Chapter 3
Recent Studies in Regional Urban Systems in India: Trends, Patterns and Implications

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Abstract An urban system is defined as a network of towns, cities and its hinterland characterized by exchange and interdependence. These cities and towns are arranged in a hierarchical settlement pattern within the development continuum in which people, goods, services and capital flow in the city system hierarchy. A national urban system comprises regional urban systems (RUSs) which is dominated by a large urban area. The Indian RUS can be delineated into four broad macro-regional urban systems: Delhi, Kolkata, Chennai, and Mumbai. Given this background this chapter addresses three questions: (1) What are the broad trends of RUSs research in India? (2) What insights have the various conceptual approaches provided to the understanding of Indian regional urbanization? (3) Is there a new approach that can manifest an alternative insight to Indian RUS? Four observations can be made: (1) Indian cities have grown rapidly followed by polarization reversal, (2) hierarchic studies have sparked an interest in regional service development planning utilizing location-allocation models (3) Indian urbanization is characterized by a lack of national primacy but the presence of state primacy and regional rank-size tendency, and (4) complexity approach is a novel approach to model macro-behavior such as city development or urban sprawl using micro-motives or local interaction such as land use changes.

Keywords Colonial space economy model • Hierarchic models • Indian urbanization • Non-hierarchic models • Regional urban systems • Urban development theories

3.1 Introduction

India has been urbanizing since the pre-independence period and rapidly increasing the share of urban population during the post-independence period (Fig. 3.1). India's urban population has increased from 62.4 million in 1951 to 286.1 million in 2001

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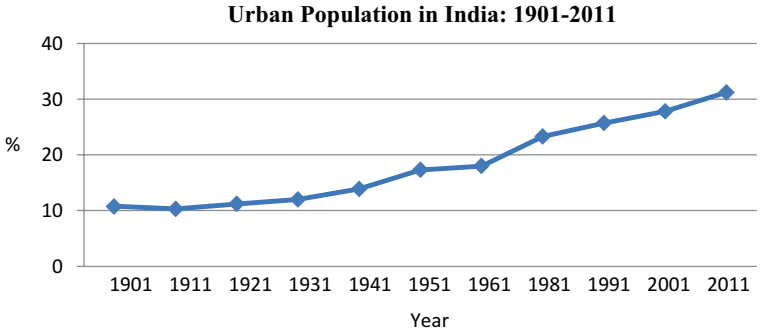

Fig. 3.1 Urban population in India: 1901–2011 (Source: Statistical Outline of India (2008–2009), Tata Services Limited, and Selected Socio Economic Statistics in India, 2011)

and further to 370.7 million in 2011 in absolute terms i.e. over a sixfold increase during the period. This leads to the question what pulls the labor force from rural to urban areas? It is argued that agglomeration economies, employment opportunities, better education, health services, and housing amenities attracts people from rural and relatively smaller urban areas to larger cities. The Indian economy since the adoption of the new economic policy (NEP) of 1991 has unleashed a vast potential of economic growth. This is expected to increase employment and location of tertiary sector activities in urban areas further fuelling rural–urban migration. An urban system consists of a network of towns, cities and its hinterlands. It constitutes a system since it depends upon the movement of goods, services, people, information, capital, and financial flows through the network of cities. The Indian space economy is a grid of urban system nested within macro regional urban systems (RUSs). Broadly speaking four RUSs can be delineated in India: Delhi, Mumbai, Kolkata and Chennai RUSs (Fig. 3.2).

3.1.1 Research Questions

Given this conception of a RUS the overarching question addressed in this chapter is why have some cities (Delhi, Mumbai, Chennai, and Bengaluru) experienced tremendous urban growth, while others (like Kolkata) have experienced urban decline during the past 60 years? Can analytical models identify a pattern of relationship between population size and ordering of cities? This paper is an attempt towards identifying the trends in research on Indian RUSs with scope for future research. A survey of urban systems research in the West documented various unifying themes that have been addressed during the past 60 years such as: 'interdependence', 'structure of spatial relationships', 'diversity and complexity of growth processes', and 'temporal paths of change', (Bourne 1980; Simmons and Bourne 1981). The Canadian Regional Science Association published a set of discussion papers on the 'Past, Present and Future' of Urban Systems Research (Coffey 1998).

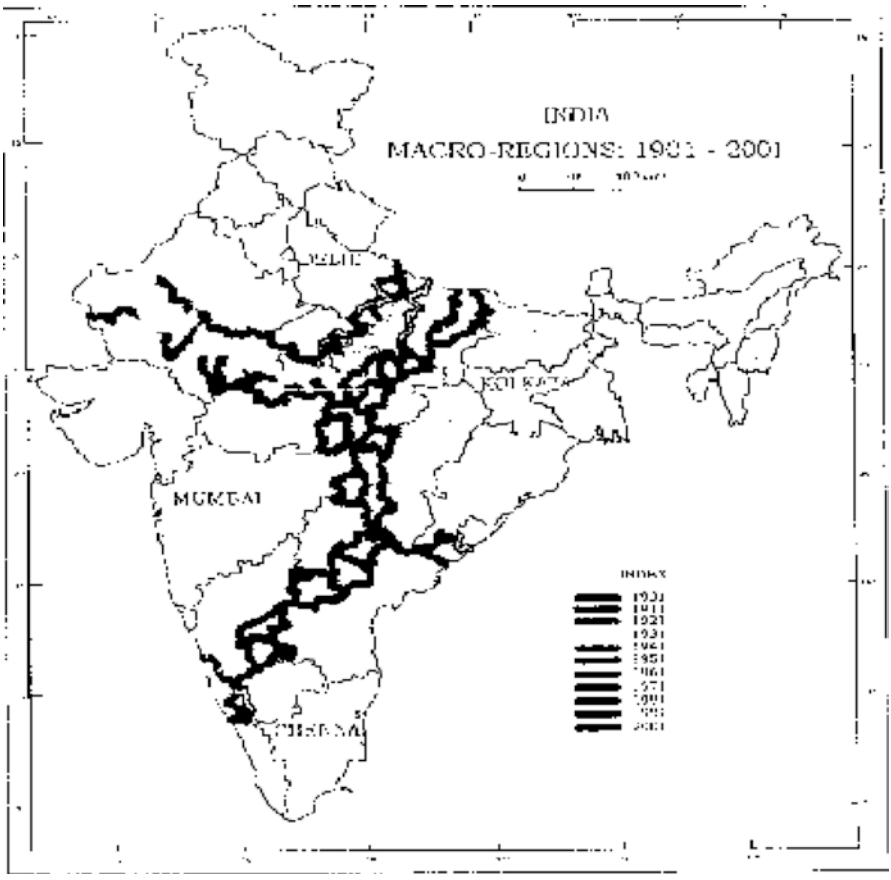

Fig. 3.2 Macro-regional urban systems in India (Source: Dahiya (2005))

In this discussion Bourne (1998) reckoned the marginalization of urban systems research due to 'analytical difficulty', 'lack of theoretical framework', 'lack of dialogue among government and planning bodies', and 'a failure to market ideas in a competitive marketplace for research'. Whitelaw (1983) reiterated the importance of urban systems research more so in times when regional agencies have dwindling resources. Also, Goddard (1977, 1978) placed importance on the role of technology and large corporations in shaping the urban and regional systems.

