

# Population Carrying Capacity in Urban Areas

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**Abstract** - Considering the mounting pressure on Indian cities to expand sustainably, The Population Carrying Capacity of an Urban Area examines this idea. The goal of the study is to estimate the carrying capacity of urban areas for population growth as well as the limit of environmental pressure caused by urban activity. The framework of study involves the evaluation of environmental thresholds, land capabilities, and urban development indicators to quantify supply and demand for resources, which ultimately affects population quality of life. The findings emphasize the criticality of resource provision for human needs and the necessity for effective management to achieve better results. The assessment framework provides a comprehensive analysis of various dimensions, guiding the prioritization of sectors for development and spatially identifying potential areas for improvement. Overall, the study underscores the significance of sustainable urban development and resource management in addressing the challenges of population carrying capacity and ensuring the quality of life in urban areas.

**Key Words:** Population carrying capacity, Sustainable urban development, Urbanization, Environmental pressure, Resource management, Quality of life, Urban development indicators, Environment thresholds, Land capability analysis, Indian cities.

## 1. INTRODUCTION

Indian cities face immense pressure due to urbanization that has exceeded previous projections. Planning for sustainable city development is crucial. Sustainability principles dictate that the environment has limits on accommodating population growth. To ensure cities' sustainable development, understanding the environment's capacity to handle urban activities is vital. This necessitates determining the "Population Carrying Capacity of Urban Areas," defined as the land's ability to support population growth within defined thresholds, promoting a high quality of life.

The Population Carrying Capacity relies on available resources meeting population demands, ultimately affecting people's Quality of Life. Establishing a framework to gauge resource demand, supply, and its impact on the population's quality of life is essential. Quality of Life in cities hinges on dynamic urban development indicators, land capability, and environmental thresholds. Urban development indicators encompass aspects like Safety, Health, Education, Recreation, Housing, Equity, Natural Environment, Infrastructure, Transportation, and Governance. Environmental thresholds include Water, Air quality (including GHG emissions), Disaster resilience, and biological aspects. Land capability involves analyzing spatial resources to support the population.

By combining analysis of urban development indicators, environmental thresholds, and land capability, it yields quantitative data highlighting sector-specific deficiencies and spatial information indicating potential development areas. This guides prioritization of sectors for development and spatially directs developmental focus.

## 2. Urban areas and their significance

India experienced a monumental shift in its population dynamics since 2011, with a 31.1% urbanization rate and a total population of 1.21 billion. Despite relatively low urbanization, India's urban populace constitutes a significant 11% of the global urban population, surpassing highly urbanized regions like the US, Japan, Western Europe, and South America. Forecasts indicate that by 2027, India will surpass China as the most populous nation. The surge in urban growth is anticipated to account for 73% of the overall population increase between 2011 and 2036, with projections suggesting an additional 416 million urban residents by 2050, making India 50% urban.

This profound urbanization wave is transforming rural areas into quasi-urban settlements, placing immense strain on infrastructure, and grappling with challenges posed by climate change and poverty. The Ministry of Finance highlights a notable upsurge in urban poverty levels. If not properly planned, this unregulated development could potentially have adverse effects on society, the economy, and the environment.

With urbanization accounting for almost 60% of GDP, India's economy is largely driven by this phenomenon. However, when it comes to utilizing urbanization's potential to increase per capita GDP, India lags other significant Asian economies. Unrealized economies of scale have the potential to occur, necessitating efficient interventions in domains like governance, urban land markets, and urban and spatial planning. In alignment with global commitments like the UN's Sustainable Development Goals (SDGs) 2030, India aims to create inclusive, safe, resilient, and sustainable cities. The New Urban Agenda, which emphasizes participatory and integrated urban planning, acts as an accelerator for SDG 11. India's commitments under the Paris Agreement to reduce emission intensity significantly rely on the effective urban planning of its cities.

India's economic objectives include reaching a \$5 trillion GDP by 2024, creating a significant amount of jobs, particularly in cities, building infrastructure such as industrial corridors, and launching environmental protection projects. Achieving these goals, promoting sustainable development, and reducing the negative effects of urbanization all depend heavily on strategic spatial planning. The National Infrastructure Pipeline (NIP) aims to invest Rs 111 lakh crore between 2020-25, with a substantial 17% allocated to the urban sector. This underscores the urgent need for robust, resilient, and equitable urban infrastructure to support economic growth and human well-being.

