Transition of Cities by City Size Distribution for Different Regions of India using Markov Chain Model

1. Introduction

According to United Nations World Development Report 2011, the distribution of urban population by city size class is an important aspect to study the structure and characteristics of a region or a country. The city size distribution and its hierarchy show growth and distribution of region or country population. The most important thing in the study of urbanization is the structure of urban population, and this may be obtained by examining the distribution of urban population in different size.

A great variation in the distribution of urban population by cities of different size classes for different regions of the world following a great variation is observed in the distribution of urban population. The experience gained by more developed countries suggest that the increasing concentration of the urban population in cities of higher order size is a natural concomitant phenomenon associated with growing proportion of urban population. However, in a few developed countries a tendency of counter urbanization, that is decentralization of population from large metropolitan areas towards medium and smaller size cities was observed for some time (Berry, 1976). The equilibrium urbanization is achieved by most of the developed countries, future growth of urbanization is seen in less developed countries only (Devis, 1951).

Globally, more people live in urban areas than rural ones, with 55 percent of the world's population residing in urban areas as of 2018. This marks a substantial shift from 1950, when only 30 percent of the world's population was urban. By 2050, projections indicate that 68 percent of the world's population will live in urban areas. Levels of urbanization vary significantly by region. The most urbanized areas include Northern America (82 percent urban in 2018), Latin America and the Caribbean (81 percent), Europe (74 percent), and Oceania (68 percent). In Asia, urbanization is nearing 50 percent, whereas Africa remains predominantly rural, with only 43 percent of its population living in urban areas. There are notable differences in urbanization patterns between more developed and less developed regions. While nearly half of the population in less developed regions still lives in rural areas, the majority in more developed regions resides in urban areas. However, urban populations in less developed regions have been growing significantly faster than in more developed regions, leading to an increasing share of the world's urban population in these areas (World Urbanization Prospect, 2018). Initially in 1950, there were only 3 agglomerations giving residence to 34 million urban inhabitants, and rest of them were promoted to the lower size categories during 1950-85. There were 11 urban agglomerations in 1985 each having 10 million and more inhabitants, by 2000 the cities have got increased to 24 with 334 million inhabitants accounting for 11 per cent of the world urban population. It is projected that in 2000 3.7 per cent of the world urban population resided in cities of size 10 million plus inhabitants and by 2015 that proportion is expected to rise to 4.7 percent (Megeri M. N. 2002). In the World for 1950, 25 decades about 18 percentage of increase in cities is observed in 10 million or more inhabitants, 14% of increase in 5 to 10 million inhabitants, 8% increase in 1 to 5 million inhabitants, and 7% of increase in cities in 5,00,000 to 1 million inhabitants. Compared to more developed countries less developed countries cities are growing faster (Kengnal P.R., 2014).

The number of people in the city is represented as the city size. The causes of changes in the city size are random in nature, and the city size variable is treated as a stochastic variable. Most of the city size distribution analysis are concerned either to identify the increases in the number of urban places or to identify the difference in the size classes at a particular point of time (Prashanth C.B and Ravikumar K., 2020). City size distribution has been the subject of numerous empirical investigations by urban economists, statistical

physicists, and urban geographers (Gonzalez-Val et al., 2010). Based upon the finite Markov Chain Model the growth and decline of individual cities and changes in size categories over time is seen and this changes in size specially in the number and proportion of towns is due to the growth of these places to large size categories in the state of Wisconsin, U.S. during the period 1880-1960 (Fuguitt G. V. ,1965). A Markov Chain Model has been used to predict the distribution of towns and cities amongst size classes to demonstrate the equilibrium state (William F. Lever, 1972). Within the industries Adelman (1958) detailed the Stochastic nature of the size distribution. In terms of the Stochastic Model, he suggests that size distribution of a firms changes overtime, and such model might be used to the size distribution which would be attained in long run dynamic equilibrium that is the steady state. Pedberg (1962) studied the changes in the size distribution of firms within an industry, the result of the study indicates that during the study period the smaller firms were moved towards largest. Preston et.al., (1961) has studied the change of size distribution of large firms in the food processing and chain store food distributing industries during 1948-1958 by using the Stochastic Model.

The analysis of the evolution of city size distribution in the regional urban system of Kerala is carried out using a Markov Chain Model. The results show that cities in Class I and towns in Class VI tend to exhibit high levels of persistence, remaining in their respective size classes over time. In contrast, medium-sized cities and towns display a stronger tendency to transition to higher size classes, indicating upward mobility within the urban hierarchy. (V. Christopher. Amalraj, G. Kumar and A. Subbarayan, 2015). By using Stochastic Model Prashanth C B and Ravikumar K. (2020) has projected number of cities by city size distribution by using transition probability matrix by considering 56 cities of Ernakulum district in Kerala shows the suitability of the model, and also the projected urban population shows the number of cities increases in class 5000-10000 & 10000-20000 and decreases in class 20000-50000 with respect to migration and reconstruction of the area of cities. For the period 1951-2001 the temporal dynamics of city size distribution is studied for the state Andra Pradesh of India by using the Markov Chain Model where the largest and smallest cities/towns tend to remain stable, while medium-sized cities are more likely to grow or shrink into different size categories. This highlights the crucial role that medium-sized cities played in the urban agglomeration process in Andhra Pradesh from 1951 to 2001 (G. Kumar and A. Subbarayan, 2014). Black D. and V Henderson (2003) has explored the reason why there is a wide distribution of city sizes, documenting growth in sizes and number of cities and whether the relative size distribution of cities has remained stable over time. Using the average transition probability ergodic probability distribution is computed, where the concentration of frequencies around 1 would imply convergence to the mean and the result shows that no such convergence for the entire data relating to the regional city size distribution for the Kerala state is seen (V. Christopher. Amalraj, G. Kumar and A. Subbarayan, 2015).

In Indian context, the cities are classified into six categories based on the size of towns/cities, they are (1) Class I-1,00,000 and above (2) Class II- 50,000 to 99,999 (3) Class III- 20,000 to 49,999 (4) Class IV- 10,000 to 19,999 (5) Class V- 5,000 to 9,999 (6) Class VI- below 5,000. Many demographic, Economic and other studies divide India into five regions arbitrarily. The regions are different from study to study. According to Mitra, Mukaherji, 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, Chhattisgarh, and West Bengal. The Western regions are Gujarat, Goa, Maharashtra and Dadra and Nagar Haveli and Central regions are Madhya Pradesh, Uttar Pradesh and Uttarakhand.

In this paper an attempt is made to study the transition of cities by city sizes using Markov Chain Model. The first section of this paper consists of introduction, the methods and materials are given in second section, third section is about the analysis of interpretation of data and final section concludes the study.

2. Methodology

2.1 Markov Chain Model

The finite Markov Chain Model is used to study the growth and decline of different classes of cities. In Markov Chain, one can visualize a process which moves from state to state. With probability p_{ij} it starts in s_i then it moves on the next step to s_j between time t and t+1. Thus, the probability of moving from s_i to s_j depends only on the state at time t and is assumed to be constant over the sequence of time interval.

The P_{ij} may be arranged in a matrix of transition probabilities and is denoted as [P]. The i^{th} row of [P] gives the probability of going from i at time t to each of the states j at time t+1. One could apply the matrix of transition probability to obtain the expected distribution at time t+1, if one started with a distribution of observation in different states at time t. Since, it is assumed that these probabilities do not change over time.

The Markov Process may be used to evaluate the size distribution of cities and shift in individual cities over time. At any given census years, places may be classified according to size classes, analogous to states in Markov Process, over decades shifts of cities between size classes may be represented by transition probability matrix.

Classification of States

A state is said to be recurrent if, the state leaves that state at any time and will return to that state in the future with probability one. On the other hand, if the probability of returning is less than one, the state is called transient. Which is given by

For any state, we define

$$f_{ii} = P(X_n = i, for\ some\ n \geq 1/X_0 = i)$$

Where,

State is recurrent if f_{ii}=1, and it is transient if f_{ii}<1.

An ergodic Markov chain is a type of stochastic process where every state can be reached from any other state, and the system does not exhibit periodic behaviour. This ensures that regardless of the initial conditions, the system will eventually settle into a stable pattern described by the stationary distribution.

2.2 Equilibrium Distribution

By using the transition probability matrix, the equilibrium distribution of different classes of cities is calculated. The equilibrium is unique and independent of the initial distribution. An equilibrium structure in this model may be defined as the distribution for which the average number of cities entering a given size class per census equals the average number of cities leaving it. By the repeated application of [P] to any initial distribution vector until the constant values occur, the equilibrium solution may be derived.

Using the transition matrix P, where p_{ij} reflects the chance of moving from state i to state j. The first passage time T_{ij} is the random variable denoting the number of steps required to reach state j for the first time, starting from state i, The expected first passage time from state i to state j, denoted by m_{ij}=E [T_{ij}], satisfies,

$$m_{ij} = 1 + \sum_k p_{ij} m_{ij} \qquad \text{for } i \neq j$$

m_{ij} tells you how many time steps (e.g., decades) on average it takes for a city starting in class i to reach class j for the first time.

2.3 Expected city size distribution

By using the transition probability matrix, proportion of cities and by adding in and subtracting out the new added towns and declassified towns, the expected number of the city size distribution for 6 decades from 1961 to 2011 is obtained.

