Chapter 7
Smart Chandigarh Tri-City Region: Spatial Strategies of Transformation

Asfa Siddiqui, K. K. Kakkar, Suvankar Halder and Pramod Kumar

Abstract The inception of the "*City Beautiful*" dates back in the early 1950s, right after India attained independence. The planned visionary modernist settlement designed by famous architect Le Corbusier started gaining a 'magnet' status. The regional phenomenon observed around Chandigarh gave way to the establishment of counter magnets Panchkula and Mohali, together referred to as "*Tri-city*". Soon, the green buffer zones around the city got into urbanisation processes and started showing signs of uncoordinated growth. The demographic profile suggested a slowing pace of growth in Chandigarh Union Territory (UT) while other settlements in the Chandigarh region (the 16 km periphery Control Area) kept expanding. A need for regional development was felt in 1970s resulting in various regional plans severely lacking legal status and hence had no prominent effect. A region can attain a planned development through careful understanding in incorporating sub-regional objectives through *Smart Information, Smart Decision-making, Smart Connections* and ultimately leading to *Smart Development*. Smart tools and techniques offered by the geospatial technology can play a pivotal role in analysing the existing scenarios of an urban purlieu and aid significantly in the decision making process for better development. The study asseses the spatial growth of Chandigarh region using Neural Network based modelling growth scenarios and suggests that nearly 400 sq. km. of area will be urbanised by 2048. The study effectively demonstrates the importance of geospatial techniques and recommends spatial strategies in order to have a holistic development in the region.

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Smart strategies incorporating inclusive planning can for transform settlements into Smart Metropolitan Regions.

Keywords Smart city · Tri-city · Geospatial technology · Chandigarh region

7.1 Introduction

After India attained Independence in 1947, a new capital for undivided Punjab was approved in March, 1948 called Chandigarh-'The City Beautiful'. With a vision of modernist thinking conceived by Pandit Jawahar Lal Nehru, the then Prime Minister of India, a 70 sq. km. space was earmarked between rivulets Sukhna Choe (in the east) and Patiala-ki-Rao Choe (in the west) for developing Chandigarh by Dr. M.S. Randhawa, the then Deputy Commissioner of Ambala. The Master Plan of the Chandigarh city was designed by the famous and renowned Architect- Le Corbusier and was assisted by Pierre Jeanneret, Jane B Drew and Maxwell Fry. In 1966, after the reorganization of the state of Punjab, Chandigarh was announced the capital of Punjab and Haryana, bearing an area of approx. 114 sq. km. (70 sq. km. urban area with 44 sq. km. covering an area of 26 adjoining villages). Le Corbusier designed the iconic city with a vision of 'modernism' and thus translated his geometric modular thought into reality. The work is still considered an iconic piece of work shaped through deep thinking explicitly demonstrating freedom, wisdom and perseverance. It is one of the live examples of a symbiotic relationship between the built and the un-built. The foundation stone of the beautiful city was laid in 1952.

Earlier in Punjab, Chandigarh was declared a Union Territory directly under the Central Government after reorganization of Punjab state on November 1, 1966 into three states, namely Punjab, Haryana and Himachal Pradesh. The first planned city of India, Chandigarh, and a Union Territory (UT) is the hub of political and bureaucratic activities of adjoining states. Its existence as a planned capital designed with a view of urban containment theory, as a result of Garden city concept, makes it a design to cherish and emulate. Although, the city was conceived to have a regulated planned growth, unfortunately the subsequent peripheral growth (areas like SAS Nagar, Zirakpur, Panchkula, etc.) suggests that this vision of the designers was not fulfilled. Some defend sprawl as an inescapable phenomenon, while others advocate its essentiality in preserving the character of the city core, the reality can be understood as the details of the Chandigarh and its environs are studied in detail.

The need of understanding the intra-city growth and the inter-city growth in the outskirts (called the Periphery) like Mohali in Punjab and Panchkula in Haryana (regarded as satellite towns) becomes inevitable in order to understand the regional dynamics of the area. There may be certain drivers of growth that also need to be studied. It is pertinent to mention that Chandigarh faces a legal framework restricting a regional plan that can be adhered to while designing the city. The laws guiding the development scenario is studied in detail in this chapter. This study attempts to understand the sprawl in time line from 1990 onwards with the help of remote sensing, GIS and online information available and ends in providing

recommendations and strategies for Smart Growth leading to a Smart Metropolitan Regional Development.

7.2 The Shaping of Chandigarh: The Inception Phase

The land designated at the foothills of the Himalayas was selected for developing the 'dream' city of Pandit Nehru's vision. His notions of having a futuristic city catering to the need of tomorrow, bounded by a gambit of organized planning was to be achieved by a collaborative Indian and team of European architects and planners. While the location of the site was a constraint, first site specific Master Plan was prepared by the American lead planner Albert Mayer and Mathew Nowicki. Although, not much credit has been given to Albert Mayer for his rigorous efforts and hard work in bringing out the neighbourhood block, curvilinear fan shaped plan in merely six months' time from the approval of the city to be constructed. The fan shaped module was inspired by the Garden City concept (proposed by Ebenezer Howard in 1902) keeping enough circulation space and green belts. Emphasis in Mayer's plan was laid on placing the neighbourhood block in the centre [1]. The rest was built upwards from it. Mayer's aim was to build a simplistic urban centre possible [2]. The planner duo were replaced later due to administrative hitches and other unforeseen circumstances. The big project fell into the laps of the then lead, Le Corbusier (see Fig. 7.1).

In light of understanding the significance of self-contained neighbourhoods and essence of green spaces in an urban setting, Chandigarh was planned with focus on preservation of the unbuilt, urban design principles and aesthetic appeal. Urban containment theory was inherent in Garden City concept proposed by Ebenezer Howard adopted by the planners of Chandigarh.

The design of Chandigarh was more inspired from the original fan-shaped design proposed by Mayer. The improvisations in the plan restricting a grid-iron movement approach and phasing of city functionalities resembling intrinsic body parts into work, living and leisure, were worth admiring. The city was decided to be built in two phases consisting of Sectors 1–30 in phase 1 efficient to accommodate 1.5 lakh people and a rather dense development accommodating 3.5 lakh people in sectors 31–47 making it a total of 5 lakh people.

It was a vision of Le-Corbusier where his emphasis not only dwelled on the urban core development but also on the rural-urban transitional zones in the fringes. His work clearly depicts his passion for preserving agricultural activities and open spaces for a serene site like Chandigarh amidst Shivaliks. The perfect assimilation of town and country was addressed through the design keeping in view the problems faced by an urban setting due to urban sprawl. This decentralized solution was also helpful in driving planned growth and at the same time posed limitations on the ad hoc growth pattern resulting due to poor management of land resources and Indian way of organic city development. According to Howard, green and open

Fig. 7.1 Chandigarh and its sectors. *Source* Chandigarh Master Plan-2031

spaces around the cities paves way for a rationalistic self-contained developments scenario where the satellite towns shall grow and help cores to grow economically and socially, subsequently. But as is said, land is a resource and it is scarce, greenbelts were gradually sacrificed in to the process of urbanization.

7.3 Chandigarh: Planning of the City

The planning of Chandigarh does not follow the typical planning principles and is seen as a departure from conventional planning approaches in Indian framework [3]. With aspirations of Nehru in looking forward overlooking the past, modernism in planning and architecture found its way in the so called 'Nehru era' soon after Independence. The idea was to build modern but connecting with the character inherent in an Indian city. Had it been draping an Indian city into western town planning, the job would have been easier. The intermingled localism approach suffering the architect's design need the vision of parties/government involved in the project was a challenging task [4, 5]. Prior to the development of cities like Chandigarh and Bhubaneswar [6], the town planning principles were followed by

trained Architects and city planners, mostly abroad. We heavily relied on the west and their expertise in this subject. But later in 1930s, emphasis was laid on training young minds in this direction. It was also observed that India was fascinated by the idea to 'modernise' but lacked indigenous professionals who could delve into city planning and design without guidance and help. It was also noticed that city planning was more seen as a piecemeal approach to parts of the city and lacked holistic approach [5].

After partition in 1947, the capital of Punjab was given to West Pakistan (now called Pakistan) and there was a dual need to accommodate refugee resultant of partition and to have an administrative and political capital for the state of Punjab [1]. Bureaucrats A.L. Hether and P.L. Verma were the first to examine the need for a new city and later together with P.N. Thapar, member of Indian Civil Service and Administrative Head of the Capital Project in 1949, guided the development of the city [4, 5].

Le Corbusier made important amendments on the plan developed by Albert Mayer and Mathew Nowicki on the 8500 acres of fertile land site [1]. Le Corbusier built the city cantering monumental government buildings [7]. Le Corbusier was an Architect who utilised his experience from the America and translated them in India in the form of hierarchical roads (V1–V7), roundabouts and big self-sustained sectors which he regarded as 'essential function' of his plan [5, 8]. His grid-iron pattern (replacing the curved streets in Mayer's plan) also revealed Le-Corbusier's imposing and dominant personality. He incorporated philosophies picked from Ebenezer Howard called Garden City concept introduced in 1898 (followed in planning of cities like Radburn) and changed it to principles based on CIAM (Congress Internationaux d'Architecture Modern) [1, 5, 6, 9–11]. The Architect invested in picking concepts like posting network of green spaces in the urban core functioning as 'lungs of the city' as per the CIAM principles [12].

Chandigarh, around 240 km North of New Delhi was planned on a mildly sloping terrain amidst Himalayan Shivalik range foothills. Standing currently at 30° 50′ N and 76° 48′ E longitude and 304.8–365.76 m (above sea level) altitude, is the legendary example of a planned city. Pandit Jawahar Lal Nehru mentioned the city in a way "Let this be a new town, symbolic of freedom of India unfettered by the traditions of the past…an expression of nation's faith in the future".

Symbolic to human body, the planned city had a head (the Sector 1 Capitol Complex), the heart (Sector 17 City Centre), the Lungs (the open spaces), the intellect (institutions), the circulatory system (the hierarchy of roads, the 7 V's) and "*the viscera"* (Industrial Area). The city caters to four main functions: ***living, working, leisure and circulation.*** Capitol Complex houses three architectural marvels-Secretariat, high Court and Legislative Assembly. Large piazzas separate the three monument/buildings, where the symbol of Chandigarh-The open hand (demonstrating the philosophy of open to give, open to receive) stands upright. Enough circulation space, green spaces within the sectors, roundabouts, market places, shopping complex, gives a holistic look to the city. Out of the 20,000 acres (80.93 sq. km.) required for Chandigarh in the first phase, 2000 acres (8.09 sq. km.) was meant for recreation spaces. In a grid of horizontal (northwest/southwest) and

vertical (northeast/southwest) roads, the city depicted a decorum of circulation and movement. The entire logic behind the designing of the city Chandigarh was to ensure a sustainable neighbourhood, hierarchy of circulation pattern and ample amount of breathing space in the form of green/open spaces.

Initially, the city had Phase 1 and Phase II due to various constraints, administratively and financially. Phase I comprised of 30 sectors which were developed with keeping an agenda of low density spread over 9000 acres (Sectors 1–30). The sectors were capable of accommodating 1.5 lakh population. The Phase-II consisted of 17 sectors having relatively higher density (Sectors 31–47) capable of accommodating 3.5 lakh population in 6000 acres of unbuilt land. The sector was the smallest unit bearing a population varying between 3000 and 20,000 persons. The circulation within the city was forecasted to be planned in a way that it is able to cater to the motorised vehicular requirement of the future. Emphasis was laid on systematically designing wide enough roads for easy movement so that the city escapes from the burden of higher traffic volume and does not lead to congestion in the future [13].

Apart from the inner city planning regulations, certain architectural controls were also imposed on the city. To preserve the natural environment and to prevent deterioration of the cityscape, it was made inadvertent to ensure a dignified living for all classes and proceed with sustainability in one of the top agendas to cater. The vernacular touch to the architectural built-ups including local building materials, fenestrations, shading mechanism, pilotis, courtyards, louvers and brick jalis were just made in conjunction with the micro-climatic conditions. The stability as evident in stringent planning of the grid-iron city can also be seen in wise utilization of the local materials and using them for sustainable built forms. The high rise complexes were avoided in the city's planning, as a result of a written contract between P.L. Thapar and Le Corbusier, the cityscape witnesses a low skyline [13].

