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Greencoin – educational information system for ecoinclusion and empowering urban adaptability

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ABSTRACT

The SARS-CoV19 pandemic exposed a broad spectrum of challenges for modern cities, societies and the environment at large. The post-Covid transformation requires new social, ecological and educational solutions, adjusted to modern challenges, but also equipped with technological advances that allow for digital inclusion and sustainable urban development to benefit the local economy and society. Many information systems designed to enable pro-environmental behaviours are being tested or implemented worldwide, mostly in developed countries; however, most of them focus on a sectorial approach only. On the other hand, community currencies (CCs) consider social, economic, and environmental issues yet do not fully exploit the potential of the current technological advancement. Therefore, the paper describes the process of defining the theoretical framework for Greencoin as an information system designed to be a supportive tool while shaping urban adaptability and mitigating climate change, within which a CC is embedded. The 120 social currencies and information systems (IS) analysed in this research provide valuable data that is essential to shaping the framework of the Greencoin IS, to be implemented in the subsequent stages of the project. Greencoin IS aims to operate based on an application, the work resulting from studies of existing solutions, their functionalities and technological aspects, which enable social engagement and eco-inclusion. It responds to the question of how the new types of currencies and applications enriched with gamification elements can encourage residents to get

involved in shaping urban resilience. This research goal is to build a future framework for Greencoin IS based on the performed systematic literature review and case studies.

Keywords: climate change education, ICT for inclusion, information systems, post-pandemic transformation, urban adaptability

1. INTRODUCTION

When participating in pro-environmental actions, a strong motivation for people is the collectivity and the element of social interaction. Pro-ecological activities are often organised as events, but recently, because of the Covid pandemic, restrictions and the limitations of interaction, they are much less frequented or less attended because of the possibility of contamination (Robinson, 2021). Reduced social contact, reduced vocational training, and professional activity have increased the number of problems we face (Spiro et al., 2021). Moreover, the pandemic has generated new problems, bringing us closer to an environmental disaster (Watson et al., 2020). It is becoming necessary to develop tools that will support education for sustainable development, adapted to the new reality in which we find ourselves (Yigitcanlar et al., 2020).

The ecological aspects of eco-living choices or urban resilience and adaptation to changing environmental conditions are often emphasised as essential factors in sustainable development (Garcia et al., 2017). Up to 70% of greenhouse gas emissions result from the activity of residents of cities, which includes electricity generation, transportation, waste and energy use (Mutizwa-Mangiza et al., 2011). The assumption of sustainable development and eco-inclusion is to meet the basic needs of all people, to preserve, protect and restore the health and integrity of the Earth's ecosystem without compromising the ability to meet the needs of future generations while not exceeding the long-term limitation of ecosystem capacity (Kasztelan, 2017).

Changing people's behaviour without the support of education is difficult (Varela-Candamio et al., 2018; Garcia et al., 2017). When planning the implementation of systems focussed on urban adaptability, it is impossible not to consider the critical learning component. Faced with a reality transformed by a pandemic, it is necessary to create solutions that respond to hitherto unknown social problems in an innovative way. Existing traditional methods, which the pandemic has severely curtailed, must be replaced by tools that use new forms and channels of communication to educate people (Dwivedi et al., 2020). The emerging solutions to support education for

sustainable development should meet the current pandemic reality and the future post-pandemic reality that awaits us (Anderson et al., 2021).

Changing behaviour to be more environmentally friendly is necessary for a modern economy (Demuzere et al., 2014). Such changes require an adaptive approach to urban planning, which does not establish one future configuration, assuming the precise predictions of urban development and its factors, but supports a range of configurations (Wilkinson, 2012). Another key factor in the successful operation of city-systems is urban resilience – the ability of an urban system to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to changes and to quickly transform systems that limit the current or future adaptive capacity (Meerow et al., 2016). The possibilities of digital twins are not fully embedded in the process of engaging residents while mitigating climate change; the initial concept of Greencoin – designed as an Information System (IS) – has emerged (Bryan, 2020).

In response to the problems outlined, the "Greencoin" project aims to create an ecology-oriented IS (Wiener, 2019) based on interdisciplinary assumptions of cybernetics in the city of Gdańsk (Poland) – a city in a transition economy. A system of human social activity, composed of elements belonging to five classes, including data, methods, information and communication technology (ICT), organisation, and people (Piccoli & Pigni, 2016; Roztocki et al., 2020). Thus, an IS covers a formal set of human and capital resources and algorithms that function by collecting, processing, communicating, decoding, and using data for decision-making and management (Piccoli & Pigni, 2016).

Our project could be a factor for sustainable development concerning support mechanisms, such as appropriate assessment of the context of eco-inclusion, approach to educational IS design and implementation, availability and use of unique resources, including ICT and digital innovation (Bailey & Osei-Bryson, 2018). Thus, a literature review of social currencies and ISs needs to be performed in order to provide a solid foundation for the creation of the future Greencoin IS framework, to be implemented as the next stage of the project.

The IS can be presented as a specific algorithm of successive procedures, as depicted in Fig. 1. As transition economies, we describe countries or regions moving from developing to developed status, to a free market system, and towards a knowledge-based economy (Roztocki et al., 2020). Our system should steer the process of change: it should provide knowledge, motivate to take

action through rewards, manage the action and influence the emergence and repetition of new pro-ecological behaviours through encouraging rewards resulting from green points collected by the user, among others.

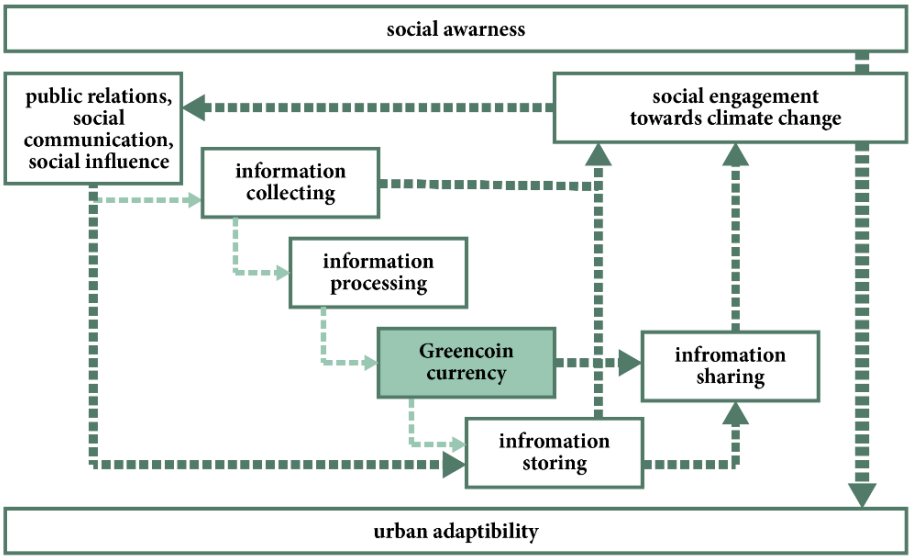


Fig. 1. Algorithm of information system (IS) as a basis for research format.

