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Research Article

Roles of mobile applications in removing barriers to individual recycling: Case of Türkiye

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ABSTRACT

Recycling literature lists barriers that deter individuals from engaging in recycling behavior. These barriers comprise cost-related barriers such as the behavior being challenging, personal barriers such as lack of knowledge or laziness, social barriers such as lack of support from family, believing that others do not recycle, and structural barriers such as hard-to-access recycling bins or lack of incentives. Removing or alleviating these barriers is critical for increasing source separation and recycling rates. In addition to other measures taken, mobile applications (recycling apps) developed to support recycling may also have a significant potential for removing certain barriers. This study aims to evaluate the functions of recycling apps used in Türkiye and highlight their potential to support the behavior through removing the barriers. For this purpose, content analysis of recycling apps was performed. Following the PRISMA protocol, 19 applications were identified and reviewed in detail. The findings revealed ten distinct functions provided by apps. The role of each function in removing specific barriers is evaluated. It was found that recycling apps have huge potential to promote individual recycling by alleviating critical barriers when apps are widely used and their functions consistently meet user expectations. Problems related to some neglected barriers and low usage rates are discussed, and implications of findings are provided.

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INTRODUCTION

Recycling is promoted as a critical approach for reducing waste, alleviating the need for disposal areas, and protecting natural resources. While some countries reached high recycling rates [1] thanks to policies and implemented regulations, some countries, particularly developing countries, still need to increase the low recycling rates [2]. Municipal waste in Türkiye reached 32.3 million tons in 2020, and only 13.2% of it was recycled [3] despite all improvements in waste management legislation, policies, and an increased number of licensed recycling and recovery facilities. Like other developing countries [4, 5], the low source segregation rates and household waste recycling appear to be significant obstacles to increased recycling rates. It was found that, in different cities in Türkiye, 25–30% of household wastes comprises recyclable solid wastes [6]. So, increasing individual recycling rates appears as a promising approach to reach the targeted 35% recycling rates for 2023 [7] and go beyond it. However, encouraging individuals to change their waste disposal behavior and engage in recycling is challenging.

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Unlike mixed waste disposal, recycling requires time, place, and effort since consumers must separate and clean the waste, store it for a certain period, and carry or drive it to appropriate recycling bins. On the other hand, in Türkiye, individual recycling has been a voluntary behavior that is not subject to a national-wide incentive program but to some local and temporary rewarding implications. However, the lack of incentive is not the unique barrier to individual recycling. The literature identifies barriers that deter consumers from engaging in individual recycling behavior. Reference [8] provides a literature review on the barrier studies, lists the most prominent barriers, and groups them thematically. The Table 1, which is adapted from [8], shows the most frequently reported barriers in literature. Accordingly, one of the most reported barrier groups is the cost of recycling, referring to the effortful, time-consuming, and economically costly nature of the behavior. Structural barriers comprise the long distances to recycling bins, problems in the waste collection services, and the deficiencies of the policy implementations that support recycling. Personal barriers cover lack of awareness and knowledge regarding why and how to recycle, denying the need for recycling and personal responsibility, suspicions about the recycling system, concerns about storing the waste at home, laziness, and insufficient recyclable waste. Social barriers include unsupportive families and a non-recycling community that consumers live in.

Reference [9] found that Turkish consumers also encounter similar barriers to recycling house waste. Those barriers are likely to directly hinder the behavior or indirectly impair recycling by triggering one other barrier or diluting essential determinants of the recycling behavior (such as personal norms or attitude). For this reason, barriers, especially prominent ones, should be removed or at least alleviated. In this context, mobile applications appear as digital solutions for overcoming some of those barriers and improving recycling behavior.

Mobile applications are software products developed specifically for mobile operating systems installed on handheld devices such as smartphones or tablet computers. Mobile apps are pre-installed on mobile devices or downloaded from various mobile app stores such as Google Play, Apple Store, and iTunes [10]. These applications are free and paid applications in many segments, such as finance, music, education, health, games, entertainment, sports, travel, shopping, books, magazines, and navigation [11]. As in the world, the number of mobile application downloads in Türkiye has gained increasing momentum from year to year. The number of mobile application downloads in Türkiye increased by 8.6 percent from 2021 to 2022, and Turkish users installed mobile applications approximately 5.6 billion times in 2022 [11].

