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Dimensions of Population Projections for a City: How to Make a Conscious Decision About the Form of Urban Planning

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Abstract: Population projections are pivotal to shaping urban planning strategies, as they provide essential data that informs decisions on infrastructure, resource allocation, and long-term city development. As urbanization accelerates, cities face challenges such as overcrowding, resource shortages, and environmental stress. Accurate population forecasting allows planners to anticipate these challenges and implement sustainable solutions.

This dissertation explores the dimensions of population forecasting, emphasizing the methodologies used and their applicability in preparing city master plans. Case studies, particularly from Indian cities, for instance, the Master Plan for Chennai Metropolitan Area illustrates the effective use of the Urban-Rural Growth Difference (URGD) method, while the Bengaluru Master Plan adopts cubic modelling to account for urban growth patterns. These examples showcase how tailored approaches to population projections can address unique urban challenges. This research highlights the importance of a multi-method approach, blending traditional and modern techniques to achieve precision in population projections. It advocates for continuous investment in data quality and accessibility, fostering informed and adaptable urban planning strategies for the future. Through a combination of theoretical exploration and practical application, the study contributes to the evolving field of urban demography and planning.

Keywords: Dimensions, Population Projection, Urban Planning, Methods of Population Projection.

I. INTRODUCTION

Empirical population research has been significantly influenced by the ongoing demographic transition, which has generated new insights and methodologies. Access to comprehensive information regarding historical trends, current demographics, and future population projections is crucial for effective planning in both political and business contexts. Accurate forecasts of population size and structure are essential to support these planning processes with reliable data (United Nations, 2009).

The future development of a country's population is determined by three key factors: (I) fertility, (II) net migration, and (III) mortality. Usually, population predictions start with population numbers at a certain moment that are unique to age and sex. Forecasts of fertility, migration, and death patterns are used to extrapolate future population estimates from this baseline. To improve accuracy, death and net migration projections are typically broken down by age and sex.

This contribution aims to introduce and discuss various fundamental concepts related to population projections. The term "population projection" is often used interchangeably with several other terms in the literature, which can lead to confusion due to the lack of clear and consistent definitions. For instance, the literature frequently fails to distinguish between forecasts or predictions and projections or simulations. It is important to clarify how these terms can be meaningfully differentiated.

A population projection illustrates how a population is expected to evolve under specific assumptions regarding its size and structure, thus possessing a conditional character based on if-then statements. Demographic processes tend to unfold gradually, with their true impact often becoming evident only after many years. This is particularly true for fertility and mortality, which are long-term processes of natural population change. In this regard, the inertia of demographic dynamics is a well-established phenomenon. Conversely, migration processes can be influenced abruptly by political or economic changes, making them more challenging to predict (Keyfitz, 1977). Population projections are typically long-term, often extending over several decades, as they inform long-term planning efforts, such as infrastructure projects.

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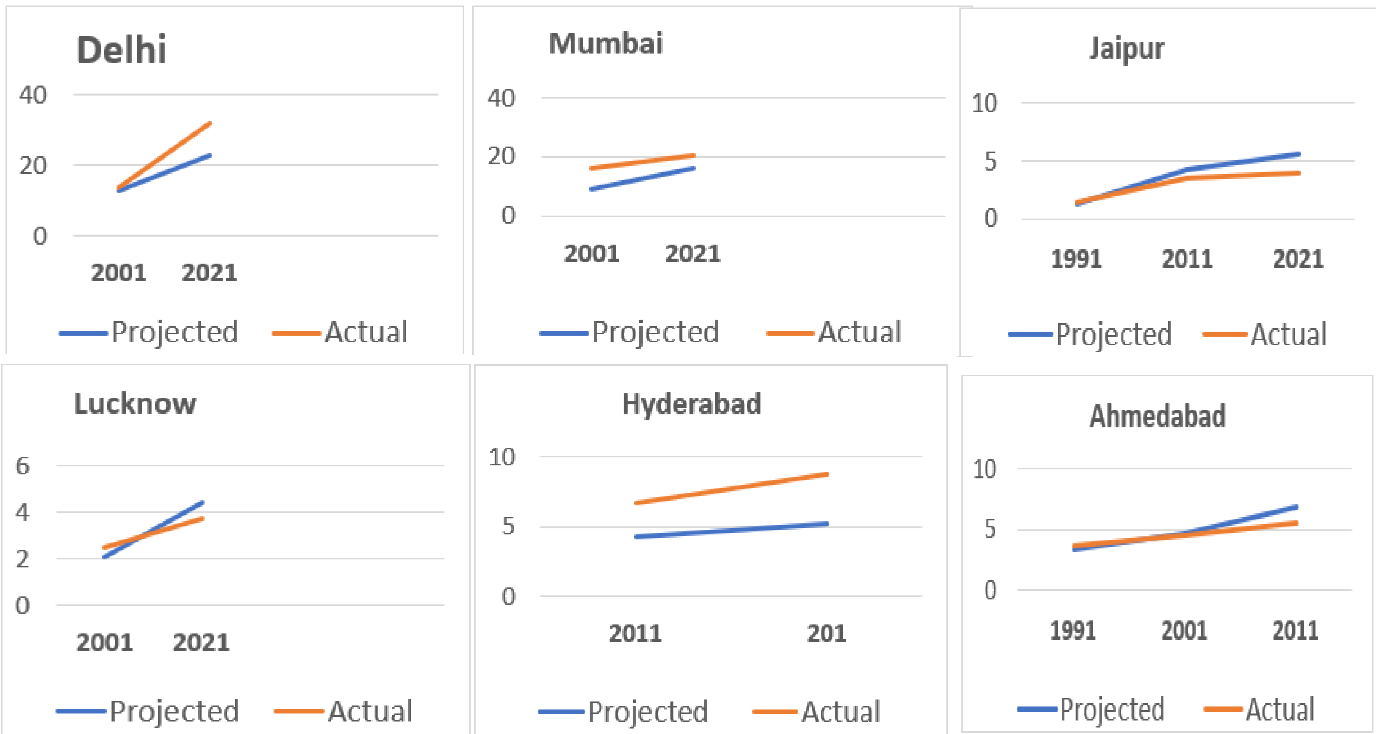
Timely interventions are made possible by early detection of potentially troublesome developments. However, as the projection horizon lengthens, uncertainty increases, further emphasizing the hypothetical nature of these projections.

Various scenarios are frequently calculated to highlight particular plausible events or to better depict the variety of potential developments. Even if such scenarios are not anticipated to occur in the future, some simulations can portray stylized events and their possible outcomes. For example, a simulation might estimate population changes if the total fertility rate were to reach a replacement level of 2.1 children per woman.

In contrast, a population forecast makes claims about expected future population developments, asserting a degree of accuracy in these predictions. The scientific literature frequently addresses potential sources of error in such forecasts to enhance their utility for urban planners and other stakeholders. Forecasts can have short, medium, or long-term horizons, with uncertainty naturally increasing as the forecast period extends. As a result, the probabilities corresponding to several possible development routes are frequently used to quantify the uncertainties in population estimates.

