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Unveiling the Green Mirage: Unearthing Weaknesses in Pro-Environmental Applications

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Completed Research Paper

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Abstract

Growing ecological concerns and a general shift towards tailored digitized solutions in cities lead to an increased popularity of pro ecological applications, especially those associated with transport-oriented functionalities. This research focuses on the results from a testbed of a pro-environmental application deployment among early adopters. Based on quantitative and cartographic analysis enriched with interviews' results, by applying a triangulation research approach, we are able to answer three research questions: related to potential constraints or unintended negative outcomes of pro-environmental educational applications, deviation from the intended use of these apps, as well as range of climate-responsive behaviors these applications promote. Research results allow us to analyze to what extent a pro environmental application affects users' behavior and ecological choices. It also helps to critically evaluate potential technological weaknesses, their interaction with end users and an impact on motivations and habits of urban dwellers.

Keywords: Application weaknesses, ICT for inclusion, Pro-environmental application, Quantitative and cartographic analysis, Spatial analysis, Technology-enhanced learning.

Introduction

The emergence and integration of mobile applications (or apps) dedicated to environmental education and actions mark a significant shift in how individuals engage in pro-environmental behaviors (Holden et al., 2018). These digital tools, transcending mere repositories of knowledge, act as interactive platforms to instigate a broad spectrum of climate-responsive actions with a particularly impactful role in the realm of sustainable transportation (Zhang et al., 2020; Nicol et al., 2023). Such sustainable transportation systems strive to reduce environmental impact, promote public health, and increase economic efficiency through reduced emissions and renewable energy, making transport equitable for all societal layers (Banister, 2008; Black, 2010).

In addressing the 'Green Mirage', a critical examination of pro-environmental apps is crucial in discerning their genuine contribution to a shift towards sustainable transportation instead of merely projecting an illusion of environmental progress (Banister, 2008; Holden et al., 2018). This paper aims to unravel the complexities and potential unforeseen outcomes when end-users interact with apps. We focus on those applications that purportedly guide behaviors toward sustainable transportation choices.

Despite the evident educational impact of environmental apps such as EcoIsland and Greenify in promoting environmental awareness (Fryers, 2017; Lavtizar et al., 2021; Obracht-Prondzyńska et al., 2021), a targeted cadre of 'pro-environmental apps' have honed in on transportation—a sector pivotal in climate change mitigation due to its significant carbon footprint (Pan & Ryan, 2023). These apps not only equip users with the means to alter their travel behavior but also may trigger broader changes in lifestyle and environmental stewardship (Pocock et al., 2018; Pan & Ryan, 2023).

However, a discernible research gap exists in evaluating the broader behavioral impacts of these apps beyond just modifying transport habits (Noij, 2019; Nicol et al., 2023). This study aims to bridge this gap, scrutinizing how the transportation functionalities within pro-environmental apps can profoundly influence users' environmental actions and decision-making, reinforcing the ultimate objective of sustainable transportation.

This investigation is driven by observations from the PULA app, which is being developed for Gdańsk and features a strong emphasis on transportation functions (Obracht-Prondzyńska et al., 2021; Duda et al., 2023). Our preliminary analysis raises the concern that while these transportation functions can modify some behaviors beneficially, they may also unintentionally encourage other behaviors that do not align with environmental sustainability, or that may even be counterproductive (Schultz, 2014; Nicol et al., 2023).

Accordingly, the study is structured around research questions that focus on understanding of the broader impacts of transportation functionalities within pro-environmental apps:

RQ1. What are the potential constraints or unintended negative outcomes associated with emphasizing transportation in pro-environmental applications?

RQ2. How might users deviate from the intended use of these apps, possibly engaging in behaviors that undermine their pro-environmental purpose?

RQ3. To what extent do transport-focused features align with user motivations for environmental behavior change, and what range of climate-responsive behaviors do they promote?

In pursuing these questions, the study seeks to critically assess whether the transport functionalities embedded in pro-environmental apps serve merely as a digital facilitator for single-axis behavioral change or if they effectively contribute to a broader suite of climate-responsive behaviors. Here, 'climate-responsive behaviors' refer to actions and lifestyle changes that individuals can adopt to reduce their carbon footprint, adapt to the impacts of climate change, and support the transition to a low-carbon society.

Research background

Role of applications in shaping pro-environmental behaviors

In an era marked by rapid technological advancements and growing environmental concerns, the role of applications has become increasingly significant in shaping pro-environmental behaviors (Balińska, et al., 2021). These digital tools have the potential to foster a profound shift in how individuals and communities interact with their surroundings and make choices that benefit the planet. This study explores the multifaceted role of applications in promoting pro-environmental behaviors, emphasizing their power to educate, motivate, and facilitate sustainable actions.

