Assessing Walking Accessibility: A GIS-Based Analysis of Postal Services in the City of Naples

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Abstract. The current patterns of rapid urbanization pose significant challenges to social and economic inclusion. The planning of local services within urban environment is crucial in addressing issues of accessibility. The assessment and resolution of shortcomings depends on holistic assessment of disparities in accessibility.

This paper examines the accessibility of population to local services, with a particular focus on postal services in the city of Naples. In the Italian context, as in many other nations, national posts provide a broad range of essential logistical, financial and social services, making their accessibility a key factor in urban inclusion. In the case of Poste Italiane, in line with obligations under European and national law, the company explicitly states that the strategic positioning of its offices is essential to effective community service.

The study develops a modified Two Step Floating Catchment Area (2SFCA) methodology to measure the levels of accessibility to post offices during both morning and afternoon hours. The research aims to identify spatial disparities in service accessibility and to provide insights into improving urban planning and service distribution, particularly for more vulnerable population groups. The methodology used in this study is based on Geographic Information Systems (GIS) and considers the supply and demand of urban services as well as the mobility patterns and behavioral traits of the population.

The application of the 2SFCA methodology in Naples reveals significant variations in accessibility levels. The findings indicate that substantial portions of the population, particularly in the urban periphery, experience poor accessibility to post offices, and that spatial accessibility to services varies remarkably depending on the setting of opening hours by Poste Italiane.

The study underscores the importance of tailored urban strategies in ensuring equitable access to essential services, thereby enhancing the quality of life.

Keywords: Urban accessibility · Urban services · Post office

1 Introduction

In the current era of rapid urbanization and growing socio-economic disparities, one of the most pressing challenges facing cities is that of ensuring equitable access to essential services [1, 2]. The constant increase in urban populations can lead to critical failures in

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the performance and accessibility of the service networks necessary for daily life. Urban residents, particularly those in socio-economically marginalized and more distant areas, often face significant barriers in accessing essential services. The more vulnerable populations tend to be disproportionally affected by problems such as poor spatial distribution of services, which may then operate on limited hours and lack integration with sustainable transportation [3, 4]. Moreover, these are the same populations that also tend to lack awareness, education and logistical opportunities in accessing digital services [5, 6]. Adding to the shortcomings of traditional infrastructure, the digital divide thus further deepens the disparities in accessing essential services.

The complex interplay of inequalities in accessing essential services, ranging from issues of spatial and temporal distribution to technological exclusion, demands a comprehensive approach that not only addresses physical access but also considers the role of digital literacy and on-line service delivery. Within this scenario, the current research addresses the challenge of optimizing service distribution in urban environments, in this case with a particular application to the Italian national post, a provider of highly diversified financial-logistical-administrative services. The research provides a data-driven framework for assessing and improving service accessibility, aimed at not only at revealing the limitations of any current network, but also at supporting public and private stakeholders in overcoming the revealed challenges through concrete evidence-based proposals of solutions.

Central to this study is the recognition that the aims of urban inclusivity and service accessibility are deeply interconnected with issues of environmental responsibility and sustainable mobility [7, 8]. The challenges of inclusivity and accessibility to services are to be met by actions at the key levels of environmental and spatial planning, through integration with sustainable transport options, and even in details such as adjusting hours of operation and inter-relations with other services. The current research confronts the challenges head-on, offering a pathway to planning and development of urban environments where all residents, regardless of socio-economic context or mobility level, have equal access to vital services and where cities as a whole are more equitable and sustainable.

The current research examines the specific issue of accessibility to postal services. National postal networks are widespread across their territories, aimed at providing access to the entire population regardless of geographical location or socio-economic status. The posts of Europe are not limited to delivery services, instead having the potential offer of a wide range of services, from banking, mortgage, lending and financial management to money transfer, credit card and bill payment services, certification of documents and payment to government accounts, mobile phone subscriptions and energy services. Given this rich offer, postal services play a crucial role with respect to the entire population and in the daily lives of single individuals. Furthermore, national postal services operate under distinct regulatory frameworks, which shape their structure, distribution, delivery and accessibility to different societal sectors. Thus, in focusing on postal services, the current research explores the challenges and opportunities that arise in optimizing access to an important example of a widely used essential service.