Entries and exits are not explicitly accounted for in the Markov Chain Model. To incorporate incorporations and dis-incorporations, an additional analysis was conducted. Expected distributions of places by size were obtained over several decades using two approaches: (1) the transition probabilities of a single decade combined with the observed incorporations and dis-incorporations of each decade in the period, and (2) the incorporations and dis-incorporations of a single time period combined with the observed transition probabilities of each decade. This method analytically separates the effects on the distribution of towns from both incorporations and dis-incorporations, as well as shifts between size categories.

2.4 Projection of cities by city size distribution

The Projection of cities by city size is obtained by using the Chapman Kolmogorov equation, where the initial transition probability matrix is multiplied by the vector of number of cities as described below, where (s_j) is the vector of number of cities.

$$(s_j) = (s_0^n, s_1^n, s_2^n \dots \dots s_m^n)$$

The components of which represent the number of cities in each size class at that time, the distribution after the next time step may be found from,

$$(s_j)\ [\mathrm{P}] = s_j^{n+1}$$

By successive substitutions, one may write,

$$(s_j)\ [P]^{n+1} = (s_j^{n+1})$$

3. Analysis and interpretation of the data

In this study we have used the Markov chain model to study the transition of cities by city size distribution for the census period from 1961-2011 for all the five regions of India. A finite Markov chain model is an effective method for analysing simultaneous changes in places and size categories because it models transitions between states (e.g., location categories or size classes) in a system. This model uses a set of states and transition probabilities, allowing one to predict or analyse the likelihood of moving from one state to another over time. In this approach, each place or size category represents a distinct state, and the probability of moving from one state to another is captured in a transition probability matrix. The study is concerned to all the regions of India for the period 1961-2011 and for all the classes like class I, II, III, IV, V and VI categories.

3.1. New added and declassified towns.

The information about the distribution of cities by city size classes for each census starting from the census 1961 to 2011 along with the new incorporations and disincorporation is studied in this section for all the five regions of India from 1961-2011 census.

In the Northern region, the number of cities has increased from 441 in 1961 to 811 in 2011 almost 1.83 times. The class VI and class V cities of Northern region show decreasing trend, remaining other class of cities are increasing from 1961 to 2011.The highest number of new incorporations is observed during 2001-11(129) as there has been a significant investment in infrastructure in the northern region, including

roads, highways, and transportation networks. This has improved connectivity and accessibility, making it easier for new towns to emerge and grow. The least number of new incorporations is observed during 1961-71(28). The disincorporation is high during 1981-91(15) and the least number of disincorporation is noticed during 1971-81(1) (see Table 1).

Table 1: Distribution of cities by city size class, number of new incorporations and disincorporation for Northern and Southern Region :1961-2011.

	Northern Region							Southern Region						
	VI	V	IV	III	II	I	Total	VI	V	IV	III	II	I	Total
Number of places, 1961	140	108	92	62	19	20	441	35	128	237	158	45	29	632
New incorporations, 1961-1971	10	12	6	0	0	0	28	28	36	32	8	0	0	104
Disincorporations, 1961-1971	0	0	0	0	0	3	3	0	0	0	0	0	3	3
Number of places, 1971	115	110	117	72	26	26	466	49	114	248	207	61	47	726
New incorporations, 1971-1981	21	32	38	3	1	0	95	3	37	33	26	0	0	99
Disincorporations, 1971-1981	0	0	0	0	1	0	1	2	1	3	1	1	0	8
Number of places, 1981	98	122	163	105	33	38	559	28	110	237	283	93	66	817
New incorporations, 1981-1991	14	25	14	3	0	0	56	1	32	34	31	3	2	103
Disincorporations, 1981-1991	8	6	1	0	0	0	15	0	2	1	0	0	0	3
Number of places, 1991	77	103	185	130	58	48	601	12	110	248	329	126	92	917
New incorporations, 1991-2001	19	43	21	7	0	0	90	11	214	271	67	1	0	564
Disincorporations, 1991-2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of places, 2001	64	109	192	184	68	74	691	24	289	472	420	161	115	1481
New incorporations, 2001-2011	15	97	13	4	0	0	129	1	3	1	0	0	0	5
Disincorporations, 2001-2011	5	3	1	0	0	0	9	1	1	0	0	0	0	2
Number of places, 2011	67	179	175	226	70	94	811	26	240	458	417	187	157	1485

In the Southern region the number of cities increased from 632 to 1485, almost more than double from 1961 to 2011. Here the new incorporation is least during 2001-11 i.e., only 5 number of towns and highest new incorporation is noticed during 1991-2001(564), this is because the 1990s marked a period of economic liberalization in India, leading to significant growth in the information technology (IT) and software services sectors. Cities like Bangalore (Bengaluru), Hyderabad, and Chennai became major IT hubs, attracting investment, talent, and businesses. This growth extended to surrounding areas, resulting in the development of new towns and urban centres. The least disincorporation is observed during 2001-11(2) and the highest number of disincorporation is observed during 1971-81(8).

Table 2: Distribution of cities by city size class, number of new incorporations and disincorporation for Eastern and Western region of India :1961-2011.

	Eastern Region							Western Region						
	VI	V	IV	III	II	I	Total	VI	V	IV	III	II	I	Total
Number of places, 1961	27	123	124	90	38	18	421	21	106	131	86	24	19	387
New incorporations, 1961-1971	23	58	23	7	1	0	112	2	22	4	4	0	0	32
Disincorporations, 1961-1971	0	0	1	0	0	0	1	0	0	1	0	0	0	1
Number of places, 1971	39	125	164	123	51	29	531	13	83	155	101	42	24	418
New incorporations, 1971-1981	23	70	36	5	1	0	135	10	21	5	4	0	0	40
Disincorporations, 1971-1981	4	2	2	1	0	0	9	0	0	0	0	0	1	1
Number of places, 1981	41	133	201	158	78	46	657	18	72	148	129	57	39	463
New incorporations, 1981-1991	32	99	38	13	0	0	182	10	41	28	10	1	1	91
Disincorporations, 1981-1991	0	1	0	0	0	0	1	2	0	0	0	0	0	2
Number of places, 1991	56	179	243	200	86	74	838	20	82	160	165	66	53	546
New incorporations, 1991-2001	41	142	26	8	0	0	217	15	37	49	21	0	0	122
Disincorporations, 1991-2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of places, 2001	77	286	252	245	92	103	1055	30	90	176	222	83	67	668
New incorporations, 2001-2011	89	309	119	18	0	0	535	26	143	17	6	0	0	192
Disincorporations, 2001-2011	1	0	1	0	0	0	2	2	1	0	1	0	0	4
Number of places, 2011	159	563	346	285	96	139	1588	44	219	168	249	86	90	856

The Eastern region in Table 2 shows that the number of cities have increased nearly four times from 1961-2011, and the new incorporations is highest during 2001-11, this might be because of states like Jharkhand and Odisha are rich in natural resources, including coal, iron ore, and other minerals, and also may be because of this region has experienced significant rural-urban migration as people move from rural areas to urban centres in search of better employment opportunities, education, and healthcare purposes. This migration has contributed to the growth of new towns. The exploitation of these resources has led to the development of towns near mining areas, which serve as hubs for industrial and economic activities, whereas the least new incorporations is observed during 1961-1971. During 1961-71 and 1981-91 only one city is disincorporated which is the least, and during 1971-81 the highest number of towns are disincorporated as compared to other decades.

And the number of towns in the Western region have increased from 393 in 1961 to 1588 in 2011, the increase was approximately four times. The new incorporations are highest during 2001-11, and the least number of incorporations is seen during 1961-71. The disincorporation is highest during 2001-11 and the lowest number of disincorporations is found during 1961-71 and 1971-81 as compared to other decades. The maximum number of new incorporations is observed during 2001-11 which might be true because in western region, especially Gujarat and Maharashtra, which became hub of industrialization and economic growth. This economic dynamism has driven urbanization, with many new towns emerging as industrial centres or supporting urban areas, and the growth of the tourism and service sectors in the western region has also played a major role in the emergence of new towns, especially in coastal areas and regions with cultural or natural attractions

Table 3: Distribution of cities by city size class, number of new incorporations and disincorporations for Central Region and India :1961-2011.

