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Geo-Refill Jakarta: Integration of GIS and Smart Mapping for Planning Public Drinking Water Stations as a Strategy to Reduce Single-Use Plastic in DKI Jakarta

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Abstract. Single-use plastic waste from bottled drinking Water contributes to urban environmental pollution. Limited access to public drinking Water refill stations remains a barrier to reducing plastic consumption. This study developed a GIS-based smart mapping system to plan the locations of public drinking Water refill stations to support the Jakarta Zero Plastic program at the urban village level. Secondary data, including administrative boundaries, land use, activity centers, and the coverage of the PAM Jaya Water network, were combined with primary data collected through a questionnaire survey of 103 respondents. Spatial buffering, overlay, and assessment techniques were applied to identify priority zones for the placement of refill stations. The study's findings include a map of recommended refill station locations and an "Adopt-a-Fountain" collaboration model that integrates QR code tracking and digital incentives. This approach provides a spatially adaptive solution to reduce plastic consumption and support sustainable urban development.

Keywords: Refill Station; Smart Mapping; Plastic Waste; Sustainable City; Zero Plastic.

1. Introduction

Pollution caused by single-use plastics, particularly from bottled Water, poses a serious threat to the urban environment in Jakarta. As a metropolitan city with high levels of mobility and public activity, the consumption of bottled Water has become an integral part of daily life, while the limited availability of public drinking Water facilities (refill stations) remains a major barrier preventing residents from adopting a reuse-oriented lifestyle (72% of households) (Kooy & Walter, 2019). Monitoring of land-based waste in the Greater Jakarta (Jabodetabek) region has confirmed that plastic is the dominant type of waste entering Jakarta Bay, accounting for 59% by volume and 37% by weight of the total collected waste, with styrofoam being the most prominent type (Cordova & Nurhati, 2025). Amid growing public awareness of environmental issues, the government and the public need to promote concrete and integrated alternatives to reduce dependence on single-use plastics, one of which is utilizing Geographic Information System (GIS) technology and smart mapping in the strategic and targeted planning of public drinking Water stations.

Based on this background, this study formulates three research questions: how to design an effective GIS- and smart mapping-based planning system for public drinking Water stations in Jakarta; which zones should be prioritized for the construction of public drinking Water stations to support the Zero Plastic program; and how the Geo-Refill implementation model can support changes in public behavior and sustainable urban governance (Panusunan et al., 2025; Wicaksono,

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2021; Widayani, n.d.). Accordingly, this study aims to design a GIS- and smart mapping-based planning system for public drinking Water stations in Jakarta, as well as to identify and map priority zones for the construction of refill stations based on spatial analysis (Kooy & Walter, 2019; Laseldawati, 2015; Science, n.d.-b). Academically, this study enriches the literature on the application of GIS and smart mapping in the planning of sustainable urban public facilities (Kuller et al., 2022; Prasetyo et al., 2018); practically, it serves as a reference for local governments, communities, and the private sector in developing collaborative and data-driven public facility planning (Amras Mauluddin, Rizki Ramdani, Nasrul Alfhy Nurohmatulloh, Lira Serli Selviana, 2026). From a socio-environmental perspective, it raises public awareness of the importance of a reuse-oriented lifestyle and supports Jakarta's vision of becoming a plastic-free city through the promotion of refill systems and community-based reuse practices (2023, n.d.; Indonesia, n.d.; Jobling et al., 2025).

A sustainable city is a concept of urban development that prioritizes a balance between economic, social, and environmental aspects to meet the needs of the current generation without compromising the needs of future generations; therefore, plastic waste management and the provision of environmentally friendly public facilities are an integral part of sustainable development strategies (Rachmawati et al., 2024). The smart city approach leverages information technology to improve the efficiency of public services, residents' comfort, and environmental sustainability; in this context, Geographic Information Systems (GIS) enable the analysis of optimal locations based on population density, activity distribution, and supporting infrastructure (R. Rachmawati, R. A. Ghiffari, A. F. Wijdani, M. Qonita, N. Tania, 2024; Taki & Trisakti, 2022). A study on the spatial equity of public facilities in the Greater Jakarta area using Moran's I spatial autocorrelation index indicates that many densely populated zones still suffer from inadequate facility provision(Panusunan et al., 2025; Ramadhanis et al., 2025). Consumption behavior in urban areas is also heavily influenced by ease of access to facilities; limited availability of public drinking Water drives people to choose instant solutions such as purchasing bottled Water, in line with Environmental Behavior Theory and Theory of Planned Behavior (TPB), which state that facility accessibility and perceptions of behavioral control significantly influence people's consumption preferences (Handayani et al., 2025; Tri et al., 2025).