There are some green applications designed to support environmental behaviors such as energy and water saving, eco-friendly mobility, waste reduction, and recycling (See [12] for a review). Recycling applications, among those, are designed to facilitate recycling with functions such as providing content about proper waste classification, reminders about recycling, analyzing both the waste impact and the environmental impact of users, conveying current environmental news, and showing the nearest recycling facilities [13]. These functions are provided to encourage recycling by providing convenience, increasing knowledge, and promoting positive attitudes toward recycling.

Table 1. Most frequently reported barriers to individual recycling

Cost of recycling
Recycling is effortful
Recycling takes time
Recycling programs are expensive
Structural barriers
Insufficient recycling collection facilities
Unsatisfactory collection services
Mixed collection and disposal issues
Recycle bins are far away
Lack of incentives
State municipalities do not support recycling.
Inadequate legal regulations
Personal barriers
Lack of knowledge about how to recycle
Lack of awareness
Lack of trust in actors in the recycling process
Do not believe in the necessity of individual recycling
The belief is that separated wastes will somehow be mixed again
Denial of resposibility
Concerns about storing waste at home
No place at home for the storage of waste
Lack of recycling habit/routine
Laziness
The insignificant amount of recyclable waste
Social barriers
Lack of family support
Others do not recycle

Source: Adopted from [8].

The recycling literature provides empirical evidence regarding mobile applications' effect on recycling behavior, recycling knowledge, and perceptions. For instance, [14] showed that using a green app increases recycling and indicated that promoting the use of green apps is one remarkable way to increase recycling behavior and enhance recycling knowledge. Besides, [13] emphasized that the intention to use mobile applications has a positive and significant effect on recycling intention, and mobile applications should be used as a tool to get in the habit of recycling. Reference [15] proposed a new recycling mobile application using the RANAS (risks, attitudes, norms, abilities, and self-regulation) approach. In this application, each user tracks their recy-

Table 2. Descriptive information for the apps

App name	Owner type	Geographical scope	Downloads	User reviews	Review score
Waste Log Atık Bildir	Private	No information	500+	–	–
KONYA Sıfır Atık	Local government	Konya	10+	–	–
Bucak Sıfır Atık Projesi	Local government	Burdur-Bucak	100+	–	–
Biriktir-Çevreye Hareket Kat!"	Academia	Türkiye	5.000+	106	3.8
Çevreci Komşu Kart	Local government	Antalya	1.000+	31	4.0
GOP Sıfır Atık	Local government	İstanbul-Gaziosmanpaşa	10.000+	111	4.0
Geri Dönüşüm Noktaları	Local government	İstanbul-Büyükçekmece	500+	12	4.3
AtıkNakit	Local government	İstanbul-Başakşehir	1.000+	39	4.2
Dönüştür Kazan	Local government	İstanbul-Beşiktaş	1.000+	21	4.3
Sultangazi Atıkla Katıl	Local government	İstanbul-Sultangazi	1.000+	8	4.9
Ayrıştır Dönüştür Kazandır	Local government	Adana-Seyhan	100+	–	–
Atık Kazanç	Local government	İstanbul-Zeytinburnu	500+	6	2.8
Şehitkamil Sıfır Atık	Local government	Gaziantep-Şehitkamil	10+	–	–
Bahçelievler Sıfır Atık	Local government	İstanbul-Bahçelievler	100+	–	–
Eyüpsultan Atık Nakit	Private	İstanbul-Eyüpsultan	100+	–	–
Çorlu Sıfır Atık	Private	Tekirdağ-Çorlu	100+	6	3.2
Atık Topla	Local government	İstanbul-Beylikdüzü	100+	–	–
myBiyom-Geri Dönüştür, Kazan	Private	No information	100+	15	3.9
Depozito Bilgi Sistemi	Government	Türkiye	1000+	17	3.4

clable contribution by issuing personal QR code tags. The study results displayed that mobile applications encourage recycling rates to 40% and reduce contamination rates below 2%. Also, [16] revealed that the intention to use mobile apps positively affects recycling intention.