Source: Authors own elaboration from: Wrona (2012) and Kowal & Węgłowska-Rzepa (2013)

We based the research framework (Fig. 1) on the concept of an interdisciplinary cybernetic system (Kharchenko et al., 2020). It assumes a change in social behaviour through an IS built on economic knowledge about cryptocurrencies, gamification processes, and social and economic behaviour. The first step is collecting data that is influenced by public relations (PR) about social communication and methods of social influence. These factors impact all stages of building a cybernetic system/process in which information is processed. The Greencoin currency appears *de facto* as an effect of information processing because, based on various evidence of pro-ecological activities, users are assigned points for which information is stored (Fig. 1 and Fig. 2). We also assume that our cybernetic system is self-learning and recursive because the change in attitudes and behaviour to pro-ecological will be manifested in the form of messages which can re-stimulate the process of change from the beginning.

In order to construct such a system, we assume the study of cognitive processes, mechanisms responsible for learning and analysis, and concepts such as adaptation, effectiveness, connectivity,

efficiency, convergence, and feedback (Kelly, 2009). This is why we use knowledge in the field of IS design, psychological knowledge of methods and techniques of exerting a social influence (Cialdini & Sagarin, 2005; Jacobi, 2020), knowledge of behavioural economics (Kahneman, 2003; Smith, 2005), Goal-Framing Theory (Hameed & Kahn, 2020), Gamification theory (Van Houdt et at., 2020) and theory of virtual currencies (Yano, 2020).

In the scientific literature, researchers have not identified the functioning of the community currency (CC) system and the ISs associated with them in the Eastern bloc countries, as opposed to those developed and used in more developed European countries (Roztocki et al., 2020). We identify the lack of such a system as a research gap that needs to be answered. The current study aims to identify the elements of the CCs and ISs, developed in other regions in Europe, to form a set of solutions for the future.

We have therefore analysed a set of case studies regarding their operational, social, educational and technological aspects. Firstly, we have recognised the existing theoretical frameworks of tested, implemented, or operating digital currencies and ISs that encourage environmentally-friendly behaviours. Secondly, we have conducted a critical analysis on both local and global solutions influencing social attitudes towards climate change. The aim of the study, based on the outcome from the systematic literature review and 120 SC and IS analysis, is to provide the foundations for the future framework of the Greencoin IS.

2 THEORETICAL BACKGROUND

Sustainability Development. Cities must become resilient to face climate change, which requires the promotion of sustainable development (Leichenko, 2011). The ability of urban adaptation becomes more urgent as cities, due to their inherent instabilities and vulnerabilities, are hotspots of high risks given their concentrations of population and infrastructure (Birkmann et al., 2010). Yet, the scientific discourse is focussed on how to address the implications of climate change for urban areas. Urban planning for adaptation is recognised as a collective process and a key prerequisite of success (Giordano et al., 2020).

Climate Adaptation. So far, urban climate adaptation is characterised by public tasks while personal responsibility is often limited (Mees, 2014). The research shows that cities should approach mitigating climate change in both multilevel and multidimensional ways, where community-based adaptation presents an opportunity for participation in framing planning and

activities (Archer et al., 2014). While cities seek to facilitate the engagement of different civil society actors, the potential of participatory approaches associated with climate change is still not well understood (Chu et al., 2016). Missing connections in the interaction among actors-resources-tasks hamper the effectiveness of urban resilience (Giordano et al., 2020).

Utilising tools and approaches intended to integrate participation, engaging efforts to mitigate climate change, and increasing interest in community-based adaptation's potential can help build adaptive capacity (Lisa et al., 2014). However, studies prove that urban dwellers are familiar with the concepts of climate change in an urban context, such as droughts and floods, with consequences for health and water, energy, and food availability, however the knowledge of individual activities to diminish the consequences remains limited (Martínez et al., 2018).

Climate change awareness has been recognised as a driver of change for climate adaptation to be successful (Marshall et al., 2013). Mavrodieva et al. (2019) prove the potential of a soft power tools in raising public awareness and in addressing climate change as the general public was given the opportunity to share opinions and engage with the issue in a new dimension. However, the possibilities of using the IoT and digital twins to engage citizens in the process of shaping urban adaptability are not fully recognised.

Gamification. In the proposed IS, we will be based on theoretical assumptions included in the following definitions of gamification. One of the earliest and the most popular definitions described gamification as the "use of game design elements in a non-game context" (Deterding et al., 2011). Apart from the following, a few definitions describe the means and goals more adequately regarding the issues discussed in this paper. Another definition is related directly to a computer or mobile application design "adding game elements to an application to motivate use and enhance the user experience" (Fitz-Walter et al., 2011).

The Greencoin project as an interdisciplinary approach in IS. We have based the Greencoin IS design (Fig. 1, Fig. 2) on the assumptions of cybernetics, the science of the general rights of receiving, storing, transmitting, and processing information in complex control systems (Wiener, 2019). Control systems in cybernetics are technical systems and biological, social, and administrative systems, e.g., the management processes in human society. An IS means a particular example of a cybernetic system. Thus, cybernetics finds analogies between the principles of operation of living organisms, social systems (communities), and machines (holism), discovers

general laws common to various sciences, and enables the transfer of these laws from one field to another (Pickering, 2010). This is why we are constructing our system so that it uses, among others, the methods of social influence, behavioural economics, and the theory of digital currencies. We presented the IS in the form of an algorithm of successive procedures. The diagram (fig 2) shows the stages of the design of the IS in which we plan to use methods that exert social influence.