The selection of locations for public facilities such as charging stations must take five key criteria into account. First, population density, as public facilities tend to be concentrated in densely populated areas with a larger potential user base and higher cost efficiency per unit of service. Second, proximity to public facilities such as parks, schools, transportation terminals, and markets, as locating these facilities in bustling areas can significantly reduce travel distances for users. Third, pedestrian routes, in line with the concept of walkability, which emphasizes that convenient access for pedestrians will increase the utilization of public facilities. Fourth, the service coverage area of PAM Jaya to ensure a reliable supply of clean Water. Fifth, plastic waste generation, as areas with high waste generation require immediate intervention to reduce reliance on single-use packaging. These five criteria are combined objectively and measurably to determine the priority for refilling station placement. Previous applications of GIS to map the distribution of drinking Water facilities and determine the shortest routes to public facilities further demonstrate the practicality of spatial analysis in optimizing the location of public services (Fasilitas et al., 2026; Informasi et al., 2023).

From a policy perspective, the DKI Jakarta Provincial Government has issued Governor Regulation No. 142 of 2019 on the mandatory use of eco-friendly shopping bags. However, it focuses on plastic bags; the spirit of reducing single-use plastics aligns with efforts to provide drinking Water refill stations(Kurnia & Akram, 2023). The National Geospatial Information Agency (BIG) also

promotes the use of spatial data in regional and urban planning to support inclusive and efficient development. Previous research also serves as an important foundation: a WebGIS-based system has been successfully developed to map the distribution of public facilities and improve public access to location-based information (ICHSAN, 2023); the application of an expanded Theory of Planned Behavior has identified attitudes and perceptions of behavioral control as significant predictors of the intention to reduce single-use plastics (Cordova & Nurhati, 2025; Haryanto & Environ, n.d.; Tri et al., 2025); while an assessment of spatial equity in the Greater Jakarta area highlights the need for more targeted placement of facilities in densely populated zones that lack such facilities (Science, n.d.-a). Based on these theories, policies, and previous research, this study developed Geo-Refill, a GIS-based and smart mapping approach for planning public drinking Water collection sites, equipped with real-time QR code monitoring, a digital points system, and a collaborative dashboard, as well as the "Adopt-a- -Fountain" scheme that adapts the "Adopt-a-Park" principle to encourage collaboration between the government, the private sector, and the community in the sustainable management of public drinking Water access points.

2. Method

This study employs a quantitative descriptive approach combined with Geographic Information System (GIS)-based spatial analysis to formulate a spatial planning framework for public drinking Water refill stations to support the "Zero Plastic City" initiative in Jakarta. The analysis was conducted at the urban village level throughout the Special Capital Region of Jakarta, using spatial units as the basis for identifying areas with the highest potential demand and accessibility to public refill stations.

Primary data were collected through an online questionnaire administered from January to March 2026 using purposive sampling. Respondents were required to reside in the Special Capital Region of Jakarta, be at least 17 years old, and have internet access. A total of 103 valid responses were obtained. The questionnaire consisted of four components: (1) demographic characteristics, (2) drinking Water consumption patterns, (3) environmental awareness and attitudes toward the Zero Plastic program, and (4) preferences regarding the design and spatial location of refill stations. Most questionnaire items were measured using a five-point Likert scale. The collected data were analyzed descriptively using frequency distributions and percentages in Microsoft Excel to identify respondent characteristics, behavioral patterns, and community preferences.

Secondary data were obtained from government sources and relevant agencies. These data include administrative boundary data from the Jakarta Capital Region Development Planning Agency (BAPPEDA), PAM Jaya Water distribution network data, land-use and activity center shapefiles from the National Geospatial Information Agency (BIG), population density data from the Jakarta Capital Region Statistics Agency (BPS), and plastic waste production data from the Jakarta Capital Region Environmental Agency (DLH). This dataset was standardized to a common spatial reference system prior to spatial analysis.