The regulatory framework for postal services is outlined in European Directive 97/67/EC, which stipulates that Member States must guarantee permanent, accessible

and universal postal service across their entire territory, meeting standards of quality at prices affordable to all citizens. To ensure comprehensive coverage, they may designate one or more entities as universal service providers. Such universal providers are classified as public utilities, obligated to ensure essential services for all citizens, independent of local territorial factors or economic issues.

In Italy, Legislative Decree No. 261/1999 transposes the provisions of the European Directive and assigns Poste Italiane S.p.A. the responsibility for delivering the universal service. The relationship between Poste Italiane and the state, represented by the Ministry of Economy and Finance, is regulated through five-year renewable program contracts. The proposed contracts, which specify the provision of services, are subject to further evaluation and approval by the Communications Regulatory Authority (AGCOM).

In the Italian context, Ministerial Decree 1444/68 regulates the urban planning of all collective spaces and facilities of common interest, including post offices. In particular, the General Regulatory Plans of all municipalities must ensure minimum distributions of green spaces and facilities for educational, religious, cultural, health, sport and administrative services – including postal services - per resident citizen. In total, the requirement for such spaces – including parking but excluding roadways - is a minimum non-negotiable provision of 18 m^2 per inhabitant.

Moreover, Ministerial Decree of 2008 "Approval of the general conditions for the provision of the universal postal service" clearly recognizes Poste Italiane as an essential service, held to the provision of equitable coverage across the national territory and setting out operational benchmarks in meeting universal obligations. In particular, Table 1 below, reports the criteria in the matter of distribution of access points to the universal service.

Table 1. Criteria on distribution of access points to the public postal network (DM 2008).

Access points to postal service	Service terms
One access point within a maximum of 3 km from the place of residence	For 75% of the population
One access point within a maximum of 5 km from the place of residence	For 92.5% of the population
One access point within a maximum of 6 km from the place of residence	For 97.5% of the population
At least one post office	For 96% of municipalities

2 Literature Review

This literature review aims to provide a critical analysis of the methodologies for measuring urban accessibility to neighborhood services, with a focus on the evolution from early cumulative measures and gravitational models to the adoption of the Two-Step Floating Catchment Area (2SFCA) method.

Early methodologies, based on cumulative measures and gravitational models [9], quantified the potential for supply-demand interaction by measuring the total number of opportunities in an area and weighting it by distance to population. Although useful as a first instrument of measurement, gravity-based formulations only consider the supply aspect of accessibility, neglecting fundamental aspects such as demand and the true travel times to reach the service, not necessarily quantified by distance alone. Such approaches were prone to overestimating accessibility due to uniformly weighting all opportunities, and also proceeded from the weak assumption of homogeneous population distribution. Moreover, the early gravity-based models suffered rigid dependence on administrative boundaries, meaning that the results of the spatial analysis depended on the zoning used (municipal, provincial, regional and so on), which typically does not reflect the true spatial heterogeneity [10]. The assumptions of uniform population distribution across the territory, equal accessibility for all the population of a given area, and the rigidity of the spatial conception, therefore all represented critical weaknesses [11]. Finally, there was a lack of analysis of correlation between opportunities available in an area and the potential demand of the population. Although subject to various criticisms, incidence-based gravitational measures have been the most widely used in studies regarding accessibility, because they provide an aggregate indicator of accessibility that is, to some extent, relatively easy to calculate and interpret [12].

Building on the state of the art, Radke & Mu [13] (2000) and later Luo & Wang [14] (2003) developed a gravity-based measure intended to overcome the limitations of earlier models, initially applying it to accessibility for medical services. Instead of relying on rigid administrative boundaries, the 2SFCA method (Two-Step Floating Catchment Area) introduces the concept of a "floating area", in which circular buffers are defined around each service point, based on a distance threshold d_0 beyond which an individual would not travel to the service. The concept of distance threshold establishes the margin from which accessibility suffers significant decrease, reflecting the lower propensity of users to travel to services that are too far away. This parameter, defined based on empirical evidence, assigns a decreasing value to users as distance increases, thus differentiating the impedance of distance throughout the catchment area. In this way, a specific "fluctuating" area is determined for each service location j, within which the potentially affected population is considered for the calculation of the supply-to-population ratio (R_j). The latter, defined as the number of services available at j divided by the population residing within distance d_0 from j, introduces the concept of user competition. Then, for each point of residence i, the method identifies all areas j accessible within the threshold d_0 and sums the relative R_j ratios to obtain the accessibility indicator A_i. The 2SFCA thus provides a dynamic, replicable indicator for more accurate measurement of accessibility, responding in particular to criticisms of traditional gravity models, which had not adequately considered heterogeneous population distribution and other factors of spatial variation.