Various government schemes—such as the Smart Cities Mission, FAME Scheme for electric mobility, and the concept of developing 'Green Cities'—emphasize the necessity for a multi-sectoral approach in spatial planning. However, coordination between different government departments and local levels remains a challenge, necessitating stronger urban planning ecosystems.

The 15th Finance Commission underscores cities as drivers of economic growth and adopts a differentiated approach in

allocating grants to Urban Local Bodies (ULBs). Effectively managing the transition from rural to urban settlements, implementing schemes, and achieving national targets requires heightened capacities in urban planning across sectors and levels.

The shortage of qualified urban planners—only about 0.23 per 1 lakh population, contrasting starkly with developed countries—highlights the urgency in addressing the supply and involvement of planners in urban planning and development.

India grapples with a monumental wave of urbanization with far-reaching implications for its economy, environment, and society. Addressing these challenges necessitates robust urban planning, technology integration, multi-sectoral coordination, and a substantial increase in qualified urban planning professionals to ensure sustainable and equitable urban development.

### 3. Population Carrying Capacity

As per the prevailing conditions of the urban areas and the requirement of sustainable urban development, Population carrying capacity assessment will act as a tool to ascertain the possible impact of the urbanization process on the resources and to manage the same. It will provide a basis for the policy making process of the area to balance the economic, social, cultural, and environmental factors in a sustainable way.

Demand and supply of resources must be managed as per the population and its growth. Therefore, it is necessary to understand the carrying capacity of the area which can support the population with desired quality of life, growth thresholds and land capability to devise development policies in the area/region.

Thomas Malthus developed the concept of carrying capacity in 1798. Carrying capacity is like the concept of sustainability especially when sustainability is divided into ecological, technical, socio-economic, and cultural components (Schroll et al. 2006) Urban population carrying capacity for this study is defined as “the supportive capacity of the land to accommodate population within the developmental thresholds and progressive urban development resulting in quality of life.”

The urban population carrying capacity is assessed based on the following objectives, which are to be fulfilled to arrive at quality of life for citizens directing the sustainable urban development strategy.

1. Public perception and societal acceptance of urban development: Urban development is a continuous process of betterment of the service provision for better living. It can be assessed by setting up benchmarks for identified indicators and its performance on delivery of services so as to assess the resultant of any policy or plan.

2. Developmental Thresholds: Analyze the thresholds posed by the natural and manmade resources for meeting the demand of the population.

3. Land Capability: Assess the capacity of the land pockets to direct development spatially.

It is necessary to understand the meaning of the objectives to proceed further. The terms quality of life, thresholds and land capability is defined by various agencies and much research is being carried out. For this study purpose, it is necessary to understand the framework and methodology adopted to define and derive each factor and its use in this study.

Population Carrying Capacity assessment is an analytical study from which strategies can be drawn and used further by design tools such as compact city, smart city and so on.

### 4. Importance of understanding urban areas' capacity to support population

The key factors that determine a country's population optimum include economic and social aspirations, environmental factors, quality of life, and resource availability. The concept of carrying capacity is also important, which refers to the absolute upper limit of population that can be accommodated in each territory, assuming some specified standards of living and taking account of identified constraints. The optimal population size takes into consideration further restrictions such as social and economic aspirations, environment, and quality of life. Consequently, a territory's optimal population will be smaller than its carrying capacity. Other factors that determine a country's population optimum include the efficient use of resources, deeper study of climatological factors, and the elimination of unscrupulous egoism in international relations to support a larger population. Achieving a population optimum requires moral and physical organization, equitable economic coordination, and goodwill among nations. Additionally, fundamental changes in international economics and moral aspects of national and international life are necessary to support a larger population. The cultivation of neglected areas is also important, as is the need for in-depth analysis of existing statistical material to gain insights into the implications of population growth and resource utilization.

