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# Multi-level Accessibility Analysis of Hyderabad City Using GIS-based Network Evaluation

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ABSTRACT

Transportation accessibility plays a pivotal role in transport geography, serving as a critical indicator of mobility for both people and goods. High levels of accessibility reflect a well-developed urban environment with fewer transportation challenges. In this study, Geographic Information Systems (GISs) are employed to conduct a comprehensive network analysis of accessibility across various zones in Hyderabad city, Telangana, India. Using a city-wide methodology for evaluating urban service availability and distance-based accessibility, the study incorporates a weighted scoring model. This model assigns varying weights to different urban services based on their relative importance, enabling a nuanced accessibility analysis. The study assesses accessibility at three distinct spatial scales: Macro-level Cluster Zones, Meso-level Strategic Zones, and Micro-level Traffic Analysis Zones (TAZs). By analyzing accessibility at these scales, the study offers a detailed and layered understanding of how different locations in Hyderabad perform in terms of access to essential services and opportunities. The results provide valuable insights for urban planners and decision-makers, helping them identify areas where accessibility can be improved, thus supporting more equitable and efficient urban development.

***Keywords:*** Weighted scoring model, Macro-level cluster zones, Meso-level strategic zones, Micro-level traffic analysis zones (TAZs), Accessibility analysis.

## INTRODUCTION

Accessibility has varied definitions, one of which refers to the capacity of a location to be reached by or to reach different locations from a place. Accessibility is the people's all-inclusive ability to achieve desired services to perform their daily activities, and consequently, it accounts for the time and wealth that people and businesses devote to transportation. The concept of accessibility depends on two main elements: the location, where the relativity of space is evaluated concerning the transport framework, and the means to support movements. Therefore, the capacity of a location and the transport framework are prominent constituents for accessibility evaluation.

Accessibility is a fundamental concept in urban planning, significantly affecting how individuals and businesses interact with their surroundings to access services, employment, and other opportunities. While there has been extensive research on accessibility, several gaps remain, particularly regarding the methodologies employed to assess it in complex urban contexts. Traditional approaches often depend on aggregate data that fails to capture the nuanced experiences of diverse populations within a city. This can result in skewed interpretations, especially in cities experiencing rapid urbanization and socio-economic diversity, like Hyderabad, India, where disparities in access to urban services can be pronounced.

Moreover, the potential of Geographic Information System (GIS)-based methods for assessing accessibility remains under-explored. GIS offers advanced tools for spatial analysis, yet many studies have not fully utilized its capabilities to generate detailed, localized, and multi-scale indicators of accessibility. This research seeks to address these limitations by implementing a GIS-based framework to analyze accessibility in Hyderabad. The study aims to disaggregate accessibility at multiple levels-macro, meso, and micro-to offer a more comprehensive understanding of access to urban services across different zones. Furthermore, it seeks to determine the quantity and distribution of opportunities required to improve accessibility in areas currently lacking services, thereby providing valuable insights for urban planners and policy-makers.

The concept of accessibility is central to urban transportation planning, focusing on the ease with which people can access essential destinations from their locations. Handy and Niemeier (1997) identified factors, such as travel costs, destination choice, and travel mode, as key determinants of accessibility. They emphasized that a better understanding of land use patterns and the disaggregation of accessibility measures by activity type are crucial for effective analysis. Similarly, Folkesson et al. (1998) critiqued traditional zone-based methods and proposed a more accurate individual-centered approach, treating both residents and opportunities as point patterns. This method addresses the issue that aggregate measures often overlook important details, thus providing a more realistic representation of accessibility.

Spatial analysis and network analysis techniques have become increasingly popular in accessibility research. For example, Montis et al. (2011) incorporated Spatial Complex Network Analysis (CNA) to develop two distinct accessibility indices. Their findings suggested a strong relationship between economic performance and accessibility, particularly in municipalities with national road connections. Similarly, Hu Weiping and Wu Chi (2014) used GIS techniques to assess accessibility in urban road networks, discovering that areas with greater opportunities tended to have higher accessibility levels. Ronghua and Feibiao (2011) evaluated the accessibility of rail networks using indicators, such as travel time and network distance, to measure spatial separations between cities.

In the realm of network analysis, Aman Arora et al. (2011) employed GIS-based tools, such as Network Analyst, to assess the shortest routes from accident sites to hospitals, and compared the accessibility of ATMs across different banks. Likewise, Andre Tome et al. (2019) expanded a GIS-based approach to assess the accessibility of community services in medium-sized cities, calculating travel times and determining access levels for public transport.

