# Using Geospatial Intelligence to Enhance Voting Access in Local Elections for People with Disabilities

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**Abstract**

Ensuring accessible elections for people with disabilities remains a significant challenge in democratic systems worldwide. This study leverages geospatial intelligence to enhance voting accessibility by developing an algorithmic approach that helps individuals locate the nearest Accessible Polling Station (APS). Implemented during recent local elections in Israel, the system integrates Voronoi-based spatial partitioning, statistical analysis, and real-time geolocation processing to optimize APS assignment and minimize voter travel distances. A total of 2,658 individuals used the interface, with 84.4% of surveyed users expressing satisfaction, highlighting its effectiveness in reducing accessibility barriers. The spatial distribution of APSs and voters revealed that most users were from central Israel, with an average voter-to-APS distance of 794 meters, varying by region: 660±1,537 meters in the north, 539±1,909 meters in the center, and 2,245±8,442 meters in the south. Additionally, 735 areas (71%) had an average voter-to-APS distance of less than 500 meters, suggesting widespread accessibility. However, regional disparities persist, particularly in southern Israel, where the desert landscape and low population density limit APS availability. In Israel's largest cities, most areas show a strong spatial association between voters and nearby APS locations. However, some areas in these cities exhibit localized accessibility gaps, indicating potential barriers to equitable voting access. The findings of this study underscore the critical role of geospatial intelligence in identifying spatial disparities and improving electoral accessibility for people with disabilities.

## 1. Introduction

The notion of an inclusive city is a cornerstone of modern urban planning, aiming to create equitable environments that ensure access and opportunities for all individuals, regardless of socio-economic status, gender, age, disability, ethnicity, or other defining characteristics. As cities worldwide seek to adopt sustainable and equitable practices, the principles of inclusivity are increasingly embedded in urban policies and development strategies.

The key components of an inclusive city ensure equitable access, participation, and opportunities for all residents. Accessible infrastructure supports mobility for all, particularly individuals with disabilities (Liang et al., 2021; Rebernik et al., 2019). Participation and Representation ensure diverse voices shape urban policies (Fricano, 2008). Economic opportunities promote fair employment and financial inclusion (Liu et al., 2020). Social cohesion fosters a sense of belonging and community engagement. Sustainable development integrates resilience and inclusivity for long-term urban growth (Duconseille and Saner, 2020). Equitable access to services guarantees essential resources like healthcare, education, and public amenities (Mirzoev et al., 2021). Our focus is on improving access to services by assisting individuals with disabilities in locating the nearest Accessible Polling Station (APS) and providing navigation support through an adapted web interface, thereby enhancing electoral participation and accessibility.

People with disabilities face significant barriers to voting, leading to lower turnout compared to individuals without disabilities. These barriers include physical challenges, such as inaccessible polling places lacking ramps and audio-equipped voting machines (Schur et al., 2017), as well as privacy concerns that discourage participation (DuHaime and Cohen, 2022). Informational barriers further restrict engagement, as election materials are often unavailable in accessible formats such as large print, Braille, or audio (Teglbjærg et al., 2022). Procedural obstacles, including complex voter registration requirements (Johnson and Powell, 2020) and limited voting methods (Matsubayashi and Ueda, 2014), can also disenfranchise individuals with disabilities, as traditional voting systems do not always accommodate their needs. Psychological and social factors, such as the persistent inaccessibility of the voting process and the perception of reduced political influence, further contribute to lower participation rates (DuHaime and Cohen, 2022; Schur et al., 2017).

Improving voting access for people with disabilities requires a multifaceted approach that addresses physical, informational, and procedural barriers. Ensuring polling place accessibility by complying with governmental disability rights laws, providing accessible voting machines, and training election officials helps reduce barriers and improve the voting experience for individuals with disabilities (Schur et al., 2015). Alternative voting methods, such as no-excuse mail ballots and permanent absentee voting, allow individuals to vote without physically accessing polling places, increasing participation among those with mobility limitations. Convenience voting reforms, including same-day and election-day registration, further reduce administrative burdens, while all-mail elections have been shown to narrow the turnout gap between disabled and non-disabled voters (Kuhlmann and Lewis, 2024; Miller and Powell, 2016). Providing accessible election information in formats such as large print, Braille, tactile writing, and audio-based systems ensures individuals with visual or cognitive impairments can make informed voting decisions (Teglbjærg et al., 2022). Additionally, tailored support for specific disabilities, including voter assistance programs, localized polling stations, and disability-friendly regulations, enhances the voting experience for individuals with mental and intellectual disabilities (Annisa et al., n.d.). Implementing these strategies is essential to fostering an inclusive electoral process where all citizens, regardless of ability, can fully exercise their right to vote.