	Central Region							India						
	VI	V	IV	III	II	I	Total	VI	V	IV	III	II	I	Total
Number of places, 1961	31	175	135	88	25	23	477	254	640	718	485	151	109	2357
New incorporations, 1961-1971	6	51	15	1	0	0	73	69	179	80	20	1	0	349
Disincorporations, 1961-1971	1	2	0	0	0	0	3	7	3	7	1	0	0	18
Number of places, 1971	19	177	172	112	34	33	547	235	609	856	615	214	159	2688
New incorporations, 1971-1981	74	246	122	8	0	0	450	131	406	234	46	2	0	819
Disincorporations, 1971-1981	1	0	0	0	0	0	1	7	4	5	2	1	0	19
Number of places, 1981	87	334	324	144	64	44	997	272	771	1073	819	319	233	3487
New incorporations, 1981-1991	4	108	53	6	0	1	172	61	305	167	63	4	4	604
Disincorporations, 1981-1991	0	0	0	0	0	0	0	10	9	2	0	0	0	21
Number of places, 1991	46	339	423	219	75	67	1169	211	813	1259	1043	411	334	4071
New incorporations, 1991-2001	14	59	30	9	0	0	112	100	495	397	112	1	0	1105
Disincorporations, 1991-2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of places, 2001	40	269	472	318	93	89	1281	235	1043	1564	1389	497	448	5176
New incorporations, 2001-2011	57	118	8	3	0	0	186	110	710	155	40	1	0	1016
Disincorporations, 2001-2011	2	2	0	0	0	0	4	10	8	2	1	0	0	21
Number of places, 2011	81	322	461	375	106	119	1464	303	1550	1606	1569	544	598	6170

The Central region has the highest incorporations during 1971-81 because the census of 1970s was a period of infrastructure development in India, with significant investments in roads, railways, and electricity. Improved infrastructure made previously remote areas more accessible, facilitating the establishment of new towns, also might be because of re-organization of states and the creation of new administrative divisions also led to the recognition and development of new towns. The lowest number of cities was incorporated during 1961-71, where the disincorporation is high during 2001-11 and lowest during 1971-81. And the total number of towns have increased from 477 in 1961 to 1464 in 2011. The raise in the number of towns is approximately thrice from 1961 to 2011 (see Table 3).

The number of towns in India have increased by 3 times from 1961 to 2011. The highest number of newly added towns was observed during 1991-2001 as the economic liberalization policies introduced in the early 1990s opened the Indian economy to global markets. This led to a surge in foreign direct investment (FDI), the growth of industries, and the expansion of the service sector, particularly in information technology (IT) and software services. This economic boom contributed to the development of new urban centres and towns across India. Whereas the least number of newly added towns was observed during 1961-71. As there may have been administrative reorganizations or changes in governance that affected the classification of certain areas. For example, areas previously considered independent towns might have been absorbed into larger municipalities or urban agglomerations, leading to a loss of their independent town status. During 1981-91 where we can see the highest de-classification of towns and the lowest de-classification is observed during 1961-71.

3.2. Proportional distribution of cities by city size classes.

In this section proportional distribution of cities by city size classes is shown for all the five regions of India from the period 1961-2011.In India in the beginning of the study period i.e., 1961 census, proportion of small cities namely class IV, V, and VI is more as compared to the higher size classes i.e., class I, II, and III and at the end of the study period 2011 census, this process is almost reversed i.e., the proportion of cities by city size classes increasing more in class I and II as compared to other small size categories. The increase in class I and II cities in India from 1961-2011 is by 5 per cent, for class III by 7 per cent, whereas for the lower size classes the cities have declined by 7 per cent from 1961 to 2011 by 5 per cent in class V and declined by 1 per cent in class IV cities. This is true because in recent decades there will be more job opportunities in bigger size cities compared to small cities, and also the availability of more educational and infrastructural facilities in bigger cities as compared to smaller size classes. Finally in India we can say that the highest increase of cities is observed in class III and, highest decline of cities is observed in class VI.

In the Northern region class I, II, and III cities the proportion of cities went on increasing gradually viz., 7 per cent, 6 per cent and 14 per cent from 1961 to 2011, but in class IV the proportion of cities has increased from 1961-2001, again it got declined from 2001-2011, in class V the proportional in case of cities went on decreasing by 8 per cent from 1961-2001, but in 2011 it got increased by 4%, lastly the class VI cities the proportion of cities went on decreasing from 1961-2011 by 26 per cent. In the Northern region the highest percentage decrease of cities is observed in class VI and highest percentage increase is observed in class III. The northern region is experiencing significant urban upgradation, moving away from small towns towards Class III and I cities. Urban development is more concentrated around regional urban centres.

The proportion of cities have increased by 6 per cent in class I and II, and in class III the cities got increased by 3 per cent in Southern region of India. The decline of cities is observed in class IV, V and VI cities where class IV cities declined by 0.8 per cent, class V cities by 8 per cent from 1961-91 and then increased by per cent from 1991-2001, later during 2001 -11 the cities declined by 4 per cent. Lastly, the class VI cities show a decline of cities by 4 per cent during 1961-2011. The highest percentage increase in cities is seen in class I and II, whereas the highest decline of cities is seen in class VI. Southern India shows a well-distributed urban pattern, with sustained growth in mid-sized cities (III & IV), but also growing presence of large cities. The share of the smallest towns is minimal, indicating mature urbanization.

The hilly region or the region which has the most mountains i.e., the Eastern region which is also called the backward region has many fluctuations in proportion of cities where from 1961-2011 increase in class I cities by 6 per cent, fluctuating in class II and in class III decline of cities is observed by 2 per cent. In the same way the cities of class VI decreased by 6 per cent from 1961-2011, declined by 8 per cent from 1961-91 and later increased by 14 % from 1991-2011, and finally in class IV the cities declined by 0.7 per cent from 1961-2011. Class I cities of Eastern region show the highest percentage of cities increase in class I, and the highest percentage of decline of cities is in class VI. Unlike other regions, the Eastern region shows concentration in Class V towns, which may reflect slower urban transformation and a lag in metropolitan expansion. There's some progress toward larger cities, but less than in the Northern or Southern regions.

Table 7: Proportional distribution of cities by city size classes for different regions of India- 1961-2011.

India						
Years	Size Classes					
	VI	V	IV	III	II	I
1961	0.11	0.27	0.3	0.21	0.06	0.05
1971	0.09	0.23	0.32	0.23	0.08	0.06
1981	0.08	0.22	0.31	0.23	0.09	0.07
1991	0.05	0.20	0.31	0.26	0.10	0.08
2001	0.05	0.20	0.30	0.27	0.10	0.09
2011	0.04	0.22	0.26	0.28	0.11	0.10
Northern region						
Years	Size Classes					
	VI	V	IV	III	II	I
1961	0.32	0.24	0.21	0.14	0.04	0.05
1971	0.25	0.24	0.25	0.15	0.06	0.06
1981	0.18	0.22	0.29	0.19	0.06	0.07
1991	0.13	0.17	0.31	0.22	0.10	0.08
2001	0.09	0.16	0.28	0.27	0.10	0.11
2011	0.08	0.22	0.22	0.28	0.10	0.12
Southern region						
Years	Size Classes					
	VI	V	IV	III	II	I
1961	0.06	0.20	0.38	0.25	0.07	0.05
1971	0.07	0.16	0.34	0.29	0.08	0.06
1981	0.03	0.13	0.29	0.35	0.11	0.08
1991	0.01	0.12	0.27	0.36	0.14	0.10
2001	0.02	0.20	0.32	0.28	0.11	0.08
2011	0.02	0.16	0.31	0.28	0.13	0.11
Eastern region						
Years	Size Classes					
	VI	V	IV	III	II	I
1961	0.06	0.29	0.29	0.22	0.09	0.04
1971	0.07	0.24	0.31	0.23	0.10	0.05
1981	0.06	0.20	0.31	0.24	0.12	0.07
1991	0.07	0.21	0.29	0.24	0.10	0.09
2001	0.07	0.27	0.24	0.23	0.09	0.10
2011	0.10	0.35	0.22	0.18	0.09	0.10
Western region						
Years	Size Classes					
	VI	V	IV	III	II	I
1961	0.05	0.27	0.34	0.22	0.06	0.05
1971	0.03	0.20	0.37	0.24	0.10	0.06
1981	0.04	0.16	0.32	0.28	0.11	0.09
1991	0.04	0.15	0.29	0.30	0.12	0.10
2001	0.04	0.13	0.26	0.33	0.12	0.10
2011	0.05	0.26	0.20	0.29	0.13	0.11
Central region						
Years	Size Classes					
	VI	V	IV	III	II	I
1961	0.06	0.37	0.28	0.18	0.05	0.05
1971	0.03	0.32	0.31	0.20	0.06	0.06
1981	0.09	0.34	0.32	0.23	0.06	0.06
1991	0.04	0.29	0.36	0.24	0.06	0.06
2001	0.03	0.21	0.37	0.25	0.07	0.07
2011	0.02	0.20	0.31	0.26	0.07	0.08

The higher size classes of Western region viz. Class I, II, and III cities have shown an increasing trend from 1961 to 2011 by 6 per cent in class I and 7 per cent in class II and III. Whereas in the lower size classes the cities are fluctuating by increasing and decreasing in class VI, and 14 per cent of cities got declined from 1961-2001 and later increased by 13 per cent from 2001-11 and the class IV cities have declined by 0.14 per cent from 1961-71. Both the class II and III cities show the highest increase of cities in this region and the class VI, V and IV cities show fluctuating trend. The Western region exhibits a shift from mid-size

(IV) to large-size (I & III) cities, driven by states like Maharashtra and Gujarat. Consistent growth in Class I cities is seen here.

The Central region proportion of cities got increasing gradually from 1961 to 2011 in class I and II by 3 per cent and III by 8 per cent. The class IV cities increased from 1961 to 2001 by 0.9 per cent, later during 1961-2011 the proportion decreased by 0.06%. In class VI and V, the proportion of cities decreased from 1961-2011 by 4 per cent, and 17 per cent respectively. The highest increase in the number of cities is in class III in the Central region and decline in class V. The Central region is urbanizing slowly, with continued dominance of small to medium towns. The movement toward Class I cities is weaker than other regions, suggesting less dynamic urban growth.