Although the 2SFCA method was initially developed for measurement of spatial accessibility to primary health care, it has since been applied in respect of other services, in general as a convenient indicator of stresses arising from origin-destination relationships. Over the years, the method has been used to measure accessibility to work activities, to parks [15] and other urban amenities [16], to green areas [17], and more

recently to postal services. In studies such as those conducted in Lyon [18] and rural Croatia [19], the 2SFCA indicator was found to support intuitive, replicable and easily interpreted analysis of the number and distribution of postal service branches, their hours of operation and the services offered, in relation to population density and distribution. Such results provide crucial support for decision-making in integrated urban planning, aimed at ensuring equitable access to services in line with national and European regulations. In general, the literature reveals the importance of integrated approaches that consider the interactions between land use, transportation systems and the characteristics of the individual services and populations. For these reasons, 2SFCA emerges as the most appropriate methodological approach for measurement of accessibility in complex urban settings, in support of urban design and intervention aimed at improving quality of life.

3 Methodology

This section describes the analytical framework applied to assess spatial inequalities in access to postal services in the city of Naples. The methodology, organized in four steps, is designed to ensure consistency, transparency, and replicability, in line with best practices in urban spatial analysis.

1. Data collection - This first step provided for the identification and acquisition of the spatial and alphanumeric data necessary for the study, including demographic data (population aged over 15), data on street networks and building footprints, and the spatial distribution of post offices. Most datasets were sourced from national and regional open data portals (ISTAT, OpenStreetMap and National Geoportal). Postal service data were manually geocoded from information provided on the Poste Italiane website (https://www.poste.it/cerca/index.html#/vieni-in-poste).
2. GIS Data processing - In this step, all collected data were organized within a GIS environment, i.e. the operational geodatabase. Population data were proportionally allocated to a grid of hexagonal cells (50 meters per side) based on building footprint [20]. The hexagonal grid ensured spatial accuracy and efficiency in distance computation [21, 22]. Street network data were refined and converted into a routable graph to support calculation of catchment areas and travel distances. Services and population data were spatially joined to the grid for subsequent computations of accessibility.
3. Accessibility measurement - The levels of accessibility were calculated using a modified Two-Step Floating Catchment Area (2SFCA) method, including a weighting coefficient (k) to reflect time-dependent availability of services (post offices open only part of the day). The method involved calculating supply-demand ratios for each post office, including at different times of day, and then assigning accessibility scores to each hexagonal cell using a Gaussian decay function.
4. Results interpretation and policy integration - The final step involved interpreting the resulting accessibility index in relation to spatial patterns of service provision and population distribution. Results were visualized through maps and statistical analysis, highlighting inequalities and potential service gaps. This evidence-based approach supports public decision-makers in designing equitable service planning policies, especially for vulnerable populations such as the elderly.

The method used to measure accessibility to postal services is a modified 2SFCA, specifically developed with respect to the research aim. The first step is to compute, for each post office j, a ratio Rj (Eq. 1) of supply and demand [20]. The supply of post services is quantified by the number of services available from each office (S_j); the demand is the sum of the population over 15 years old in location i, with Pi weighted to consider a walking-distance-decay function, W_{ij}, which is a function of the total distance. The distances between residential locations i and post offices j are estimated by Network Analyst and ArcGIS Pro, taking into account both walking and transit routes [23].

Although many offices of Poste Italiane are open from 8:30 a.m. to 7:30 p.m., some locations close in the afternoon, with significant impacts on accessibility. Hence, to consider the reduction of postal services during the afternoon, a k coefficient was introduced, varying between 0 and 1 in representation of the availability of services. The coefficient is a ratio of the services available Sj at a given time, relative to the number of services functioning in the morning.

