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ESTIMATION OF FUTURE POPULATION AND WATER DEMAND OF URBAN CENTERS OF INDIA: A CASE STUDY OF JAIPUR CITY

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Abstract: *The rapid urbanization and population growth in India have led to increased pressure on water resources in urban centers. As one of the fastest-growing cities in the country, Jaipur is facing significant challenges in meeting the water demands of its expanding population. Therefore, it is crucial to estimate the future population and water demand of Jaipur city to develop effective strategies for sustainable water management. This case study aims to estimate the future population and water demand of Jaipur city using a comprehensive analysis of demographic and water consumption trends. The study utilizes a combination of statistical methods, demographic projections, and water demand modeling techniques to provide a holistic understanding of the city's future water requirements. The results of this case study provide valuable insights into the future population growth and water demand trends of Jaipur city. The findings can assist urban planners, policymakers, and water resource managers in formulating effective strategies for sustainable water management and infrastructure development. The study emphasizes the importance of incorporating future population growth projections and water demand estimations into long-term urban planning processes. This case study contributes to the understanding of the challenges posed by population growth and urbanization on water resources in India, using Jaipur city as a specific example. The estimation of future population and water demand serves as a foundation for developing proactive measures to ensure adequate water supply and sustainable urban development in the face of increasing demand and limited resources.*

Key words: Water Resources, Future Population, Water Demand, Urban Centers

Introduction

Water is a precious, non-renewable, non-sustainable natural resource that sustains life on our planet Earth. Availability and distribution of both surface and ground water resources varies widely in different parts of the Earth. Today almost every country is facing paucity of water to meet their needs for irrigation, industry and domestic consumption specifically in large urban agglomerations. This vital resource is critical parameter for proper functioning and development of cities. Water resources (both ground and surface) are depleting day by day due to various reasons related to distribution patterns, quality issues and other management issues. Out of many factors that impact water availability and the cadence of water cycle, mostly through management, distribution and water utilization pattern in urban areas. Water management also includes storage, supply infrastructure and water treatment are becoming increasingly important in large and heavily urbanized areas. Apart from being used for Domestic, Industrial and Commercial purposes water also has ecological functions linked with landscaping, biodiversity, temperature buffering. Water becomes a complex but an important topic affecting quality of life, climate protection, and resource and energy efficiency in urban areas. Due to the lack of good governance and management and rapid increase in population, urban water resources have been over exploited in India and 31.16 percent of total Indian population lives in urban areas (Census 2011) expected to reach 40 percent by 2030 and 50 percent by 2050 (UN survey), with an alarming increase in urban population which would add further increased pressure on water resources. In last few years, ground water level in India as a whole and Rajasthan is continuously going down. Many dams of Rajasthan are completely or is verge of drying. The situations of dams are not good as their dependability is decreasing on account of siltation, low run off from the catchment etc. Major cities like Jaipur are facing problem of drinking water. In last few years population of Jaipur city has increased sharply, leading to shortage of drinking water especially in drought years.

Historical Review

Jaipur city with about 4 million populations is facing problems of drinking water supply. Initially Jaipur city was designed for 1, 50,000 people over an area of 1658 acres (6.7 km^2). Source of water was mainly ground water as open wells, baori etc. During early 1940's walled city become congested and Jaipur expended beyond walled city in properly planned manner under the guidance of Sawai Man Singh II in the 05 colonies namely C-scheme, Adarsh Nagar, Banipark, New colony and Fateh Tibba. After 1940's Jaipur was developed as center of trade and industries like National Ball Bearing Company (NBC), Rajasthan electric Industries (1959) etc. During 1940's population of Jaipur has started increasing rapidly specially in 1947 because of large number of immigrations from Pakistan and declaration of capital of Rajasthan state (1949). On account of this rapid population increase original, symmetry and design are compromised to settle this additional population. To meet the immediate need of these people city planning and infrastructure for amenities and facilities were neglected. As a result, Jaipur started expending in unplanned manner.