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A practical initiative based on this concept was implemented during the recent local elections in Israel through a collaboration between the "Access Israel" organization[1], the Ministry of the Interior, the Technion - Israel Institute of Technology, and Ariel University. The primary goal was to increase voter turnout among people with disabilities by identifying the nearest APS and providing optimized route guidance. In addition to improving accessibility, we gather, through the interface and a user survey, the shared voter locations, matched APS assignments, and demographic and election behavior data. This data was used to evaluate the service's impact on voting behavior and to analyze the distribution of travel distances to APSs across different regions in Israel, by using geospatial intelligence.

Geospatial intelligence plays a crucial role in modern election analysis, offering powerful tools to assess voting accessibility, identify spatial disparities, and enhance the accuracy of electoral data. Geospatial intelligence enhances the visualization of election results, improving transparency for both the public and officials (Salubre et al., 2022). It also increases the accuracy of geographic election data through techniques like toponym disambiguation, ensuring precise mapping of polling locations (Hu et al., 2023). Advanced methods, such as persistent homology, analyzing complex voting behaviors and spatial relationships, particularly in densely populated areas (Feng and Porter, 2021). Geospatial data further reveals how proximity to significant events, such as pre-election police killings, affects voter turnout, with studies showing declines of up to 5.9 percentage points among Black voters (Markarian, 2023). Additionally, geospatial analysis of cell-phone mobility data helps assess how polling station distance influences turnout, reinforcing the role of travel costs in voting decisions (Harada et al., 2024). In this study, we demonstrate how geospatial intelligence is leveraged to develop the algorithm behind our service and how geospatial analysis facilitates the monitoring of disparities in voting accessibility.

## 2. Methodology

The Implementation Stages included: Preprocessing Stage and Real-Time Processing Stage.

### 2.1 Preprocessing Stage

This study's dataset includes polling station information from the Ministry of the Interior, divided into city-based and regional council-based locations. Our raw data consisted of two Excel files provided by the Ministry of the Interior (Gov.il, 2024), containing information on all polling stations in Israel. The first file includes polling stations for each city, where citizens are restricted to voting at the station assigned to their city of residence. The second file lists polling stations located in regional councils, which may serve one or more towns or villages under the same jurisdiction, allowing citizens to vote either in their hometown or at another APS within the same regional council. Both files include details such as the polling station's address, location type (e.g., school or public building), and accessibility status. Additionally, the second file specifies the regional council's name, and for some polling stations, both files provide geographical coordinates. Where geographical coordinates were not available, we utilized ArcGIS geocoding to generate the missing location data based on the polling stations' given addresses (ArcGIS, 2024). Furthermore, all non-accessible polling stations were filtered out to ensure the dataset focuses exclusively on accessible voting locations. The subsequent steps were designed to enhance the accuracy and efficiency of real-time data processing.

To ensure accurate real-time processing of voter locations, a standardized approach was applied to APS data, ensuring consistency with voter inputs regardless of formatting or language variations. First, all place names (cities, towns, and villages) in the raw data were cleaned by removing special characters such as quotation marks and hyphens. Second, since all voter-entered addresses in real-time processing are processed through the Google Maps Geocoding service, which returns geographic coordinates and a standardized English place name—while correcting typos, handling alternative names, and supporting multiple languages—APS data was aligned using the Google Maps Reverse Geocoding service (Google, 2024). This ensures that each APS is assigned a consistent English place name, as recorded in Google's database. This process enables seamless matching between voter-inputted locations and APSs, eliminating language and formatting inconsistencies.

To optimize the efficiency of APS assignment, we implemented a structured spatial approach that minimizes search time. To ensure fast processing when a voter submits their address, the algorithm must efficiently determine the nearest APS. Instead of performing a brute-force search across all APSs, we utilize a Voronoi diagram, a spatial partitioning method that divides the plane into regions based on proximity to a given set of points—in this case, APS locations. Each Voronoi cell contains all locations closer to a specific APS than to any other, significantly reducing search time. Then, we use a *spatial join* in GeoPandas package in Python, which leverages R-tree indexing to quickly locate the Voronoi polygon containing the voter's location (Geopandas.org, 2024). The Voronoi polygons were generated using the GeoVoronoi package in Python (Konrad et al., 2022).