Other studies have integrated hybrid methodologies to enhance accessibility assessments. Bounaceur et al. (2022) applied a fuzzy classification approach within GIS to assess road network vulnerability, categorizing accessibility into different levels based on structural and functional factors. Zhao et al. (2023) used a multi-criteria GIS-based method to examine accessibility in a mid-sized Chinese city, considering factors, such as proximity to public services and socio-economic characteristics. Meanwhile, Lee and Heo (2023) focused on evaluating the accessibility of green spaces in Seoul, South Korea, using network-based methods to calculate travel times from residential areas to parks. Similarly, Singh and Sharma (2023) assessed healthcare service accessibility in an Indian metropolitan area, identifying healthcare deserts based on travel time analysis.

Additionally, some studies have adopted a combined approach using GIS and remote sensing to analyze accessibility across different socio-economic groups. Chen et al. (2024) used this hybrid method to assess accessibility in a rapidly growing metropolitan area, revealing variations in accessibility across income levels and highlighting areas in need of targeted infrastructure improvements.

Building on these diverse methodologies, the current study focuses on assessing the accessibility of Hyderabad city. The study classifies traffic analysis zones into three levels: Macro (Cluster Zones), Meso (Strategic/Forecast Zones), and Micro (Detailed Traffic Analysis Zones). It aims to evaluate the accessibility of each zone based on urban services and determine the number of services required to improve accessibility in low-accessibility areas. This approach will provide valuable insights into the distribution of urban services and assist in targeted infrastructure development.

## METHODOLOGY

Hyderabad city is chosen for the accessibility analysis. The data of the city required for the analysis is collected and also the number of opportunities (or) urban services, like schools, hospitals, colleges, ATMs, theatres, bus stops, parks, police stations, petrol bunks, and banks in the city area, are collected, imported into the ArcGIS software and analysed. The opportunity index of the zones is calculated using a weighted scoring model and compared with the minimum opportunity index for the zones, respectively, and conclusions are then drawn. The methodology followed for the study is represented in the flow chart shown in Figure (1).

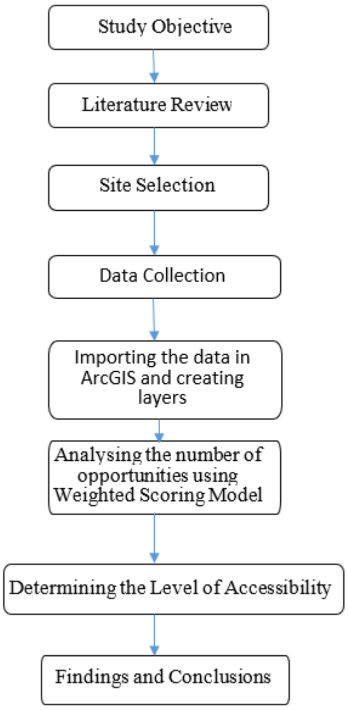



**Figure (1): Flow chart of study methodology**

### Study Area and Data Collection

As accessibility measures the ease of reaching destinations or activities distributed in a place, it accounts for enhancing land use and attaining sustainability in the transportation system. Therefore, it is essential to assess and analyze accessibility. In that process, a study area is chosen, and the data required is collected and used to analyze accessibility.

### Site Selection

Hyderabad city, one of the fast-developing cities where accessibility becomes an integral part of urban planning, is chosen as the study area. The location of the study area is shown in Figure (2).