The distinction between projections or simulations and predictions or forecasts is crucial to prevent misinterpretation of results by users of simulation outputs. In the 1970s, demographer Nathan Keyfitz pointed out that while a demographer may create a projection, readers often treat it as a forecast. He made this observation. Although a population estimation is always included, any forecast that is presented as an interactive model is by definition a projection. However, the opposite is also true; a projection does not necessarily qualify as a forecast because it does not make a claim to be accurate.

In addition to discussing popular methodological techniques and their various benefits and drawbacks, this article attempts to give an overview of the most significant differences in population estimates. Our target audience includes individuals with a basic understanding of statistics or forecasting, who are interested in how population forecasts serve as the foundation for various applications. We strive to cover a broad topic succinctly and offer literature recommendations for further reading on the concepts discussed in this report. We will first go over some basic conceptual approaches to population projection methods in the sections that follow. For readers who are unfamiliar with population forecasts, this introduction will present different methods and discuss their importance as planning tools in other domains, like economics. This will shed light on the various ways that population predictions are used. We want to provide a general, though not comprehensive, review of a range of forecasting subjects where population projections are essential, if not essential, as baseline information. This encourages people who are not in the field of demography, as well as those who are in related subjects, to learn more about the methods used to undertake population predictions and to acknowledge the limitations of the particular approaches used.



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This references major Indian cities, including Delhi, Mumbai, Jaipur, Ahmedabad, Lucknow, and Hyderabad. This indicates that the analysis is likely focused on urban population dynamics, which are critical for urban planning and resource allocation. Analysis of population estimates and actual data for major Indian cities, with a focus on the significance of precise demographic forecasts for efficient policy making and urban planning. The comparisons between projected and actual figures highlight the need for continuous refinement of demographic models to better understand and anticipate population changes.

The focus on projected populations indicates the significance of these estimates for planning purposes. Accurate population projections are crucial for infrastructure development, resource management, and policy-making in rapidly urbanizing regions like those mentioned.

1.1 Aim

To foresee the population growth and the resultant requirement of facilities, services and utilities to overcome the difficulties which are associated with unprecedented growth of population.

1.2 Objectives

i. To analyse present method of forecasting population growth.

ii. Examine the difference between the year's anticipated and actual population increase.

iii. To find dimension of efficient population projection for city.

1.3 Scope

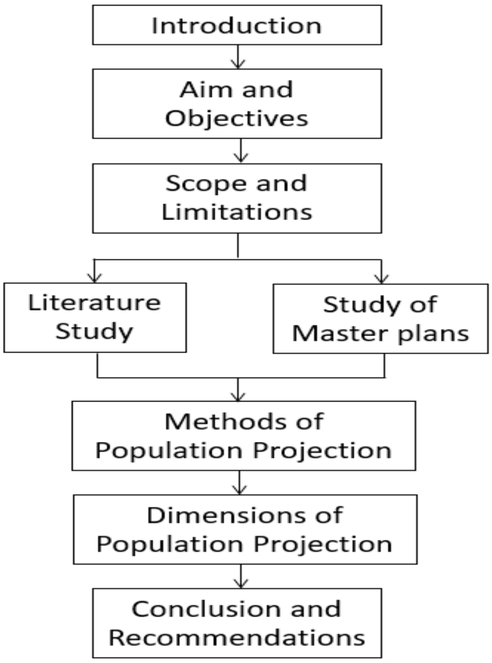
The ongoing demographic shift has given accurate population projection research a lot of additional impetuses. Planning procedures in the creation of Masterplans and City Development Plans depend on the availability of data on the past, present, and future population growth in a city or other spatial unit. For planning procedures to be supported as effectively as possible, projections of the future population's number and composition are crucial.

1.4 Limitation

This study is limited to Indian cities.

For planning procedures to be supported as effectively as possible, projections of the future population's number and composition are crucial.

1.5 Methodology



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II. LITERATURE STUDY

2.1 Literature Study 1:

CENSUS OF INDIA, 2019. POPULATION PROJECTIONS FOR INDIA AND STATES 2011 – 2036, New Delhi: NATIONAL COMMISSION ON POPULATION, MINISTRY OF HEALTH & FAMILY WELFARE, GOVERNMENT OF INDIA.

Population projection is a systematic approach aimed at forecasting future demographic scenarios based on historical data and specific assumptions. The accuracy of these projections hinges on the validity of the assumptions made, which must hold true over time. Predicting future trends in fertility and mortality is inherently complex, influenced by a multitude of factors including medical advancements, health interventions, food production and distribution, climate variability, socio-cultural dynamics, and political-economic conditions. These complexities necessitate a cautious approach when interpreting projected population figures, as they are contingent upon various prevailing conditions.

The necessity for population projections in India has been recognized since 1958, particularly in the context of planning for the Third Five-Year Plan. Given that India is the second most populous nation globally, understanding its population dynamics is crucial not only for domestic policy but also for international observers. Various governmental and non-governmental organizations, including the United Nations Population Division (UNPD), the World Bank, and the United Nations Population Fund (UNFPA), regularly produce population projections at both national and sub-national levels.

2.1.1 Historical Context of Population Projections

Historically 1958, the Planning Commission has depended on the Office of the Registrar General and Census Commissioner of India to deliver demographic projected outcomes. The first Expert Committee on Population Projections was established in 1958 to generate projections for India and its states, which were essential for the Third Five-Year Plan. This committee has been periodically revived to update projections based on the latest census data.

2.1.2 Current Technical Group on Population Projections

i. To enhance the accuracy and relevance of population projections, a Technical Group on Population Projections (TGPP) was formed to provide projections for the period 2011-2035. The group's objectives include:
ii. Reviewing past methodologies for population projections.
iii. Developing updated projections for fertility rates.
iv. Creating new mortality rate projections.
v. Producing thorough population estimates at five-year intervals through 2035, broken down by age, sex, urban/rural status, and state/UT designations.
vi. Estimating when the total fertility rate (TFR) will reach the replacement level of 2.1 across various states and the country as a whole.
vii. Analyses were conducted using information from the 2011 Census, National Sample Survey (NSS), Sample Registration System (SRS), and National Family Health Survey (NFHS).
viii. Taking into account factors such as contraceptive use, the proportion of married women, and the impact of diseases like AIDS, as well as migration patterns.
ix. The group also aims to adjust existing projections based on the 2011 Census data and provide guidance for future adjustments when the 2021 Census results are available.

2.1.3 Methodology for Population Projections

Because it accurately takes into consideration the three fundamental factors of population change—fertility, death, and migration rates—the Cohort-Component Method (CCM) is the main technique used for population forecasts. This method has been applied to 21 states and one Union Territory (UT) in India, including Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Delhi, West Bengal, Jharkhand, Chhattisgarh, Uttarakhand, Tamil Nadu, Telangana, Odisha, Punjab, Rajasthan, and the Jammu and Kashmir region (UT), which stands are all considered National Capital Territories (NCTs). The same methodology has also been used to aggregate the forecasts for the seven northeastern states (except from Assam).