3.3. Transition of cities by city size classes.

The transition of cities by city size classes refers to changes over time in the population size categories that cities occupy. These transitions can occur as cities grow or shrink, leading them to move between defined size classes (e.g., small, medium, large). Analysing these transitions helps researchers understand patterns of urban growth, regional development, and migration. A Markov chain transition matrix can quantify the probability of a city moving from one size class to another over time.

Table 8: Transition Probability matrices of cities by city size of India: 1961-2011.

Decade	Size at Beginning of Decade	Size at End of Decade						
		Class VI	Class V	Class IV	Class III	Class II	Class I	(N)
1961-71	Class VI	0.64	0.34	0.01	0.00	0.00	0.00	247
	Class V	0.01	0.53	0.44	0.02	0.00	0.00	637
	Class IV	0.00	0.01	0.68	0.30	0.00	0.00	711
	Class III	0.00	0.00	0.01	0.76	0.22	0.01	484
	Class II	0.00	0.00	0.01	0.01	0.68	0.30	151
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	109
1971-81	Class VI	0.41	0.26	0.20	0.08	0.05	0.00	158
	Class V	0.06	0.34	0.52	0.07	0.00	0.00	443
	Class IV	0.01	0.06	0.54	0.37	0.02	0.00	784
	Class III	0.01	0.02	0.07	0.61	0.29	0.01	596
	Class II	0.01	0.00	0.00	0.12	0.54	0.32	213
	Class I	0.00	0.01	0.00	0.01	0.00	0.99	159
1981-91	Class VI	0.59	0.27	0.08	0.04	0.02	0.00	114
	Class V	0.01	0.46	0.49	0.03	0.00	0.00	276
	Class IV	0.00	0.01	0.63	0.35	0.00	0.00	740
	Class III	0.00	0.00	0.00	0.77	0.22	0.00	731
	Class II	0.00	0.00	0.00	0.01	0.71	0.28	312
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	232
1991-2001	Class VI	0.53	0.36	0.10	0.01	0.00	0.00	80
	Class V	0.01	0.48	0.45	0.06	0.01	0.01	197
	Class IV	0.00	0.01	0.63	0.35	0.01	0.00	644
	Class III	0.00	0.00	0.01	0.79	0.19	0.01	843
	Class II	0.00	0.00	0.00	0.00	0.75	0.25	388
	Class I	0.00	0.00	0.00	0.00	0.01	0.98	324
2001-11	Class VI	0.70	0.27	0.04	0.00	0.00	0.00	142
	Class V	0.04	0.71	0.25	0.00	0.00	0.00	768
	Class IV	0.00	0.03	0.75	0.22	0.00	0.00	1244
	Class III	0.00	0.00	0.01	0.85	0.13	0.01	1100
	Class II	0.00	0.00	0.00	0.00	0.71	0.28	423
	Class I	0.00	0.00	0.00	0.00	0.00	0.99	326

The transition patterns help identify urbanization trends, the stability of city sizes, and the effects of policies or economic shifts on city growth dynamics. Understanding these transitions is valuable for urban planning, resource allocation, and policymaking, as it provides a way to anticipate changes in urban and regional development. This transition probability matrix of cities by city size classes is obtained for all the five regions of India from 1961-2011 by considering the number of cities transmitted from one size classes to another size classes from beginning of decade to end of the decade and dividing these transmitted cities

by total number of transmitted cities in that class, this process is repeated for all the size classes. During the decade 1961–71, over 50% of Indian cities remained in the same size class, while less than 45% transitioned to the next higher size class. Only around 1% of cities experienced counter-urbanization, moving to a lower class. Similar trends were observed in the decades 1981–91 and 1991–2001, with more than 45% of cities showing persistence in their original size class. In contrast, during 1971–81, the proportion of cities that remained in their original class dropped to just above 30%, with the majority moving up to higher size classes. Notably, the decade 2001–11 recorded the highest rate of class retention—over 70% of cities remained in their initial size class, while the rest progressed to higher classes.

An important observation is that retention rates are lower in the smaller city classes and higher in the larger ones. This implies that lower-tier cities exhibit higher transition rates, while larger cities show more stability. Backward movement (i.e., cities shifting to a smaller class) has been minimal throughout the period, less than 5% overall, and only about 1% in most decades. These few cases are largely attributed to a lack of urban infrastructure and services. Overall, the Indian urban system appears to be stabilizing. However, mobility from smaller city classes is declining, indicating a slowdown in the growth trajectory of smaller urban centres. This highlights the urgent need for targeted development policies aimed at Class V to Class III cities. Investments in infrastructure, economic incentives, and integrated urban planning are essential to support upward mobility and promote balanced urban growth.

Table 9: Transition Probability Matrices of cities by city sizes of India for Northern region: 1961-2011.

Decade	Size at Beginning of Decade	Size at End of Decade						
		Class VI	Class V	Class IV	Class III	Class II	Class I	(N)
1961-71	Class VI	0.75	0.23	0.01	0.01	0.00	0.00	137
	Class V	0.02	0.59	0.38	0.01	0.00	0.00	108
	Class IV	0.00	0.02	0.75	0.23	0.00	0.00	92
	Class III	0.00	0.00	0.00	0.79	0.18	0.03	62
	Class II	0.00	0.00	0.00	0.00	0.79	0.21	19
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	20
1971-81	Class VI	0.67	0.25	0.05	0.01	0.02	0.00	114
	Class V	0.00	0.56	0.43	0.01	0.00	0.00	109
	Class IV	0.00	0.00	0.62	0.38	0.00	0.00	117
	Class III	0.01	0.00	0.00	0.75	0.24	0.00	72
	Class II	0.00	0.00	0.00	0.00	0.50	0.50	26
	Class I	0.00	0.00	0.00	0.04	0.00	0.96	26
1981-91	Class VI	0.64	0.23	0.06	0.06	0.01	0.00	90
	Class V	0.03	0.48	0.47	0.03	0.00	0.00	116
	Class IV	0.01	0.00	0.69	0.30	0.01	0.00	162
	Class III	0.01	0.00	0.00	0.68	0.31	0.00	105
	Class II	0.00	0.00	0.00	0.00	0.70	0.30	33
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	38
1991-2001	Class VI	0.56	0.29	0.13	0.03	0.00	0.00	77
	Class V	0.02	0.43	0.48	0.07	0.01	0.00	103
	Class IV	0.00	0.00	0.61	0.37	0.03	0.00	185
	Class III	0.00	0.00	0.00	0.77	0.21	0.02	130
	Class II	0.00	0.00	0.00	0.00	0.60	0.40	58
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	48
2001-11	Class VI	0.81	0.15	0.04	0.00	0.00	0.00	48
	Class V	0.05	0.65	0.29	0.01	0.00	0.00	80
	Class IV	0.00	0.01	0.65	0.33	0.01	0.00	164
	Class III	0.00	0.01	0.02	0.85	0.11	0.01	157
	Class II	0.00	0.02	0.00	0.00	0.71	0.28	58
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	54

The transition probability matrix for the Northern region of India was calculated for the period from 1961–71 to 2001–11. The analysis reveals that during 1961–71 and 1971–81, over 55% of cities across all classes remained in their original size class, while approximately 45% transitioned to higher size classes. Instances of counter-urbanization were minimal, affecting less than 2% of cities. In the subsequent decades, 1981–91 and 1991–2001, more than 40% of cities remained in their original classes, while around 60% advanced to higher classes. Counter-urbanization during these periods was also limited, involving less than

3% of cities. The period 2001–11 exhibited the highest level of persistence, with over 65% of cities retaining their existing class, while the remaining 35% moved to upper classes. During this decade, fewer than 5% of cities showed signs of counter-urbanization. A closer examination of the transition matrix shows that Classes VI, V, IV, III, and II function as transient states, while Class I acts as a recurrent (absorbing) state throughout all census periods except for 1971–81, during which all city classes were recurrent. In this particular decade, the chain was ergodic, meaning all states were recurrent, communicating, and aperiodic. Notably, only one Class I city exhibited counter-urbanization during this time (see Table 10). From 1961 to 1991, the region experienced strong upward mobility, with a fluid and evolving urban hierarchy. Smaller towns frequently transitioned into middle and large-sized cities, with Class II cities playing a key role in the expansion of Class I cities. However, the period 1991–2011 marks a decline in urban mobility. Cities in Classes VI and V began to exhibit signs of rigidity, with stagnation linked to limited development initiatives. Classes III, II, and I became increasingly stable and saturated, and Class I cities emerged as terminal absorbing states, rarely experiencing downward transitions once reached.

Table 10: Transition Probability matrices of cities by city sizes of India for Southern region: 1961-2011.