Although empirical evidence is still limited, it is safe to state that recycling applications are promising tools for fostering recycling behavior. But how? Understanding the dynamics of recycling applications' role is critical for designing and managing effective applications. For this reason, app functions and their possible outputs need to be investigated. In this context, this research aims to provide an overview of existing recycling applications (hereafter called recycling apps) used in Türkiye that are designed to promote individual recycling. We specifically focus on uncovering these apps' functions and potential roles in removing well-defined barriers to recycling. The research provides a new perspective on the app-behavior relationship since it is the first study in the literature that examines the effects of apps on barriers to recycling. In addition, the study provides useful insights into the effectiveness and limitations of recycling apps in Türkiye and suggestions on how to improve the apps' promoting impact on recycling behavior.

MATERIALS AND METHODS

For research purposes, a content analysis was conducted on recycling apps. PRISMA protocol (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) was employed to review the apps. In the identification stage of the protocol, apps were searched in the largest platform for apps, "Google Play Store," in June 2023 using keywords including "waste," "recycle," "recycling," and "environment." In the screening stage, apps that are not directly related to recycling were eliminated. In the eligibility stage, apps were evaluated considering the inclusion and exclusion criteria specified. Accordingly, apps that are (1) developed for facilitating or promoting individual recycling in Türkiye (2) currently available for free download were included, while (3) recycling games and (4) apps for the recycling industry were excluded. Following the criteria, 25 applications were downloaded, but 6 were excluded from the study because the content and information about the applications could not be accessed. So, 19 apps were included in the scope of the study. All applications were downloaded by the researchers and analyzed in detail to answer the following questions;

- Which functions do apps provide to facilitate or promote individual recycling?
- Which barriers can be removed through the apps?
- What are the prominent problems or limitations of the apps?

FINDINGS

Table 2 provides descriptive information for the 19 apps, user ratings and download statistics. Accordingly, applications are mostly local and designed for citizens living in a specific district of seven cities in Türkiye. Nine recycling

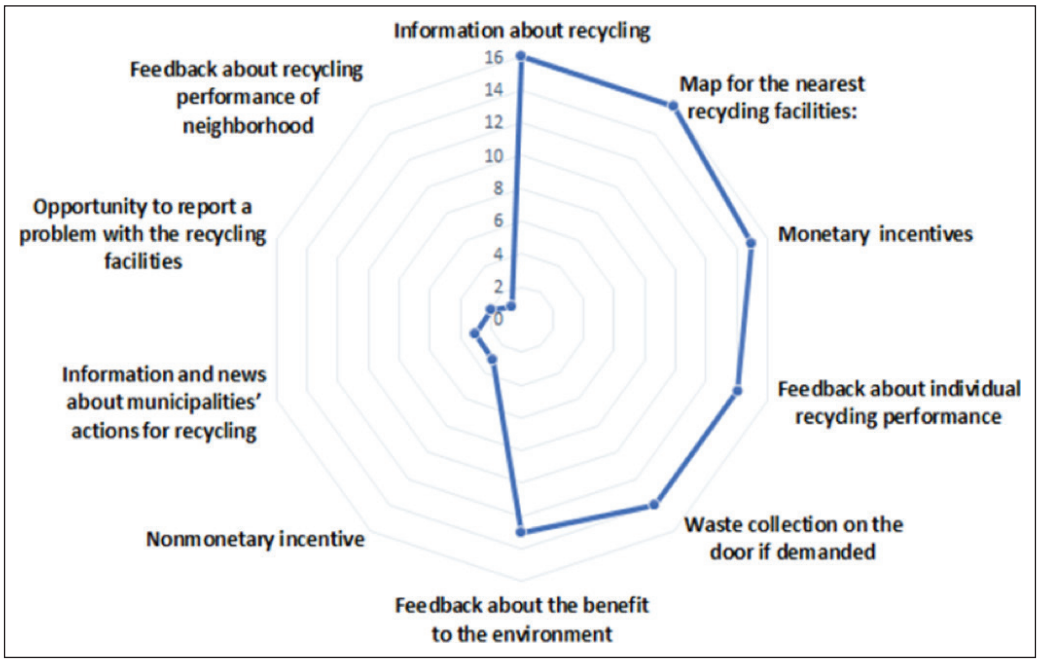

Figure 1. Functions offered by recycling apps.

apps are available for different municipalities of Istanbul, which is the most crowded city in the country, with 18,49% of the population [17]. According to the download statistics, we can generally conclude that applications, except for two, are not yet popular in Türkiye. The "GOP Sıfır Atık" application is the most downloaded, with over 10.000 downloads and 111 reviews. Although GOP is a local application developed for a district of Istanbul, it is remarkable that it has the highest number of downloads. With 5,000+ downloads and 106 reviews, the second most downloaded recycling app is "Biriktir-Çevreye Hareket Kat!" a nationwide app. General low download rates can be attributed to the citizens' low intention to recycle or unawareness of the applications and their functions. Indeed, these applications cover many valuable functions for individual recycling.