7.4 Acts for Chandigarh's Development: Legal Framework

While we turn the leaves of historical documents, the growth pace of the urban areas was negligible enough to have foreseen the scenario where Le-Corbusier's spirit of a greenbelt can be defeated.

a. **Punjab New Capital (Periphery) Control Act of 1952**: Going back to history and remembering notes on the effectiveness of having a green belt around the main city core, a fringe area termed as 'Periphery' was introduced. This philosophy was adopted in various states in the United States and the United Kingdom. Same philosophy reflects in the designing of Letchworth and Welwyn. The Periphery Zone consorted to having a large chunk of agrarian land, 8 km (5 miles) around the urban core. The greenbelt was legally restricted to have any developments under the Punjab New Capital (Periphery) Control

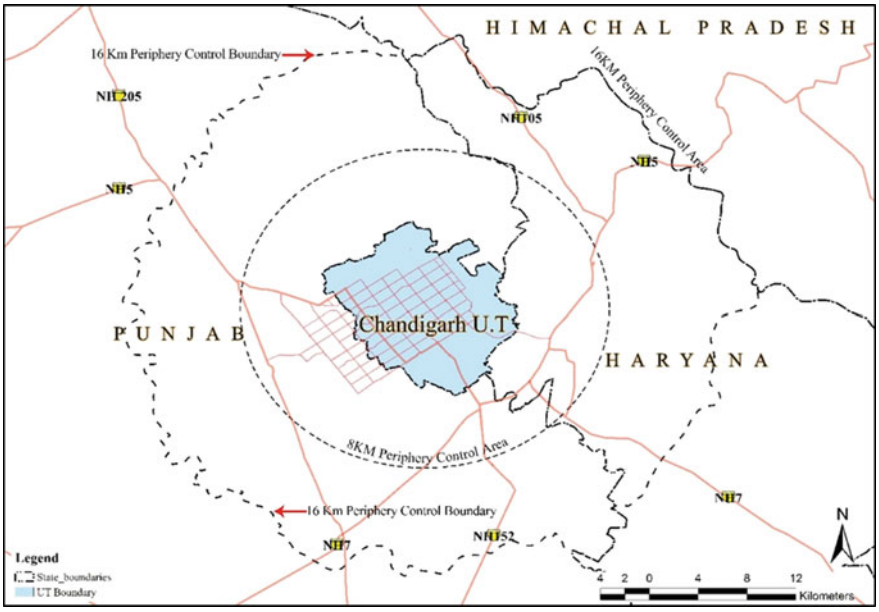

Fig. 7.2 8 and 16 km Punjab New capital (periphery) control boundary. *Source* Author and Chandigarh Master Plan Report-2031

Act of 1952 (see Fig. 7.2) [14]. The essence of 8 km buffer space can only be realized if we understand the basics of regional planning and the laws governing the same. The need of the Act is the resultant of concerns raised due to development in and around the city in a planned manner.

b. **Revised Punjab New Capital (Periphery) Control Act of 1962**: Punjab New Capital (Periphery) Control Act of 1952 was revised in 1962 suggesting a 16 km (10 miles) buffer as a result of establishment of an Army Cantonment, coming up of an Air Force and new township (see Fig. 7.2). However, in 1966 when Punjab was reorganized as Punjab and Haryana State, out of the total peripheral area called Periphery Control Area 1315 sq. km., 1021 sq. km. went to Punjab and 295 sq. km. went to Haryana and 114 sq. km. was reserved for capital city Union Territory (UT) Zone.

The Punjab New capital (Periphery) Control Area (5 mile or 8 km periphery) was a zone of fertile land comprising agricultural lands of the Indo Gangetic plans and forests of the Shivaliks. This periphery called "controlled area" had development restrictions beyond the urban context. This area consists of small agricultural settlements, villages like Manimajra (east of Chandigarh urban) and Kansal (north of Chandigarh urban) and Naya gaon (north of Chandigarh urban). The Act preserved the chances of development potential in the land for future development/expansion (indicated by Lal Dora) for residential activities. The 8 km periphery was falling under Punjab's jurisdiction (Ambala District) [12, 15]. It was clear that

development rights were reserved with the state's government as per the public acquisition clauses for **"*public purpose*"** [16]. The Govt. of Punjab justified the clauses by ensuring "*future extension of the capital*" *according* to a healthy and coordinated development and saving it from sprawl [12].

The prime concern behind demarcating the "Control Area" called "Periphery" was:

(a) Conserving the rural area comprising of village settlements and fertile agricultural land.
(b) To refrain from unplanned development outside the urban core.
(c) To discourage sprawl and development of suburbs.
(d) To preserve land prices in the urban core.
(e) To adhere to concepts proposed for Garden city.
(f) To maintain the importance of the built—Le Corbusier's built creation.

Le Corbusier's confidence in this dream creation, away from haphazard development (called sprawl evident in the cities of UK and UK) made him develop Chandigarh. His linkage with the city and the country made him propose the ideal situation, difficult to be maintained in the authoritative land of Punjab and Haryana [5, 17]. Le Corbusier was fascinated by the agricultural area and said that the "rural site must remain intact" [5, 17]. He wished to conserve the rural way of living where the urban areas could be dependent on rural for various agricultural produce and poultry requirements. He conceived that the rural periphery be maintained without any much infrastructure development possibility. Hence, for his dream, the sets of urban amenities were stitched into the preexisting rural fabric through minor or "light roads" restricting too much development. This harmonious-rural-urban agenda for an Indian scenario was more of a camouflage concept unaware of the Indian social way of living and the organic pattern of growth that it has witnessed in the past.

7.5 Growing Chandigarh: Development of Squatter

The Periphery Control Act of 1952 could not control the development in and around Chandigarh in an unplanned manner. The development took place in many phases.

The Le-Corbusier plan is considered to have overlooked the social fabric of the country and the essence of the economic strata was deeply neglected. The planning of Chandigarh catered to the need of all the sections of Indian society. It did not have housing provisions for many other non-governmental workers. Indian cities are hugely dependent on sweepers, maids, rickshaw pullers and drivers. The land allocated for this section was too costly and hence was beyond affordable limits for the daily wagers with limited income source. The city accommodated temporary shelters for this section, at the same time, areas in the adjoining villages within the periphery were urbanised due to the needs of the informal sector and slums.

The need was enhanced due to the in-migration the city witnessed due to the construction activities that was flourishing during 1955 and later years. The vernacular architecture approach in utilising the skill and material availability locally, made Pierre Jeanneret built nearly 50 styles of housing overall including housing, service buildings, schools, health centres, etc. [5]. The sectors were planned for setting a new style of urban living in the country, the needs of migrants made them settle in the periphery. Moreover, it was observed that Chandigarh's housing plan was restricted to public servants and had no consideration for floating population. Temporary migrants involved in construction activities were considered to leave once the task allotted was completed. But, the economic viability and Chandigarh's development (in phases) made way for their permanent settlement in the periphery abutting the urban area [5, 18].

In earlier designs developed by the principle, architects, sector 22 was earmarked for the lowest-level government workers. In one of the literature by Annapurna Shaw it is mentioned that "*Like all other sectors, it is fairly self-contained and crossed north-south by a land of greenery and east-west by a bazaar or Commercial Street lived with shops. The green area contains the educational and recreational features of daily life and lies within walking distance of the houses. The houses looked inward toward the green and away from the perimeter road that carries faster moving traffic. The sector is fed by a figure-eight slow road that connects all the housing areas. Some of the groups of houses possess their own internal green space. The cheapest housing provided two rooms, a veranda, kitchen courtyard and water supplied sanitation and washing facilities. Many devices were used to provide modern innovations, maximise space and still provide protection from hot sun*" [5].

When the need in 1959 was felt, then less developed sector like 15, 9, 20 & 24 accommodated low cost houses for low income worker known as 'labour colonies'. Ownership was transferred on nominal payment basis. However, as the other temporary sites were developed during 1950's and 60's, labour colony residents were moved to the periphery. Few households found place in resettlement colonies while others were accommodated in "transit camps" near the Periphery around existing villages. The initial settlements (called unauthorized settlements) were located near the capital complex abutting construction sites. Later in mid-1970's allotment of serviced plots with one room tenants were designated on the land acquired in villages surrounding master plan area. As per a survey by Estate office in 2006, mostly unauthorised settlements are located near the southern and eastern edge of the Union territory. At present there are 18 unauthorised settlements and 23,974 households. The unauthorised slums as per Chandigarh Master Plan-2031 [14] are:

(1) Kalyan Colony
(2) Kumhar Colony
(3) Shahpur Colony
(4) Rajiv Colony
(5) Guru Sagar Colony

(6) L.B.S Colony
(7) Nehru Colony
(8) Pandit Colony
(9) Kuldip Colony
(10) Mazdoor Colony
(11) Colony no.5 Labour
(12) Ambedkar Colony
(13) Kabari Colony
(14) Sanjay Colony
(15) Labour Colony
(16) S.B.S Colony
(17) Madrasi Colony
(18) Janta Colony

Within the lal dora boundary, currently unauthorised colonies bear a population of approx. 70,000 persons occupying 20,911 units in 2006 as per Census 2011 [19], the population residing in slums was 94,950 persons.

7.6 Chandigarh: The Demographic Profile

The earliest Master Plan prepared by Le Corbusier suggest phase-wise development. Phase 1, 2 & 3. Initially planned for 5 lakhs population in Phase-I, 36 sq. km. of land was acquired by the administration of the city for construction of 30 sectors. In the second phase, land was acquired for 3.5 lakhs population (Table 7.1).

The development in the third phase was not planned initially, but has now started in certain sectors beyond sector 47. The statistics of the population reveal that between 1951 and 1961, the decadal growth rate was 394.13%. The high growth rate was due to post independent time of housing requirement. Between 1951 and 1971, the population growth rate was 114.59%, one of the highest within any urban area at that time period. Subsequently, as the holding capacity of the two phase development ceased, the growth rate started declining from 75.55% between 1971 and 1981 to 40.28% during 1991–2001 (see Fig. 7.3). The current population within Chandigarh Union Territory as per census 2011 is 10.54 lakh [20], way beyond the actual carrying capacity limit estimated by Le Corbusier and team. It was during 1981 and 1991, the growth of the population rose beyond the estimated

Table 7.1 Composition of growth in Chandigarh UT

Composition of growth	1981–1991	% of total	1991–2001	% of total
Natural increase	63,505	1.41	86,110	1.34
In-migration	126,900	2.81	172,510	2.69
Total increase	190,405	4.22	258,620	4.03

Source Chandigarh Master Plan report–2031

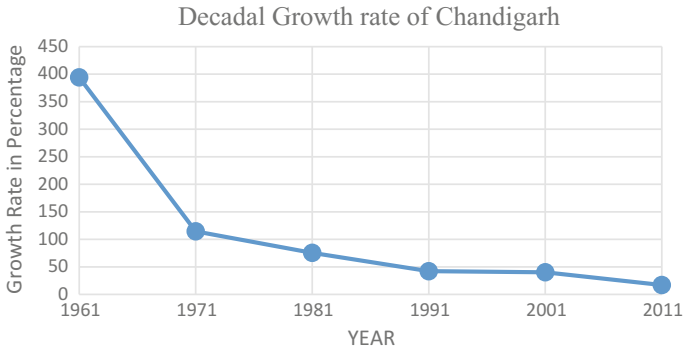

Fig. 7.3 Decadal growth rate of Chandigarh (1961–2011). *Source* District Handbook Census of India, 1951–2011

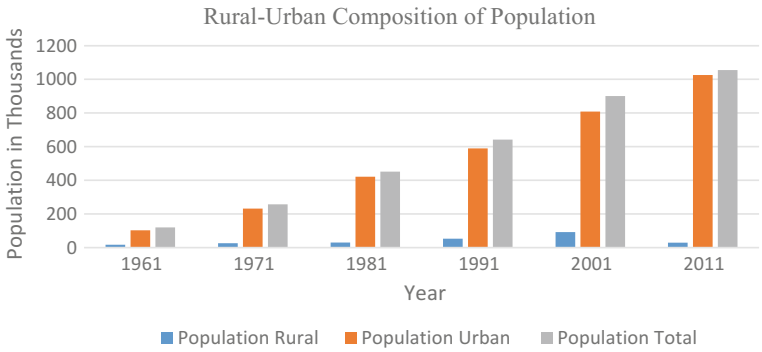

Fig. 7.4 Rural-Urban composition of Chandigarh UT. *Source* District Handbook Census of India, 1951–2011

5 lakh population limit for Chandigarh. It is also noteworthy that, as per the census 2011, 97.25% (10.25 lakh) of its population was urban and only 2.75% (29,004) was rural as compared to 82.80% urban and 17.20% rural in the year 1961 (see Fig. 7.4) [20].

The growth rate of the Chandigarh if observed and projected for the future, proposes an increase to 19.5 lakh (if the current rate of growth is considered)—almost four time to which it was originally built. It can also be observed the rural composition has declined over the period. This can be attributed to the fact that Chandigarh UT (Chandigarh and Manimajra settlement) has witnessed the need of outmigration. Also, the fact that the population residing in rural are resettled in the rehabilitation colonies falling under the gambit of urban area [14].

Another important issue while understanding the demographic dynamics of the city is to understand the population density pattern. The density of population

has witnessed a nine fold increase from 1051 person per sq. km. to 2257 person per sq. km.. Subsequent decades also saw increase in the population density with 3961 person per sq. km. in 1981 to 5632 person per sq. km. in 1991, 7900 person per sq. km. in 2001 to 9252 person per sq. km. in 2011, recently. The population and population density increase from 1961 to 2011 shows the requirement of the settlement within Chandigarh UT or to develop counter magnets around the UT so as to absorb the pressure of in-migration. In the context of planning, it is a well-known phenomenon, wherever cities do not expand horizontally due to constraint of the land or the natural barrier like in the case of Chandigarh, where land for UT is limited and abutted by lake and Shivalik ranges, it either tends to grow vertically with minor FAR modifications (under governance agenda) or the nearby settlement start developing and result in conurbations. Once the city planned for having a density of 16 persons per acre has grown to 26 person per acre in phase I and from design density of the 59 person per acre in phase II to 60 person per acre in 2001 [14]. The population worked on the basis of holding capacity, the density of phase II and 100 person/acre (highest density) for phase III sectors. It is also observed that sector in each phase have varying density of population. As per Chandigarh Master Plan-2031 [14], the sector III is expected to accommodate the rising need of population and settlement in the form of group housing and large scale rehabilitation of unauthorised settlements in these sectors. Population projection made by census through various methods for Chandigarh reveal that the population may remain between 14 and 33.5 lakhs approximately in 2031 (Refer Table 7.2)

It is inadvertent to understand that the land resource within the Chandigarh UT is limited and is exploited at high pace. In order to preserve the image of city Chandigarh as an administrative city, the influx of the population in the form of in-migration should be avoided to a greater extent. Moreover, since the land resource is limited within the UT boundary, the uses pertaining to administration sector and the governance related centres shall get priority during the allocation of available land. Any additional population beyond the holding capacity of the city

Table 7.2 Sector-wise density pattern of Chandigarh

Phase	Planned density (persons/acre)	Density as per census 2001 (persons/acre)	Density as per holding capacity (persons/acre)	Area planned (in acres)	Planned population
I—(Sector 1–30)	16	26	34 (33.37%)	9398.83	1.5 lakhs
II—(Sector 31–47)	59	60	83 (18.31%)	5158.76	3.5 lakhs
III—(Sector 48–56, 61, 63)	~	Under process of development	100 (6.64%)	1870.54	~

Source Chandigarh Master Plan report–2031

i.e. 15.5 lakhs, need to be diverted to settlements adjoining the city, keeping in the view of the regional context of planning.

