

Estimation and Forecasting of Urban Population of Male and Female for Different Regions of India Using Growth Models

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ABSTRACT

The region wise study of urbanization of India is an important phenomenon to understand the urbanization with socio-demographic characteristic of the nation. In the present study, India is divided into five regions VIZ. Northern, Southern, Eastern, Western and Central regions with respect to gender. The data for the study is collected from census of India from 1901 to 2011 census. For estimation of urban population for male and female two growth models are used-Modified Exponential and Gompertz models, the parameters of the models are estimated by using Method of Partial Sums and testing of accuracy and bias, MALPE and MAPE is calculated. The analysis of the study shows Western region shows highest level of urbanization whereas Eastern region has lowest level, estimation and forecasting results of the model demonstrates that modified exponential model good fit compared to Gompertz model for all the regions except male and total urban population in eastern region, measure bias shows Modified exponential shows underestimates and Gompertz shows overestimates for all regions of India except Eastern Region as this region shows overestimate for both the curves.

Keywords : Urbanization, Regional development, Growth models, Estimation and Forecasting, MAPE & MALPE.

Journal of Economic Literature (JEL) Classification System : P25, P48, O41, C53, C13 and C32.

Mathematics Subject Classification : 34L15, 11D68.

1. INTRODUCTION

Urbanization is a process of shift of labour and capital predominantly from rural to urban activities during the process of development. It is predominantly the process by which towns and cities are formed and become larger as more people live and work in central areas. Globally, according to World Urbanization Prospect (2018), about 55 per cent of the population lives in urban area. The World's urban population has grown rapidly from 751 million to 4.2 billion in the year 1950 to 2018. About 68 per cent of the population is expected to increase by 2050. The world's urban population got further increased in the size accounting for 35 per cent of the projected growth between 2018 and 2050 and is expected to be highly concentrated in few countries of the World viz, India, China, and Nigeria.

There is significant diversity in the urbanization levels reached by different geographic regions. The most urbanized geographic regions include 81 per cent of Latin America and Caribbeans who live in urban areas i.e., 74 per cent, 68 per cent and 82 per cent respectively in Europe, Oceania, and Northern America in the year 2018. Nearly Asia has 50 per cent of level of urbanization.

The growth of urbanization in India is similar to other development in the country, the growth of urban population is very slow before the independence. In 1901, the urban population is hardly 11% and it is increased 14% in 40 years period that is 1901 to 1941, during 1941-51 the percentage of urbanities increased by nearly 3.4%, which may be due to economic depression and spread of independence movement against British colonial rule, for this reason people moved from rural to urban areas and due to massive displacement of people during partition of India and Pakistan in 1947. Many people from Pakistan came to India and settled in large cities of India in the year of independence (Kundu, 1992). After the independence of India, the urban population has doubled till 2011 i.e., about 31.54% than the earlier period, this may be due to the better employment opportunities and infrastructural facilities in urban areas and also due to the change in the definition of rural and urban in 1971. Many demographic, Economic and other studies divide India into different regions. The regions are different from study to study. The region is categorised to study the infrastructural development by using weighted factor analysis, study categorized into five regions – Highly developed, Developed, Developing, Less developed and Least developed districts of Uttar Pradesh (Dube et. al., 2022). According to Mitra, Mukherji, and Bose (1980), India is divided into five regions- Northern, Southern, Eastern, Western and Central regions. Northern region includes– Chandigarh, Delhi, Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab, and Rajasthan. Southern regions are Andhra Pradesh, Karnataka, Kerala, Lakshadweep Island, Pondicherry, and Tamil Nadu. Whereas Eastern regions include Assam, Arunachal Pradesh, Bihar, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Sikkim, Tripura, and West Bengal. The Western regions are Gujarat, Goa, Maharashtra and Dadra and Nagar Haveli and Central regions are Madhya Pradesh and Uttar Pradesh.

The most parts of India have very low level of urbanization they are Central, Eastern, and North-Eastern parts. On the other hand, the states which have higher urbanization level than the national average are Northern and Western regions of India such as Punjab, Haryana, Gujarat, and Maharashtra, but Goa which is small state continues to top the list among states with 62% urban followed by Mizoram (51.5%) (Bhagat R. B., 2018).

In the present paper, an attempt is made to study the growth pattern of urbanization for five regions of India with respect to gender by using two growth curves viz, Modified Exponential Curve and Gompertz Curve. This paper includes Introduction in the first section, Methods, and materials in the second section, Analysis and interpretation is included in the third section and last section concludes the study.

2. METHODS AND MATERIALS

The data required for Urban, Rural and Total population with respective to gender for five regions of India is collected from Census of India, New Delhi for decades from 1901 to 2011. To study the trends

for the selected variables, the study uses two different growth curves namely Modified Exponential Curves and Gompertz Curves. For testing accuracy and bias of the model MAPE and MALPE is used.

2.1. The Modified Exponential Growth Curve

By assuming that the rate of growth is proportional to the size of urban population increase, the Exponential growth model can be modified. Where the rate of growth is proportional to the number of urban population at that time in Exponential growth model, whereas in Modified Exponential, the rate of growth does not depend only upon the urban population, but there are several other factors that affect the growth rate.

Thus, the following equation is the Modified Exponential growth model,

$$P_t = \alpha + \beta \rho^t$$

Where, $\alpha > 0, \beta > 0$ and $0 < \rho < 1$.

2.2. The Gompertz Curve

The Gompertz Curve was originally derived to estimate human mortality by Benjamin Gompertz (1825). This Gompertz Curve has been used by various authors as a growth curve, for both the biological and economic phenomenon. The Gompertz Curve was used in actuaries.

For this model,

$$P_t = \alpha \beta \rho^t$$

Where, $\alpha > 0, \beta > 0$ and $0 < \rho < 1$

Hence,

$$\log(P_t) = \log(\alpha) + \log(\beta) \rho^t$$

Equation (3) is the form of the Modified Exponential Growth Curve. The Gompertz Curve is related in a similar fashion to the Modified Exponential curve as the Simple Exponential is to the straight line. As ρ^t tends to zero for large t, P_t tends to the constant asymptotic value α ; modification of the curve is possible which will allow for a sloping asymptotic.

2.3. Mean Absolute Percentage Error (MAPE)

MAPE is the average percentage error when the direction of the error is ignored (Smith, 1987). In the fitted time series value in statistics, it is the measure of accuracy, specifically in growth curves. MAPE is most used to evaluate cross-sectional forecast (Rayer, 2007; Hyndman and Koehler, 2006). It usually expresses accuracy in percentage as is defined as,

$$MAPE = \frac{1}{n} \left(\sum_{t=1}^n \left| \frac{A_t - E_t}{A_t} \right| \right) \times 100$$

Where, A_t - The Observed urban population at time t.

E_t - The Estimated urban population at time t.