The inclusion of both city-based and regional council-based polling stations in the voting system introduces additional complexity. To address this, a dictionary was created from the raw dataset, mapping each location either to itself (in the case of cities) or to its corresponding regional council. To streamline the process further, each place in the dictionary was assigned a value based on the number of associated APSs. places with a value of 1 represent cases where only one APS exists, requiring no further search. Places with a value of 2 indicate two APSs, enabling a direct distance comparison without the need for Voronoi analysis. Places with a value of 3 signify more than APSs, necessitating a Voronoi-based approach to identify the nearest one.

Then, Voronoi polygons were generated for each city or regional council based on the APSs, as illustrated in Figure 1. For locations without an assigned APS, a nationwide Voronoi dataset was created to first determine the appropriate place and subsequently identify the nearest APS. The final database consisted of Voronoi polygons, APS data, and the place dictionary. In addition, Python code for location identification (Cohen, 2024) was developed and deployed on a Vercel server, enabling real-time processing[2]. This structured approach enhances both the accuracy and efficiency of the system while addressing the inherent complexities of the voting framework.

[1] https://aisrael.org/en/

[2] The server, available at https://vercel.com/achituvs-projects/kalpi-server , is not publicly accessible

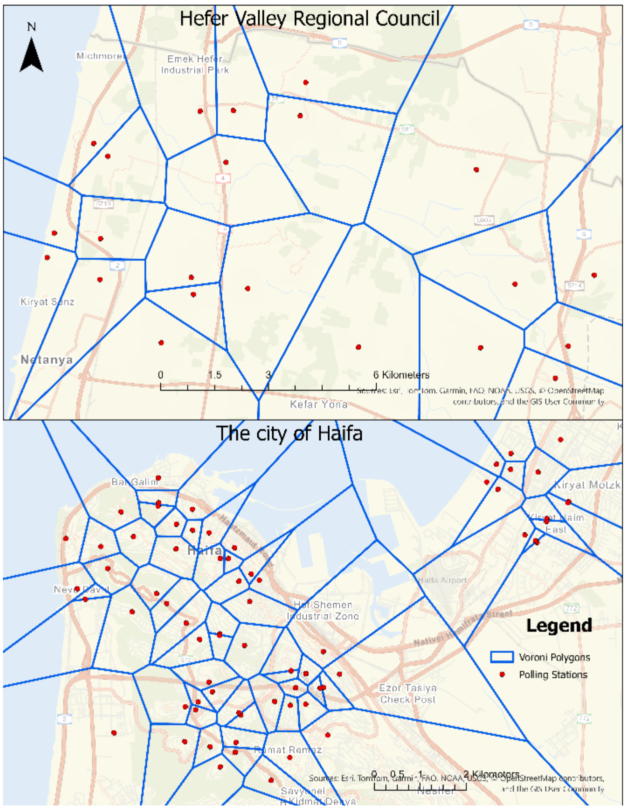


*Figure 1. Two examples of Voronoi polygons generated from APS locations – Hefer valley regional council (top) and the city of Haifa (bottom)*

### 2.2 Real-Time Processing Stage

The real-time processing stage is fully detailed in the flowchart in Figure 2. The process begins when the voter submits a location via the web interface, which is then transmitted to the Vercel server for processing. The system first parses the input string, extracting the address and verifying whether the location exists in the place dictionary.

If the location exists in the dictionary - If the place is assigned a value of 1, the system immediately returns the only APS associated with that place. Otherwise, the system sends the address to Google's geolocation services to retrieve its coordinates. It then re-evaluates the value, and if it is 2, indicating that only two APSs are associated with this location, the system selects the nearest APS based on the voter's location. If the value is 3, indicating that many APSs are associated with this location, the system retrieves all relevant Voronoi polygons associated with the place and selects the polygon containing the voter's location, returning the corresponding APS.

If the location is not found in the place dictionary - The system uses the nationwide Voronoi dataset to determine the place before proceeding with the APS selection process as described above. Finally, the web interface allows voters to open the APS location in external applications, such as Google Maps or Waze (Waze, 2024), to get navigation directions from their entered address to the nearest APS.