The functions offered by the applications to support individual recycling have been examined. It was found that there are ten different functions, and recycling apps cover a combination of those functions. Figure 1 shows how many of the apps offer each function.

Table 3 shows which functions are included in the 19 recycling apps examined. It was observed that 16 apps cover the function of information giving about recycling and maps for the nearest facilities. Besides, 15 apps offer monetary incentives for recycling. 14 of 19 apps give feedback on users' recycling performance and provide an on-demand waste collection on-the-door service. Another prominent function is the function of feedback about the environmental benefits of users' recycling behavior, provided by 14 recycling apps. Nonmonetary incentives, information and news about municipalities' actions for recycling, the opportunity to report a problem with the recycling facilities, and feedback about recycling amount in the neighborhood are rarely covered functions. Examination of barriers to individual recycling and the functions offered by recycling apps revealed that the functions have a great potential to contribute to the removal of barriers. Table 3 also shows which barriers can be entirely removed or alleviated by the reviewed recycling apps.

DISCUSSION

In line with sustainable development goals, it is an essential but very challenging aim to transform individuals' current lifestyles and habits into a more environmentally friendly and sustainable way. Recycling behavior, which is a voluntary action in Türkiye, is one of the high-cost environmental behaviors that are difficult to develop. Many studies in the literature list the barriers to recycling behavior [18–26]. At this point, digital technologies and information systems help achieve challenging goals and enable behavior change [12]. This study provides a review and content analysis of recycling apps used in Türkiye to give a deeper understanding of the apps' potential to remove the well-accepted barriers and encourage recycling. As summarized in Table 3, each recycling app offers a combination of various functions, and those functions have a significant potential for removing specific barriers to individual recycling. Figure 2 shows which barriers are more often subject to removal by recycling apps.

The Role of Apps in Providing Information

One of the functions offered by almost all applications is the information function. Recycling apps provide information about the purpose of recycling, recyclable materials, or deposits for recyclable materials. Indeed, knowledge and information are investigated as critical antecedents of the behavior in the literature since people can not take action if they do not know the problem or how to solve it. Reference [27], in their meta-analysis comprising 63 empirical studies, reports that it is a well-accepted fact that information

Table 3. Functions provided by each mobile app and barriers removed

App name	Recycling app functions to support individual recycling										Which barriers can be removed through the apps?
	Feedback about individual recycling amount	Feedback about recycling amount in the neighborhood	Feedback about environmental benefits	Waste collection on the door if demanded	Monetary incentive	Nonmonetary incentive	Opportunity to report a problem with the recycling facilities	Directions from the map for the nearest recycling facilities	Information about the purpose of recycling recyclable materials	Information and news about municipalities' actions for recycling	
Waste Log Atık Bildir	✓		✓	✓	✓			✓	✓		1,2,3,4,5,6,7,8,9,11,12,13
KONYA Sıfır Atık		✓		✓				✓	✓	✓	1,2,3,4,5,6,8,9,10,14
Bucak Sıfır Atık Projesi							✓	✓	✓		1,2,3,9,10
Biriktir- Çevreye Hareket Kat!"	✓		✓		✓	✓		✓	✓		1,2,3,7,9,11,12,13
Çevreci Komşu Kart				✓	✓					✓	1,2,3,4,5,6,7,8,10
GOP Sıfır Atık	✓		✓	✓	✓			✓	✓		1,2,3,4,5,6,7,8,9,11,12,13
Geri Dönüşüm Noktaları								✓	✓	✓	1,2,3,9,10
AtıkNakit	✓		✓	✓	✓			✓	✓		1,2,3,4,5,6,7,8,9,11,12,13
Dönüştür Kazan	✓		✓	✓	✓			✓	✓		1,2,3,4,5,6,7,8,9,11,12,13
Sultangazi Atıkla Katıl	✓		✓	✓	✓			✓	✓		1,2,3,4,5,6,7,8,9,11,12,13
Ayrıştır Dönüştür Kazandır	✓		✓	✓	✓			✓	✓		1,2,3,4,5,6,7,8,9,11,12,13
Atık Kazanç	✓		✓		✓			✓			1,2,3,7,11,12,13
Şehitkamil Sıfır Atık	✓		✓	✓	✓			✓	✓		1,2,3,4,5,6,7,8,9,11,12,13
Bahçelievler Sıfır Atık	✓		✓	✓	✓			✓	✓		1,2,3,4,5,6,7,8,9,11,12,13
Eyüpsultan Atık Nakit	✓		✓	✓	✓			✓	✓		1,2,3,4,5,6,7,8,9,11,12,13
Çorlu Sıfır Atık	✓		✓	✓	✓			✓	✓		1,2,3,4,5,6,7,8,9,11,12,13
Atık Topla				✓					✓		1,2,3,4,5,6,8,9
myBiyomGeri Dönüştür, Kazan	✓		✓	✓	✓	✓			✓		1,2,3,4,5,6,7,8,9,11,12,13
Depozito Bilgi Sistemi	✓				✓	✓	✓	✓	✓		1,2,3,7,9,10,13