About 60 acre of land was acquired by the Chandigarh administration in 1989 for building more dwelling units called modern housing complex and understanding the need of housing due to population increase. Chandigarh UT houses 201,878 total households as per 2001 and 235,061 households in 2011 [21, 22].

7.7 Chandigarh: Land Uses/Land Cover

The existing land use of Chandigarh comprises of planned developments of Phase-I & II and the proposed subsequent development of the phase-III (the extended sector grid). Predominantly, in Phase-I & II, 39 out of 46 sectors are Residential, while the remaining are governed by Institutional and commercial land use. Some section of the light industrial and Sukhna lake also fall under the same category. (Refer Fig. 7.5 and Table 7.3)

Out of the total development area i.e. 16427.73 acres, 9398.83 acres (nearly 33.37% of the UT area) is developed under Phase-I. The area Under Phase-II is 5158.76 acres (nearly 18.31% of UT area). Phase-III has designated 1870.54 acres of land (nearly 6.64% of UT area) for development purpose. Out of total 28,170 acres, 41.68% falls within the remaining periphery area within UT category.

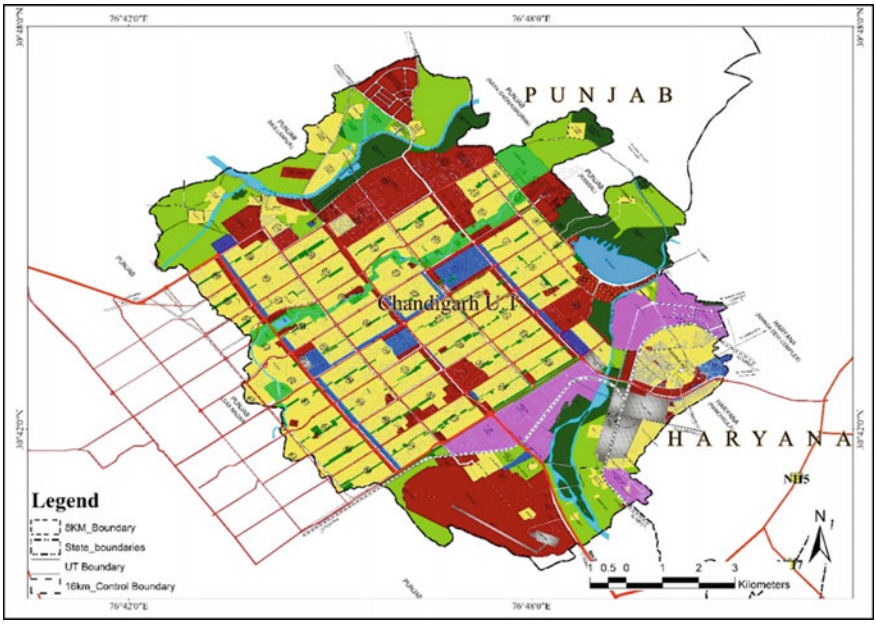

Fig. 7.5 Chandigarh existing land-use map 2008. *Source* Chandigarh Master Plan Report-2031

Table 7.3 Chandigarh existing and proposed land-use distribution—2008

Chandigarh UT land use	Existing area (ha)	Percentage (%)	Proposed Area (ha)	Percentage (%)
Residential	4319	37.9	4398	38.6
Commercial	542	4.8	599	5.3
Transportation	828	7.3	849	7.4
Indus/IT Park	537	4.7	652	5.7
Pub./Semi-Public	1201	10.5	1386	12.2
Recreational	983	8.6	1141	10
Agricultural	0	0	272	2.4
Public Utilities	122	1.1	138	1.2
Railway Land	128	1.1	128	1.1
Defence	637	5.6	637	5.6
Forest	855	7.5	1038	9.1
Reserved	0	0	125	1.1
Vacant land	1248	10.9	46	0.4
Total	11,400	100	11,400	100

Source Chandigarh Master Plan report–2031

Phase-III has the lowest area possible (1/4th of the Master Plan Area). The peripheral area within the Chandigarh UT boundary comprises of village abadis (population), agriculture land and unplanned need based development (accounting to 11741.88 acres) (Refer Fig. 7.6).

7.7.1 Phase-I, II & III

Largest proportion of land within the residential area is allocated to residential (42.69%) in Phase-I. In Phase-II, the residential component is the highest i.e. 67.08% of the total area. Residential area within Phase-III also occupies nearly 3/4th of the total area.

7.7.2 UT Periphery

Large chunk of land in the periphery have been acquired for accommodating new land use. The road networks were accordingly enhanced for catering to the need of development. 1/6th of the area has been allotted for residential use. This area caters 4.5% industrial area or industries. Total area under forest and agriculture covers 21.67% within the periphery. Le Corbusier also envisioned Chandigarh as a radio-concentric urban area surrounded by agriculture land. He thought that the city should not experience the dirt of industrial establishment. According to him,

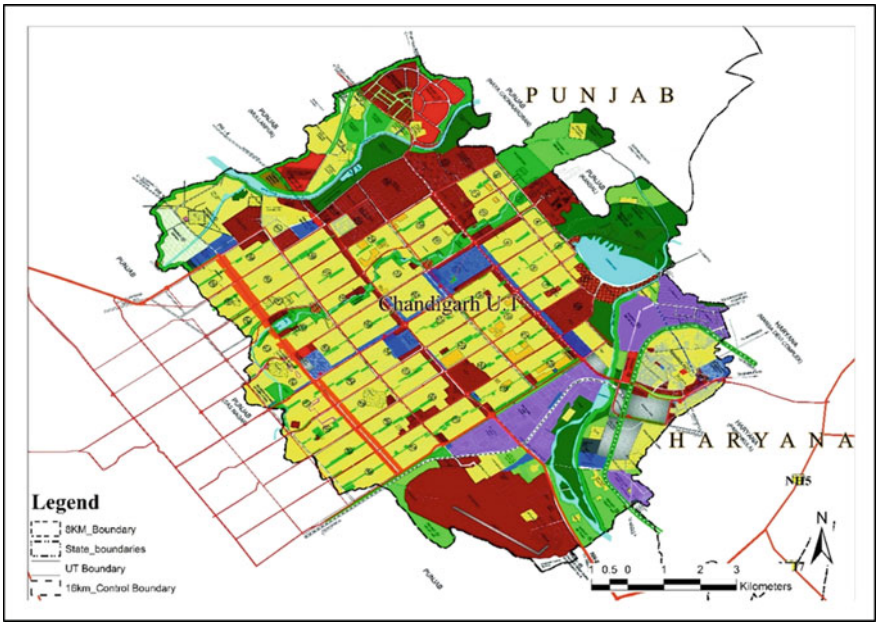

Fig. 7.6 Chandigarh proposed land-use map 2031. *Source* Chandigarh Master Plan Report-2031.

Chandigarh had to be developed as an administrative city. He writes that "Chandigarh is an administration-city and in consequence is a 'RADIAL-CONCENTRIC' city. It has never to become 'industrial-city". Regardless of his aspirations of an industrial free administrative centre, under administrative and official pressure, Le Corbusier reserved 580 acres at the south-eastern edges of the urban core for industrial setup. Out of 580 acre, initially for Phase-I, 338 acres were made available for development [12]. Today, the total industrial area within the UT has risen to 1326.50 acres, almost thrice the allocated land during the 1960s.

7.7.3 Development Within the 16 Km Periphery Control Area

Although, no development was initially planned for periphery, but as per the requirement and need of national defence by the government, Chandigarh's location prompted its choice for the government defence settlement. In spite of Le Corbusier's vehement opposition to all proposed military projects on the periphery, the Cantonment (called Chandigarh Cantonment, headquarter of western command of Indian Army) was proposed near lake Sukhna and capitol complex. Apart from Cantonment, Air force Station and township of state-owned Hindustan Machine Tools (HMT) as also planned. All the project called 'Special project' were

identified in the 'Periphery Control Plan of Chandigarh' after 1962. It was in 1962 that 5 miles (8 km) radius boundary was extended to 16 km radius boundary [23]. It was later after Le-Corbusier's death in 1965, the Army Cantonment was built which was otherwise a non-appreciated construction requirement as per the principle Architect & Planner, Le Corbusier and his team. Today, the Chandigarh cantonment is serving as an economic base to Chandigarh. It is spread across 385 acres and contain all essential establishments like family quarters, stadium, hospitals, schools etc. The terminal Ballistve Research Laboratory also sprawls within the periphery.

Subsequently, in 1966, the state Punjab was further divided into the state of Haryana and Punjab based language speaking capability. After two decades of partition between India and Pakistan, this partition left Chandigarh serving as the capital to both the state. This proved the threefold richer administrative position of Chandigarh. With the creation of the Union Territory of Chandigarh having 70 sq. km. as the city and a very meagre part of the Periphery i.e. 44 sq. km. as a part it. The remaining 1021 sq. km. of the Periphery Control Area went to Punjab (75%) and 295 sq. km. (22%) fell into Haryana's jurisdiction. The sanctity of the Periphery Control Act was maintained but also paved ways for complex decision making related to development scenario [24]. An unwanted but natural competition now existed pertaining to the development of the two states of Punjab and Haryana, covering the majority of the Periphery Area of the UT of Chandigarh.

7.7.4 Establishment of Mohali and Panchkula

Mohali, also called Sahibzada Ajit Singh Nagar (SAS Nagar) was conceived in late 1966. The site of Mohali, immediate south of Chandigarh was a home to Harappa's around 8000 years ago. In 1967, around the existing Mohali Village was conceived to be developed as an industrial hub. On 1st November 1975, foundation stone for Mohali was laid. The land allocated for Mohali, industrial Estate was 5500 acres in Punjab. The sectorial grid of Mohali which were known as Phases here, few sectors fall under Chandigarh and Mohali both, like sector 48, 51, 52, 54 and 56 onwards. The development of Mohali was a landmark event in the history of development potential into an industrial area in Punjab. Impressed by the Chandigarh's grid-iron design, not much emphasis was laid on the designing of sectors and the extension in contiguity was picked up.

Simultaneously, plans for Panchkula in Haryana were approved in 1970, 4 km east of Chandigarh bearing 500 acre land. The Mohali made a contiguous development leaving no buffer and following same design, Panchkula maintained a slight buffer of 4 km and used a fan shaped grid plan. It seems, plan of Panchkula was inspired by the original plan of Chandigarh proposed by Albert Mayer. As a matter

of fact, Chandigarh was more set built as a residential area, Panchkula and Mohali both were setup as industrial establishment in their urban development strategy.

It is notable to mention, that despite 'No Construction' in the Periphery, the two major counter-magnets, Panchkula in Haryana and Mohali in Punjab came up to accommodate population influx. It is also observed that the growth of the city of Chandigarh was slower as expected by the planner. This involved the need of satellite town for attracting the population to Panchkula and Mohali in search of jobs.

Meanwhile in Chandigarh, the village of the Manimajra, south-east of Sukhna lake and after the Phase-I industrial establishment, was given the urban status. Immediate construction with apartments and malls are passed. Unlike the actual agenda, Information Technology (IT) Parks like Rajiv Gandhi Chandigarh Technological Park (was developed south of Lake Sukhna) in 123 acres transforming agriculture land into the IT setup. Desires to setup IT industries due to demand and additional 272 acre of land was acquired for the same. Chandigarh was never meant to delve into competitive endeavours relating to IT sector and SEZ (Special Economic Zone).

Now, the tri-city—Chandigarh–Mohali–Panchkula can be seen to developing with visions of development within the periphery paving ways for a regional development with each passing decade. Contradictory to the agriculture based periphery the 16 km periphery control area has seen even more small settlements behaving as counter magnat to the tri-city. All attempts of planned development are compromised and the regional development plans hold no legal status in proving its eminence.

7.8 Regional Planning Initiatives

Township in the periphery, now emerged due to the pressures of development and resulted in regulated and unregulated growth. In 1975, a coordination committee was set up chaired by the Secretary, Ministry of Urban Development, GoI and chief secretaries of the state of Punjab and Haryana with chief commissioner of UT Chandigarh to resolve the matters related to development scenario in and around the UT without compromising the original intent of the original Chandigarh master plan. However, the development of Panchkula and Mohali in close proximity abutting the UT boundary within the 16 km Periphery Control Area had already compromised the original sanctioned and approved plan. It was only in 1977, a Regional Plan for Chandigarh known as **Chandigarh Urban Complex (CUC)** was delineated as the immediate region covering an area of 330 sq. km. (see Fig. 7.7). It consisted of the Chandigarh UT, part of Mohali with adjoining 27 villages and parts of Panchkula with 23 villages. The CUC covered the region only within the 8 km (5 mile) periphery region. It was felt that region conceptualised is too small and may need revision later.

