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FUTURE WATER DEMAND FOR BENGALURU, SILICON VALLEY OF INDIA

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***Abstract*— Water plays a major role in the journey of life on earth. Decrease in water resources and a consistent increase in water demand deserve more attention in the field of proper assessment of water requirement of a population group. Bengaluru, being the economic capital of Karnataka, considered as the Silicon Valley of India, is the only major metropolis in the country which is far from a perennial river source. The city has been experiencing huge depletion of green cover and ground water potential due to rapid urbanization.**

The city also faces the challenge of huge component of transient population which shows a distinct behaviour in comparison with the resident population of the city. For a growing city like Bengaluru, the challenge is to arrive at the average water consumption standard to determine the appropriate water demand. The water demand is calculated using the right population for future years and the per capita consumption standards specific to the water consumption scenario of the city.

The study gives an attempt to arrive at the appropriate water requirement of Bengaluru undertaking population as a crucial factor. Based on the trends shown by the past population, the future growth scenario is arrived by identifying the appropriate factors contributing to the population growth. Logistic projection method is chosen for projecting the population based on the identified growth scenario. The water consumption pattern (LPCD-Litres per capita per day) for Bengaluru is arrived using a three-pronged approach viz: published water consumption standards, previous studies done for other similar Indian cities and a sample survey. The survey was done to validate the consumption standards taking into account different strata of population in the city viz; LIG (Low Income Group), MIG (Middle Income Group) and UIG (Upper Income Group) in a representative area. Based on the projected population and the per capita consumption, the demand for water is calculated for future years till 2031

***Index Terms*— Bengaluru, Logistic model, Population Projection, Sample Survey, Water Consumption standard; Water Demand**

I. INTRODUCTION

Bengaluru, the socio-economic capital of southern state of Karnataka is a metropolitan city in India bordering Tamil Nadu. The city is spread over southern part of Deccan Plateau at an altitude of 950 meters above mean sea level [1]. Bengaluru is the fifth most populous city in India and the 18th most populous city in the world [2]. The city witnessed fast urban development and population growth (decadal growth rate of 42% for the period 2001-2011) majorly due to IT industry [3]. Bengaluru is the 2nd largest technology hub after Silicon Valley. The city bears fifty percent of the world's SEI CMM Level 5 certified companies and have the highest number of R&D centers in India [4].

Bengaluru is a unique metropolis where the perennial river source, Cauvery, which is the major source of drinking water, is situated about 100 km from the city. Ground water is also used alternatively to meet the water requirement of the city. Ground Water has experienced huge exploitation & witnessed drastic depletion in the recent past years. Unprecedented growth of the city also contributes to the deterioration of environmental factors as shown in the figure below

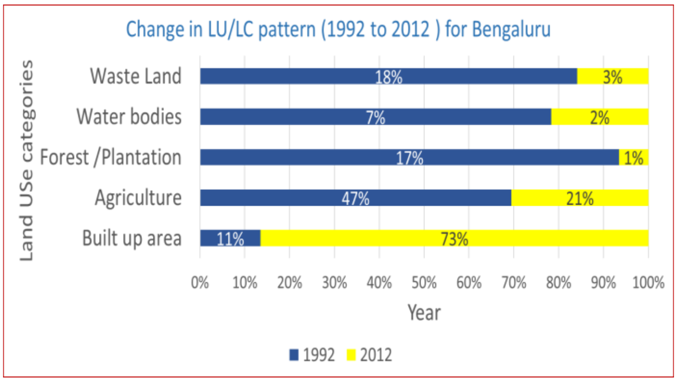

Fig.1 Change in Environmental factors for Bengaluru [5]

As referred in few earlier studies, the unprecedented growth of the city adversely affected the water demand. Groundwater consumption created critical areas where ground water exploitation is greater than recharge [6]. Bengaluru is the fifth largest city in India in terms of population which meets its water demand from municipal water source (BWSSB supplies Cauvery water) and ground water. Fourty percent of population of Bengaluru depends on ground water to meet their daily water demand [7]. Bengaluru known as 'Garden City of India' lies on top of four river valleys-Koramangala, Challaghatta, Hebbal &Vrushabhavathi valleys, contributing large number of lakes & ponds. But these lakes and tanks are getting deteriorated due to anthropogenic activities(Fig.1). Extensive ground water supply through private self supply, ground water supply by water utility and informal water tanker market cause drastic ground water depletion in the city [8].

Water management is a major area where the government officials and policy makers of the city face enormous challenges viz; rising costs of bringing municipal water from river Cauvery, rapid urbanization and unplanned growth of the city non-confirming to master plan and lack of comprehensive management of water resource by a unified agency.

To overcome these challenges, a comprehensive water demand pattern analysis is essential for Bengaluru urban region. This is a prelude to identify the gaps in water management (demand Vs supply) available for the city in future. The population projection studies done earlier[3] did not take into account the trend in contributing factors and its effect on the selection of the projection method to determine the future population. Also, a comprehensive water demand calculation for the city area was not attempted taking into account the jurisdictional inconsistencies of various agencies and the actual water consumption patterns of different strata of the population. Taking all these factors into account consideration of care has been taken in this paper to arrive at the demand of water consistent with the ground water situation in the city at present. The major goal of the work is to give a reasonable estimation of future demand for water of the city using appropriate population projection methods and existing public water consumption standards. A sample survey was also conducted to validate the average water consumption of the city population at present.

II. Study Area

The study area includes Bengaluru Urban District which is located in the South-Eastern part of Karnataka. It is the principal administrative, industrial, commercial, educational and cultural capital of the state of Karnataka [9].

Bangalore city is located at more than 950 m amsl (above mean sea level) [3]. The study area includes 711 sq.km of BBMP area with 198 wards providing municipal water distribution by BWSSB (Bengaluru Water Supply and Sewerage Board) boundary of 623 sq.km (Fig.2). BBMP area lies between 12° 49′ 34″ N and 13° 18′ 9″ N lat., and 77° 27′ 41″ E and 77° 47′ 5″ E long.