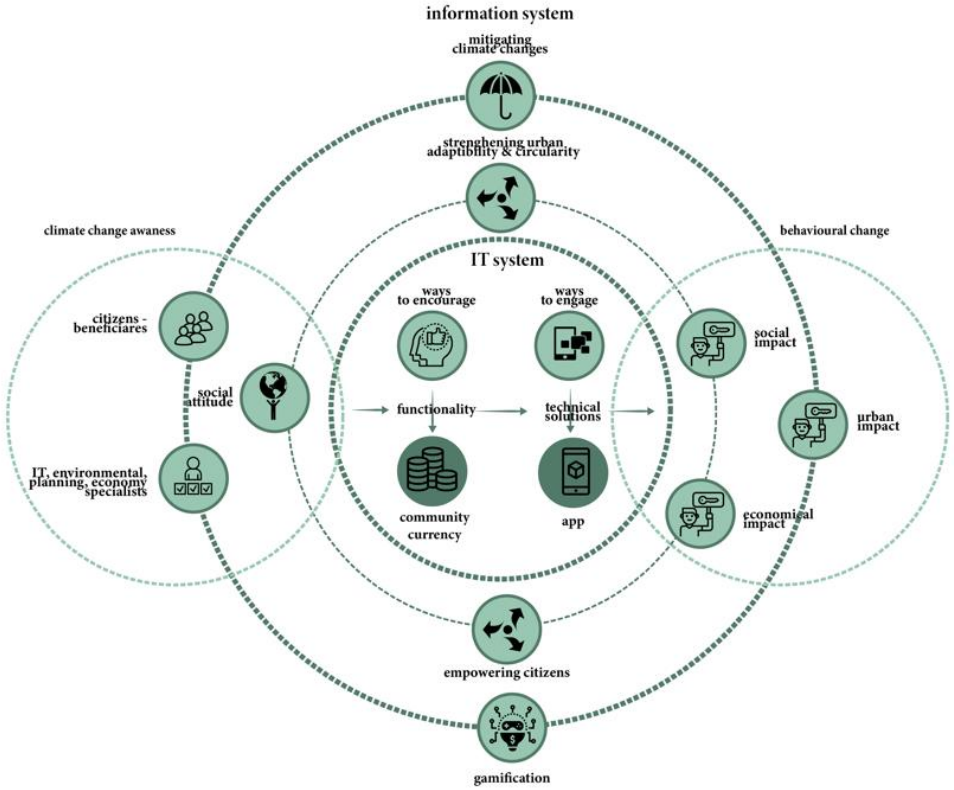


Fig. 2. Conceptual model of the Greencoin information system (IS).
Source**:** Author's own elaboration

Behavioural economics. Behavioural economics studies how psychology influences management, how thinking and perceiving the world, and emotions influence economic decisions. It explains why people make irrational decisions and why their decisions are not in line with projections based on economic models (Kahneman, 2003). It has little to do with behaviourism, rather it draws from cognitive psychology. The word behavioural introduce other social sciences to economics: psychology, sociology, and political science (Shiller, 2005). Kahneman (2003), Smith (2005), and Keynes (Pech and Milan, 2009) laid the foundations for behavioral economics and developed it

towards marketing, including PR. They also indicated the basis of changes in economic behavior, which is one of the foundations of our project.

Digital, complementary and community currency. Digital currency is one of the possible tools of behavioural economics and socio-economic to influence attitudes and behaviours. It is an electronic representation of a monetary value that can be issued, managed and controlled by private issuers, developers, or a founding organisation (Investopedia, 2021). It is often identified as a virtual currency and digital currency and is a medium of exchange that acts like money (it can be exchanged for goods and services) but is independent of the national currency, borders, and central banks. A digital currency exists entirely in the virtual world and is traded on multiple platforms. Parallel to the government financial system, different sustainable monetary systems are being developed by non-governmental organisations and social groups (Collom & Lasker, 2016). Currencies have emerged as a "not-for-private-profit" tool to promote local economics, sustainable living choices, and sustainable development (Lietaer, 2001). The assumptions of the socio-economic basis for creating cryptocurrencies are the motivators in our project to change behavior to pro-ecological.

2 RESEARCH STRUCTURE

There are many examples of applications and currencies focused on mitigating climate change that are being tested or implemented worldwide. However, only a few are embedded and operate within an IS designed from the very beginning to answer the climate change crisis. Another gap is the limited number of solutions dedicated to central European countries where the urban policies regarding climate vulnerability call for action. On the other hand, when implementing climate-oriented policies, cities are focussed on urban resilience, while the opportunities resulting from social engagement in shaping urban adaptability are not fully recognised. In the era of the IoT and digital twins, new opportunities arise, and the new approach to designing enhances urban dwellers' eco-living choices.

On the basis of the defined gaps, research questions have been formulated that respond to the research problem and help to define the aims of the paper:

Step 1 – Q1: Are there any information systems (ISs) enhanced by gamification elements to encourage urban dwellers to get involved in the process of shaping urban adaptability?

Step 2 – Q2: How do the new types of currencies and applications respond to climate change's challenge and the need to shape urban adaptability?

Step 3 – Q3: What functionalities and technological solutions used in the analysed IS, currencies or applications were applied in order to achieve urban resilience?

Step 4 – Q4: What made the solutions successful tools in the process of mitigating climate change?

3 AIMS

The main aim of the research was to introduce a theoretical framework as a foundation for the design of the Greencoin IS. As the system is planned to enable the engagement of urban dwellers in the process of shaping adaptable cities, it was further defined with supplementary goals responding to the research steps (Fig. 3) which are as follows:

Step 1 – A1: Recognising existing theoretical frameworks, tested, implemented or operating digital currencies and apps that empower environmentally friendly behaviours.

Step 2 – A2: Analysing existing solutions that approach the process of mitigating climate change.

Step 3 – A3: Evaluating the technological, functional, educational and social aspects of solutions that assist in the process of shaping urban adaptability.

Step 4 – A4: Critically analysing both local and worldwide solutions that influence social attitudes towards climate change and engage citizens in the process of shaping resilient cities.

