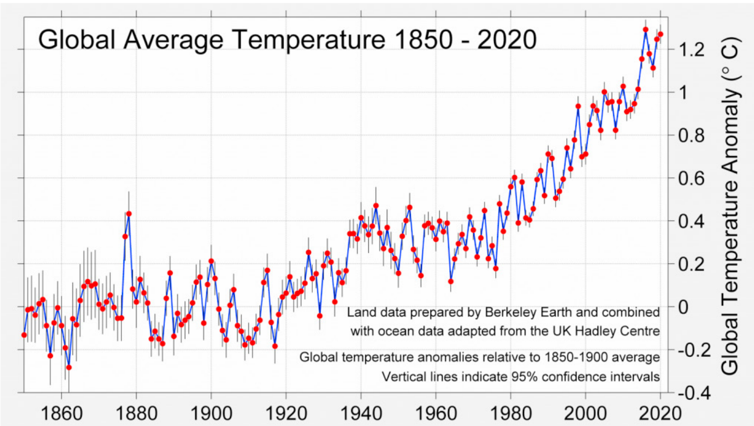
The modern development of digital technologies allows for the digitization of user behavior on an unprecedented scale [28, 40, 42]. Cell phones, thanks to technologies such as WiFi, Bluetooth, GPS, built-in camera, continuous access to the mobile Internet and the ability to install applications, have changed the meaning of this device; today telephone calls are one of many functions, but we now call them “smartphones” [10].

The concept of “smart” today applies to virtually all available artifacts: wearables [13], kitchen appliances [53], buildings [44], cities [54, 48], transport [36, 69] and energy [21]. Thanks to the ability to continuously acquire data on the functioning of devices and to exchange this data with others in real time, today we are dealing with a network of autonomously functioning elements of our space [7]. Nowadays, smart devices form a network called the Internet of Things. A novel paradigm that is rapidly gaining ground in the scenario of modern wireless telecommunications. The basic idea of this concept is the pervasive presence around us of a variety of things or objects [27], such as Radio-Frequency IDentification (RFID) tags, sensors, actuators, and mobile phones [8], which through unique addressing schemes are able to interact with each other and cooperate with their neighbors to reach common goals [22].

By combining both public and private sector data sources and physical objects, the IoT changes the concept of the “Smart Cities,” defined by IBM as the use of information and communication technology to sense, analyze and integrate the key information of core systems in managing cities [11]. Smart Cities can make intelligent responses to different kinds of society needs [50], which include: daily livelihood, environmental protection, public safety and city services, industrial and commercial activities [47, 55].

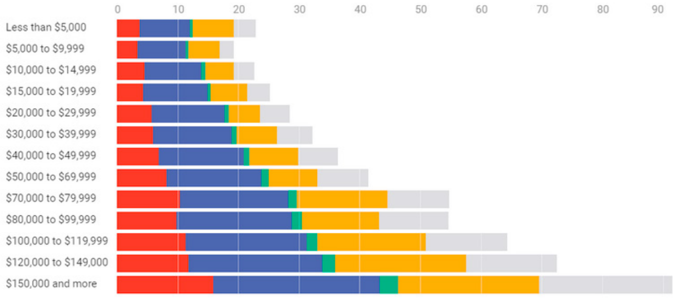
According to data gathered by the World Meteorological Organization, the year 2020 was one of the three warmest years on record and the last decade was the warmest ever [33]. Despite the global lockdown, the concentration of the greenhouses gases in the atmosphere continued to rise. As a result of the global temperature growth, on average since 1993 the sea level has risen at a rate of 3.3 mm per year. Due to the heatwaves, the near-surface layer of the oceans is becoming unable to sustain marine life, and combined with the increased rates of floods, droughts, fires, cyclones and storms ever recorded, approximately 10 million people worldwide have already been displaced. According to the Food and Agriculture Organization of the United Nations, over 50 million people have been doubly affected by climate-related disasters and the COVID-19 pandemic in the most recent year. For example, Jocobson has shown a direct link between rising levels of carbon dioxide and increased human mortality [31]. Moreover, it is claimed that for each celsius degree rise, caused by the emitted carbon dioxide, 1000 additional deaths occur in the United States of America along with many more cases of asthma and other respiratory related illness.