Beyond education, applications have the capacity to motivate individuals to adopt pro-environmental behaviors (Wong, et al., 2022). Gamification, a popular strategy, incorporates game-like elements into apps to engage users and reward sustainable actions. For instance, eco-friendly transportation apps, such as e.g. MOVES+, MapMyWALK or Walkup, reward users for walking, cycling, or using public transportation instead of driving, ultimately reducing carbon emissions (Sadeghian, et al., 2022). Social networking apps also play a significant role in promoting pro-environmental behaviors by leveraging the power of social influence (Li & Fang, 2022). Users can share their sustainable choices, achievements, and experiences with their networks, inspiring others to follow suit (e.g. Social Power, CAPS, My Eyedro). This sense of community and peer support can be a powerful catalyst for behavioral change (Fortuna et al., 2019).

Broad literature confirms positive and tangible impact of pro-environmental applications on the changes in users' behaviors, e.g. by stimulating active collaboration, ecological brainstorming and learning processes

among users in group activities (Cellina et al., 2020), changing users' mobility behaviors towards more sustainable ones, e.g. with non-motorized means or public transport (Anagnostopoulou et al., 2020) and by reducing households energy consumption, waste and emissions while using collective social incentives and gamification means (Douglas & Brauer, 2021). In addition to gamification, community and peer support, such mechanisms as development of common aid, mutual surveillance and a combination of both negative and positive reactions proved to be effective mechanisms to shape application users' behaviors (Kimura & Nakajima, 2011). Overall, the measures of effectiveness of applications solutions to change users' behaviors are diversified across mentioned studies and in general they apply a combination of both quantitative data analysis on the applications and qualitative ones, e.g. using interviews or questionnaires, in order to effectively evaluate the application impact on users behaviors.

Facilitating Sustainable Choices

Applications also facilitate pro-environmental behaviors by simplifying sustainable choices (Wong et al., 2022). Ride-sharing apps, for example, make it convenient for users to carpool, reducing the number of vehicles on the road and lowering emissions. Similarly, food delivery apps can provide information about restaurants that prioritize sustainability, helping users make eco-conscious dining choices (Susilo & Santos, 2023). In addition, smart home and energy management apps empower individuals to monitor and control their energy consumption, contributing to reduced energy waste and lower carbon footprints (Bastidaet al., 2019). Such apps provide real-time data and actionable insights, enabling users to make environmentally responsible decisions in their homes.

Innovations in this field include the integration of augmented reality (AR) and virtual reality (VR) experiences within environmental education apps (Mei & Yang, 2019). These technologies immerse users in interactive simulations, allowing them to witness the direct impact of their choices on the environment, thus enhancing motivation and understanding. A varied palette of the mentioned technological solutions demonstrate timeliness and importance of technology in solving modern environmental problems at the individual level, as well as a general trend towards applying tailored mobile application functionalities to shape people's behaviors. While applying different technical workmanship, all the mentioned cases have one common feature: they try to scientifically evaluate applications' impact on users' behaviors while at the same time attempting to solve a real-life problem with means of Information and Communication Technology (ICT). According to literature an Action Design Research method (ADR) proved to be an effective way to achieve both above mentioned goals and is broadly used in similar research (Collatto et al., 2018; Mullarkey & Hevner, 2019; Coghlan, 2022).

In conclusion, applications have emerged as powerful tools in shaping pro-environmental behaviors, and recent innovations have expanded their potential even further. They educate users, motivate them to take sustainable actions, and facilitate eco-friendly choices. As technology continues to advance, it is imperative that app developers, environmental organizations, and individuals collaborate to harness the full potential of these digital tools in the ongoing effort to protect and preserve our planet (Becker et al., 2015). By leveraging the capabilities of applications, we can inspire a global shift towards more sustainable and environmentally responsible lifestyles.

Existing solutions and designated climate-oriented functionalities

Our preliminary research conducted as an enabler for PULA design proves that transport-oriented applications dominate among others. We evaluated 120 applications and digital currencies at very diverse stages of their development (Obracht-Prondzyńska et al., 2021), defining a base for PULA design, hence focusing on social, environmental and technical aspects as well as operating bases. We learnt from the pre-study that over 30% of existing solutions focus mostly on transport related functionalities.

Such a finding was also confirmed with our research described below. Among all the functions available in the application (Figure 1) mobility options gathered most of the attention of early adopters (Duda et al., 2023). Thus, we decided to evaluate transport-oriented functionalities more carefully to recognize the environmental impact.