SRS fertility and mortality figures were used to make projections for Jammu & Kashmir, and the residual population estimates of Jammu & Kashmir were used to make projections for Ladakh. A mathematical method based on exponential growth rates was used to project the states of Goa and other smaller UTs, which make up a small percentage of the total population. These estimates are based on information from the 2011 Census and the SRS, which offers time series data on fertility and death.

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2.1.4 Base Level Population and Data Accuracy

It is acknowledged that age-sex data, regardless of its source, may contain errors. Misreporting of age is often due to respondents' lack of knowledge. Therefore, it is essential to smooth the age-sex distribution to enhance data accuracy. Various indices, such as the sex ratio score, age ratio score, Whipple's index, and Myers' index, are utilized to measure the accuracy of age-sex data. Several smoothing methods are available to refine the age-sex distribution data.

2.1.5 Assumptions Regarding Fertility

The SRS and NFHS provide estimates of the Total Fertility Rate (TFR) for different states in India. Historical SRS data indicates a consistent decline in fertility levels since 1971. The trend analysis of TFR can be modeled using various mathematical approaches, including Exponential, Log-linear, Logistic, and Gompertz models, to project future fertility levels for both states and the country.

2.1.6 Sex Ratio at Birth (SRB) and Population Sex Ratio

The Sex Ratio at Birth (SRB), defined as the number of females born per thousand males, is derived from the SRS report for the period 2009-2011. This data is crucial for the current projection exercise. The population sex ratio used for projections is based on the 2011 Census data. During the projection period, the SRB is expected to vary by state. For states where the SRB was below 909 in 2015-2017, a linear projection to 909 by 2031 is anticipated. For other states, the SRB is projected to remain constant at 943, aligning with international standards.

2.1.7 Assumptions Regarding Mortality

To project life expectancy at birth (e0), the models developed by the United Nations are employed. These models account for varying rates of improvement in life expectancy, which tend to slow as they reach higher levels. Age-specific survival rates are calculated based on the mortality patterns observed in the SRS data from 2009-2011, which are expected to gradually align with the West model life table as life expectancy increases.

The average SRS-based Age-Specific Death Rate (ASDR) for 2009-2011 serves as the baseline for creating separate life tables for males and females, accounting for reporting omissions. A three-year average is utilized to mitigate variability in mortality rates, particularly at the state level. The West model life tables are adopted as the standard for this purpose.

2.1.8 Assumptions Regarding Migration

Migration data from the 2011 Census indicates that inter-state net migration during the decade from 2001 to 2011 is assumed to remain constant throughout the projection period for states using the Component Method. International migration is considered negligible and is therefore excluded from the projection calculations.

2.1.9 Population Projection of Urban Population

The UN Manual's Urban-Rural Growth Differential (URGD) approach is used to project the urban population. This method is predicated on the assumption that urban-rural growth differentials will follow a logistic pattern. The URGD for the period from 2001 to 2011 is projected to remain consistent through to 2036. The projected urban population figures, disaggregated by sex for India, states, and union territories, are provided for specific dates throughout the year.

2.2 Literature Study 2:

United Nations, 1974. Methods for Projections of Urban and Rural Population. New York: United Nations Publication.

2.2.1 Urban-Rural Growth Differences:

The United Nations Method of Urban and Rural Population Projections emphasizes the differences in growth patterns between urban and rural populations, which arise from varying rates of fertility, mortality, and migration. These differences are essential for understanding the redistribution of population between urban and rural areas and planning effectively for urbanization and rural development.

$$U^1 = \left[\frac{T^1 + dR}{T} \right] \times U$$

where U - Urban population at time 't';

U^1 - Urban population at time 't+1';

T - Total population at time 't';

T^1 - Total population at time 't+1';

d - u-r, where u - urban growth rate; r - rural growth rate;

R - Rural population at time 't';

The United Nations Method of Urban and Rural Population Projections is a comprehensive framework developed to estimate population trends and distributions for urban and rural

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areas. It acknowledges the unique demographic dynamics of these two settings and integrates critical factors such as fertility, mortality, and migration into its projection models. This method is particularly significant for governments and planners, as it provides insights to address urbanization challenges, rural depopulation, and sustainable development goals.

One of the key elements of the UN method is its emphasis on the dual focus for urban and rural populations. Urban population projections take into account migration patterns, infrastructure development, and socio-economic conditions, often characterized by lower fertility and mortality rates. In contrast, rural population projections focus more on natural population growth (births and deaths), alongside migration losses due to rural-to-urban migration. By treating these areas distinctly, the method provides more precise projections that reflect the unique characteristics of each population.

A significant strength of the UN method is its adaptability. It can be applied in diverse contexts, from highly developed nations with extensive data to developing countries with more limited resources. The method's reliance on scenario-building allows planners to simulate various future conditions, such as rapid urbanization or policy-driven rural development. However, the methodology also faces challenges, including data limitations, uncertainties in migration trends, and the reclassification of urban and rural areas, which can introduce inconsistencies over time.

The United Nations method for estimating urban and rural populations is explained in Chapter V of the handbook. This method is designed to provide a systematic approach to estimating future population distributions based on observed trends and demographic data. The chapter emphasizes the importance of understanding urban-rural growth differences and outlines the formulae and methodologies used for projections.

2.2.2 Important Elements of the UN Approach

The chapter begins by discussing the significance of actual observations concerning urban-rural growth differences. These differences are crucial for understanding how populations transition between urban and rural areas over time.

i. The method recognizes that urban and rural populations do not grow at the same rate and that these rates can be influenced by various factors, including migration, economic opportunities, and social changes.
ii. Iterative Calculation Formula:
iii. The United Nations method employs an iterative calculation formula to project urban and rural populations. This formula allows for year-to-year interpolation of five-year projections, facilitating a more dynamic approach to population forecasting.
iv. The iterative nature of the calculations helps to refine projections by incorporating new data and adjusting for observed trends.
v. Year-to-Year Interpolation:
vi. The method includes techniques for year-to-year interpolation, which is essential for creating annual estimates from quinquennial projections. This method insures that the forecasts will continue to be accurate and pertinent throughout time.
vii. The chapter details how to apply these interpolation techniques effectively, allowing for adjustments based on changing demographic patterns.
viii. Applications of the Method:
ix. The United Nations method is versatile and can be applied to various contexts, including national, regional, and local population projections. It is particularly useful for urban planners and policymakers who need to understand population dynamics for effective resource allocation and planning.
x. The chapter provides examples of how the method can be applied to different geographical areas, highlighting its adaptability to local conditions and data availability.
xi. Exponential Rates:
xii. The chapter discusses the use of exponential rates in projections, which allows for a more nuanced understanding of population growth patterns. Exponential growth models are particularly useful in scenarios where populations are expected to grow rapidly.
xiii. The flexibility of the method enables users to adjust assumptions about growth rates based on historical data and anticipated future trends.
xiv. Flexible Assumptions:
xv. The United Nations method allows for flexible assumptions regarding growth rates and demographic changes. This flexibility is crucial for adapting projections to reflect real-world conditions, such as economic shifts or changes in migration patterns.
xvi. The chapter emphasizes the importance of regularly updating assumptions to ensure that projections remain accurate and relevant.