2.4. Mean Algebraic Percentage Error (MALPE)

MALPE is the average percentage error when the direction of error is accounted for (Smith, 1987). It is the measure of bias in fitted time series data in statistics (Siegel and Swanson, 2004). Negative error indicates a tendency that the projection is an underestimate and a positive error indicates that the projection is an overestimate and is given by,

$$MALPE = \frac{1}{n} \sum_{t=1}^n \left(\frac{E_t - A_t}{A_t} \right) \times 100$$

3. ANALYSIS AND INTERPRETATION OF DATA

3.1. Growth and distribution of India

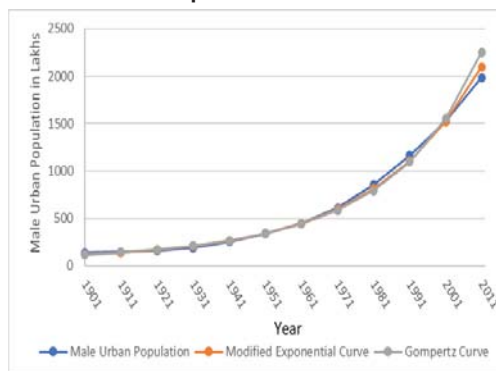
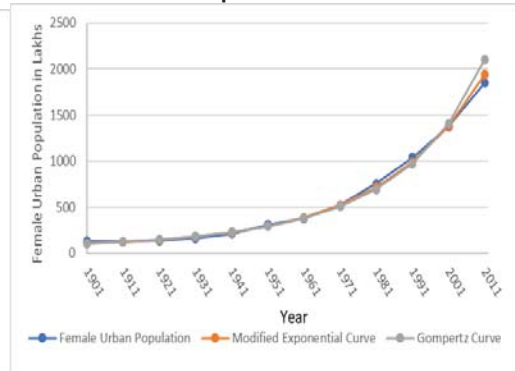
The urban population of India got increased gradually from 11.21% to 31.67 %, it increased nearly three times in eleven decades, and urban population of male is higher than that of female for every decade starting from 1901 to 2011. After the independence of India, the urban population of India is almost alike to that of the other modern developments that have been taking place. The growth and development of urban area have increased after the implementation of five-year plan by the Government of India. The total percentage of urban population in India is 31.14% as per the census 2011. The urban population growth rate has shown a declining trend in during 1971-1981, and in 1991 census it got reversed at the national level, in the year 2001-2011 the level of urbanization has increased faster. in the year 2001 the urban population has increased moderately from 286 million to 377 million in 2011, an increase of 91 million larger than the rural area which is about 90.5 million. This increase was due to rural to urban classification and migration, and due to the greater number of new towns which emerged during the last decade (Bhagat R. B., 2011).

According to Census of India 2011, the sex ratio in India got declined from 1901 census to 1941 and after 1961 its value gradually increased up to 2011. In the year 1901 sex ratio of India was 907 and it decreased to 828 in 1941, and after that sex ratio increased to 929 in 2011. The sex ratio increased rapidly from 1991 census onwards as there was a strict implementation of female foeticides in India in 1994. Therefore, it is necessary to study the urban population with respect to gender.

Table 1: Urban Population and its Estimation by Modified Exponential and Gompertz Curves in India with Respective Gender.

Year	Urban Population			Modified Exponential Curve			Gompertz Curve		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
1901	14071548 (11.65)	12775500 (10.89)	26728822 (11.21)	11979906.71	10570789.9	22688542.41	11846035.25	10376286.38	22322149.36
1911	14518986 (11.31)	1265294 (10.23)	27179506 (10.78)	14002940.5	12178974.95	26240152.93	14214333.02	12346349.71	26594175.95
1921	15959443 (12.42)	13526092 (11.02)	29555887 (11.76)	16831595	14471845.7	31266789.54	17289060.58	14915030.78	32153070.3
1931	19051153 (13.33)	16007982 (11.79)	35112318 (12.59)	20786687.79	17740907.45	38381048.12	21337633.69	18317817.96	39498434.13
1941	25553370 (15.61)	21175190 (13.69)	46758675 (14.67)	26316793.67	22401774.07	48449942.89	26749902.61	22904064.89	49367367.71
1951	34008129 (18.33)	30922672 (17.61)	63132015 (17.48)	34049120.77	29047007.27	62700569.41	34104010.72	29202527.35	62868437.75
1961	44668286 (19.74)	37763063 (17.73)	82431350 (18.77)	44860646.55	38521452.23	82869650.61	44273096.19	38030890.51	81703526.85
1971	60974358 (21.47)	52138956 (19.74)	113113314 (20.64)	59977582.01	52029647.43	111415191.1	58601656.29	50683240.48	108543680.3
1981	85705443 (24.25)	75374355 (22.84)	161079798 (23.57)	81114444.86	71288964.31	151816034	79203305.7	69259261.73	147681534.4
1991	116347981 (26.48)	103953981 (25.54)	220301962 (26.03)	110668515	98747946.13	208995827.5	109474946.8	97258369.64	206193722.6
2001	152740196 (28.70)	137604017 (27.71)	290344210 (28.22)	151991727	137897604.9	289923069.3	155006176	140684000.6	296070384.8
2011	198751903 (31.89)	184717415 (31.44)	383469318 (31.67)	209770836.1	193715252.7	404460357.1	225229276.3	210161972.6	438234564.6
Mean Absolute Percentage Error (MAPE)				4.54	5.70	4.71	6.34	7.81	6.82
Mean Algebraic Percentage Error (MALPE)				-0.57	-0.58	-0.59	0.33	0.46	0.37

Note: Figures in the parenthesis are the urban percentage.

a. Male Urban Population

b. Female Urban Population


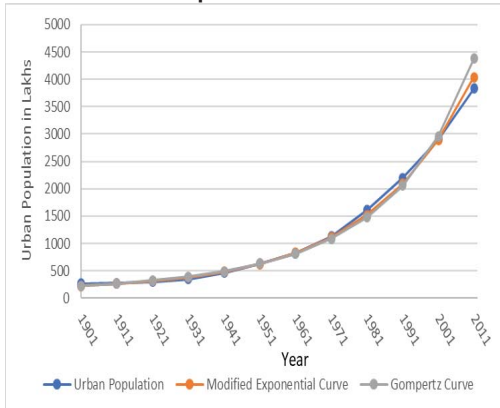
c. Total Urban Population

Figure 1. Fitting of Male, Female and Urban population by Modified Exponential and Gompertz Curves of India

Analysis of the study reveals that both curves Modified Exponential Curve and Gompertz Curve fitted well for all the three variables. The value of MAPE for Modified Exponential Curve is 4.54 for male, 5.70 for female and 4.71 for both sex, and Gompertz Curve has these values respectively 6.36, 7.81 and 6.82 for male, female, and total urban population. Therefore, Modified Exponential Curves shows good fit for all the three variables as compared to Gompertz Curve.

In MALPE the male population has -0.59, female population has -0.58 and for the total urban population, its value is -0.59 for the Modified Exponential Curve, and for the Gompertz Curve 0.33 for male population, 0.46 for female population and 0.37 for urban population. The value of MALPE for Modified Exponential Curve has negative value whereas Gompertz Curve shows positive values, this indicates Modified Exponential Curve model underestimate and Gompertz Curve shows overestimate for all the three variables (see Table 1 and Figure 1. a, b and c).

3.2. Growth and distribution of urbanization in different regions of India.

3.2.1. Northern Region

Analysis of the result presented in Table 2 reveal that Northern Region consists of 7 states and its percentage people living in urban area are Chandigarh (97.25%), Delhi (100%), Haryana (34.88%), Himachal Pradesh (10.3%), Jammu and Kashmir (27.38%), Punjab (37.48%) and Rajasthan (24.87%). The urban population of Northern Region in 1901 was 13.45 % and it increased gradually to 34.46 % in 2011 and similar observation is made in case of male and female urban population which is higher than the Indian average. In this region, Chandigarh and Delhi has achieved and had the maximum level of urbanization than other states of this region, where as Delhi has 100 per cent of urban population and Chandigarh has 97.25% which is near to 100%, where Delhi is a Union Territory situated in the northern part of India, and it is the largest metropolitan city by area in India. Delhi is the second world's largest city with an urban agglomeration of 29 million inhabitants (World Urbanization Prospect, 2018). Whereas Chandigarh is one of the highest per capita incomes in the country and

globally this state is ranked 4th in the top 50 cities as emerging outsourcing and IT services destinations ahead of cities like Beijing. It was a Union Territory in the year 1966 and later this was included in the state of Punjab.