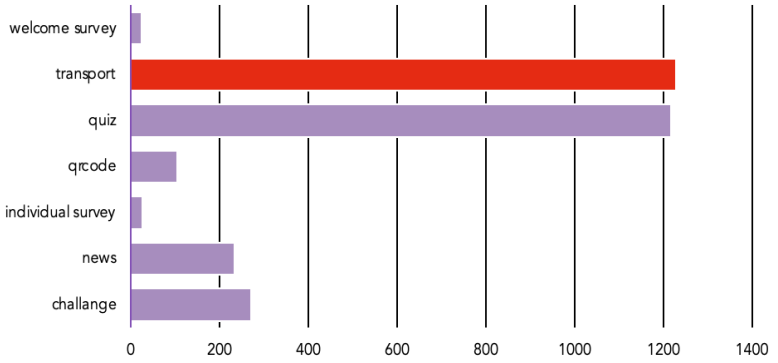

Figure 1. Number of undertaken types of actions by early adopters of PULA

Methodology

Current Study

To address the raised research questions, based on the literature review, we adopted the Action Design Research approach proposed by Sein et al. (2011). This methodology, based on stages presented in Figure 2, emphasizes the iterative approach of designing and implementing solutions, which offer a systematic way to integrate practical insights into the research framework. The implementation of the action design research approach provided valuable guidance in understanding the nuances of the app development process in which the authors of the text are involved.

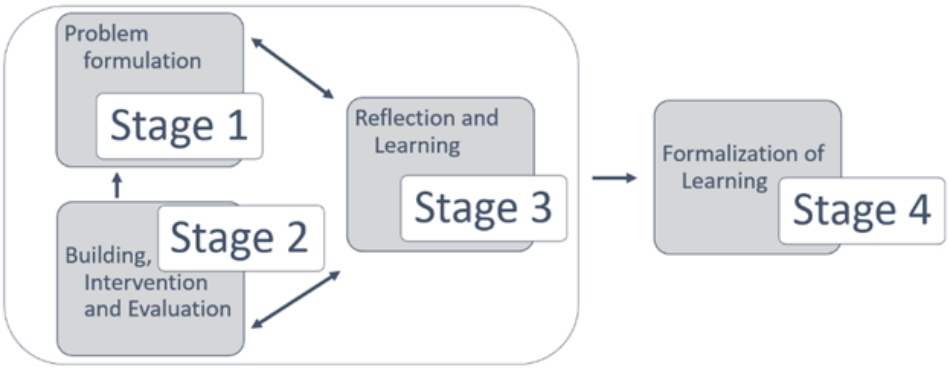

Figure 2. Action Design Research framework adopted, based on Sein et al. (2011)

Aligned with the research framework adopted, the first phase was triggered by the growing concerns of city dwellers, municipal authorities and local activists regarding the ongoing global climate crisis. As a response to this problem, in the second stage, the PULA app was developed. The objective of this initiative is twofold: firstly, to promote environmentally conscious behavior among city residents (app's features based on motivational nudges) and secondly, to engage local stakeholders in the development of effective strategies for incentivizing and rewarding such behavior, like offering free coffee to consumers who bring reusable cups. In the initial stage of testing the app, its functionalities such as encouraging learning about the environment (reading articles, short news items, taking knowledge quizzes), promoting urban public transport and cycling, encouraging the purchase of local products, etc. were active. Further details about the PULA application are available in the article authored by Duda et al. (2023). The third stage of our process entailed reflecting and learning, prompting us to examine why users are inclined to utilize the transport and educational features of the application, as well as the ramifications of this behavior. Following

the iterative approach taken, we revisited phase one and identified three research questions to guide the study at hand. Subsequently, we conducted a reflective analysis of the research material gathered during testing.

In the initial testing stage of the PULA mobile application, the developers issued an open invitation to corporate institutions and universities in Gdańsk, Poland, to encourage voluntary participation. A requirement for joining this phase was that participants would agree to be interviewed at the end of the application testing period. In the end, 29 early adopters (M_{age} = 30.7, *SD* = 10.1) gave their consent to take part in the research. The study sample consisted of 20 women (M_{age} = 32.4, *SD* = 11.7) and 9 men (M_{age} = 26.9, *SD* = 8.2). The test phase continued for a period of nine weeks. The early adopters aimed to test the pool app's functionalities, including recycling, waste segregation, using reusable containers, purchasing and eating locally-sourced food, carrying own reusable shopping bags, reading short articles on environmental topics, taking environmental knowledge quizzes, and choosing sustainable modes of transport. Participants gave consent to collect data on their activity while using the app and its analysis by the research team. They were also provided with the researchers' details before the study began, so that they could always ask questions and be kept informed of the study results.