The term quality of life refers to the well-being of people in an environment intended to lead a satisfactory life. The term environment in the above sentence refers to a wide range of elements which are subjective in matter and are being defined and debated by various researchers around the world. The environment spans across the fields of wealth and employment, built environment, physical and mental health, education, recreation and leisure time, and social belonging. It is the quantification of satisfied living. The term QOL is not to be misunderstood with standard of living, which is primarily based on income. QOL is assessed based on achievement of quality to a desired standard identified for an indicator identified. QOL assessment is necessary to assess a nation's or city's livability. Cities are considered as engines of economic growth. Economic expansion leads to worsening living circumstances and an increase in crime if it does not also provide for an urban quality of life. Therefore, for assessment of the quality of life a base standard must be established upon which the development or degradation of QOL can be assessed.

#### QOL in Indian Cities

India is becoming more urbanized, and this has led to an increase in the size of cities due to the spike in urban population. Due to factors including traffic, pollution, social injustice, congestion, and urban decline, many of our cities struggle to address social, economic, and environmental issues. According to the UN, between 1990 and 2005, the percentage of urban people living in slums dropped from 47% to 37% in developing nations. But in India's urban areas, especially in the country's more than a million cities (40 in 2011), slums are growing at a rate of 5-6% annually, which is double that of urban expansion. This demonstrates clearly how some members of society are

excluded and how urban living standards have declined. The "broken window theory," as was previously mentioned, is responsible for the entire state of development.

#### Development Thresholds

Development thresholds are the maximum limit for growth after which the resource will degrade or cannot serve the purpose which it has intended to be. Development thresholds can be classified as Environmental Thresholds consisting of air, water, soil parameters and Utility Thresholds consisting of physical & social infrastructure, roads.

#### Utility thresholds

Infrastructure provisions such as accessibility and physical infrastructure services may pose a constraint for development as it can only serve a particular population above which it will degrade the resource provision capacity.

#### Environment Thresholds

The growing transformative demand that human production and consuming activities place on natural resources and ecosystems makes the study and monitoring of environmental thresholds increasingly important for policy makers. Many of these natural systems are only resilient to disturbances up to a limit (also known as a "tipping point"), after which ecological discontinuities with undesirable social, economic, and environmental effects—as well as potentially irreversible ones—are likely to arise. It's critical to determine the locations of potential thresholds and their actual values to prevent such outcomes. To help policymakers comprehend the issues and take appropriate action, early warning systems should incorporate the scientific research of environmental thresholds, including their knowledge, modeling, and prediction. Sectors in Environmental Threshold

1. Air Threshold – GHG Emissions
2. Water Threshold – Availability of water
3. Biological Threshold – Eco sensitive/ conservation areas
4. Disaster Vulnerability Threshold -

#### Land Capability

It is the capacity of the land to hold the population by providing services. The services may be natural or manmade/ provided by human interference (eg: infrastructure). The assessment can infer which pocket of the land in the urban area to be prioritized for development and the conflicting areas with natural environment.

Kevin Lynch's assessment framework outlines five key performance dimensions crucial for evaluating a city's quality of life (QOL): vitality, sense, fit, access, and control. Vitality encompasses sustenance, safety, and consonance, ensuring the settlement supports life functions and ecological stability. Sense emphasizes residents' mental differentiation and perception of the environment, encompassing identity, structure, transparency, and legibility. Fit refers to the alignment between the settlement's design and inhabitants' behavior patterns. Access pertains to reaching people, resources, and services, focusing on diversity, equity, and management. Control addresses the degree of user control over spaces and activities within the environment. Lynch also includes two overarching criteria: efficiency in maintaining the settlement and justice in the distribution of environmental benefits and costs among individuals.

The Human Development Index (HDI), a composite statistic created by Mahbub ul Haq and Amartya Sen, gauges countries'

development based on life expectancy, education, and income indices. It evaluates life expectancy, education levels, and per capita income.

The Economist Intelligence Unit's quality-of-life index assesses determinants like material wellbeing, health, political stability/security, family/community life, climate/geography, job security, political freedom, gender equality, to rate countries.

Mercer's Quality of Living Reports analyze over 460 cities, considering political/social environment, economic conditions, socio-cultural factors, healthcare, education, public services, recreation, consumer goods, housing, and natural environment to evaluate living conditions.

The Ministry of Urban Development's Sub Committee on Sustainable Habitat Parameters published indicators for sustainable development in urban planning.