Table 2: Urban Population and its Estimation by Modified Exponential and Gompertz Curves in Northern Region with Respective Gender

Year	Urban Population			Modified Exponential Curve			Gompertz Curve		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
1901	2064058 (13.39)	1819658 (13.47)	3891505 (13.45)	1938486	1479087	3247566	1694711	1425549	3128634
1911	1986759 (12.90)	1678230 (12.67)	3664989 (12.79)	2141949	1670243	3677500	2011158	1680023	3695780
1921	2190231 (14.20)	1773416 (13.38)	3963647 (13.82)	2445315	1950130	4303222	2424144	2013311	4437224
1931	2733950 (15.96)	2188091 (14.74)	4922041 (15.39)	2897643	2359935	5213894	2971990	2457587	5423231
1941	3629535 (18.13)	2867668 (16.40)	6427203 (17.14)	3572073	2959963	6539280	3711792	3061425	6759291
1951	4825327 (22.12)	4085464 (21.12)	8910791 (21.65)	4577665	3838511	8468237	4730416	3899895	8607338
1961	6454152 (23.56)	5339514 (22.02)	11793667 (22.84)	6077026	5124862	11275629	6163009	5091970	11222001
1971	7873973 (22.45)	6639000 (21.30)	14512973 (21.91)	8312609	7008311	15361488	8224984	6831440	15014235
1981	12144745 (26.58)	10318322 (25.20)	22463067 (25.93)	11645917	9766017	21308021	11268767	9443496	20666293
1991	15928864 (27.20)	13682868 (26.16)	29611732 (26.71)	16615957	13803792	29962564	15887422	13491818	29346087
2001	24023195 (32.18)	20395509 (30.53)	44418704 (31.40)	24026405	19715818	42558328	23109851	19988628	43120618
2011	30964519 (34.98)	27261009 (33.88)	58225528 (34.46)	35075560	28372082	60890119	34780942	30823108	65783113
Mean Absolute Percentage Error (MAPE)				5.947	5.792	5.285	6.276	7.615	7.021
Mean Algebraic Percentage Error (MALPE)				2.155	-0.532	-0.587	0.335	0.497	0.409

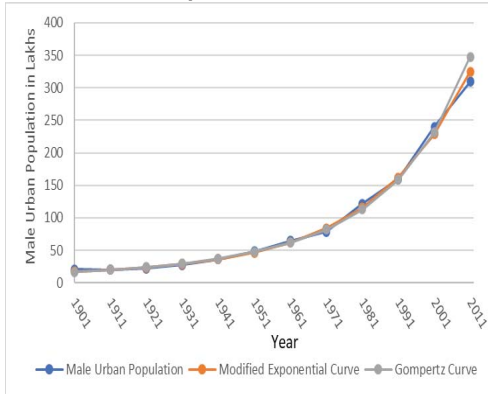
Note: Figures in the parenthesis are the urban percentages

To study the trend in the urban population, two growth curves are fitted namely Modified Exponential and Gompertz Curves for male, female, and total urban population separately. Both the curves are fitted well for all the three variables, test for accuracy of the fit is calculated and the result shows MAPE for male population is 5.95 for Modified Exponential Curve and 6.28 for Gompertz Curve, for female its value respectively are 5.79 and 7.62 and similarly for total urban population 5.28 for Modified Exponential Curve and 7.02 for Gompertz Curves. The value of MALPE for male population is 2.15 for Modified Exponential Curve and 0.33 for Gompertz Curve, its value for female population respectively are -0.53 and 0.49 and the total urban population these values are -0.59 and 0.41.

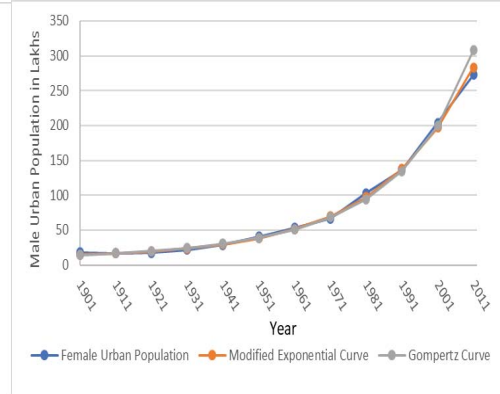
The Modified Exponential growth model has smallest MAPE value for all three variable namely male, female, and total urban population as compared to Gompertz Curves. Hence, Modified Exponential Curve is best fitted to these variables. The MALPE value is negative for female and for total urban population in Modified Exponential which shows these variable population underestimate, whereas for male population

MALPE value for Modified Exponential shows overestimate and for Gompertz Curve all the three variables are overestimates (see Table 2 and Figure 2 a, b and c).

a. Male Urban Population



b. Female Urban Population



c. Total Urban Population

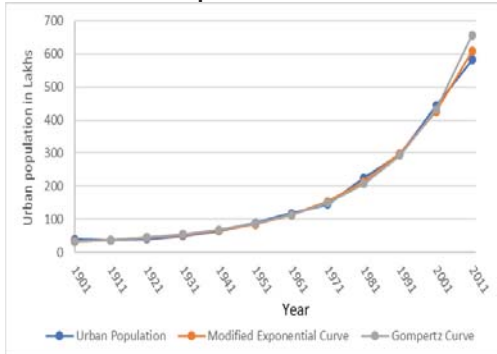


Figure 2. Fitting of Male, Female and Urban population by Modified Exponential and Gompertz Curves of Northern Region.

3.2.2. Southern Region

Southern Region has 41.01% urban population in the year 2011 which is more than the country's urbanization and it is the second highest in all regions of India as the Southern Region contains 9 metropolitan cities and one mega city, they are Bangalore in Karnataka, Chennai, Coimbatore, Madurai and Salem in Tamil Nadu, Kochi, Kozhikode, and Thiruvananthapuram in Kerala and lastly Vishakhapatnam in Andhra Pradesh. Southern Region contains 6 states Andhra Pradesh, Karnataka, Kerala, Lakshadweep Island, Pondicherry, and Tamil Nadu having urban population respectively as 33.36%, 38.67%, 47.70%, 78.07%, 68.33%, and 48.40% in the year 2011. All the states in this region have the urban population, which is more than the national average, therefore this region is the second largest region by urban population in India in the decade 2011. Lakshadweep state has highest urban population of 78.07% in the decade 2011 as this state is the Union Territory and the second highest urban population state is Pondicherry, the region for high urban population is migration

from adjoining rural areas and medium town for better education, job opportunities and quality life (Sangaradasse P. and Eswari S., 2019).