Fig. 1. Global annual mean temperature difference from preindustrial conditions (1850–1900). The two reanalyses (ERA5 and JRA-55) are aligned with the in situ datasets (HadCRUT, NOAAGlobalTemp and GISTEMP) over the reference period 1981–2010. Data for 2020 are from January to October. Source: [2].




In their Fifth Assessment Report, the Intergovernmental Panel on Climate Change, which consisted of 1300 independent scientific experts, concluded that there is a 95% probability that over the past 50 years, human activities were a cause of the rise of the global temperature [51]. It is estimated that more than 15% of global green house gases were generated due to the U.S. household consumption in 2009, with a carbon footprint that is 82.3% domestic and 17.7% overseas. The household expenditures were divided into 5 categories, and the domestic carbon footprint share was estimated as follows [59]: housing (33.6%), transportation (29.8%), services (19.3%), food (16.7%), and clothing (0.1%). It is essential to take note of the correlation between the households' income and carbon footprint, which grows proportionally.

Fig. 2. Household carbon footprint by income level. It can be noticed that the more money a household has, the more average tons of carbon dioxide equivalent it emits per year. Source: [52].




The Natural Resources Defense Council lists methods that each individual can undertake to reduce their cargon footprint: driving hybrid vehicles, taking public transport or cycling, using household appliances and devices of a lower energy consumption, using "green" technologies, and being involved in community-level projects promoting awareness of the causes and effects of climate change.

With reference to the following environmental studies, both the IoT and Smart Cities have the potential to mitigate the negative impact of humans on the natural environment. The paper introduces the idea of the "Greencoin" app which is currently under it's first phase of the development, the aim being to involve the citizens in city-related pro-ecological activities by the application of game theory elements and the IoT concept. The goal of this paper is twofold: first, to introduce and discuss the developed first prototypes of the Greencoin application, and second to analyze the state of the art regarding similar initiatives organized and administered worldwide.

It is worth noting here that the Greencoin project is a result of The IdeaLab workshop, which is a part of the *Applied Research* programme operated by the National Centre for Research and Development under the EEA and Norway Grants. The workshop entitled *Cities for the future: services and solutions*, took place in March 2020, and based on the interdisciplinary work among Polish and Norwegian participants, the concept of a system based on the new technologies, the smart city concept and game theory emerged, promoting pro-ecological human behavior.

The rest of the paper is structured as follows. Section 2 is devoted to the related work. Section 3 presents the low- and high-fidelity prototypes of the Greencoin mobile application. Section 4 is a brief discussion, including the study limitations as well as the directions of our future research. Finally, Section 5 concludes the paper.

## 2. Related Work

Evidence of geo-located social activity is finding a place in urban studies. Georeferenced data from, e.g. social media can be applicable while mapping public sentiment [3], predicting of social deprivation [56], modeling human and crowd activity patterns [45], examining land use [19], depicting the character of an urban area [9], measuring national mood fluctuations [15], life satisfaction [68], etc.

However, recent years have proved an urgent need to mitigate climate changes in urbanized areas [5]. Climate change imposes critical risks for global cities. Heat islands, flooding, air quality and pollution are among the most significant challenges to the health and well-being of residents in urban regions [43]. Research on shaping urban resilience has made progress in recent years, although successful applications in climate risk mitigation are rare [29, 57]. Several projects evidencing social behaviors in terms of approaching resilient urban development can be found. Models have been designed to collect census data on the quality of urban life and to assess how urban dwellers respond to climate changes or solutions aiming to mitigate climate changes. At the same time, there are still limited studies which introduce models to measure different aspects of resilience using Big Data in a holistic manner.

The Sponge City approach was found as one of the aims of resilient urban fabric. Wang et al. [62], by examining the spatial-temporal patterns of public responses toward urban flooding in Nanjing, introduce an approach based on the fusion of social media data, land use data and other information which can be useful for planning practice. A sustainable green space in cities can potentially affect human well-being, social cohesion and interaction. Therefore, sensing the urban microclimate to encourage implementation of solutions diminishing heat island effects [17] is one of the needed solutions. The quality of life is influenced by the air pollution. Yan et al. [67], based on Weibo data (daily records of all the monitored pollutants for 251 cities), measured the impact of air pollution on urban activity.