Decade	Size at Beginning of Decade	Size at End of Decade						
		Class VI	Class V	Class IV	Class III	Class II	Class I	(N)
1961-71	Class VI	0.63	0.38	0.00	0.00	0.00	0.00	32
	Class V	0.00	0.52	0.45	0.03	0.00	0.00	127
	Class IV	0.00	0.00	0.67	0.32	0.01	0.00	232
	Class III	0.00	0.00	0.02	0.76	0.22	0.00	157
	Class II	0.00	0.00	0.02	0.02	0.56	0.40	45
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	29
1971-81	Class VI	0.51	0.43	0.02	0.04	0.00	0.00	47
	Class V	0.01	0.46	0.50	0.03	0.00	0.00	113
	Class IV	0.00	0.00	0.59	0.40	0.01	0.00	245
	Class III	0.00	0.00	0.00	0.75	0.24	0.00	206
	Class II	0.00	0.00	0.00	0.00	0.70	0.30	60
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	47
1981-91	Class VI	0.39	0.50	0.11	0.00	0.00	0.00	28
	Class V	0.00	0.58	0.38	0.03	0.01	0.00	108
	Class IV	0.00	0.00	0.70	0.28	0.01	0.00	236
	Class III	0.00	0.00	0.01	0.81	0.18	0.00	283
	Class II	0.00	0.00	0.01	0.00	0.74	0.25	93
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	66
1991-2001	Class VI	0.67	0.33	0.00	0.00	0.00	0.00	12
	Class V	0.05	0.63	0.27	0.05	0.00	0.01	110
	Class IV	0.00	0.00	0.67	0.31	0.00	0.01	248
	Class III	0.00	0.00	0.02	0.82	0.16	0.01	329
	Class II	0.00	0.00	0.00	0.01	0.83	0.16	126
	Class I	0.00	0.01	0.00	0.00	0.02	0.97	92
2001-11	Class VI	0.76	0.24	0.00	0.00	0.00	0.00	17
	Class V	0.02	0.75	0.22	0.00	0.00	0.00	202
	Class IV	0.00	0.03	0.82	0.15	0.00	0.00	330
	Class III	0.00	0.00	0.01	0.82	0.15	0.01	272
	Class II	0.00	0.00	0.00	0.01	0.77	0.23	133
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	82

In the Southern region of India, the transition probability matrix for the decade 1961–71 reveals that approximately 50% of cities transitioned to higher size classes, while the remaining 50% retained their original classification. Only 2% of cities in Class III and Class II experienced counter-urbanization, moving to a lower size class. During 1971–81, 45% of cities remained in their original size class, while the rest

moved upward. Counter-urbanization was limited, with just 1% of Class V cities declining in size. The pattern during 1981–91 was similar to 1961–71, but with slightly greater stability over 55% of cities retained their class, and 45% moved up the urban hierarchy. In the 1991–2001 period, 60% of cities stayed in their existing class, and 40% advanced to higher size categories. Fewer than 5% of cities moved downward, indicating a small degree of counter-urbanization. The decade 2001–11 exhibited the highest level of class retention, with more than 75% of cities remaining in the same class. The remaining 25% moved to higher size classes, while just under 3% showed signs of counter-urbanization.

An analysis of the transition probability matrix indicates that during 1991–2001, all city size classes were recurrent, communicating, and aperiodic, making the Markov chain for this period ergodic. In this timeframe, only two cities experienced counter-urbanization (see Table 10). For the other census periods, Classes VI, V, IV, III, and II function as recurrent states, while Class I behaves as a transient state, suggesting that cities rarely remain in or return to Class I once reached. In the earlier decades, the Southern region demonstrated strong upward mobility, particularly from Class V to IV, Class III to II, and eventually into Class I. This reflects a pattern of balanced and structured urban growth, with consistent development of mid-sized cities. However, in recent decades, mobility from lower classes (Class VI and V) has slowed, indicating increasing rigidity. The urban hierarchy is becoming more stable and stratified, with Classes III and IV showing greater resistance to transition.

Table 11: Transition Probability matrices of cities by city sizes of India for Eastern region: 1961-2011

Decade	Size at Beginning of Decade	Size at End of Decade						
		Class VI	Class V	Class IV	Class III	Class II	Class I	(N)
1961-71	Class VI	0.52	0.44	0.04	0.00	0.00	0.00	27
	Class V	0.01	0.42	0.54	0.03	0.00	0.00	123
	Class IV	0.01	0.02	0.61	0.36	0.00	0.00	122
	Class III	0.00	0.00	0.00	0.75	0.23	0.02	91
	Class II	0.00	0.00	0.00	0.00	0.76	0.24	38
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	18
1971-81	Class VI	0.51	0.43	0.03	0.03	0.00	0.00	35
	Class V	0.00	0.38	0.55	0.07	0.00	0.00	123
	Class IV	0.00	0.01	0.58	0.41	0.01	0.00	162
	Class III	0.00	0.00	0.02	0.64	0.34	0.00	122
	Class II	0.00	0.00	0.00	0.00	0.67	0.33	51
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	29
1981-91	Class VI	0.49	0.39	0.12	0.00	0.00	0.00	41
	Class V	0.03	0.45	0.49	0.02	0.00	0.00	132
	Class IV	0.00	0.02	0.67	0.31	0.00	0.00	201
	Class III	0.00	0.00	0.00	0.76	0.23	0.01	158
	Class II	0.00	0.00	0.00	0.03	0.64	0.33	78
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	46
1991-2001	Class VI	0.55	0.43	0.00	0.02	0.00	0.00	56
	Class V	0.03	0.65	0.32	0.01	0.00	0.00	179
	Class IV	0.00	0.02	0.68	0.30	0.00	0.00	243
	Class III	0.00	0.00	0.02	0.82	0.16	0.01	200
	Class II	0.00	0.00	0.00	0.00	0.69	0.31	86
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	74
2001-11	Class VI	0.63	0.33	0.05	0.00	0.00	0.00	43
	Class V	0.07	0.77	0.15	0.00	0.00	0.01	188
	Class IV	0.01	0.03	0.72	0.24	0.01	0.00	188
	Class III	0.00	0.00	0.01	0.84	0.15	0.01	198
	Class II	0.00	0.00	0.00	0.01	0.62	0.36	69
	Class I	0.00	0.00	0.00	0.00	0.02	0.98	59

In the Eastern region of India, the transition probability matrices for the decades 1961–71 and 1981–91 show that over 40% of cities remained in their original size class, while the remaining 60% moved to the next higher size classes. Counter-urbanization was minimal, affecting only 1–2% of cities. During 1971–81, approximately 35% of cities retained their original size class, with nearly 65% moving up the urban hierarchy. Again, counter-urbanization affected fewer than 2% of cities. In 1991–2001, 55% of cities remained in the same class, while 42% transitioned to higher classes and 3% showed downward mobility.

The period 2001–11 recorded the highest-class retention, with over 60% of cities staying in their existing class. About 37% moved upward, and counter-urbanization was observed in fewer than 3% of cities. Analysis of the transition matrices indicates that Classes VI, V, IV, III, and II functioned as transient states, while Class I was a recurrent state across all periods—except during 2001–11, when all city size classes were recurrent. This makes the 2001–11 Markov chain ergodic, as all states were recurrent, communicating, and aperiodic, primarily due to one Class I city that underwent counter-urbanization (see Table 12). In the earlier period, the region demonstrated strong upward mobility, especially from Class V to IV and Class IV to III in earlier decades. Class II cities played a consistent role in the formation of Class I cities, with significant movement observed during 2001–11, where 36% of Class II cities transitioned into Class I. The urban system expanded steadily, driven by bottom-up growth. In recent years, particularly from 2001–11, cities in Classes VI and V have shown reduced mobility, with over 60% remaining static. Class IV cities have become increasingly stable, indicating a slowing rate of upward transition. Meanwhile, Class I cities continue to exhibit stability and saturation, serving as terminal absorbing states.

Table 12: Transition Probability matrices of cities by city sizes of India for Western region: 1961-2011

Decade	Size at Beginning of Decade	Size at End of Decade						
		Class VI	Class V	Class IV	Class III	Class II	Class I	(N)
1961-71	Class VI	0.43	0.52	0.05	0.00	0.00	0.00	21
	Class V	0.02	0.46	0.50	0.02	0.00	0.00	106
	Class IV	0.00	0.01	0.74	0.25	0.00	0.00	130
	Class III	0.00	0.00	0.01	0.72	0.27	0.00	86
	Class II	0.00	0.00	0.00	0.00	0.79	0.21	24
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	19
1971-81	Class VI	0.67	0.25	0.08	0.00	0.00	0.00	12
	Class V	0.00	0.57	0.43	0.00	0.00	0.00	83
	Class IV	0.00	0.01	0.68	0.32	0.00	0.00	155
	Class III	0.00	0.00	0.01	0.75	0.24	0.00	101
	Class II	0.00	0.00	0.00	0.00	0.64	0.36	42
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	24
1981-91	Class VI	0.50	0.25	0.19	0.00	0.06	0.00	16
	Class V	0.03	0.51	0.40	0.06	0.00	0.00	72
	Class IV	0.00	0.00	0.67	0.32	0.01	0.00	148
	Class III	0.00	0.00	0.01	0.78	0.20	0.01	129
	Class II	0.00	0.00	0.00	0.04	0.73	0.24	51
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	39
1991-2001	Class VI	0.55	0.45	0.00	0.00	0.00	0.00	20
	Class V	0.05	0.51	0.40	0.04	0.00	0.00	82
	Class IV	0.00	0.01	0.59	0.39	0.01	0.00	160
	Class III	0.00	0.00	0.00	0.82	0.17	0.01	165
	Class II	0.00	0.00	0.00	0.00	0.80	0.20	66
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	53
2001-11	Class VI	0.50	0.40	0.10	0.00	0.00	0.00	10
	Class V	0.06	0.62	0.32	0.00	0.00	0.00	66
	Class IV	0.00	0.05	0.66	0.27	0.01	0.01	143
	Class III	0.00	0.00	0.01	0.89	0.09	0.01	191
	Class II	0.00	0.00	0.00	0.00	0.75	0.25	77
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	51