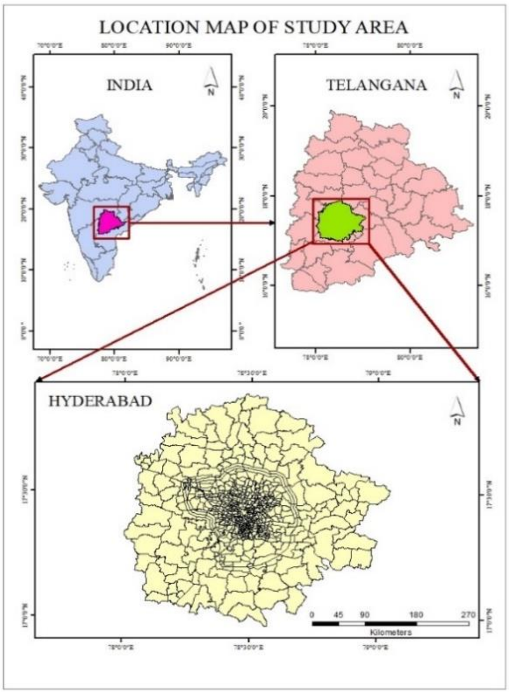



**Figure (2): Location map of study area (source: diva-gis.org)**

### Zoning System of Hyderabad

Hyderabad city is divided into zones in three categories. The zoning system classifies the city into traffic analysis zones. These zones are used for modeling purposes, and the zoning system includes aggregating households and surroundings into manageable localities. The size of the zones plays a notable role in capturing the travel patterns in those areas. The more the number of zones, the smaller the area of the zones would be, therefore providing a better picture of the travel patterns of the zones and *vice versa*. It is noted from the literature that all the properties and attributes are assumed to be concentrated at a single point, and the point is termed as "zonal centroid," and this assumption could be used for modeling purposes.

As mentioned below, three different traffic analysis zoning schemes have been developed to analyze travel patterns and travel demand modeling (Source: Comprehensive Transportation Study Report, HMA, 2013):

i. Micro-lvel: Detailed Traffic Analysis Zones (TAZs)-695,

ii. Meso-level: Strategic/Forecast Analysis Zones (FAZs)-193, and
iii. Macro-level: Cluster Zones-21.

**Macro-level: Cluster Zones**

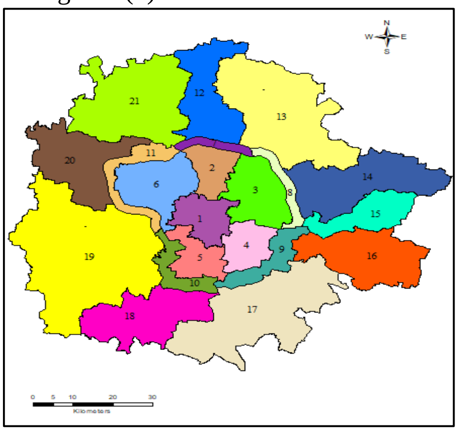
The city is divided into 21 cluster zones. This aggregate-level classification is made such that it assists in broad understanding and judgment of various planning parameters. HMDA divided the whole HMA on potential growth and investment initiatives, and the clusters are shown in Figure 3 (a).

**Meso-level: Strategic/Forecast Analysis Zones**

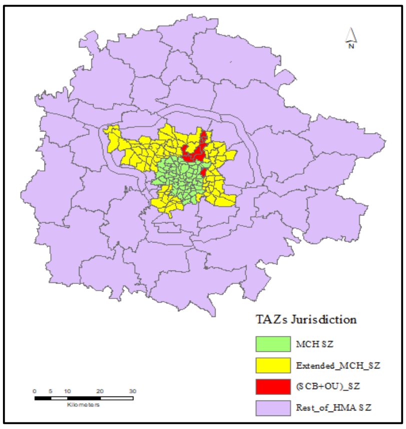
The city is divided into 193 strategic zones (SZs). They are also called Forecast Analysis Zones (FAZs). These are classified to assist in policy decisions for the zones; i.e., the zones are classified with relatively larger areas than the detailed TAZs. These are useful in strategic modeling. The FAZs and the classification are shown in Figure 3(b).

**Micro-level: Detailed Traffic Analysis Zones**

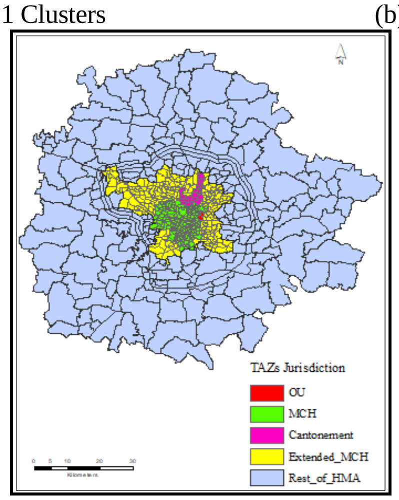
The city is divided into 695 detailed traffic analysis zones (TAZs). The zones are classified as shown in Figure 3(c). These zones are divided mainly for assisting in purposes like modeling. The smaller the areas of zones (micro-level), the better the picture of travel patterns. The zones' boundaries were made such that they align with census and administrative boundaries. Therefore, the zones would assist in capturing the socio-economic data of the city. The zones were classified such that each zone, on average, contained a population value between 20,000 and 30,000. The literature noted that the zones were classified so that any detailed TAZ population value did not exceed 50,000. The main areas within the HMA (Hyderabad Metropolitan Area) were relatively delicately zoned to account for good modeling of traffic movements. Codes were allotted to each TAZ in order to ensure uniqueness and make identification of TAZs easy.