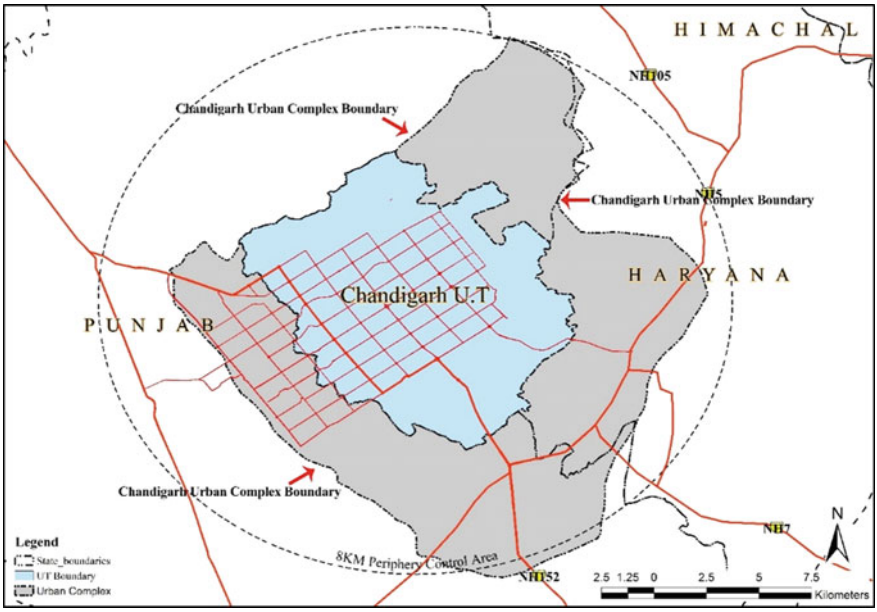

Fig. 7.7 Chandigarh Urban Complex (CUC) Boundary. *Source* Author and Chandigarh Master Plan Report-2031

Within the CUC plan, north of the capitol complex was declared as '*No development Zone*'. In 1984, the CUC plan was reviewed and need for a regional plan was felt. Therefore, an 'Interstate Regional Plan for Chandigarh region' [25] was prepared in 2001 by Town and Country Planning Office for 25 lakh population distributed in 7 categories of settlements (see Fig. 7.8). This plan was also known as the structure plan. This plan was an outcome of the forth coordination committee meeting held on 22nd May 1997. The committee figured a need to give statutory shape to the regional plan. It was also decided to follow up the preparation of Regional Plan by the respective state/UT Chandigarh and areas around it considering Ambala district (Haryana), Solan district (Himachal Pradesh) and Rupnagar and Patiala district (Punjab) covering an area of 2421 sq. km., averaging to a radius of 35 km from the core of Chandigarh city.

ISCR-2001: The ISCR-2001 plan (Refer Fig. 7.8) was a comprehended document indicating the delineation criteria for the region catering to the administrative boundaries already existing within the identified area. It laid emphasis on the Regional Development policy control and made recommendation for strategies Regional Development. The ISCR was more of a policy-cum-advisory document focusing on integrated, coordinated and wholesome development for the region. The plan had its own policy agendas to cater to following reasons:

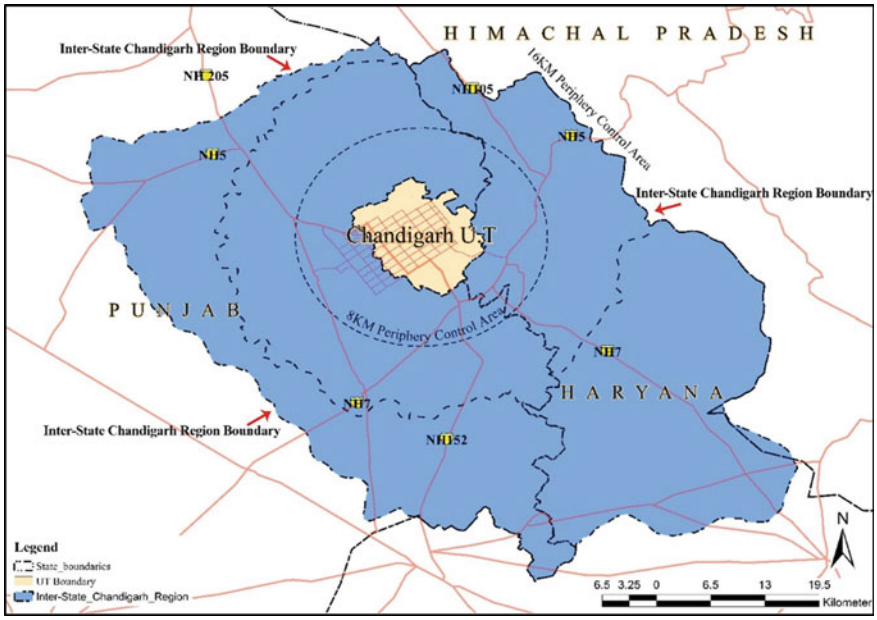

Fig. 7.8 Inter-State Regional Boundary for Chandigarh-2001. *Source* Author and 'Concept note on Chandigarh and its region', 2011

(a) Hierarchy of settlement: First order to Seventh order
(b) Development of rural areas
(c) Providing housing
(d) Promoting trade and commerce
(e) Development of Industries
(f) Conservation of environment and ecology
(g) De-centralisation of Government (quasi and semi-govt.) offices from Chandigarh.

The hierarchy of settlement identified by ISCR plan is as under (Table 7.4). The ISCR was a holistic regional development plan suitable for a planned and entangled relationship with the surrounding regions. However, the plan could not be implemented due to lack of legal stature and no enabling provision and notification. It can inferred that in 1984, effect were made for planned regional development in and around Chandigarh laying emphasis on two important aspect of development, trade & commerce and industrial development as a part of globalization era in India.

Chandigarh Inter-state Metropolitan Regional Plan 2021 (CISMeR): Professor E.F.N Riberio emphasised on the need of having a comprehensive framework for metropolitan regional development (Refer Fig. 7.9). The CISMeR Plan was proposed for a total of 5702 sq. km. (more than double the area identified for the ISCR-2001 plan. The Metropolitan plan proposed development in six layers [26]. Layer-I & II consist of Chandigarh's Phase-I & II catering to an area of

Table 7.4 Hierarchy and number of settlements within ISCR zone

Order	Settlement units	Number
1st	CUC	1
2nd	Regional Town	10
3rd	Sub-Regional Town	4
4th	Growth Centres	10
5th	Sub-Growth Centres	10
6th	Focal Villages	–
7th	Basic Villages	–

Source Concept note on Chandigarh and its region, 2011

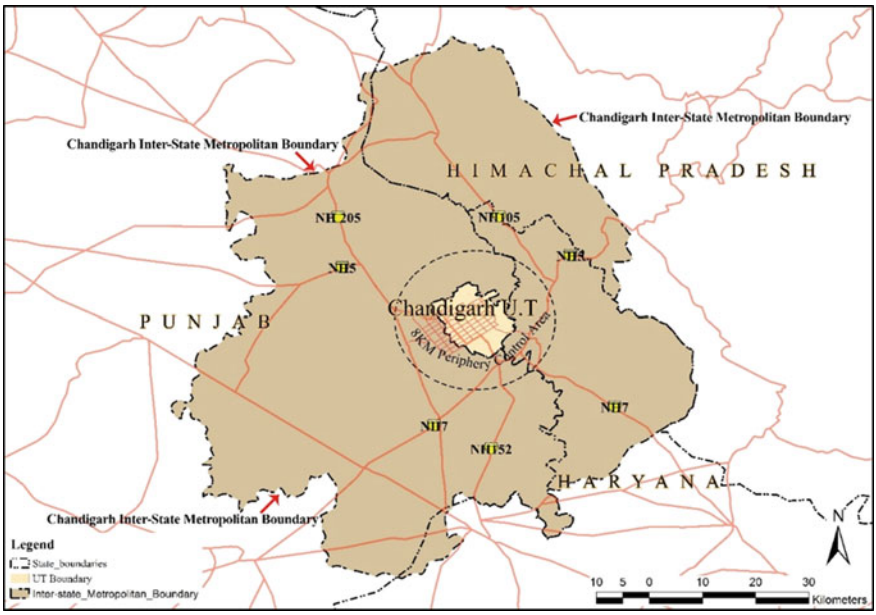

Fig. 7.9 Chandigarh Inter-State Metropolitan Regional Boundary-2021. *Source* Author, Concept note on Chandigarh and its region, 2011

70 sq. km. Layer-III is the old 8 km peripheral belt (1952), layer-IV deals with the Chandigarh Metropolitan Complex i.e. the CUC outside Chandigarh UT in Punjab and Haryana possessing an area of 435 sq. km. Subsequently, layer-V with 613 sq. km., a 16 km peripheral control belt in Punjab and Haryana and finally layer-VI, possessing 4158 sq. km. with a radius of 50 km area beyond layer-I & II totalling to an area of 5702 sq. km. (refer Tables 7.5 and 7.6)

Basically, the development scenarios proposed by CISMeR is a layering concept spread to approximately a fifty km (31 mile radius) for a project population of 65 lakhs. Considering Chandigarh to be the major metropolitan centre of growth, the CISMeR-2021 focused on developing all classes of town with villages. The primary

Table 7.5 Layers of Chandigarh Inter-State Metropolitan Region Plan

Layer	Area (sq. km.)	Constituents	Remarks
Layer I	43	Phase I: Sector 1–30	Original planned and designed part of Chandigarh
Layer II	27	Phase II: Sector 31–47	Original planned but not designed part of Chandigarh
Layer III	44	Sector 48–56	Part of old 8 km peripheral belt of 1952
Layer IV	435	Chandigarh Metropolitan Complex	Outside Layer I–III in lieu of the 1975 Chandigarh Urban Complex outside Chandigarh UT in Punjab and Haryana.
Layer V	613	16 km Peripheral Control belt in Haryana and Punjab	Outside Layer I–IV
Layer VI	4158	Radius of 50 km beyond layer I & II	10 tehsils (4 in Punjab, 3 in Haryana & 3 in Himachal Pradesh
Total Area	5702		Layer I–VI

Source Concept note on Chandigarh and its region, 2011

Table 7.6 Development proposal in six layers of CISMeR

Layer	Designed for population	Planning and development proposal
Layer I	3 lakh	Layer I to be preserved as per its original character
Layer II	5 lakh	Layer II to be preserved as per its original character, however 4 urbanised villages are to be included
Layer III	13 lakh	Layer I + II + III planned development to accommodate 13 lakh population by 2021
Layer IV	12 lakh	Punchkula + Mansadevi + Mohali + Kharar
Layer V		16 km Peripheral Control belt in Haryana and Punjab
Layer VI	Around 38 lakh by 2021	Outside Periphery Control Area of 16 km

Source Concept note on Chandigarh and its region, 2011

objective was to create a regulated development framework for residential and industrial zone which shall accommodate a uniformly distributed population influx. This was essential for refraining the region from experiencing uncoordinated growth in ecologically sensitive areas, agriculture land and already populated area like Chandigarh [3, 27]. CISMeR-2021 was more so an effort for developing the three state Haryana, Punjab, Himachal Pradesh and one UT Chandigarh in a decentralised manner [3].

Again due to lack of enabling powers, legal status and lack of support from states from Punjab and Haryana, the CISMeR-2021 plan could not be implemented [28]. Lack of carrying capacity analysis, incorporation of environmental perspective and lack of inclusion of financial implication has put the plan in question.

7.8.1 Chandigarh Master Plan-2031

In 2008, the requirement to control inconsistence prevailing due to land acquisition surrounding the Rajiv Gandhi Chandigarh Technological Park RGCTP (built on agriculture land, followed by protest from farmers and environment & ecology community), Chandigarh Master Plan-2031 Chandigarh Master Plan [14] was released in July 2015 [29]. The plan focuses on planning control within the UT portion of the Periphery covering the urban core.

7.8.2 Greater Mohali Region: Regional Plan-2058

The Regional Plan for Mohali discusses the proposals and strategies for Greater Mohali Region (GMR) covering an area of 1190 sq. km. located westwards to Chandigarh. It is divided in six planning zones viz. SAS Nagar, Zirakpur, Kharar, Mullanpur, Banur and Derabassi. The report discusses that the 60% population of the 0.7 million is rural and the other 40% is concentrated in SAS Nagar and Zirakpur coming out as satellite establishments acting as counter magnets to Chandigarh. The comprehensive document deals with the planning strategies and recommendations for almost all sections of the development sector. Recently, the Local Planning Area of Mullanpur is renamed as 'New Chandigarh' and a Master Plan for its development was proposed to be prepared in 2007. The primary objective was to ease out the pressure in Chandigarh and Mohali due to economic developments proposed to boom in the next 20 years.

7.9 Defining Chandigarh Region

The entire region of Chandigarh bearing a legal status can be regarded to be that of the 16 km periphery as per the Periphery Act, 1984 and consists of three major region Chandigarh, Punjab, Haryana (see Table 7.7). The 16 km periphery comprises of the many major settlements.

The growth and development in and around Chandigarh has finally resulted in exerting pressure on the services and utilities within Chandigarh (refer Figs. 7.10, 7.11 and 7.12). This has eventually given birth to adjoining towns within the Greater Mohali Region and Panchkula Region in Punjab and Haryana, respectively. The three major urban centres called the Tri-city viz. Chandigarh, Mohali and Panchkula form a triangle of activities and the other towns adjacent to the three towns support its development in the form of satellite towns. Due to legal constraints, no metropolitan regional plan could be devised for Chandigarh, but the 16 km Periphery has legal sanctity, hence the Periphery Region is considered further for recommendations and strategies helping in translating the Tri-city Region into a Smart Metropolitan Region.