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2.3 Inferences from the Literature Study

2.3.1 Purpose and Importance of Population Projections

i. Planning and Policy Development: The manual emphasizes the necessity of accurate population projections for effective economic and social planning. Projections help in anticipating future needs for infrastructure, services, and resources, which are critical for both urban and rural areas.

ii. Understanding Demographic Changes: Projections serve to understand the dynamics of population shifts, particularly the movement from rural to urban areas, which has significant implications for resource allocation and policy formulation.

2.3.2 Methodological Framework

i. Iterative Calculation and Year-to-Year Interpolation: The United Nations method employs an iterative calculation formula that allows for year-to-year interpolation of five-year projections. This approach enhances the accuracy and relevance of population estimates over time.

ii. Use of Exponential Rates: The method incorporates exponential growth rates to model population changes, which is particularly useful in scenarios where rapid growth is anticipated.

iii. Flexible Assumptions: The methodology allows for flexible assumptions regarding growth rates and demographic changes, enabling adjustments based on historical data and anticipated future trends.

2.3.3 Components of Population Change

i. Migration Dynamics: Both urban and rural population structures are significantly shaped by migration. The manual highlights that both in-migration and out-migration trends significantly affect population growth and distribution.

ii. Reclassification of Areas: The reclassification of previously rural areas as urban due to administrative changes or population growth is a significant factor in population projections. This aspect complicates the projections as it intertwines with migration patterns.

2.3.4 Challenges in Projections

i. Data Limitations: The manual acknowledges that many countries, especially less developed ones, may lack detailed demographic statistics, which can hinder the accuracy of projections. The methods presented are designed to be simple and adaptable to varying data availability.

ii. Uncertainty in Migration Trends: The document points out that migration trends can be unpredictable, leading to significant uncertainty in population projections. This uncertainty necessitates the calculation of "high" and "low" alternative scenarios to account for potential variations.

The "Methods for Projections of Urban and Rural Population" manual by the United Nations provides a robust framework for understanding and projecting demographic changes in urban and rural contexts. The methodologies outlined are designed to be adaptable to various data conditions, emphasizing the importance of accurate projections for effective planning and policy development. The challenges associated with migration dynamics, data limitations, and the need for flexible assumptions highlight the complexities involved in demographic forecasting. Overall, the manual serves as a valuable resource for demographers, planners, and policymakers aiming to navigate the intricacies of population dynamics in a rapidly changing world.

III. STUDY OF MASTER PLANS

3.1 Master Plan for Chennai Metropolitan Area, 2026

3.1.1 Urbanization in Tamil Nadu

At the moment, Tamil Nadu's economy is 3rd in India. Cities expand and flourish as a result of economic activity like trade and industry. Liberalization, the quickly growing IT sector, and its well-educated, disciplined workforce have all contributed to the state's success. The total area of Tamil Nadu is 130,058 square kilometers, of which 12,525 square kilometers are urban. The urban population of this state, which is among the most urbanized in India, increased from 13 million in 1971 to 28 million in 2001, outpacing the national average.

3.1.2 Chennai City's and CMA's population growth.

Founded in 1639 as a port for the East India Company, Chennai (previously Madras) has expanded to become India's fourth-largest metropolitan area. Over 4 lakh people lived in Madras by the late 1800s, and the George Town region saw the growth of industry. Chennai's population growth surged during the 1950s and 60s due to industrialization and

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economic opportunities. In 1978, areas like Velacheri and Kodambakkam were incorporated into the city, which led to slower population growth in some zones during the 1971-81 period. Currently, Chennai City's Corporation area consists of 155 divisions across 10 zones, showing varied population growth, with zones like Saidapet and Mylapore experiencing over 2% growth during 1991-2001.

The Chennai Metropolitan Area (CMA), established in 1974, spans 1189 sq. km, encompassing the Chennai City Corporation as well as the nearby towns, villages, and panchayats. Municipalities like Maduravoyal, Valasaravakkam, and Pammal recorded the highest growth rates, while areas like Kathivakkam and Tambaram had slower growth.

3.1.3 Migration

Chennai has long been a destination for migrants from all over India, particularly from Tamil Nadu and neighboring states. In 2001, about 75 % of Chennai's immigrant population was from Tamil Nadu, with the remaining 24 % being from other parts of India. A significant trend was the increasing migration from urban areas, especially among women. The reason for migration was often job-related or for family reasons like marriage. Notably, Chennai has also seen significant out-migration, with many residents relocating to suburban areas within CMA due to a shift in the city's housing patterns towards commercial developments.

3.1.4 Birth Rate, Death Rate, and Natural Increase

In Chennai, the birth rate decreased from 38.6 in 1971 to 22.62 in 2003, and the mortality rate decreased from 13.1 to 8.01 within the same time frame. This resulted in a reduced rate of natural increase, from 26.3 in 1971 to 14.61 in 2003. These changes are linked to improved health facilities, family planning efforts, and changes in the population's age structure.

3.1.5Age Structure

When it comes to urban planning, Chennai's population's age distribution is crucial.Over time, the proportion of young school-age children and secondary school-goers has decreased, while the proportion of the elderly population has risen. This shift in age demographics highlights the changing demands for educational, health, and other public services.

3.1.6 Sex Composition

Chennai's sex ratio, the number of females per 1000 males, has improved over the decades, remaining higher than the national urban average but still lower than the Tamil Nadu average.

3.1.7 Literacy

Literacy in Chennai, defined as the ability to read and write in any language, is higher than the state average, reflecting the city's relatively high educational standards.

3.1.8 Population Projection

Various methods, including the Linear, Geometric Growth, Exponential Curve, and Urban-Urban Growth Difference (URGD) methods, were used for projecting the population of Chennai and CMA up to 2026. The URGD method proved most suitable for the overall metropolitan area, while the exponential curve method was best for projecting population growth in specific municipalities and local bodies.

3.1.9 Floating Population

The floating population in Chennai is significant, with an estimated 1.125 lakh daily passengers arriving by intercity trains, along with 83,000 passengers arriving by intercity buses. An additional 20,000 people commute for work, education, and business, bringing the total floating population to approximately 2.25 lakh. This daily influx and outflux should be considered in infrastructure planning for CMA.

The projected population growth reflects historical trends and is influenced by factors such as migration, urbanization, and future development strategies outlined in the master plan.

3.1.10 Population Projection Methods used

The following methods were used to project the population of Chennai.

i. Linear Method
ii. Geometric Growth Method
iii. Exponential Curve Method
iv. Urban - Rural Growth Difference (URGD) Method

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3.1.11 Inferences

i. The Linear Method is most suitable for stable growth, but it may underestimate the potential for rapid urban expansion.

ii. The Geometric and Exponential Growth Methods offer more realistic projections for rapidly growing areas like Chennai City and CMA, especially when considering industrial and infrastructure development.

iii. The URGD Method is highly relevant for metropolitan regions experiencing significant urban-rural migration differences, especially in cities like Chennai.