(a) Dividing area into 21 Clusters




(b) Strategic 193 FAZs




(c) Detailed 695 TAZs

**Figure (3): A function map of Hyderabad**

The methodology adapted in the study can be applied to any city by adjusting the weights for urban services according to local priorities, making it adaptable to different urban structures. Cities with uneven resource distribution can use the methodology to identify gaps and allocate resources more efficiently to under-served areas. The zoning system can be modified based on the city's size and complexity, whether it's a large metropolitan area or a smaller town. The methodology can also be tailored for cities with different demographic profiles by focusing on services, like healthcare or education, depending on the city's needs. It is scalable and can be used in both small and large cities, with the flexibility to start with simpler data and improve as more detailed information becomes available.

**Data Collection**

Besides the data regarding the study area – its location, zoning systems of the study area, there is a need for urban opportunities or urban services for the analysis. The opportunities, such as schools, hospitals, colleges, ATMs, theatres, bus stops, parks, police stations, petrol bunks, and banks, being the primary urban services, are considered for the analysis. The maps showing the locations of schools are shown in Figure (4) as a sample for collection of different opportunities. Similarly, all types of opportunities are located and represented in the maps for further analysis. The detailed description of data sources, data collection, and pre-processing methods is discussed in the following sub-sections.

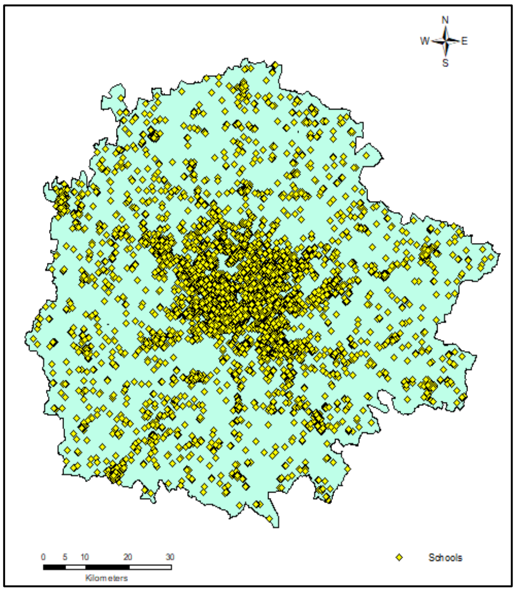



**Figure (4): Map showing schools in Hyderabad**

**Data Sources**

**Urban Service Data**: Information on schools, hospitals, ATMs, bus stops, and other urban services was collected from Hyderabad Metropolitan Development Authority (HMDA) reports, municipal records, and supplementary data from OpenStreetMap (OSM) like Google Earth, … etc.

**Demographic Data**: Population statistics and socio-economic data have been sourced from the Census of India and the Telangana State Statistical Abstract to understand distribution across different zones.

**Geospatial Data**: Maps, shapefiles, and administrative boundaries were obtained from HMDA's Comprehensive Transportation Study and GIS databases, forming the basis for spatial analysis.

**Types of Data**

There are two types of data:

a) **Spatial Data**: Locations of urban services were collected, verified, and geo-referenced using ArcGIS software. Each service type was mapped to visualize distribution patterns.
b) **Attribute Data**: Supplementary attributes, such as service capacities and coverage areas, were gathered from official documents and local surveys to enrich the spatial dataset.

**Data Pre-processing**

The processing of the present data went through the following steps:

1) **Data Cleaning**: Removing duplicates, correcting errors, and standardizing entries to ensure data consistency.
2) **Geo-coding**: Converting address data into precise geographic coordinates using ArcGIS for accurate mapping.
3) **Zonal Classification**: The city was divided into three levels—Macro (Cluster), Meso (Strategic/ Forecast), and Micro (Detailed TAZs). Zonal boundaries were aligned with administrative and census divisions for consistency.
4) **Weighted Scoring Model**: A weighted scoring model was applied to calculate the Opportunity Index (OI) for each zone, reflecting accessibility based on a pre-determined weighting of urban services.

