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*Research article*

# A GIS-Based Analysis of the Public Open Space Distribution and Accessibility in Gurugram City, India

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## Abstract

The rapid pace of urbanization and increasing urban density in India has led to critical concern about the sustainability and livability of urban environments. In the city of Gurugram, public open spaces (POS) like parks and playgrounds are limited, highlighting the problem regarding their availability and accessibility. This study analyzes the current distribution of POS in the city of Gurugram at the ward level and compares the existing situation with national planning guidelines. It also aims to identify the population served by POS and the areas deficit in POS provision. The analysis reveals a deficit in per-capita POS at the city level, which stands at 3.14 $m^2$ and shows high variability across different wards. A significant gap in the provision of housing area and neighborhood level POS was observed. The accessibility index calculated using Geographic Information System (GIS) based network analysis, reveals uneven access patterns across the city, with five wards lacking POS accessibility for residents, located primarily in central and southern-central areas. None of the wards of the city had all of its area serviced by POS, and only six wards had above 50 percent of the population residing in area serviced. These findings emphasize the need for strategic interventions to ensure universal access to POS, aligning with the sustainable development goals for urban areas.

Keywords: GIS; Network Analysis; Public Open Space; Urban Planning.

## 1. Introduction

Cities are vibrant centers of public life (Brenner *et al.*, 2009; Gehl *et al.*, 2011). The identity of a city is shaped by its public spaces, as they are the assets of urban areas available for the collective enjoyment of the people. The term "public space" encompasses all places that are publicly owned or utilized and open to the public free of charge and without any commercial agenda. They are open to everyone, irrespective of gender, race, ethnicity, age, or socio-economic status (Chan, 2023). Public open space is an important component of public space, which includes publicly accessible parks, gardens, playgrounds, beaches, riverfronts or waterfronts.

The quality of life in cities is determined by the relationship between individuals and their urban environment (Das, 2008). In order to cultivate a sense of community in urban areas, building environments that encourage communication across all demographic groups and their surroundings is essential. Public open spaces (POS) provide people the opportunity to interact with nature as well as other urban residents, making them a crucial component of the urban environment.

POS are integral parts of a city's everyday life (Johnson & Glover, 2013). They have a central role to play in promoting social inclusion (Seeland *et al.*, 2009; Hadavi & Kaplan, 2016), fostering active citizenship (Di Masso, 2015) and enhancing overall quality of life (Beck, 2009). Moroni and Chiodelli (2014) state that one should never narrowly perceive POS solely as a space for recreation but also as a place where individuals can gather to engage as people rather than mere customers or clients. When POS are well-connected and easily accessible, they serve essential cultural services and contribute significantly to the urban environment (Peters & De Haan, 2011; Ye, 2019). Activities like people-watching, participating in sports, attending events, running or walking, unwinding and socializing can all be done in public open spaces (Francis *et al.*, 2012; Hadavi & Kaplan, 2016). Significant positive correlations have also been found between public green use and physical (Holy-Hasted & Burchell, 2022) and mental well-being (Dadvand *et al.*, 2016; Hunter *et al.*, 2019). Cohen *et al.* (2008) found a strong association between living environments with ample parks and a higher level of satisfaction with social relationships. The use of POS fosters a sense of comfort, familiarity, togetherness and facilitates acquaintance with neighbors, thereby potentially enhancing social ties (Peters, 2010). Wan *et al.* (2021) also performed a systematic literature review validating the relationship between public green space use and enhanced feelings of social cohesion.

A growing body of research explores the wider implications of adequate POS distribution, like enhanced landscape quality (Shahfahad *et al.*, 2019) and quality of life (Nasution & Zahrah, 2014). One of the key ways POS promotes well-being appears to be by encouraging residents to walk, both within their neighborhoods and within the POS itself (Giles-Corti *et al.*, 2005;

Sugiyama *et al.*, 2010). Visual quality in a landscape with many open spaces is also rated higher by the residents (Wartmann *et al.*, 2021).

Despite their numerous benefits, public open spaces face challenges, particularly in rapidly urbanizing regions such as major cities in India. These challenges are a result of large-scale migration, high population density, and increasing land prices. Urbanization, driven by population growth, often leads to densification. This means denser housing developments, like high-rise buildings, replace older, lower-density structures to accommodate more people. While densification offers advantages in land use, it can come at a cost. Large-scale densification can threaten open spaces, potentially leading to the disruption of social networks and a weakening of local culture and identity (Haaland & van Den Bosch, 2015; Yung *et al.*, 2014). The impact of urban densification on POS is evident in studies such as Lin *et al.* (2015), which provide evidence of a marked decrease in both private and public green spaces in Sydney, Australia. These losses are often attributed to built-infrastructure development to make room for residential, industrial or commercial complexes. Urban renewal projects, with their focus on densification, can put POS at risk (Byrne *et al.*, 2010). Therefore, a key challenge lies in planning POS that effectively connects people within a densifying urban environment.

The development plans of many cities in the developing world show low open space per capita and fail to meet national and international standards. In Indian cities, researchers have also quantified the existing status of POS. The integration of remote sensing and GIS (Geographic Information System) has proven to be invaluable for studying the distribution and accessibility of green spaces. Satellite data is highly favored in identifying open green spaces, as many studies have used the NDVI metric for determining their availability (Bathinda: Singh, 2018; Raipur: Kamble, 2022; Mumbai: Sathyakumar *et al.*, 2019). Research has revealed that Bathinda has a per capita availability of 21.7 $m^2$ (Singh, 2018), New Delhi registers at 21.52 $m^2$ (Bhalla & Bhattacharya, 2015), Varanasi records 6.3 $m^2$ (Verma *et al.*, 2020) and Chennai has only 0.46 $m^2$ green open space (Mitra, 2013). Assessing the availability of POS in various Indian cities is recognized as an essential step toward sustainable urban planning (Lahoti *et al.*, 2019; Singh, 2018; Verma *et al.*, 2020). Studies also place a particular emphasis on identifying areas that are underserved by POS (Kaur *et al.*, 2022; Lahoti *et al.*, 2019). Yet, studies that evaluate access to POS are limited to a few cities of India.

Buffer analysis in GIS is commonly used for studying the accessibility to open spaces (Kamble *et al.*, 2022; Kaur *et al.*, 2022; Lahoti *et al.*, 2019). However, it has been noted that, since the simple buffer analysis does not consider the actual routes taken by people, it tends to present an inflated portrayal of accessibility (Gupta *et al.*, 2016). To address this limitation, network analysis has proven to offer a more precise measure of accessibility (Comber *et al.*, 2008; Gupta *et al.*, 2016; Koohsari, 2011). In order to conform to the principles of sustainability, it is essential to expand research regarding green space access to other rapidly expanding urban centers in the country.