1. Recycling is effortful
2. Recycling takes time
3. Insufficient recycling collection facilities
4. Unsatisfactory collection services
5. Mixed collection and disposal issues
6. Recycle bins are far away.
7. Lack of incentives
8. State municipalities do not support recycling.
9. Lack of knowledge
10. Lack of trust in actors in the recycling process
11. Do not believe in the necessity of individual recycling.
12. Laziness
13. The insignificant amount of recyclable waste
14. Others do not recycle

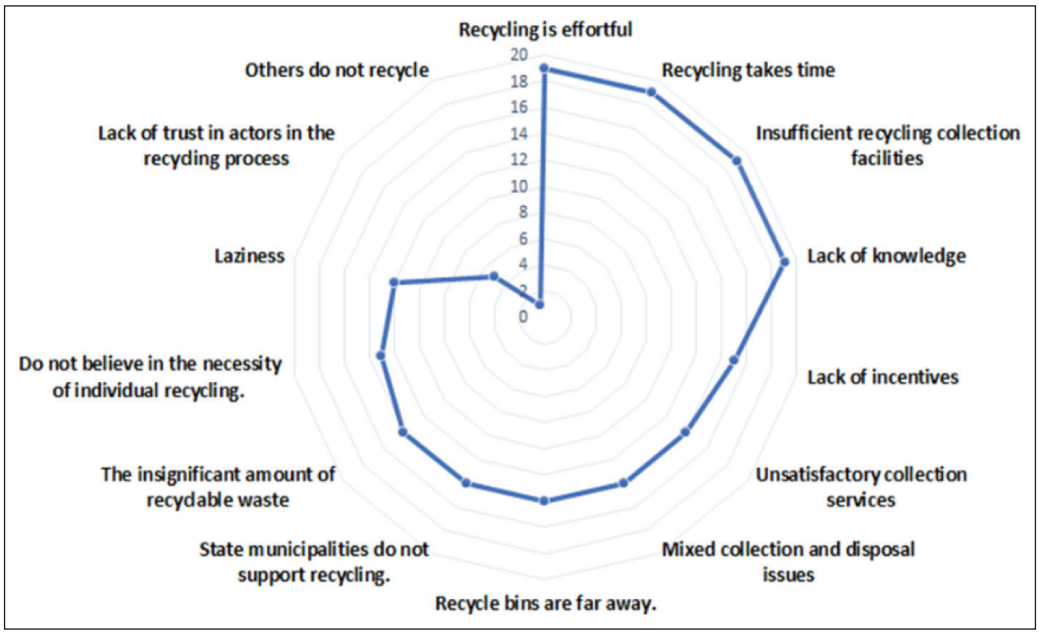

Figure 2. Barriers that can be removed or alleviated by recycling apps.

has a positive and significant correlation with recycling behavior. From the opposite perspective, "lack of knowledge" on what, why, and how to recycle is among the most common barriers to individual recycling in the literature [e.g., 28–30]. Information provided by the apps helps to remove the "lack of knowledge" barrier since users get a deeper understanding of the purpose and positive outputs of individual recycling, identify recyclable materials clearly, and learn how to recycle appropriately. App-provided information is more likely to promote behaviors than conventional communication campaigns since app users are a specific target group already interested in and intent on recycling. However, there is room for functional development for apps through tailoring the information according to the needs of the user. As stated by [31] information tailored according to the characteristics and needs of a specific target group will be more effective in promoting the behavior. However, apps provide generic information for all users. To increase the effectiveness of the recycling apps, they can customize the information provided to users after discovering their primary intentions, beliefs, and needs for recycling. Besides, new ways of information giving can be employed. For instance, an interactive training module customized for specific user segments can be more effective for recycling education. Short video content can also be beneficial in demonstrating visually how recyclable waste should be separated and stored. Furthermore, if videos feature reliable celebrities or opinion leaders, videos not only give information about recycling but also inspiration for recycling.