### Limitations of the Data Collected

The data used in this study has some limitations that could influence the results. Firstly, some data on smaller or informal services may be incomplete or unavailable, potentially leading to an under-estimation of accessibility in certain areas. Additionally, the data represents a specific time frame, which may not capture recent urban developments, infrastructure changes, or shifts in service availability. Another limitation arises from the subjective nature of the weight assignment in the Opportunity Index, as the weights were determined based on past literature and expert judgment. If the importance of certain services is not accurately reflected, this could affect the overall assessment of accessibility. Despite these challenges, efforts were made to minimize their impacts and ensure the reliability of the analysis.

### Data Analysis

The results of this work are presented in the following sub-sections.

### Accessibility Analysis

Schools, hospitals, colleges, ATMs, theatres, bus stops, parks, police stations, petrol bunks, and banks are the opportunities considered for the analysis. ArcGIS 10.3 software was used for getting the values of opportunities for each zone from the absolute values of the opportunities from the data collected for the entire Hyderabad city. The process is repeated with each opportunity type for the 21 clusters. Similarly, the procedure is carried out for the 193 strategic level zones for all the opportunities and the 695 detailed level traffic analysis zones (TAZs). These values are analyzed using the weighted scoring model.

### Weighted Scoring Model for Opportunity Index

Weighted scoring model (WSM) is a tool that provides a systematic process for prioritizing requirements based on several criteria. This method helps rank the requirements while prioritizing them according to a pre-determined scale. It provides a balance in determining the priority of the requirements. Percentages (scores) are assigned to the ten opportunities, as per their importance, as shown in Figure (5).

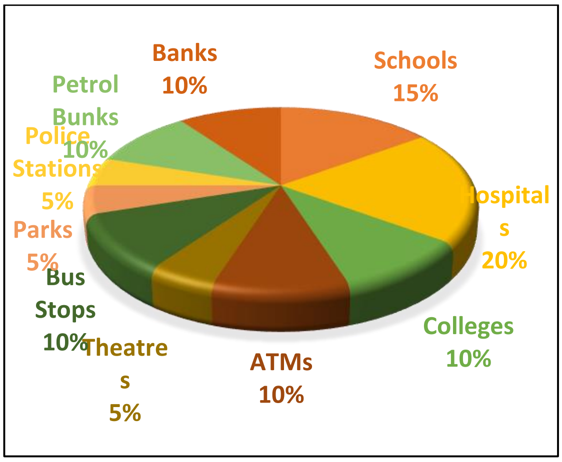



**Figure (5): Weights assigned to the opportunities (source: Sahitya, K. S. et al.)**

In this study, weights were carefully assigned to various urban services based on their significance to accessibility, reflecting a prioritization that aligns with the practical needs of urban residents. The weighting strategy prioritizes essential services to ensure a comprehensive and relevant accessibility analysis.

The assignment of weights follows a structured approach:

- **First Preference:** Emergency services (e.g. hospitals) are given the highest priority. These services are crucial for immediate and urgent needs, making them the most significant contributors to accessibility.
- **Second Preference:** Educational facilities (e.g. schools, colleges) are ranked next in importance, reflecting their critical role in supporting long-term societal and individual development.
- **Third Preference:** Infrastructure (e.g. ATMs, banks, police stations, public transport stops) focuses on facilitating day-to-day convenience and economic activities, playing a significant role in enhancing the overall urban mobility and functionality.
- **Fourth Preference:** Recreational services (e.g. parks, theatres) are considered last. While not essential for emergency or daily needs, they contribute to the quality of life, social well-being, and sustainability.

The choice of weights is informed by a thorough review of past research and literature. Studies such as Sahitya and Prasad (2020) and Modinpuroju, Prasad and Chandra (2016) highlighted the critical factors influencing accessibility in urban environments. These studies suggest that prioritizing emergency and educational services is a common and effective strategy in urban accessibility planning. The prioritization framework used in this study aligns with these established guidelines, ensuring that the analysis is based on empirical research and best practices.

By adopting this weight structure, the methodology aims to provide a realistic and practical assessment of accessibility, focusing on services that have the greatest impact on residents' well-being and urban mobility.