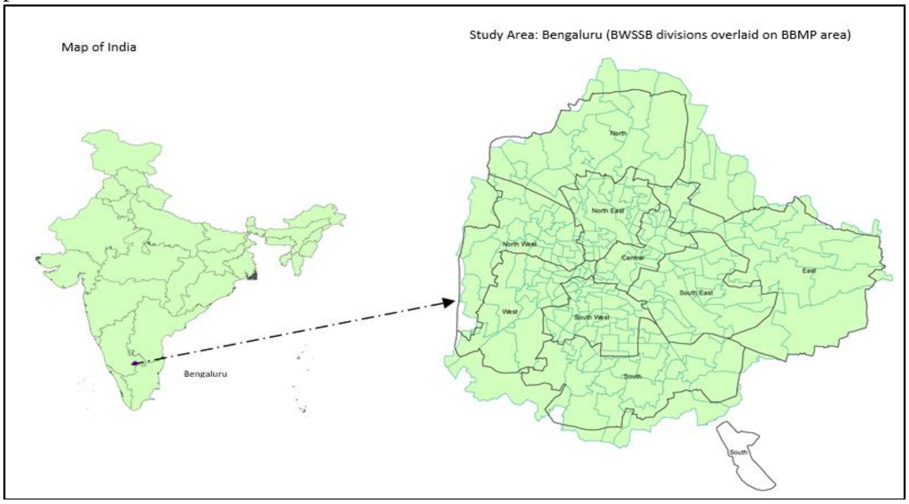

Fig. 2 Study Area

III. Aim & Objective

The major aim of the study is to determine the water demand among the existing population of Bengaluru for future years (till 2031). A population projection has been done based on previous growth trends(from1971) for future year till 2031 to arrive at the correct demand profile for the city. The study also aims at assessing the reasonable water consumption pattern using published consumption standards and secondary data from previous studies. A sample survey has conducted in J P Nagar sixth phase, in south Bengaluru to arrive at an approximate water requirement in a city like Bengaluru. The following are the broad set of objectives attempted in this paper:

•To arrive at the appropriate population projection of the city for future

•To assess the average consumption standards for the city

•To provide a visual representation of the regional variation in water demand.

IV. Methodology

Population increased many folds in the city for the last few decades, indirectly affecting the water demand pattern. Growing demand for water coupled with the scenario of absence of a perennial river water source in the premise of the city puts more pressure on the system to determine the appropriate quantity of water to be distributed in specific regions. To ensure urban water security for a city like Bengaluru, there is a need to develop correct approach to arrive at the demand which involves population projection and assessment of average consumption.

A. *Population Projection*

Population is a milestone in the accurate assessment of demand of water in a metropolitan city. The work uses the past data of population collected from Census department (1971 to 2011) to arrive at the right population projection in the future (Table I). Care has been taken to select the suitable projection method in line with the population growth scenario.

Table I: Data Collected for population study

Data collected	Source	Details	Used for
Population figures in 2001 and 2011 ward wise	Census Department	Ward wise population figures	Calculating population density, projections of population for future years
Factors for extrapolation of population	Department of Statistics	% increase of population	Projection of population per year or decade for future

To arrive at the apt projection method for future population calculation, care has to be given to identify the right population scenario at present which can be determined by identifying the contributing factors and its trend across the time horizon. These factors are classified according to their degree of influence viz; positive, negative and neutral. Based on the population scenario, logistic projection method is chosen as the appropriate projection algorithm to identify the figures for 2031.

B. *Average Water Consumption Standards*

A city like Bengaluru with its varied socio-economic factors needs a careful examination of the right consumption standards to arrive at the water demand. A three-pronged approach is used to arrive at the right consumption standards as follows

•Published standards of consumption from UN and WHO

•Published literature of consumption standards for other similar Indian cities which share the same characteristics of Bengaluru in water consumption pattern

•A sample survey (based on stratified quota sampling) was conducted on a representative area in Bengaluru which has the cross section of different types of dwellings. The nature of consumption was studied by a structured questionnaire combined with face to face interview to arrive at the consumption patterns. The consumption metrics (litres per capita per day – LPCD) thus arrived were compared against the published standards to arrive at the real water consumption pattern applicable for the city.

C. *Water demand*

The present study provides the water demand structure of the city using population framework and average consumption in LPCD, using the formula

Demand for water = Population X Consumption standards [10].

V. Results and Discussions

A. *Population projection*

Bengaluru has grown leaps and bounce and population increased many folds for the past decades. The city contributes 1.9% of GDP of India and 33.6% of State GSDP in year 2012-2013 [3]. The largest metropolis in Karnataka has witnessed 43 % growth rate in the period 2001-2011 (Table II).

1) *Trends in population Growth in the past*

As per Revised Master plan 2031 [3], Bengaluru Metropolitan Area (BMA) is spread over 1294 sq. km consists of 711 sq. km under city municipal corporation, BBMP (Fig.2) and 251 villages with remaining area of 583 sq.km [3]. The population growth trend shows an increase rate of 3.4 % in BBMP areas over the past four decades and the villages grew at 4.26% over the past 40 years (Table. II)

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Table II. The Population growth decadal 1971 to 2011 in BMA[11]

Year	BBMP			251 Villages			Total BMA		
	Population	GR%	CAGR %	Population	GR%	CAGR %	Population	GR%	CAGR %
1971	1897826			113879			2011705		
1981	310081	63.4	5.03	157664	38.4	3.31	3258475	62	4.94
1991	4320297	39.3	3.37	209550	32.9	2.88	4529797	39	3.35
2001	5887953	36.3	3.14	302163	44.2	3.73	6190016	36.7	3.17
2011	8443675	43.4	3.67	600989	98.9	7.12	9044664	46.1	3.87
Diff	6545849	344.9	3.8	487110	427.7	4.26	7032959	349.6	3.83

However, the percentage composition of villages is a mere 7% of the total population and hence large-scale changes with respect to growth in the villages may not affect the population of Bengaluru(Fig.3). Due to large amount of land area available in these villages, the percentage composition of growth in the villages are going to increase over future years [3]

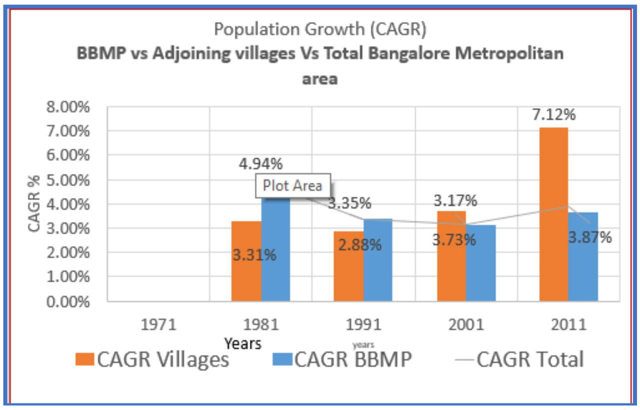


Fig. 3: Population Growth (CAGR %), BBMP areas Vs. Adjoining Villages

1) Future Population Scenario

There are numerous assumptions and considerations to be done to predict the population for Bengaluru for future years. The trends of contributing factors for population growth scenario is analysed in detail as follows:

a) Migration or Population growth levers

Past high population growth of Bengaluru was due to the factors like growth of industries including IT sector and biotechnology[3]. Salubrious climatic condition of the city in conjunction with less pollution contributed to heavy migration from various parts of the country. Attempt is made to analyse the recent changes in the IT sector growth and environmental / climatic conditions affecting population growth of the city.