Gurugram has emerged as a global city over the past two decades, witnessing a steady influx of migrants working in the Delhi-NCR region. This has led to intense land transformations, densification and pressure on cities' resources, raising the question of urban sustainability (Pramanik *et al.*, 2021). One key element of urban sustainability is ensuring residents' access to open spaces and recreational opportunities. With urbanization leading to denser housing with less open space and fewer private gardens, POS become even more critical for the well-being of city dwellers. Thus, it is imperative to address the POS organization in Gurugram.

This study aims to analyze the availability, distribution and accessibility of POS, including parks and playgrounds, in the city of Gurugram, through the development of an availability and accessibility index. We employ GIS to assess the per capita availability of POS at the ward level while measuring how the city aligns with the national planning norms. GIS is also used to ascertain the proportion of the population without access to POS, thereby highlighting disparities in distribution. The analysis identifies the wards that require priority attention and contributes to a broader understanding of declining POS quantity in post-modern cities and the need for city-level assessment for the development and revitalization of POS.

## 2. Research Methods

### 2.1. Study Area

Gurugram city is situated on the outer fringe of the National Capital Territory of Delhi (Figure 1). It underwent rapid transformation from a village to a postmodern city, attracting substantial investments from both the government and private sectors. Quickly emerging as one of India's most

prosperous cities, Gurugram boasts towering skyscrapers, expansive shopping malls, bustling commercial hubs, multinational service centers and efficient transit systems. Catering to an affluent urban lifestyle, it offers a diverse range of luxurious leisure activities, earning it the moniker 'Millennium City' of India (Gururani, 2013).

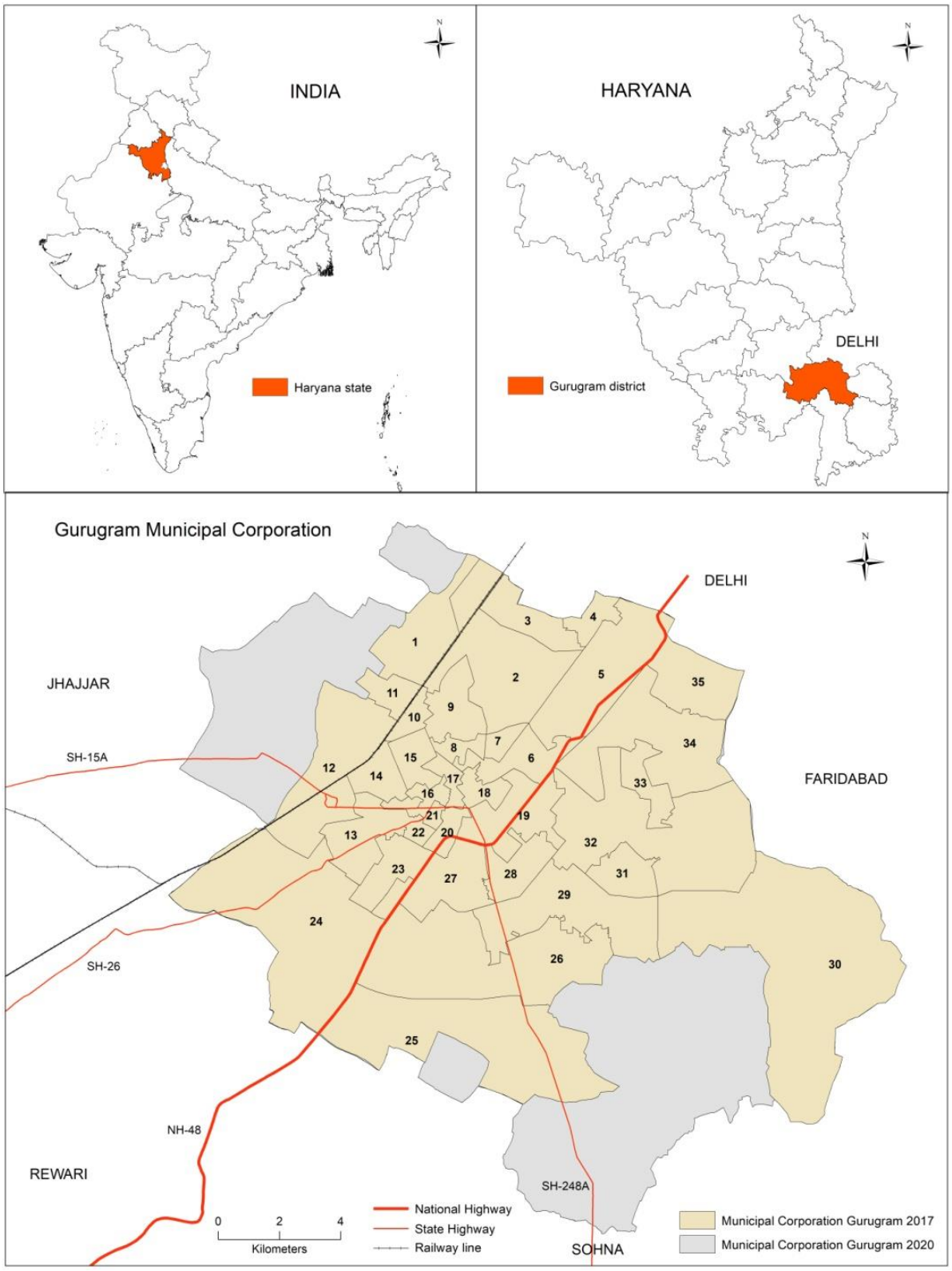


**Figure 1.** Location of study area. Ward-level Map of Gurugram Municipal Corporation (2017) is considered for analysis.

The trajectory of Gurugram's growth and development gained traction with the establishment of HUDA (Haryana Urban Development Authority) under the HUDA Act of 1977. This impetus was amplified by the entry of both auto industries and private developers starting in 1981, sparking a significant boom in construction activity within the region.

In 1981, the Haryana Urban Development Act was implemented, and DLF obtained the first license. In 1985-86 DLF sold its first plot in Gurugram, marking the beginning of a series of initial developments. Among the early projects were DLF and Ansals, which were situated to the east of the old NH8. These projects, including the Old DLF Colony and Ansal's Palam Vihar, are primarily limited to Old Gurugram. The contributions of these developers had a profound impact on shaping the direction of the city's growth and defining the landscape of present day Gurugram (Mehtani, 2012). Since then, a number of private developers have contributed to the housing and commercial infrastructure in the city, changing the nature of the cityscape.

A significant contributing factor to Gurugram's growth is the availability of relatively affordable housing, particularly catering to the working class. There has been a notable shift from agriculture to service-based livelihoods, as reflected in the decrease in the percentage of agricultural and open land from 77% in 1991 to 45% in 2018 (Pramanik *et al.*, 2021). The city experienced a surge in population growth between 1991 and 2011, driven by the growth of the tertiary sector due to new policies at the state and central levels. The rampant urbanization has engaged various players, including the government and private developers. Throughout its expansion, the cityscape of Gurugram became segmented and transformed into distinct private spaces with controlled access coexisting within the urban landscape.