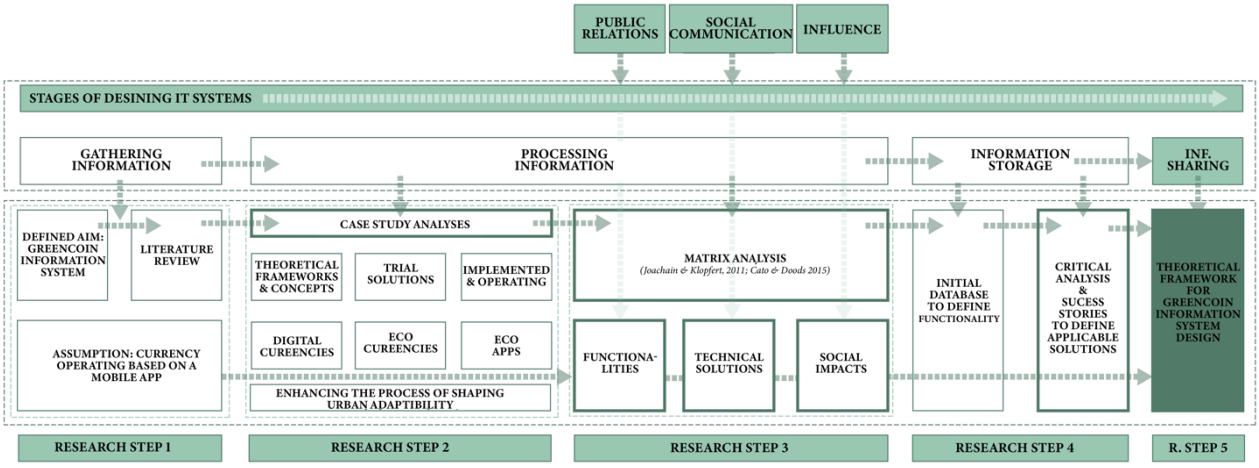


Fig. 3. Methodological approach – research steps embedded in the process of IS design

Source: Author's own elaboration based on Burrough et al. (2015); Wrona (2012)

4 METHODOLOGY

The research methodology responds to the steps defined above and is presented on Fig. 3. The chosen methodology is assigned to particular steps embedded in the approach to IS design based on Burrough et al. (2015) and Wrona (2012), and has been selected based on the type of information searched:

Step 1: The initial stage of the search process was launched in March 2020. Using a brainstorming method, the authors of the study made suggestions for keywords as the basis for the planned searches. Then, in the course of the discussion, a composition of keywords "incentives + behaviour change + environment" emerged, which was adopted in a further stage. Two databases were used for the search: the EBSCO platform and Google Scholar. In the first step, 1071 records were retrieved from the EBSCO platform. In the second step, the results were restricted to 323 full-text English-language publications.

Access to the full-text articles was provided through a license from one of the affiliated universities. In a further step, after reviewing the abstracts and full texts of the publications, the results were restricted to 60 studies presenting the implementation of various currencies and 45 studies presenting real-life examples of the use of mobile applications or the gamification method for the transition towards environmentally friendly behaviours. In the last step, using the snowball method and the Google scholar database, 15 further examples meeting the conditions of the study were identified, eventually forming a database of 120 articles which were used in the next step of the research.

Step 2: The literature review allowed us to find and study theoretical frameworks, existing – implemented and tested – solutions for community currency designs. A case study search was used to select the currencies, applications and initiatives most relevant to the initial concept of Greencoin IS. Aiming to define a theoretical framework for Greencoin as an IS, we selected 120 existing solutions for further evaluation.

Step 3: Those cases were further systematically evaluated. We focussed on their functionalities, embedded technological solutions and social impacts. To approach the evaluation, based on the methodologies of Joachain & Klopfert (2012) we defined the assessment framework presented at Fig. 4 and described in detail below.