Several others have analyzed the Indian urban system. Ahmad (1965) argued that the Indian urban system is characterized by a hierarchical arrangement of cities. Indian cities are interdependent and interacting and have been the focal points of manufacturing, transportation function and administrative roles. Dahiya (2005) posited large-size of the Indian economy does not permit a primate city at the national level, but regional primacy exists within three of the four macro-regional urban systems (Delhi, Mumbai, Kolkata and Chennai). The eastern region is dominated by Kolkata; northern by Delhi, western by Mumbai and southern has no primate city as

Chennai is competed by Bengaluru. Further, Dahiya (2005) observed that national or regional primacy is inversely related with the level of economic development. Thakur and Parai's (1993) review of Indian urban geography emphasized the importance of studying structure, function and behavior of urban systems at both the regional and national scales.

With this overview this chapter addresses the following three research questions: (1) what are the broad trends of RUSs research in India? (2) What insights have the various theoretical and conceptual approaches to RUSs analysis provided to the understanding of Indian urbanization? (3) Is there a new theoretical approach that can manifest an alternative insight to Indian RUSs? To answer these questions, this chapter is divided into seven sections. The second and third sections deal with definition(s) of urban systems and overview of urbanization and urban systems in India. The fourth and fifth sections deal with hierarchic and non-hierarchic models and its application in India. The sixth part deals with a new approach called the complex systems approach to urban analysis followed by conclusion.

3.2 Urban System and Urban Hierarchy: Concept and Definitions

An urban system consists of a collection of innumerable *elements* (such as central places) such that each element directly or indirectly is interacting and interdependent with every other element in the system. The element occupies space and has *attributes* (such as population, business types, traffic counts, production, distribution, and exchange). A national urban system is characterized by exchange and interdependency among cities that produces a well-articulated and balanced urban system (Bourne and Simmons 1978). A system is characterized by *functional wholeness* which implies cities within an urban system are interrelated with other cities within a geographical boundary called s*ystem boundary*. The interrelationship between cities can be at a mid-point between two cities, or there could be uniform spacing within a system of cities. Cities outside an urban system are part of another urban system. Thus, the elements of an urban system are interconnected and articulated into a network via which goods, services, people, information and finance flow in the city system hierarchy (Thakur 1978). Thus, a city can be viewed as a 'system within the larger system of cities' (Berry 1964).

An urban system can be *organized or disorganized* (Thakur 1978). The entropy measure describes the tendency of a system organization and measures the randomness contained in an urban system. The larger the randomness, the greater the entropy and the higher the disorder the larger the disorganization contained in the system. The inverse of this process is reckoned as organization. The presence of a high degree of complexity in an urban system implies larger degree of organization in the system. The systems approach has been utilized to analyze, explain the structure characterizing the urban system at different geographical scales. The system analysis has its own language of inquiry. For instance, a system can be classified as

open and closed. A closed system is where there is no exchange of energy or matter across their boundaries. This implies interactions between various elements and the attributes of an urban system take place within the system boundary. An open system is where there is continuous flow of energy and matter across the system boundary. An example of an open system is where a city located in an urban system is interacting with a city located in another urban system via exchange of goods and services. Also, an urban system is characterized by *stability and instability* of its system. The notion of stability implies the continuance of structure in a temporal sense. Structure is defined as the location pattern of the various elements and attributes of a system as they exist at a given site and as they change over time. The perpetuation of structure does not negate change in time or space in a system. A stable system is where change occurs but it is recognizable. An instable system is characterized by growth and evolution. The state of the system changes through a sequence of unrepeated states and may attain a new preferred state (Thakur 1978).

Also, a system is characterized by *equilibrium*. The notion of equilibrium signifies a state in which a balance exists in the totality of interaction and interdependencies of the elements and attributes representing a system. A systems behavior is governed by the type of *feedback mechanisms*. Feedbacks are of two types: *positive and negative*. Positive feedback is defined as a state where the effect of a feedback loop is to magnify an initial disturbance to the system. In contrast, a negative feedback is where the effect of a feedback process is to minimize the impact of a disturbance to the system such that the output remains constant. Finally, a system has the characteristic of either being *static or dynamic*. The urban system evolves with time as growth occurs and new conditions sets in due to changes in the attributes of the urban system. An example could be improvement of transportation infrastructure, new routes, and land use changes would lead to economic transformation. A lack of any change in the attributes of the system will force the system to remain static. An analysis of such mechanisms allows for a deeper understanding of the organization of an urban system (Thakur 1978).

Implicit in this view is the notion of urban hierarchy. Hierarchy implies that various cities within a region are of different population sizes and varying economic power and thus cities could be ranked utilizing this ordering process (Kaplan et al. 2009). The development of modern transport infrastructure, communication technology, internet, and mobile phones has led to a stronger interaction among urban places. It is the quality of interrelatedness among urban centers that is important. The urban system changes constantly in response to external stimuli of the environment (Thakur 1978). This conception of an urban system provides an understanding of the long-term processes of urbanization at different geographical scales.

3.3 Urbanization and Urban Systems

Urban growth pattern can be analyzed as the space-time variations in percent of urban to total population in a region. Figure 3.3 shows Delhi and Chandigarh have urbanized rapidly. Haryana, Rajasthan, and Andhra Pradesh urbanized at

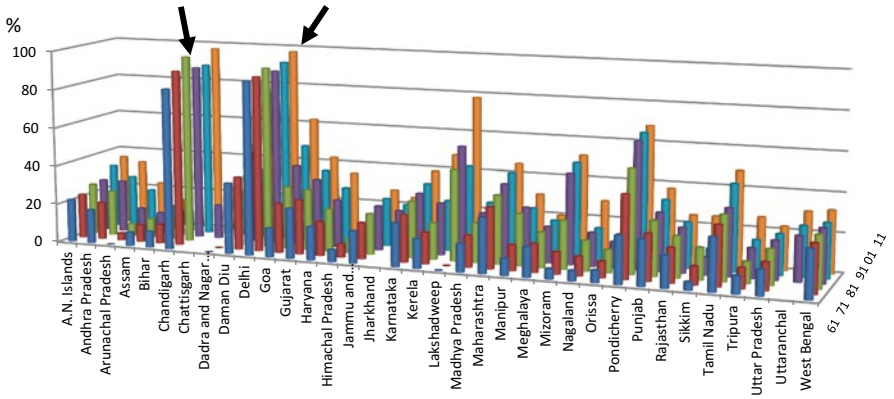

Fig. 3.3 Regional pattern of urbanization in India: 1961–2011 (Source: Selected Socio-Economic Statistics India 2008, 2011)

intermediate levels and the North Eastern states of Mizoram, Nagaland, Assam, Sikkim, Bihar and Himachal Pradesh in the East and Northern parts of India have undergone slow urbanization. This section addresses three themes: *urban development theories*, *colonial space economy model*, and *regional urban growth patterns* in the Indian context.