Jaipur city, like other urban agglomerations, is also facing crisis of drinking water supply. This crisis of acute water scarcity is giving a huge impact on lives and livelihood of millions of residents (Chari, 2019). With population growth beyond control, the condition will be worst in coming years as demand for water will increase with the time and going to impact lives of hundreds of millions population due to severe water scarcity. As per (MOHUA, 2019) 255 districts or 756 ULBs in the country are severely water stressed. Almost 17 percent of notified towns and cities in the country are facing extreme scarcity of water, among them Jaipur is one of the most affected one besides Hyderabad, Bengaluru, Delhi, Puducherry, Chennai, Mumbai and Amravati. Rajasthan with a geographical area of 342,239 square kilometers and

uncertain, erratic rainfall pattern it is among the driest state of India. The state is comprised of Thar Desert and Aravalli Mountain ranges which are specially facing shortage of water. State is divided into 236 blocks (Central Ground Water Board), out of which 204 blocks are in dark zone, 26 districts out of 33 districts are in drought like situation. 140 blocks are over exploited, 50 blocks are in critical stage and 14 blocks in semi critical stage.

Present Scenario

Infect, the water supply scheme of historic city of Jaipur was centuries old, which was initially, taken care by open local wells and later in 1918 the increasing population was served through large diameter open wells with tap water at common points. In 1952 Ramgarh dam was used as key surface source supplying 7 MLD water which was further augmented to 27 MLD in sixties. Same time drilling of new tube wells came into existence as surface water was not enough. With urban population increasing and expansion of concrete jungles, new colonies and residential complexes mushroomed the city and the ground water started depleting. Looking to key challenge in water supply Rajasthan state government initiated in 2009 a very costly arrangement of bringing and supplying drinking water from distant source Bisalpur dam which was almost 120 kms away from Jaipur. Bisalpur dam supply to Jaipur city was reduced to 307 MLD before August 2019, which was 450 MLD in 2018 and 540 MLD in 2017 and the dam is used to supply water to half of Jaipur population. This reduction in supply was mainly due to low rainfall in these years but in 2021 despite better rainfall (above average) dam could be filled almost half of its capacity and water supply is reduced to the level of 422 MLD per day against the requirement of 540 MLD. The demand supply deficit is almost 125 MLD which is further aggravating the vulnerability. The monitoring and regulation of extraction of ground water through almost 20,000 private tube wells and 2000 tube wells managed through Public Health Engineering Department is almost difficult. Currently (March 2022) contribution of tube wells is only 6.55 MLD. With increasing population and urbanization there has been inundating task of supplying water to 4 million urban population of Jaipur. The problem of water is further aggravated by large number of floating population due to high inflow of tourists and students in the specific times/ seasons.

At this point of time Jaipur has 40 million populations which would increase with the time. As per the minimum criteria of water supply (135 liters per day per head), total water requirements of Jaipur city come to around 541 million liters per day. This requirement does not include industrial and other requirements. Jaipur started facing the crunch of water scarcity as it is largely dependent on ground water as a result ground water depleted considerably. Water table has gone more than 25 meters below in last one decade leading to extreme deterioration of ground water quality with higher concentration of TDS, fluoride, nitrate and salinity a common feature across whole Jaipur. By 2019 all the 13 blocks of Jaipur city declared as dark zones as per survey by central ground water board, which means the recharge is just half of the total exploitation. The situation is reached to alarming level in 2018 when average water supplied was just 15 minutes in most of the area with very low pressure. In other areas the water supply was just once in 2 days or once in three days. The situation has been critical in last 20 years.