For the second step, A_i, the accessibility of each hexagonal cell was obtained (as reported in Eq. 2) by summing the supply-demand ratios of the j postal offices serving the i cell — multiplied for the impedance function coefficients W_{ij}, to take into account both the spatial distribution of postal offices and the population.

$$R_j = \frac{S_j \bullet \left(\frac{S_j}{S}\right) \bullet k}{\sum P_i \bullet W_{ij}} \tag{1}$$

$$A_i = \sum R_j \bullet W_{ij} \tag{2}$$

The distance-decay function W_{ij} was introduced to reflect people's mobility habits: a Gaussian impedance function, whose values vary between 1 and 0, was used. This function's main characteristic is that it quickly decreases when time of travel is close to the maximum minutes supportable by each age category to access the service, in keeping with their physical capabilities [24].

$$W_{ij} = e^{-d_{ij}^2 / \beta} \tag{3}$$

The coefficient β was set equal to 200 in order to best represent mobility attitudes of different population categories according to outcomes in the scientific literature [25–27].

The above methodology requires only open-source data, thereby ensuring full applicability in other territorial contexts.

Table 2 lists the alphanumeric and spatial data (vector and raster) sourcing for application of the GIS-based procedure.

4 Case Study

Naples is the third largest Italian city by population and the fifth in population density. As of 2020, the city has 908,082 inhabitants living within an area of 119,02 km^2, resulting in a density of 7,629 inhabitants per km^2 (ISTAT, 2025). The city is divided into 10 administrative municipalities and more informally into 12 quarters. Given the substantial urban dimensions and highly varied physical and social character of the different quarters, Naples seems a good choice for testing the modified 2SFCA.

Table 2. Alphanumeric and spatial input data.

Dataset	Format	Type of geometry	Source	Year
Population	Alphanumeric	–	ISTAT	2021
Census sections	Geometric	Polygon	ISTAT	2021
Walking street network	Vector	Polyline	OpenStreetMap	2023
Buildings and land use	Vector	Polygon	National Geoportal	2022
Post office locations	Vector/ alpha-numeric	Point	Poste Italiane (manual input)	2025

The center of Naples, featuring high population densities and many buildings of historic importance within intensely developed neighborhoods, consists of the quarters of Monte Calvario, San Giuseppe, Porto, and San Ferdinando. The peripheral quarters, developed mainly between the late-nineteenth and twentieth centuries, are characterized by more varied and sprawling urban development with buildings of lesser importance. Social and economic conditions vary significantly. The quarters of Posillipo, Vomero, and Chiaia, for example, are characterized by greater wealth and a higher quality of life, while residents of Pinera, Scampia, and Ponticelli are more likely to face economic disadvantages.

Within the 12 quarters there are a total of 61 Poste Italiane offices. Of these, 31 are open from 8:20 a.m. to 7:05 p.m., Monday to Friday, and Saturday from 8:20 a.m. to 12:35 p.m. The other 30 offices are open from 8:20 a.m. to 12:35 p.m., Monday to Saturday. All post offices offer basic post and parcel services but also additional services which may include current and checking accounts, teller and/or ATM cash deposit and withdrawal services, automatic deposit and payment services, postal money orders, loans, investment services, cash cards, acceptance of government vouchers, acceptance of tax and pension contributions, provision of pensions and welfare, payments of fines, administrative and utilities bills, various insurance services, electronic passport requests, digital identity services, fiber-optic internet and mobile telephone services, energy contracts. The number of these services in each office ranges from a minimum of seven to a maximum of eleven. Figure 1 shows the distribution of post offices in the municipalities of Naples.

The evaluation of walkability considers the category of individuals over 15 years of age who are resident in Naples (792,675), possessing the autonomy and legal right to assess most of the offered services. The results of the study would also be relevant for the population of younger individuals, able to utilize a more restricted range of services.