The formula used for determining Opportunity Index (OI) is:

Opportunity Index = (0.15 x Schools) + (0.2 x Hospitals) + (0.1 x Colleges) + (0.1 x ATMs) + (0.05 x Theatres) + (0.1 x Bus Stops) + (0.05 x Parks) + (0.05 x Police Stations) + (0.1 x Petrol Bunks) + (0.1 x Banks).

The values mentioned in the formula above are the weights assigned to the respective opportunity type. Each type of opportunity in a zone is multiplied by the weight allotted to the respective opportunity. All such values are then added. This summation value is the Opportunity index (OI). This procedure is repeated for all the opportunities at all three levels of zoning classification. Therefore, now the weighted scores of each opportunity of each zone of all the three zoning systems are calculated and the findings indicated that the analysis of the Opportunity Index at the levels of Cluster, Forecast Area Zones (FAZs), and Traffic Analysis Zones (TAZs) reveals significant disparities in accessibility and opportunity distribution across Hyderabad. At the Cluster level, Cluster 1 stands out with the highest Opportunity Index (4,953), indicating exceptional access to services, resources, and economic prospects, likely a key commercial or economic hub, while Clusters 7, 8, and 15 exhibit notably low indices, signalling underdeveloped regions with restricted access. The FAZ level reflects similar patterns, with high Opportunity Index scores in areas like FAZ 105 (363) and FAZ 180 (334), indicating major business districts, while FAZ like 124 and 54, with scores as low as 3, point to areas with limited opportunities. At the TAZ level, areas such as TAZ 513 and TAZ 688 exhibit higher scores (191 and 193), indicating better access to services and infrastructure, while others, like TAZ 8 and TAZ 53, show a score of 0, indicating severe limitations in opportunity and accessibility.

**Minimum Opportunity Index**

The calculated weighted scores, termed Opportunity Index (OI) values, are compared with Minimum Opportunity Index (MOI) values. The same weighted scoring model calculates MOI, but the number of opportunities considered in the calculation is taken based on the minimum number of opportunities required for the 1,00,000 population. These standards are obtained from National Building Code (NBC, Part-3), Urban Development Plans Formulations and Implementations (UDPFL 1996) Guidelines, and Urban and Regional Development Plan Formulations and Implementations (URDPFI 2014) guidelines issued by the Ministry of Urban Development and Housing, Govt. of India. Recommended minimum numbers of opportunities are presented in Table 1.

**Table 1. Minimum number of opportunities for 1,00,000 population**

| Opportunity | Minimum number of opportunities for 1,00,000 population | Opportunity | Minimum number of opportunities for 1,00,000 population |
|---|---|---|---|
| Schools (S) | 4 | Bus Stops (BS) | 3 |
| Hospitals (H) | 17 | Parks | 28 |
| Colleges (C) | 2 | Police Stations (PS) | 3 |
| ATMs | 8 | Petrol Bunks (PB) | 3 |
| Theatres (TH) | 1 | Banks | 8 |

(Source: NBC - Part-3, UDPFL 1996, URDPFI 2014 issued by MoUD&H, GOI).

The analysis of the Minimum Opportunity Index (MOI), based on population across Clusters, Strategic Zones (SZs) and Traffic Analysis Zones (TAZs), highlights disparities in access to urban services and amenities in Hyderabad. At the Cluster level, larger populations, such as Cluster 1 (3,768,716 populations, MOI 273), benefit from a high concentration of infrastructure, including schools, hospitals, and bus stations, while smaller clusters, like Cluster 7 and Cluster 8 (populations 17,932 and 30,218, MOI 2 and 3), have limited amenities and services. Similarly, in SZs, larger zones, such as SZ 127 and SZ 135 (populations over 114,000, MOI 10), exhibit enhanced access to services, while smaller zones, like SZ 133 (population 4,244, MOI 1) are under-served. A similar pattern is seen at the TAZ level, where zones with larger populations, such as TAZ 617 and TAZ 688 (populations around 48,000, MOI 4), enjoy better access to opportunities, while smaller zones, like TAZ 607 (population 5,290, MOI 1), experience limited services. Zones with zero population exhibit a MOI of 0, indicating undeveloped areas, while mid-sized zones show moderate MOIs, suggesting the need for further improvements in service accessibility.