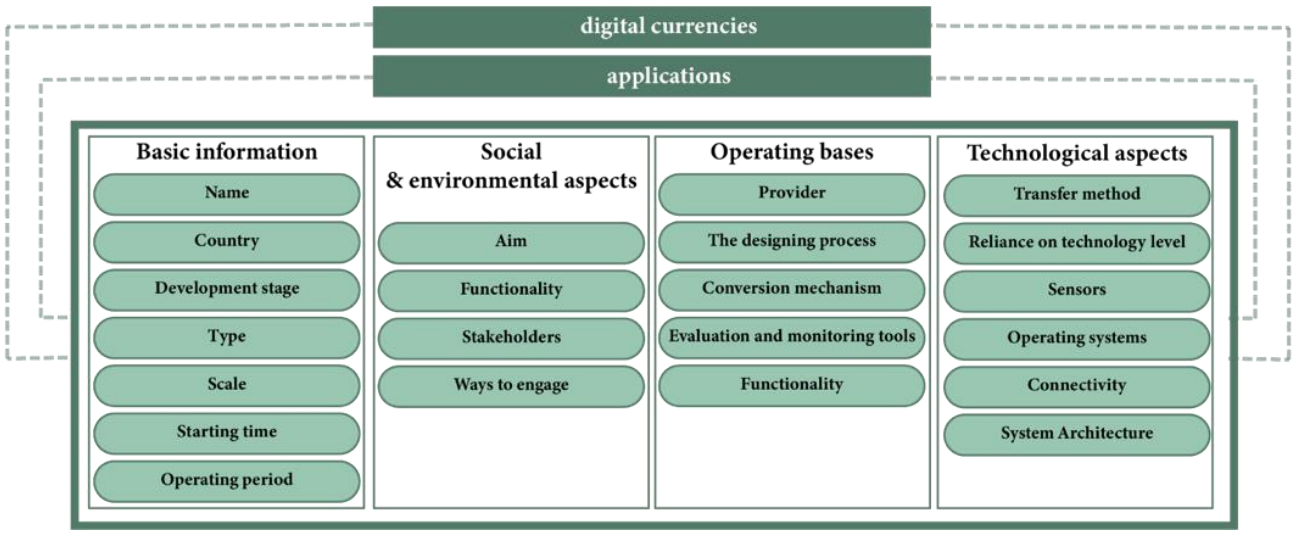


Fig. 4. Criteria for matrix analysis

Source: Author's own elaboration

Basic information	Social aspects	Operating bases	Technological aspects
Name The name of the evaluated application or community currency.	**Aim** What the currency, system or application has been designed and implemented to do.	**Provider** Answers whether the system runs under the supervision of the public or private sector or a consortium is involved.	**Transfer method** Means of currency transfer between peers or between peers and a central unit based on the reliance on the technology.
Country The country where the application, system or community currency operates.	**Functionality** The main functions of the currency, system or application.	**Designing process** The methodology behind defining the functionality and the final scope of functions.	**Level of reliance on technology** The level of functionality dependence on technology. A measure of the extent of which a solution relies on technology.
Development stage Defining whether the solution was an experiment, testbed or operatial system.	**Stakeholders** For who the currency, system or application has been designed and who is using the solution.	**Conversion mechanism** How the values of the rewarding system are defined, what the profits and benefits are.	**Sensors** The list of all of the IT system sensors for data collection, e.g., camera, fingerprint, GNSS, accelerometer, gyroscope, microphone.
Type Introducing on which technical solution the application, system or currency is based.	**Ways to engage** Defines the promotion mechanism, benefits, and the rewarding system.	**Evaluation and monitoring tools** How the impact is measured/evaluated and what the tools for assessing users' engagement include.	**Operating systems** The list of supported operating systems or the platforms that users can use to interact with the system. E.g., Symbian, Android, iOS, Java Me.
Scale Introducing the solution's users' geographical range.		**Functionality** Technologies which allow users to operate with the system. E. g. blockchain, PIN card, QR code, Banknotes, NFC.	**Connectivity** Communication technology standard used by the solution. E.g., IrDA, Bluetooth, NFC, Wi-Fi, Cellular Network.
Operating period For how long the application, system or a			**System Architecture**

community currency has been operational.			Whether the architecture of the system is centralised or distributed.

Table 1. Criteria for matrix analysis

Source: Author's own elaboration

Step 4: All of the general findings were further summarised by the research team. On the bases of the case study evaluation, we performed a critical analysis to identify trends and themes. The most important part of this was to find the pros (inspirations, ideas and most relevant and applicable solutions) and to define the cons (to recognise what did not work, what was missed, what limitations the author faced, what could have been done to improve those solutions).

With such a methodological approach, we are attempting to introduce a theoretical framework for a territorially oriented information system that aims to empower urban adaptability.

5. EMPIRICAL STUDIES AND CRITICAL ANALYSIS

Following the measures for critical analysis, the case studies were evaluated and a brief summary of selected findings is described below. As we approached the evaluation systematically, a keyword list has been defined for each criterion. The summary introduced below was done quantitatively (Fig. 6) to recognise trends and find the main challenges to be faced while designing the Greencoin IS.

5.1 Basic information

Aims and main functionalities. The, most of the existing solutions tackle the challenge of energy saving systems, or reducing emissions or consumption. Additionally, they respond to the issues of transportation and waste management systems in the city. In general, they were designed with an aim to change behaviours and habits while promoting sustainability. It can be observed that the solutions are rather sectoral and some aspects of sustainable development aims have not been included.

Location. From the basic criteria list, the location was found to be crucial for our research. The list of analysed pro-environmental applications and systems worldwide is highly consistent with the World Bank list of high-income economies (The World Bank, 2021). A correlation between the country's development level and environmental protection initiatives in the form of applications

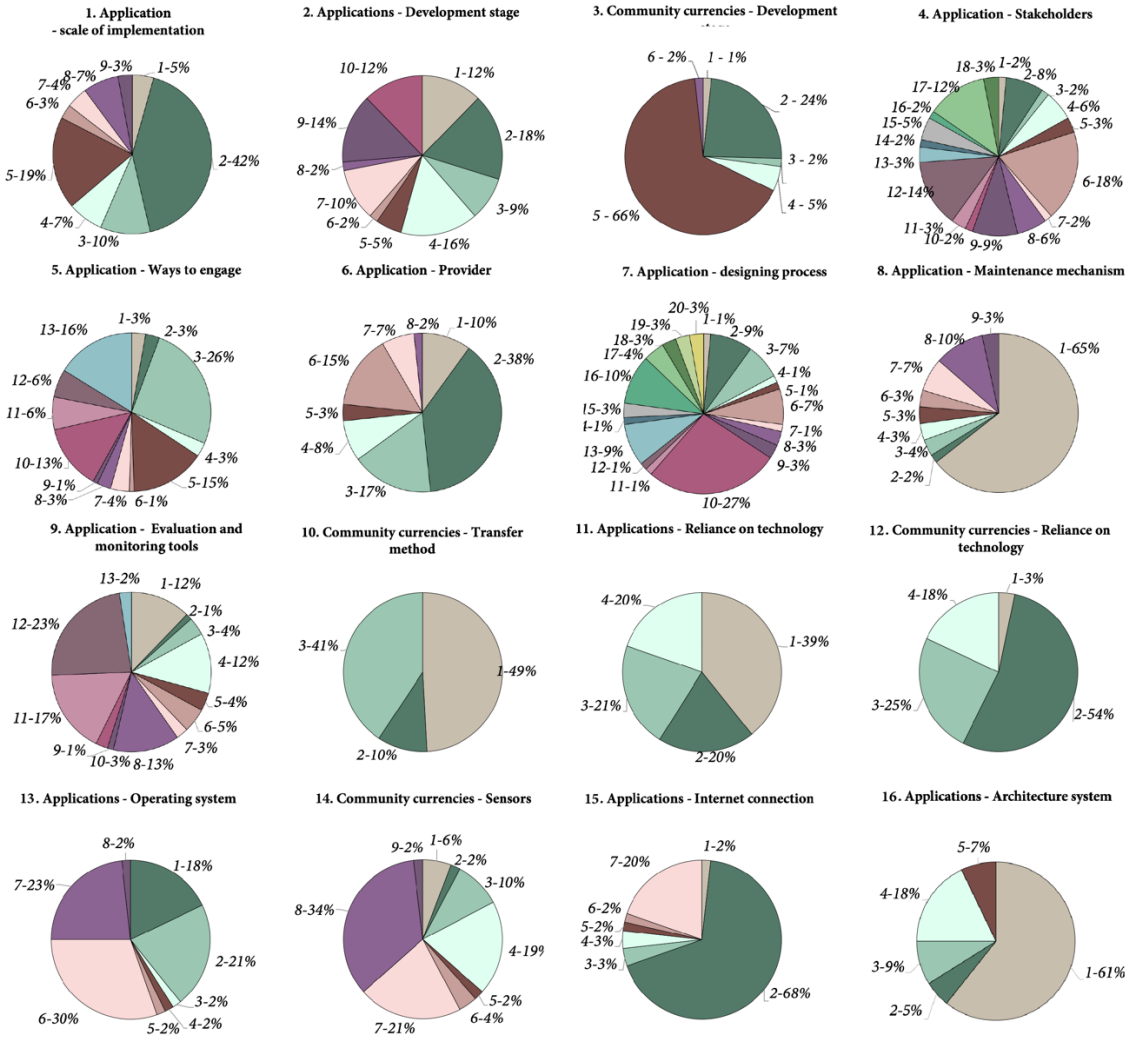
and CCs was observed. The result demonstrates the lack of similar initiatives across central and eastern Europe (Fig. 5).