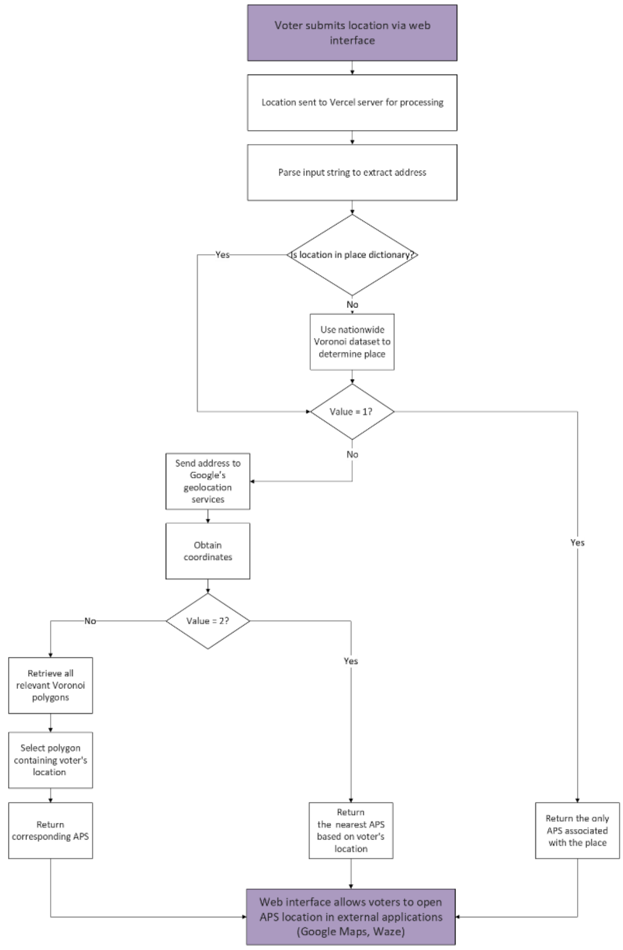


*Figure 2. Flowchart of Voter Location Processing and Assignment to nearest APS.*

## 3. Results

The developed interface was successfully integrated into the Ministry of the Interior's election website prior to Election Day and was supported by an extensive marketing campaign to enhance user engagement[3]. Out of 3,419 polling stations distributed across Israel, 2,389 (70%) were accessible. The majority of these APSs (62%) were located in central Israel, with the remainder in the periphery - 21% in the north and 17% in the south (Figure 3b).

The survey provided valuable insights into voter demographics, spatial distribution, and accessibility patterns, highlighting regional variations and user satisfaction with the service. A total of 2,658 individuals utilized the interface, with 72 voters (3%) agreeing to complete the survey offered after using the service. Based on survey results, the largest demographic group using the service (38.2%) was aged 66 and older, followed by individuals aged 26-50 (36.2%), and those aged 51-65 (23.5%). Regarding gender, 51.5% identified as female, and 48.5% as male. Additionally, 63.2% of users reported having an academic degree. Most users (86.2%) resided in cities, and 76.5% of those who utilized the service identified as having a physical disability. Regarding transportation plans, 39.7% intended to arrive by wheelchair or mobility scooter, 29.4% by walking, and 20.6% by car. In terms of voting behavior, 52.9% of respondents stated they planned to vote regardless of the service, while 36.8% decided to

[3] https://kalpi.aisrael.org - The website was deactivated following Election Day.

vote because they discovered an accessible APS was closer than they initially thought. Conversely, 10.3% decided not to vote after learning the accessible APS was farther than expected. Overall, 84.4% of users expressed satisfaction with the service, highlighting its effectiveness in addressing accessibility challenges.