**Calculation Process for Opportunity Index and Minimum Opportunity Index**

The Opportunity Index (OI) calculation process utilizes a weighted scoring model to assess the accessibility of urban services across different zones in Hyderabad. Each type of opportunity-such as schools, hospitals, and ATMs—is assigned a weight based on its significance to accessibility. For example, hospitals are given a weight of 0.20, while schools have a weight of 0.15. The number of each opportunity type within a zone is multiplied by its respective weight, and the results are summed to derive the OI for that zone. This process is repeated across various zoning levels, including Cluster, Strategic Zones (FAZs), and Traffic Analysis Zones (TAZs), allowing for a detailed analysis of service distribution and accessibility disparities.

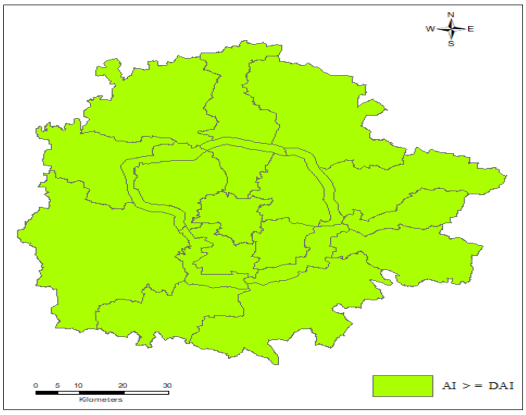
The Minimum Opportunity Index (MOI) calculation similarly employs the weighted scoring model, but based on minimum service standards recommended for a population of 100,000, as per guidelines from sources, like the National Building Code (NBC) and URDPFI. The MOI uses the same weights as the OI, but applies the minimum number of required services for each category. The resulting MOI values are then compared to the OI of each zone to identify gaps in accessibility. A zone where the OI is lower than the MOI indicates a need for additional services to meet accessibility standards, highlighting areas for targeted urban development and infrastructure investment.

**Comparison of Opportunity Index and Minimum Opportunity Index**

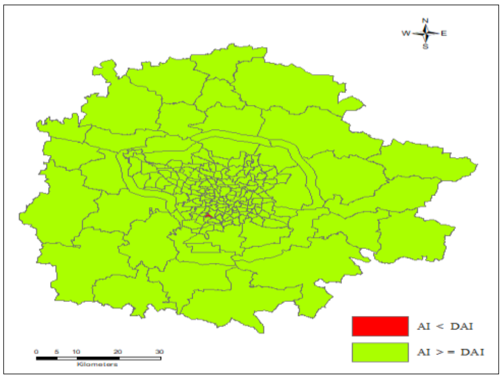
A comparison of the Opportunity Index and Minimum Opportunity Index is made, and the zones with OI less than MOI are identified. The minimum opportunity index of clusters is shown in Figure 6(a). The comparison of OI and MOI for FAZs is presented in Figure 6(b). Similarly, the MOI of TAZs is given in Figure 6(c). The comparison of the Opportunity Index (OI) and Minimum Opportunity Index (MOI) reveals critical insights into service accessibility across zones in Hyderabad. At the cluster level, no zones have OI<MOI, indicating effective large-scale urban planning. At the FAZ level, only 1 out of 193 zones has OI<MOI, suggesting mostly adequate service provision, with the exception likely due to transitional land use or connectivity issues. At the TAZ level, 34 out of 695 zones have OI<MOI, highlighting localized gaps, particularly in peripheral or densely populated areas, where services lag behind demand. Figures 6(a-c) depict these patterns, emphasizing that while clusters and most FAZs are well-serviced, specific TAZs require targeted interventions. Addressing these deficiencies through improved infrastructure, connectivity, and resource allocation will enhance urban equity and inclusivity.

**Table 2. TAZs with OI < MOI within MCH**

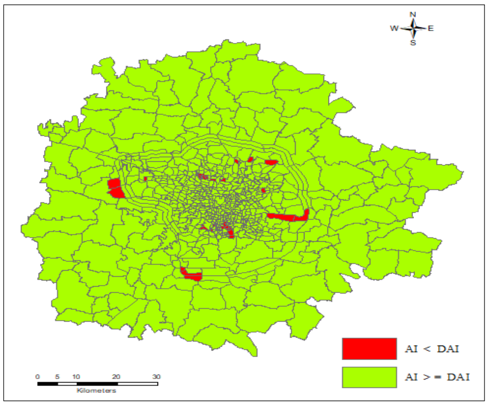
| S. No. | TAZ No. | S. No. | TAZ No. |
|---|---|---|---|
| **1** | 7 | **8** | 43 |
| **2** | 8 | **9** | 46 |
| **3** | 9 | **10** | 53 |
| **4** | 11 | **11** | 55 |
| **5** | 21 | **12** | 56 |
| **6** | 22 | **13** | 67 |
| **7** | 24 | **14** | 71 |