GIS-based spatial analysis was conducted using ArcMap 10.8. Priority locations for public drinking Water stations were identified through a three-stage analysis. First, a buffer analysis was applied to delineate potential service areas, including a 300-meter service radius around selected high-activity locations. Second, a spatial overlay analysis was conducted by integrating data on population density, PAM Jaya network coverage, land use, activity centers, and plastic waste generation. Third, the resulting spatial indicators were scored and weighted to determine relative priority levels and to generate a spatial priority zoning map for the development of public drinking Water refill stations.

The spatial analysis was then integrated with the questionnaire findings to formulate the Geo-Refill conceptual model. This model comprises five complementary components: smart spatial planning, QR code-based monitoring, digital incentive mechanisms (Refill Points), and the "Adopt-a-Fountain" co-governance scheme. This integration is intended to ensure that the proposed system not only responds to spatial and infrastructure conditions but also to community preferences and behavioral considerations.

Several limitations must be acknowledged. These include the relatively limited number of questionnaire respondents, potential variations in socio-infrastructural conditions across subdistricts, and limited access to real-time PAM Jaya network data, which may affect the accuracy of the spatial prioritization results.

3. Result

The study area is located in the Special Capital Region of Jakarta, which is divided into five administrative cities (Central, West, South, East, and North Jakarta) and one administrative regency, the Thousand Islands. The land area of DKI Jakarta spans approximately 661.5 km², with a population exceeding 10 million and an average density of over 15,000 people per km², concentrated in densely populated residential areas. The relatively flat topography (0–50 meters above sea level) and the presence of 13 major rivers make parts of the region prone to waterlogging and flooding, while the dominance of residential, commercial, and transportation land limits the availability of green open spaces.

The results of a questionnaire administered to 103 respondents showed that 40.2% of the public still purchase bottled drinking Water 1–2 times per week. In contrast, 62.7% are aware of or have used a refill station, and the same proportion expressed a willingness to use one in the future. A total of 72.5% of respondents believe that bottled Water contributes significantly to urban pollution, and support for the "Zero Plastic Jakarta" program reached 100%. Regarding service quality, 38.2% of respondents are willing to use refill stations as long as the Water provided is clean and safe to drink, while 31.4% emphasized the importance of equipment hygiene. These findings indicate significant potential for public acceptance of refill stations, particularly when accompanied by guarantees of cleanliness and policy support for plastic reduction.

Spatial data processing was conducted through preprocessing, classification, and scoring, followed by a weight-based multi-criteria analysis of five parameters: population density, proximity to public facilities, pedestrian paths, PAM Jaya service areas, and plastic waste generation. Population density is very high in parts of Central, South, and East Jakarta, while coastal and outlying areas are relatively less densely populated (Figure 1).

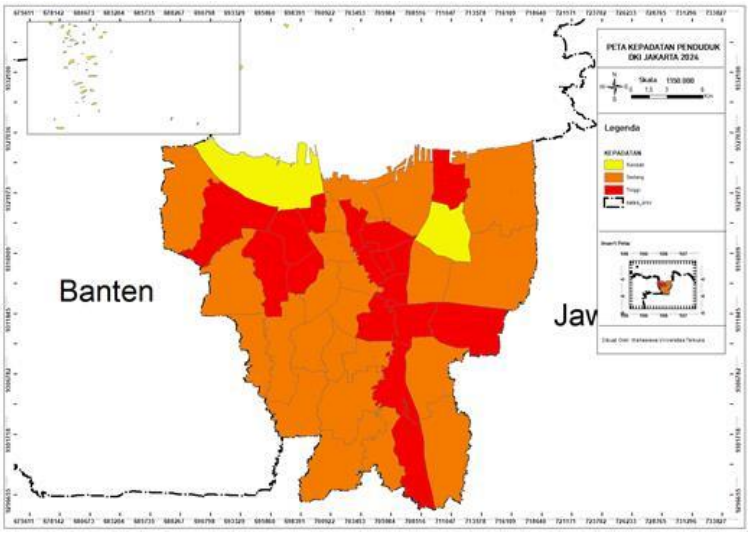


Figure 1. Population Density Map
Source: DKI Jakarta Provincial Statistics Agency, 2025

Public facilities such as bus stops, train stations, and terminals are concentrated in city centers and along major corridors, making it easier to locate refill stations due to their proximity to passenger traffic; conversely, outlying areas with a sparser distribution of facilities require specific strategies to ensure they remain accessible. The PAM Jaya service network also shows a similar pattern, with full coverage concentrated along major corridors, while outlying areas generally lie outside the coverage of the main pipeline network (Figure 2).