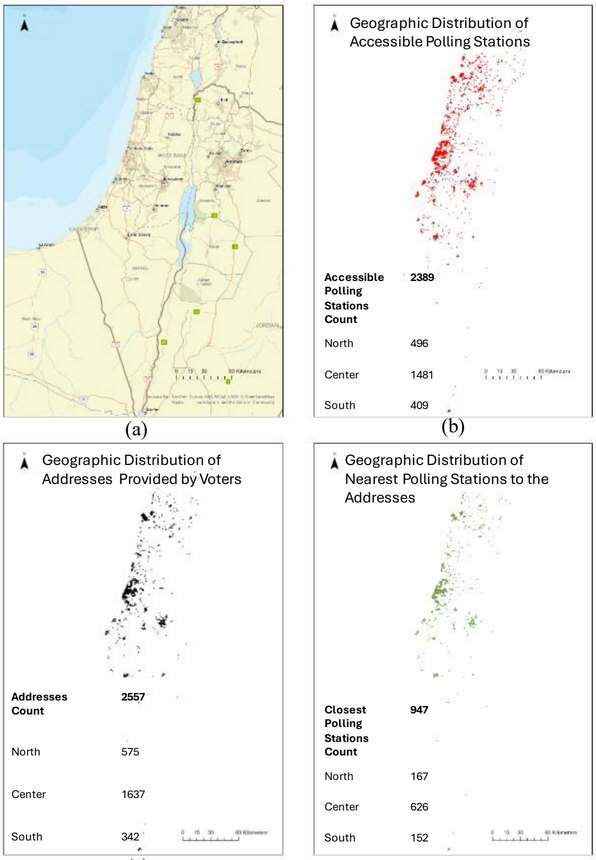


*Figure 3.(a) map of Israel (b) geographic distribution of all APSs, (c) the voters using the service, (d) and their nearest APS across regions (North, Center, South) in Israel.*

### 3.1 Spatial Distribution of Voters and Accessible Polling Stations

Reflecting the distribution of APSs and voters, most of them are from the center of Israel, followed by the north and then the south. Among the voters, we successfully extracted addresses from 2,557 individuals. Based on their locations, 64% came from the center, 22% were from the north, 13% from the south (Figure 3c). From the pairing of user addresses with the nearest APSs, the algorithm matched 947 different APSs, with 66% in the center, 18% in the north, and 16% in the south (Figure 3d).

The analysis of APS usage revealed significant variations in how frequently each APS was identified as the nearest one, highlighting regional patterns that may be influenced by population density, demographics, and technological accessibility (Figure 4). The most frequently selected APS, located in central Tel Aviv, was matched to 38 addresses. Analyzing this area reveals that all APSs were selected at least once as the nearest APS, and in most cases, multiple times. Additionally, this area includes a high number of voters using our service, which aligns with its high population density. Moreover, central Tel Aviv is known for its relatively young population, which may contribute to a higher proportion of young individuals with impairments utilizing the service. Approximately 18% of residents in this area are between the ages of 20 and 30, compared to the national average of 13%. The area's technological advancement may also contribute to higher engagement with digital services for voting accessibility. Following this, an APS in Haifa was matched 37 times, and another in southern Tel Aviv was matched 33 times. Additionally, 26 APSs were matched between 10 and 30 times, primarily in Israel's largest cities: Jerusalem, Tel Aviv, and Haifa. Another 463 APSs were matched between 2 and 10 times, reflecting a more widespread distribution across the country.

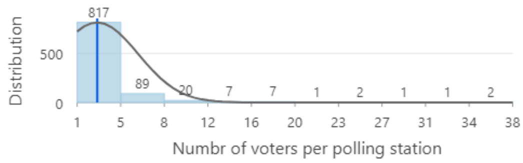


*Figure 4. Distribution of number of voters per nearest APS*

### 3.2 Assessing Regional Variations in Voter Proximity to Accessible Polling Stations

The spatial distribution of APSs in relation to voter addresses was analyzed to assess accessibility across different regions. The average distance between voters and their nearest APS was 794 meters, with regional variations: 660±1537 meters in the north, 539±1,909 meters in the center, and 2,245±8,442 meters in the south.

The analysis revealed regional disparities in APS proximity, with most areas nearby but some require much longer travel, especially in remote regions. We use Israel's predefined statistical areas (Central bureau of statistics, 2024) as spatial units to facilitate spatial analysis, identify trends and disparities. Figure 5 presents all statistical areas containing voter locations, categorized by the average distance between voters and their nearest APSs. The findings reveal an inverse relationship between voter-to-station distance and the number of statistical areas: as distance increases, the number of statistical areas within that range decreases.

The results indicate that 735 statistical areas had an average voter-to-APSdistance of less than 500 meters, with these areas widely dispersed across the country. An additional 180 statistical areas had distances between 500 and 1,000 meters, following a similar spatial pattern. Fifty-two statistical areas exhibited distances ranging from 1,000 to 2,000 meters, predominantly in the northwestern region, which is characterized by a high concentration of small villages and towns. Twenty-six statistical areas had distances between 2,000 and 5,000 meters, scattered sporadically across the country. Seventeen statistical areas had average distances between 5,000 and 10,000 meters, including villages near the Sea of Galilee, where geographical constraints hinder the equitable distribution of APSs. Finally, 15 statistical areas had distances exceeding 10,000 meters, primarily in southern Israel, where the desert landscape and low population density limit access to APSs. As a result, voters in these remote areas must travel significantly greater distances to cast their ballots, highlighting disparities in electoral accessibility. Two exceptions are the southernmost cities in Israel, where statistical areas have an average distance of less than 500 meters to the nearest APS.