The transition probability matrix for the Western region during the decade 1961–71 shows that over 40% of cities remained in their original size classes, while less than 60% transitioned to higher size classes. Counter-urbanization was minimal, involving fewer than 2% of cities. During 1971–81, more than 55% of cities retained their existing class, while less than 44% moved to larger size categories. Only 1% of cities experienced downward movement. A similar trend continued in the subsequent decades 1981–91, 1991–2001, and 2001–11 with approximately 50% of cities showing no transition, remaining within their original classes, and the remaining 50% advancing to higher size classes. Across these three decades, counter-urbanization remained under 6%. For all census periods, the Markov analysis indicates that Classes VI, V, IV, III, and II act as transient states, while Class I is a recurrent state, suggesting that once cities reach Class

I, they tend to remain there. The Western region does not exhibit ergodic behaviour in any census period, as confirmed by the structure of its transition matrices. Historically, the region has shown strong upward mobility, particularly from Classes V and IV, and consistent transitions from Class II to Class I, contributing significantly to the growth of metropolitan cities. In recent decades, increasing stability in Classes III and I reflect a consolidation of the urban structure. However, Classes VI and V have become increasingly rigid, showing less movement, while Class IV continues to act as a transitional zone. Overall, the pace of upward mobility has slightly declined.

Table 13: Transition Probability matrices of cities by city sizes of India for Central region: 1961-2011

Decade	Size at Beginning of Decade	Size at End of Decade						
		Class VI	Class V	Class IV	Class III	Class II	Class I	(N)
1961-71	Class VI	0.43	0.57	0.00	0.00	0.00	0.00	30
	Class V	0.00	0.62	0.37	0.01	0.00	0.00	173
	Class IV	0.00	0.01	0.68	0.30	0.00	0.00	135
	Class III	0.00	0.00	0.01	0.77	0.22	0.00	88
	Class II	0.00	0.00	0.00	0.00	0.60	0.40	25
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	23
1971-81	Class VI	0.68	0.32	0.00	0.00	0.00	0.00	19
	Class V	0.00	0.46	0.53	0.01	0.00	0.00	177
	Class IV	0.00	0.00	0.63	0.37	0.00	0.00	172
	Class III	0.00	0.00	0.00	0.63	0.38	0.00	112
	Class II	0.00	0.00	0.00	0.03	0.65	0.32	34
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	33
1981-91	Class VI	0.47	0.52	0.00	0.00	0.01	0.00	87
	Class V	0.00	0.55	0.45	0.00	0.00	0.00	334
	Class IV	0.00	0.01	0.68	0.31	0.00	0.00	324
	Class III	0.00	0.00	0.00	0.78	0.20	0.01	144
	Class II	0.00	0.00	0.00	0.00	0.70	0.30	64
	Class I	0.00	0.00	0.00	0.00	0.00	1.00	44
1991-2001	Class VI	0.52	0.48	0.00	0.00	0.00	0.00	46
	Class V	0.01	0.53	0.45	0.01	0.00	0.00	339
	Class IV	0.00	0.02	0.67	0.31	0.00	0.00	423
	Class III	0.00	0.00	0.01	0.80	0.18	0.00	219
	Class II	0.00	0.00	0.00	0.00	0.69	0.31	75
	Class I	0.00	0.00	0.00	0.01	0.01	0.97	67
2001-11	Class VI	0.61	0.39	0.00	0.00	0.00	0.00	23
	Class V	0.00	0.67	0.32	0.00	0.00	0.00	232
	Class IV	0.00	0.02	0.77	0.21	0.00	0.00	419
	Class III	0.00	0.00	0.01	0.86	0.13	0.00	282
	Class II	0.00	0.00	0.00	0.00	0.67	0.33	86
	Class I	0.00	0.00	0.00	0.01	0.00	0.99	80

In the Central region of India, the transition probability matrix for the decade 1961–71 indicates that over 40% of cities remained in their original size class, while less than 60% transitioned to higher size classes. Only 1% of cities experienced counter-urbanization, moving to a lower class. During 1971–81 and 1981–91, less than 55% of cities advanced to higher size classes, whereas more than 45% remained in their existing class. In 1981–91, counter-urbanization was observed in only 1% of cities. In the 1991–2001 period, more than 50% of cities showed no transition, maintaining their size class, while less than 50% moved upward and fewer than 2% moved downward. The decade 2001–11 recorded the highest-class retention across all census periods, with over 60% of cities remaining in their original size class. Less than 40% advanced to the next higher class, and 1–2% showed counter-urbanization.

Transition probability matrices for all decades reveal that Classes VI, V, IV, III, and II consistently functioned as transient states, while Class I served as a recurrent (absorbing) state, except in 1991–2001, where all city classes were recurrent. This unique configuration makes the 1991–2001 period an ergodic Markov chain, as all states were recurrent, communicating, and aperiodic, with one Class I city showing counter-urbanization in that period. In the starting of the period from the study, the Central region experienced strong upward mobility, particularly from small and mid-sized towns, with Class II cities consistently supporting the expansion of Class I metros—up to 40% in some decades. Classes III and IV

played stable yet productive roles within the urban hierarchy. However, in recent decades, mobility from Classes VI and V has declined notably. Class IV and III cities are now acting as transition points, but the pace of movement toward higher classes is slowing.

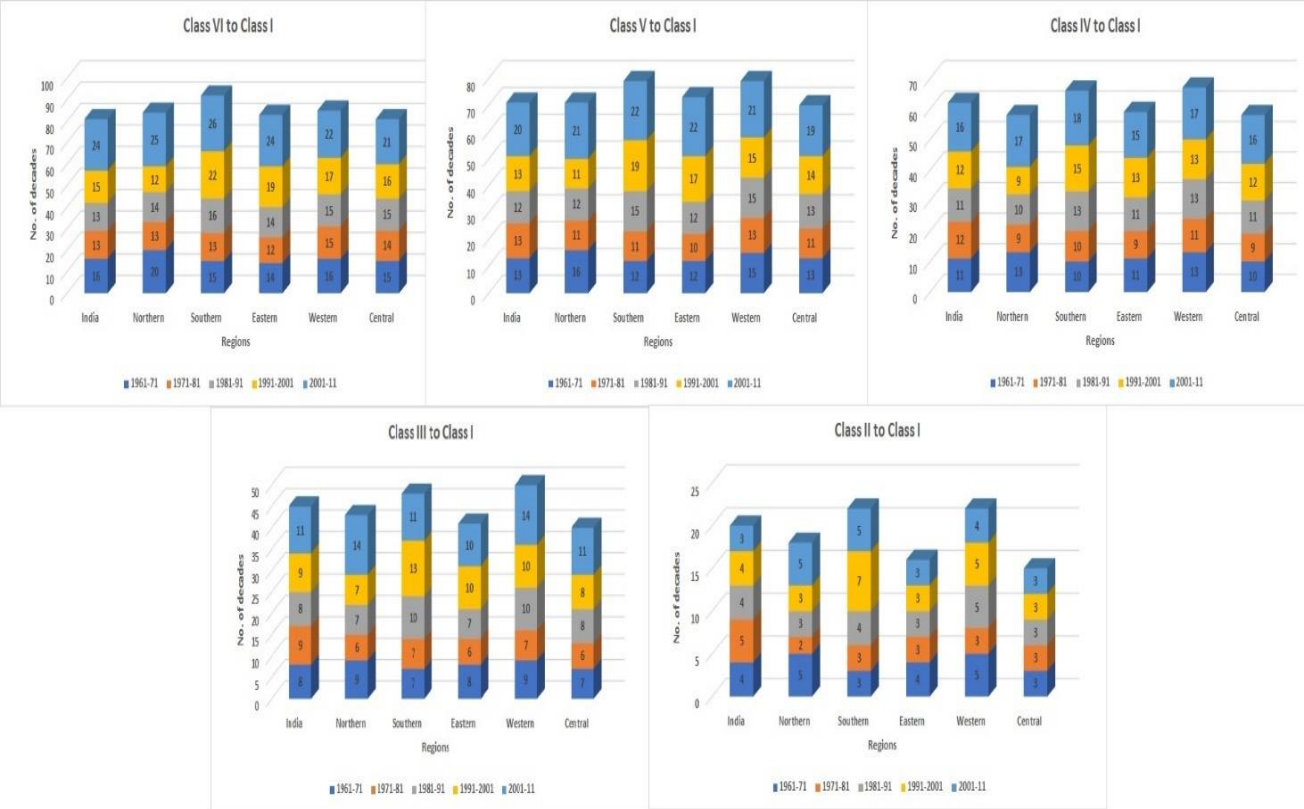
3.4. Average time taken to reach absorption state.