3.1 Master Plan for Bengaluru – 2031

Bengaluru has a rich history, with its population census records beginning in 1871. Since the first census, Bengaluru is the most populous city in Karnataka, maintaining this status for over a 100 years. The Revised Master Plan (RMP) for 2031 has utilized available census data to analyze the population of the Bengaluru Metropolitan Area (BMA) over the past five decades, specifically from 1971 to 2011. This census data aligns with the establishment of the Bengaluru Development Authority (BDA) in 1976, and the jurisdiction of the BMA has remained largely unchanged, aside from some administrative adjustments. But every ten years, Bengaluru’s urban agglomerations and municipal borders have changed. For the Bruhat Bengaluru Mahanagara Palike (BBMP), current municipal boundaries have been used to compile historical data.

The Bengaluru metropolitan area includes the Local Planning Area of the Bengaluru Development Authority (1207sq km) and a portion of the LPA of the Bengaluru Metropolitan Infrastructure Development Authority (BMICAPA) (87.03 sq km). The BBMP and the neighbouring regions are part of the Bengaluru Development Authority. The Master Plan takes into account the entire BMA, including the BBMP and villages, for population extraction and analysis because, notably, both the villages and the BBMP are administered by two bodies (BDA and BMICAPA).

3.2.1 Population Trends

The BBMP has consistently shown high growth rates, although these rates have varied across decades. The growth rate in the villages within the BMA doubled between 2001 and 2011. Because of the BBMP's strong effect on the BMA, the BMA's general trend closely resembles the BBMP's and is probably going to stay that way, especially considering the large amount of land that is available for development in the adjacent areas. For the BMA's agricultural land to be used efficiently while maintaining its production, a clear policy and regulatory framework are required.

An analysis of growth rates within the BMA over the past census decade reveals that many wards in the city’s core area (inside the Outer Ring Road, ORR) have experienced over the past ten years, the majority of Bengaluru's municipal wards in the more remote districts have had positive growth rates.

3.2.2 Spatial Distribution of Population in BMA

Wards inside the ORR, municipal wards outside the ORR up to the municipal boundary, and villages inside the Bengaluru Metropolitan Area are the three zones into which the Bengaluru urban area has been divided. This categorization aids in comprehending the population's geographical distribution.

3.2.3 Population Density

Population density is defined as the number of individuals per hectare (PPH). According to census data from 2001 and 2011, the population density for the urban area increased from 47 to 70 PPH, while for the municipal area, it rose from 82 to 119 PPH. From 5 to 10 PPH, the population density in the communities quadrupled. During the period from 2001 to 2011, an average of 23 inhabitants were added per hectare in the BMA, while the BBMP saw an increase of 37 persons per hectare. The core areas of the city have a high density, which decreases as one moves toward the periphery. the percentage change in density was highest in the wards outside the Bengaluru’s ORR in the BBMP, with an increase of 120%, followed by the rural areas, which saw a 99% increase. The core urban region, or the wards inside the Bengaluru’s ORR, on the other hand, only had a 20% growth throughout that time period.

3.2.4 Birth and Death Rates

Due to the lack of a well-defined administrative structure for the BMA, the necessary demographic rates for projections are unavailable. Therefore, demographic rates from the Registrar of Births and Deaths for defined regions like BBMP/BUD have been used, assuming these rates are applicable to the BMA. The birth rates for municipal area were 20.3830 in 2001 and 16.4699 in 2011, while the corresponding death rates were 8.3395 and 5.7309. The natural increase rates of births were 12.0435 in 2001 and 10.7390 in 2011, indicating a decline of birth rates 1.3045 in the natural increase rate between past these years.

3.2.5 Migration

Migration is the movement of people from one location to another over a definite time period. It is characterized by its place and time specificity and can be directional, indicating movement from and to specific areas. Migration is a crucial factor in population change, as it responds more rapidly to shifts within and beyond the area in question compared to natural factors like fertility and mortality.

Since Independence, Bengaluru, as the state capital, has experienced a significant influx of migrants seeking better employment and livelihood opportunities. Census data from 2001 shows that approximately 19% of all in-migrants to the state settled in the Bengaluru Metropolitan Region (BMR), with 12% residing in the Bengaluru Urban Agglomeration (BUA) alone. Between 1971 and 2001, the BUA's in-migration rate increased at a compound annual growth rate of 4.2%. The total number of migrants increased from 624,215 in 1971 to 2,086,719 in 2001, with in-migrants constituting about 36.5% of the city's population by 2001. Except for the decade from 1981 to 1991, all other decades have shown a significant rise in in-migration.

Around 60% of migrants to the Bengaluru metropolitan area come from within Karnataka state, while 38.7% are from outside the Karnataka state. In 2001, about 28% of all migrants moved to the Bengaluru metropolitan area for better work opportunities, with only 11% being female. The percentage of female migrants is higher among those who migrated for reasons such as marriage (60%) and moving with households/family (97.2%). Various social and economic factors, in addition to employment, have contributed to the migration trend.

3.2.6 Sex Ratio

The sex ratio has improved in the Bengaluru urban area, rising from 902 in 1981 to 918 in 2011. Between 1991 and 2011, the sex ratio in the Bengaluru Metropolitan Area's villages dropped from 884 to 857.

3.2.7 Literacy Rate

Bengaluru recorded a high literacy rate, accredited to its strong educational infrastructure. The literacy rate in the BMA increased from 77.5% in 1991 to 88.3% in 2011, surpassing the Karnataka Urban average of 85.7%.

3.2.8 Population Projections

The Master Plan-2031 has showed population projections for the spatially constant Bengaluru Metropolitan Area based on population historical trends using various projection methods and the cohort component method. The models used include:

a. Linear Growth Model: Accepts a steady increase in population.
b. Quadratic and Cubic Models: Account for fluctuations in growth patterns.
c. Logistic Model: Suggests that the population will reach a saturation point in the future.
d. Ratio Method: Projects population growth in relation to the Karnataka Urban Population.
e. Component Method: Utilizes birth and death rates along with migration data.

Population projections for the metropolitan area, based on different statistical and demographic projection models, range from 12 million to 25 million by 2031. The The two extremes of these forecasts are represented by the Linear Method and the Component Method; the Linear Method projects the lowest population for 2031. with the Linear Method predicting the lowest population for 2031. However, these estimates may be reached as early as 2017, making them less reliable. Conversely, the Component Method projects a population nearly 2.5 times that of the 2011 BMA population, suggesting that this estimate may also be unrealistic.

3.2.9 Inferences

i. For 2031, the population estimates based on three separate methods—Logistics, Ratio, and Cubic—all fall between 19 and 20 million.
ii. This consistency among the methods suggests that the overall trend of population growth is expected to be stable and predictable, even with different modeling approaches.
iii. The Cubic method projection of 20.3 million is considered appropriate for planning purposes, considering the potential for future growth and the statistical reliability of the model.

IV. METHODS USED IN POPULATION PROJECTION

4.1 Arithmetic/Linear Method

The Arithmetic or Linear Method assumes that population growth occurs at a consistent, steady rate over time. This method projects future population by adding a fixed increase, based on historical trends, to the current population for each subsequent year or decade.