Data-based research

Each action undertaken by the early adopters was recorded with the application as it registered Global Positioning System (GPS) data. Thus, the results could be further evaluated. During the testbed we collected 3313 recorded actions, within which 1476 was focused on transport functionalities. Date, time and earnings, geolocation of activity and users data (age, gender) was saved in the database. We evaluated the results with quantitative and cartographic methods. Geographic information system (GIS) tools were used to study the limitations of application usability. The GPS data was visualized with Quantum Geographic Information System software (QGIS), while the application data was compared with space syntax analysis (to estimate walkability index) and network analysis (to estimate public transportation accessibility). The ambition was to capture dependencies between users' behaviors and urban form. Such an approach allowed us to better understand to what extent the behaviors are encouraged by the application or rather result from the quality of life in the city.

Interviews to verify findings

The conducted interviews lasted approximately 30 minutes. Interviews were carried out by members of the research team, following a pre-designed interview scenario. The focus of the inquiry encompassed the motivation for utilizing the PULA application, its advantages for users, the planet, and the application's functionality in general. In addition to the planned transcription of the interviews, every interviewer was requested to create notes and analytical summary of the crucial findings during the interview. This study is not intended for detailed analysis of the research material during interviews but rather to complement the conclusions drawn from the analytical spatial data. As data from the app can be misleading in some aspects, we assume that the declarations in the interviews will help to clarify users' motivations for undertaking certain activities while testing the app. Therefore, we adopted a triangulation research approach. A table of key findings from the interviews containing qualitative data is considered sufficient for the chosen approach of the research (Clausen, 2012).

Results and Discussion

Based on quantitative and spatial data analysis few clear trends in users' behaviors were observed:

- RQ1: users behaviors will result from the built environment attributes and they will look for weak points of the application design so they can benefit more. However, more likely the willingness to find gaps will differ depending on gender.
- RQ2: Analyzing the georeferenced results it can be observed that the users will more likely find the application gaps allowing them to earn more while choosing transport-oriented functionalities and they will be tempted to find functionalities which they can use without behavior change. It requires high considerations by the applications' designers to go beyond such tendencies to achieve climate positive impact.

- RQ3: It proves that the benefits unfortunately are of higher importance than the idea of pro-environmental behaviors, however such temptations can differ between social groups. Despite such observations, these applications can encourage behavioral change, however it requires careful design based on extended users' tests.

This can be confirmed by the examples discovered in the observation process and described below. While the examples provided might not entirely reflect early adopters' actual behavior, as they were aware of being the initial app testers, the identified trends suggest that prospective app users may also tend to seek out app weaknesses.

Influence of built environment

Ewing and Cervero (2010) proved that the built environment shapes the behaviors of urban dwellers. Our research confirms this finding as we observed that the early adopters used public transportation when it was convenient and easily accessible. This excludes the users from earning and participating in pro-environmental activities when they live outside well connected neighborhoods (Figure 5, Figure 6) - RQ1. The cartographic observations show that the users were encouraged to use the walking function mostly in the neighborhoods of high walkability measures. The application fails in the areas of poor urban design and car-oriented development (Figure 3, Figure 4) and encourages to overtake app-based actions with a purpose differing from the initially designed - RQ2. Despite the city-oriented design of the application functionality, it should also serve for the residents of suburban areas as they are tempted to use the application and it is highly needed to encourage the shift from car to public transport daily commuting.