Public open spaces found in Gurugram city are mainly parks and playgrounds. These parks and playgrounds can be further categorized into different types based upon their size, such as housing area, neighborhood, community, district and sub-city, as per the classification given by Urban and Regional Development Plans Formulation and Implementation, India (URDPFI, 2014).

**Table 1.** Hierarchy of Organized Greens.

| Category of POS | Area requirement in $m^2$ |
|---|---|
| Housing Area | Less than 5,000 |
| Neighborhood | 5,000 - 10,000 |
| Community | 10,000 - 50,000 |
| District | 50,000 - 250,000 |
| Sub-City | Above 250,000 |

**Source:** Urban and Regional Development Plans Formulation and Implementation (URDPFI) Guidelines, Ministry of Urban Development, India (2014; pg 363).

Smaller units of POS catering to the proximal residential areas, like 'Housing Area Park' or 'Neighborhood Park' are maintained and managed by Resident Welfare Associations (RWAs). They typically contain usual amenities like walking paths, children's play equipment and sports areas. On the other hand, the larger city-level parks are managed by the Municipal Corporation of Gurugram. These parks are known for their scenic landscapes, natural beauty and diverse recreational opportunities.

## 2.2. POS Digitization

POS that are accessible to the general public were manually digitized using high-resolution remote sensing images available through Google Earth, simultaneously verifying that no restrictions exist for their use. This included all publically owned parks and playgrounds. The analysis excluded golf courses, gated communities' gardens, private school grounds and theme parks, as a person can face restraint these areas are not freely accessible to everyone for everyday use. This helps focus on spaces that are more relevant for public use.

## 2.3. Network Analysis

To analyze the accessibility, we chose the road network over Euclidean distance in GIS. While some argue that Euclidean distances are more fitting for evaluating access to POS due to their inclusion of informal routes that usually exist in cities (Cutts *et al.*, 2009), we've opted for road network distances as Gupta *et al.* (2016) provided convincing evidence against Euclidean distances, stating that they tend to overestimate POS provision. Mavoa *et al.* (2015) also advised against Euclidean buffering as it fails to consider barriers like infrastructure, cul-de-sacs and water bodies.

Several studies, like those by Comber *et al.* (2008), employed network analysis in the UK to assess parks and green space accessibility for various ethnic and religious groups. Bennet *et al.* (2012) utilized network analysis to compute walking distance to the nearest playground and estimate the playground's service area's user count. Kuta *et al.* (2014) employed network analysis to evaluate the accessibility of green space for socio-economically weaker populations. Pearce *et al.* (2006) also used network analysis to measure the accessibility of services like education, recreation and health at a neighborhood level in New Zealand. The preference for the network analysis method

lies in its accuracy in reflecting actual travel routes, including barriers that could hinder pedestrian accessibility. Thus, for this study, we used the service area analysis tool of the network analyst in ArcGIS 10.8.

In our digitization process, we regarded POS as polygons, much like their general representation in spatial data sets. However, while projecting the service areas of POS, the network analyst requires the facilities to be represented as point data. Theoretically, the ideal method should be to incorporate actual access nodes or entry points to the POS. In reality, acquiring this data is difficult and manually creating such points is quite time-consuming. Many researchers usually represent POS as either a centroid of the polygon or a series of points along its boundary (Mavoa *et al.*, 2015). Thus, in this analysis, the center point of the POS is representative of its location.

Studies using network analysis typically assess accessibility from users' residences to the service point (a POS, in our case). However, in the concerned study area, it is highly challenging to create a spatial data frame of users' residences due to the sheer density and number of housing units. Consequently, accessibility was calculated from POS by treating them as public facilities and polygons of their respective service areas were generated away from their entry nodes in all possible directions.

## 2.4. Road Network

A detailed road network database of the study area with categories like footway, residential, secondary, tertiary, etc. was obtained from MapCruzin (mapcruzin.com). However, no restrictions on movement were imposed on any category of road for the analysis. This decision was made because, usually in Indian cities, there is limited availability of POS (Mckinsey, 2010). Thus, it is a necessity for people to navigate through highways and tertiary roads to reach well-maintained, secure and high-quality POS.

## 2.5. Population Data

The ward-level analysis of POS accessibility requires large-scale population data. The most reliable demographic data is distributed by the Census of India, which has not been conducted since 2011. Thus, we compute the population for the year 2021 by following a ratio-growth method of population projection for smaller units given by the Indian Institute of Population Sciences (Dhar, 2022) and using ‘Census of India, 2001’ and ‘Census of India, 2011’ as base.

## 2.6. Classification at various hierarchical levels

For network analysis, the five different categories of public green spaces are defined based on their area (Table 1). Our analysis relies on the premise that ‘larger POS have a greater pulling effect, attracting people from more distant areas’. The assumption is that individuals are willing to travel longer distances to access larger POS (Van Herzele & Wiedemann, 2003). We adopted the travel distance parameters devised from "The Accessible Natural Greenspace Standards (ANGSt)" in the United Kingdom as our baseline, considering the absence of national standards for traveling distances to different POS hierarchies. These standards have been frequently used by studies pertaining to urban green space accessibility in Indian cities (Lahoti *et al.*, 2019; Gupta *et al.*, 2016). The specific distances applied were:

- 300 m for housing area and neighborhood hierarchy
- 500 m for community hierarchy
- 2 km for district hierarchy
- 5 km for sub-city hierarchy

## 2.7. Methodological Steps

The flowchart outlines the general methodology of the study (Figure 2). The unit of analysis for this study is the Gurugram Municipal Corporation (GMC). The ward-level map (year, 2017) of Gurugram city was obtained from the GMC website. Further, it was georeferenced using ArcGIS 10.8 and digitized in a GIS environment. The process begins with the identification of POS within the Gurugam city boundary from the Google Earth satellite images and their digitization to create POS polygons. This data is then imported to the GIS environment. The ‘calculate geometry’ is used to calculate the area of each POS and classify them into functional hierarchies based on the URDPFI guidelines. The ward-wise population data is derived from the Census of India. This data is then used to calculate the POS Availability Index by comparing POS area by ward and category with the population of the ward.

Next, the POS polygons are converted to point data and input to 'Service Area Analysis' tool of Network Analyst in ArcGIS 10.8 alongside the road network data. This analysis determines the area served by each POS within each ward. Finally, the ward-wise population density and service area data are used to compute the POS Accessibility Index, which provides a comprehensive measure of public open space accessibility within the city.