1. The IT Sector Growth is showing a decline from 14% to 7% from 2012 to 2017[12] is a negative contributing factor in population growth (Fig 4)
   The protectionist policies from US and UK and the migration of IT from data centers to cloud are the major reasons for growth decline in IT sector [12]

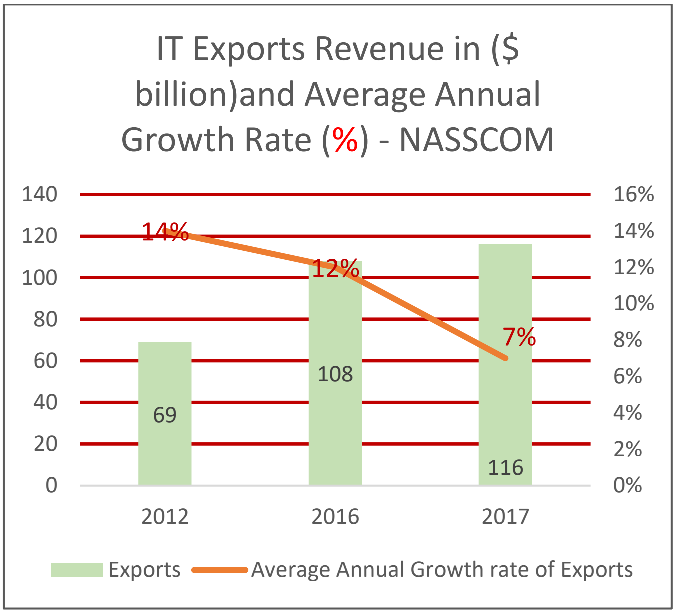


Fig. 4 IT Exports growth rate and revenue trends from 2012 to 2017

2. Favourable climate & living condition are major factors which contributed to intrastate and interstate migration in the recent past in Bengaluru. However, the climatic condition has worsened over the past few decades in Bengaluru in absolute figures[13]. The following are the adverse climatic & living conditions in the city affecting the migratory trends.

2.1 Air quality index

Air pollution mainly contributed by industrial emissions, vehicular traffic increase and construction surge is reaching severe & heavy conditions in many areas of the city

Table III Location specific air quality trends in Bengaluru (2003 to 2007)

Location for air quality monitoring	2003-2004	2004-2005	2005-2006	2006-2007
Amco Batteries	Light	Moderate	Moderate	Moderate
Graphite India	Light	Moderate	Heavy	Severe
KHB Industrial Area	Light	Moderate	Moderate	Heavy
Peenya Industrial Area	Light	Light	Moderate	Heavy
Victoria Hospital	Light	Moderate	Moderate	Moderate

Source: Air Quality trends [13]

2.2 Traffic woes

Bengaluru is experiencing high traffic levels and ill effects due to high traffic congestion (Fig 5). This is affecting the mean time of commute and the quality of ambient air which are concerns for development. Overall trends in the movement of these contributing factors for migration is negatively affecting the population growth of the city.

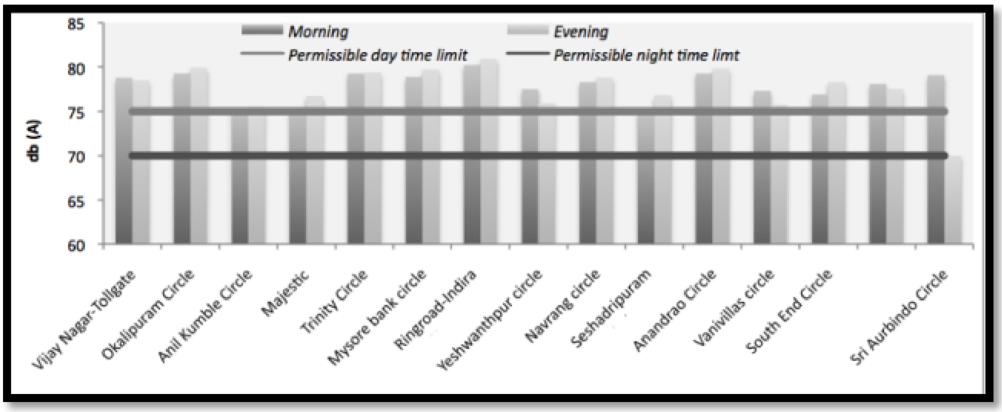


Fig 5 Traffic noise in decibels monitored by CPCB in Bengaluru [13]

b) The outlook of the state administration with respect to Bengaluru

Although Bengaluru is a leading investment destination of the state, Government of Karnataka is planning to have a balanced regional development. In conjunction with the above policy, the state is to develop ICT industries in Tier- 2 and Tier-3 cities like Hubli- Dharwad, Mysuru, Mangalore, Kalburgi and Belagavi[14].The state has already developed IT parks in Hubli Dharwad, Shivamogga and Kalburgi in tandem with Bengaluru for further future investment activities[3]. Thus, in line with the stated policy of balanced development, Government will try to bring other cities / towns into the IT sector roadmap diminishing the growing importance of Bengaluru in future, which is considered as a neutral contributing factor.

c) The trends on mortality, child birth and life span

While birth rate in the State has declined to 19.2 in 2011 (from 22.2 in the year 2000), indicating a decline of about 9%, the death rate has declined at a lower rate of 6.5% from 7.6 in 2000 to 7.1 in 2011[14]. Mortality- rate declined by 6.5%(positive factor) & Child Birth-rate declined by 9%(negative factor). As a result, net growth rate of the city shows a neutral approach towards future population growth of the city[14] .

The net effect of the above factors in general shows a decline in population growth in the city. However, the effect will be minimal and the population growth trend shows an increase in a reduced level.

Based on the above trends analysis, appropriate scenarios are identified for population projection for Bengaluru (Table IV) for future years up to 2031. According to scenario 3, which is the most likely one to happen, population growth shows a reduced pace and reaches a saturation level in future.