Fig. 5. Spatial distribution of the analysed cases (both apps and currencies)

Source: Authors own elaboration

Scale of implementation. 42% of applications is designed to be tested at the architectural level – offices, households. Solutions focussing mostly on educational aspects are not territorially oriented. On the other hand, 17% of the currencies exceed the local scale and operate at the national, European or global level. However, some of them have been designed to serve particular neighbourhoods only.

Development Stage. With regard to the criteria of the development stage (Fig. 6), it is important to note that the application implementation process includes a series of tested stages and involves different levels of readiness of the service. Evaluating the CCs brings a crucial finding that nearly two thirds of the currencies designed in Europe are currently in operation, which might be a result of the low requirements and reliance on technology of the CCs. The currencies that do not rely on technology do not include constant services and technical backend maintenance. The following leads to the conclusion that currencies high reliance on technology serve to short-term projects. The Greencoin system, which will rely on technologies such as smartphone operating systems, server-side infrastructure, Internet access, and Global Navigation Satellite System (GNSS), will respond to the current technological advancement, thus will require continuous updates and adjustments, in order to operate beyond the testing period.



1. Application – Scale of implementation

1 no info
2 architectural
3 local
4 virtual
5 local
6 European
7 global
8 national
9 supralocal

2. Applications – Development stage

1 experiment
2 implemented & operating
3 no info
4 pilot study
5 prototypes
6 start-up
7 testbed
8 tested
9 theoretical framework
10 trial

4. Application – Stakeholders

1 building users
2 companies
3 consumers
4 customers
5 cyclists
6 households
7 ICT providers
8 no info
9 office employees
10 organisations
11 property owners
12 residents
13 schools
14 seniors
15 students
16 tourists
17 transportation users
18 users

5. Applications – Ways to engage

1 educational activities
2 feedback
3 gamification
4 help provider
5 interactive dashboards

6. Application – Provider

1 no info
2 academia
3 consortium
4 local government
5 non-profit organisation
6 private sector
7 research consortium
8 start-ups

7. Application – designing process

1 behavioural science
2 case study research
3 design-based research
4 experimental designs
5 focus groups
6 game design methodology
7 indicators
8 interviews
9 machine learning
10 no info
11 pass–fail criteria
12 product design methodology
13 prototyping

8. Maintenance mechanism

1 no info
2 blockchain
3 crowd-sourcing
4 donation system
5 embedded in foundation
6 open source
7 operated by governmental units
8 paid
9 pilot study

9. Applications – Evaluation and monitoring tools

1 data analysis
2 document analyses
3 interactive dashboards
4 interviews
5 IoT sensors
6 KPI
7 machine learning
8 no info
9 observations
10 prototyping
11 real-time monitoring

10. Community currencies – Transfer method

1 Digital
2 Hybrid
3 Physical

11. Applications – Reliance on technology

1 High
2 Low
3 Moderate
4 no info

12. Community currencies – Reliance on technology

1 High
2 Low
3 Moderate
4 no info

13. Applications – Operating system

1 Android
2 Android, iOS
3 Facebook app
4 iOS

14. Community currencies – Sensors

1 accelerometer
2 BLE location sensor
3 cameras
4 GNSS
5 gyroscopes
6 IoT
7 no info
8 smart meters
9 thermostats

15. Applications – Internet connection

1 Bluetooth
2 Internet Connection
3 Internet Connection, Bluetooth
4 Internet Connection, cellular network
5 Internet Connection, NFC, Bluetooth
6 Internet Connection, ZigBee
7 no info

16. Applications – Architecture system

3. Community currencies – Development stage 1 pilot 2 experiment 3 local complementary currency 4 no info 5 operating system 8 testbed	6 know-how 7 no info 8 online quests 9 personalised plans 10 point system 11 rewarding system 12 social networking 13 tips & suggestions	14 self-determination theory 15 surveys 16 tests on limited group 17 UI design 18 urban experiments 19 User Centered Design (UCD) 20 workshops	12 surveys 13 testbeds	5 J2ME 6 no info 7 web app 8 Windows	1 client-server 2 distributed 3 hybrids 4 no info 5 standalones

Fig. 6. Quantitative summary of the results of the analysed cases

Source: Authors own elaboration

5.2 Social aspects

Stakeholders. As 32% of existing solutions focus on energy consumption and transportation, accordingly they are dedicated to households and residents. What is quite crucial is that 16% of existing solutions have been designed to be used by the business sector, including employees and consumers. Public transportation users – including cyclists – are a group found to be actively participating in such solutions. Due to the educational dimension, students as well as schools are a beneficiary of existing applications. What demands the attention is the 2% of seniors as potential users. Such findings provide an answer about how to choose the group to be invited in the process of testing the applicability of the initial Greencoin IS.

Ways to engage. We aimed to recognise what kind of embedded solutions help the application or currency to gain more attention. Without a doubt, any real-time measures, indicators and numbers presenting the impact of the user's activities to them have been found to be more attractive. Interactive dashboards enriched with rankings as well as assignments, tips and feedback make the projects more successful. 26% of the cases are based on gamification solutions, however the limited operating time has been observed. In any case, a rewarding or point system strengthens the achieved impact.

5.3 Operating bases

Provider. As the limited duration of the projects was noticed, we searched for solutions with a longer operating period. 38% of the applications and currencies designed by a granted research consortium failed after the project was finished. To maintain the designed tool, transformation into a start-up was found as a solution. Cooperation with governmental units was also crucial to make sure the climate-based solutions continue to operate. When it comes to urban adaptability, it is important to design the currency or application to respond to the city's challenges.

Designing process. The methodological aspects of the implemented solutions have been studied to help to structure the process of designing the Greencoin IS. Information on the process behind the operating solutions is limited in most cases. However, in many cases, the authors used product or game design methodologies. Most of the solutions were introduced as a result of design-based research (10%) or preceded by prototypes (9%) and testbeds (10%) supplemented with interviews and surveys (8%).

Maintenance mechanism. To make sure the applications remain on the market, 10% of the existing solutions are paid. However, 3% of the systems offer donation systems or are supported by crowdsourcing-based solutions. It can be observed that the majority of applications operated by governmental units maintain continuity.