To stimulate urban behaviors based on air pollution, warning apps have been implemented [30, 12]. As such solutions are not sufficient, a step further is needed, e.g. the Treepedia app [37] was designed to encourage residents to make cities more sustainable. Urban optimization and incentive mechanisms can be done on the bases of solutions presenting energy demands and saving systems [70]. Additionally, as urban dynamics influence pollution, we need to change urban behaviors. The unparking project proves how sharing economy-based solutions can optimize land use management to introduce sponge city concepts [34]. This concerns urban flows in a wider scale as waste tracking systems [46] and apps [26] showed increases of urban emissions. Similar observations can be made based on food flows [39], hence the introduction of such solutions can encourage residents to act locally. Once noticed, it can further be used to introduce applications, for instance such as 'KT-Energy' [35] to help mitigate climate changes.

Community currencies help to address various societal and environmental problems, they are usually adjusted to the local needs and peculiarities, gaining wide popularity worldwide. While there are hundreds of such initiatives in Europe alone, it would be valuable to focus on those 'success stories' examples that managed to overcome the survival stage. One such an example is e-Portemonnee or E-Wallet – an electronic reward initiative of Limburg that involves 44 Belgian municipalities and encourages pro-environmental behaviors, such as switching to green energy, composting organic waste and supplying items to secondhand shops [14]. According to Dodd, residents are rewarded for their pro-ecological actions with credits that are linked to their national number and can be spent on environmentally friendly products and services, for instance on organic products, public transportation or ecological courses.

Another example of community currency is Lewes Pound [25], introduced in 2008 in Lewes, East Sussex, UK, e.g. aimed at tackling climate change and supporting sustainable local initiatives. Studies by Graugaard (2012) suggest that Lewes Pound contributes to the 'social and ecological resilience' in the Lewes community by influencing consumer choices and raising ecological awareness and social interactions. Nevertheless, these paper money economic indicators are not consequently examined, meaning that a more quantitative analysis of Lewes Pound's impact on the local economy and society is needed. Another example of alternative currency from the British Isles is the Scottish EKO community currency aimed at supporting various local initiatives and projects, for example a community wind farm [14]. EKO currency circulates in the Findhorn ecovillage and can be exchanged for the GBP at a 1:1 rate, offering low-interest loans to finance sustainable, pro-environmental and socially responsible local initiatives.

An interesting example of gamification in promoting pro-environmental behaviors is WasteApp – a mobile application which aims to encourage people to reduce waste and recycle in several touristic cities in the EU [1]. Points received through the WasteApp can be exchanged for products and services offered by municipalities and different partner entities encouraging responsible and ecological actions among tourists and local communities. The gamification strategy of WasteApp differs from one participating city to another, it contains a waste-bins map adjusted to the location, ecological tips, 'useful links', cities policies and feedback forms, as well as evaluation and promotion materials. According to Bonino et. al. [4], WasteApp is an efficient tool to make recycling and ecological preservation a daily habit that in parallel increases users' and communities' overall satisfaction.

Complementary currencies are quite popular in Spain – zoquito, turuta, puma, turuta, to name a few – however, their scope is limited regionally and in terms of active users. According to García-Corral et al. [20], one such example is Ekhi, launched in 2011 in Bizkaia, intended to promote sustainable local businesses and ethical economic practices. Another example of Spanish community currency is La Pita, launched as an e-currency in Almeria and administered through the Community Exchange System [6]. La Pita is a complementary social currency, allowing its users to get involved in traditional local activities, local fairs and markets [20]. However, concerns related to safety, anonymity, potential abuses and a lack of regulations incline some alternative currencies project leaders to consider digital currency applications.

There are several examples of longstanding regional currencies in different German regions, for example, Chiemgauer, Engelgeld and KannWas [58]. According to Thiel [61], Bavarian Chiemgauer was launched in 2003 in Prien am Chiemsee in order to support local initiatives, community employment and businesses, as well as a resilient local food supply. The Bavarian community currency is exchangeable with the Euro at a 1:1 rate; it expanded to the Munich and Austrian Salzburg areas, while its partners are to be counted in the hundreds, and members in the thousands [38]. Other examples of German complementary currencies in the form of paper money are Engelgeld and KannWas, supported by local NGOs, businesses and communities [18]. However, the maintenance of paper money comes at the price of higher anonymity, potential risk of abuse and higher cost of the money, forcing project leaders to introduce small fees, as in the case of KannWas and Roland [58].