Table IV: Trends & possible scenarios in population projection

Scenario	Scenario Details (Population trends)	Occurrence probability		Projection
Scenario 1	Population will increase as per previous trends	✗	Unlikely	Linear Model
Scenario 2	Population will show fluctuations in future not as per trends in past	✓	Less Likely	Cubic Model
Scenario 3	Population will grow at reduced rate and reach a saturation point in future	✓✓	Most Likely	Logistic Model

For the most likely scenario (Scenario 3), logistic model is used for population projections till 2031 According to the projection, Bengaluru will witness a population increase to 1.9 crores by the year 2031(Justfying Logistic Model using R square value of 0.99376(Table V).

Table V: The projected population figures for BMA using Logistic model

Year	Total BMA Population (Actuals)	Projected Population using Logistic Model
1971	2011705	2124304
1981	3258475	3060246
1991	4529797	4408554
2001	6190016	6350910
2011	9044664	9149045
2016		10981095
2021		13180004
2026		15819234
2031		18986956
R square		0.99376

2) Context of selection of Logistic Population Projection Method

Logistic Model is thus used to arrive at population for 2031 due to the following reasons:

- A historic,mountainous city like Bengaluru is undergoing considerable development for the past few decades. Population growth follows a normal trend according to birth rate, death rate and migration. The city has not witnessed any natural calamities like flood, earth quake etc which helps the population to grow according to normal trend in the past.
- As per the assumption in scenario 3 (Table IV), where population will reach into a saturation level in future years, Logistic Model is a suitable population projection method for the city of Bengaluru.

Migration trend and growth rate pattern shows no positive effect on population growth in future years for Bengaluru. Present study identifies logistic projection method (population reaches a saturation in future), as the most likely case for population growth in the city compared to cubic model (Table IV). In this paper, an attempt is done for comparison of various population projection methods(cubic model and logistic model) to emphasize the authenticity of logistic projection model for assessing the population for the year 2031(Fig .6).

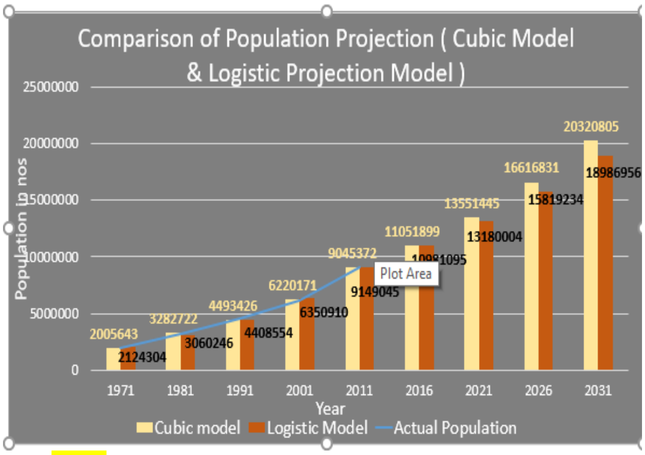


Fig 6 Comparison of population projection by Cubic and Logistic Models

Based on the parameters of the assumption, logistic model could be the most appropriate mathematical function to determine the population growth rate for the city in future years. Logistic model is the closest to the assumption of scenario made in population function as demonstrated in the figure below (Fig 7)

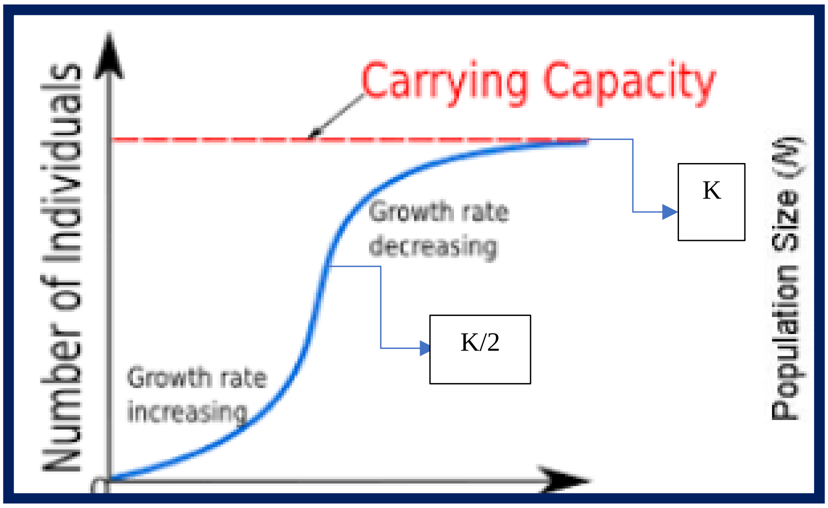


Fig.7 Logistic Projection Model

The assumption that is going to be a saturation point in population growth rate, results in shape of the population curve changing from concave to convex. The logistic function assumes that the midpoint (K/2) is the point of saturation where the curvature switches [10]. K is the carrying capacity of the city where the population stabilizes.

Based on the logistic model, the population projection for the BMA (Bengaluru Metropolitan Area) reaches 1.9 crore in 2031(Table V). According to the population growth as per logistic model, The CAGR (Compound Annual Growth Rate) is going to reach a plateau (Fig 8)

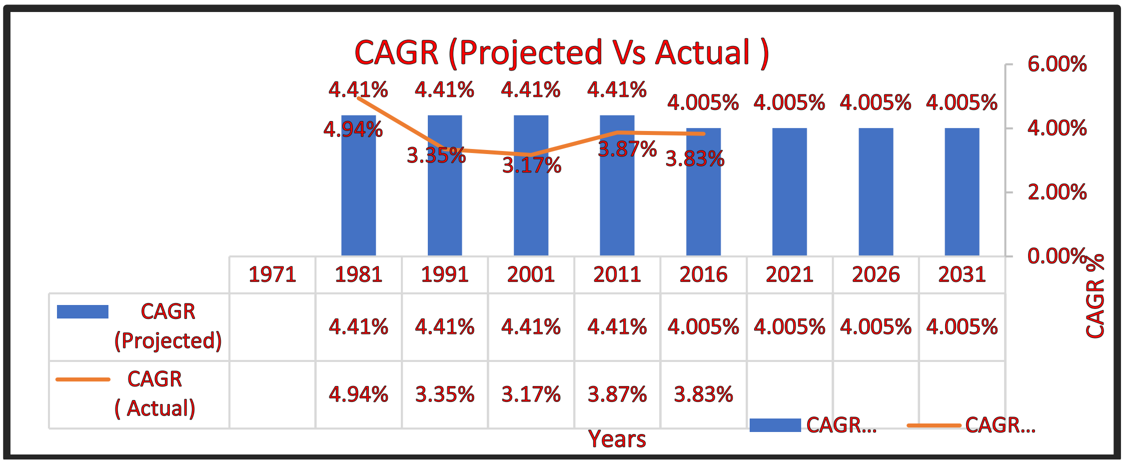


Fig 8 Compound Annual Growth Rate in Population

B. *Average consumption per day*

The per capita consumption of water by consumers in Indian urban centres are difficult to predict and measure. The consumption patterns are way lower than the standards imposed by World Health organization and Bureau of Indian Standards. This is due to the fact that the water intake is throttled by reduced supply and practices linked to socio economic condition of population