Table 3 : Urban Population and its Estimation by Modified Exponential and Gompertz Curves in Southern Region with Respective Gender

Year	Urban Population			Modified Exponential Curve			Gompertz Curve		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
1901	3122983 (16.00)	3144349 (16.04)	6096276 (15.66)	2664917.9 2	2720707.1 94	5333570.7 79	2719621	2734285	5398227.63 9
1911	3530572 (16.62)	3526706 (16.48)	7064854 (16.56)	3290857.1 12	3281950.4 84	6527478.5 89	3376824	3352055	6677811.80 1
1921	3914962 (17.63)	3832254 (17.21)	7749032 (17.43)	4144152.3 18	4056736.6 07	8163806.7 83	4235632	4157825	8349487.95 8
1931	4838795 (19.63)	4682400 (18.91)	9521195 (19.20)	5307384.6 5	5126314.7 15	10406500. 85	5369632	5221576	10557510.3
1941	6089412 (21.97)	5914162 (21.45)	1200357 4 (21.63)	6893130.6 52	6602847.7 82	13480258. 72	6883415	6643957	13507787.8 6
1951	8846499 (27.55)	8625197 (26.94)	1748491 0 (27.26)	9054857.3 43	8641174.7 46	17693043. 52	8927365	8571739	17497876.7 2
1961	1297894 7 (21.33)	1229823 5 (20.59)	2527718 2 (20.96)	12001774. 62	11455047. 93	23466938. 7	1172033 0	11222098	22963345.8 7
1971	1605398 7 (23.68)	1520102 5 (22.91)	3125501 2 (23.30)	16019082. 39	15339548. 54	31380437. 05	1558483 2	14921351	30550445.6 5
1981	2266339 4 (27.18)	2161161 4 (26.41)	4427500 8 (26.80)	21495571. 95	20702030. 76	42226400. 49	2100246 6	20167783	41231642.9 1
1991	3012271 6 (30.21)	2897618 3 (29.69)	5909889 9 (29.95)	28961252. 87	28104839. 64	57091497. 81	2870230 3	27735329	56492079.3 9
2001	3806411 4 (33.74)	3713286 4 (33.29)	7519697 8 (33.52)	39138646. 78	38324282. 25	77465079. 14	3980398 7	38847799	78635231.7
2011	5175796 0 (41.01)	5184252 8 (41.04)	1036004 88 (41.02)	53012712. 4	52432036. 35	105388395. 6	5605293 3	55477273	111292232. 8
Mean Absolute Percentage Error (MAPE)				6.21	5.58	5.71	7.33	7.01	6.90
Mean Algebraic Percentage Error (MALPE)				-0.16	-0.17	-0.17	0.34	0.32	0.30

Note: Figures in the parenthesis are the urban percentage.

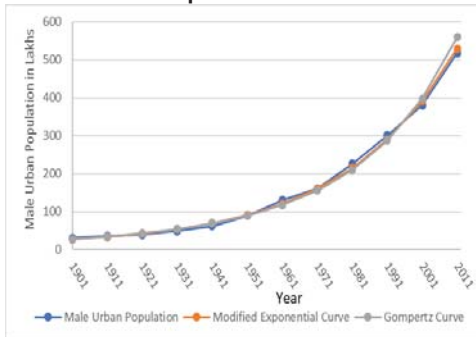
The urban population in this region has increased from 15.66 per cent in 1901 to 41.02 per cent in 2011 about 25.36 per cent of increase in urban population from 1901 to 2011 and similarly for male and female population.

South India has the highest sex ratio with Kerala and Tamil Nadu being the top two states. Where Kerala is the only state not only in the region but also in the country where female population is more than the male population. Kerala is the only state where the sex ratio has historically been above the 1000. The reason for highest sex ratio in Kerala are better health, high literacy rate among women and better standard of life (Gender Statistics, 2017-18).

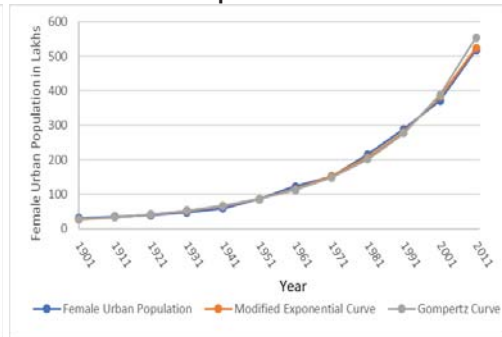
For both the Modified Exponential and Gompertz Curve the test of accuracy and bias have been conducted by using MAPE and MALPE, where for the test of MAPE the Modified Exponential curve for male, female and total urban population the results show respectively are 6.21, 5.57 and 5.71, and in Gompertz Curve its value for male population is 7.34, female population is 7.01 and urban population is 6.90 and similarly for MALPE result for the Modified Exponential for male population is -0.16, for female population is -0.17 and for urban population is -0.16, in the same way for Gompertz Curve the results for male, female and urban population has viz, 0.36, 0.32 and 0.30.

The value of MAPE for the Modified Exponential growth model is smaller than the Gompertz growth model for all the three variables, hence the Modified Exponential Curve has good fit for all the three variables. The MALPE value is negative in Modified Exponential Curve indicating underestimate (see Table 3 and Figure 3 a, b, and c).

a. Male Urban Population



b. Female Urban Population



c. Total Urban Population

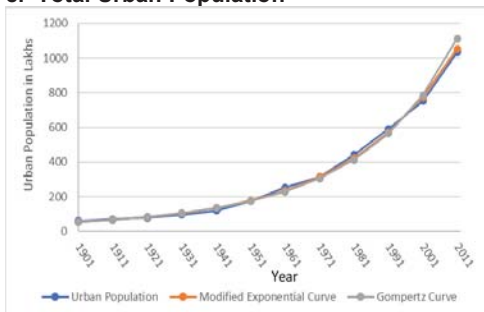


Figure 3. Fitting of Male, Female and Urban Population by Modified exponential and Gompertz Curves of Southern Region.

3.2.3. Eastern Region

Eastern Region has 19.87% urban population which is below the national average in the decade 2011 and lowest among all the regions of India, even though it has many states compared to other regions. Whereas West Bengal's capital Kolkata is the largest city in Eastern part of India and, Kolkata is the

country's third largest metropolitan area, and is the biggest metropolitan and economically dominant city of the region, and one of the fastest growing cities in the world. Another fast-growing city in this region is Patna in Bihar.

The Eastern Region has 11 states they are with urban population according to 2011 census i.e Assam (14.10%), Arunachal Pradesh (22.94%), Bihar (11.29%), Manipur (29.21%), Meghalaya (20.07%), Mizoram (52.11%), Nagaland (28.86%), Odisha (16.69%), Sikkim (25.15%), Tripura (26.17%) and West Bengal (31.87%). Urban population in all these states in this region are below the national level except for West Bengal and Mizoram. The urban population in this region has steadily and gradually increased by 13.32 per cent from 1901 to 2011. Similarly, the female population has increased by 14.16 per cent from 1901 to 2011 and male population by 12.3 per cent. Overall, in this region, Mizoram has high urban population, during the year 1951-71 the highest percentage of urban population in this region was noticed in Meghalaya after 1971 Mizoram took the place and even now Mizoram is the highest urban population in Eastern Region as compared to other states.

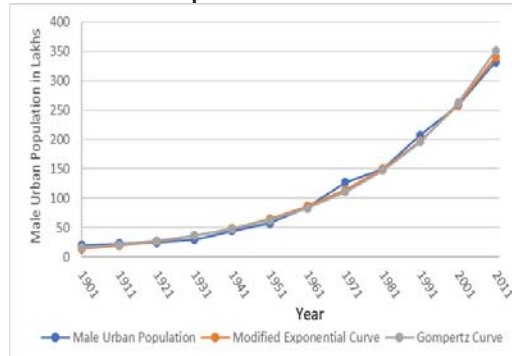
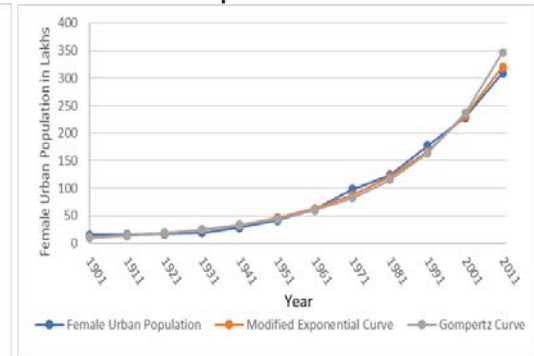
The percentage of urban population in this region is basically slow because of location and infrastructure problems. This region has very dependency on agriculture sector due to no development of secondary sectors up to the mark (Kh. Bimolata Devi, 2012). Mizoram has been greatly influenced by politico-administrative process to be an urbanized state (Singh, 2017). West Bengal is the second highest urban population in Eastern Region as it has Kolkata as a mega city. As British brought trade which subsequently led to industrialization, and hence urbanization got highly concentrated in Kolkata. Kolkata was the centre of colonial trade and was the seat of colonial administration. It was the third most populous metropolitan area in the country in 2011 as the urban agglomeration was the home to over 14.1 million populations (Census of India , 2011).