Table 7.7 Major settlements within 16 km Periphery region and its functions

State/UT	Settlement	Population			Function(s)
		1991	2001	2011	
Chandigarh	Manimajra	44,710	5521	15,489	IT Hub
Punjab	Mohali/SAS Nagar	78,547	123,484	166,864	Industrial City
	Kharar	26,109	42,289	74,460	Education hub
	Zirakpur		25,022	95,553	Business hub
	Banur	10,014	15,013	187,755	Institutional hub (Knowledge-Business-Technological)
	Derabassi	9602	15,841	26,295	Industrial City
	Mallanpur	419	6147	6165	Resort centre and Regional Playground
Haryana	Panchkula	70,375	140,925	2,11,355	Industrial City
	Pinjore	13,529	29,609	35,192	Industrial City
	Kalka	27,281	30,830	34,134	Army Base
Himachal Pradesh	Parwanoo		8609	8758	Industrial City
	Baddi		22,601	25,639	Industrial City
	Barotiwala		2460	1743	~
	Kasauli		4990	3885	Cantonment Town

Source Census of India-1991–2011; Chandigarh Master Plan-2031; Greater Mohali Regional Plan; Report on Formulating a Master Plan for Chandigarh, 2009

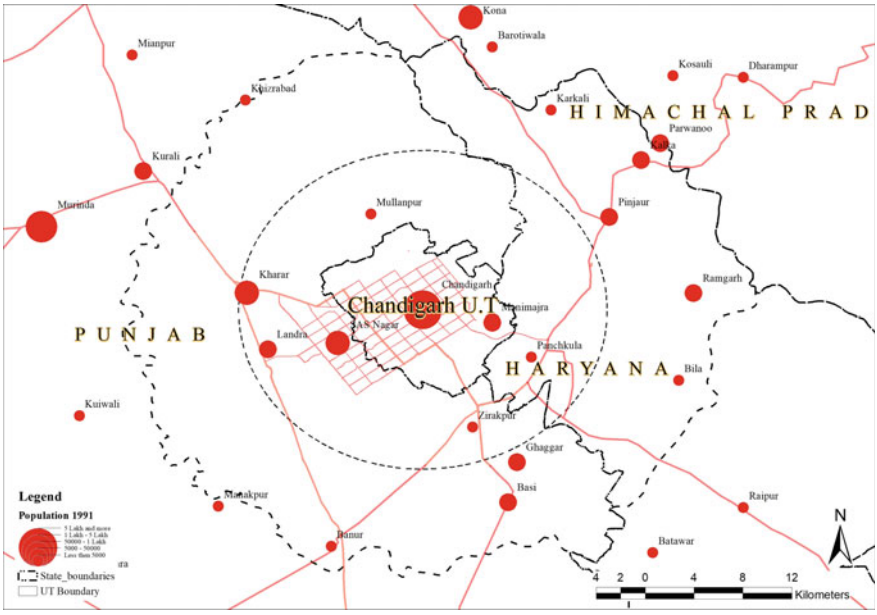

Fig. 7.10 Chandigarh and its region including major growth points-1991. *Source* Author and Concept note on Chandigarh and its region, 2011

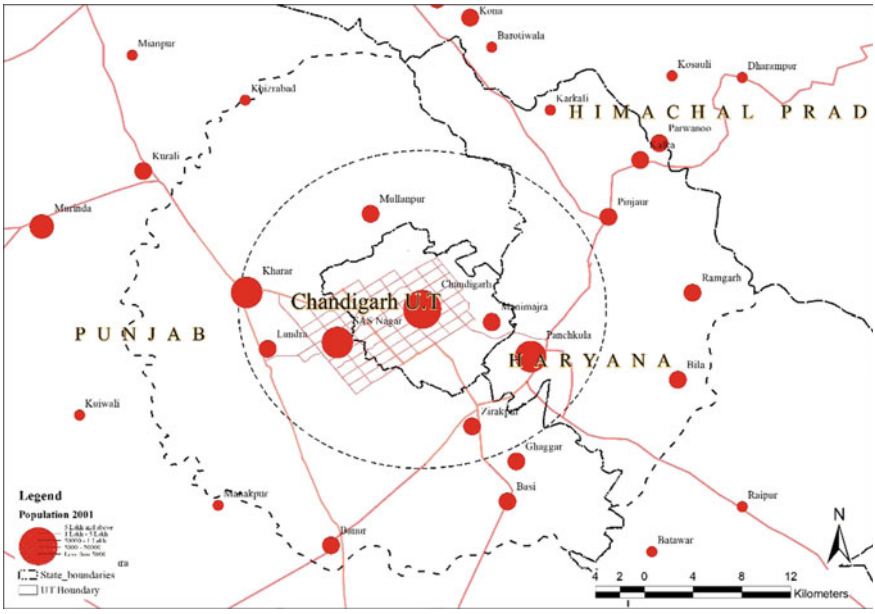

Fig. 7.11 Chandigarh and its region including major growth points-2001. *Source* Author and Concept note on Chandigarh and its region, 2011

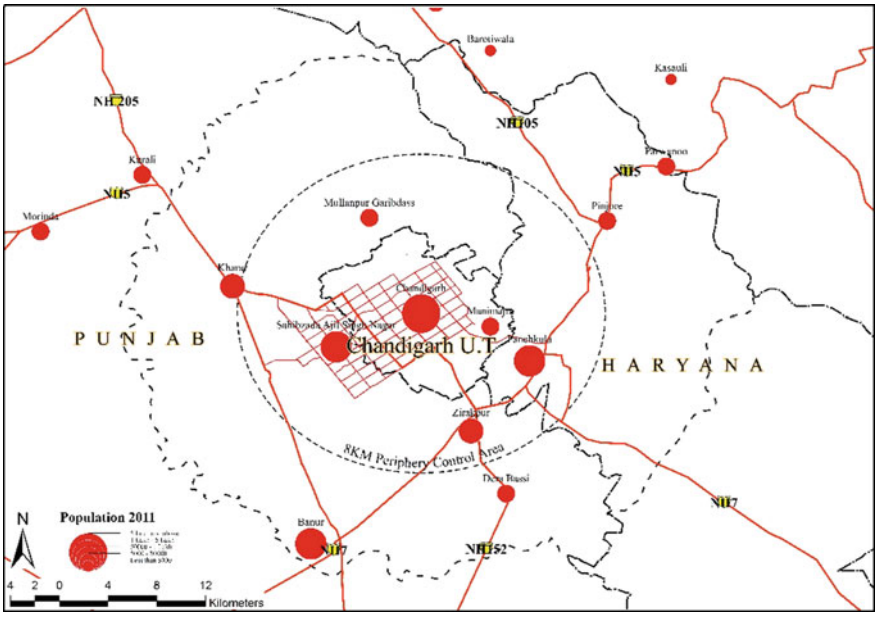

Fig. 7.12 Chandigarh and its region including major growth points-2011. *Source* Author and Concept note on Chandigarh and its region, 2011

The 16 km Periphery Region currently consists of the following areas:

1. Chandigarh
2. HMT Township
3. Chandimandir Cantonment
4. Manimajra
5. 22 villages
    a. Sectoral Villages (Burail, Badheri, Buterla, Attawa, Kajheri, Palsora)
    b. Non-sectoral villages (Kaimba, Khuda Ali Sher, Khuda Lahora, Khuda Jassu, Sarangpur, Dhanas, Dadumajra, Maloya, Kishangarh, Hallomajra, Behlana, Daria, Mauli Jagran, Makhan Majra, Raipur Kalan, Raipur Khurd)
6. Sukhna Wildlife Sanctuary
7. Panchkula
8. Panchkula Extension-1
9. Panchkula Extension-2
10. Shree Mata Mansa Devi Complex
11. Kalka Pinjore Urban Complex
12. Mohali (SAS Nagar)
13. Mullanpur
14. Derabassi
15. Banur
16. Kharar
17. Zirakpur
18. Proposed New Chandigarh
19. Kansal
20. Naya Gaon

Chandigarh UT (114 sq. km.)

Haryana Part of Periphery (235 sq. km.)

Greater Mohali Region (GMR)

Punjab Part of Periphery (1021 sq. km.)

Primarily, Chandigarh UT is developed and further refinements in the name of densification is the process being followed to accommodate the increasing population in Phase 3 construction sectors. Chandigarh UT comprising of 114 sq. km. of area comprises of fully developed 70 and 44 sq. km. periphery area within UT. The 44 sq. km. of the area within Chandigarh UT is regulated by the Punjab New Periphery Control Act, 1952 with the exception of abadi areas of the villages falling within it like Dadumajra, Palsora, Kajheri, Sarangpur, Khudda Ali Sher, Khudda Jassu, Khudda Lahora, Maloya, Raipur Kalan, Raipur Khurd, Behlana, Hallomajra, Makhanmajra, Kishangarh and Manimajra. It also comprises of two river channels called Sukhna Choe and Patiala ki Choe [14, 30].

As per Le Corbusier, the primary intent of the plan was to make a CITY as container and the PERIPHERY as provider. But recently, it was observed that the over spilling of abadi of the peripheral villages led to the changed character of PERIPHERY region within the 16 km radius. To understand the unregulated, unprecedented and haphazard growth has to be systematically monitored from time to time, functional relationships has to be understood leading to growth and its

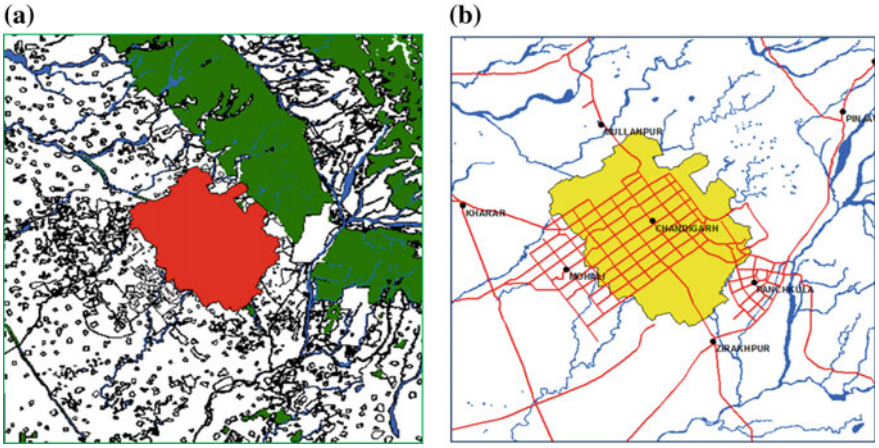

Fig. 7.13 Shivalik foothills running NW to SE, NE of UT influencing the local climate and Drainage NE to SW with Chandigarh's grid-iron pattern

directions. Finally, a suitable framework of spatial design strategies in terms of demand, present condition and future demand scenario can be assessed keeping in mind the legal stature of the available land.

7.9.1 Regional Setting: The Periphery Zone of 16 Km

The total area within the periphery zone (approx. 2431 sq. km.) falls under three jurisdiction of Chandigarh UT, Punjab and Haryana. The area around Chandigarh is surrounded by fragile and environmentally sensitive Himalaya ecosystem zone. This area comprises of protected reserved forests. The entire region forms the foothills of the Shivalik hills in Himalaya and has mainly a flat topography with a gentle slope towards southern-western part of the area. Ghaggar River & its tributaries form the major surface hydrological feature in the area. The area experiences an average annual rainfall of 111.4 cm/year. The soil is extremely fertile with annual deposition of river silt suitable for raising multiple crops. The subsurface formation comprises of beds of boulders, pebbles, gravel, sand, silt, clay and Kankar. The average elevation of the region ranges from 400 m above MSL to about 200 m MSL in the plains (refer Fig. 7.13).

Climate: this area has humid subtropical climate characterised by very hot summer, mild winter with great variation in the temperature pattern. Areas closer to Chandigarh receives cold wind from the north near Shimla and Jammu & Kashmir. The area can be regarded to have a dry weather where evaporation exceeds precipitation.

Linkages Transport: located at the northern part of the country, four national highway intercepts the region, namely NH21 to Ropar, NH95 to Ludhiana, NH22 to Shimla and NH1 to New Delhi via Ambala.

The entire area has an excellent road network link. Apart from highways, railways provide a means of intercity transport for the majority population. Twin railway tracks meet at Ambala. Single railway track joins at Chandigarh & forward to Kalak. The north-east and north-west part of the region is served by the newly build single track from Chandigarh to Morinda. An airport at Chandigarh (domestic) serves the connections with most part of the nation, but no international airport is built in this region.

The region is fertile, nearly flat and observes a view of Shivaliks with healthy environment. The prevalent ecosystem is an added advantage which prevents unscrupulous builders from building in the sensitive sites. Apart from Sukhna Lake as a major tourist destination within Chandigarh, the periphery houses Siswan Lake (about 13 km NW of Chandigarh) and Satluj Yamuna link canal (about 17 km SW of Chandigarh).

7.9.2 Factors Affecting Growth

The growth of any region is governed by some stimulating factors that control the pace and direction of growth in an area. The Periphery Zone is governed by few such major urban centres/settlements that have their unique reasons depicting scenarios of growth. In order to understand the spatio-temporal analysis of urban growth scenario in cities, it is important to identify and analyse the factors that drive urban development. There are various factors responsible for the process of sprawl like demographic, social, economic, cultural, physical/spatial, environmental, governance, proximate causes, biophysical, existing conditions, etc. The most indicating factor for urban growth to take place is demographic characteristics of the city which can be due to population growth or the migration scenarios. Economic factors are such as the job and business opportunities, trade and commerce, industrialization, land prices, market failures, etc. which have huge impact on the changes in the growth pattern of cities. Upcoming new industries or infrastructure projects also have huge impacts on the same. These indicators build competency between cities which is an invisible economic and social factor of urban growth. The planning and governance policies, also the regulatory framework play a major role in dealing with urban sprawl which are formulated to regulate and channelize the growth of cities. Land use zoning, investment plans, transportation policy, Govt. schemes, land management, FAR/FSI restrictions in the city are examples of this.