These methodologies offer diverse approaches to assess quality of life. Lynch's dimensions emphasize environmental support, mental perception, behavioral alignment, access, and control. The HDI focuses on life expectancy, education, and income for country-level assessment but doesn't provide insights into diverse characteristics of Indian cities. The Economist Intelligence Unit and Mercer use multiple factors to assess various aspects of living conditions at both country and city levels. The Ministry of Urban Development's report highlights indicators for sustainable urban development.

Each methodology offers unique perspectives but has limitations. While Lynch's framework is comprehensive, it lacks quantifiable metrics. The HDI is country-centric and may not capture nuances within India's cities. The Economist Intelligence Unit and Mercer's assessments are comprehensive, considering various factors, but might overlook specific local issues. The Ministry of Urban Development's indicators provide insights into sustainable urban planning but require implementation to impact QOL.

These diverse methodologies serve as valuable tools to evaluate quality of life. Combining Lynch's dimensions with data-driven assessments like HDI, The Economist Intelligence Unit, Mercer, and the Ministry of Urban Development's indicators could offer a more holistic understanding of quality of life, enabling comprehensive improvements in urban planning and development tailored to India's diverse cityscapes.

## 5. Factors influencing urban areas' capacity

The factors influencing the capacity of urban areas, particularly in the context of population carrying capacity assessment, include various dimensions such as urban development, environment, societal acceptance, urban economy, and institutional capacity. These factors are assessed through a set of indicators that cover aspects such as urban environment, societal acceptance, economic growth, job opportunities, equity, and institutional constraints. Additionally, the assessment considers the quality of air, water, soil, infrastructure, and environmental sources and sinks, as well as socially determined unacceptable changes in the urban area. The framework also considers the assimilative capacity of nature, politically or legally enforced threshold standards, and reforms related to urban development. These factors collectively contribute to the determination of the population carrying capacity and the quality of life in urban areas.



The integration of three key frameworks: The Urban Development Assessment Framework, Environment Development Threshold Framework, and Land Capability Assessment. These frameworks are integrated to derive the quality of life (QOL) and population carrying capacity. The process includes the identification of indicators, assignment of indicator assessment framework for each indicator, assigning weightages, and tabulation of final scores as output. The results from each framework are aggregated based on weightage and normalized to a score of 100, with the resultant percentage being directly proportional to the population carrying capacity. This comprehensive approach allows for a holistic assessment of the factors influencing the population carrying capacity of an urban area.

## 6. Physical factors

### Availability of land for expansion

The Land Capability Assessment framework evaluates the potential for development by analyzing natural and human resources, and it provides spatial outputs indicating areas with potential for development. The assessment considers both manmade and natural resource supportive capacity for existing built areas and future buildable areas, with the central area of the city typically having higher supportive capacity that diminishes as one moves to outer areas. This analysis helps in prioritizing development works area-wise and provides insights into the level of capacity to offer the population in different areas. Therefore, the framework provides a comprehensive understanding of the availability of land for expansion and its potential to support population growth in urban areas.

### Natural resources and their sustainability

The framework evaluates the capacity of natural resources to support population growth and urban development. It considers the assimilative capacity of natural resources, which refers to the ability of the environment to absorb and process the waste and impacts generated by human activities without detrimental effects. Additionally, the assessment analyzes the natural resource supportive capacity for future buildable areas, aiming to minimize the impact on built areas and ensure sustainable development.

Furthermore, the importance of maintaining a stable resource base and avoiding over-exploitation of renewable resources, as well as depleting non-renewable resources only to the extent that investment is made in adequate substitutes. This holistic approach to natural resource assessment and sustainability contributes to the understanding of the environmental thresholds and the long-term viability of urban development in relation to natural resources.

### Infrastructure and transportation networks

The assessment of infrastructure and transportation networks considers the availability and quality of essential services such as water supply, sewage treatment, waste disposal, and stormwater control systems. It also evaluates the transportation network, including public transportation systems and highways, to ensure efficient and sustainable mobility. The assessment aims to identify deficiencies in infrastructure and transportation networks and prioritize development works accordingly.

## 7. Social factors

### Quality of education and healthcare systems

The framework for Urban Development Assessment encompasses an evaluation of various aspects including the

urban environment, societal acceptance, urban economy, and institutional capacity, which encompasses education and healthcare systems.