The test for accuracy MAPE and the test for bias MALPE is done for both the curves, the values of MAPE for male and total urban population for Modified Exponential is 9.92 and 10.42 respectively, whereas for Gompertz the male and total urban population is 8.91 and 10.19 respectively. And for the female population the Modified Exponential value is 11.45, and for Gompertz the value is 12.08. Hence, for male and total urban population Gompertz growth curve is the best fit, and for female population Modified Exponential growth curve is best fitted. Similarly, the test for bias is done for both the curves, also here the results of MALPE for Modified Exponential Curve is 0.05, 0.69 and 0.31 for male, female, and urban population respectively, and for the Gompertz Curve the results are 0.63 for male, 1.01 for female and 0.77 for urban population. Therefore, in all the variables MALPE values are positive for both the curves indicating the curves overestimates the urban male, female, and total population (see Table 4 and Figure 4 a, b, and c).

Table 4: Urban Population and its Estimation by Modified Exponential and Gompertz Curves in Eastern Region with Respective Gender

Year	Urban Population			Modified Exponential Curve			Gompertz Curve		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
1901	2005872 (7.40)	1543422 (5.61)	3576125 (6.55)	1391955.337	1067751.028	2482516.705	1585446	1165593	2764510.794
1911	2254670 (7.75)	1626158 (5.54)	3880828 (6.64)	1948684.42	1398890.512	3358226.474	2080694	1487638	3577871.939
1921	2459601 (8.22)	1701793 (5.73)	4161394 (6.99)	2676409.667	1859413.704	4536146.672	2735928	1920082	4660843.878
1931	2924558 (8.68)	1954556 (5.94)	4879114 (7.34)	3627651.576	2499873.756	6120571.15	3604515	2507485	6112364.575
1941	4468888 (11.31)	2887360 (7.60)	7356248 (9.51)	4871062.013	3390576.079	8251785.922	4758177	3315030	8071093.091
1951	5767620 (12.91)	4143327 (9.75)	9910947 (11.37)	6496378.877	4629296.007	11118490.18	6293496	4439278	10732705.57
1961	8454790 (16.22)	6242645 (12.71)	14697435 (14.52)	8620902.551	6352011.912	14974503.87	8340789	6025169	14375305.19
1971	12695007 (17.22)	9846384 (14.37)	22541391 (15.85)	11397961.56	8747832.003	20161241.03	11076236	8293282	19397025.23
1981	14954533 (18.34)	12404552 (16.27)	27359085 (17.34)	15027978.41	12079753.36	27137938.88	14738503	11584156	26372092.51
1991	20782048 (20.45)	17777132 (18.95)	38559180 (19.73)	19772934.24	16713531.97	36522318.98	19651554	16431475	36135054.24
2001	25858427 (18.31)	22916832 (17.41)	48775259 (17.87)	25975276.21	23157833.01	49145280.66	26256027	23684806	49908309.02
2011	33263813 (19.97)	30972671 (19.77)	64236484 (19.87)	34082632.14	32120068.67	66124469.48	35152486	34718843	69496758.31
Mean Absolute Percentage Error (MAPE)				9.93	11.45	10.42	8.91	12.08	10.19
Mean Algebraic Percentage Error (MALPE)				0.05	0.69	0.31	0.64	1.01	0.77

Note: Figures in the parenthesis are the urban percentages

a. Male Urban Population

b. Female Urban Population


c. Total Urban Population

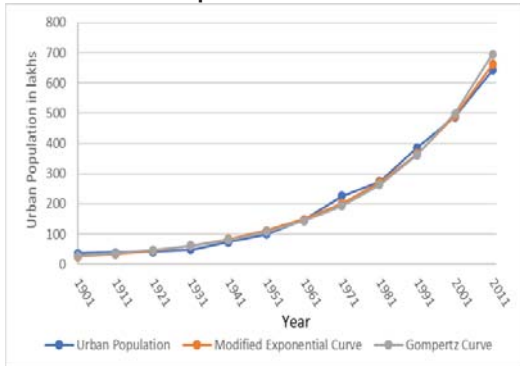


Figure 4. Fitting of Male, Female and Urban Population by Modified Exponential and Gompertz Curves of Eastern Region.

3.2.4. Western Region

This region has 5 states Goa, Gujarat, Maharashtra, Daman and Diu and Dadra and Nagar Haveli. This region had 44.48% urban population in the year 2011, this percentage is the higher than the country's urbanization and is the highest in all other regions of India in that year. This region has 5 metropolitan cities they are Ahmadabad and Surat in Gujarat, Mumbai, Nagpur, and Pune in Maharashtra, and one mega city that is Mumbai. Due to physical proximity, better connectivity, rising literacy, adoption of urban lifestyle and an increase in non-agriculture activities, Goa rural areas have been transformed into urban. Goa does not have a single city with million-plus people due to its small size and however despite of having high level of urbanization. It has the highest GDP per capita among all states of India and it is the third-highest ranking among Indian states in the human development index. The land of Goa away from the cast is rich in minerals and ores, and mining is the second largest industry. Goa is the tourist place surrounded by sea, most of the people living in Goa are urbanities (62.17 %). Here in this region, Maharashtra is the second most populous state and the third largest state by area in India. Mumbai, the capital city of the state, is India's largest city and the financial capital of the nation. This region is highly industrialized, with a large urban population. Urbanization of Maharashtra is above 50 % and there are three million plus cities in Maharashtra. Gujarat is the fifth largest state by area, covering some 196,024 square kilometres and the percentage of urban population of this state is 42.60% which is lower than the regions urban population but higher than the countries urban population. Gujarat has traditionally low unemployment and the economy of Gujarat state is the fourth largest in India and this state is widely considered as one of the most industrially developed states of India and a manufacturing hub. Daman and Diu have the urban population 75.17%, this state was administered as a part of the union territory of Goa, the Goa portion of the territory was granted full statehood within the Indian union on 30 May 1987. Later in the year 2019, legislation was passed to merge the union territory of Daman and Diu with its neighbouring union territory, Dadra and Nagar Haveli, to form the new union territory of Dadra and Nagar Haveli and Daman and Diu with the effect from 26 January 2020. Where Dadra and Nagar Haveli have 46.72% of urban population.