(a) Minimum OI of Clusters




(b) Minimum OI of FAZs




(c) Minimum OI of TAZs

**Figure (6): Maps comparing opportunity index (OI) to MOI**

## CONCLUSIONS

The study highlights the importance of evaluating the Opportunity Index (OI) and Minimum Opportunity Index (MOI) to identify zones with inadequate accessibility, offering valuable insights for urban planning. It was found that smaller zones, like TAZs, provide a more accurate reflection of travel patterns, with increased zoning granularity improving the understanding of accessibility gaps. The research revealed that parks are more deficient in the city than other amenities, emphasizing the need for more green spaces in under-served areas to enhance residents' quality of life. Specific zones, including TAZ No. 43, were identified as needing additional parks. The Municipal Corporation of Hyderabad (MCH), despite being the core area, exhibited significant accessibility deficits, with 14 TAZs requiring urgent attention. The deficit opportunities at TAZ level are presented in Figure (7). The zones with Opportunity Index less than Minimum Opportunity Index are presented in Figure (8). The study recommends more targeted urban-planning policies for high-density areas to address these gaps. Limitations include focusing on only ten opportunities and subjective weighting of priorities. Future research could expand to include additional opportunities, like offices, supermarkets, and public transport, as well as incorporating road-network data to better understand accessibility and congestion. Research could also explore how accessibility varies across different times, aiding in flexible urban planning.

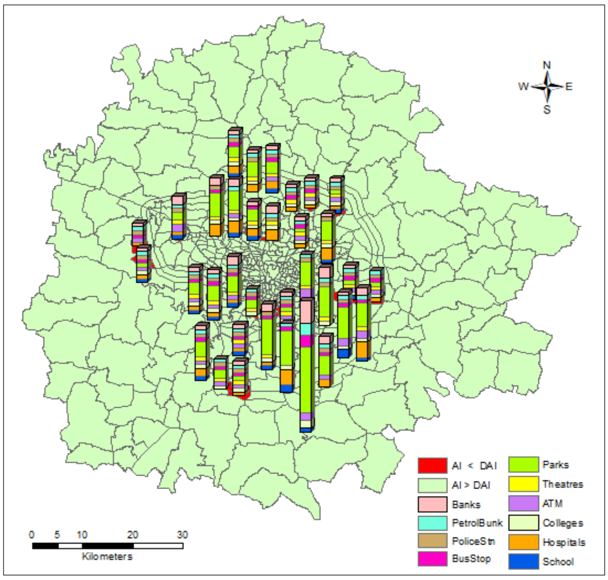



**Figure (7): Pictorial presentation of deficit opportunities at TAZ level**

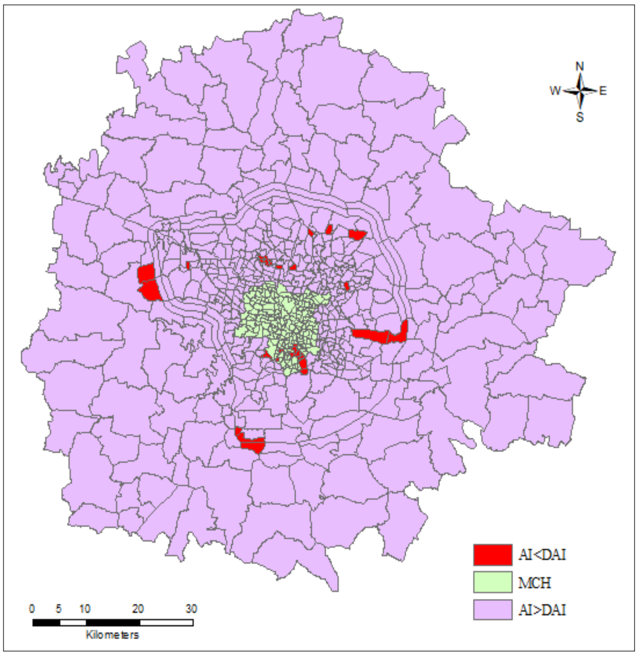



**Figure (8): Map showing zones with OI < MOI within MCH**

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