When assessing the quality of education and healthcare systems, the focus lies on gauging the availability and accessibility of educational and healthcare facilities, as well as the standard of services offered. Additionally, it involves an evaluation of the fairness in access to education and healthcare services across different sectors and genders. The primary goal of this assessment is to pinpoint any shortcomings in education and healthcare systems and subsequently prioritize development initiatives.

Moreover, it underscores the significance of sustainable development in the realm of education and healthcare systems, considering their enduring impact on the populace's quality of life. Consequently, the evaluation of education and healthcare systems assumes a pivotal role in ascertaining the population carrying capacity of an urban area and in fostering sustainable urban development.

The framework delineated in the document offers a comprehensive analysis of the quality of education and healthcare systems, with the aim of facilitating well-informed decision-making pertaining to population carrying capacity and sustainable urban development.

### Availability of social services and amenities

The assessment of the availability of social services and amenities encompasses an evaluation of the accessibility and quality of services such as safety, health, education, housing, and recreation. It aims to identify any deficiencies in these services and prioritize development initiatives accordingly.

### Cultural and recreational opportunities

The stated choice approach used in the research involves presenting respondents with hypothetical scenarios and asking them to make choices among alternative configurations of a multi-attribute good.

This approach helps measure social carrying capacity by capturing visitors' preferences and decision-making processes in response to different recreational scenarios.

## 8. Economic factors

The challenges and implications of population growth, stressing the necessity of moral and physical organization, equitable economic coordination, and international cooperation to sustain larger population sizes. It underscores the urgency of addressing these complex issues and emphasizes the importance of statistical analyses in comprehending the world's progress and challenges. The author (Wickens, 1988) highlights the need for in-depth analysis of existing statistical material to gain insights into the implications of population growth and resource utilization. Furthermore, the paper discusses the modern world's response to global population trends and the potential implications of global overpopulation. It emphasizes the complexity of reducing population growth and the necessity of international cooperation in implementing economic and population policies. The author argues that time is short and that solutions should be found before the global population surpasses approximately 8,000 million. Overall, the paper provides a comprehensive exploration of the challenges and implications of population growth, emphasizing the need for moral and physical organization, equitable economic coordination, and international cooperation to support larger population sizes. It also underscores the importance of statistical analyses in

understanding the world's progress and challenges, highlighting the urgency of addressing the complex issues associated with population growth and resource utilization.

## 9. Methods to assess urban areas' capacity

### Development Density Allocation Model

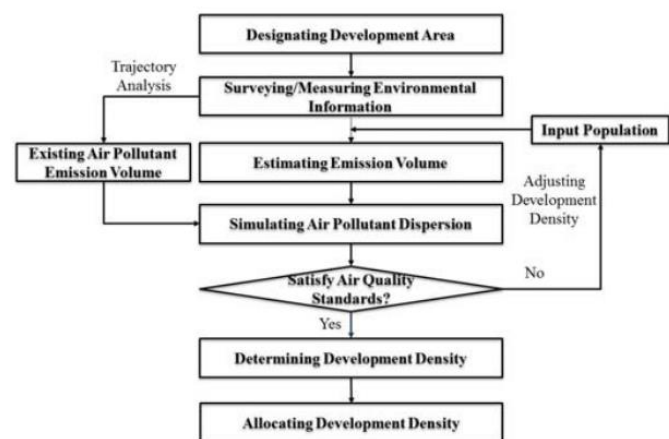


Fig -1: Figure

The study of model for sustainable urban development in Korea, using environmental carrying capacity theory and technology. It focused on NO<sub>2</sub> as a key air pollutant, crucial in Korea. The model comprised three steps: trajectory analysis, air pollutants dispersion assessment, and development density allocation. By analyzing emissions and dispersion patterns, it calculated suitable population densities for new urban areas based on environmental standards. The model's outcomes aid in creating density and land-use maps, facilitating informed planning processes for urban development while considering environmental factors.