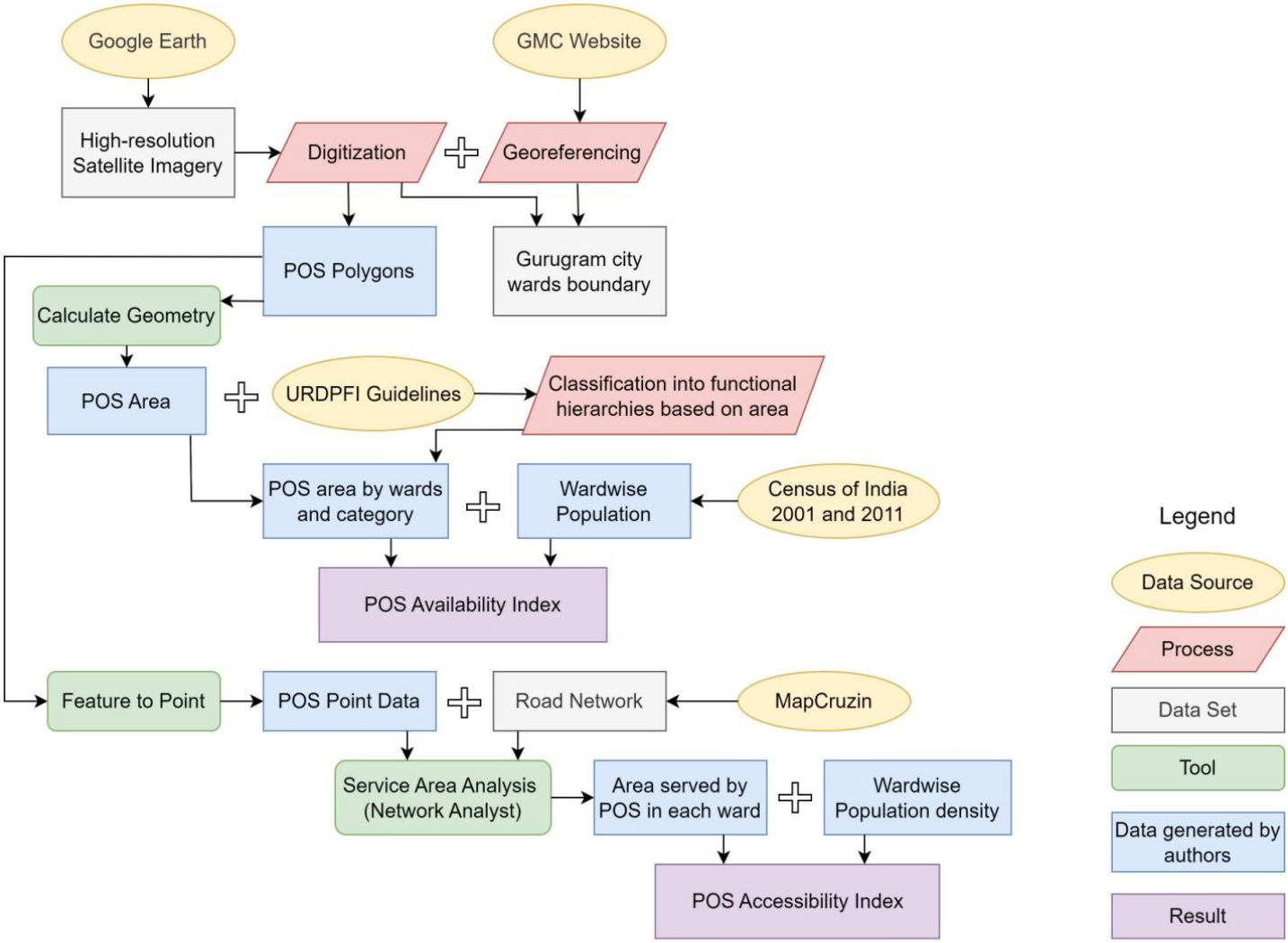


**Figure 2.** Flowchart of methodology.

## 3. Results

### 3.1. Availability

An analysis of the availability of POS in Gurugram was first conducted. The per capita POS was calculated for each ward. The total POS in each ward is computed through the "calculate geometry" tool in ArcGIS 10.8. Employing the projected population data for each ward, the below equation is used for calculating availability Equation 1

$$\text{POS Availability Index} = \frac{G}{P_i} \quad (1)$$

Where G represents the area of open spaces in $m^2$ of the $i^{th}$ ward and $P_i$ denotes the population of the $i^{th}$ ward. The per capita POS index serves as an indicator of the amount of public open space available in a ward for each resident (Figure 3b). The total area under POS in the city is 3240110.4 $m^2$ and the total estimated population of the city is 1,029,170.

URDPFI proposes a desirable 10 to 12 $m^2$ of open space per person for Indian cities (URDPFI, 2014). However, in Gurugram, the city falls short of this standard, with 3.14 $m^2$ of POS per capita for the city as a whole. Calculating per capita POS for each of the 35 wards revealed that wards 11, 22, 24, 25, 27, and 33 reported 0 $m^2$ of POS per capita. This deficiency might be attributed to their classification as commercial areas or undeveloped outskirts. In contrast, ward 35 boasted the highest value at 715 $m^2$, justified by its non-residential status and the presence of a biodiversity

park. Ward 34 followed behind with 27 $m^2$, given a lower population density. More than half of the wards in the city have less than 1 $m^2$ of POS area per capita. These wards might benefit from the creation of mini-green belts, as spare land is not available for POS creation. Notably, just a few wards, including ward 14, 19 and 32, demonstrated somewhat adequate per capita POS, ranging from 6 $m^2$ to 9 $m^2$. The correlation observed in Figure 3a and Figure 3b distinctly illustrates the connection between the existing recreational POS in each ward and their corresponding proportional population, as well as the per-capita availability of POS within the city. From Figure 4 it is evident that even though POS are frequent in many wards of the city, their areas are too small and inadequate. This leads to a major insufficiency in the per capita availability of open space.