1) Published Consumption Standards

As per the Bureau of Indian Standards, IS:1172-1993, a minimum water supply of 200 litres per capita per day (LPCD) should be provided for domestic consumption in cities with full flushing systems. IS:1172-1993 also mentions that the amount of water supply may be reduced to 135 LPCD for the LIG and the economically weaker sections (EWS) of the society and in small towns[15]

World Health Organization(WHO) has laid down standards for water consumption which ranges to 200 – 220 LPCD. However, the regions have peculiar characteristics which warrants less water usage. WHO in its report “Health Development in South East Asia Region” stated that, in most countries like Bangladesh, Bhutan, India and Nepal draws water from spot sources and the demand varies from 100 to 250 litres per capita per day (LPCD). Also, the piped water supply in Indian cities varies from 45% to 98% and thus will have varied levels of consumption patterns [16].

2) Derivation from published sources

There are limited studies done on water consumption pattern analysis of cities in India. A study done by Abdul Shaban on seven cities in India viz; Delhi, Kanpur, Kolkata, Ahmedabad, Mumbai, Hyderabad and Madurai based on water consumption patterns. According to the study, a sampling had been done among population and actual data on consumption pattern of the corresponding samples were collected. Based on consumption patterns of the cross section of population, the study derived the distribution of consumption (mean and variation) of different strata of population(Table.VI). Also the work made an attempt to gauge the water consumption per household activity and the variables affecting the consumption for various Indian cities [17].

Table.VI Water Consumption Statistics in Major Indian Cities

Cities	Per House hold		Per Capita	
	Mean	Std Deviation	Mean	Std Deviation
Delhi	377.7	256.8	78	49.9
Mumbai	406.8	158.6	90.4	32.6
Kolkata	443.2	233.6	115.6	64.9
Hyderabad	391.8	172	96.2	43.8
Kanpur	383.7	286.2	77.1	58.2
Ahmedabad	410.9	224.1	95	54.6
Madurai	363.1	182.1	88.2	44.4
Total	398.3	220.2	91.56	51.51

Though the study did not include Bengaluru the average consumption level of Bengaluru is established by using the following considerations:

• Population characteristics: Type of population (income and age level), extent of migrant population vs indigenous population and the approximate area where population is distributed are the important characteristics considered in this comparison study between Bengaluru and other cities (Table VII)

• Supply characteristics: The percentage coverage of municipal water supply to the population and the percentage coverage of water supply in terms of hours per day are the characteristics which are considered for estimating analogous city to Bengaluru in terms of water consumption.

Table VII. Comparison of the population & Supply characteristics of different cities compared to Bengaluru
**BBMP Area only

	Coverage of piped water supply (%)		Municipal coverage area (sq.km)		Population (crore) 2001		Demographics of occupation	
Cities	Value	Rank of similarity	Value	Rank of similarity	value	Rank of similarity	value	Rank of similarity
Delhi	91.9	Low	1484	High	9,80,000	High	Business, Govt service	Low
Mumbi	98.6	Low	604	Low	11,90,000	Low	Migrant workers, Business	High
Kolkata	98.8	Low	200	Low	4,60,000	High	Migrant workers, Govt. Service	Low
Hyderabad	99.7	Low	650	High	3,50,000	High	Migrant workers, Business	High
Kanpur	54.1	High	404	Low	2,50,000	Low	Agriculture	Low
Ahmedabad	94.2	Low	465	Low	3,50,000	Low	Business, Govt service	Low
Madurai	98.5	Low	148	Low	92,000	Low	Agriculture	Low
Bengaluru	60		711**		6,20,000		Migrant workers, Business	High

Based on the above characteristics, Kanpur is closest to Bengaluru with respect to supply characteristics. It is due to the fact that 54 % of Kanpur has piped water supply against 60% of Bengaluru population which is having municipal water supply. All other cities have more than 90% coverage in piped water supply. Hyderabad and Delhi are closer to Bengaluru with respect to population characteristics. However, culture, climatic condition and terrain of Hyderabad have better similarity with Bengaluru regarding population. Hence Hyderabad is chosen as a city which has closer resemblance to Bengaluru in water consumption pattern.

Table VIII. Similarities of cities in average consumption vis a vis Bengaluru

Cities	Supply Characteristics	Population characteristics	Average (LPCD) house hold	Average LPCD including commercial & others
				Additional 35% as per standards
Delhi	Low	High	78	
Mumbai	Low	Low	90.4	
Kolkata	Low	High	115.6	
Hyderabad	Low	High	96.2	125.06
Kanpur	High	Low	77.1	100.23
Ahmedabad	Low	Low	95	
Madurai	Low	Low	88.2	
Bengaluru				Appropriate to have 135 LPCD

Even though Hyderabad and Kanpur show an approximate LPCD of 100, 35 % allowance is introduced for the commercial and transient population water usage. Hence the figure of 135 LPCD for consumption looks logical for the city of Bengaluru (Table VIII).

C. *Sample Survey for Bengaluru*

A sample survey was done for the city to determine the actual water consumption patterns. A stratified sampling was conducted in an area which was representative of the dwellings & population in the city. The purpose of the survey was to fix the following parameters for the city

1. Validate the consumption standards from published sources based on actual consumption in Bengaluru
2. Get an overview of the storage,consumption & usage patterns of water and classify the same into
   - Type of dwellings
   - Type of demographic profile
   - Choice of Area & Sampling plan

The variables and the dependent factors analysed are as follows (Table IX)

Table IX. Variables & the dependent factors

Variable	Type	Comments
Quantity of water consumed in a dwelling	Dependent variable	Calculation of water consumed per house in Litres
Quantity of water per person consumed	Dependent Variable	Quantity of water / no of people staying in the dwelling
Type of dwelling	Independent variable	Grouped into LIG, MIG – complexes, MIG – Individual houses, UIG – Individual houses)
Area of dwelling	Independent variable	Average built up area of the dwelling
No of residents	Independent variable	No of people residing in the dwelling
Water Source	Independent variable	Whether the source of water is (Municipal water only, Ground Water only, Combined: Municipal water plus Ground Water)

Primary data collection was attempted in a neighbourhood of South Bengaluru (Fig 9).