3.3.1 Urban Development Theories

The urban development process can be understood by exploring two selected theories. The first theory is referred to as *differentiated urbanization model (DUM)* (Geyer and Kontuly 1993). The DUM postulates large, intermediate-size, and small cities undergo successive periods of alternating fast and slow growth in a cycle of development. During this process of urban development a major proportion of population and economic activities cluster in a few dominant cities. Simultaneously, suburban nodes, the nuclei of a future multimodal city begin to develop rapidly with their advantageous locational attributes. Subsequently, the largest city becomes unsustainable due to agglomeration diseconomies leading to the growth of a metropolis. In sum, the large cities retain their urban dominance along with a group of intermediate-sized cities as part of a larger urban system (Pacione 2009). The DUM thesis has been applied in the Indian context (Mookherjee 2003; Mookherjee and Hoerauf 2004; Mookherjee and Geyer 2011). Using Indian Census data for 1971–2001 an overall dominance of large cities has been identified. Mookherjee and his colleagues further observed several states (Andhra Pradesh, Bihar, Gujarat, and Karnataka) showed a trend of growth in intermediate cities outstripping million plus cities suggesting a polarization reversal. These trends suggest that Indian urbanization has been characterized by large city growth (during 1961–1981) and

polarization reversal during 1981–1991. A concentrated urbanization of Delhi metropolis has been followed by polarization reversal to satellite towns (during 1971–2001) in the NCR due to regional dispersal of manufacturing, trading, and tertiary sector activities (Mookherjee and Geyer 2011). Lall and Thirtha (1971) echoed a similar observation that large cities grew disproportionately during 1931–1951 due to increased private and public investments in cities and, hence, satellite towns were necessary around major metropolises.

The second theory is called the '*stages of urban development model*' (SUDM) (Klaasen et al. 1981; Van Den Bergh et al. 1982). The SUDM postulates four stages of urban development in which the urban core and fringe grow at different rates and relative direction: 'urbanization', 'suburbanization', 'counter-urbanization', and 're-urbanization'. In the first stage settlements grow at the cost of fringe; during the second stage fringe grows at the cost of urban core; at the penultimate stage population loss in urban core is larger than the gain in the fringe; and, finally, in the last stage the urban core regains population and the fringe loses population (Pacione 2009). In the context of Indian urban–rural fringe development, a stage model has been proposed consisting of five stages: (a) rural stage, (b) stage of agricultural land use change, (c) the stage of occupational change, (d) the stage of urban land-use growth, and (e) the urban village stage (Ramachandran and Srivastava 1974). Dixit (2011) has recently examined the historic development of suburban areas for selected large cities in India and its urban expansion. This book explores the rural–urban dichotomy, facets of acceptable and unacceptable changes, and the overall impact of urban expansion on people's lives.

3.3.2 Colonial Space Economy Model

Late Moonis Raza and his colleagues articulated the *colonial space economy* model to understand the political economy of urbanization in India. His approach was to select urban development indicators, map it, and apply statistical tools to identify causal patterns. A dynamic model of India's colonial economy has been elaborated with a view to link dependent enclaves of the hinterland areas to the British metropolitan economy. This approach sheds significant light on the spatial analysis of urban and regional inequalities in India (Chattopadhyay and Raza 1975). The notion of urbanization and development are intertwined and interlinked. His approach opines that Indian urbanization has been characterized by 'urban atrophy', 'growth of satellite primates', 'deindustrialization' that has all led to tertiarization of the urban economy in India. These attributes are an outcome of a long drawn dominance-dependent relationship promoted during the colonial period (Raza et al. 1980c). This theme has been further explored by examining the fragmentation of the urban–rural continuum as a direct consequence of the historical hiatus between the twin processes of industrialization and urbanization; and between *vertical shifts and horizontal mobility* within the labor force in the development process. Their analysis revealed an agglomerated and dispersed pattern of regional industrialization in

India. The former is characteristic of capital-intensive and large-scale manufacturing and are concentrated in big cities, while the latter is relatively less capital-intensive and is spread across small towns and rural settlements. Further, both the patterns are considered to be partial and fragmented due to technological and spatial considerations. An agglomeration without dispersion pattern produces dysfunctional enclaves; and dispersion without agglomeration pattern leads to technological stagnation. The integration of the two patterns along a rural–urban continuum can generate a balanced urban and regional development. The development planning efforts in India have not been able to produce this outcome during the past 60 years (Raza and Kundu 1982).

3.3.3 Regional Urban Growth Patterns

The processes of urban growth in India, encapsulating the past and present trends are highly complex and varied. These trends are interplayed by socio-cultural, political administrative, economic, and geographical forces. Ramachandran's (1989) seminal book – *Urbanization and Urban System in India* has successfully established an inter-relationship between micro-level studies and macro-level generalization to the analysis of urbanization and structure of urban system. His substantive contribution is a creative work shedding light on the processes of urbanization and the nature of interdependence among urban centers, and between urban centers and their hinterlands.

Upon dividing India at three levels of urbanization: urban (more than 31 %), intermediate (17–31 %), and rural-based on the percent urban of the districts; this categorization reveals a north–south regional association of urban correlates (Dutt et al. 1989). The study demonstrates higher density of population and higher proportion of non-agricultural workers, female literacy, and sex-ratio associated with districts that are highly urbanized. In the northern region female literacy is a stronger indicator of urbanization than male literacy; and male household workers are strongly correlated with urbanization than female household workers. Concurrently, in the southern region male literacy is a better indicator of urbanization and household workers correlate strongly with intermediate districts. These relationships have been synthesized in a descriptive model of rural–urban continuum (Dutt et al. 1986) and its north–south variations for Indian sub-continent (Dutt et al. 1989).

The adoption of new economic policy (NEP) by policy-makers in India has encouraged higher private investment in cities especially in such areas as: automobile production, consumer electronics, computer software, information technology, chemicals, petrochemicals, and steel production. Such an investment pattern has led to the generation of new urban cores like: Ahmedabad-Pune urban corridor, southern urban triangle of Bengaluru-Chennai-Coimbatore, northern region centered upon Delhi, Rajasthan, and Punjab; and new hubs of growth in the south focusing on Hyderabad, Vishakhapatnam and Kochi. The remaining urban centers seem to have been neglected thus creating urban and regional disparities (Shaw

1999). In the past few decades Bengaluru has become an exemplar due to the agglomerative effect of information and communication technology (ICT) production and services and its effect on urban growth. Its growth has been driven by six factors: 'historical growth and cluster of electrical and electronics industries', 'the availability of highly skilled, communicative and low-cost technical manpower', 'the growth of external demand for ICT services', 'generous public policy incentives and concessions', and 'competitive advantage in both the business environment and investment climate' (Narayana 2011). This model of ICT driven urban growth can be emulated by other comparable urban economies in India to promote development in a global environment.

Several studies have investigated the theme of structural patterns of urbanization in India and its determinants. Chapman and Wanmali (1981) noted that Indian urban system is marked by a rural–urban dichotomy. Utilizing 1971 Census data they implemented a population potential surface analysis at the national and district levels. Their conclusion purports a lack of small-sized towns that can perform the integrative function between urban and rural regions. Further, they posited there are places of high urban growth that are push-created by outmigration from impoverished rural regions. In contrast, there are regions such as: Punjab, Haryana, Rajasthan, Tamil Nadu, Western Uttar Pradesh and South Bihar where urbanization is pull created due to dynamic urban expansion. In a similar paper Chapman (1983) identified a dichotomous growth pattern of urbanization between modern industrial centers and traditional centers based on trading activities. The former is associated with high rates of growth, organized industry, industrial specialization, and high employment rates. The latter is associated with balanced sex ratio, low growth rates, high levels of unemployment, high levels of literacy and a higher proportion of employment in trade and services. He utilized selected variables from the 1971 Census data (size, growth rate, and specialization) for mapping across space to identify regional patterns. The analysis suggested strong regionalization delineating India into two parts: (a) an emerging system of dynamic interdependent cities, and (b) areas of stagnation that are deficient in specialization. In an analogous paper Misra and Chapman (1991) examined the patterns of Indian urban growth in large cities utilizing 15 variables related to employment structure. An important conclusion is that forces affecting urbanization operate upon interlinked sets of cities. Thus, regional policies relying upon singular growth poles will be ineffective. Their analysis suggested the continuation of growth in larger centers of North and West India and stagnation in the Eastern region. Sridhar (2010) analyzed the determinants of city growth and output in India at the district and city levels. Her analysis suggests a higher proportion of manufacturing to service employment, proximity to large cities, and public services such as primary school coverage per population causes cities to be larger. The human capital as measured by literary rate has a significant impact upon city-level non-primary output per capita.