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$$Pn=P0+(n\times r)$$

Where:
Pn = Population size at future year
P0 = Population size in the base year
n = Number of years between the base year and future year
r = Average annual growth rate

This approach is simple and appropriate for regions with steady, predictable growth trends. However, it is less effective in dynamic urban environments like Bengaluru, where factors such as migration and varying growth rates in different zones significantly impact population changes.

4.2 Geometric Increase Method

The Geometric Increase Method assumes that population grows at a constant percentage rate rather than a fixed amount. This method is based on the principle of compound growth, where the population increases proportionally to its current size, leading to an exponential growth pattern over time.

$$Pt=P0\times(1+r)\ n$$

Where:
Pt = Projected population at time tt
P0 = Current population (base year)
r = Growth rate of population
n = years into the future

The Geometric Increase Method is a powerful tool for projecting population growth, especially in scenarios where populations are expected to grow exponentially. It is particularly useful for long-term planning and analysis in urban development, resource allocation, and policy-making.

4.3 Incremental Increase Method

The Incremental Increase Method assumes that the population increases by a specific, constant number of individuals at regular intervals (e.g., annually). This method is particularly useful for short-term projections where growth patterns are stable and predictable.

$$Pt=P0+(I\times n)$$

Where:
Pt = Projected population at time tt
P0 = Current population (base year)
I = Incremental increase (the fixed number of individuals added each time period)
n = time periods into the future

The Incremental Increase Method is a useful approach for making population projections, particularly in stable environments where growth is expected to occur in fixed increments. However, for more complex and long-term projections, other methods such as the Geometric or Logistic models may be more appropriate.

4.4 Logistic Growth Model

According to the Logistic Growth Model, a population increases quickly while resources are plentiful and then more slowly when it gets closer to the environment's carrying limit. This results in an S-shaped curve when population is plotted with time.

$$dP/dt=rP(1-P/K)$$

Where:
P = Population size at time t
r = growth rate
K = The environment's carrying capacity, or the largest population that it can support
dP/dt = Change in population size over time

4.5 Cohort Component Method

The CCM divides the population into distinct cohorts, typically based on age and sex, and projects the future population by considering the changes in each cohort over time. This method accounts for the dynamics of population change, including births, deaths, and migration, making it a comprehensive approach to demographic analysis.

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Components of the Method: The CCM involves three main components:

i. Fertility (Births): The number of births in each cohort is projected based on age-specific fertility rates. This is often done using the Total Fertility Rate (TFR) or age-specific birth rates.

ii. Mortality (Deaths): The number of deaths in each cohort is projected using age-specific mortality rates. This can be derived from life tables that provide the probability of death at each age.

iii. Migration: The method also accounts for migration, which can affect the size and structure of the population. This includes both immigration and emigration.

$$Pt+1=Pt+B-D+I-O$$

Where:
Pt+1 = Projected population at the next time period
Pt = Current population
B = Number of births during the time period
D = Number of deaths during the time period
I = Number of in-migrants
O = Number of out-migrants

The Cohort Component Method is a powerful tool for demographic analysis and population projections. By considering the dynamics of births, deaths, and migration across different age and sex cohorts, it provides a nuanced understanding of population changes over time. This method is particularly valuable for policymakers, urban planners, and researchers seeking to make informed decisions based on demographic trends.

4.6 Exponential Growth Model

The Exponential Growth Model assumes that the population grows at a constant percentage rate, leading to a rapid increase in population size. Plotting population size against time reveals curve of a shaped J, which is indicative of this kind of expansion.

$$P(t)=P0\times ert$$

Where:
P(t) = Population size at time tt
P0 = Initial population
r = growth rate
e = natural logarithm (2.71828)
t = Time

A fundamental insight of how populations can expand under optimal circumstances is offered by the Exponential Growth Model. It is a valuable tool in various fields, including biology, economics, and public health, for modeling rapid growth scenarios. However, it is essential to recognize its limitations and the need for more complex models, such as the Logistic Growth Model, when considering long-term population dynamics.

4.7 Cubic Model

The Cubic Model uses a polynomial equation of degree three to describe population growth. This allows it to capture more complex growth patterns, including acceleration and deceleration in population size over time. The cubic function can model scenarios where growth is not constant and can change direction.

$$P(t)=at3+bt2+ct+d$$

Where:
P(t) = Population size at time tt
a,b,c,d = curve is determined by coefficients
t = Time

The Cubic Model is a valuable tool for population projections, particularly in scenarios where growth patterns are expected to change over time. Its flexibility and ability to capture complex dynamics make it suitable for various applications in demographics, urban planning, and environmental studies. However, careful consideration must be given to the model's complexity and the potential for overfitting when using it for forecasting.

4.8 Ratio Method

The Ratio Method involves calculating the ratio of the population at two different time points and using this ratio to project future population sizes. This method assumes that the growth pattern observed in the past will continue into the future.

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$$P_t = P_0 \times (P_t / P_{t-n})$$

Where:
Pt = Projected population at time tt
P0 = Current population (base year)
Pt−n = Population at a previous time point (n years ago)

The Ratio Method is a useful approach for making population projections, particularly in stable environments where growth is expected to continue in a similar pattern to the past. However, for more complex and long-term projections, other methods such as the Cohort Component Method or the Logistic Growth Model may be more appropriate.

4.9 Gompertz Method

The Gompertz model describes a growth process that is initially exponential but slows down over time, resulting in a sigmoidal (S-shaped) curve. This model is often used in ecology, demography, and marketing to represent populations or phenomena that exhibit growth followed by a plateau.

$$P(t)=P0 \cdot eb \cdot (e-c \cdot t)$$

Where:
P(t) = Population size at time t
P0 = Initial population
b = A factor that establishes the starting rate of growth
c = A constant that determines the rate of growth deceleration
e = About 2.71828 is the base of the natural logarithm.
t = Time

4.10 Urban-Rural Growth Difference (URGD) Method

The URGD Method focuses on measuring the growth rates of urban and rural populations over a specific period. It highlights the disparities in growth patterns, which can be influenced by factors such as migration, economic opportunities, and access to services.

$$U^1 = \left[\frac{T^1 + dR}{T} \right] \times U$$

where U - Urban population at time 't';
U¹ - Urban population at time 't+1';
T - Total population at time 't';
T¹ - Total population at time 't+1';
d - u-r, where u - urban growth rate;
r - rural growth rate;
R - Rural population at time 't';

The Urban-Rural Growth Difference (URGD) Method is a valuable tool for analyzing population growth disparities between urban and rural areas. By quantifying these differences, the method provides insights that can inform urban planning, policy development, and resource allocation. Addressing the benefits and problems brought about by population shifts in various geographic contexts requires an understanding of the dynamics of urban and rural expansion.

4.11 Mean Absolute Percentage Error (MAPE)

Without taking into account the direction of the errors (i.e., whether the forecast is an overestimate or an underestimate), MAPE calculates the average magnitude of the errors in a collection of forecasts. It provides a clear indication of how far off the predictions are from the actual values.

$$\text{MAPE} = \frac{1}{n} \sum_{t=1}^{n} \left| \frac{A_t - F_t}{A_t} \right| \times 100$$

Where:
n = Number of observations
At = Actual value at time tt
Ft = Forecasted value at time tt
|At−Ft| = The absolute difference between the predicted and actual values

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The Mean Absolute Percentage Error (MAPE) is a helpful indicator for assessing the accuracy of forecasting models. Its ease of interpretation and ability to provide a relative measure of error make it widely applicable in various fields. However, users should be aware of its limitations, particularly regarding division by zero and sensitivity to small actual values. By understanding both the advantages and disadvantages of MAPE, analysts can make informed decisions about its use in forecasting evaluations.