Some recycling apps also regularly inform users about municipalities' investments, activities, events, waste management, and recycling achievements. In this way, apps may help overcome the barrier of distrust in the recycling actors about the proper collection, care of, and management of recyclables [24, 32]. The removal of this barrier is crucial since the feeling of distrust in recycling actors makes recycling a meaningless action for consumers.

Finally, two applications were found to enable reverse information flow from users to app owners through the reporting function. The function allows users to inform the authorities about the problems in recycling facilities. Although the reporting function is not directly related to the behavior, it may still provide distal support for recycling because contributing to the solution of the problem may increase users' involvement in recycling. More importantly, a quick solution to the reported problem can strengthen participants' trust in the system and alleviate the "lack of trust in actors in the recycling process."

The Role of Apps in Providing Feedback

Providing feedback about individual recycling performance is another function of recycling apps. Users are given statistics about the amount of material they collect for a period. Thanks to this function, users can see that recyclable wastes, even low in quantity, create significant waste when collected after a certain period. So, the function may alleviate the barrier of "the insignificant amount of recyclable waste" [28, 33, 34]. This barrier appears when consumers argue that they produce a minimal amount of recyclables and yields to the belief that recycling is unnecessary. More importantly, feedback about users' recycling performance may promote their perceived behavioral control, which refers to the conviction that they have the ability to recycle their waste. The Theory of Planned Behavior [35] indicates that perceived behavioral control increases recycling both directly and incorrectly. Furthermore, by adding a new function to the apps, users can be given the opportunity to set daily, weekly, or monthly recycling goals; notifications can be sent to encourage users to achieve these goals and give feedback about their final achievement.

Not only the amount of materials collected, but apps also give feedback about the environmental benefits of users' recycling efforts. Through this function, users are informed about how much environmental benefit their recycling efforts achieve. The benefit is usually expressed in statistics indicating the reduction in carbon emissions or carbon footprint. Particular apps also provide statistics regarding saved trees, energy, petrol, raw material, and disposal areas depending on the amount of recycled material. This function will likely remove the "do not believe in the necessity of individual recycling" barrier by providing diagnostic information about the benefits of individual recycling efforts. Besides, the function helps consumers to understand their contribution to saving the environment through their recycling efforts. This feedback may be an internal motivator for users with strong environmental value to sustain their recycling efforts. Even it can have a stronger impact than incentives, as [36] indicated. For this reason, feedback on environmental benefits may also help users overcome their "laziness" and take action.

Besides, a certain app gives feedback about the recycling performance of the neighborhood. This additional function helps users track recycling performance in their area (e.g., their street, neighborhood, and city) from the cumulative amount of material that was collected in the area. This function is promising for overcoming the "others do not recycle" barrier since the user will see how much material others recycle. The belief that "others do not recycle" may hinder the behavior in two ways. First, consumers may worry about feeling shame for being one of the few people in a community who recycle [37]. The function helps to observe others' recycling efforts and normalize recycling as a waste disposal behavior. This feedback shows that a significant number of people are recycling in a neighborhood. In this way, recycling transforms into a mutually agreed action [37], which helps to create subjective norms that the Theory of Planned Behavior considers an essential determinant of behavior [35]. Second, the belief that "others do not recycle" may fuel helplessness, referring to the fact that consumers can not solve a problem alone with individual effort. So, realizing the collaborative effort for recycling through feedback from the app is likely to motivate the users to take future actions. Unfortunately, this function is provided by only one of 19 recycling apps. To overcome the feeling of helplessness and build a social norm, consumers should see how much "others" recycle. So, this function is a must for all applications, especially in Türkiye, where recycling is a behavior that has not yet become widespread.