Sivaramakrishnan et al. (2005) identified four trends of spatial-temporal urbanization in India. First, during the 1950s the three metropolises – Kolkata, Mumbai, and Chennai maintained highest share of urban population and the same continues. Second, during the period 1950–1991 the level of urbanization in developed states

remained high although they experienced medium or low urban growth. In contrast, less developed states experienced high urban growth and low percentage of urban population. Further, the 1990s witnessed a significant departure in this trend as the developed states observed urban growth above the national average, and the less developed states experienced urban growth either below or equal to national average. Third, the class-size distribution of towns and cities has shown a change in pattern across space and time. The class I cities in developed states grew at a higher rate relative to less developed states prior to 1990. Also, in less developed states the smaller towns have grown at similar or rapid pace relative to class I cities. This pattern changed during the 1990s as many of the less developed states showed high urban growth among their class I cities. Fourth, the share of class II and III towns have shown stability in growth in most of the states as well as at the national level. Overall, the rapid growth of one million plus cities has increased to 53 during 2011 relative to 35 in 2001 (Census of India 2011). This tends to locate an overall suboptimality in investment planning since the widening gap between urban areas and lagging regions affect adversely the development of human capital resources and produce social tensions (Chakravarty 1989).

3.4 Hierarchic Models

There are two classes of theories that are significant in the study of RUSs and they are: hierarchic and non-hierarchic. The former comprises the Central Place Theory (CPT) pioneered by Christaller (1966); and the latter constitutes rank-size rule and primacy in the context of settlement system analysis. This section is an overview of the notion of hierarchy through the lens of CPT in the Indian context. CPT portrays a hierarchic structure of settlements in a macro-region. It presumes that metropolitan city at the apex with several settlements of various sizes in the hierarchy which it serves by providing goods and services of different values. The central place analysis is the theory of the inter-relationships among different settlements of varying size classes (Ramachandran 1989). CPT was popular amongst Indian geographers as a theoretical construct to evaluate urbanization patterns during the 1970s and 1980s (Thakur and Parai 1993). Several scholars have tested the notion of hierarchy of central places in India against the theoretical formulation of CPT in the search for central place systems (Mayfield 1967; Berry 1969; Dutt 1969; Wanmali 1970; Vishwanath 1972; Dutt and Banerjee 1970; Singh 1968). The concept of range of a good in CPT has been empirically investigated based on field study in the Indian Punjab. The question of travel behavior has been analyzed by taking into account 'price willingness', 'distance factor', and 'type, quantity, and price' of a good (Mayfield 1963). A similar study was conducted utilizing primary survey data to understand the mobility patterns and the consumer travel behavior of rural folks in Uttar Pradesh. Four factors were identified that explain consumer behavior: 'rural folks discriminate among central places in the purchase of consumer items', 'central places differ in the mix of purposes for which they are visited', 'endowed

population tend to skip lower order central places', and 'choice of central places are influenced by multiple purposes and price differentials' (Prakasa Rao and Ramachandran 1971).

An articulated analysis of the Kanpur region suggested a strategy of attaining a complete spatial system of urban centers arranged in a hierarchy from 'village' to 'market towns' and 'metropolis'. Christaller's administrative principle suggested growth impulses could be transmitted across Kanpur's urban system (Berry 1969). A pioneering analysis was delivered on the planning of social facilities for the Vidharba and Nagpur regions in Eastern Maharashtra utilizing Christaller's framework of analysis (Wanmali 1970). A common policy advocated by both Berry (1969) and Wanmali (1970), i.e. hinterlands in India need more market villages at closer proximity for transmitting economic stimulus to rural areas. An analysis of the relationship between urban centers and rural development has been investigated in the context of growth centers and growth points in the South East Resource region in India (Sen et al. 1975; and Ramachandran 1976). Later, an exceptional analysis was delivered by Wanmali (1970, 1983, and 1987) in providing insights into the application of central place concepts and the analysis of spatial and temporal nesting of service centers in India. Diddee (1988) provided an in-depth analysis of the micro-central place systems of the Pune region. A similar delineation of Siwan region provides substantive insight to the understanding of structure and perspective function of micro-regional central place systems developed in the periphery of Patna urban system (Thakur 1985). Thakur (1979, 1981) utilized entropy approach to analyze the settlement system in Eastern India comprising five macro-regions and North Eastern India. His study focused upon spacing of urban centers and a pattern analysis. His analysis concluded an increase in entropy during the 1872–1971 and 1901–1971 time periods. The analysis identified a center-periphery dichotomy in the evolution of urban patterns in Eastern India.

These studies have generated further interest in urban development especially from an urban planning perspective. The first interest is in the spatial organization, periodicity, and synchronization of markets and consumer preferences and perceptions in rural areas (Wanmali 1983, 1985) and a second theme is that of service development planning (Rushton 1984, 1988; Wanmali 1992). The theme of improved accessibility of amenities and service facilities in rural areas has been addressed taking Bellary district of Karnataka as an example. The analysis of Miryaguda taluk in Andhra Pradesh and Nagpur metropolitan region have concluded that spatial intervention in a region does improve the articulation of settlement system and improves access to services in rural areas (Wanmali 1987). Wanmali (1992) applied CPT in the analysis of infrastructure planning and distribution of goods and services in North Arcot, Tamil Nadu. His analysis suggested the investment in new fertilizer establishments in larger settlements so that smaller settlements could be adequately served. The urban functions in rural development and location-allocation approaches have been used extensively in the provision of health services, school location, and regional settlement planning (Rushton 1984, 1988; Tiwari 1992). However, in recent times Indian urban geographers have shifted their interests from CPT based analysis due to the stringent assumptions of the model and paucity of relevant data.

3.5 Non-hierarchic Models

A German geographer postulated that if settlements were arranged in order of size, the population sizes of some regions would be related (Auerbach 1913). Thus, the population of the nth city is 1/nth the size of the largest city's population. This inverse relationship between the population of a city and its rank within a set of cities is termed the *rank-size rule*. The population size is depicted on the y-axis and the rank on the x-axis of a two-dimensional graph. If the values on the axes are transformed to logarithmic scale, then the curve becomes a straight line. Zipf[1] (1949) presented a general theory of human behavior to explain the frequency distribution of different aspects of human behavior. In the context of cities he addressed two pertinent questions. Firstly, why are there small number of large cities and large number of small cities in a nation? And secondly, what is the relationship between population of cities and their ranks? Two opposing forces control the size and number of settlements in a region and these are: diversification and unification. The former produces a large number of settlements which are small in size, and the latter results in the emergence of a few large settlements. A balance between the two forces results in the regularity of settlement size and number. Further, Jefferson (1939) developed the theory of primate city which focused on the forces of agglomeration and its cumulative effect in the growth of large cities. These forces have a snowballing effect once the city attains a dominant position in a region. The largest city will overshadow all other cities in the region and may even retard its growth. Another empirical regularity observed by Gibrat (1931) states that the growth rate of city population does not depend upon the size of the city.