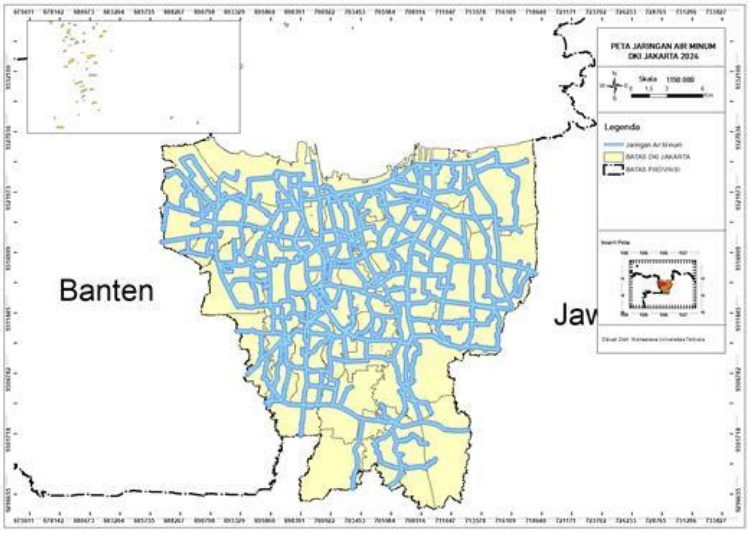


Figure 2. Map of the PAM Jaya Drinking Water Network

The results of the Multi-Criteria Decision Analysis (MCDA) applied to these five parameters yielded three priority zones for the placement of refill stations, as shown in Table 1.

Tabel 1. Multi-Criteria Decision Analysis (MCDA)

Priority Zone	Area (ha)	Persentase (%)
High	1.394,61	2,33%
Medium	29.116,02	48,61%
Low	37.479,21	49,06%
Total	67.989,84	100%

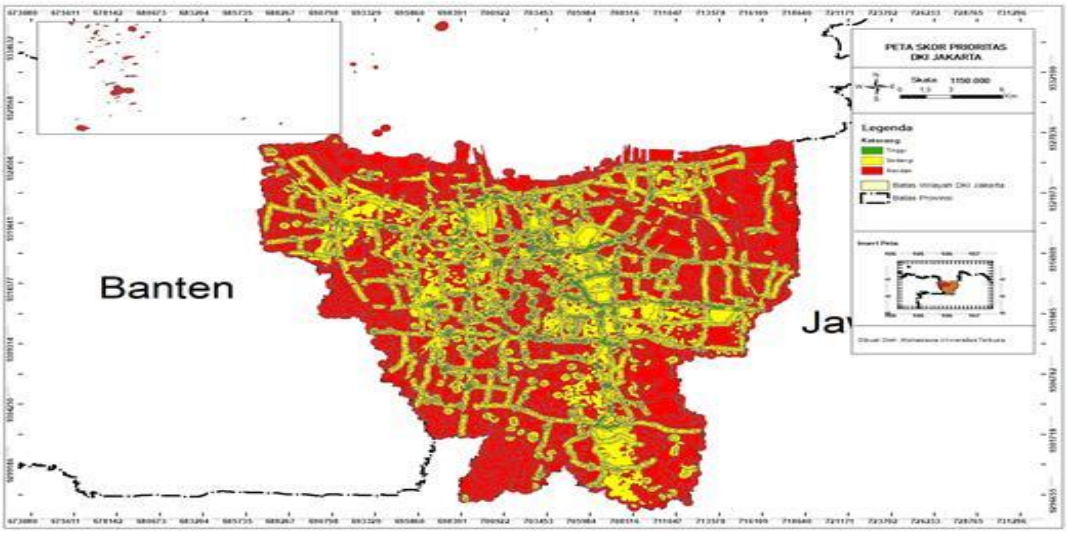


Figure 3. Priority Score Map

High-priority zones account for only 2.33% of the total area. They are scattered across several locations, primarily around the city center, while most of Jakarta falls into the medium- to low-priority categories. An overlay of the priority zones and existing refill stations using a spatial join shows that only 15.46% of the high-priority zone area is covered by existing refill stations. In contrast, the medium- and low-priority zones are covered by only 2.05% and 0.07%, respectively. These findings confirm a significant gap between demand (high-priority zones) and the availability of existing services.