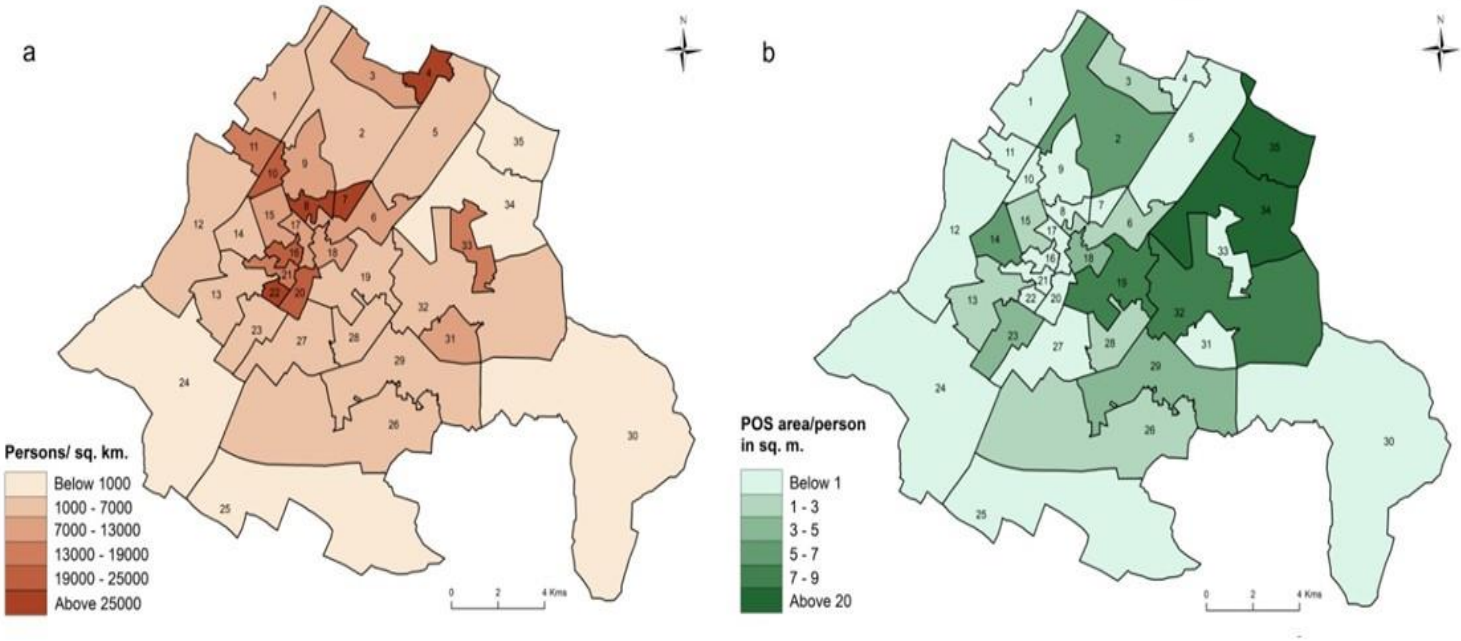


**Figure 3.** a) Population density in Gurugram by wards. b) Per capita POS area in Gurugram by wards.

**Table 2.** Recommendations for the number of Open Public Spaces (URDPFI, 2014).

| Category | Population served | Minimum no. of organized green spaces |
|---|---|---|
| Housing Area | 5,000 | 3 local parks and playgrounds |
| Neighborhood | 15,000 | 3 local parks and playgrounds |
| Community | 100,000 | 2 community level parks |
| District | 500,000 | 1 district level park and sport center |
| Sub-city | 1,000,000 | 1 sub-city level park/ sport complex/ botanical/ zoological garden |

**Source:** Urban and Regional Development Plans Formulation and Implementation (URDPFI) Guidelines, Ministry of Urban Development, India (2014; pg 363).

The examination of availability is extended to a comparative analysis with the national provisioning norms stipulated by the URDPFI guidelines. Here, the availability of POS is studied in regards to their number and the calculation of service-side gap is focused solely on the number of parks, playgrounds, sports complexes, etc. In this analysis, the data about the number of POS is systematically contrasted with the URDPFI guidelines, as shown in Table 2 and Table 3.

**Table 3.** Service gaps in the number of POS in Gurugram (calculation).

| Category | Recommended no. for Gurugram (approx.) | Existing number of POS in Gurugram | Service Deficit/Surplus |
|---|---|---|---|
| Housing Area | 612 | 361 | − 251 |
| Neighborhood | 204 | 36 | − 168 |
| Community | 20 | 21 | +1 |
| District | 2 | 4 | +2 |
| Sub-city | 1 | 1 | = |

**Source:** Computed by the authors (Based on Table 2)

The results of this calculation depict the service gap within each category, highlighting a substantial deficit in the provision of recreational POS within the city. Remarkably, the city aligns with the URDPFI guidelines in the sub-city and district POS provision categories. However, the deficit becomes apparent in other categories, especially the housing area and neighborhood categories.

It emphasizes the pressing need for strategic interventions to address the substantial shortfall in recreational POS provisions near high-density residential centers.

## 3.2. Accessibility

For studying the accessibility of people in Gurugram to POS, service area polygons are devised using the service area analysis tool in ArcMap's Network Analyst (Figure 4). Service area encompasses streets which are within the specified distance impedance (varying with POS hierarchy). Figure 4 shows the distribution of all the POS in the city and their respective service areas.