A hypothesis believes that nations having stringent land use policy controls, considerate and less dispersed governance system, very well manage the land development available in the area. It is also inadvertent that urban sprawl is also considered an intrinsic phenomenon of cities, sometimes promoted by local governance as well. Some local authorities like municipalities may facilitate growth directions to attract new inhabitants and increase the population and some restrict the growth. The evolution, spatial patterns of growth since the city existed, land use, density, regional setting and infrastructure are some of the spatial factors responsible

for growth. The biophysical factors refer to the characteristics and processes of the natural environment like climate change, topography, soil types, availability of natural resources, etc. Proximity causes are one of the most talked about in researches where the areas located in the proximity to infrastructure facilities, roads, rivers, central business districts, etc. are studied which generally tend to grow in future due to potential benefits like ease of access and social services. Existing built-up is also one of the game changing factors around which the future urban growth is indicated to take place. Political situations also affect the growth pattern.

The growth scenario in Chandigarh can be attributed to several factors listed below:

- **Regional Centre**: Chandigarh serves as the capital for two prime states: Punjab and Haryana. Being a regional centre, it is a centre of administrative and political activities from the adjoining states. As a result, the UT attracts population from various parts of the adjoining states. Chandigarh has seen an in-migration of 1.269 lakh to 1.725 lakh in 1981–91 to 1991–2001, respectively.
- **Location**: The picturesque location of Chandigarh is an added advantage for the residents residing in the foothills of Himalayas.
- **Socio-Economic Status**: There is a close co-relation between social infrastructure, social performance and economic development in any setting that drives settlement in those areas. The UT has gained good economic status when compared with other cities of the nation. With an average per capita income of Rs. 67,350 (Indian average Rs. 23,241 as per 2001, three times the national average) [31], Chandigarh is rated as the '*Wealthiest Town*' in India. Also, it was rated sixth most prosperous city in terms of family wealth. The city is regarded to have first rank in overall Human Development Index with a relative positioning of Chandigarh UT based on health (life expectancy), education (literacy) and standard of living (per-capita income adjusted for inequality) as 0.784 in 2007. Chandigarh holds 3rd position in Health Index and Education Index, and 1st position in Income Index and Human Development Index [32]. Chandigarh has one of the least percentage of population below poverty line amongst north Indian states with only 7.1% of population below poverty line. The income inequality is not prevalent as per the Planning Commission report, Reverse Bank of India [33]. The Infant Mortality Rate (IMR) in Chandigarh is 20 deaths per 1000 live births in 2012 [34]. As per the Educational Development Index (EDI) of Indian States, with a score of 0.690, Chandigarh obtains 5th positions all over India [35].
- **Connectivity**: The UT has good road connectivity intra-territory and inter-territory. The internal roads are fully functional and in good shape designated as V1 to V7. The total road network within Chandigarh Municipal Corporation jurisdiction is approximately 1250 km. Moreover, the good connectivity with states like Haryana, Chandigarh, Delhi, Himachal Pradesh and Punjab paves way for effective in-migration.
- **Economic Base**: The transformation in economy of Chandigarh is witnessed in the form of knowledge based economy. Information Technology (IT) and IT

enabled services (ITES) due to policies of the Government is gaining momentum. Industrial technology and Bio-technology is flourishing in the area. This has two major implications: educational front in-migration and employment centric in-migration. With the promotion of tertiary sector over primary and secondary sector, a significant proportion of jobs is reserved paving way for employment. Recent advancements depict Chandigarh as 'large and thriving mega IT hub' through initiatives like Rajiv Gandhi IT Park, development of hi-Tech city, encouragement to private sector, Software Technology Park in Chandigarh, e-governance initiatives.

It can be observed that Chandigarh's population is growing and the state has the power to flourish dependent on economy, commerce, tourism, infrastructure, communication, quality of life and other service and tertiary sectors.

Within the Tri-city Region, there are other factors of growth in various settlements which not only propels in-migration in Chandigarh but diverts population in surrounding regions explained below:

- **Mohali (SAS Nagar)**: Mohali is seen as a financial district with a medical hub and is an administrative capital. In the North-eastern end of the city; airport and manufacturing hub can be found. Most of the developments in the Mohali region is basically an extension to the Southern peripheral area of Chandigarh. It is the most urbanized area within the Greater Mohali Region. The Aerotropolis-airport city planned in the Greater Mohali Region (GMADA) is one of the major triggers of growth in the area and acts as a catalyst for growth and a major economic boost to the area. Its close connectivity with Chandigarh makes it one of the most conducive places to reside in where residents can enjoy educational and social facilities from Chandigarh. Mohali, with super-speciality hospitals is also being regarded as a medical hub.
- **Panchkula**: Panchkula, the Haryana state's initiative is a fast growing residential and financial hub.
- **Kharar**: Kharar is primarily an agricultural hub but is slowly finding residential development due to its close connectivity with Chandigarh and Mohali and also due to district change from Rupnagar district to Mohali in 2006.
- **Zirakpur**: Zirakpur, south-east of Mohali has recently been recognised as a fast growing warehousing hub with manufacturing and wholesale trade. Its close proximity with Mohali and Panchkula also paves way for its development.
- **Derabassi and Banur**: The vision for Derabassi is identified as a core industrial town for Punjab.
- **Mullanpur**: Mullanpur is a low density country living centric settlement. Its locational proximity to proposed film city and educational city developments of Chandigarh offers potential to develop north of Chandigarh through a regional leisure space and adding tourist value to the place.

It is quite evident that the Regional scenario near, in and around the Tri-city area is Chandigarh development centric. Number of developments in the form of film city, educational city, new international airport, IT hub, etc. is paving ways for

regional development within the 16 km Periphery region of Chandigarh. Proximity to Chandigarh is regarded as one of the major reasons for the development of settlements near the Chandigarh Delhi Highway and the advent of New Chandigarh being proposed North-West of Chandigarh.

7.10 Components of Smart Regional Planning

The Regional Plan of any area focuses on the physical development of the region keeping the future demand into consideration in terms of population, economic drivers, connectivity and governance. The location and the historic importance of Chandigarh makes it one of the most important locations for living offering the masses with a good quality of life. Hence, drivers of growth in Chandigarh suggests that the area is suitable for living and planning lives ahead. The region is slowly reaching a stage where it is unable to accommodate population any further. Ever since Chandigarh's inception, it has acted as a growth driver to the entire region and not alone to Chandigarh city. People have migrated and settled in Chandigarh enjoying better housing, infrastructure, and employment opportunity in various sectors of the economy acting as a magnet. Limited geographical area of the UT posed restrictions and exerted an outward pressure on the expansion on the periphery areas. It was obvious that the existing scenario would infuse changes in functional relationships amongst the regions surrounding Chandigarh UT per say.

In the case of Chandigarh, the primary components to be considered while assessing Regional Planning agenda can be:

(a) Self-sufficiency in terms of employment, basic services, facilities, amenities and infrastructure
(b) Area (s) acting as magnet (givers) while others as supporting suppliers and satellite towns
(c) Fruitful functional relationships around and with Chandigarh
(d) Supporting economic activities driving the wheels of progress, growth and prosperity
(e) Wholesome growth in terms of identified Magnets suitable for settling down, making investments, industrial growth, service sector growth, production or transient stay
(f) Incorporating the governance issues and within the legal framework.

For all kinds of planning, the major resource available is Land. Land is a scarce resource and has to be managed so as to utilise its potential for the benefit of the area it is falling in. There can be many ways in which an area can be smartly planned with smart agendas pertaining to planning. One of the primary objectives of Smart Planning that can be applied to Chandigarh and could focus on the following:

- **Smart Information**: Tools and Techniques can be used for basic data assimilation through platforms like Remote Sensing, Geographic Information System (GIS), and Global Navigation Satellite System (GNSS).
- **Smart Decision Making**: Decisions related to monitoring and allocation of land through suitability can be easily performed with the help of remote sensing techniques and specialised software for specific requirements like Urban Growth Modelling Software, Air Pollution Modelling Software, etc. catering to city and region issues both.
- **Smart Connections**: Spatial, Economic, Social, Governance and Functional relationships should be considered before designing for a balanced development scenario.
- **Smart Development**: Development scenario can be achieved only through careful inter-city and intra-city or inter-city and intra-region strategies having a long-term vision and a holistic approach incorporating innovative models of development like Compact City, Green City, Solar City, Transit Oriented Development, Smart Regional Transportation Plans, Comprehensive Mobility Plans, Inter-city Special Economic Zones, etc.

7.10.1 Smart Information-Tools and Techniques for Smart Regional Planning

Every planning exercise involves a comprehensive framework of data base generated in various layers helpful in decision making for planning of a city or region. This information extraction is extremely essential for proper planning and helps reduce the possibility of misguided and erroneous data. Smart Regional Planning can also be aided through proper monitoring of an urban area. The regular monitoring of an urban area helps in understanding the development scenario of a region and helps in careful land use mapping. Mapping of information and data is a basic component of data driven Smart Planning. Creation of suitable base maps delineating natural features from built forms, natural boundaries, and reserved forests can be done through Remote Sensing.

The recent developments in the field of geospatial technology has facilitated the availability of new tools and services for data management. The evolution of Remote Sensing (RS), Geographic Information System (GIS) and Global Navigation Satellite System(GNSS) has enabled easy collection and analysis of data in the most easiest and convenient way. Multi-dimensional and multi-faceted data and its immense capability has several useful dimensions.

A. **Global Navigation Satellite System (GNSS)**

The term GNSS stands for Global Navigation Satellite System(s). A GNSS typically consists of three major segments—(a) Space segment: which typically

includes the satellites orbiting the Earth, (b) Control segment: includes the stations on the ground to track and monitor the satellites, (c) User segment: comprises of the users who rely on the satellites to compute their position and motion. Hence, GNSS is considered as one of the paramount technological interventions for provision of geo-enabled location data. There are several independent GNSS systems in operation around the world which are as follows: GPS, GLONASS, Galileo, BeiDou, IRNSS, etc.

GNSS system caters to high-precision positioning services with such accuracy that could be envied by conventional surveyors. Presently, the GNSS technology has been adopted by the consumer market; in an ever increasing range of products, Transportation, Port automation, Parking automation, Machine control, Precision Agriculture, Surface mining, Mapping and Geodetic data capture, Aerial Photogrammetry and Marine navigation. Its use has seen an increment in day to day life with increasing use of navigational applications and services.

B. **Geographic Information System (GIS)**

Geographic Information System (GIS) or Geo-Spatial Information System is an amalgamation of technologies that helps us to visualize, question, analyse and interpret data to understand relationship patterns and trends. In crude terms, GIS is a combination of cartography, statistical analysis and technology. The graphical displays that can be further used for analysis are prepared using GIS enabled software platforms. The inherent capability for statistical analysis of data and establishing new data base through spatial analysis is an added advantage to most extraordinarily working platform. The many benefits/advantages of using GIS in Regional planning and development include;

(a) Thematic Mapping
(b) Land use management
(c) Land availability and development monitoring
(d) Management of land use records
(e) Land use/Transport strategic planning
(f) Environmental Impact Assessment
(g) Public facilities and shops catchment areas/accessibility analysis
(h) Facility Planning
(i) Management of Land Registries
(j) Social and Economic analysis

C. **Remote Sensing (RS)**

The technology of Remote Sensing (RS) is very useful for accessing datasets and information of the area of interest. Its efficiency can be enhanced by using it in combination with GIS permitting multiple analytical domains. RS can widely be used for regional planning and development using a sequential framework of resource inventory and its collection/preparation, analysis of existing scenarios along with time-series data analysis. RS and GIS together can be considered as the Smart means of data collection and presentation techniques.

7.10.2 Smart Decision-Making

For sustainable urban development and smart regional development, geospatial technology can provide a useful platform for assimilation and formulation of methodological spatial analysis. Examining the various phases of strategic regional development, database inventory is the pre-requisite. However, geospatial technology can aid in all phases of strategic planning starting from objective framing to providing alternate scenarios of planning, evaluation of proposed plan and final plan monitoring [36]. For following the above mentioned methodology, geospatial technology could be of great help for operationalising the proposed strategic framework. GIS can provide tools for display and analysis of datasets using location based specific information systems [37]. Hence, it can be concluded that mapping, monitoring, planning and modelling of land cover can all be performed using the geospatial technology [38].

The pattern of urban growth can be analysed critically using satellite data products in the form of imageries and other ground based measurements backed by secondary data. Linear and radial growth patterns can be easily depicted using image processing tools available in any standard software. The spatial data in the form of topographical maps, geological maps, forest types, vegetation type, soil type, and land cover type, etc. can easily be generated and several layers can be extracted representing data in the form of thematic maps. The underlying spatial pattern of the urban growth phenomena over a different periods of time can be not only systematically mapped and monitored but also accurately assessed from satellite data. Land use/Land Cover mapping, spatial metrics, buffer analysis, urban growth driving factors' analysis, network analysis, urban growth modelling and many other terms are the ways to study the spatial and temporal changes of any place. This can help decision makers to find out the future growth directions or previously wrong practiced planning to efficient plan for a better future. Researches have applied different techniques to understand and model the land dynamics at various levels of planning i.e. micro, meso or micro scale [38].

One such information system portal developed by Indian Space Research Organization potentially for urban and regional planners is called Bhuvan-NUIS. Thematic maps, Land Cover maps, administrative boundaries, etc. are different layers available for browsing in Bhuvan-NUIS (refer Fig. 7.14).