Evaluation and monitoring tools. 17% of the solutions are based on real-time monitoring tools. In 16% of cases, this includes big data analysis and IoT sensors. Mostly however, the evaluation tools depend on the number of users. When it comes to local solutions, 28% are based on KPI systems, surveys or more qualitative methods. It is crucial that in most cases, the users have access to real-time data.

5.4 Technological aspects

Transfer method. 60% of the analysed currencies in Europe operate digitally, while 10% of them operate both physically and digitally. In Utrecht (the Netherlands) and Övre Norrland (Sweden), 95% of adults made use of the Internet for banking in 2019. By contrast, this applies to less than 10% of adults in the majority of Bulgarian and Romanian regions (Eurostat, 2021). Although CC transfer and management are possible via digital access, their adoption relies on the citizens' preferences, which differ among geographic areas and age ranges.

Reliance on technology level. It was observed that 49% of the CCs in Europe do not require any kind of software to operate and only 5% depend on external devices and sensors. Nearly 40% of the analysed application-based solutions communicate with external services or devices. It is important to notice that many of the currencies are being transformed into digital ones (Bristol Pound, Brixton Pound) and this trend is highly anticipated to continue.

Sensors. Among the analysed applications, 26% do not utilise any built-in or external sensors. 44% of the sensors are smart meters, which allow data collection of energy or water consumption. The

second most utilised sensor is GNSS, which provides position, navigation and timing for an application. With the increasing popularity and accessibility of Internet of Things technology, it possible to predict an increase in the number of applications and systems communicating with household sensors and devices to monitor the user's environmental impact.

Operating systems. A majority of the analysed systems are based on web applications, which allows the users to access them from any device. Alternative smartphone access is provided by 50% of the systems. While the Internet accessible via computers, tablets and smartphones, it requires an Internet connection.

Connectivity. 68% of the analysed applications require at least an Internet connection to operate, the second communication technology is Bluetooth which is a part of 7% of the systems. In regard to the CCs, the majority (57%) can operate without any communication technology, utilising physical banknotes or vouchers.

System Architecture. Both in applications and CCs, the client-server architecture is the dominant solution. The alternative, a distributed system architecture, covers half of the remainder of the solutions. It is important to mention that distributed CC system architectures are currently being developed.

6. LESSON LEARNT – DISCUSSION

The main objectives of implementing innovative solutions based on CCs and ISs that use the gamification methodology in the case studies considered were to raise environmental awareness and knowledge and encourage the reinforcement of environmentally friendly behaviour in their users. Despite the common goal, both the course and the outcomes of the individual projects were different. The analyses allowed us to identify difficulties that arise during the implementation of new solutions and indicate practical actions convergent with the Greencoin idea, which would be worth using at the conceptual stage of the created support model.

The literature review confirmed our assumptions about the positive aspects of using currency/virtual currency-based systems as a tool to influence behavioural change. Participants of the research presented that joining the initiative contributed to the transformation of their attitudes towards environmental issues. They felt more motivated by the reward system or exchange of services. Moreover, participants expressed rejection of the optional traditional payment, especially

participants with environmental motivations (Akin et al., 2021), prioritising trust and neighbourly solidarity. Users expressed the opinion that, thanks to the solutions presented in Fig. 6 and Chart 5, they have deepened their knowledge on pro-environmental activities. The educative role of the alternative form of payment reinforces autonomous social organisation, personal capacities, creativity, and self-management (Dini & Kioupkiolis, 2014).

Our research framework assumes an alternative type of intervention supported by cybernetic, IS-based solutions. We employ Information and Communications Technologies for Development (ICT4D) using computers, mobile phones, tablets, and other devices enabling information management on the Internet, which is necessary in the modern economy (Dearden, & Kleine, 2021). Individuals linked in the social network support each other by promoting and motivating environmentally friendly behaviour, recognising that they are not alone in their actions. The important lesson is that these processes increase awareness of their environmental impact (Joachain & Klopfert, 2012; Ro et al., 2017).

What is more, ICT4D solutions will help reach a larger audience in a shorter period, significantly increasing the number and variety of green behaviours. Our innovative project will support the region in combatting climate change and helping poor, socially excluded, and marginalised communities, which also has an ethical dimension (Dearden & Kleine, 2021).

Another lesson was that the feedback, often presented through an interactive dashboard (Fig. 6, Chart 9), should play a significant role in the project. It could be provided throughout a variety of channels or forms, as a Smart Meters display (Mihaylov et al., 2014), a metaphor of a sinking virtual island (Shiraishi et al., 2009), Blockchain technology (França et al., 2019) or teaching presence (Marinakis et al., 2020), but should be one of the essential components to support the behaviour change process. Feedback can also be enhanced by including activities to further activate system users through tips, hints, quizzes, and challenges that are easily integrated into people's daily lives (Chen et al., 2015). Although these activities are time-consuming and require additional effort among the developers, operators, and users of the system, they bring tangible benefits, so should be included as a significant component in the Greencoin system.

Furthermore, the key role of public authorities should be emphasised so various stakeholders should be invited to support the Greencoin. Public authorities and stakeholders could, among others, influence the resident's choices, remove formal obstacles, and promote more sustainable

patterns of behaviours (França et al., 2019). It is not only authorities that influence sustainable actions. The group working and social networks strengthened eco-friendly behaviours. Participants who felt encouraged by others undertook actions more frequently (Kuntz et al., 2012), felt related to the community (Lee et al., 2013), and could coach each other (Ro et al., 2017).

Finally, one of the advantages of the virtual currency approach is also the possibility of obtaining effective results with low amounts of incentive money (Aguiar-Castillo et al., 2019) using the excitement mechanism (Walker, 2018). Ongoing contact reinforced with even small incentives helps to keep system users engaged. For best results, simple communication is complemented with a user-friendly, graphic message, with the rewarded behaviour being multi-step, impacting multiple faces or dimensions.

7. GREENCOIN THEORETICAL FRAMEWORK

Fig. 7 introduces guidelines for the Greencoin IS design that were gathered based on the lessons learnt from the matrix analysis described above. Evaluation of 120 cases allowed gaps and good practices to be recognised. In Fig. 7, the first row introduces the criteria of evaluation, the second shows the most common results of the analyses. The third introduces the bases of the Greencoin design.