Table 5: Urban Population and its Estimation by Modified Exponential and Gompertz Curves in Western Region with Respective Gender

Year	Urban Population			Modified Exponential Curve			Gompertz Curve		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
1901	3427943 (23.32)	3102109 (21.71)	6530052 (22.53)	2984925.165	2667811.076	5685716.612	2918943	2586512	5530998.378
1911	3462903 (21.37)	2987334 (19.16)	6450237 (20.29)	3434324.483	3007391.34	6472958.267	3463935	3021889	6513065.874
1921	3963165 (24.52)	3356574 (21.85)	7388275 (23.44)	4055034.525	3487243.874	7571814.214	4161898	3581813	7772678.676
1931	4532632 (24.53)	3881741 (22.16)	8467556 (23.53)	4912358.828	4165311.711	9105630.906	5067337	4312883	9410955.617
1941	6214777 (29.44)	5269846 (26.34)	11584738 (28.18)	6096494.591	5123472.725	11246579.09	6258236	5283315	11574114.06
1951	8796370 (35.01)	7430537 (31.24)	16226907 (33.18)	7732022.13	6477426.532	14234979.96	7847930	6594959	14477315.18
1961	9095817 (28.83)	7571361 (25.53)	16667178 (27.23)	9991011.691	8390665.42	18406281.16	10003891	8403130	18443152.15
1971	12823691 (31.48)	10814037 (28.46)	23637728 (30.02)	13111126.59	11094216.32	24228710.79	12978001	10950154	23965077.15
1981	17809986 (34.88)	15466768 (32.24)	33276754 (33.60)	17420627.23	14914537.74	32355835.88	17156286	14623556	31814266.14
1991	24038807 (38.21)	21287860 (36.22)	45326667 (37.25)	23372906.7	20312940.14	43699925.32	23142313	20059796	43223972.6
2001	32415168 (41.74)	28394450 (39.66)	60809618 (40.74)	31594191.17	27941290.06	59534351.83	31900134	28334751	60215679.92
2011	41073188 (45.17)	36740414 (43.69)	77813602 (44.46)	42949423.9	38720724.06	81636527.97	45004986	41324745	86191879.78
Mean Absolute Percentage Error (MAPE)				5.21	5.83	5.39	6.08	6.94	6.36
Mean Algebraic Percentage Error (MALPE)				-0.66	-0.72	-0.69	0.31	0.39	0.34

Note: Figures in the parenthesis are the urban percentages

The MAPE and MALPE is calculated for Modified Exponential and Gompertz Curve. The MAPE result for Modified Exponential are 5.21, 5.83 and 5.39 for male, female, and urban population respectively and for the Gompertz, 6.08 for male population, 6.94 for female population and 6.36 for urban population. Similarly for MALPE the Modified Exponential has -0.66 for male, -0.72 for female and -0.69 for urban population and for the Gompertz Curve 0.30, 0.39 and 0.33 viz. for male, female and for urban population. Hence in the MAPE test Modified Exponential will fit best for all the three variables and when we compare between the variables, both the models show good fit for male population and MALPE values are negative for Modified Exponential Curve and positive for Gompertz Curves, hence Modified Exponential Curve shows underestimate and Gompertz Curve shows overestimate for all variables (see Table 5 and Figure 5 a, b & c).

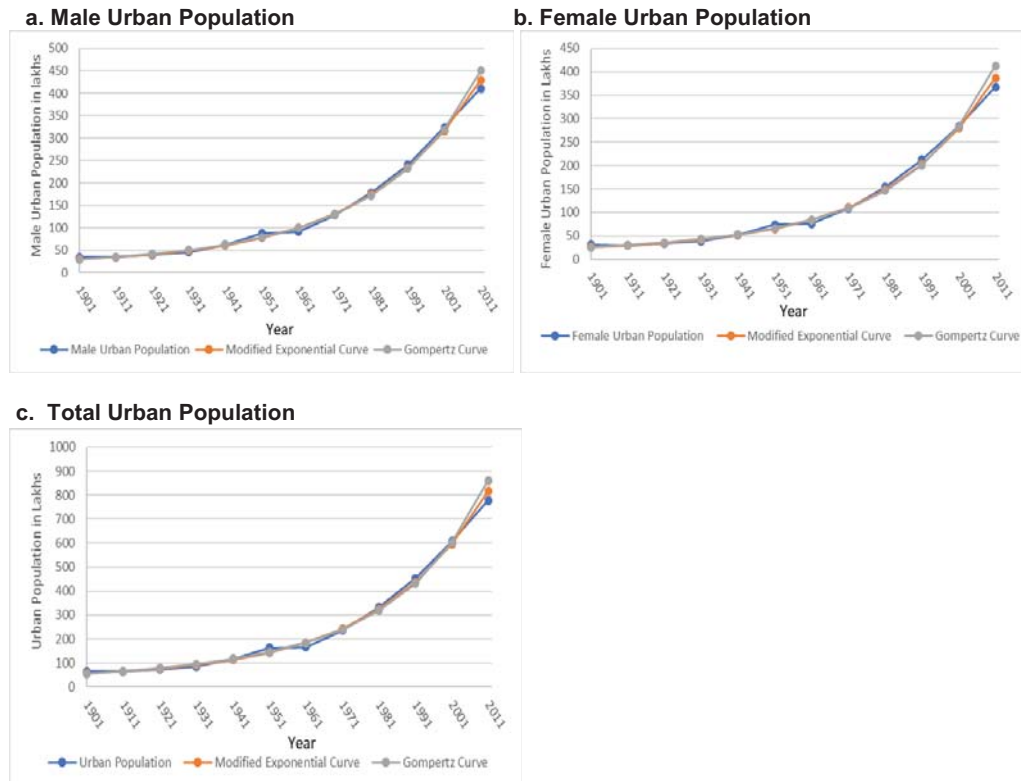


Figure 5. Fitting of Male, Female and Urban Population by Modified Exponential and Gompertz Curves of Western Region.

3.2.5. Central Region

The Central Region has 4 states with 3 metropolitan cities they are Gorakhpur and Kanpur of Uttar Pradesh, and Raipur of Chhattisgarh. Urban population of this region has increased gradually from 10.45% for the year 1901 to 26.71% for the year 2011 which is lower than the country's urbanization similarly the percentage of male, female and population of urban has also increased from 1901 to 2011. Madhya Pradesh only has urban population, which is more than the national average, in this region remaining three states are lower than the country's urban population. Uttar Pradesh (23.79%), Madhya Pradesh (35.81%), Chhattisgarh (23.65%) and Uttarakhand (30.23%) according to 2011 census. The highest number of urban population in Madhya Pradesh lives in Indore and the percentage of urbanization is highest in Bhopal. Madhya Pradesh is rich in mineral resources that have the largest reserves of diamond and copper in India. The economy of Madhya Pradesh is the 10th largest in India Uttar Pradesh is the most populated state in India and this state has 3 World Heritage sites and ranks first among tourist destination in India. Chhattisgarh is a densely forested state in the central region. A resources rich state, Chhattisgarh provides electricity coal and steel to the rest of the nation. The population of the state is rising considerably due to rapid effort towards development and progress. Uttarakhand is often referred to as the land of the Gods due to its religious

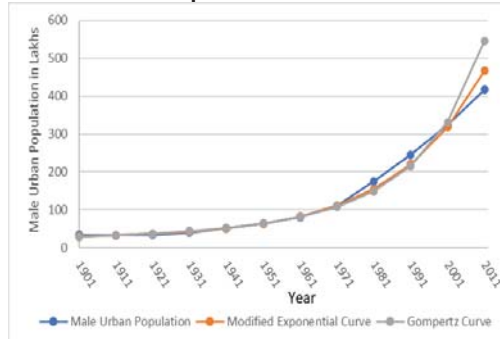
significance and numerous Hindu temples and pilgrimage centres found throughout the state. And also, is known for the natural environment of the Himalayas, the Bhabar and the Terai regions. This state is the second fastest growing state in India due to its industrial sectors and tourism.