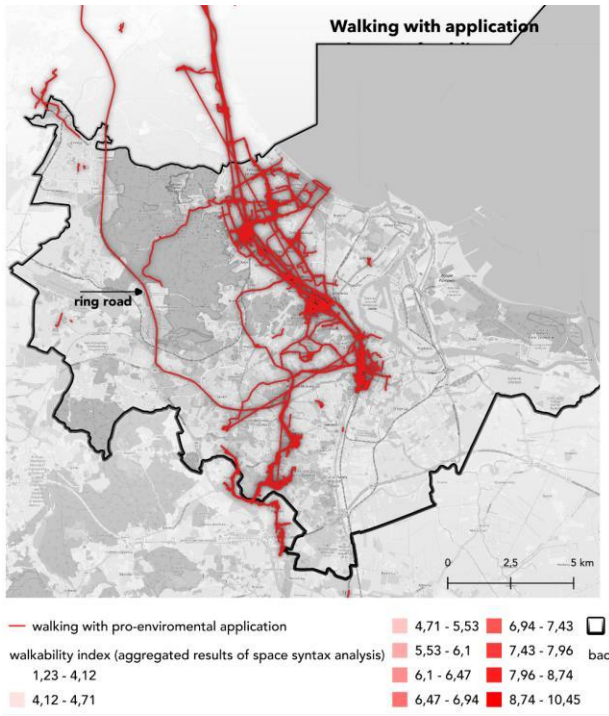

Figure 3. Walking with the application. Authors' own elaboration

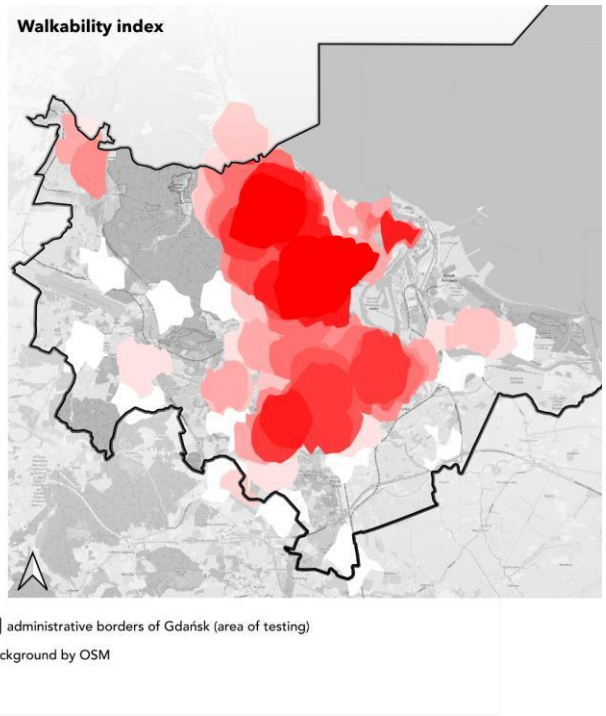

Figure 4. Walkability index in Gdańsk. Authors' own elaboration

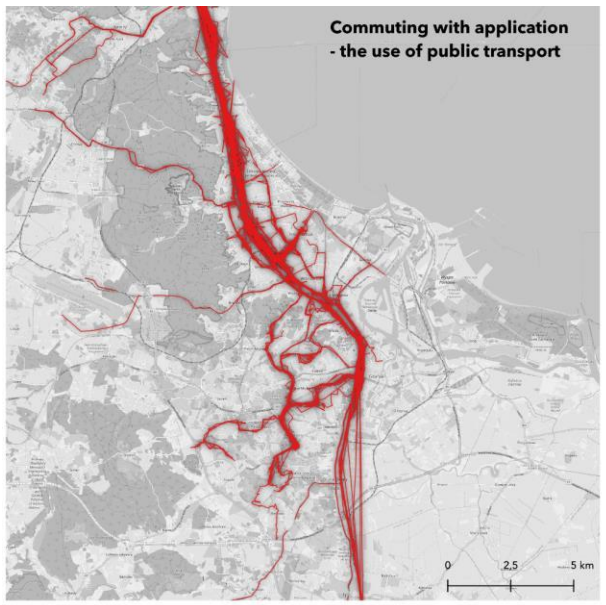

Figure 5. Using the application for public transportation commuting. Authors' own elaboration

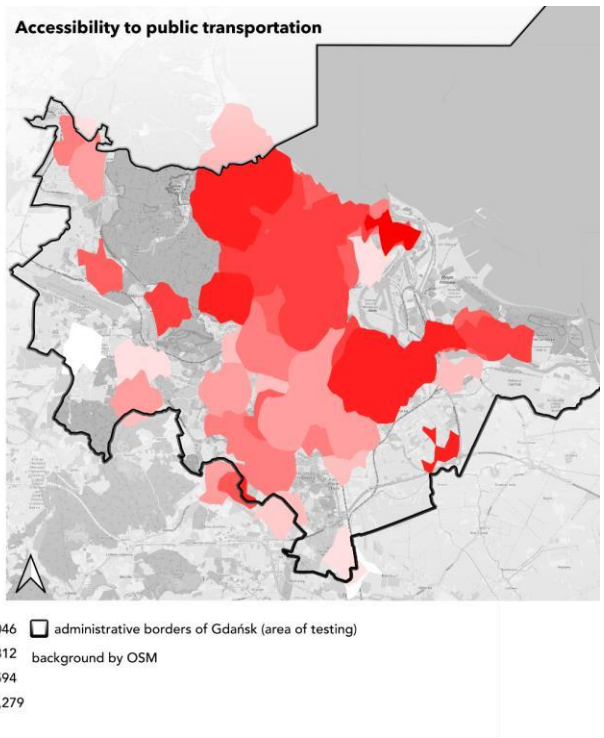

Figure 6. Accessibility to public transportation in Gdańsk. Authors' own elaboration

Need of boundaries

We observe that the majority of early adopters tested whether it is possible to cross the boundaries either the administrative or of pro-environmental behaviors as they searched for options allowing them to earn credits from the most beneficiary options available in the applications (RQ1). This was proven by the cartographic observations of GPS data that proved travels outside the city for which the application was intended for. We found travels to other cities (even outside suburban areas) or within other cities (Figure 7, Figure 8). As the benefits are offered by the city of origin, such practices should be limited.