The slope of the rank-size equation has been postulated as the equilibrium slope of a general growth process (Simon 1955). Simon, an organization behavior theorist interpreted this growth process in which each city initially has a random size, and henceforth, grows exponentially that is proportional to the initial random size. He further reiterated that processes of this kind tend to produce distributions that approximate rank-size form. His analysis suggested that lognormal distribution is produced as a limiting case by stochastic growth processes based on the notion of general systems theory. Simon's (1955) approach introduced the element of time in urban development and rank-size models and the effect of a few powerful forces that produced distortions in the national urban system (Haggett 2001).

Berry (1961) evaluated Simon's hypothesis in urban terms. He analyzed the rank-size distributions of towns with population of 20,000 or more in 38 countries. The analysis identified 13 countries in the sample that showed rank-size distribution. Examples among them were: US (largest country), India (with a long history of urbanization), and South Africa (politically complex). Of the samples, 15 showed

[1] Zipf (1949) postulated the mathematical formulation between size and number of settlements. This relationship can be expressed as: $\left(P_r = P_{1/r^q}\right)$ where P_r is the population of the ranking city P_1 is the population of the 1st ranking city, r is the rank of the city and q is an exponent which can assume any value. Its value is assumed to be equivalent to 1 implying equality between the forces of diversification and unification. If the value of q is within 0–1 then the decline of population with rank is gradual. Further, if the value of q is larger than 1 there is rapid decline in size of settlements with its rank.

	Rank-Size	Primacy
Temporal	Temporal Rank-Size	Temporal Primacy
Spatial	Spatial Rank-Size	Spatial Primacy

Fig. 3.4 Spatial and temporal non-hierarchic models of urbanization

primate city distributions. His analysis identified three kinds of city-size distributions: lognormal, primate and intermediate. A lognormal distribution appears as a straight line on a double logarithmic graph. Primate city distributions show a distinct gap between the largest city and smaller cities and the intermediate shows the dominance of small cities. Berry's (1961) study proposed a testable hypothesis: increasing entropy is accompanied by a closer approximation of a city-size distribution to log-normality. Likewise, Curry (1964) asserted that rank-size distribution is the outcome of an entropy maximization process.

Fewer forces will affect the national urban structure if it is smaller than average, has a shorter history of urbanization, and has simpler economic and political structures. In a subsequent study Rosen and Resnick (1980) were the first to test for a possible deviation from the linear relationship postulated among the logarithms of the size of cities and it rank. The analysis tested negative for 36 of the 44 countries sample set using 1970 dataset. Their analysis showed that city-size and its rank approximates a parabolic curve that can be studied by adding a quadratic term to the Zipf's equation (Rosen and Resnick 1980). Further, Soo (2005) utilized data set for the period 1972–2001 and tested Zipf's law for 73 countries. Utilizing Rosen and Resnick's equation he found that 2/3rd of the countries in the sample had a quadratic term significantly high (convexity) or lower (concavity) than zero, while 1/3rd of the countries in the sample showed a quadratic term significantly in proximity to zero.

A temporal and spatial non-hierarchic model of urbanization can be conceptualized for a space economy (Fig. 3.4). It is possible that within different types and levels of space economy rank-size and primacy may or may not exist or overlap at different geographical scales. The existence, non-existence or overlapping of these models in an economy could provide similarities, differences in mechanisms that generates rank-size and primacy tendencies at various geographic scales. It can be conjectured that rank-size rule and primacy are relevant at the regional and state levels in India but not necessarily at the national level. However, India may be progressing towards national primacy in the long-run.

3.5.1 National Trends

Several studies have examined the Indian urban system using longitudinal (Raza and Habeeb 1988; Thakur 1979, 1981; Das and Dutt 1993; Sharma 2003), cross-sectional (Ahmad 1965; Alam 1980) and panel data (Dahiya 2005). Ahmad (1965) postulated that rank-size relationship holds good for the Indian cities with one-lakh

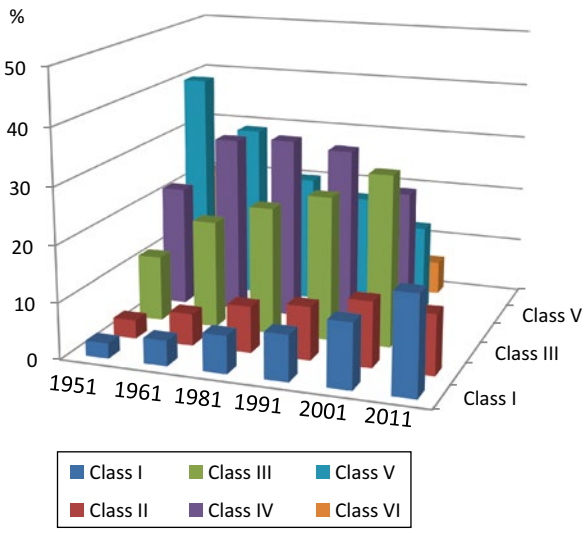

Fig. 3.5 Size distribution of towns and cities in India: 1951–2011 (Source: Statistical Outline of India 2008–2009)

(lakh is a measurement unit equivalent to one hundred thousand) population during 1951 and 1961. This interpretation has been criticized as all Class I cities according to the 1981 Census of India data have population much larger than estimated according to the rank-size rule. However, Das and Dutt (1993) have shown that during 1911–1981 the value of exponent (q) has been increasing with a slope value of 0.893 in 1981. This implies the force of diversification has been more influential than unification in defining the size and number of settlements. But that influence is diminishing since the magnitude of the slope term (q) increased during 1991 implying the number and growth of settlements are being determined by tertiary sector activities. It is expected that the magnitude of the slope term during 2011 and 2021 would even further accentuate. The tertiary sector activities happen to be market-oriented and have an agglomerative as opposed to dispersive effect (Ramachandran 1989). Further, Das and Dutt (1993) suggest the empirical city-size distribution in India at the national level is tending towards the rank-size rule as postulated by Zipf.

Also, Fig. 3.5 shows that the percentage of Class I cities have increased almost six times during 2011 relative to 1951 and has increased almost three times in 2011 relative to 1981. It also shows the preponderance of Class I, II and III cities during the period 1951–2001 and relative decline of Class IV, V and VI during the same period. An implication of such a pattern is the lack of a balanced development of settlements at the national level. This pattern is quite expected in a heterogeneous and diverse economy like India (Ramachandran 1989). The Indian urban system does not have a primate city at the national level. The absence of urban primacy is due to colonial rule, large-size of the nation and lack of the forces of nationalism in the country. During most of India's urban evolution Kolkata was the leading metropolis followed by Mumbai and Delhi. Delhi has been growing rapidly and it is expected in the next few decades to supersede Kolkata and Mumbai. The reason for

a lack of urban primacy in India is the political set up of the country. India has a partial federal political set up with the Center and State sharing power. This constitutional set up allows for the development of national and state level urban primate cities (Ramachandran 1989).