To summarize, there are hundreds of alternative local currencies and pro-ecological initiatives that are aimed at promoting sustainable ecological and social actions. However, it should be noted that their methods and scope are highly differentiated, while the failure rate is quite high, making us conscious of the potential risks and limitations that need to be addressed in our pilot project.

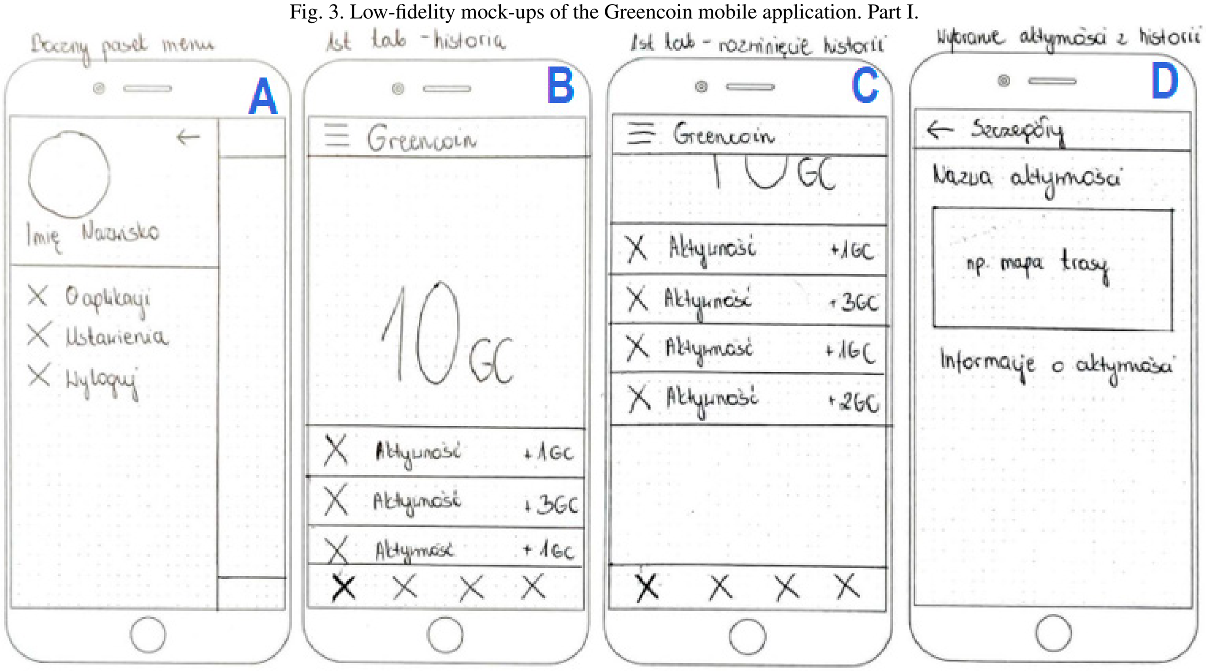
## 3. Greencoin Mobile Application Prototype

Typically, prototyping can serve several purposes [66]. First, a group of stakeholders can use it to clarify the product requirements. Second, the prototypes can be the subject of the product feasibility in terms of available technologies. Third, one can use prototypes to communicate the changes expected to be applied in the current version of the product. Taking into account the goal of the present study, the role of the Greencoin prototyping refers to the first and second objectives.

### 3.1. Low-fidelity Prototypes

On Fig. 4 the low-fidelity mock-ups show a static and preliminary visual representation of the Greencoin mobile application design. We intentionally focus on the information architecture and flow, rather than on the colored details.

Fig. 3. Low-fidelity mock-ups of the Greencoin mobile application. Part I.