4.12 R-Square

R2 is a measure of how well the independent factors explain the variability of the dependent variable.When the model's R2 score is 1, it means that all of the response data variability around its mean is explained by the model; when it's 0, it means that none of the variability can be explained by the model.

$$R^2 = 1 - \frac{SS_{res}}{SS_{tot}}$$

Where:

SSres = Sum of Squares of Residuals (the sum of the squares of the differences between the observed and predicted values)

SStot = Total Sum of Squares (the sum of the squares of the differences between the observed values and the mean of the observed values)

Interpretation of R-Square:

i. $R^2 = 1$: The dependent variable's variability is fully explained by the model.

ii. $R^2 = 0$: The variable's mean is the best predictor; the model do not account for any variation.

iii. $0 < R^2 < 1$: The model explains some portion of the variability, with higher values indicating a better fit.

The R-Square (Coefficient of Determination) is a fundamental statistic in regression analysis that provides insight into the explanatory power of a model. While it is a useful tool for assessing model fit, it is essential to consider its limitations and complement it with other metrics, such as Adjusted R^2, to ensure a comprehensive evaluation of model performance.

4.13 Economic Base Method

Economic base methods derive a population projection directly from an exogenous projection of employment or another economic indicator. They are predicated on the idea that the main factor influencing demographic (and other) changes in the research area is economic development. Such forecasts are frequently included in the environmental impact assessment of a planned large-scale project for specific localities.

4.14 The Housing Unit Method

The housing unit method calculates total population as the number of private housing units multiplied by the proportion which are occupied on a usual residence basis multiplied by the average number of people living in non-private housing as well as the number of people living in each housing unit. Expressed algebraically it is:

$$P(t) = [H(t) \times OCC(t) \times PPH(t)] + PNPD(t)$$

where represents the population in non-private housing, the average number of people per housing unit, the percentage occupied on a regular basis, and the number of private housing units. It is necessary to project each of these terms onto the equation's right side.

4.15 Land Use Allocation Models

Land use allocation models distribute an independent dwelling projection for an urban region to small geographical zones by representing the land development process. Allocation is based on an estimate of each zone’s probability of development in each projection interval, which is often assumed to be influenced by factors such as:

the amount of available land,

a. land zoning regulations,
b. distance from employment nodes,
c. transportation availability,
d. access to schools,
e. distance to retail facilities, and
f. adjacency to existing development.

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Land use allocation models are not population projection models in themselves but, because they are usually combined with some version of the housing unit method, they are the driving force behind many sets of small area population projections.

V. DIMENSIONS OF POPULATION PROJECTION

5.1 Population Size

The population size refers to the total number of individuals in a specified geographic area at any given point in time. It serves as the foundational data for any population projection, providing the starting point for all demographic calculations. The size of the population has a direct impact on the projection methods used: larger, more stable populations are generally easier to forecast due to more predictable trends, while smaller, more volatile populations present challenges because their growth patterns may vary significantly based on regional factors like migration or policy changes. The United Nations highlights the critical role of accurately determining baseline population size, as it influences subsequent calculations in population forecasting models (UN, 2008).

5.1.2 Total Population

Total population refers to the complete count of all individuals residing within a specific geographic boundary at a given time. This number is fundamental for population projections as it serves as the baseline for most methods, including linear, geometric, and exponential models. By understanding the total population, planners can identify overall growth trends and predict future aggregate demands, such as the need for housing, schools, and healthcare facilities. When it comes to urban planning, the overall population is essential for directing thorough resource planning. For example, in the Delhi Master Plan 2021, total population data is used to estimate housing and transport needs, ensuring that infrastructure is developed in line with demographic changes.

5.1.3 Urban Population

The urban population is the segment of the total population that resides within urban areas, as defined by administrative boundaries. This category is particularly important for models like the Urban-Rural Growth Difference (URGD) and other urban-centric projection methods, which focus on migration and urbanization rates. Urban population data is essential for determining the scale of infrastructure needs in cities, such as roads, drainage, and public transportation systems. As cities continue to grow rapidly, projections of urban population help cities plan for future demand. For instance, the Revised Master Plan for Bengaluru 2031 places heavy emphasis on urban population growth due to the city's ongoing rapid urbanization, influencing everything from housing policies to public service delivery.

5.1.4 Resident Population

The resident population refers to individuals who live permanently in a particular area, excluding temporary migrants or visitors. This population is a key factor in methods such as housing unit projections, where stable, long-term population data is required to predict future housing needs. By analyzing the resident population, city planners can determine the demand for housing and community services. For example, in the Chennai Metropolitan Area Master Plan 2026, resident population data plays a critical role in planning sustainable housing schemes that cater to the city's growth and demographic needs over time.

5.1.5 Migratory Population

The migratory population consists of individuals who move between geographic areas, either temporarily or permanently. Migration is a significant variable in many population projection methods, particularly the Cohort-Component Method and URGD models. Understanding migration trends is vital for urban areas experiencing high levels of in-migration, as it impacts housing demand, transportation infrastructure, and social services. In cities like Mumbai, the master plans take into account the migratory influx, particularly for projects like slum rehabilitation, where high levels of migration influence the need for new housing and basic services.

5.1.6 Working Population

The working population refers to the economically active segment of the population, typically aged 15–64. This demographic group is essential for economic growth and productivity, and its size and characteristics are often linked with economic base models to correlate employment opportunities with population changes. Projections of the working population help planners to develop industrial zoning, employment hubs, and skill development programs tailored to the labor force's needs. For example, in the National Capital Region (NCR), industrial corridor planning is driven by projections of the working population, ensuring that infrastructure and employment opportunities align with the growing labor force.

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5.1.7 Dependent Population

People who are not employed, such as young children (ages 0–14) and the elderly (ages 65 and over), make up the dependent population. The working-age population provides these populations with services and financial support. In demographic projections, dependency ratios (the ratio of dependent population to working-age population) are critical for understanding the future demands on healthcare, education, and social services. In areas like Kerala, where the population is aging rapidly, master plans account for high dependency ratios, influencing the design of healthcare services and facilities for the elderly, as well as programs targeting the younger population, such as schools and childcare.

5.1.8 Floating Population

The floating population refers to people who are temporarily present in an area, such as tourists, business travelers, or seasonal workers. Though not permanently settled, this population can still have a significant impact on local infrastructure needs, such as transportation, tourism facilities, and temporary housing. Projections of floating populations are often based on surveys and are included in short-term projections, particularly in cities with high levels of tourism or seasonal migration. For example, in Goa, the floating population is factored into infrastructure development plans to accommodate the influx of tourists, ensuring that transportation hubs and temporary housing are adequately provided during peak seasons.