Indian urban geographers have investigated the structural aspects of Indian urban system utilizing flows, networks, graph theory, and system of cities approaches. However, researchers have been frustrated by the paucity of data required in utilizing these approaches. Nevertheless, several substantive works have been accomplished utilizing these methodologies. The Indian urban system is highly distorted being dominated by large cities leading to hypertrophy of metropolitan centers. This was a direct outcome of the colonial rule to concentrate investment, administrative and political functions in a few large urban centers such that raw materials could be siphoned off and shipped to Britain, while manufactured goods could be sold in the hinterland in India. This pattern of colonial capitalist development arrested the diffusion of technology, caused stagnation of the hinterland economy and prevented the articulation of a hierarchical system of settlement (Alam 1980, 1984; Alam and Reddy 1987). This trend has been an outcome of the weak linkages among urban centers and its hinterlands (Ramachandarn 1989).

Reed (1970) utilized inter-city airline flow data to reveal hierarchical structure of connectivity amongst cities and groups of cities in India. A dominant city is one which is held to mediate the flows of subordinate cities amongst themselves and between them and the rest of the urban system. He identified layers of connectivity amongst cities and a set of regional hierarchies. In the first tier the most dominant cities were located: Mumbai, Kolkata, Delhi, Chennai and Hyderabad in each of the four macro-regional urban systems. The importance of metropolitan centers has been analyzed utilizing the Indian railways based commodity flow data (Raza et al. 1980b). The organization of the Indian space economy and the consequent integration of the home market have been constrained by the inherited characteristics of an underdeveloped regional urban structure. The large metropolitan cities and its hinterland have been engaged in a dominant-dependent metropolis-satellite exchange relationship. The imbalances in the space economy have been generated by the distorted role of the metropolis and have been themselves sustained by these distortions. The weakness of the metropolis lies in the economic base, with a weak secondary sector and a bloated tertiary sector. This economic characteristic has made the metropolitan cities weak in the production system and has essentially made them centers of consumption albeit centers of production. The strength of this malaise shows signs of greater intensity as we drop down the urban system hierarchy. Further, analysis reveals that population size, share of manufacturing sector, and transport sector strongly influence the levels of spatial linkages (Raza et al. 1980a). Later, Raza and Aggarwal (1986) conducted a substantive study of the commodity flows in relation to the regional structure of the Indian economy. They used point to point flow data generating flow matrices to further enhance their colonial space economy model to the understanding of Indian regional structure and space economy.

Several urban economists have analyzed the rank-size and city growth theme in India. Schaffar and Dimou (2012) raised two pertinent questions: firstly, does city-size distribution follow Zipf's rule? And secondly, does Gibrat's law hold that is whether city growth depends on city-size? The analysis utilized dataset for 1981, 1991 and 2001. They made three generalizations. Firstly, Indian city-size distribution for million plus population follows a Pareto law. This finding contradicts with observations of other scholars who posit that city-size distribution is log-normal. Secondly, the Indian city-size distribution rejects Zipf's law as there is substantial dominance of small cities relative to a small presence of large cities. Gangopadhyay and Basu (2009) utilized Kolmogorov-Smirnov statistic to obtain an inverse conclusion, i.e. city-size distribution follows Zipf's law for a restricted sample with large cities. Thirdly, Gibrat's principle cannot be rejected, and urban hierarchies show a higher degree of stability revealing parallel growth patterns. Further, Sharma (2003) examined the Indian urban growth during the period 1901–1991. She rejected Gibrat's Law when studying the long-term effects of India's partition on urban hierarchies in relation to city-size, and in relation to city's relative growth. Her analysis suggests that there is persistence or stability in city growth. Any increase or decrease in the pace of population growth rate is a short-run phenomenon. During the long-run every city converges to its natural growth rate, i.e. to the overall population growth rate. Short-run fluctuations in population sizes are accounted due to exogenous shocks such as: influenza epidemic in the post-World War I period and the partition of India that led to influx of population in Indian cities.

3.5.2 Regional Trends

The rank-size rule focuses upon the regularity in city-size distributions, while the primate city construct emphasizes upon abnormally large city in a nation or region. Berry's (1966) study of commodity flows among India's trading block identified a set of four RUSs. The Indian RUSs envelops its largest metropolitan cities: Kolkata, Delhi, Mumbai, and Chennai to form a functional entity. The metropolitan areas constituted the principal manufacturing areas, through which import–export trading goods such as: agricultural, manufactured and other commodities were traded inter-regionally. This regional interaction allowed for the integration of the regions and integrated the regional economies into a national urban system. A similar study was delivered by Reed (1967) in his microanalysis of commodity flows in the Bengal-Bihar region. He concluded that commodity trades in the area were found to vary inversely with the distance shipped and directly with the demand and supply conditions in India. Both of these studies utilized flow data which is difficult to obtain and estimate. The former utilized regional input–output tables and the latter commodity shipments and receipts data for India.

Ramachandran's (1989) analysis of settlement systems provides insights to the state level trends of rank-size and primacy characteristics in India. During 1981, 13 of the 25 states in India had primate cities. West Bengal is an ideal example of state

level primacy where Kolkata is five times larger in population size relative to the second largest city Asansol. Chennai and Mumbai urban agglomerations dominate Tamil Nadu and Maharashtra states but relatively to a lesser extent. All three examples of state primacy are the outcome of colonial rule. However, during the post-independence period Indian policy-makers adopted structural reforms and NEP (1991) that led state capitals to assume importance in economic and political decision-making. Such a trend has manifested the generation of state primate cities. It is asserted that India does not have rank-size relationships at the national level but prevails in selected states such as: Rajasthan, Haryana and Uttar Pradesh. In the Indian context rank-size rule seems to be an exception though primate city characteristics are more commonly identified.

Das and Dutt (1993) examined the historical changes in city-size distribution in India. They argued that the Indian urban system is devoid of a primate city at the national level but regional systems are characterized by primacy. Further, Dahiya (2005) analyzed the spatial-temporal behavior of the rank-size rule and primacy for the four regional urban systems (Fig. 3.2). These RUSs have traversed through structural changes during the past century. Kolkata, Delhi and Mumbai in the Eastern, Northern, and Western RUSs have been the regional primate cities. Kolkata's regional primacy was at the apex in 1951. However, its primacy has been declining relative to the other three cities within the three RUSs. Chennai was never a primate city except during 1911. Mumbai during the period has shown considerable oscillations. Delhi's regional primacy has continuously increased during the past century except in 1941 when Kanpur became the second largest city in the Northern regional system.

3.5.3 Northern

In Northern India, Delhi had the lowest primacy index till 1951 as compared to Mumbai, Chennai and Kolkata regional macro-urban systems. It attained primacy status during 1971, and since then its primacy level has been increasing rapidly (Dahiya 2005). It is expected to exceed Kolkata primacy level by 2021. The most populous states of Uttar Pradesh, Punjab and Haryana have not shown any tendency towards primate city formation in the Northern region since its growth has been inhibited by its proximity to Delhi (Ramachandran 1989). The dominance of Delhi in the northern region can be explained due to the following five reasons: (1) it is the capital city with federal powers to make investment decisions, (2) Delhi has displayed rapid growth of industrial and information technology clusters, (3) Delhi houses the most important publication centers, (4) Most premier research and educational institutions are located in the capital city and (5) people have the perception that Delhi is a national city capable of becoming a national and regional primate city (Das and Dutt 1993). Likewise, Madhya Pradesh has grown rapidly but its capital city Bhopal has not shown a trend towards primate city growth. Further, Jain's (1982) rank-size rule analysis for Malwa plateau (Madhya Pradesh) during 1971

showed a lognormal distribution. It showed an ascending upper part and abruptly descending tail end leading to an S-shaped curve. His analysis showed Bhopal had 56 % excess population in relation to rank-size rule estimate.