A. **Classification and Modelling**

Remote sensing and GIS techniques using information sources from satellite imagery and other information from open source information portals can be used for identifying land use/land cover changes. Classification of satellite imageries of different time periods can be achieved through standard techniques like pixel based classification or object based classification with the help of maximum likelihood classifier (MLC). Later, change detection can be done for understanding the process of urbanization in a region. The change detection methods can divided into two categories viz. pre-classification and post-classification techniques like image

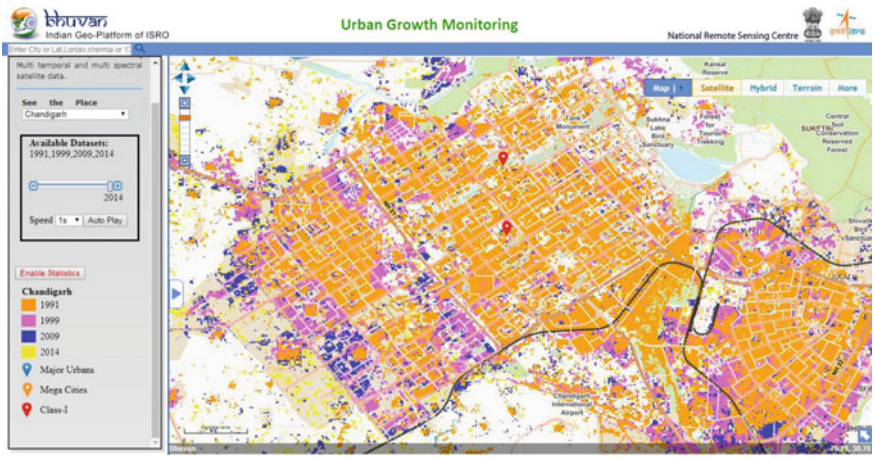

Fig. 7.14 Urban growth monitoring using Bhuvan Portal. *Source* http://bhuvan.nrsc.gov.in/urban/sprawl/urbangrowth.php

difference, image ratioing to single/multiple bands, etc. [39–41]. It is important to map changes as it helps in providing quantitative analysis for the spatial distribution and spatial pattern. This helps in decision making to the planners for further allocation of services and infrastructure corresponding to magnets of growth.

It is important to include drivers of growth for the definite understanding of urban growth scenario. There are various factors responsible for the process of sprawl like demographic, social, economic, cultural, physical/spatial, environmental, governance, proximate causes, biophysical, existing conditions, etc. The most indicating factor for urban growth to take place is demographic characteristics of the city which can be due to population growth or the migration scenarios. Economic factors such as the job and business opportunities, trade and commerce, industrialization. Land prices, market failures, etc. which have huge impact on the changes in the growth pattern of cities. Upcoming new industries or infrastructure projects also have huge impacts on the same. These factors build the competency between cities which is an invisible economic and social factor of urban growth. The planning and governance policies and also the regulatory framework play a major role in dealing with urban sprawl which are formulated to regulate and channelize the growth of cities. Land use zoning, investment plans, transportation policy, Govt. schemes, land management, FAR/FSI restrictions in the city are typical examples of this process. The evolution, spatial patterns of growth since the city existed, land use, density, regional setting and infrastructure are some of the spatial factors responsible for sprawl. The degree to which these driving forces can contribute can also be assessed using modelling software (refer Table 7.8).

Towards spatial growth modelling, various modelling techniques are available for building scenarios that support in the process of land use planning and policy making. There are many land use models available which based on mathematical expressions. In a nutshell, there are three types of growth modelling softwares:

Table 7.8 Overview of driving factors of urban growth

Factors	Types
Bio-physical	Slope, forest, wetland, waterfront, degree of steepness/slope percentage/elevation, rivers, lakes, soil
Demographic	Population (natural and migrated), Population density, Annual population growth, Rate of population growth
Plans, policies and governance	Evolution, Change in boundaries, city development policy, protected lands, cantonment policy, farmland protection policy, zoning, land reforms, investments, Master Plans, Government interventions like
Proximity causes	Distance to major roads, Distance to minor roads, Access to water supply, Access to sewer line, Distance to CBD, Proximity to State Highway, Access to electricity, Distance to educational institutes, Distance to medical facility, Proximity to open spaces/green spaces/recreational facility
Existing scenario	Distance to existing urban area/cluster, Number of cells within 5 × 5 window of cells
Economic	Per capita income, employment rate, poverty rate, land value, high rental value

empirical estimation based models, dynamic simulation based models and rule based simulation based models [42, 43]. The models developed for growth modelling are Cellular Automata (CA), spatial statistical models, Agent Based Models (ABM), Artificial Neutral Network (ANN), fractal based modelling and Chaotic and Catastrophe modelling concerned with simulating future urban growth scenarios [44, 45]. There are many other softwares that not only support in simulations but also help in future predictions and aid planners in decision making for future cities (refer Table 7.9).

Tools and techniques constantly aiding in growth monitoring and modelling can be useful in decision making to a very large extent. In a similar attempt to understand the growth dynamics of Chandigarh 16 km Periphery region, a growth modeling using "*CA Markov*" and "*Multi-Layer Perceptron* (*MLP*)" was performed for the year 2024 and 2048 using datasets for the years 2000, 2006 and 2012 [11].

7.10.3 Smart Connections

A region shall cater to all major spatial, Economic, Social, Governance and Functional relationships before planning for a region. In case of Chandigarh, the spatial connectivity is facilitated with the help of a well-defined 7-level road network. Pedestrian facilities are available to 90% of the municipal roads. With more than 85% households owning vehicles and approximately 227 four-wheelers per thousand population (highest in the country), traffic congestion is now bubbling as a

Table 7.9 Land use models and tools of modelling spatial growth

Application	Models	Source
Land use models	Cellular Automata Models (SLEUTH, Clarke Urban Growth Model (UGM) and Deltatron Land Use/Land Cover Model (DLM), Fuzzy Cellular Automata Urban Growth Model (FCAUGM), MOLAND), Agent Based Models (ABM), Agent Based Cellular Automata (ABCA), Logistic Regression (LR), Artificial Neural Network (ANN), California Urban Futures Model (CUF), CUF-2, UPlan, FUTure Urban-Regional Environment Simulation (FUTURES) in R, UrbanSim,	http://www.urbansim.org/Main/WebHome
Tools for growth modelling	STARLOGO	http://www.media.mit.edu/starlogo/
	SWARM	http://www.santefe.edu, http://www.swarm.org/
	REcursive Porous Agent Simulation Toolkit (REPAST)	http://repast.sourceforge.net/
	ASCAPE	http://www.brook.edu/es/dynamics/models/ascape/default.htm
	NetLogo	http://ccl.northwestern.edu/netlogo/
	RAISE	
	Agent Building and Learning Environment (ABLE)	http://www.alphaworks.ibm.com/tech/able
	ZEUS	
	Java Agent DEvelopment Framework (JADE)	
	TerraMe	http://www.terrame.org/doku.php

key concern for the area [14]. The densification of areas around and within Chandigarh increases the demand of a by-pass and city to city connectivity in Chandigarh. Chandigarh, Panchkula, Mohali and all the other satellite settlements are connected through well-defined National and State Highways. The presence of an airport provides an exposure to the other parts of the nation. The airport in Chandigarh catering to the Tri-city Region in the 16 km Periphery is a domestic airport at present. All spatial connections in the form of built up area, corridor development, road connectivity, rail connectivity, air connectivity and natural barriers need to be carefully understood. Also, the social status of the population residing in the area should be carefully examined to design and develop for all sections of the society preventing unauthorised constructions in and outside the city.

Sometimes, the vision envisaged for development are not materialised due to restricting policies in the regions and differing jurisdictional limits. Hence, acts and policies play a pivotal role in guiding a region's development and shall be

understood before arriving at spatial planning decisions. Also, the Government envisions a role for all cities in the jurisdictional control of the state or UT. The city is expected to grow in a particular way with the drivers of growth either modelled, superimposed or growing in a particular way. These drivers are to be understood and connections between drivers of the region has to be established resulting in a functional relationship. This aids in deciding factors of growth for the newer settlements.

7.10.3.1 Smart Developments

In India, cities are either developed naturally or as a result of demand in living due to natural growth and in-migration in search of facilities and employment opportunity. Chandigarh is planned city and subsequently, Mohali and Panchkula got developed as planned establishments following a planned town planning approach. Smart approaches of further developing a planned city could be intra-city or intra-region approaches. Some of the approaches that could be considered to develop according to the requirement and potential of the region like Smart ICT, Smart Mobility, Smart Energy, Smart Environment initiatives, Compact City development, Transit Oriented Development, Green City Development, etc. These visions for the city if understood and applied, can result in fruitful regional development scenario where the individual nodes are developed keeping in view the future.

7.11 Spatial Planning Strategies and Recommendations

The planning strategies and recommendations of an area can only be recommended with the help of proper analysis of the growth pattern of the study area into consideration regarded as Chandigarh Region. An attempt was made to study the same using geospatial technology.

7.11.1 Land Cover/Land Use (LCLU)

Keeping into consideration the need for the study at a regional scale, the study of transition of land use in terms of growing urbanization in the area, the classification scheme was devised. A total of ten classes relating to urban areas were chosen and the LULC map was prepared for the years 2000, 2006 and 2012. The classes defined were: (a) Built-up Urban, (b) Built-up Rural, (c) Built-up mixed, (d) Recreational or Urban Green, (e) Agricultural Land, (f) Forest Land, (g) water bodies, (h) Open/Barren land and, (i) Restricted Areas, (j) Land Under Plotting [11]. Both supervised and unsupervised classification schemes were adopted. Due

to unsatisfactory results, Object Based Classification system was tested. Object Based Image Analysis (OBIA) is a fuzzy technology based classification unlike the regular pixel based classification approaches. Later, it was realised that pixel based mage classification and OBIA shall nor render the desired results and hence, visual interpretation was considered to be the most viable method of image classification producing an accuracy of 85% and even more [11].

A fused LISS IV and IRS 1C PAN product was felt suitable for classification purpose. Considering WGS 84 datum, UTM projection and map boundaries as defined and made available through Survey of India, Land cover maps were prepared. An approximation based area of 20 times the core area (UT) was used covering an approx. area of 2300 sq. km. for the purpose of digitization. This formula was decided by understanding the National Capital Region (NCR) where the influence area was found to be approximately. 23 times the National Capital Territory (NCT) area. The existing development status was also taken into account while preparing the land cover maps. The Master Plans for Panchkula, Pinjore-Kalka urban complex, SAS Nagar, Banur, Dera Bassi, Zirakpur, Kharar, Mullanpur were included for easy understanding of the study. Under the study, the entire 16 km periphery area has been divided into six rings or buffers of 4 km each (refer Fig. 7.15).

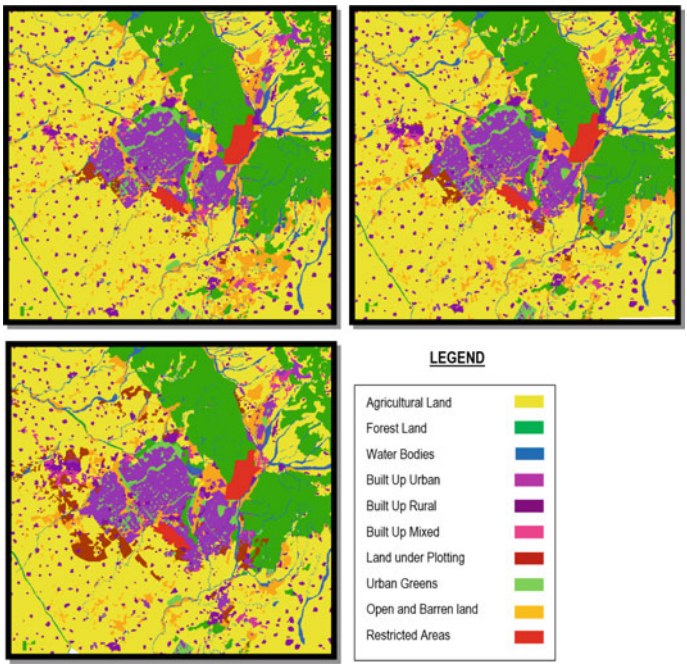

Fig. 7.15 Land cover/land use maps for the year 2000, 2006 and 2012 (clockwise starting from above-left). *Source* Author [11] LULC maps 2006, 2010, and 2016

7.11.2 Chandigarh Region: Possible Urban Forms

In 1966, Prof. LR Vagale of School of Planning and Architecture, presented a paper on "*A Case Study of Chandigarh and its Environs in the Regional Setting*" at UN sponsored seminar at Japan. It was later published also. From his understanding, it can be derived that in Punjab, the settlement pattern was characterised by presence of large towns developed along intersections of highways and like other small developments, settlements were either along the river banks and river courses or ribbon developments along corridors. Conventionally, urban areas are surrounded by smaller settlements forming a hierarchy of settlement pattern. In order to understand the growth pattern in and around Chandigarh, few types of growth patterns can be considered. The possible six conceptual patterns could be:

- Expansion of Chandigarh Urban area
- 'Linear township' along the transport corridors
- New township around existing smaller township
- New town on new site functioning as satellite/Counter magnet towns
- Combination of new satellite towns surrounding Chandigarh and its vicinity
- Expansion of Chandigarh in the form of corridor developments and wedges.

7.11.3 Growth Pattern: An Analysis

The analysis of the existing urban form is actually a combination of the proposed urban form on 1966. The development of adjacent areas in mid 1990s can be considered a beginning of 'Regionalization' of the area. Settlements like Kharar, Zirakpur, Dera Bassi are acting as satellite settlements to Chandigarh. No wedge and corridor development could be noticed in Chandigarh.