Based on this gap, high-priority zones that do not yet have refill facilities were identified using the "feature-to-point" technique to generate coordinates for new potential locations, spread across various subdistricts such as Cakung, Cempaka Putih, and Cengkareng (Figure 3). Spatially, the concentration of recommended locations appears denser in central and southern Jakarta. At the same time, in the eastern, northern, and western areas, their distribution is sparser, consistent with the patterns of population density and public activity described earlier.

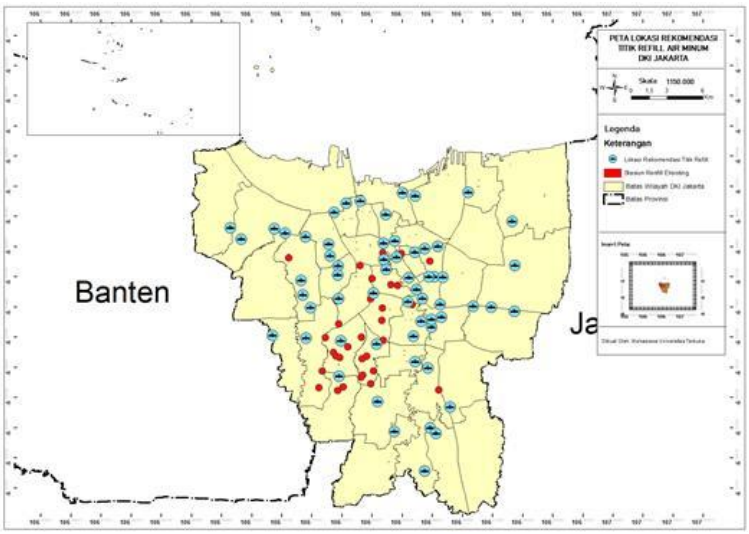


Figure 4. Map of Recommended Locations for New Drinking Water Refill Stations

Based on the results of spatial analysis and questionnaires, this study proposes the Geo-Refill model as a prototype for planning public drinking Water stations that integrates GIS-based smart spatial planning, QR code mapping with real-time status updates, a digital incentive system (Refill Points System), and a crowdsourcing-based participatory dashboard. This model incorporates an

"Adopt-a-Fountain" collaboration scheme that adapts the "Adopt-a-Park" principle, in which the government, the private sector, and the community share responsibility for the operation, maintenance, and behavioral incentives for users of public drinking Water stations. However, because the spatial and social characteristics, as well as the infrastructure capacity, of each subdistrict in Jakarta vary greatly, the implementation of Geo-Refill cannot be carried out in a one-size-fits-all manner and requires local adaptation; therefore, strengthening multi-stakeholder collaboration and ensuring the flexibility of spatial technology-based systems are key to the success of its implementation.

4. Discussion

The findings of this study confirm that the gap between the public's willingness to reduce single-use plastic consumption and the availability of physical infrastructure remains a major barrier to sustainable Water consumption behavior in Jakarta. Although 100% of respondents support the Jakarta Zero Plastic program and 62.7% expressed a willingness to use refill stations, currently only 15.46% of high-priority zones are served by existing facilities. This imbalance between behavioral intent and infrastructure provision empirically supports Environmental Behavior Theory, which states that pro-environmental intent alone is insufficient to change consumption habits unless accompanied by easily accessible, barrier-free alternatives. In other words, the continued purchase of bottled Water among 40.2% of respondents despite their high environmental awareness should not be viewed as a behavioral failure, but rather as a structural failure and an infrastructure deficit, not an attitude deficit.