POPULATION PROJECTIONS AND PROJECTED WATER DEMANDS

Population Projection: Human being involved under condition of high mortality due to accident, infection, illness, and war therefore the relatively high fertility rate is essential for species survival In Spite of the relatively high fertility rates it took all the time for evolution of mankind to the middle of 19th century for the global population to reach 1 billion. The 20th century with the unpredicted rapid improvement in health care technologies and access to

health care all over the world as a result there is steep fall in mortality and steep increase in immortality. The population released these changes and took steps to reduce the fertility but decline in fertility is not so steep as a result the global population has under the fourth found increase in a hundred year and has reached 6 billion. Population refers to human aggregate to define space now the signal outstanding fact about the population is the rapidity of its growth in the past 200 years. A rapid accelerated expansion in the population can be seen since 1750. According to the World health organization (WHO) human beings are born every second the net increment works out at 250 per minute 15,000 per hour 360,000 per day and nearly 2.52 million per week. The human population has two fundamental characteristics that reduce the uncertainty about how they will develop in the future. Now the first fundamental characteristics are that a sustainable overlap exists between the current population and the future population. Secondly, the fundamental aspect of the human condition is that we grow alter by one year and to eventually die these two facts constrain possible future development in a population equivalent in other fields. Methods involved in population projection take advantage of both these points. Population projection can be defined as a computation procedure to calculate population size and structure at one time from population size and structure at another time together with a specification of how changes take place during the interim period. Now it can be distinguished from forecast as it can be defined as projection based or assumption that are protective and considered to yield to most probable estimates of the development in the future. It deals with computation of future projections size and characteristics that attempt to peek into future population scenarios by using the assumptions and probability in future projections as merely an exercise for protecting the fate of the current population under specified assumptions of fertility, mortality, and migration. Protecting the causes of human fertility and mortality is not easy especially when looking beyond much further in time. At the country level different population projections are meant by the government, national and international agencies from time to time adding to it. World Bank united nation population division United Nation population front are international agencies who map projection for the world and also for the individual countries.

Population of Jaipur city is increasing with rapid rates since beginning as it is a capital town and a premium tourist destination. Jaipur city being part of the semi-arid zone of the country, is the capital of Rajasthan state, has a population of 3.1 million as per 2011 census. Population of Jaipur City is estimated to reach almost 3.5 million in 2020. The city has been included in the Smart City Program and is expected to undergo massive urban restructuring. Population projections show that after independence population of Jaipur city increased with more than 4 percent per annum and approximately 35 percent in a decade till 2001. After that rate of increase declined slightly and remain between 2 to 3 percent annually and about 31 percent in a decade. Population of Jaipur city has been estimated by various methods and found that population of Jaipur would convert to 77 million by 2050.

Population Projection

The need for the population projection in India at various level and by different components like age, sex, rural, urban etc. for the use by the official agencies uniformly both at center and state level in 1958 on the eve of the formulation of third five-year plan beginning in 1958. It has been regular by government of India for official purposes through various expert committees constituted time to time for this purpose.

Population Forecasting

Design of water supply and sanitation scheme is based on the projected population of a particular city, estimated for the design period. Any underestimated value will make system

inadequate for the purpose intended; similarly overestimated value will make it costly. Change in the population of the city over the years occurs, and the system should be designed considering of the population at the end of the design period.

These are the various Methods by which we can calculate Population Projection

1. Arithmetic Increase Method
2. Geometric Increase Method
3. Incremental Increase Method
4. Logistic Curve Method
5. Decrease Rate of Growth Method
6. Simple Graphic Method
7. Comparative Study Graphical Method

The present and past population record for the city can be obtained from the census population records. After collecting these population figures, the population at the end of design period is predicted using various methods as suitable for that city considering the growth pattern followed by the city.

Arithmetical Increase Method: This method is suitable for large and old city with considerable development. If it is used for small, average, or comparatively new cities, it will give low result than actual value. In this method the average increase in population per decade is calculated from the past census reports. This increase is added to the present population to find out the population of the next decade. Thus, it is assumed that the population is increasing at constant rate.

Hence, $dP/dt = C$

i.e., rate of change of population with respect to time is constant. Therefore, Population after n^{th} decade will be

$$\mathbf{P_n = P_0 + n\,x}$$

Where,

P_n is the population after n decade and

P_0 is present population.

X = Average of population increase

For this study we considered arithmetic Increase method of population forecasting because Jaipur is already developed city and the rate of change of population of Jaipur city is constant.