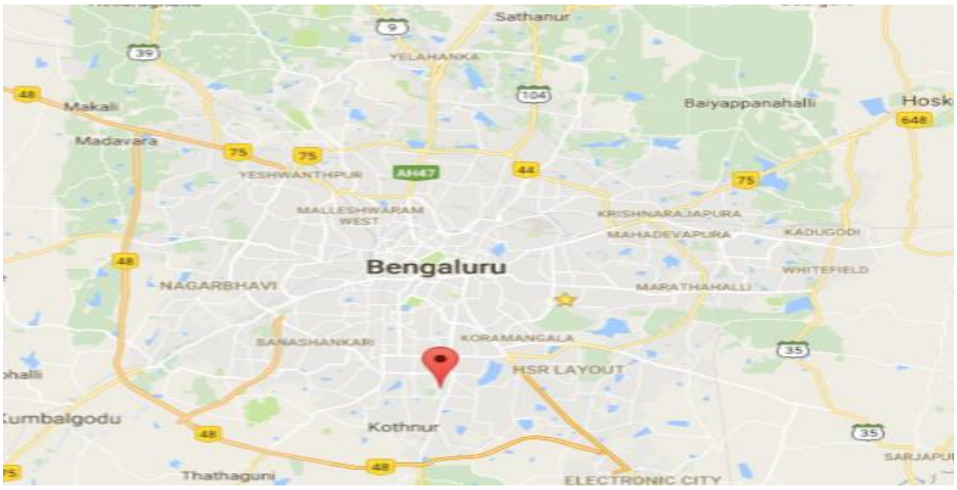


Fig .9 Position of the area covered in the survey in the city

Areas were chosen in this region so that a cross section of society is taken into consideration (Fig 10). The following were the key areas chosen for this sampling procedure.

Area A: This is primarily a slum area which are being inhabited by people doing manual labour and there are not pucca houses. This area can be classified as Low-Income Groups (LIG).

Areas B: This area covers a group housing complex comprising about 2000 apartments belonging to Middle Income Groups (MIG - complexes). However, the distribution and water supply are managed by the resident groups in a streamlined manner

Area C: This area primarily belongs to middle class families. The plot areas are 9 m x12 m or lesser and the houses are two storied. All the houses have primarily a 4-wheeler or 2-wheeler vehicle as means of communication which can be classified as Middle-Income Groups (MIG – Individual dwellings)

Area D: This area is primarily an upper middle-class society having houses in areas approximately 12 m x 18 m. Houses are mainly two or three storied and inhabitants have more than one 4 wheeler as means of transport. This area can be classified as Upper Income Group (UIG – Individual)

Area E: This area is primarily another residential area where upper middle-class families reside. However, the inhabitants are primarily old age residents (UIG – Individual)

Fig 10 Area covered in the sampling study

1) Method of Administering

A sample questionnaire which was administered gave a summary of water consumption in the specific dwelling. . The questionnaire was administered and implemented by doing door to door visit of the houses/ dwellings in the period (June to Oct 2016).

2) Analysis of survey results

The ‘characteristics of response of different type of dwellings is tabulated in the table below:

Table X. Response Characteristics of Different Dwellings

Area	Type	Variable	Average	Response / Range
Area A	LIG	% of data received/validated from sample size	NA	77%
		Area of dwelling	100 sq. ft.	60 sq. ft. to 150 sq. ft.
		No of people per dwelling	5	3 to 6
		Water Source	Ground Water	GW from tankers
Area B	MIG Complexes	% of data received/validated from sample size	NA	100%
		Area of dwelling	1800 sq. ft.	1200 sq. ft. to 3000 sq. ft.
		No of people per dwelling	5	3 to 8
		Water Source	Combined	GW and Municipal water mixed at Complex inlet level
Area C	MIG – Individual	% of data received/validated from sample size	NA	77%
		Area of dwelling	108 sq. m and 2 floors	108 sq. m with 2 floors (80%), 1 floor (10%) and 3 floors (10%)
		No of people per dwelling	6	3 to 8
		Water Source	Municipal Water	Mainly municipal water with very occasional GW use
Area D	UIG – Individual	% of data received/validated from sample size	NA	65%
		Area of dwelling	216 sq. m in 2 floors	216 sq. m with 2 floors (70%), 1 floor (10%)and 3 floors (20%)
		No of people per dwelling	3	2 to 6

		Water Source	Combined	Mainly Municipal water with weekly once operation of GW tube wells
Area E	UIG – Individual	Data received/validated from sample size(%)	NA	87%
		Area of dwelling	216 sq. m in 2 floors	216 sq. m with 2 floors (80%), 1 floor (10%)and 3 floors (10%)
		No of people per dwelling	4	2 to 6
		Water Source	Municipal Water	Mainly municipal water with very occasional GW use

Summary results are tabulated in Table XI

Table XI. Summary of results of the survey

Area	Type	Comments	No of dwellings administered	No of dwellings where data was validated	Average (mean of the values)	Std Deviation
Area A	LIG	Migrant Workers – One room houses	35	27	90.5	12.8
Area B	MIG-Complexes	2 and 3 BHK Apartments with area 1200 to 3000 Sq. ft.	50	50	121	23.1
Area C	MIG – Individual	9m X 12 m sites with 2 floors	40	31	192.5	22.17
Area D	UIG – Individual	12 m X 18 m sites with 2 or 3 floors	23	15	165	22
Area E	UIG – Individual	12 m X 18 m sites with 2 or 3 floors	57	50	171	15.87

The qualitative findings from the survey can be summarized as follows:

- The consumption patterns and LPCD of the dwellings vary significantly with respect to the type of dwelling and the type of population resides in the area.
- LIG dwellings will not have municipal water supply at their individual houses but have access to piped water supply or tanker water (ground Water) at close proximity within 200 m periphery
- MIG Complexes have separate water management system which is a combination of municipal water and ground water distributed in tanks. Although un-interrupted water supply is provided to the complexes, the average per capita consumption is lower than the MIG Individual apartments
- The UIG groups have to be studied in detail further to understand the consumption patterns and the areas where the consumption is more than the MIG groups
- Rapid usage of Reverse Osmosis Water Filters in the dwellings is a source of wastage of water (approx. 60 % of the total edible water)
- The quality of GW in a vicinity also varies substantially due to infiltration of sewage water