The results of the spatial analysis reinforce this interpretation. High-priority zones account for only 2.33% of Jakarta's total area. However, they are concentrated in the city center; the distribution patterns of public facilities and the coverage of the PAM Jaya Water network overlap very strongly. This pattern aligns with the findings of Santosa and Wijaya (2021), which show that the buffer and overlay methods are effective in identifying optimal facility locations in densely populated urban environments; this study expands on those findings by integrating a fifth criterion—plastic waste production which directly links facility placement to environmental impacts, rather than merely service efficiency. Compared to a study by Shi, Zhang, and Yang (2020) on the distribution of public facilities in densely populated Shanghai, the case of Jakarta reveals a more pronounced center-periphery disparity, likely due to the uneven expansion of the PAM Jaya pipeline network into outlying subdistricts such as North Jakarta and East Jakarta. Similar disparities between the center and the periphery have also been reported in other Asian cities undergoing rapid urbanization. For example, a GIS-based multi-criteria analysis of public service facilities in Seoul revealed a significant lack of services in outlying districts despite their high population density (Chae et al., 2021)Water and sanitation facilities are heavily concentrated in the city center, resulting in very low coverage in outlying areas (Peungnumsai et al., 2020). This international comparison confirms that spatial inequality in Jakarta is not unique. However, the situation is particularly difficult due to a combination of high plastic waste production and uneven piped Water coverage.

In addition to reinforcing existing theories of spatial planning, this study contributes two unique aspects. First, this study operationalizes facility planning not merely as a matter of site selection, but as a matter of behavioral change infrastructure, by integrating digital incentive mechanisms (Refill Points) and real-time QR code monitoring directly into the spatial model. This elevates GIS outputs beyond static priority maps toward actionable and trackable interventions, addressing the limitations noted in the Bandung-based crowdsourcing platform developed by Hidayat, Pratama, and Wulandari, which mapped facilities but lacked a behavioral incentive layer.

Second, the "Adopt-a-Fountain" scheme views the provision of refill stations as a co-governance model rather than a model funded entirely by the government by adapting the "Adopt-a-Park" logic to a resource (drinking Water) that has direct implications for public health. This represents an innovative governance approach that is applicable and has not been previously mentioned in the reviewed literature.

Theoretically, these findings expand the discourse on smart cities by demonstrating that GIS-based optimization is indeed necessary but not sufficient: without aligned behavioral and governance mechanisms, even well-targeted infrastructure risks low utilization rates. Practically, the results of this study suggest that the DKI Jakarta Government treat urban villages with high priority but low coverage (e.g., Cakung, Cempaka Putih, Cengkareng) as pilot sites, while noting that Duren Sawit, Cengkareng, and Cakung also showed the strongest demand based on respondent feedback—indicating an alignment between spatial urgency and community readiness that can be leveraged to mitigate implementation risks in the early stages.

Nevertheless, the model's generalizability is limited by significant social and infrastructural heterogeneity across Jakarta's sub-districts, as reflected in the wide disparity between the coverage rates of medium- and low-priority zones (2.05% and 0.07%, respectively). This reinforces the need for a spatially adaptive rather than uniform governance framework and suggests that future implementation should be carried out gradually, monitored, and tailored to each sub-district, rather than rolled out as a single citywide policy.

5. Conclusion

This study successfully designed a GIS- and smart mapping-based planning model for public drinking Water stations as an innovative solution to support the Jakarta Zero Plastic program. The Geo-Refill model is not only based on a spatial approach but also integrates community participation, digital technology, and multi-stakeholder collaboration through the Adopt-a-Fountain scheme. A multi-criteria analysis identified high-priority zones that are currently only 15.46% covered by existing refill stations, with recommendations for new stations spread across various subdistricts such as Cakung, Cempaka Putih, and Cengkareng. At the same time, questionnaire results indicate that the subdistricts of Duren Sawit, Cengkareng, and Cakung, where respondents primarily reside or conduct their activities, have the potential to serve as initial pilot sites with high levels of community participation.

The implementation of Geo-Refill is context-specific and requires local adaptation based on the social characteristics and infrastructure readiness of each subdistrict; therefore, cross-sectoral collaboration among the government, communities, and the private sector, as well as integration into official local policies, are key to the program's sustainability. Local governments are advised to adopt Geo-Refill as part of their plastic reduction policies and integrate it into municipal services such as JAKI, designate subdistricts with high readiness as pilot project sites with periodic monitoring, and actively involve the private sector and local communities in the Adopt-a-Fountain program. Further development can be achieved through piloting a digital incentive system, conducting further research on the impact of changes in public behavior, and adaptively expanding the program to other regions while taking into account the specific spatial and social conditions of each area.

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