3.5.4 Western

Mumbai is the largest urban agglomeration in the Western RUS. The primacy level of Mumbai was the highest during 1901, then decreased during 1911 and 1931, increased during 1961, 1971, and 1981 and further declined during 1991 and 2001 (Dahiya 2005). This checkered growth pattern is due to the presence of two million-plus cities competing with Mumbai and they are: Ahmadabad and Pune. The analysis of Class I cities during 1901–1971 in Maharashtra suggested varying degrees of instability in the urban growth process. The growth pattern of cities was turbulent in North Konkan and near Mumbai and was modest in the remote areas of southern and eastern Maharashtra. Greater Mumbai retained its apex position along with improvements in the ranks of Class I cities close to Mumbai such as: Nasik, Pune and Malegaon (Malshe 1982). Sita and Phadke (1982) recognized the positive relationship between accessibility and centrality in the growth of Mumbai metropolitan region. Further, Spodek (1981) identified dichotomous urban growth pattern, i.e. 'generative' and 'parasitic' in Saurashthra region. The former is associated with cities having favorable economic growth in the region and the latter with economic decline. The cities in Saurasthra have played a generative role as the bourgeoisie linked the agrarian sector with the urban–rural market economy.

3.5.5 Eastern

Kolkata is an example *par excellence* of a primate city in the eastern region. Its primacy index increased between 1901 and 1951, and has been declining since then (Dahiya 2005). Two reasons for Kolkata's eminence as a primate city were: (1) it was selected by the colonial power for administrative, military and business activities, and (2) other cities could not compete since Kolkata's hinterland (Western Odisha, Southern Bihar, and North East India) were located in a hilly terrain which discouraged high levels of urbanization (Das and Dutt 1993). A political-historic approach has been utilized to understand the distortions in the settlement system and the roots of colonial urbanization in India with reference to Hyderabad and Kolkata (Alam 1980; Raza and Habeeb 1988). The colonial power concentrated its investment in selected cities leading to hypertrophy and unbalanced growth among the primate city and its hinterland. Raza and Habeeb's (1988) analysis concluded that Kolkata's primacy during the early twentieth century distorted the settlement system hierarchy in relation to its catchment area. Further, it developed not as the node but at the cost of it. Such development was not an instrument of urbanization

but of urban atrophy. Two other states in the region – Bihar and Odisha could not promote primate cities due to its proximity to Kolkata (Ramachandran 1989).

Dayal and Thakur (1982) studied the settlement systems of Bihar plains and Chotanagpur plateau. They observed similar systems characteristics during 1872–1971 periods. A rank-size analysis indicated a trend toward regularity and orderliness in both systems. The Bihar plain was dominated by Patna and Jamshedpur-Ranchi has dominated the Chotanagpur plateau. The position of primacy has not changed in the former but the position of the largest city has changed in the latter region. Bihar is one of the most natural resource rich yet impoverished states in India. The appalling state of Bihar is an outcome of a long drawn process of colonial drain and acute under-urbanization. Saha's (1987) analysis of rank-size rule for Bihar during the period 1901–1981 observed the largest cities were located in the Gangetic Plains of North and Central Bihar, but this position showed a reversal, and by 1981, the largest cities were located in Southern plateau of Chotangpur region. The division of Bihar in 2000 into two separate states (Bihar and Jharkhand) has deprived of the mineral rich resources of southern Bihar and the fertile and natural resources of northern Bihar to the states of Bihar and Jharkhand respectively. This division will generate a distinct urban system trajectory in the two states over time. For the northeast region, Singh (1968) delivered a study of the urban settlement systems of Manipur region. Rank-size analysis reveals lack of regularity and continuum in the hierarchy of settlements. The urban system is focused around Imphal city and is characterized by a weak economic base that lacks spatial linkages with smaller towns.

3.5.6 Southern

The primacy index for Chennai was highest during 1911 and since then it has been declining through 2001 (Dahiya 2005). This can be broadly explained due to two reasons: (1) the hinterland of Chennai has a limited areal extent, and (2) the ascendency of Bengaluru due to the ICT-led development has inhibited Chennai's formation into a primate city. In an earlier study, Reddy (1969) identified weak rank-size regularity in the Krishna and Godavari deltas in Southern India. This implied lack of any evidence of log-normal distribution. Kumaran and Ramesh (1982) discerned an association between the size of towns and the extent to which they deviate from rank-size rule. Further, an analysis of the Rayalaseema region in Andhra Pradesh suggests the applicability of rank-size predictions during the period 1901–1971.

In sum, the decline of the regional level dominance of the three colonial cities (Mumbai, Chennai, and Kolkata) has been due to the ascendancy of a large number of new urban centers (Class I and II) in various parts of post-colonial India as centers of production, consumption and exchange. These cities have become centers of employment, private sector development, hubs of multinational corporations and information technology clusters. The colonial primate cities were built to serve the economic necessities of the colonial state to siphon off raw materials and industrial surplus and sell its manufactured products in the Indian hinterland.

3.6 Modeling Complex Urban Systems

Urban planners have often taken an isolated and a 'top down approach' to the planning of infrastructure, economic activities and social amenities in urban areas. Such an approach is ineffective and counterproductive leading to a loss of financial resources. The process of urban development can be exemplified using a 'bottom up approach', such that the aggregate level spatial pattern can be well understood and efforts made to generate an ideal urban structure. Cities can be treated as complex systems since the local interaction amongst objects can produce an ordered pattern in the aggregate such as large scale spatial clustering of different socioeconomic groups in various residential localities (Torrens 2000). A novel approach to understand the integrative, quantitative, science-based understanding of the dynamics, growth and organization of cities is called the complexity approach (Miller and Page 2007; Bettencourt and West 2010). Two types of models have been utilized to stimulate urban development: cellular-automata (CA) and agent-based models (ABM).

Cellular-Automata (CA) offers a framework for the exploration of complex adaptive systems. This approach contains five principal elements: a lattice, cells, neighborhood defined by the lattice, transition rules and a temporal component (Torrens 2000). It mainly utilizes cells and agents as interrelated elements in the process of simulating city formation. The cells represent the physical and spatial structure of the city, and the agents represent the human, social, agencies and actors involved in motivating development and growth in the city. The cells are fixed and agents are mobile. In the simplest CA model cells compare location of activities, in which change is generated by agents which influences the behavior of the nearest neighboring cells. The cells represent an attribute of urban environment such as land use, population density, and land cover to stimulate the phenomenon of urban sprawl. Such a behavior generates spatial regularity at a macro-scale that is initiated by the action of agents at the local level (Batty 2002). The formation of cities typically depends upon location and agglomeration effects. The former determines proximity and access to natural resources and hence value and prices. The latter attracts agents to cities that can have positive and negative feedbacks. Therefore, small events at the local level can generate large and unpredictable global outcomes giving rise to complex spatial structure. Thus, micro-motives can lead to macro-behavior such as city development (Miller and Page 2007). Further, AB models are a type of computational model for simulating the actions and interactions of agents in a system with the purview of assessing their effect on the system as a whole.