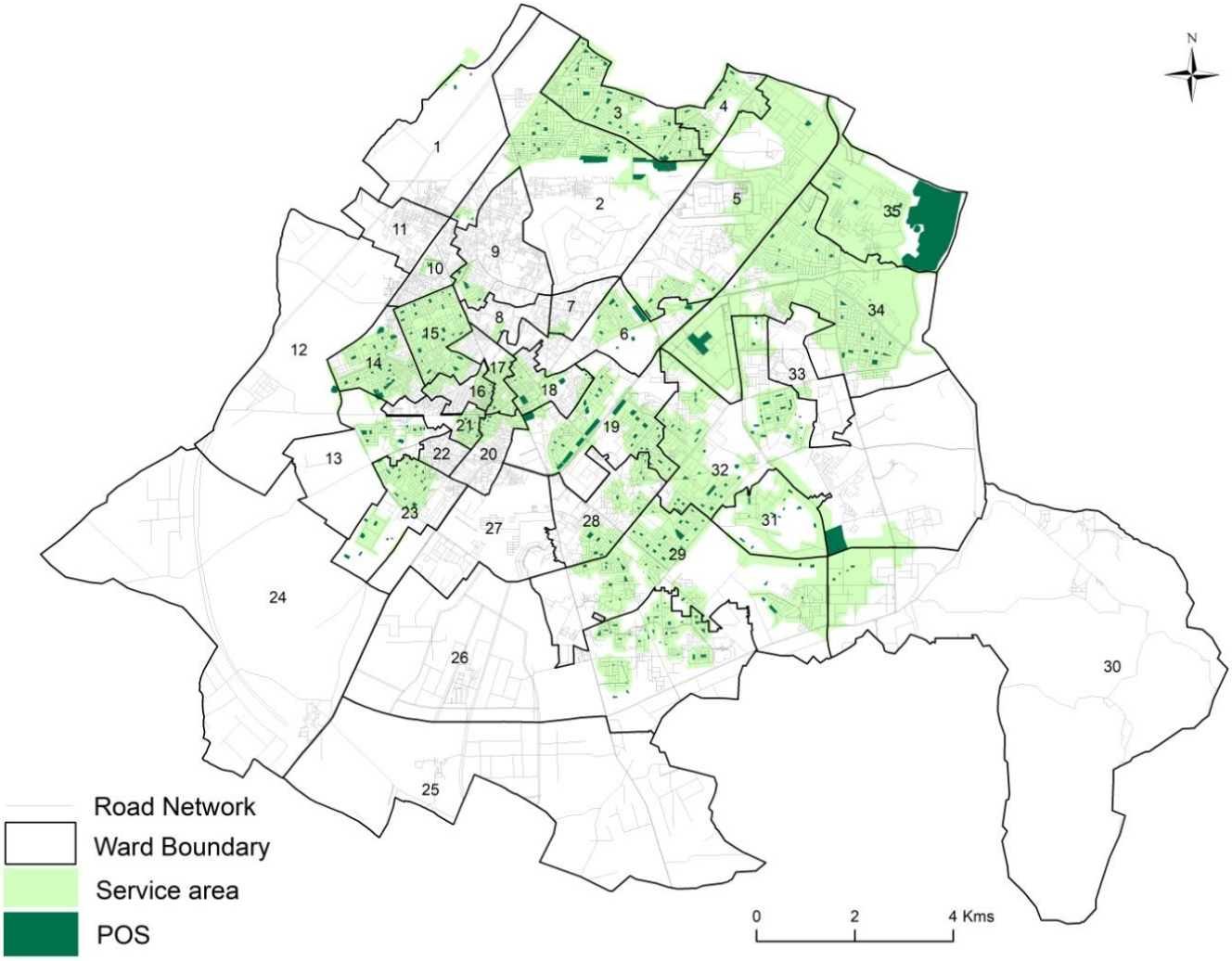


**Figure 4.** Distribution of public open spaces in Gurugram and their service areas.

Once the service areas are computed, they can be used for evaluating accessibility. It is assumed that the population situated within the service area polygons has access to the POS. The service area polygons for each ward are derived by using the 'clip' tool with the administrative layer with ward boundaries and the area is calculated using the 'calculate geometry' tool. The population density of the ward is utilized to estimate the population size that falls within the service area, assuming that the population is spread evenly within the ward boundary. Once the population residing within the service area is calculated, the proportional population having access to POS (accessibility index) is calculated as followsn Equation 2

$$\text{POS Accessibility Index} = \frac{\text{Population within service area}}{\text{Total Population of the ward}} \times 100 \quad (2)$$

The word 'accessibility' denotes the distance traveled from a residential area to the closest recreational POS, which was modeled in GIS through the application of Network Analyst. The result of the accessibility analysis presents data regarding the percentage of the population with access to POS within each ward, as depicted in Figure 5.

POS are most abundant in the wards 3, 14, 15 and 19. These wards also enjoy the highest access to POS. Only 2 wards i.e., 3 and 15 have more than 70% population having access to POS. In

these wards, the distribution of POS is even and they are well-dispersed across the wards. 13 of the 35 wards have less than 10% population with access to POS. Most of these wards have minimal number of POS, either because of extreme population pressure or because they are located the outskirts of the city. It is quite apparent that the size of POS is very small, thus limiting the accessibility.

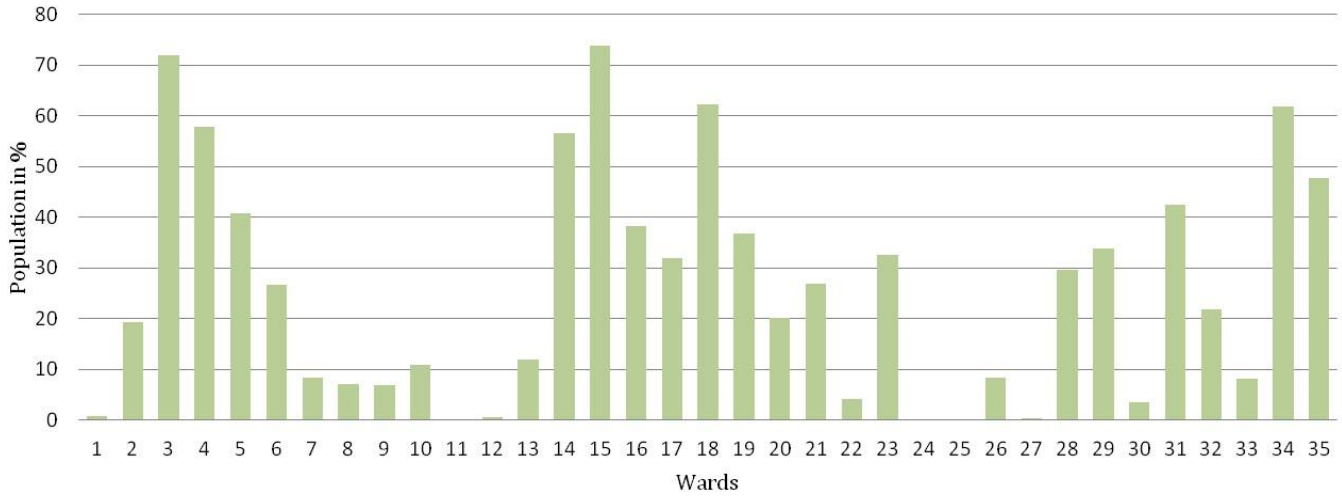


**Figure 5.** Proportional population with access to POS in each ward.

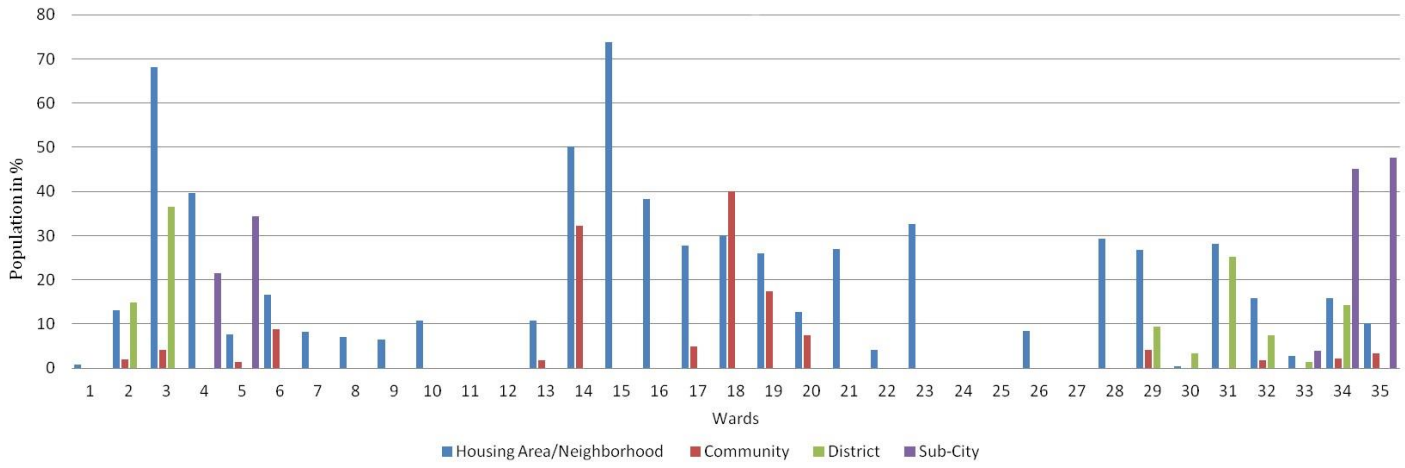


**Figure 6.** Ward-wise proportional population with access to different categories of POS.


**Figure 7.** a) POS Housing area and Neighborhood levels with a service area of 300 m. b) POS Community level with a service area of 500 m.