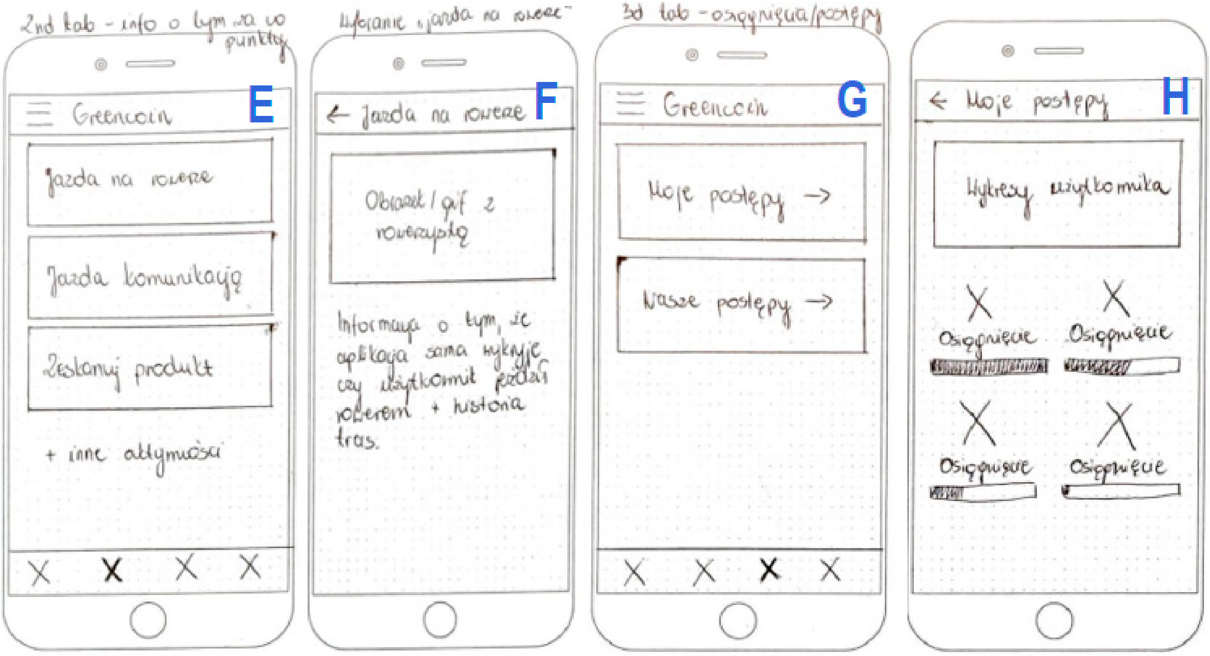



Beginning on the left, one can see that the mock-up **A** shows the personal information of the user such as first name (*Imie*) and surname (*Nazwisko*), whereas the empty ring represents the user's picture. Below, there is other information; the first piece concerns the application itself (*O Aplikacji*), and the second represents the application's settings (*Ustawienia*), while the third is the logout command (*Wyloguj*).

On the top-left of the mock-up **B** the “hamburger” menu button is visible, and on its right the name of the application is depicted. In the central place, the total number of collected greencoins is shown (10 GC). Below, the list of performed “green” activities is visible, showing the names of the activities (*Aktywność*) along with the quantity of earned (the **+** sign) greencoins. To this extent, the mock-up **C** shows the rest of the list. The mock-up **D** depicts a detailed view (*Szczegóły*).

In the early stages of planning the Greencoin application, low-fidelity mock-ups have also helped us to analyse and synthesize brainstormed ideas and collect input from stakeholders without a design background. In this case, the Fig. 6 outlines the functionality anticipated.

Fig. 4. Low-fidelity mock-ups of the Greencoin mobile application. Part II.




The mock-up **E** presents, beginning from the top, two pro-ecological activities, namely: riding a bike (*Jazda na rowerze*) and taking public transportation (*Jazda komunikacja*). Below, the user can scan a product (*Zeskanuj produkt*) in order to evidence the purchase of the selected “green” products. Eventually, there is also a suggestion to add other “green” activities which are possible for an individual user to perform.

By design, the mock-up **F** reflects the app “intelligence,” which in this case is materialized by a machine learning method which aims at recognizing the “riding a bike” activity. It is worth noting here that over time, the app will learn the user’s behavior with the goal of detecting and recognizing “green” actions in real-time, based on both current and historical data.

The mock-up **G** presents two options to view, where the top concerns the user’s achievements (*Moje postepy*), while the second represents the community achievements (*Nasze postepy*). The details of the former option is depicted by the mock-up **H**, which graphically illustrates the user’s performance (*Wykresy użytkownika*) and a list of achievements (*Osiagniecia*) along with the status of their progress, indicated by the bar below.