The time required to reach equilibrium state was estimated by successively multiplying each transition probability matrix. Since equilibrium state is approached as a limiting process that can only be approximated within a finite period, an arbitrary criterion was applied: the equilibrium time was defined by raising the matrix P to successive powers. And based on a Markov theory, the average time it would take a town/city to move for the first time from the class VI, V, IV, III, and II to the class I is obtained by using the first passage time for all the regions of India from 1961 to 2011.

Table 14: Average time to reach Absorption state using Markov Chain, based on transition probability of each decade: 1961-2011.

Size	Year				
	1961-71	1971-81	1981-91	1991-2001	2001-11
India					
Number of decades to reach equilibrium or complete absorption	40	46	37	43	55
Average time from under Class VI to Class I	16	13	13	15	24
Average time from under Class V to Class I	13	13	12	13	20
Average time from under Class IV to Class I	11	12	11	12	16
Average time from under Class III to Class I	8	9	8	9	11
Average time from under Class II to Class I	4	5	4	4	3
Northern region					
Number of decades to reach equilibrium or complete absorption	44	35	34	30	57
Average time from under Class VI to Class I	20	13	14	12	25
Average time from under Class V to Class I	16	11	12	11	21
Average time from under Class IV to Class I	13	9	10	9	17
Average time from under Class III to Class I	9	6	7	7	14
Average time from under Class II to Class I	5	2	3	3	5
Southern region					
Number of decades to reach equilibrium or complete absorption	32	32	37	42	47
Average time from under Class VI to Class I	15	13	16	22	26
Average time from under Class V to Class I	12	11	15	19	22
Average time from under Class IV to Class I	10	10	13	15	18
Average time from under Class III to Class I	7	7	10	13	11
Average time from under Class II to Class I	3	3	4	7	5
Eastern region					
Number of decades to reach equilibrium or complete absorption	32	22	32	37	42
Average time from under Class VI to Class I	14	12	14	19	24
Average time from under Class V to Class I	12	10	12	17	22
Average time from under Class IV to Class I	11	9	11	13	15
Average time from under Class III to Class I	8	6	7	10	10
Average time from under Class II to Class I	4	3	3	3	3
Western region					
Number of decades to reach equilibrium or complete absorption	37	33	45	47	69
Average time from under Class VI to Class I	16	15	15	17	22
Average time from under Class V to Class I	15	13	15	15	21
Average time from under Class IV to Class I	13	11	13	13	17
Average time from under Class III to Class I	9	7	10	10	14
Average time from under Class II to Class I	5	3	5	5	4
Central region					
Number of decades to reach equilibrium or complete absorption	37	31	36	43	48
Average time from under Class VI to Class I	15	14	15	16	21
Average time from under Class V to Class I	13	11	13	14	19
Average time from under Class IV to Class I	10	9	11	12	16
Average time from under Class III to Class I	7	6	8	8	11
Average time from under Class II to Class I	3	3	3	3	3

Fig1: The time taken to reach the class I cities from other class cities for India and 5 different regions of India.



The above Table 14 provides the data of India regarding the equilibrium distribution for transition probability matrices i.e., the approximate amount of time required to attain the condition of all towns being over 1,00,000 population or alternately the amount of time required for achieving equilibrium state. 400 decades were taken to reach equilibrium state for census period 1961-71, 460 decades for the census 1971-810, 370 decades for the census 1981-91, 430 decades for the period 1991-2001 and 550 decades for 2001-11.

The Northern region takes 44, 35, 34, 30, 57 decades to reach the equilibrium state for the period respectively 1961-71, 1971-81, 1981-91, 1991-2001 and 2001-11. In the Southern region, all the cities to reach equilibrium state took 32 decades for the census 1961-71 and 1971-81, 37 decades for the census 1981-91, for the decades 1981-91 and 1991-2001 the time taken to reach equilibrium state is 42 and 47. For the Eastern region 32 decades is required time to reach the equilibrium state for 1961-71 and 1981-91, for the census 1971-81 all the cities reaching equilibrium state is 22 decades and lastly 37 and 42 decades is required for the census 1991-2001 and 2001-11. In the Western region the required time to reach the equilibrium state is 37 decades (1961-1971), 33 decades (1971-1981), 45 decades (1981-1991), 47 decades (1991-2001) and 69 decades (2001-11). The Central region for the period 1961-71, 1971-81, 1981-91, 1991-2001 all the cities required to reach equilibrium states are 37, 31, 36, 43 and 48 decades.

Table 14 shows the average time taken to reach the class I city from class VI, V, IV, III, and II. Compared to all regions during 1961-71 and 1981-91 Northern region, Western region during 1971-81, Southern region during 1991-2001 and 2001-11 shows highest time taken to reach the absorption state i.e., class I state from the other size classes. In all the five regions of India the average time taken to reach the absorption state from different size classes got decreased from class VI to class II, and this shows that lower size classes took much time to reach the absorption state than the higher size classes.

3.5. Observed and estimated number of cities.

The expected distributions of places by size were calculated for each census years using each of the transition probability matrices. Observed incorporations and disincorporations were added in and subtracted out as they occurred. This approach allows differences between expected and observed distributions to be attributed to the transition probability matrices, isolating the effects of incorporation and disincorporation for all the five regions of India from 1961 to 2011.

Table 15: Comparison of observed and estimated number of cities for different regions of India and checking for goodness of fit: 1971-2011

India												
	Class I		Class II		Class III		Class IV		Class V		Class VI	
	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti
1971	159	159	214	214	615	617	856	855	609	610	235	233
1981	233	436	319	599	819	897	1073	759	771	573	272	224
1991	334	497	411	793	1043	1205	1259	867	813	515	211	194
2001	448	428	497	865	1389	1499	1564	1280	1043	824	235	280
2011	598	538	544	955	1569	1680	1606	1349	1550	1216	303	432
Chi-square	**155.60**		**648.34**		**43.97**		**419.11**		**390.80**		**57.54**	
Northern region												
	Class I		Class II		Class III		Class IV		Class V		Class VI	
	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti
1971	26	24	26	26	72	72	117	117	110	113	115	114
1981	38	166	33	83	105	123	163	95	122	53	98	40
1991	48	135	58	137	130	147	185	103	103	44	77	34
2001	74	122	68	105	184	202	192	134	109	81	64	47
2011	94	95	70	100	226	229	175	158	179	154	67	74
Chi-square	**173.82**		**97.71**		**6.24**		**140.88**		**182.76**		**145.30**	
Southern region												
	Class I		Class II		Class III		Class IV		Class V		Class VI	
	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti
1971	47	47	61	61	207	208	248	247	114	115	49	48
1981	66	84	93	139	283	297	237	185	110	85	28	26
1991	92	58	126	131	329	305	248	278	110	118	12	27
2001	115	35	161	133	420	380	472	529	289	325	24	78
2011	157	96	187	293	417	452	458	387	240	163	26	93
Chi-square	**245.40**		**59.65**		**9.47**		**37.02**		**48.26**		**94.16**	
Eastern region												
	Class I		Class II		Class III		Class IV		Class V		Class VI	
	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti
1971	29	32	51	55	123	122	164	164	125	120	39	38
1981	46	81	78	142	158	163	201	137	133	101	41	34
1991	74	88	86	131	200	220	243	188	179	155	56	57
2001	103	115	92	163	245	267	252	194	286	233	77	84
2011	139	182	96	218	285	292	346	314	563	421	159	161
Chi-square	**29.04**		**143.79**		**3.96**		**66.58**		**74.01**		**2.09**	
Western region												
	Class I		Class II		Class III		Class IV		Class V		Class VI	
	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti
1971	24	22	42	39	101	101	155	155	83	85	13	16
1981	39	43	51	90	129	153	148	95	72	51	18	25
1991	53	38	66	87	165	170	160	145	82	77	20	29
2001	67	37	83	95	222	219	176	172	90	97	30	47
2011	90	55	86	87	249	221	168	199	219	231	44	63
Chi-square	**53.07**		**23.72**		**7.50**		**36.04**		**10.14**		**17.19**	
Central region												
	Class I		Class II		Class III		Class IV		Class V		Class VI	
	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti	Obs	Esti
1971	33	33	34	34	112	112	172	173	177	177	19	18
1981	44	76	64	179	144	163	324	210	334	272	87	97
1991	67	192	75	301	219	304	423	180	339	167	46	25
2001	89	151	93	312	318	417	472	217	269	135	40	49
2011	119	128	106	244	375	475	461	287	322	219	81	110
Chi-square	**120.94**		**475.34**		**70.53**		**795.08**		**372.73**		**28.02**	

Note: Chi-square table value for 5 d.f. is 11.0705 for 5 % and 15.09 for 1 % level of significance

Obs=Observed values, Esti=Estimated values.

The expected distribution of number of cities by different city sizes for the census period from 1971-2011 for different regions of India is shown in the Table 16. To obtain the expected distribution of cities, we have used the above transition probability matrix from Table 9-15, and by using those matrices of each period we have multiplied by transition probability matrices of each census period by respective city size vector and by adding in and subtracting out the new added and declassified towns of that period, we have obtained the expected distribution of cities from 1971 to 2011 for all the regions of India. And we have calculated the Chi-square test to test the goodness of fit for all the five regions of India, the results show calculated chi square is greater than critical value (Chi-square critical value = 15.09 at 1% level of significance and 11.05 at 5% level of significance for 5 d.f.) except for class III in Northern, Southern, Eastern and Western region, for class VI in Eastern region and for class V in Western region, all others are significant. Hence chi-square test fits well to the data for all the six classes and for all the five regions of India except above stated regions.