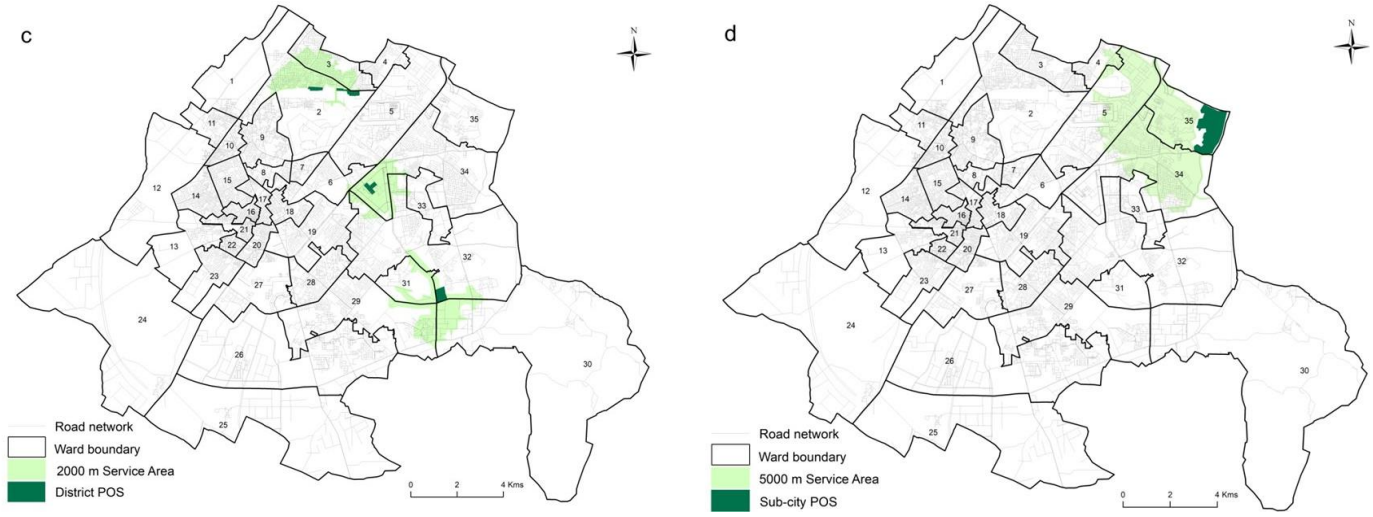


**Figure 7.** c) POS District level with a service area of 2000 m. d) POS Sub-city level with a service area of 5000 m.

In general, it is observed that the northern and north-western parts of the city have good accessibility to POS. However, for the sub-city category of POS, only four wards enjoy accessibility, all located in the north-west of the city. Only people in one ward, i.e., 34 enjoy accessibility to all five categories of POS. In ward 15, more than 70% of the population has access to housing area POS, which is the highest of any ward; however, the people do not have access to any other POS category. Only the outer wards in the western parts of the city, i.e., 11, 12, 24 and 25 have a zero accessibility index. However, these areas also house very little population and are not developed, so they do not fall under the priority areas for intervention. Wards where less than 20% of the population has POS accessibility are causes of concern and require urgent attention. These are located in the central and southern-central parts of the city. It is also to be noted that no ward fulfills the 100% Accessibility Index in any POS category or overall (Figure 5 and Figure 6).

Accessibility to housing area and neighborhood POS is highest among the categories, provided that they are present in most of the wards. However, the World Health Organization recommendation that "all people should reside within 300 m of a green space" (Konijnendijk, 2023) is not realized in any of the wards. From Figure 7a, it can be seen that service areas in the housing area and neighborhood POS categories do not cover the entire city, as they should, according to the above recommendation. Most of the wards are deprived of community POS (Figure 7b) and they are clustered together instead of being adequately spaced and distributed. The uneven distribution of district-size parks further compounds the issue (Figure 7c). Only 8 wards enjoy access to district-level parks, and even within these wards, accessibility is far from exhaustive, leaving a significant portion of the population disconnected from these communal resources. As seen in Figure 7c, two district POS are located very close together, and all of them are found in the north and north-eastern parts of the city. Currently, the city has just one expansive POS at the sub-city level, situated on the outskirts (Figure 7d). This biodiversity park on the far north-eastern side of the city demands lengthy journeys from other city corners, hindering easy accessibility.

## 4. Discussion

This research investigates the availability and accessibility of Public Open Spaces (POS) within Gurugram, a densely populated urban center in India. The approach uses GIS-based network analysis to provide valuable insights into POS accessibility across various hierarchical levels. This methodology aims to inform urban planning and decision-making processes regarding POS allocation by identifying service gaps. Particular focus is placed on identifying areas lacking sufficient POS, which may require targeted interventions.

The analysis reveals significant accessibility challenges at lower hierarchical levels, such as neighborhoods and housing areas, which are crucial for populations with limited mobility, like children and elderly residents. There is a notable correlation between high built-up density and low availability of POS in the central wards that constitute Old Gurugram. Our analysis aligns with previous research by Singh *et al.* (2018) and Kamble *et al.* (2022), demonstrating a clear inverse relationship between built-up density and the availability of open space. In these high-density areas of the study area, developing open space presents significant challenges. Further research is needed to explore specific solutions for incorporating green spaces within these

environments. Our analysis recommends establishing elongated and narrow POS in areas with existing high-density development. This includes areas surrounding NH-8, Sector-23, Sector-14, Sector-3A, Surat Nagar and Rajendra Park. A more integrated and participatory planning approach that can improve the connectivity between POS through greenways and walkable paths is suggested based on the observations.