Bettencourt and West (2010) have proposed a 'scaling theory of city' in which cities are presumed to be an idealized networks of distribution that supply people, households and institutions with infrastructure and urban amenities and discard unwanted byproducts. Their work suggests that cities are scaled versions of each other implying Paris and Delhi to a surprisingly and predictable degree, are non-linearly scaled up version of London or Mumbai cities. Such similarities suggest commonness in mechanism, dynamics and structure in the formation and growth of

all cities. Further, they reckon population as a measure of city-size that does produce scaling relations for different urban attributes (Bettencourt et al. 2009). The CA and Markov Chain Models were applied to analyze land use and transportation infrastructure interaction in the Delhi metropolitan area; and discrete choice models were applied to predict local level changes. It was revealed that the central area is 'densifying' and outskirts are 'intensifying' in urban growth and land use changes. The analysis further suggests that Delhi metropolitan region faces larger expansion and intensification in terms of the use of its land area. The process of land use expansion would be significantly affected by such factors as: industrial, office, district centers, residential land uses, highway locations, population density, and road density (Srinivasan 2005). This approach has been utilized to generate planning outcomes for future urban development with the assumption of a ring road development in Mangalore city a fast urbanizing region in Karnataka. The case of urban sprawl dynamics has been studied and shown using cellular automata and agent-based models for spatial visualization of patterns of growth in relation to the drivers of urban growth (Sudhira 2004).

3.7 Conclusion and Future Directions

India has undergone rapid urban growth and regional urbanization since the post-independence period. Delhi and Chandigarh have urbanized rapidly; Haryana, Rajasthan and Andhra Pradesh urbanized at intermediate levels; and North Eastern States, Bihar, and Himachal Pradesh urbanized at the lowest levels. An urban system is defined as a set of cities, towns and its hinterlands as part of a network in which people, goods, services, information, and capital flow up and down the hierarchic arrangement of cities. The Indian urban system can be delineated into four broad macro-regional urban systems focused upon Delhi, Kolkata, Mumbai and Chennai the largest cities within the regional economies. A review of Indian RUSs with respect to four themes manifests revealing insights.

First, with respect to *urbanization and urban systems* analysis three sub-themes have been addressed: *urban growth theories*, *colonial space economy*, and *regional urban growth patterns*. The differentiated urban model (DUM) suggests that Indian cities have undergone rapid growth followed by polarization reversal. For example Delhi metropolis has experienced concentrated urbanization followed by polarization reversal towards the National Capital Region due to regional dispersal of manufacturing, trading and tertiary activities. Also, in response to stages of urban development a rural–urban fringe model has been proposed in the Indian context comprising of five stages: rural stage, stage of agricultural land use change, occupational change, urban land use growth, and urban village stage. Further, Raza articulated the colonial space economy model to shed light on the political economy of urbanization in India. He argued that India's urban economy is characterized by urban atrophy, growth of satellite primates, and deindustrialization. These attributes are an outcome of a long drawn dominant-dependent relationship between the

hinterland and metro pole during colonial rule. The adoption of NEP during early 1990s has encouraged higher private investment in cities in consumer durable goods. Such an investment pattern has led to the generation of new urban cores like: Ahmedabad-Pune, Bangalore-Chennai-Coimbatore, Delhi, Rajasthan, Punjab, Hyderabad, Kochi, and Vishakhapatnam.

Second, there are two classes of theories that are significant to the study of RUSs. These are hierarchic and non-hierarchic. The former comprises the CPT and the latter rank-size rule and primacy studies. The CPT portrays a hierarchic structure of settlement in a macro-region. It presumes that metropolitan city is at the apex and serves settlements of various smaller sizes in the hierarchy by providing goods and services of different order. The CPT analysis has generated two implications from a planning perspective. The first, interest is in spatial organization, periodicity, and synchronization of markets; and the second, interest is in improved accessibility of amenities and social facilities. However, paucity of flow data and stringent assumptions of CPT has led to the decline of interest in CPT-based analysis of urbanization in India. The rank-size rule focuses upon the regularity in city-size distributions, while the primate city construct emphasizes upon abnormally large city in a nation or region. In the Indian urban system, urban primacy is devoid at the national level but is tending towards it in the long-run. It is hypothesized that Delhi would attain the status of a national primate city by 2021 or 2031. At the subnational level two trends can be identified. At the regional level Delhi, Mumbai, Kolkata and Chennai have dominated the four macro-regional urban systems due to regional agriculture, manufacturing and trading activities. Likewise, at the state level Chennai, Mumbai and Kolkata show primacy tendencies due to colonial rule and adoption of NEP giving state capitals power and control in economic and political affairs.

Third, complex system is a novel approach to understand urban systems. It is based on the premise that local interaction among agents can generate ordered outcomes at the global levels such as the large scale spatial clustering of various socioeconomic classes by income, ethnicity, and education criteria. The complex systems approach has three potential applications in RUSs research: to explore spatial complexity, test inter-disciplinary theories, models and hypotheses, and apply it as an operational planning tool in urban management.

Several research directions for urban systems and urban complexity analysis can be made. First, with advancements in geographic information system it is possible to analyze large scale data in delineating system boundaries of the major macroregional urban systems in India. It is difficult to collate flow data yet several researchers have utilized airline data, commodity flows, telephone contacts, newspaper circulations to delineate urban system boundary. Additional variables such as financial, migration and internet or communication flows data can be utilized in conjunction with gravity and spatial interaction models to delimit urban systems boundary. Second, the historical system boundary should also be delimited for different periods such that the declining influence of Kolkata and increasing spheres of influence of Delhi and Bengaluru can be measured. Third, urban analysts should examine the structure, function and stability or instability of RUSs and identify the processes that explain stable, growth or decline of urban systems. Fourth, a spatial-

temporal analysis of periodic markets and regional service development planning using location-allocation models can improve accessibility and optimum location of facilities. Fifth, identify the processes of ICT led-growth in Bengaluru such that it can be emulated in cities of similar levels of urban development. Finally, a focus on micro-level analysis such that it can generate macro-level generalization of urban processes utilizing modeling and theory-building framework.

Further, there are six directions in which future work on urban analysis can be undertaken utilizing complexity approach. Firstly, CA models can be put to serve three purposes: First, it can be used by both academicians and planners as an approach to understand regional urbanization in a theoretical sense and develop operational plans for combating burgeoning urban problems such as: congestion, crime, urban sprawl, and segregation. This tool can be further utilized in the exploration of urban phenomenon such as: traffic simulation, regional scale urbanization, land use sprawl dynamics, polycentricism, and historic dimensions of urban development. Secondly, models can be utilized to explore theories and hypotheses originating in cognate disciplines such as: urban economics, urban sociology, urban planning and urban management to push the frontiers of interdisciplinary knowledge. Thirdly, CA models can be used to construct hybrid models of urban growth. In this framework the best elements of a top down and bottom-up approach can be collated to generate an operational optimum urban growth model. The top down approach can use aggregate models from regional science techniques such as: regional input–output, spatial interaction, spatial optimization and demographic and forecasting techniques with given zonal constraints. These constraints can be imposed upon a bottom-up type CA or ABM models. This would link the parsimonious aggregate level constraints with the finer details at the local level through theoretically informed dynamic engines to generate a hybrid model. Fourthly, there is a need to link modeling with theory building in the context of emerging markets and developing economies taking into account the dual economy assumptions of development. Lastly, there is opportunity for incorporating and implementing concepts such as: path dependence, bifurcation, and phase transitions in complexity analysis in the CA framework for urban systems studies.

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