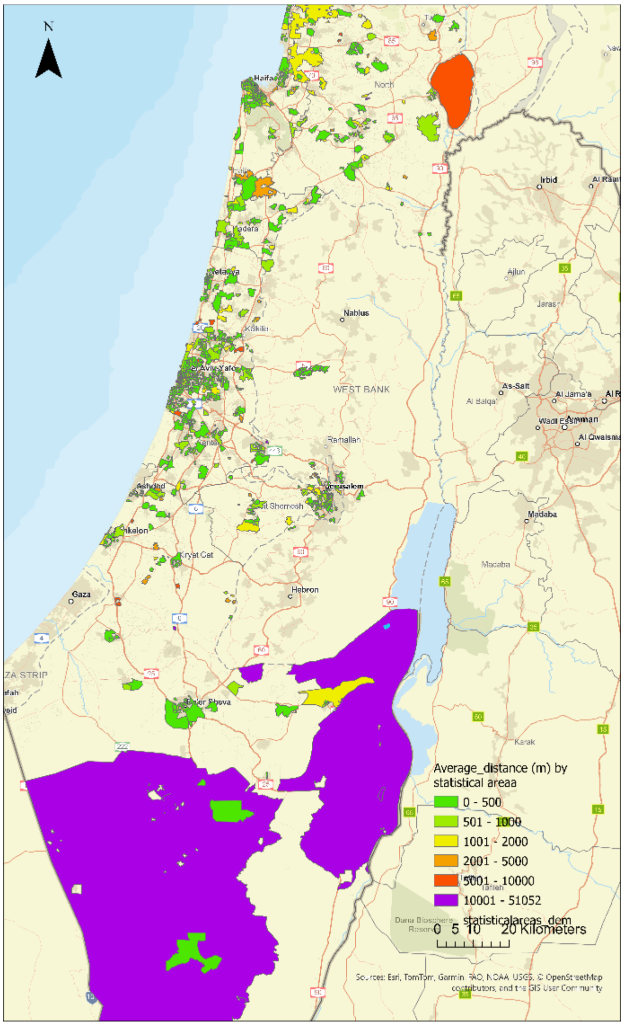


*Figure 5 displays all the statistical areas containing voter address locations. The color of each statistical area represents the average distance from voters to the nearest accessible location.*

### 3.3 Assessing Spatial Clustering and Local Disparities in Voter Proximity to Accessible Polling Stations

To further examine local variations between statistical areas, we applied Local Moran's I, a spatial autocorrelation statistic that measures the degree of clustering or dispersion within a dataset at a local scale, identifying spatial clusters and disparities. Specifically, it detects high-high clusters (areas with large average distances surrounded by similar areas), low-low clusters (areas with short average distances surrounded by similar areas), and spatial disparities such as low-high clusters (areas with short average distances within a region of large average distances) and high-low clusters (areas with large average distances within a region of short average distances). Figure 6 presents the results.

The application of Local Moran's I revealed distinct spatial patterns of clustering and disparities in APS accessibility, identifying areas with consistent proximity levels and regions with significant contrasts between local and surrounding distances. A total of 471 statistical areas were categorized as not significant, mostly located outside Israel's major cities—Tel Aviv, Jerusalem, and Haifa. Twelve areas were classified as high-high clusters, reinforcing previous findings that the southern region of Israel (excluding the city of Eilat) contains statistical areas with large average distances to polling stations. Additionally, 10 areas were identified as low-high clusters. For example, Mitzpe Ramon falls into this category; however, this classification is based on a single voter, limiting its reliability. In contrast, 496 areas were categorized as low-low clusters, primarily in the three key metropolitan areas—Tel Aviv, Jerusalem, and Haifa—which exhibit significant intra-regional variation. In these cities, most statistical areas show low-low clustering, indicating a strong spatial association of areas with short voter-to-station distances. However, many high-low clusters are also concentrated within these metropolitan areas, with 36 high-low clusters in total, suggesting localized disparities in accessibility.