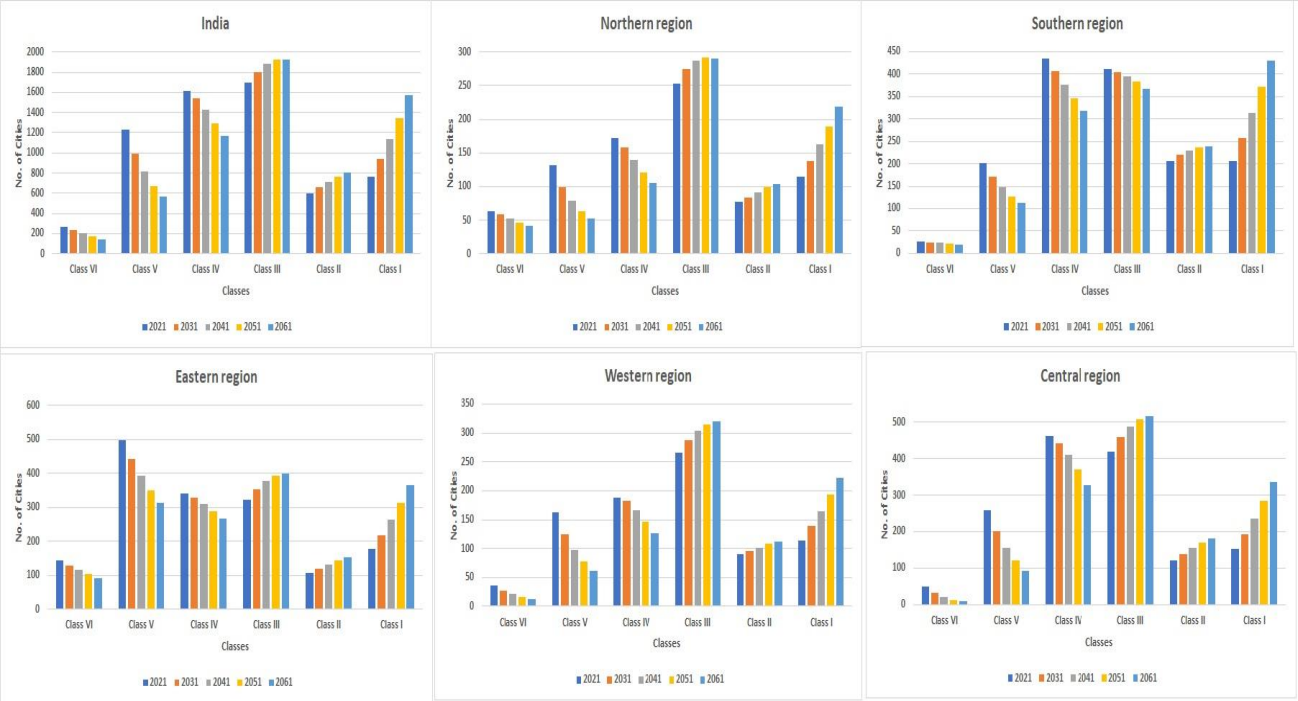
3.6. Projection of cities.

The projection of towns/cities from census 2021 to 2061 is obtained in Table 16 by using Chapman Kolmogorov equation. Multiplying the initial transition probability matrix of a particular census by number of cities of that census and resulting number of city vectors is again multiplying successively the initial transition probability matrix; the projected number of cities is obtained.

Table 16: Projection of cities for all the regions of India.

India						
Year	**Class IV**	**Class V**	**Class IV**	**Class III**	**Class II**	**Class I**
2021	269	1228	1614	1695	601	763
2031	234	991	1541	1803	658	943
2041	200	812	1427	1880	713	1137
2051	170	673	1297	1921	763	1346
2061	144	562	1165	1928	804	1567
Northern Region						
Year	**Class IV**	**Class V**	**Class IV**	**Class III**	**Class II**	**Class I**
2021	63	131	173	253	76	115
2031	58	99	158	274	84	137
2041	52	78	139	287	92	162
2051	46	64	121	292	99	190
2061	41	53	105	290	104	219
Southern Region						
Year	**Class IV**	**Class V**	**Class IV**	**Class III**	**Class II**	**Class I**
2021	26	201	434	412	206	205
2031	25	170	406	405	220	258
2041	23	147	377	395	230	314
2051	21	128	347	382	236	371
2061	19	112	318	367	239	430
Eastern Region						
Year	**Class IV**	**Class V**	**Class IV**	**Class III**	**Class II**	**Class I**
2021	144	497	341	323	106	177
2031	129	441	327	354	118	219
2041	116	393	309	377	131	264
2051	103	350	287	392	143	312
2061	93	313	265	399	153	365
Western Region						
Year	**Class IV**	**Class V**	**Class IV**	**Class III**	**Class II**	**Class I**
2021	35	162	188	266	91	114
2031	27	124	183	287	96	139
2041	21	97	167	304	102	165
2051	16	77	147	315	108	193
2061	13	62	127	319	113	222
Central Region						
Year	**Class IV**	**Class V**	**Class IV**	**Class III**	**Class II**	**Class I**
2021	51	257	462	419	122	153
2031	32	201	442	458	138	192
2041	20	156	409	488	154	236
2051	13	121	370	507	169	284
2061	8	93	328	517	181	336

Fig 2: Projected number of cities from 2021 to 2061 for India and for different regions of India.



The table presents projected counts of urban centres across class VI to class I cities (by population size) from 2021 to 2061 for India and 5 different regions: Northern, Southern, Eastern, Western, and Central regions. These projections highlight urban transition trends, i.e., how cities are expected to grow, shift between classes, or decline over time. Analysis reveals that, in all the five regions of India the class I, II, III are increased except in Class III of Northern, Southern, and Eastern region, they went on increasing from 2011 to 2041 but in the census 2051 the cities got decreased, and class IV, V, and VI cities got decreased for all the five regions of India and for all the census periods (see Table 16).

4. Conclusion

This study applies a Finite Markov Chain Model to analyze the growth and transition of city size classes across India's five regions from 1961 to 2011. The number of cities has doubled over six decades, with the Southern region seeing the highest number of newly incorporated towns during 1991–2001, largely due to government policies and administrative changes. In contrast, the Eastern region experienced the highest declassification during 1971–81, mainly due to natural disasters and population decline. Analysis of city transitions shows that lower size classes have lower retention rates, while Class I cities (population > 100,000) consistently retain their status across all regions and decades, with no backward transition observed. The Western region recorded the highest upward transitions, while counter-urbanization remains low (less than 5%) across all regions and classes. In all regions, Classes VI to II act as transient states, and Class I is a recurrent state, except in specific decades where all states became recurrent, indicating ergodic behaviour notably in Northern region (1971–81), Southern and Central regions (1991–2001) and Eastern region (2001–11)

The number of decades to reach equilibrium or attain complete absorption is observed for all the five regions of India. From this study we can say that during the census 1961-71 Southern and Eastern regions have shown least time to reach equilibrium state, 1971-81, 1981-91 and 2001-2011 Eastern region, during 1991-2001 Northern region takes least time to reach equilibrium state and for India 1981-91 census takes least time reach it. Whereas in 1961-71 and 1971-81 Northern

region takes highest time to reach all the cities to the equilibrium state and during 1981-91, 1991-2001 and 2001-2011 Western region takes highest time to reach all the cities to the equilibrium state as compared to other regions of India.

The average time taken to reach class IV to I, class V to I, class IV to I, class III to I and class II to I is studied, and there we can see that lower size classes takes more time to reach class I than upper size classes in all the regions of India and for all the decades. All the classes of Eastern regions take less time to reach Class I cities from 1961-71 to 1981-91, during 1991-2001 Northern region and 2001-2011 Central region takes less time. Northern regions take the highest time to reach class I during 1961-71, the Western region shows highest during 1971-81 for all the classes and from 1981-1991 to 2001-2011 Southern region, class IV, V, IV, III, II and I cities take highest time to reach class I.

The observed and expected number of towns from 2011 to 2051 show good fit by using the Chi-square test except for class III in Northern, Southern, Eastern and Western region, and for class VI in Eastern region and class V in Western region. Projection of cities shows that upper size classes i.e., class I, II, and III are increasing and the lower size classes i.e., class IV, V, and VI cities are decreasing as time passes except class III cities in Northern, Southern and Eastern region the number of cities got increased from 2011 to 2041, in 2051 the class III cities will get decreased. This shows that in future bigger size class cities namely Class I, million plus Cities, Metropolitan Cities and Megha Cities are increasing. Hence government of India, must give more budget to create sufficient infrastructural facilities in future. The research framework proposed and utilized in this study effectively captures the movement of cities and towns within a regional urban system. This framework provides a valuable tool for evaluating regional urban policies and their impact on the economic development of the region. By tracking changes in city and town sizes and transitions over time, it allows policymakers to assess how various policies contribute to balanced urban growth, infrastructure development, and regional economic stability.

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