5.2 Age and Sex Structure

The distribution of people in a population across various age and gender groupings is known as its age and sex structure. This demographic dimension is vital for understanding various social and economic factors, such as dependency ratios (the ratio of the dependent population—children and elderly—to the working-age population), workforce potential, and the demand for age-specific services like healthcare and education. Methods like the Cohort-Component Method (CCM) use detailed age-specific data to project future population trends, taking into account varying mortality, fertility, and migration rates across different age and sex groups. For example, countries with aging populations, like Japan, rely heavily on age structure data for long-term planning, particularly in areas like healthcare and pension systems (Sanderson & Scherbov, 2008).

5.3 Fertility Rates

Fertility rates, usually represented as the number of children born per woman throughout her reproductive years, calculate the average number of children born to a woman over the course of her lifetime. This is a crucial factor in determining future population growth, as regions with high fertility rates are likely to experience more significant population growth. Fertility rates vary widely across different countries and regions, influencing demographic projections and regional development plans. For instance, in India, fertility rates differ substantially between states, which affects how resources are allocated and development plans are structured at the state and national levels (Census of India, 2019).

5.4 Mortality Rates

Mortality rates refer to the number of deaths within a population over a specific period, often broken down by age and gender. This dimension is integral to understanding trends in life expectancy and how populations age over time. By analyzing changes in mortality rates, projections can estimate how long people are likely to live, and how the aging population might affect future needs in healthcare and social services. Scholars like Bongaarts (2009) emphasize the significance of mortality trends in shaping the long-term stability or decline of populations, particularly in countries with low fertility rates where mortality plays a key role in population stabilization.

5.5 Migration Patterns

Migration patterns involve the movement of people between geographic areas, whether within a country (internal migration) or across borders (international migration). Migration is a key driver of demographic change, particularly in urban areas where significant population shifts from rural to urban regions are common. The impact of migration on population projections includes changes in urban and rural dynamics, which in turn influence policies related to housing, transportation, employment, and infrastructure. In India, for example, migration trends in cities like Bengaluru have led to the revision of master plans to accommodate growing urban populations, necessitating updated projections and planning (Master Plan, Bengaluru, 2031).

5.6 Urban-Rural Dynamics

Urban-rural dynamics refer to the distribution of the population between urban and rural areas. As urbanization continues to accelerate globally, understanding this balance becomes essential for effective planning and policy-making. A growing urban population requires significant investment in infrastructure, housing, and public services, whereas rural areas may need policies focused on agricultural sustainability, education, and healthcare. The United Nations' Urban-Rural Growth Difference (URGD) method emphasizes the role of urbanization indices in making accurate population

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projections. The growth of urban populations and the ongoing shift from rural to urban living are major factors influencing projections and policy strategies for both urban and rural areas (UN, 1974).

VI. CONCLUSIONS

To sum up, this analysis has attempted to highlight recent developments in the content and technique of global population estimates, with an emphasis on the several aspects of population change that must be explicitly incorporated into such projections.

From a methodological perspective, the Census of India and the UNPD have employed the Cohort Component Method (CCM) to ensure internal consistency in age and sex distributions over time, starting with historical estimates from 1958 and 1950. This approach is also applied to projections up to 2036 and 2100, allowing for the estimation of future population sizes based on various demographic assumptions. In forecasting future fertility and mortality, probabilistic techniques such as the Bayesian Hierarchical Model (Raftery et al.) are used to account for uncertainty in the projections, incorporating both available data and expert assessments. Initially, summary statistics such as total fertility rates and life expectancy are projected, which are then used to derive age-specific projections based on established age schedules. These projections reflect the experiences of individual countries while considering the uncertainty of future developments using the experiences of other countries in similar circumstances. Alongside the middle variant, several other variants are presented to demonstrate the sensitivity of the projections to changes in underlying assumptions, allowing for the exploration of alternative scenarios in population development.

In India, the choice of population projection methods varies based on the scale of the study, data availability, and regional growth characteristics. For instance, the Delhi Master Plan 2041 used the Cohort Component Method to forecast population growth, factoring in age-specific fertility, mortality, and migration rates. The Bengaluru Master Plan employed the Cubic Method for metropolitan projections and the Exponential Curve Method for smaller local bodies. The Chennai Master Plan relied on the Urban-Rural Growth Difference (URGD) Method for projecting population dynamics in the metropolitan area.

Creating a best-practice guide for population projections could enhance the comparability of different sets of projections by establishing standardized principles regarding the projection horizon, number of scenarios considered, and the processes of dissemination and documentation.

VII. RECOMMENDATIONS

Adopt a Multi-Method Approach:

Planners and policymakers should utilize a combination of methodologies for population projections to capture the complexities of demographic changes. This approach can enhance the accuracy and reliability of forecasts, accommodating various growth patterns and socio-economic factors.

Incorporate Birth rate, Death rate and Migration Trends:

Birth rate, Death rate and Migration should be a key parameter in all population projections, as it significantly influences growth patterns. Understanding both internal and external migration trends will help in anticipating demographic shifts and their implications.

Utilize Error Metrics for Validation:

Employ quantitative measures such as Mean Absolute Percentage Error (MAPE) and R-Square to assess the accuracy of different forecasting methods. This validation process can help identify the most reliable models for specific contexts.

Focus on Localized Projections:

Given the regional variability in population dynamics, localized projections should be prioritized. Tailoring methodologies to specific urban and rural contexts will yield more relevant insights for planning and resource allocation.

Enhance Data Quality and Availability:

Continuous investment in data collection and management is essential. Improving the quality and availability of demographic data will support more accurate projections and enable better-informed decision-making.

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Way Forward

Method	Dimensions/Parameters	Application
Arithmetic/Linear Method	Current population, average Population change, projection years	Suitable for regions with steady, linear growth trends.
Geometric Growth Method	Current population, annual growth rate, projection years	Used for populations experiencing consistent proportional growth.
Exponential Growth Method	Initial population, exponential growth rate, time period	Best applied for rapid urban growth scenarios or high population density regions.
Cohort-Component Method (CCM)	Base population, births, deaths, net migration	Comprehensive method suitable for national and regional level detailed projections.
Ratio Method	Regional population, ratio derived from historical data	Effective for regional planning based on state-wide trends.
Logistic Method	Carrying capacity, growth rate, midpoint year	used in regions when growth is getting close to saturation.
Quadratic Method	Base population, linear growth term, quadratic term, years	Useful in regions with non-linear growth dynamics.
Cubic Method	Base population, terms for linear, quadratic, and cubic growth rates	Applied to model growth with higher-order variations.
Urban-Rural Growth Difference (URGD)	Urban population, rural population, growth differential	Focused on migration and urban-rural population shifts.
Quadratic Method	Base population, linear growth term, quadratic term, years	Useful in regions with non-linear growth dynamics.
Cubic Method	Base population, terms for linear, quadratic, and cubic growth rates	Applied to model growth with higher-order variations.
Mean Absolute Percentage Error (MAPE)		used to assess population projection models' accuracy.
R-Square Method		Evaluates the goodness of fit for projection models.

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