### Utility carrying Capacity.

This research focuses on developing an integrated framework for evaluating urban carrying capacity to manage growing urban populations and environmental issues. It identifies seven key factors—energy, green spaces, transportation systems, water supply, sewage, and waste treatment—to create an assessment framework. Using GIS, the Urban Carrying Capacity Assessment System (UCCAS) was developed. A case study in Seoul, South Korea, demonstrated UCCAS's effectiveness in determining carrying capacity, showcasing its potential as a decision support tool for more effective urban development planning and management.

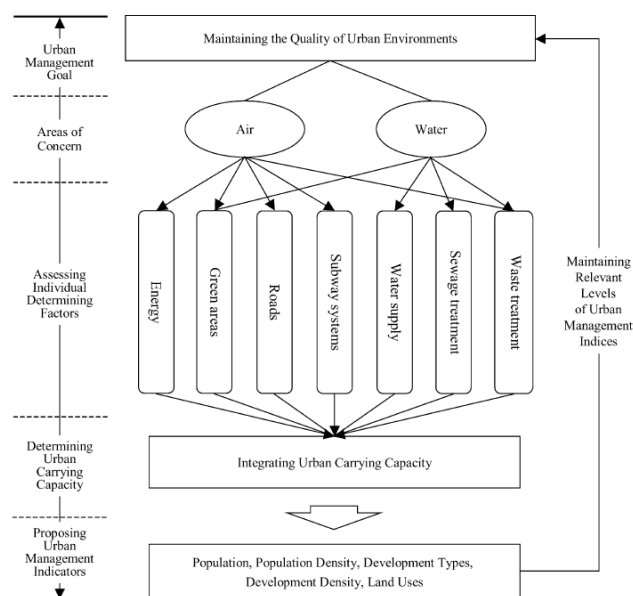


Fig -2: Figure

## 10. Case study

"The Population Growth and Carrying Capacity in Semarang City" is a study that explores the impact of population growth on the carrying capacity of Semarang City, Indonesia. The study was conducted by Hariyanto, Sudharto P Hadi, and Imam Buchori from the Doctoral Program at Environment Science of Post Graduate School Diponegoro University Indonesia and the Department of Urban Planning, Engineering Faculty Diponegoro University Indonesia.

The study begins by highlighting the importance of land as a natural resource for human life and the various activities that require land, such as agriculture, industry, and settlement. However, as the population in Indonesia continues to grow, land use competition has become a significant issue, particularly in urban areas. The study notes that population growth leads to an increase in land consumption, which can lead to the conversion of unproductive land, such as farmland, into other uses.

The study uses the concept of carrying capacity to measure the ability of the natural resources in Semarang City to support the population. Carrying capacity is defined as the maximum population that can be sustained by the available natural resources. The study calculates carrying capacity using the land function area divided by the population. The study notes that the more population in a city, the lower the land consumption per capita will be.

The study analyzes the population growth in Semarang City from 2000 to 2015 and calculates the carrying capacity for each sub-district in the city. The study finds that 14 out of 16 sub-districts in Semarang City have overshoot their carrying capacity, with only Tugu sub-district being quite safe and Mijen sub-district being in threshold. The study notes that the outskirts areas of the city, such as Mijen, Gunungpati, Genuk, Tembalang, and Ngaliyan, have experienced rapid population growth, indicating that these areas are more attractive than downtown areas.

The study concludes that population growth has a significant impact on carrying capacity, and the government of Semarang City should control population growth by restricting building permits or controlling farmland conversion. The study suggests that policymakers should pay attention to the distribution of the

population and implement sustainable development strategies to ensure that the natural resources in Semarang City can support the population.

In summary, "The Population Growth and Carrying Capacity in Semarang City" highlights the importance of land as a natural resource and the impact of population growth on carrying capacity. The study provides valuable insights into the dynamics of urban development and sustainability and suggests that policymakers should implement sustainable development strategies to ensure that the natural resources in Semarang City can support the population.

## 11. Conclusion

When considering Population Carrying Capacity, physical infrastructure and slums become essential city sectors. This study emphasizes how important it is to allocate resources in a way that meets basic human needs. It becomes essential to manage resources effectively to provide better results. Within the parameters of the Population Carrying Capacity paradigm, it is possible to manage resources more effectively and create an environment that is more sustainable and favorable for urban living by concentrating on these sectors, attending to the needs of slum populations, and improving the physical infrastructure of the city.

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