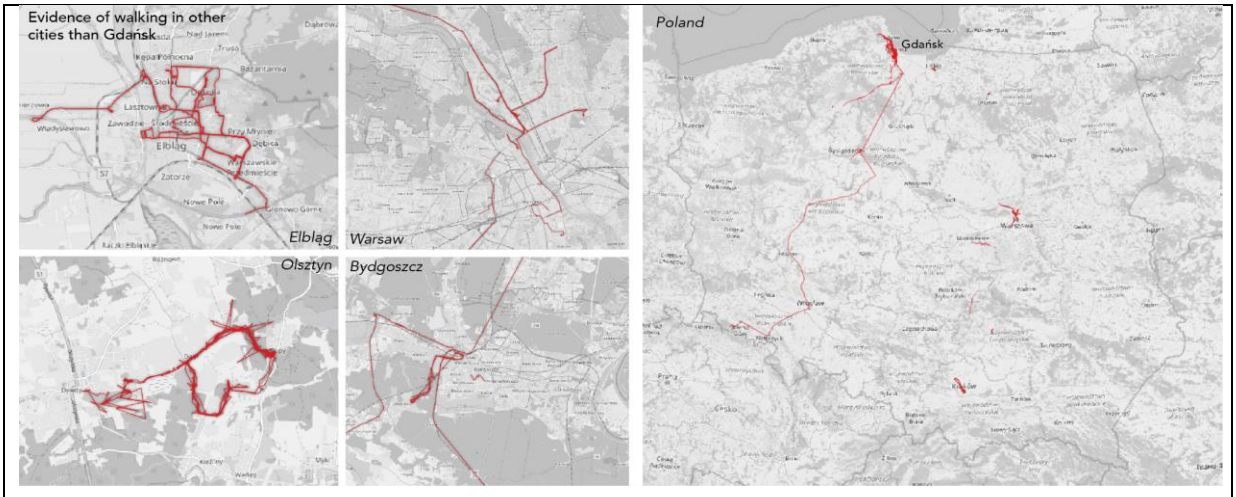

Figure 7. Evidence of using the application outside the designated area. Authors' own elaboration

The walking function was used in the job places for moving between campus buildings which is another risk which occurred as a response to the addressed RQ1. We found evidence of using the walking function within shopping centers (Figure 7) which do not serve as climate responsive urban solutions - RQ1. The users were also choosing this option when commuting with a ring road where walking is forbidden (the Tri-City ring road, the expressway or walking along bus route (Figure 3). Despite speed limitations, when traveling in a high traffic the application did not recognize car drive (RQ1).

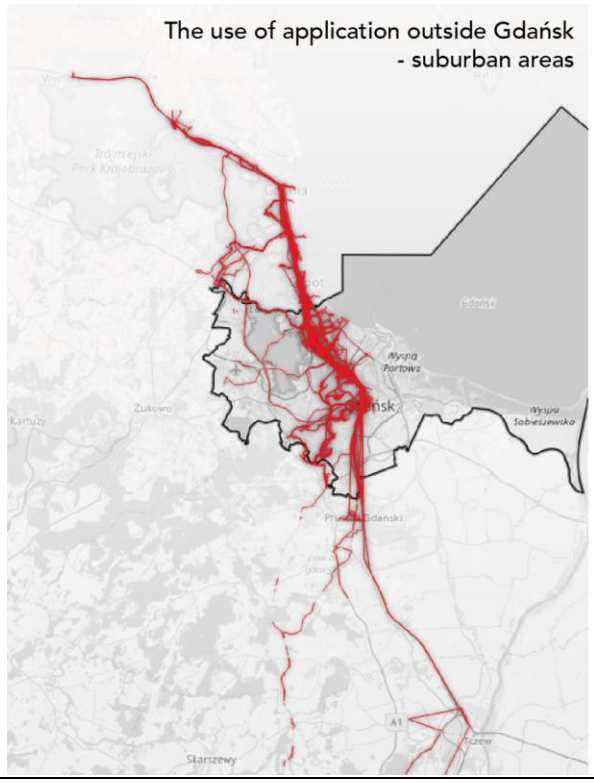

Figure 8. Encouraging pro-environmental behaviors of suburban residents. Authors' own elaboration