### *3.2. High-fidelity Prototypes*

In Fig. 5, the mock-up **A** shows the welcome screen of the Greecoin mobile app. The interface depicts the summary of the activities that the user has performed and the earned greencoins, with the total number of collected greencoins (which is 36 on the screenshot above), as well as a history of the performed activities. It is worth noting that each activity is clickable. The color of the tile changes for different numbers of greencoins (lighter green for fewer greencoins and so on). The mock-up **B** shows when a user clicks on the activity, and as a response displays its details. For example, the distance and number of collected greencoins. Based on the users' evaluation, particular types of activities will have different appearances. The next mock-up (**C**) is the second tab in the Greencoin application prototype. It is designed to store all the activities that the user can do in order to earn greencoins. There are two example eco-activities: riding a bike and catching public transport. Clicking on one of them redirects to the screen with descriptions of what to do to complete them. The mock-up **D** opens up from the activities tab. It has a description of the "Riding a public transport" activity and a history of the completed activities of this type. Similarly, all items in the history are clickable.

In Fig. 6, the mock-up **E** opens up from the activities tab. Its main purpose is to describe the activity. In this particular case, it depicts the "Riding a bike" activity and a history of completed activities of this type. Again, all the items in the history are clickable. The mock-up **F** shows the application response to a user click action on the third tab, called "Achievements." There are two options available: "My achievements" showing the user's achievements, and "Our achievements" displaying the achievements of all the users that are using the app, or all the users from a certain

Fig. 5. High-fidelity mock-ups of the Greencoin mobile application. Part I.

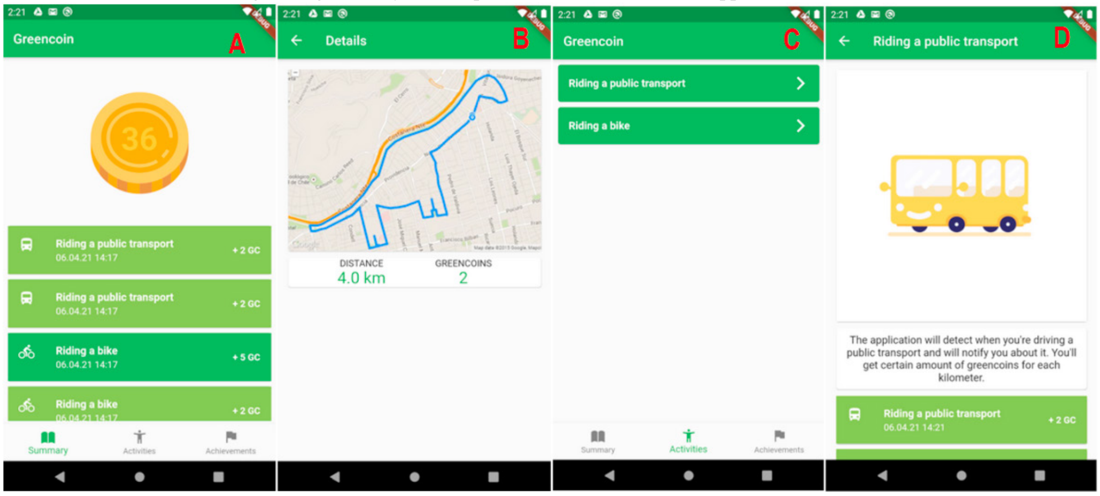
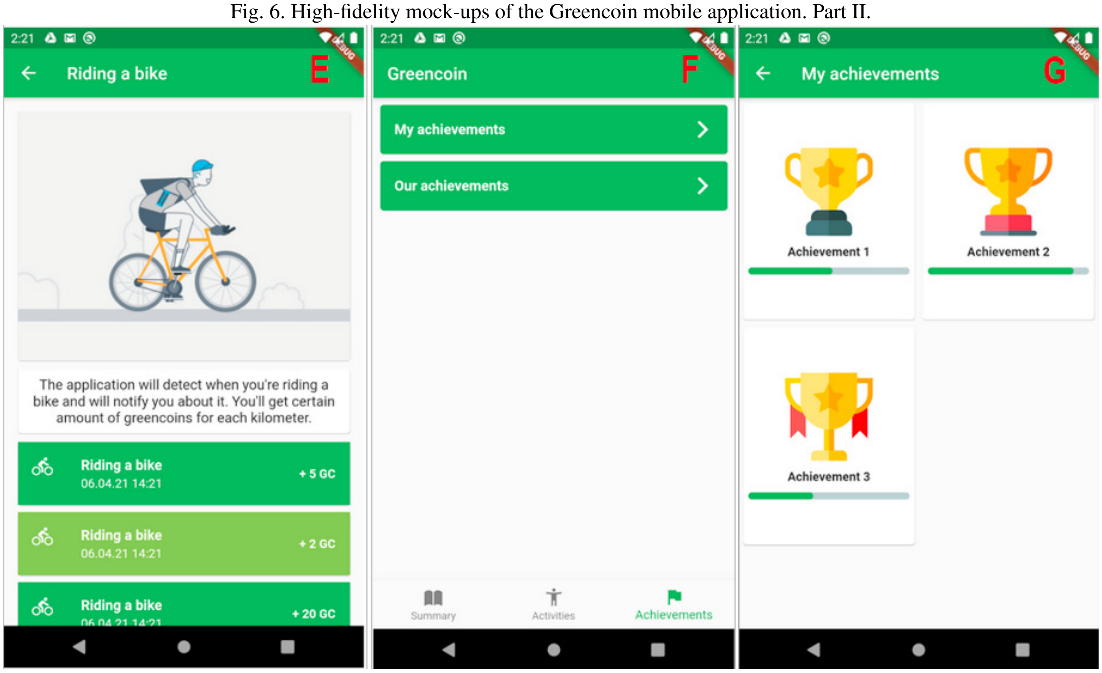