5 Results

The application of the modified 2SFCA method to the city of Naples yields important insights into the accessibility of postal services over the course of the day, in relation to their distribution throughout the entire urban area. The analysis reveals important

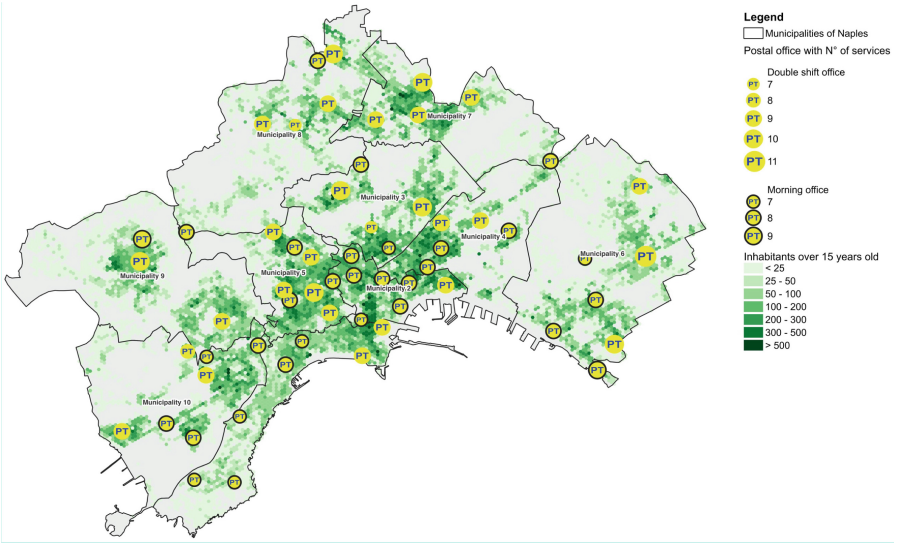

Fig. 1. City of Naples, distribution of post offices and residents over age 15 (elaboration of ISTAT data, 2021).

differences in service availability between the morning and afternoon scenarios and with respect to the varying population densities and socio-economic character of the different urban quarters.

During the morning hours (Fig. 2), when all 61 post offices are operational, accessibility levels are generally high across the city. The historic central and more affluent quarters, such as Vomero and Chiaia, show robust service coverage. Here, the majority of residents can access postal services within contained walking distances. These quarters benefit from a dense urban fabric and, during the morning hours, a high spatial concentration of services. The peripheral quarters, however, present a more heterogeneous scenario. While the analysis reveals acceptable levels of accessibility for certain quarters, others, particularly those with irregular urban structures, show reduced accessibility. The Gaussian impedance function reveals the potential for residents in these neighborhoods to experience lengthy travel distances to the nearest postal offices, therefore with impracticable levels of walkability.

In the afternoon (Fig. 3), accessibility is significantly impacted by the closure of 30 out of 61 post offices. The incorporation of the k coefficient within the model reveals a conspicuous diminution in service accessibility, particularly within peripheral districts where the offices remaining operational tend to be sparsely distributed. As demonstrated in Fig. 4, however, the decrease in available services tends to have a disproportionate overall impact on the more densely populated inner-city neighborhoods.

Furthermore, the network analysis conducted using ArcGIS Pro shows that in some municipalities, the remaining open offices would face a sharp increase in demand, potentially leading to extended waiting times and overcrowded facilities. This is particularly evident in high-density areas with fewer alternative service points. The afternoon scenario challenges the regulatory thresholds set by the Ministerial Decree of 2008, as the