Table 6: Urban Population and its Estimation by Modified Exponential and Gompertz Curves in Central Region with Respective Gender

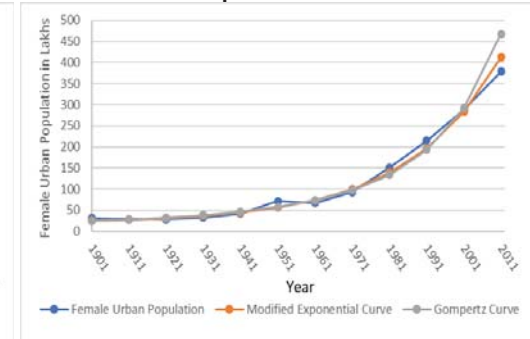
Year	Urban Population			Modified Exponential Curve			Gompertz Curve		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
1901	3450692 (10.60)	3165962 (10.22)	6634864 (10.45)	3034463	2553654	5699678	2916548	2452931	5472331.731
1911	3284082 (9.71)	2834516 (8.96)	6118598 (9.35)	3282007	2791155	6125859	3274804	2792164	6106820.411
1921	3431484 (10.38)	2862055 (9.33)	6293539 (9.88)	3654798	3145348	6776017	3744457	3235523	6942102.231
1931	4021218 (11.24)	3301194 (9.98)	7322412 (10.64)	4216208	3673569	7767859	4372366	3826159	8064073.264
1941	5150758 (12.73)	4236154 (11.31)	9386912 (12.05)	5061670	4461325	9280955	5231164	4630317	9607013.218
1951	6379916 (14.23)	7179450 (17.30)	11747366 (13.61)	6334904	5636133	11589247	6437079	5752660	11788065.07
1961	8160868 (15.29)	6742945 (13.72)	14903813 (14.54)	8252345	7388167	15110642	8182800	7363913	14971954.94
1971	11097317 (16.77)	9328115 (15.72)	20425432 (16.27)	11139940	10001039	20482679	10800687	9752554	19798052.23
1981	17519282 (21.17)	15106893 (20.26)	32626175 (20.74)	15488549	13897709	28677944	14890117	13425552	27442674.6
1991	24586598 (23.49)	21510254 (22.99)	46096852 (23.25)	22037390	19708953	41180164	21587602	19313650	40192055.88
2001	32379292 (25.01)	28764362 (24.40)	61143651 (24.72)	31899697	28375473	60252823	33173935	29211112	62776239.68
2011	41692423 (26.91)	37900793 (26.49)	79593216 (26.71)	46751959	41300167	89348962	54530531	46771266	105706792.4
Mean Absolute Percentage Error (MAPE)				5.249	9.361	5.716	8.288	11.850	9.045
Mean Algebraic Percentage Error (MALPE)				-1.084	-0.654	-1.083	0.682	0.978	0.798

Note: Figures in the parenthesis are the urban percentage.

a. Male Urban Population



b. Female Urban Population



c. Total Urban Population

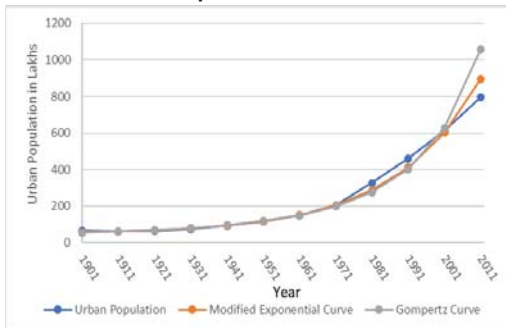


Figure 6. Fitting of Male, Female and Urban Population by Modified Exponential and Gompertz Curves of Central Region

In the Central Region MAPE values of Modified Exponential Curve for male population is 5.25, female population is 9.36 and urban population is 5.71, likely for the Gompertz Curve is 8.29, 11.85 and 9.05 for male, female, and urban population respectively. The MALPE values of Modified Exponential for male population is -1.08, for female population is -0.65 and for urban population -1.08 and for the Gompertz Curve 0.68 for male, 0.98 for female and 0.79 for urban population. Hence, here by observing the values we can say that for MAPE Modified Exponential is the good fit and for the MALPE the values are negative for Modified Exponential so we can say that the fit is underestimate and positive for Gompertz Curve hence Gompertz Curve is overestimate for all the three variables (see Table 6 and Figure 6 a, b & c).

4. Projection of Urban Population

Forecasting generally refers to the formation of expectations about the future states or processes specific historical entities (Duncan 1973, Henschel 1976, Schuessler 1968). In case of national population forecasting, the future states are number of individuals in the population usually by age, sex, and race, but sometime also by region and other social-economic characteristics corresponding to future process are fertility, mortality, migration and mobility among regions or states. Armstrong et. al. (1987) explained the comparative forecasting model performance of the sales. Chaddha and Chitgopekar (1971) were among the first to apply Logistic Curve to penetration of telephones.

The projection of urban population was initiated by United Nation in the year 1978; after this initiation the characterization of urban development process gained increasing importance. In the first it started with only percentage of urban population and later used the geometric growth rate (Rogers, 1995). Lin et.al., (2003) studied the projection of China's urbanization at national level and provincial levels by Linear Regression model and S-curve Regression model. Bocquier (2005) proposed the projection of world urban population and compared this with UN projection.

In the process of urbanization by which many people became permanently concentrated in small areas forming cities. The urban population projection is a basic tool for Government as well as for private sectors (Stoto, 1983). By using the projection of urban population many decisions are taken.

Planning of schools, hospitals, shopping centres, housing developments, electric power plants and many other projects is mainly dependent on the future urban population change (Smith, 1987).

The urban population projection is a scientific method to see into a future population scenario, conditioned by making certain assumptions, by using the data relating to the past available at the point of time. The Modified Exponential Curve and Gompertz Curve are used for projection and estimation of urban population of India with respective to different regions.

As we have used 2 growth models Modified Exponential and Gompertz Curve, in these two growth curves α , β and ρ are the parameters and we have used the Method of Partial Sums to estimate these parameters. Where α is the asymptotic value, β is the intercept, and ρ is the slope (growth) parameter.

We have done forecasting from 2021 to 2101 for male, female, and total urban population for all the five regions of India by using two growth models viz., Modified Exponential and Gompertz model. Where for the Northern region the female urban population in Modified Exponential Curve has is increased from 4 crores in 2021 to 86 crores in 2101 and similarly for male population 5 crores to 122 crores and for the total urban population 9 crores in 2021 to 246 crores, and in Gompertz Curve projections shows higher projections as compared Modified Exponential Curve model, male population has increased from 6 cores to 10991 cores in 2021 to 2101, for the female population 6 cores in 2021 to 28910 cores in 2101.

Table 7 : The Estimated Parameters of Modified Exponential and Gompertz Curves for Urban Population of Different Regions of India with Respective Gender

Regions	Parameters	Gompertz Curve			Modified Exponential Curve		
		Male	Female	Total Urban	Male	Female	Total Urban
Northern Region	α	257957.6408	284028.1965	566559.3691	1218038.63	1067271	2303473.895
	β	6.5697259	5.019041114	5.522165032	543067.059	411816	944092.4966
	ρ	1.090943425	1.101814035	1.097494202	1.44546542	1.464179	1.455393299
Southern Region	α	26961.31448	79166.95639	78335.54518	941629.986	1245621	2111712.325
	β	100.8712279	34.53821319	68.91159851	1723287.93	1475086	3221858.455
	ρ	1.046911662	1.057509809	1.050254782	1.3632238	1.380482	1.370564948
Eastern Region	α	3.98662E-11	5788.156407	103.2043907	-420642.471	220245.9	-55011.86884
	β	3.97692E+16	201.3755426	26786.75564	1812597.81	847505.1	2537528.573
	ρ	1.007112055	1.045985233	1.025295511	1.3071443	1.390723	1.345103412
Western Region	α	273804.0448	482535.7575	749207.7766	1806016.21	1845733	3696881.566
	β	10.66069944	5.360248921	7.382462582	1178908.95	822078.1	1988835.046
	ρ	1.072334274	1.092657006	1.081757472	1.38119934	1.413075	1.395830542
Central Region	α	1392812.195	957696.3199	2855049.352	2545209.88	2070277	4888741.419
	β	2.09399961	2.561282254	1.916720539	489253.236	483377.1	810936.8313
	ρ	1.156759415	1.137727042	1.168611746	1.50596223	1.491336	1.525541786
India	α	1023577.2	1415784.927	2773109.771	6899767.19	6793496	14136871.77
	β	11.57317225	7.328999044	8.049500813	5080139.53	3777294	8551670.639
	ρ	1.07443066	1.087274828	1.083962393	1.39822406	1.425751	1.415311893

For the Southern Region of India, the growth of male population has increased from 7 crores in 2021 to 84 cores in 2101 and for female and total urban population has increased respectively from 7 cores to 93 cores and 14 cores to 176 cores from 2021 to 2101 in Modified Exponential Curve. In the same way the Gompertz Curve has also shows an increasing trend for all the three variables.