Fig. 6. High-fidelity mock-ups of the Greencoin mobile application. Part II.



city (i.e. Gdańsk). The last mock-up (**G**) aims at presenting all the achievements that the user has already gained for his/her activities. It is planned to add the possibility to share these achievements via social media channels.

## 4. Discussion

The Greecoin initiative is concerned with the continued challenges and opportunities of motivating and facilitating pro-environmental behaviors, among individual citizens as well as local city communities. The success of this initiative will be dependent on the popularity of the Greencoin mobile application, which will be used by citizens in the pilot stage of the project. The presented high-fidelity prototype was well received by the stakeholders from Norway and Poland for its intuitive design and ease of use. Based on project partners' reactions to the prototype, in addition to research on related works, the prototyping has been recognized as one of the most important ways to validate the team's ideas at the current stage of development of the Greencoin mobile application. The current feedback on the prototype is crucial for the development team to plan future versions of the application. Some remarks and comments helped not only to improve the user interface, but also to design new app functionalities, e.g. new pro-ecological activities to be monitored by the system.

Obviously, the current prototype version has its limitations. Only the proposed GUI of the application is presented. Without a dedicated application server, most of the functionalities of the system cannot be tested. In order for the mobile application to be fully functional, it should utilize APIs of other systems to read their data (fit trackers, public transport applications, social media, etc.), and such integration with other systems is not currently presented in the prototype. The future pilot version of the Greencoin mobile application will be developed and evaluated in collaboration with end-users, focusing on its usability [65]. In particular, our future studies will address the application qualities such as efficiency, effectiveness and satisfaction [63], reported to be the most significant attributes contributing to the perceived usability of mobile applications [64].

Moreover, our further research work will also focus on the development of a model for estimating the value of individual pro-ecological activities, and motivations behind the citizens' engagement [60], on the one hand, and on the integration issues with current IT systems and applications [23], implemented so far in the related areas, on the other hand. We think that the successful adoption of the Greencoin application is directly determined by its integration and compliance with existing solutions, devoted to public services such as communication, travelling, energy and water consumption (e.g. moBILET), as well as concerning private services such as payment or discount cards [24].

## 5. Conclusions

In this paper, we have introduced and discussed the low- and high-fidelity prototypes of the Greencoin mobile application. By design, the presented solution aims at facilitating and rewarding individuals who consciously and deliberately undertake pro-ecological actions. In this line of thinking, our study falls into the scope of the green economy that aims at reducing environmental risks and ecological scarcities. In a more narrow sense, we place our research in the context of the ongoing process of advancing and fostering sustainable development [32, 49], falling under the umbrella of the smart city notion [16, 41]. Here, it is also worth noting that from the perspective of the project's goals, the presented concept and prototype are the first sprint of the software development process. Considering the scope and time frames, we are aware that such an innovative application requires considerable effort from many different groups of stakeholders, beginning from public authorities, public and private business organizations, and ending with the city residents. Having said that, we believe that the presented mock-ups will serve to communicate and lead discussion on the further directions of research with our domestic and foreign partners with the collaboration of all interested parties. Last but not least, we hope to spark reflections on the opportunities available to be undertaken by each and every citizen in order to build a better place to live for our and the following generations of people.

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