The quantitative findings of the survey can be summarized as follows in Fig 11

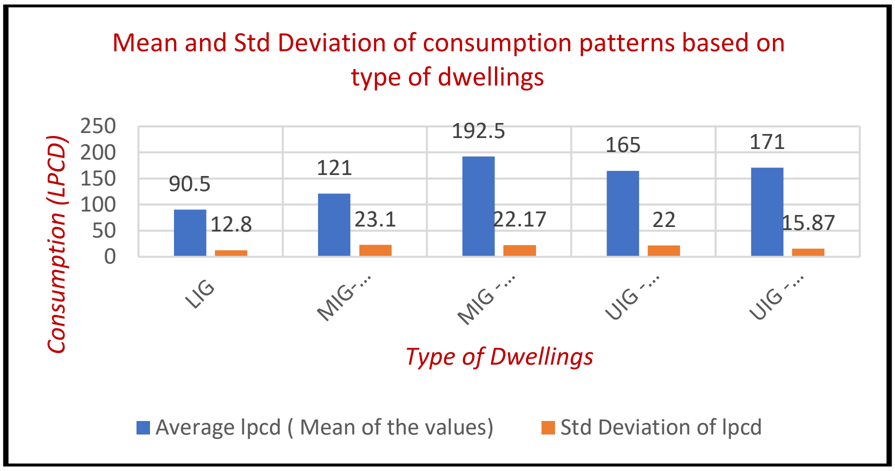
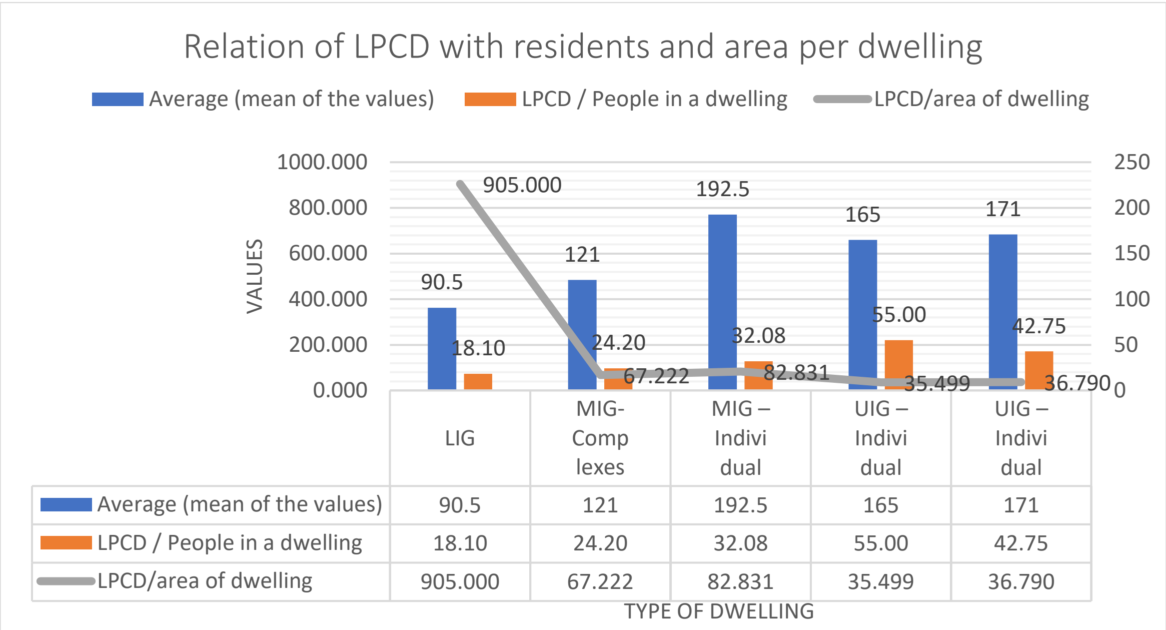


Fig 11 The mean and Standard Deviation of the water consumption patterns per dwelling type

- The LIG group has the lowest consumption in line with the expectations. This is due to the following factors:
    - The population density per dwelling is high compared to dwellings.
    - The absence of uninterrupted municipal water supply.
- The MIG Complexes have better consumption standards than MIG Individual houses. This might be due to the fact that there are no gardening / cleansing requirements per sq. ft. as required in complexes compared to individual houses. Also, the present complexes chosen had a working rain water harvesting & sewage treatment (secondary treatment) system which helps in recycle grey water for certain needs
- The MIG – Individual is higher than 175 LPCD which is a cause of concern. Further studies are required to validate these findings by using flow meters and taking a different locality under consideration
- The UIG – individual does not have significant increase in per capita consumption compared to MIG. This is the zone where there is no elasticity in water consumption based on the income levels or asset base. UIG have average consumption lower than MIG due to the lesser no of active young population per dwelling (Fig 11)

3) Correlation between Average Consumption (LPCD) and variables

LPCD is analysed for arriving at the relationship between the characteristics of dwellings as shown in Fig 1



	LIG	MIG-Complexes	MIG – Individual	UIG – Individual	UIG – Individual
Average (mean of the values)	90.5	121	192.5	165	171
LPCD / People in a dwelling	18.10	24.20	32.08	55.00	42.75
LPCD/area of dwelling	905.000	67.222	82.831	35.499	36.790

Fig. 12 Relationship between LPCD, Absolute Population & Dwelling Are

- For LIG houses the LPCD average is only having correlation to the no of people in the dwelling. However, this is not related to the area of the dwelling
- For MIG Complexes in comparison with MIG Individual, all consumption metrics (Average LPCD, LPCD per area and LPCD per people) are minimum. This is due to better management techniques of water resources including waste water recycling and absence of individual gardening in the area.
- MIG Individual shows higher consumption averages in comparison with UIG and MIG complexes. This is due to higher no teenage population in MIG individual in comparison with UIG whose water consumption is higher.
- However, UIG houses show the trend of people in a dwelling are the major factor which determines the water consumption (Fig 12).
- In a nutshell the above methods lead to an average water consumption of 135 LPCD for Bengaluru city (Table XII).