Geometrical Increase Method (OR Geometrical Progression Method): In this method the percentage increase in population from decade to decade is assumed to remain constant. Geometric mean increase is used to find out the future increment in population. Since this method gives higher values and hence should be applied for a new industrial town at the beginning of development for only few decades. The population at the end of nth decade 'Pn' can be estimated as:

$$P_n = P\,(1+ IG/100)\,n$$

Where,

IG = geometric mean

P = Present population

N = no. of decades.

Geometric Increase Method of population Forecasting is used for rapidly growing city.

Incremental Increase Method: This method is modification of arithmetical increase method and it is suitable for an average size town under normal condition where the growth rate is found to be in increasing order. While adopting this method the increase in increment is

considered for calculating future population. The incremental increase is determined for each decade from the past population and the average value is added to the present population along with the average rate of increase. Hence, population after n_{th} decade is

$$P_n = P + n.X + \{n (n+1)/2\}.Y$$

Where,

P_n = Population after n_{th} decade
X = Average increase
Y = Incremental increase

Logistic Curve Method: This method is used when the growth rate of population due to births, deaths and migrations takes place under normal situation and it is not subjected to any extraordinary changes like epidemic, war, earth quake or any natural disaster etc. the population follow the growth curve characteristics of living things within limited space and economic opportunity. If the population of a city is plotted with respect to time, the curve so obtained under normal condition is look like S-shaped curve and is known as logistic curve.

Decreasing Rate of Growth Method

The method is applied to a city that owns a limiting saturation population. In this type, the rate of growth is a function of its population deficit. That means,

$$dP/dt = K_d(S-P)$$

Where,

P is the population,
S is the saturation population
K_d is the constant.

Simple Graphical Method: In this method, the populations of last few decades are correctly plotted to a suitable scale on graph. The population curve is smoothly extended for getting future population. This extension should be done carefully and it requires proper experience and judgment. The best way of applying this method is to extend the curve by comparing with population curve of some other similar cities having the similar growth condition.

Comparative Study Graphical Method: In this method the census populations of cities already developed under similar conditions are plotted. The curve of past population of the city under consideration is plotted on the same graph. The curve is extended carefully by comparing with the population curve of some similar cities having the similar condition of growth. The advantage of this method is that the future population can be predicted from the present population even in the absent of some of the past census report. Source: United Nation World Population Prospects and using Arithmetic Increase Method of Population forecasting. Jaipur has Centralized Raw Water Treatment System and Decentralized pump stations for water supply scheme. At this moment Jaipur city is getting 440 MLD water against demand of 600 MLD from Bisalpur reservoir. This 600 MLD defecate is being managed with same hundreds tube wells which are either drying or losing their daily discharge. Therefore, dependability on surface water is increasing with the time.

Table 01: Daily Projected Water Demand

Year	Historical and Projected Population	Projected Water Demand (Million liters)
1951	307000	41.45
1961	416000	56.16
1971	644000	86.94
1981	1029000	138.92
1991	1540000	207.90
2001	2344000	316.44
2011	3074000	414.99
2021	4008000	541.08
2031	5053000	682.16
2041	6240009	842.40
2051	7702524	1039.84

Figure 01: Population Projection of Jaipur City (1951-2051)