As in the Northern and Southern Regions of India the remaining Eastern Region, Western Region and Central Region of India has also shows an increasing population in male, female, and total urban population.

Table 7: Forecasting of Urban Population for Different Regions of India with Respect to Gender Using Growth Curves

	Male			Female		Total	
	Year	Modified Exponential	Gompertz	Modified Exponential	Gompertz	Modified Exponential	Gompertz
Northern Region	2021	51550110.4	66453387.21	45788755.1	61765402.82	97478225.09	128931152.7
	2031	76114056.29	120079054.2	68658645.56	117736495.4	145081024.9	239894660.2
	2041	112739482.1	233633006.1	103284433.1	245206197.1	216627315.9	484545496.7
	2051	167348860.5	494006078.8	155709046.4	564786638.7	324160313.3	1074021930
	2061	248772738.7	1147037628	235081683.7	1458722217	485780788.4	2644799916
	2071	370177671.9	2959040513	355254540.8	4291631870	728693927.6	7336950330
	2081	551195306.2	8593452224	537200310.2	14641900487	1093788716	23292827492
	2091	821096891.4	28513988958	812672358	59118933470	1642520683	86150520807
	2101	1223526555	1.09915E+11	1229746354	2.89102E+11	2467256563	3.78784E+11
Southern Region	2021	71926168.85	80212959.15	71907533.52	80865515.13	143659114.3	160285175.9
	2031	97709442.84	116732653.9	98793102.08	120454489.3	196111619.9	235116793.6
	2041	132857815.6	172895756	135908139	183584178.3	268001185.4	351589462.8
	2051	180772913.9	260842924.1	187144770.4	286663573	366530504.1	536500566.5
	2061	246091916.3	401191721.1	257876005.4	459240371.9	501571334.6	836234338.3
	2071	335136335	629645457.4	355519185	755923770.2	686653563.3	1332824020
	2081	456523805.9	1009306030	490313813.1	1280451841	940320778.5	2174660395
	2091	622002095.4	1654105167	676395338.2	2235690299	1287988172	3636597054
	2101	847586038	2774391901	933277489.1	4030697377	1764488915	6240523180
Eastern Region	2021	44680116.24	47161148.23	44584053.11	51796284.35	88963234.31	97587349.7
	2031	58532557.16	63404545.93	61917999.04	78708408.87	119683734.8	138213922
	2041	76639696.34	85422165.81	86024710.88	121927091	161005984.9	197484804.3
	2051	100308340.1	115329767.6	119550461.9	192717042.5	216588684.4	284731767
	2061	131246672.8	156041264.2	166175484.5	311087679.9	291353163.2	414340776.8
	2071	171687538.1	211578387.1	231017961.1	513344264.8	391919118.7	608696237.8
	2081	224549584.6	287503796.7	321195864.3	866837310.4	527190728.6	902961005.6
	2091	293647907.3	391528152.5	446608320.2	1499441222	709145032.7	1352912455
	2101	383969385.8	534362866	621022267.7	2659900596	953892388	2047916776

Western Region	2021	58633263.87	65093919.07	53952877.62	62414656.46	112487420.5	127044944.9
	2031	80295773.33	96697206.69	75477059.89	97939001.88	155550038.5	193296427.3
	2041	110216017.2	147815434.2	105892353.5	160234074	215658156	304363036.5
	2051	151541838.3	233000722.7	148871458.2	274387340.5	299558902.3	497370420.1
	2061	208621035.3	379568983.5	209604175.9	493876991.8	416670126.4	846069207.6
	2071	287458784.6	640551743.7	295424088.5	938695328.7	580137550	1503126027
	2081	396349432.2	1122681740	416694100.1	1893533973	808310372.5	2798921430
	2091	546749123.1	2049213176	588057776.6	4076229472	1126800967	5483529118
	2101	754481077.4	3906796326	830207581	9421012710	1571359866	11350329262
Central Region	2021	66591575.47	93313261.5	58377287.8	76728234.72	128876114.2	187048591.2
	2031	98334947.72	178589571.2	85471257.74	138773768	192749561.8	374870823.3
	2041	145773686.5	376990720.3	125578081.3	271455044	289462820	841594732.8
	2051	216668294.7	890825929.9	184947649.7	580268311.3	435900106	2156088408
	2061	322616420.7	2396837450	272831588.7	1371505941	657626466.3	6440718007
	2071	480950117.3	7488250682	402924950.8	3632253451	993350926.9	23003643617
	2081	717571192.7	27785353504	595500329.6	10942065495	1501684322	1.0114E+11
	2091	1071188486	1.25667E+11	880566961.1	38138766703	2271371582	5.66301E+11
	2101	1599650248	7.13803E+11	1302547097	1.56804E+11	3436784841	4.20064E+12

5. Conclusion

In this paper an attempt is made to study the growth and distribution of urban population with respective gender for five regions of India. Western Region of India has the highest urban population whereas Eastern Region has the least level of urbanization. Western Region of India has highly urbanized and the states of western region are Maharashtra, Goa and Gujarat are highly urbanized as well as industrialized among Indian states, and in this region, all states of urban population is above the national average. Maharashtra state is second most populous state in this region and also Mumbai is the capital city of the state which is India's second largest city. Since Mumbai is considered and the business city and most of the people of India is migrated for business and employment purposes to this city. This region also consists of tourist states Viz. Goa and Gujarat. This is reason why this region is highly urbanized.

The Eastern Region has lowest urban population except Mizoram as this region is covered by mountains, hills, plateaus where the distribution of population is scattered. This region has low density of population which reflects the hilly topography with limited cultivated land, poor economy and underdeveloped transport and communication system. In this region Mizoram has the highest urban population (52.11%) which is more than the national average and Bihar has the lowest level of urban

population (11.29%) in this region and it is also the second lowest urbanized state in India.

Mean Absolute Percentage Error (MAPE) shows good fit for modified Exponential curve for all the regions except for Eastern region, as in eastern region only male urban population and total urban population shows good fit for Gompertz curve exponential curve. Measure of bias MALPE test for Modified Exponential curve in all the regions of India shows underestimate except Eastern region for all three variables and also for Northern male urban population both curve shows overestimate.

Forecasting of urban population by Gompertz Curve shows a very high trend as compared to Modified Exponential Curve for all the five regions of India with respect to gender, and from the test for accuracy and bias shows Modified Exponential Curve best fitted & underestimated for all the variables as compared to Gompertz Curve.

Overall conclusion of the study shows that Western Region has highest level of urbanization followed by Southern, Northern Region and least urbanization is in Eastern Region and similar observation is made from forecasting results. Therefore, it is necessary to make policy for increasing the urban infrastructure namely enough good houses and health facilities and creating the job opportunities for highly urbanized regions like Western, Southern and Northern regions but caution should be taken to control the unplanned urbanization. For low urbanized regions like Eastern and Central regions, the policy makers must make policy regarding the increasing of urbanization on par with national goals of urbanization.

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