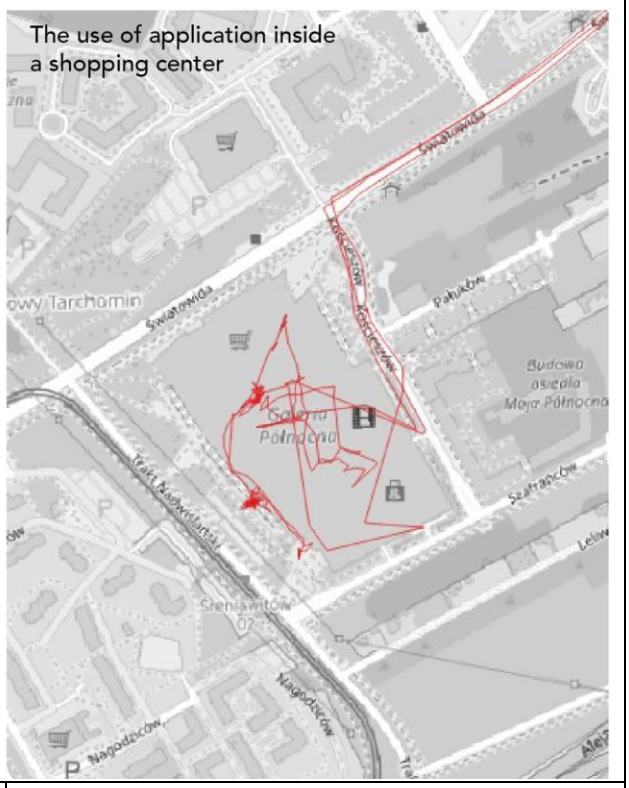

Figure 9. Evidence of using application inside the buildings. Authors' own elaboration

Gender differentiation

The application was used differently by the early adopters (see Figure 10). Female users were tempted to learn more on pro-environmental options and used other functions as often as transport. At the same time men were focused on transport only as it brings more earnings. We also observed that the female transport oriented activity drops over time while the use of other functions remain constant (Figure 11). Opposite behaviors were observed within male users. The study also shows that men are using the application when commuting to work - rash hours are observed as results, while women activities are more diverse. This proves findings of Perez (2021) that women travels correlate with other duties hence the benefits should concern different urban behaviors.

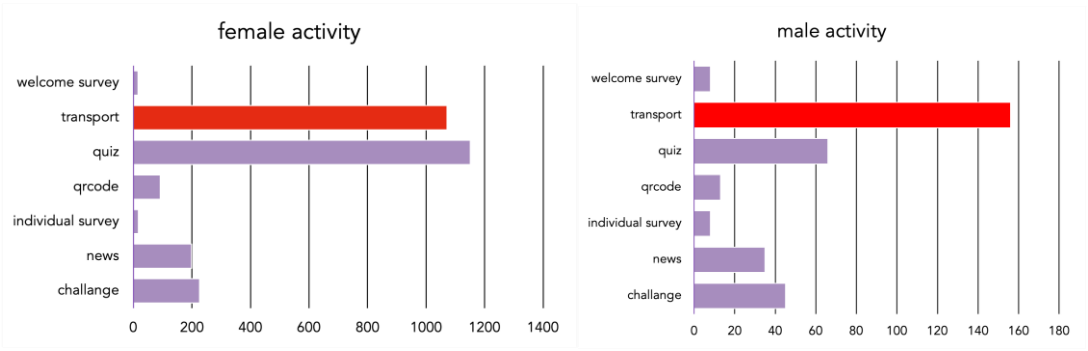

Figure 10. Gender differences while using application functionalities. Authors' own elaboration

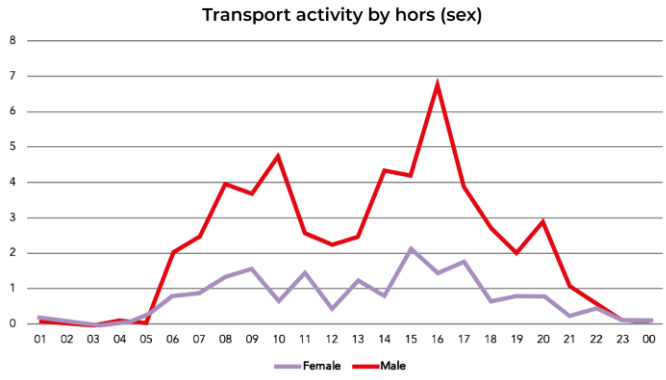

Figure 11. Gender differences while using application - time. Authors' own elaboration

Time validation

The research observations confirmed the need of providing constant interaction with the users by adding new tasks, otherwise the activity is dropping (Figure 12). We noticed that the users were willing to use the application when complimenting other activities, e.g. while commuting to work, which was confirmed during the interviews. Therefore, the time spent by the application users in public transportation can be used to serve educational activities influencing other pro-environmental behaviors, not only travel choices.