Table XII. Water Consumption Range

Source	Range	Comments
Bureau of Indian Standards	200 LPCD	With full flushing systems and can be reduced to 135 LPCD for LIG
WHO	150 to 220 LPCD	A range specifically for South Asian Countries
Secondary research from similar cities (Hyderabad and Kanpur)	135 LPCD	Combining commercial uses
Experimental Surveys	95 to 180 LPCD	Vary as per income profile

D. *Challenges in arriving at the survey results*

- The municipal water is often mixed with Ground Water in underground sumps in various dwelling types (except for LIG) and used as per their requirements. So, it is hard to determine the extent of usage of municipal water and ground water separately.
- The methodology for estimating consumption per dwelling is crude with constraints viz; determining the approximate volume of the storage sump, estimating the days of consumption of water per tank. This approximation might affect the accuracy of the results.
- The exact occupancy per dwellings are not constant with variables like people visiting during weekends, tenants occupying the house for part of the year etc
- There are no individual meters available per consumption point and hence the above approximations are used
- The type of usage varies per dwelling viz; usage for gardening, washing vehicles etc

However, under the circumstances and the resources available, the above survey yielded significant findings as follows

E. *Water Demand pattern for the city*

Based on the population estimations and the per capita consumption standards derived from the study for Bengaluru city, the water demand has been calculated. This study observes an average demand of 2563 MLD for a population of 1.9 crores by the year 2031 (Table XIII)

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Table XIII. Water demand pattern of different years in Bengaluru

Year	Total BMA Population (Actuals)	Projected Population using Logistic Model	Average Consumption standards (LPCD)	Water Demand in the city per day (MLD)
1971	2011705	2124304	135	272
1981	3258475	3060246	135	440
1991	4529797	4408554	135	612
2001	6190016	6350910	135	836
2011	9044664	9149045	135	1221
2016		10981095	135	1482
2021		13180004	135	1779
2026		15819234	135	2136
2031		18986956	135	2563

Thus, planning of water needs for the city should go almost in line with the demand patterns which can be anticipated by the city population.

Bengaluru water supply utility (BWSSB) comprises nine divisions and 32 subdivisions. Water demand variation for these divisions for the year 2016, taking into consideration of aggregating the population scenarios, is calculated to deduce the regional variation pattern. The calculated water demand was plotted using GIS technique to arrive at the heat map of water demand for Bengaluru. Heat map gives the visual representation of the demand pattern of water for the city for the year 2016. According to the study, South & North West divisions show maximum demand in 2016 followed by West & East divisions (Fig.13).

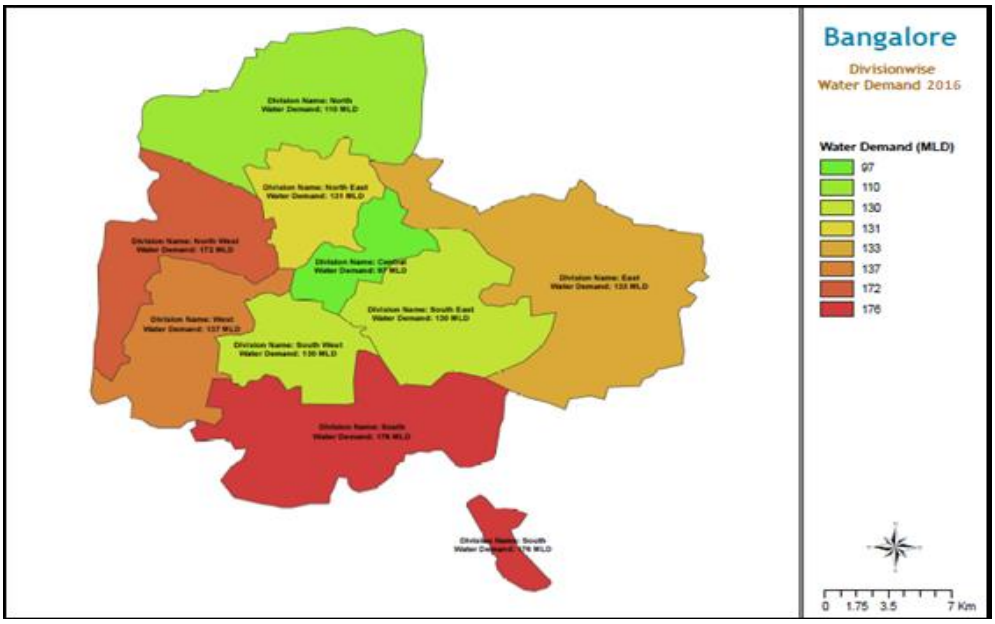

Fig. 13 Heat Map -BWSSB Division Wise Water Demand for 2016

VI. Conclusion

A thriving modern city like Bengaluru has a huge influx of migration from different parts of the country in the past influenced by various demand factors. This gave a challenge for city administration in effective water management. For effective water management the appropriate demand calculation at present and future years is inevitable. The population of the city had been analysed using the trends in the past. The past population trends as per census department data shows there was a population growth of 3.4% in BBMP area whereas adjoint villages show a growth of 4.26%. After detailed analysis of trends in movement of factors contributing to population growth in the past for the city, appropriate population projection method-logistic method is used to project population for future years till 2031. According to the model, population reaches a saturation in future and Bengaluru will have the projected population of 18.9 million which is almost 1.9 crore, in the year 2031.

Average consumption standard of the city has been calculated using secondary data collected from various sources. Using data from published standards and from previous studies in water consumption patterns for other Indian cities, average water consumption standard in LPCD is arrived. Estimated consumption standard is validated by the primary sample survey done for a representative neighbourhood in south Bengaluru. The results of the sample survey, arrives at a conservative estimate of 135 LPCD as the average consumption standard for the city. The heat map of division wise demand pattern for 2016 generated by GIS technique shows South and North-West divisions have the highest water demand followed by West and East divisions in the year 2016. According to projection method, Bengaluru city will have an approximate demand of 2563 MLD by the year 2031. The approach developed by adopting various methods- secondary data collection &sample survey method- within the framework of consumption pattern of Bengaluru, leads to 135 LPCD as the average consumption, which helps to increase the urban water security in future.

The per capita gap would be about 70 litres by 2031. Hence it is very essential to mitigate the gap with water reuse and water recycling, rainwater harvesting, fitting of plumbing fixtures with less water consumption etc. High quality water to be used only for primary purposes and for all secondary and non-skin contact purposes, treated water to be used to bridge the gap. Public awareness needs to be created. Moreover, water bodies are to be conserved, protected and developed where ever possible in order to ensure water security of the city for future years.

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