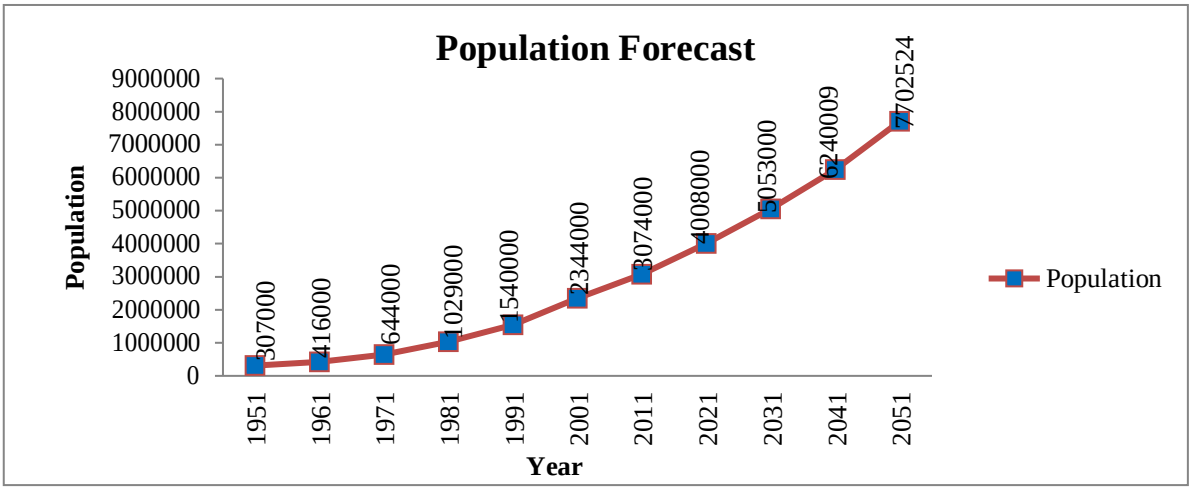
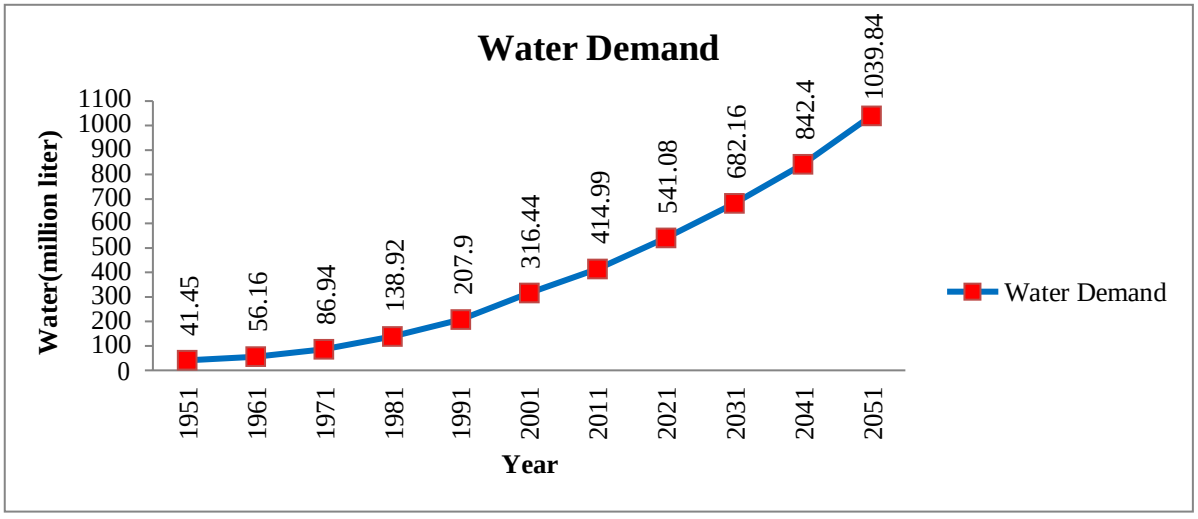


Figure 02: Daily Water Demand (Million Liters)



Projections shows that water demand is going to double in next 30 years which is 541 million liters per day and expected to become 1040 million liters per day by 2051. Looking to the present capacity of water supply by Bisalpur dam (422 million liters/day), which is not enough to meet the present demands. Government of Rajasthan is searching for additional source of surface water, which can be brought to Jaipur to meet the demand of increasing population. No single solution for supply of domestic water to Jaipur city is workable. Authorities has to prepare comprehensive plan for judicious utilization of available resources, recycling of water for gardens, parks, careful assessment of ground and surface water

available surrounding to Jaipur city, Inter basin transfer of water from Yamuna, Chambal rivers through canal. Management and conservation of available water resources is also equally important like harvesting of storm water, recycling of water at least for parks and gardens.

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