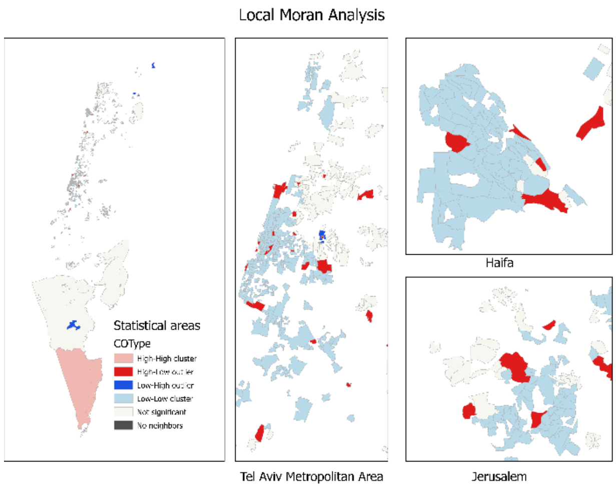


*Figure 6. Local Moran Analysis highlighting spatial clusters (High-High, Low-Low) and outliers (High-Low, Low-High) across Israel, with detailed views of Tel Aviv metropolitan area, Haifa, and Jerusalem.*

In Tel Aviv, the disparity arises from two key factors. First, not every statistical area contains an APS, requiring voters in those areas to travel to other districts to cast their votes. Second, the region comprises multiple local government jurisdictions, meaning that in some cases, the nearest APS falls outside a voter's municipal district, necessitating a longer travel distance. In Jerusalem, all high-low statistical areas lack APSs. In most cases, these areas serve non-residential functions, such as commercial or institutional zones. However, one area serves a residential function but lacks an APS. Additionally, this area is intersected by major roads, making it impractical for individuals using wheelchairs, mobility scooters, or walking to reach an adjacent APS. In Haifa, the high-low clusters are primarily located along city borders or in peripheral neighborhoods, making them less accessible. One such cluster is situated in an industrial zone, further distinguishing it from its surrounding areas in terms of accessibility.

## 4. Conclusions

The findings of this study underscore the critical role of geospatial intelligence in improving electoral accessibility for people with disabilities. By leveraging spatial analysis, the developed system efficiently assigned voters to their nearest APS, minimizing travel distances and enhancing real-time processing. The integration of Voronoi-based spatial partitioning allowed for an optimized approach, significantly reducing the computational complexity of APS assignment. The system's implementation during the recent local elections in Israel demonstrated its practicality, with high user engagement and overall satisfaction rates.

The results also highlight regional disparities in APS accessibility, with voters in peripheral areas required to travel significantly greater distances than those in urban centers. Statistical analyses, including Local Moran's I clustering, identified regions with consistently low accessibility, reinforcing the need for targeted policy interventions. The data further revealed that while most voters could access an APS within 1 km, certain remote locations required travel distances exceeding 10 km, disproportionately affecting individuals with mobility challenges.

To further improve electoral accessibility and optimize APS allocation, future research will focus on refining geospatial analyses and developing more data-driven solutions for equitable voting access. First – intersecting nationwide Voronoi polygons with statistical area polygons to integrate demographic data will enhance the accuracy of spatial analysis in assessing accessibility patterns. Additionally, analyzing APS locations that were never selected as the nearest APS can help identify underutilized sites, suggesting the need for relocation to optimize their placement and usage. Applying buffer analyses around APS can evaluate accessibility within specific distance thresholds, identifying areas that may require additional APSs or reorganization of existing APS locations. Another key direction is optimizing APS placement based on voter locations to minimize travel distances, ensuring a more equitable distribution of APS facilities. Also, refining distance measurements by incorporating walking and driving routes instead of straight-line distances will provide a more realistic assessment of accessibility barriers.

Regarding statistical interpretations, a deeper survey data analysis should be conducted to match user responses with geospatial data, enabling a more comprehensive understanding of voter behavior and accessibility challenges. Furthermore, statistical comparisons between travel distances and demographic data will help explain regional variations and highlight socio-economic factors influencing voter participation. This will improve the accuracy of geospatial models in identifying mobility challenges and designing effective solutions.

In conclusion, this study demonstrates how geospatial intelligence can transform electoral accessibility, ensuring a more inclusive voting process for individuals with disabilities. The integration of spatial methodologies not only optimizes election logistics but also serves as a foundation for data-driven policy-making, ultimately fostering a more equitable democratic system.

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