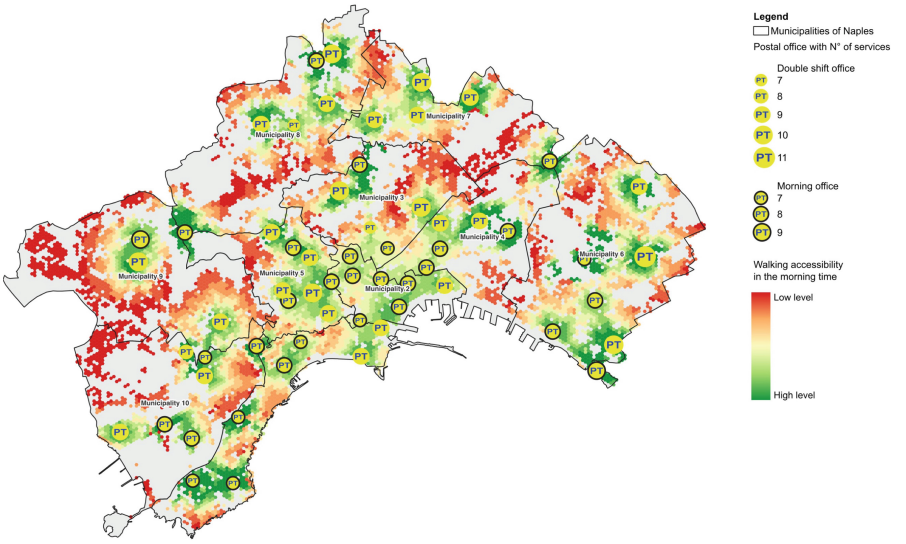

Fig. 2. The walking accessibility to post office during the morning time in the City of Naples, Italy.

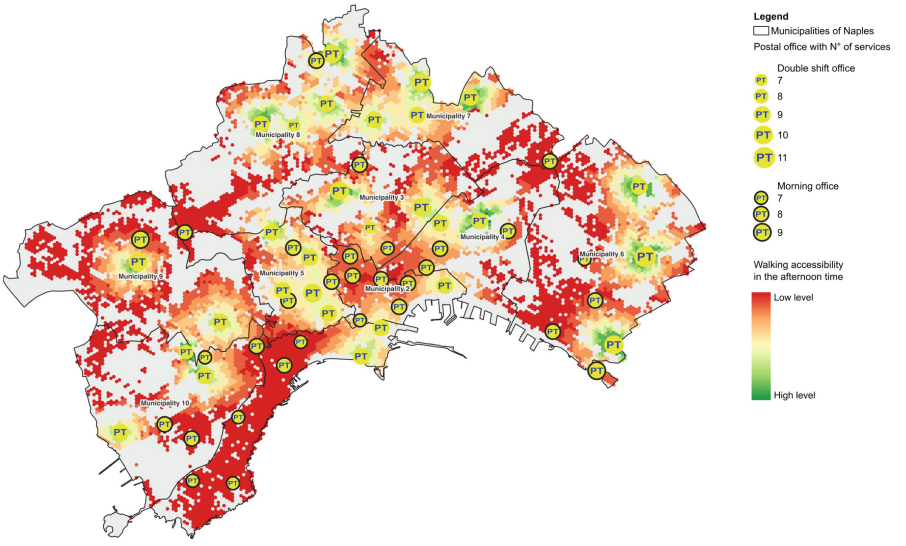

Fig. 3. City of Naples, walking accessibility to post offices during afternoon hours.

reduction in coverage results in longer walking distances to the nearest post office for significant portions of the population.

The variation in accessibility levels between the morning and afternoon scenarios is further illustrated in Fig. 4, which quantifies the number of inhabitants within each

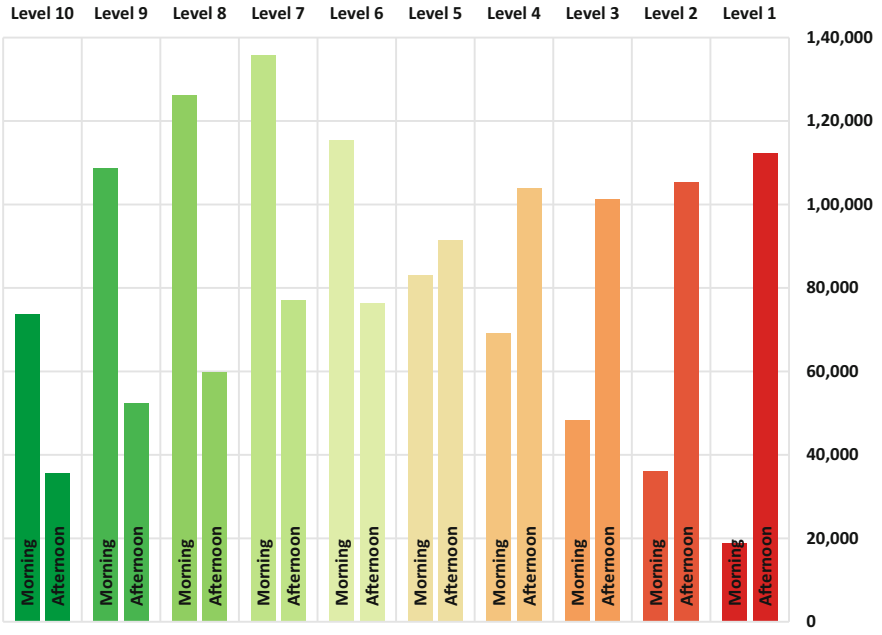

Fig. 4. Inhabitants per level of accessibility to postal services: comparison of morning to afternoon hours (respectively left/right columns).