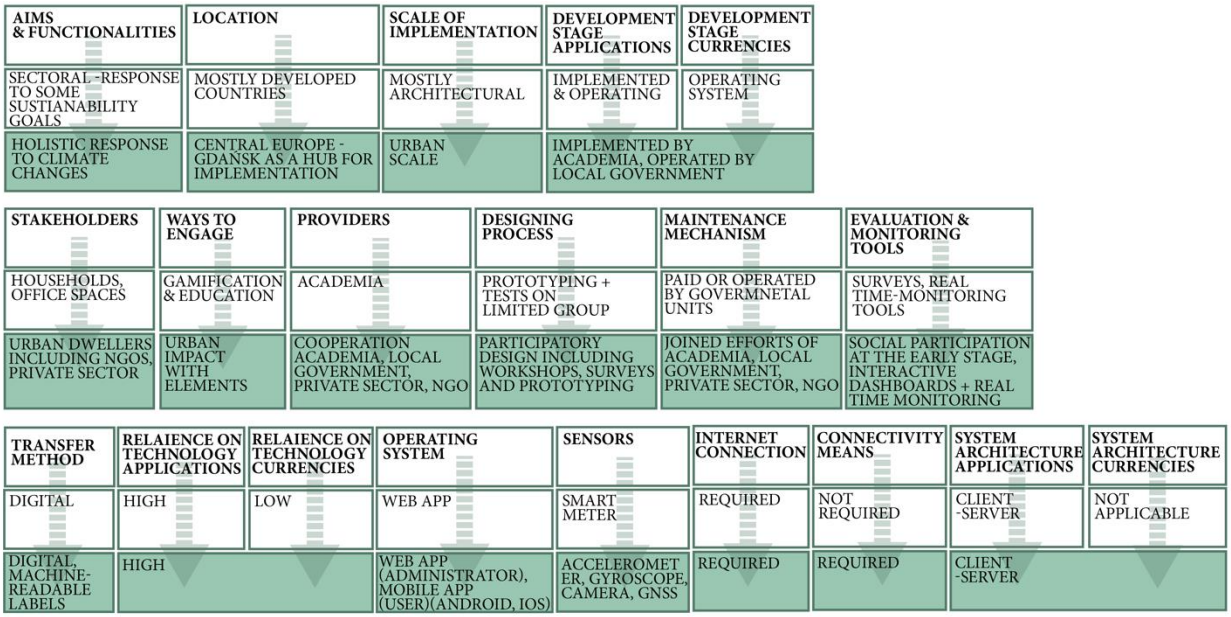


Fig. 7. Guidelines based on lessons learnt for Greencoin IS design

Source: Authors own elaboration

In terms of aims and functionalities, Greencoin should offer a more holistic approach to climate mitigation, as so far, most solutions have responded to sustainability goals sectorally. It should respond to the main challenges of central European countries as so far there is a limited number of tools shaping climate change awareness in this region. In this case, Gdańsk (PL) will act as a hub and a place where Greencoin will be tested. Compared to other solutions, we propose a shift from the architectural to urban scale. We aim to introduce a solution for urban dwellers offering different types of functionalities and benefits. The current trends that include educational and gamification-based solutions will be further enriched with the benefits and possible urban impact in climate mitigation. It will be provided and maintained based on joined efforts of academia, local government, the private sector and Non-Governmental Organizations (NGOs).

The concept will be further developed on the bases of social participation, and workshops, and Greencoin itself will be enriched with interactive dashboards and real-time monitoring tools. As in most of such tools, Greencoin will be based on the digital transfer method and at the early stage of tests it will be rather moderated, thus once implemented the reliance on technology will be high. Contrary to existing solutions, it will operate not based on a web app but on a mobile application. However, similarly, to the evaluated tools it will utilise smart meter sensors. Greencoin is to be based on the client-server architecture.

8. CONCLUSION

The evaluation of SCs and pro-environmental behaviour allowed us to meet our goals, namely to identify challenges and find appropriate solutions for the Greencoin IS. In the analysed regional currencies and IS solutions, elements of gamification are often applied in order to educate and engage citizens in pro-ecological activities that are appropriate to their local social context and goals. The growing number of CCs related to citizens' awareness of their environmental impact, and moreover ISs, are becoming a powerful tool for local governments and activists in meeting their goal of achieving urban resilience.

In terms of technological solutions, the main factor that defines the advancement, and thus possible applications, is the reliance on sensors, both integrated in the users' smart devices and external, allowing the users' activity and behaviour to be monitored (Lowe & ÓLaighin, 2014). On the other hand, the larger the number of external sensors or sources of data applied, the more technological challenges need to be solved (Corke et al., 2010). As an answer, we suggest applying peer-review

verification – a solution that can bring a gamification element to the system. While the actual impact of the analysed systems and CCs is impossible to quantify, the described solutions have proven to increase citizens' environmental awareness and inclusion.

This research novelty is developing a unique technological solution that uses CC and gamification techniques to promote pro-environmental behaviours. To the best of our knowledge, such a pro-environmental application based on CC and pro-ecological engagement has not been elaborated in the Gdańsk metropolitan area before, making Greencoin a pioneering solution to the region and the local community. Moreover, according to our preliminary research, Greencoin could fill an important niche which has so far remained unfilled, with a technological platform solution that connects the local community with pro-ecological opportunities, organisations, initiatives, and actions co-shaped by local authorities, businesses, and the citizens themselves.

Limitations of our study relate to the fact that we conducted our current research on examples of European CCs. We will address these limitations in the subsequent phases of the project, covering an analysis of the Gdańsk citizens' attitude towards pro-ecological behaviour based on focus groups and quantitative research. Additionally, the means of technological implementation will be evaluated in the context of the accessibility of local data sources and potential integration with existing systems, within both the public and private sectors.

The systematic analysis of SCs and pro-ecological ISs is the first of four steps in a long-term project to be implemented by our team. Over the next two and a half years, the Greencoin IS prototype will be developed, tested and evaluated in the city of Gdańsk. The project aims to create a system based on data, technological instruments, and elements of gamification, with the purpose of changing the habits of residents, educating them, shaping pro-ecological behaviours, and promoting eco-inclusion. The system will serve different groups of beneficiaries. The proposed prototype will be available to municipalities, educational institutions and activists worldwide, with the potential to be adjusted to address ecologically-related goals locally.

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More information can be found at https://greencoin.pl/.

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