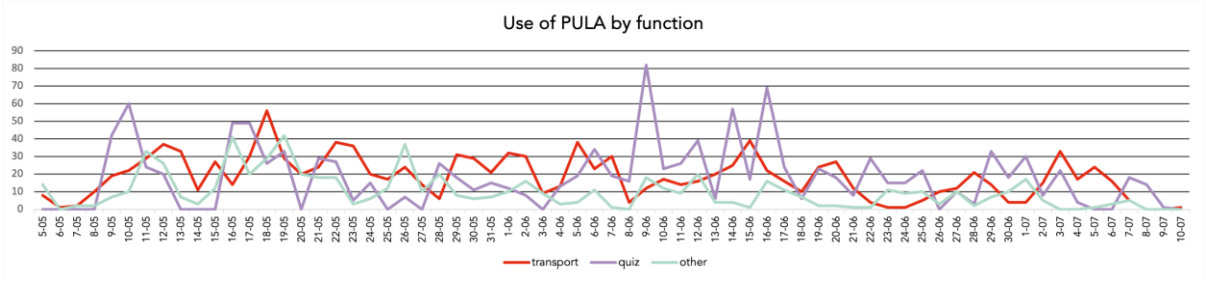

Figure 12. Use of PULA application by function

Prove of findings - early adopters' insights on PULA

Majority of such findings was proven not only with data but also during the interviews. The early adopters confirmed that they tested the application to find the most convenient way to earn points which allowed us to elaborate on the addressed RQ3. Despite a significant pro-environmental attitude, one of the users admitted to testing whether she can use walking while commuting by public transportation, as she learnt this could bring more credits. Out of curiosity the early adopters decided to check whether the application will work outside the dedicated city (2023-07-17 15:00:00) - RQ3. One of the male users confirmed to search for the options for the most profitable options (2023-07-17 15:00:00, 2023-07-20 14:00:00). Most of the early adopters emphasized the willingness to use the application without devoting additional time, limiting their activity to typical daily activities, such as commuting to work (2023-07-17 15:00:00, 2023-07-17 17:00:00). In the interviews users also emphasized the willingness to use the application in the suburban areas and neighboring cities that would increase application accessibility for them and their friends and family members (2023-07-08 16:00:00, 2023-07-06 10:00:00). This proves why the transportation function gained such popularity, as other functions required more attention. As the paper aimed to evaluate the application critically, most of the findings emphasize the weak points, however there are also strengths proving the impact of such application - *"the application was so encouraging to test new options, as finally together with my husband we decided to buy bicycles"* (2023-07-17 17:00:00). It corresponds with the RQ3 that despite many limitations such applications can be considered as a tool shaping climate-responsive behaviors.

Conclusion

While there are confirmed advantages and growing empirical evidence emphasizing value and popularity of pro-environmental applications that use transportation functionalities, the unveiled research gap is, however, in potential weaknesses of the proposed solutions, the degree of willingness to exploit those weaknesses, as well as hidden motivations behind such behaviors among end users. Therefore, this research addresses a rather unpopular, but very essential topic, related to technological drawbacks, hidden psychological and motivational aspects among technology users, and, as a consequence, the real impact of a pro-environmental application on the users' behaviors and attitudes. The following research allows us to answer three research questions, namely: RQ1 - technological limitations of a pro-environmental application are related to the appropriate action verification through boundary designation, speed restrictions, additional spatial controls of both an action and the user. RQ2 - based on the quantitative spatial analyses it is rather popular and common among application users to test and exploit application drawbacks and limitations. RQ3 - based on the conducted interviews, there are four popular reasons for technological drawbacks exploitation among users: profit maximization being the most popular, time and resources limitations related to daily routines, less prioritization of the application tasks as well as curiosity.

Initial quantitative analysis and spatial findings were enriched with 1:1 interviews with end users, which helped to verify the data, confirmed validity and supported their interpretation, as early adopters openly answered the questions and provided detailed explanations and reasoning behind their actions and motivations. Research results confirm previous studies results on academic cheating with the use of technology, where self-efficacy, awareness of the impunity of the action as well as awareness of technological limitations were frequent premises for cheating (Ghanem & Mozahem, 2019; Mukherjee et al., 2023). In this research, testbed participants were not punished for finding and openly talking about the application drawbacks that helped to surface hidden motivations and emotions, allowing early adopters to behave naturally and speak openly, while facing no negative consequences. The results enable to target an important topic of weakened and distorted impact of pro-environmental applications on behavioral changes of urban dwellers due to both technological limitations and psychological premises.

Limitations: Due to the testbed nature of this study, a rather small sample of early adopters allows us to formulate context-based conclusions and restricts us from drawing broader research generalizations. Therefore, the next research step is planned on a broader population independently accessing the application through open access. In addition, more time is required to observe how the behavior is changing over time.

Study results could be beneficial for pro environmental applications creators, educators and city authorities aiming at implementation of technological tools to improve urban ecological behaviors, as well as for the

researchers dealing with the subject. Our next research step is in addressing the unveiled limitations and drawbacks, and preparing an adjusted application tool to be able to test it on the bigger sample of users, who voluntarily access the application through open access.

Acknowledgements

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