accessibility level. The results indicate a clear shift: during the morning hours, a significant portion of the population benefits from high accessibility (Levels 10–7), whereas in the afternoon, a substantial number of residents experience a decline in accessibility. This is particularly evident in quarters with lower accessibility (Levels 1–4) with high numbers of affected inhabitants. The differences between these levels reveals the critical effect of operating hours on accessibility to urban public services, with implications for social equity and efficiency of the offered service.

Drawing on these insights, policymakers and urban planners can in general provide for enhanced connectivity to services, including through improvements in walkability, and promote sustainable active mobility, with particularly strong benefits in under-served areas. In particular, postal service providers can use this analysis in strategies for optimization of office locations, adjustments of operating hours, and better alignment of specific services with actual demand. Such integrated approaches address accessibility challenges both through general urban mobility planning and efficient management of the specific network, in this case for postal services.

6 Conclusions and Policy Implications

The results of this study underscore the necessity of developing integrated policies and planning tools that account for the multiple factors influencing urban accessibility. The accessibility of postal services in Naples is shaped by spatial, socio-economic

and mobility-related constraints, requiring multidisciplinary approaches in urban service analysis and planning. The methodology applied in this study provides a valuable framework for identifying accessibility gaps and serves as a decision-making support for policymakers and urban planners.

Optimizing the spatial and temporal distribution of post offices, particularly in underserved districts, would significantly enhance the equity and efficiency of services. The insights from this study can be integrated into the general regulatory and sustainable mobility plans for the city of Naples, ensuring that postal services are considered alongside transportation, healthcare, and social infrastructure in spatial and functional planning.

This research is closely aligned with the Research to Business (R2B) paradigm, offering practical applications that bridge the gap between academic analysis and real-world decision-making, particularly in the planning of strategic service networks. By developing a data-driven framework for assessing accessibility to essential services, the study significantly contributes to processes of evidence-based decision-making. The insights gained can guide both public and private stakeholders in optimizing service distribution. The research objective is intimately linked with broader goals of sustainable mobility and urban inclusivity. Enhancing access to postal services, through scenarios such as improved spatial planning, adjusted operating hours, and better integration with sustainable transport options, can play a pivotal role in fostering more equitable urban environments. Ensuring that essential services are universally accessible, regardless of socio-economic status or mobility limitations, contributes to the creation of a more inclusive urban landscape, while simultaneously promoting sustainable and efficient mobility solutions.

Apart from walkability, future interventions should prioritize connectivity via public transportation systems, critically important to more vulnerable groups. For this reason, additional studies could evaluate the optimal location of postal services in relation to public transport, but also to other public services of key importance to underserved sectors.

Future research could expand on the current study by testing the methodology in other urban contexts, beginning with cities of similar socio-spatial characteristics, and by investigating walkability factors that influence accessibility for specific population groups, such as the elderly, considering variations across seasons and times of day. Further improvements to the methodology could involve the integration of additional sustainable transport modes, such as bike-sharing and micro-mobility, to refine the assessment of accessibility beyond walkability. Moreover, incorporating operational data on postal service supply and demand, including average waiting times, congestion levels, and availability of digital services, would provide a more comprehensive understanding of accessibility. The use of the accessibility index in analysis of spatial equity could also be refined by weighting the offer of different services per post office, assigning higher values to offices with multifunctional roles.

In general, it is clear that the development of web-based GIS tools facilitates the visualization and interpretation of accessibility patterns, enabling more effective decision-making. By integrating data-driven analysis into urban policy and planning, cities can

enhance both the accessibility and inclusivity of essential services, ensuring that all residents, regardless of location or socio-economic status, benefit from fair and efficient provision of public services.

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