The Role of Apps in Reducing the Cost of Recycling

Long distance to the recycling bins is a prominent structural barrier often listed in individual recycling research [18, 32, 34, 38–42]. The distance increases the cost of recycling since it will increase the effort, time, and sometimes money that recycling requires. One of the most prominent functions of recycling apps is maps for the nearest recycling facilities. Users can see the location of recycling bins for different materials on these maps. Although app-provided maps can not reduce the distance to the bins, they help users find the nearest facility more easily and minimize search efforts. In this way, apps will at least help reduce the negative impact of the "recycling is effortful" and "recycling takes time" barriers, if not eliminate them entirely. Besides, these maps will help users recognize the number of bins located for recycling and alleviate the perception of "insufficient recycling collection facilities."

To increase the effectiveness of the apps, the map function can be upgraded by expanding the coverage with markets, stores, schools, or other public buildings that provide recycling bins. In this way, the perception of accessibility will increase substantially. Moreover, apps may inform users through notifications when a new recycling point is added to their area. This way, users can take advantage of the new facility and contribute to their community's recycling efforts.

In addition to the provided maps, apps mostly provide an on-door waste collection service. This function has a vast potential to remove critical structural barriers such as distance to recycling bins, insufficient recycling collection facilities, and unsatisfactory collection services. Besides, the function reduces the perception of "recycling is effortful" or "recycling takes time" since users do not have to take recyclable materials to recycle bins. If the owner of the app is the municipality, the function may also alleviate the perception that "municipalities do not support recycling." The function of on-door waste collection appears to be a sure way to motivate the behavior. However, to prevent unintended ecological harms, it will be helpful to remind users that when an on-door waste collection service is used, it increases the use of garbage collection vehicles, which in turn increases road traffic, fuel consumption, air pollution, and emissions.

In addition to the maps and online collection service, a new function can be suggested for recycling apps to reduce the cost of recycling indirectly by helping new starters to get a recycling routine, the lack of which is indicated as a barrier to behavior [34, 43, 44]. Obviously, if consumers do not have a recycling habit, it is not easy to remember their daily tasks. Recycling apps can remind users to act consistently by sending notifications. Moreover, apps may remind users to take recyclables out on waste collection days (if there are any) or deliver waste to recycling facilities. This function may help users engage recycling in their daily routines more quickly as a new waste disposal behavior.

The Role of Apps in Motivating Recycling

Another popular function of recycling apps is providing incentives for recycling. Incentives are some tangible and desirable consequence (e.g., money, privilege) that individuals receive on emitting some observable and verifiable behavior, and they are used all around the world to promote desirable behaviors [45]. Recycling apps use monetary incentives to increase the benefit/cost ratio to make the behavior more profitable for the individual and encourage the behavior [46]. Apps provide monetary incentives by allowing users to earn money, crypto money, gifts, coupons, and discounts

in proportion to the recycling they make. Satisfactory monetary incentives offered by the app can directly remove the barrier of "lack of incentives" and support behavior by decreasing the cost/benefit ratio of the recycling behaviors.

At this point, new kinds of incentives can be suggested to mitigate users' "concerns about waste storage at home," which is a barrier that apps neglect. This barrier reflects concerns that storing recyclable materials at home may cause a mess, clutter, odors, or health problems [18, 28, 47, 48]. Among the incentives provided for recycling performances, it would be beneficial to include recycling-related gifts such as aesthetic recycling bins or bags, allowing easier, neater, and safer storage of recyclable wastes at home.

Apart from monetary incentives, some apps also offer non-monetary incentives that cover the opportunities to donate to various charities in proportion to the amount of recycling. This function removes the "lack of incentives" barriers for the users who are not motivated through monetary incentives. Apps may provide some additional social incentives, such as scoring and reward systems that encourage users to recycle more. Besides, apps may offer social share buttons to allow users to share their recycling and environmental achievements with their friends and followers, which can significantly motivate the users and their social media community. Additionally, app-social media integration enables the organization of recycling-related challenges and events through which users can be encouraged to participate and make a difference in the environment and society.

Problems with Recycling Apps

In general, this research revealed that existing recycling applications provide solutions to the most reported barriers stemming from the effortful and time-consuming nature of recycling, lack of knowledge, dissatisfaction with waste collection services, and lack of incentives, to some extent. However, we must note that these optimistic inferences about the functions' potential are based on the assumption that functions operate effectively and apps are used widely. Functions that cannot steadily meet the users' expectations are likely to hinder the users' trust in the application, the owner of the application, and the recycling systems, which will, in turn, reduce motivation for the behavior. In other words, apps created for barrier removal are likely to be a barrier to the behavior if their functions fail to operate consistently.