There is poor availability of POS and most wards of Gurugram city do not meet the URDPFI recommendation for per capita open space. In fact, our analysis reveals a significant shortfall, with Gurugram's average POS per person falling well below the standard. This finding aligns with a broader national trend, as McKinsey & Company's research suggests an average of only 2.7 $m^2$ of open space per resident in Indian cities (McKinsey, 2010). Gurugram reflects this national trend with a mere 3.14 $m^2$ of POS per capita. While the Ministry of Urban Developed has established national open space standards, many urban development authorities haven't adhered to these guidelines. However, some exceptions exist, with cities like Varanasi, Chandigarh, Bhopal, Delhi, and Noida boasting open space proportions exceeding the standards (Singh, 2019). Many studies that analyze the availability of urban green spaces (UGS) in Indian cities are available. But it is necessary to acknowledge that the per capita availability results derived from our study are inherently incomparable to some of these studies, as we exclusively focus on publicly accessible spaces explicitly designed for recreation within our analysis. For a more fitting comparison, other studies examining public urban green spaces in India are scarce. One such study by Lahoti *et al.* (2019) of Nagpur demonstrated a per capita POS availability of 3.65 $m^2$, while another study by Kamble *et al.* (2022) registers Raipur at 1.35 $m^2$ per capita open space.

Gurugram's limited per capita open space likely contributes to a lower quality of life for its residents, as it ranks only 27th out of 111 cities in India on the Ease of Living Index (MoHUA, 2020). The scarcity of open spaces in Gurugram hinders residents from experiencing the numerous health advantages linked to their access. Open spaces provide essential spaces for physical activity, a crucial factor considering that 27 % of the adult population falls short of the World Health Organization's recommended activity levels (WHO, 2022). Furthermore, research suggests that physical activity in open space may offer greater health benefits than similar-intensity indoor exercise, potentially due to the psychological restoration effects of nature (Pretty *et al.*, 2007; Hug *et al.*, 2009). The correlation between the quality of POS and cardiovascular health, as noted by Paquet *et al.* (2013), contributes to a comprehensive understanding of the impact of urban design on public health. Maas *et al.* (2009) showed a link between lower levels of natural open space and feelings of isolation and a lack of social support, even after accounting for social and economic factors. Beyond providing places to gather, green spaces may also foster a sense of community (Francis *et al.*, 2012) and neighborhood cohesion (Wan *et al.*, 2021).

According to the GMDA (Gurugram Metropolitan Development Authority) Act of 2017, the metropolitan authority is mandated to formulate an urban development plan with the objective of reducing pollution levels and enhancing the green cover within the city. Gurugram's high annual average $PM_{2.5}$ concentration, highlighted by Manojkumar and Srimuruganandam (2021), draws attention towards the potential health implications of utilizing open spaces, emphasizing the interplay between urban design and environmental factors. The GMC has taken several steps to build green spaces like parks, playgrounds, and biodiversity parks in the city. In the last few years, the GMC has developed and renovated parks and playgrounds and has also allocated a budget for the development of a second biodiversity park in the city. Therefore, it is recommended that the creation of additional small pocket parks in existing high-density residential areas be carried out. It should also be ensured that these parks are well-designed to host small-scale cultural events and festivities. This could involve partnering up with local businesses to sponsor events and building lively community hubs in public open spaces.

## 5.1 Strengths, Limitations and Future Directions

The present study is valuable in its exploration of the availability and accessibility of POS in Gurugram. Service area analysis applied in the study proves to be an optimal method for measuring accessibility to green spaces. The method can be replicated in other regions for a more accurate description of accessibility. The study also emphasizes the need for studying different POS hierarchies (housing area, neighborhood categories etc.) individually in future research, as deficiencies may exist in only one category. Without the comprehensive availability analysis of different categories, it is difficult to estimate which hierarchy of POS is lacking and where timely intervention is needed.

Certain limitations of the study also warrant consideration. Firstly, the study overlooks the usability of POS in terms of quality, safety, and overall appeal—a critical aspect of accessibility

highlighted by previous research emphasizing the impact of quality on well-being (Nasution & Zahrah, 2018; McEachan *et al.*, 2018). While studies like Phillips *et al.* (2023) and Dony *et al.* (2015) have underscored the importance of quality in park visitation and incorporated the aspect of quality in quantifying access, the current study **omits** this dimension. Furthermore, the network analysis approach also hinges on a binary classification of either having or not having access to POS, overlooking factors like individuals willingly traveling large distances to access POS, thus neglecting a systematic examination of the attractiveness and accessibility of these spaces.

Given that visitors to POS in Gurugram belong to different income demographics, it becomes crucial to extend this research by exploring the perceptions of low to upper income individuals regarding both public and privatized open spaces. The potential influence of the socioeconomic status of neighborhoods on POS distribution has been extensively studied by Comber *et al.* (2008) and Shen *et al.* (2017), which could also be examined in Gurugram. This approach will contribute to a more lucid and inclusive depiction of varied perceptions across different economic statuses. The study emphasizes the need for extensive and localized research on green space accessibility and availability. By conducting frequent and updated assessments, researchers can aid the policy-makers in identifying areas with the greatest disparities and prioritizing interventions. Additionally, monitoring of ongoing green space initiatives allows for evaluation of their effectiveness and public reception, ensuring resource allocation is optimized for maximum community benefit. Researchers ought to identify the optimal levels of POS to realize social, ecological and health benefits and explore how its provision interacts with other recreation and leisure promoting amenities in the city.

## 6. Conclusion

Our examination of public open spaces in Gurugram reveals a contrasting landscape marked by stark disparities. As products of public investment, POS are expected to be equalizers, benefiting people across diverse socio-economic backgrounds. The intrinsic value placed on these shared spaces lies in their accessibility to everyone, regardless of financial standing, promoting a sense of inclusivity and community. However, our findings highlight significant challenges to this ideal. Gurugram fails to provide adequate POS to its residents as specified by national standards. The per capita availability of POS in the city is 3.14 $m^2$, with some wards having no available POS. The central wards of Old Gurugram exhibit a correlation between high built-up density and low availability of POS. The city also has a deficit in the number of neighborhood and housing area level POS. Majority of the wards of the city are left unserviced, and the population with access to POS is below 50% in 29 wards. This low accessibility index indicated that people have to travel long distances to reach a POS. These challenges collectively contribute to spatial injustice, depriving certain individuals of the desired experiences within POS. This disparity raises questions about the equitable distribution and democratization of urban spaces. The findings from this assessment can inform local authorities about the dire need to fulfill the recreational needs of the residents. The study calls for targeted goals that enhance accessibility to be set in the underserved areas, alongside a focus on creating new open spaces. This step can mitigate the adverse impacts associated with dense housing, i.e., a lack of physical activity and communal engagement. In conclusion, as Gurugram navigates the inadequate provision and distribution of its POS, addressing the challenges associated with sustainable urban development and raising the quality of life become important. Moreover, the study concludes that using GIS to illustrate both availability and accessibility results facilitates clear communication of the findings.

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**Conflict of interest**

The authors have no conflicts of interest to declare.

**Data availability**

The authors confirm that the data supporting the findings of this study are available within the article.

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