Another condition for removing the barriers through apps is that the apps should be accessed and used by a wide range of users. However, recycling apps, which are reasonably local, are limited in number. This finding indicates that millions of potential users living in many regions, cities, or districts in Türkiye have no access to a recycling app. Considering the possible contributions of applications, developing new local applications for individuals living in different regions of the country is critical. Although it is more difficult to process, the widespread use of nationwide applications will provide a similar benefit. At this point, another problem draws attention, which is that the existing apps are not widely used. The most frequently downloaded app has slightly more than ten thousand users. This finding shows that many people, even those interested in recycling, need to be made aware of the apps active in their region. It is critical to inform potential users about applications with communication and promotional campaigns since recycling apps will only be effective if people widely use them.

Moreover, it is critical that an application is easy to use, that individuals perceive it as useful, and that they have a generally positive attitude toward it [14]. However, when the apps' ease of use is examined within the study, it was observed that some applications require lots of very detailed personal information when logging in. This feature of applications is likely to discourage users who are interested in recycling but still need to have a strong motivation to start using the application. For this reason, it will be beneficial to make certain functions available without giving detailed address information in all applications. In this way, users may learn about the benefits of recycling, recyclable materials, the incentive system provided by the application, recycling bins in a certain region, and available door-to-door collection services. In this way, apps can motivate users to start recycling efforts. Finally, the interfaces of some recycling apps are not easily understood, and designs could be more creative and remarkable.

CONCLUSION

This research examines 19 mobile applications (local or nationwide) developed to support recycling behavior in Türkiye. The findings showed that there are ten different functions available in these applications. Although some of them cover different ranges of functions, recycling applications are mainly similar. These applications have great potential to remove the main barriers and increase individual recycling rates. Particularly, apps remove a well-accepted barrier called "lack of knowledge" through the function of providing information about recycling and alleviate the barrier of "lack of trust in actors in the recycling process" by informing users about municipalities' recycling actions. Another popular app function is providing feedback about users' recycling performance that hinders the obstructive belief of "producing an insignificant amount of recyclable waste." Through the function of giving feedback about the environmental benefits of users' recycling efforts, the barriers of "denying the necessity of individual recycling" and "laziness" may be overcome. More importantly, the function of providing feedback about the recycling performance of the neighborhood has enormous potential to dilute the "others do not recycle" barrier, which is found to be demotivating. Furthermore, apps help decrease "recycling costs" by providing maps showing the nearest recycling facilities and enabling collection on the door if demanded. Through these functions, the behavior-impeding beliefs of "recycling is effortful," "recycling takes time," and "recycling collection facilities are insufficient" can be diminished. Finally, apps also have a significant potential

to promote recycling behavior by providing monetary and nonmonetary incentives for emitting recycling. The findings also showed that recycling apps can be improved by adding the aforementioned new functions that will increase the behavioral impact of the apps.

However, recycling apps have a critical problem: Local applications are available in a very limited number of regions in Türkiye. On the other hand, the number of users in the regions where the recycling app is available is very low. To unlock the barrier removal potential of the apps, it is necessary to increase the number of local applications with an easy-to-use design and promote the apps to attract potential users.

The essential prerequisite for the success of these applications, even those that are well-designed and widely used, is that the functions consistently meet the users' expectations. On the contrary, applications will be a new barrier instead of facilitating the behaviors. Future studies are needed that will be conducted in regions where recycling apps are available and will examine the main motivations and challenges in using these apps, users' satisfaction with the functions offered, and the effects of the functions on behavior.

When evaluating research findings and implications, some limitations should be considered. First, this research only focuses on apps available in "The Google Play Store." So, the study did not consider recycling apps that the store does not cover. For this reason, distinct recycling apps that provide different functions may have been overlooked. Besides, the download statistics of the reviewed recycling apps only show the number of downloads in the specified store and may actually be higher. Another limitation is that apps were evaluated based on researchers' short-term experience with applications. For this reason, some specific strengths and/or weaknesses of the apps that appear in the long run may be missed. Studies based on more extended application usage may make more robust conclusions about the advantages and limitations of the applications.

DATA AVAILABILITY STATEMENT

The author confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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