7.11.4 Prediction of Growth

For estimating the future growth scenarios of Chandigarh Region, few drivers of growth were identified like (a) Proximity to existing settlements, (b) Proximity to roads, (c) Proximity to railways, (d) Proximity to UT boundary. It was of utmost importance to assess the mathematical relationship between drivers of growth. If the relationship is not strong, it may be rejected as a potential driver contributing towards assessing the future growth areas. For evaluation, a seven step procedure was adopted where buffers of fixed distances at 200 m intervals up-to 1400 m were generated. The growth area within each buffer zone was estimated using overlay analysis. Using a reclassification approach, growth areas in each buffer was extracted. Cross tabulation was used for extraction of data within the buffer area in

comparison to the total growth in terms of percentage against each buffer distance. The relationship between each year's growth with each growth driver is observed showing high degree of correlation except for Proximity to railways showed insignificant relationship with the growth area (refer Fig. 7.16)

7.11.5 *Modelling Future Growth Scenarios in Chandigarh Region*

The drivers were used to predict the growth scenarios of the future. First, the dataset for 2000 and 2006 were used for predicting the growth scenarios of 2012. The 2012 projected growth pattern was compared with the actual growth pattern observed in 2012. Towards a better and simplified understanding, the LULC classes were reclassified to obtain binary data consisting of two classes- Built-up (BU) and Non Built-up (BBU) outside the UT boundary and within the 16 km boundary.

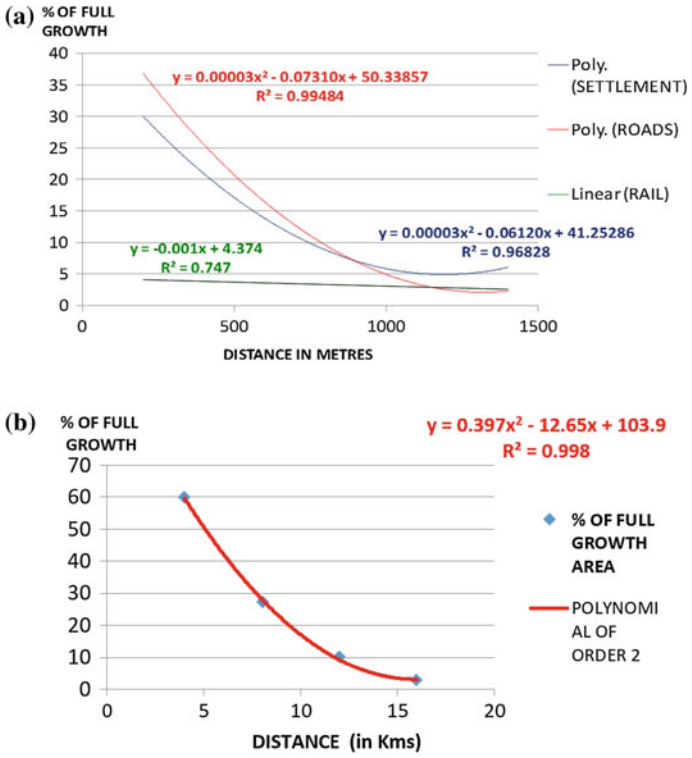

Fig. 7.16 Relationship between growth and growth drivers **a** the relationship between drivers and growth, **b** the relationship between the driver and the effect of distance of the UT boundary. *Source* Author [11] (observed 60% growth within the radius of 4 km)

Literature and site visits indicate that many planed interventions were observed east and south of Mohali around Chandigarh at a very rapid rate. Hence, the BU category consisted of amalgamating five classes together viz. BU Urban, BU Rural, BU Mixed, Urban Green or Recreational Area, Land under Plotting (LUP). The NBU category consisted of Agricultural and Barren land classes. Other three major classes like Forest Land, Restricted Area and Water Body were merged with the area under the UT boundary as masked area. These classes are static in nature and nearly show negligible signs of changes over due course of time at the regional level. It can be a criticism to the rationale on inclusion of plotted land in the built-up area leading to over classification and ultimately over prediction of results. This argument can be counter argued by the fact that prediction models are dependent upon transition probability following linear transformation procedures, whereas actual growth is generally considered to be non-linear in nature.

(a) **Built-up Area (BUA) Outside UT Boundary**

The maps for the year 2000, 2006 and 2012 suggest that there was a 31.13% increase in BUA outside the UT boundary for 2006–2012 as compared to 8.54% in 2000 to 2006. This clearly indicates the presence of unprecedented growth outside the UT boundary adjoining the Chandigarh UT.

(b) **Validation for Predicted LULC-2012**

The projected LCLU map for 2012 was validated with the actual 2012 map. Within the Chandigarh boundary, the UT Administration is effectively managing the growth with the help of building regulations such as "Floor Area Ratio". Using three binary BU images of 2000, 2006 and 2012 were prepared. Using BU 2000 and 2006, two models were tested for accuracy viz. "*CA Markov*" and "*Multi-Layer Perceptron* (*MLP*)".

The process of predicting the future scenario using 'CA Markov' is as follows:

- **Generation of transition suitability matrix**: The transition suitability matrix is generated for six years and the 'transition area' files are used to locate the future changes in different iterations.
- **Suitability Images**: Suitability maps is created using the various drivers of growth. Using min-max linear transformation, the values were normalised between 0 and 1.
- **Grouping of suitability images**
- **Running the model for output indicating future scenarios**

The process of predicting the future scenario using 'Multi-Layer Perceptron (MLP) Neural Network' Model was a three stage process as follows:

- Input as the BUA and NBU area maps for 2000 and 2006
- Change analysis using transition sub-model followed by evaluation of the growth driver's explanatory power using Cramer's V
- Drivers used for running the model for output.

The prediction accuracy evaluated for 2012 year revealed an accuracy of 86.12% using MLP and 81.34% using CA Markov. Using a cell size of 50 m 50 m, MLP showed superior results.

(c) **Predictions for the Year 2024 and 2048**

Using the BU map for 2000 and 2012, the Land Cover for 2024, 2036 and 2048 were estimated using the validated, tested and accurate model, MLP neural network based procedure. A total of six drivers were incorporated whose validity and affect tested with the help of Cramer's V where a value of more than 0.4 is considered 'Good' and values greater than 0.15 is considered useful or acceptable. The drivers were transformed using 'Evidence Likelihood Utility' for values between 0 and 1. The driver called 'Proximity to Railways' was also included as a growth driver for predicting the future scenarios of 2024 and 2048. The reason was to incorporate the actual scenarios and planning interventions subject to real world urbanization. If the urbanization pattern outside the Chandigarh UT is to be observed after 2006 and the release of GMADA plan for Mohali, most of the 'Agricultural Lands' were transformed into 'Plotted Land' subsequently in southern parts of Mohali, near the railway lies indicating the presence/proximity of railways as a potential indicator of urbanization. Railways indicated an extended boundary of built-up land near Mohali.

Using the different proximity drivers, The Cramer's V value for all the six drivers were assessed indicating the potential in decreasing order of influence as: Gains and losses (Changes between 2000 and 2012) (0.4569), Proximity of Chandigarh UT (0.4050), Proximity to CBD (0.3711), Proximity to existing settlement of 2012 (0.3668), Proximity to Major roads (0.3334) and Proximity to Railways (0.2427). The built-up scenario for 2024 suggested an area of 267.58 sq. km. and its further increase to 371.64 sq. km. in 2048 subject to existing drivers of growth. The built up area for 2024 indicate an area under built up category to be 267.58 sq. km. covering an area of 17.63% urban while in 2048 it would rise to 371.64 sq. km. with the total built-up percentage as 24.76% (refer Figs. 7.17 and 7.18).

7.11.6 Results

Keeping in view the Planning Zones proposed by "*Chandigarh Inter State Region (CISR)*" briefed in "*Concept Note on Chandigarh and its Region*" described by TCPO, a new planning zone system was analysed for Chandigarh region. If the NCR of Delhi is studied deeply, the core area of NCT is acting as a magnet to all the other 14 districts adjoining the city (8 districts from Haryana, 5 districts from Uttar Pradesh and 1 district from Rajasthan) making a ratio of 1:22 of the geographical area occupied by the UT to the surrounding region. It was observed that Chandigarh has a very less influence on the neighbourhood but indeed its influence cannot be ignored. The UT bearing an area of 114 sq. km. and the surrounding 16 km periphery, the ratio of UT area to influence zone is 1:14. The analysis of growth scenarios reveal the 4 km buffer from the UT boundary as the most potential

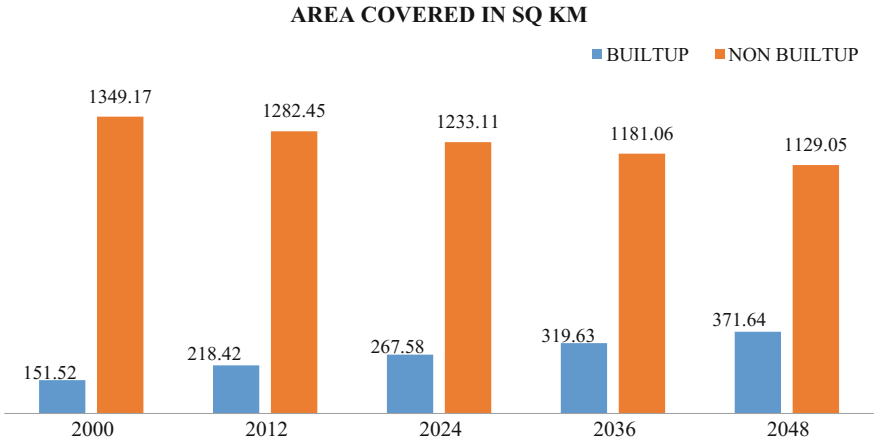

Fig. 7.17 Built-up and non built-up: 2000–2048 using MLP prediction

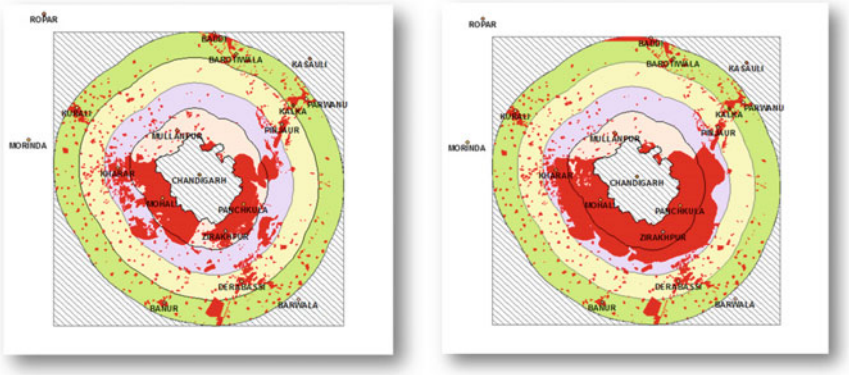

Fig. 7.18 Built-up results within the buffers for 2024 and 2048

area for future development scenarios which shall undergo rapid pace of urbanization till 2025. It is also analysed that further in 8 and 16 km buffers, the growth may be fragmented into small pockets in the future.

Hence, keeping in view the above discussion, the areas/zones mentioned in CISR can be further re-examined and classified based on the study. Zone 1 of CISR has been divided into two layers (Sector 1–56: Layer 1, rest of the UT: Layer 2), Zone 2 is divided into four layers (4 km periphery of UT: Layer 3, 4 to 8 km periphery: Layer 4, 8 to 12 km periphery: Layer 5 and further till 16 km as Layer 6) (refer Table 7.10).

Table 7.10 The description of planning zones proposed for the different layers of Chandigarh Region

Area	Chandigarh region-proposed layers	Planning zones: CISR	Remarks
UT sectors (Sectors 1–56)	Layer 1	Zone 1	Predominantly residential
Rest of UT	Layer 2		Airport, Railways, Industrial area, Forest area
4 km periphery of UT	Layer 3	Zone 2	Mohali, Panchkula, Zirakhpur, Mullanpur
4–8 km periphery	Layer 4		Kharar
8–12 km periphery	Layer 5		Dera Bassi, Pinjore
12–16 km periphery	Layer 6		Banur, Kurali, Kalka, Parwanoo, Baddi (partially), Barotiwala
Areas beyond periphery control belt	Layer 7	Zone 3	Kasauli, Barwala, Baddi (partially). Areas to be included in this layer not yet defined

7.11.7 Recommendations

Some of the spatial recommendations that can be understood by analysing the existing scenario in Chandigarh Region is as follows:

(a) ***Eco-sensitive zones***: As observed, certain regions within the buffer areas shall be earmarked as eco-sensitive zones. This shall help in maintaining the natural beauty of the region intact and aid in acting as a buffer between natural surroundings and the urban area.
(b) ***Water body***: The area within water body suggest that the region adjoining water bodies shall be earmarked as recreational spaces and potential tourist hotspots.
(c) ***Coordinated growth***: The spatial growth should be in sync with the existing social, economic and physical infrastructure.
(d) ***Holistic development***: The Chandigarh Region should develop holistically keeping in view the GMADA and Panchkula area being two major sub-regions of the Region.
(e) ***Smart Planning***: Growth scenario indicate the potential areas of growth. Subsequently, spatial planners may be aided to link the spatial growth pattern with the infrastructure development scenarios. It may be essential for incorporation in the planning and plan making process. It ca also help in decision making for better planning and placement of facilities and utilities. The datasets are one of the most inevitable inputs for regional planer as a tool for Smart Planning.

Table 7.11 The description of planning zones and the area proposed under Chandigarh Region

	Total area (sq. km.)	Agricultural land	Existing settlement	Forest land	Afforestation (proposed)	Urbanisation (proposed)
LAYER 1	55.80	–	55.80	–	–	–
LAYER 2	59.11	9.9	29.57	9.81	–	9.83
LAYER 3	235.17	–	86.69	70.31	–	78.17
LAYER 4	322.11	53.14	11.55	107.17	–	150.25
LAYER 5	421.57	172.61	8.83	102.71	43.38	94.04
LAYER 6	521.73	252.28	15.29	129.55	56.13	68.48
	1615.49	487.93	207.73	419.55	99.51	400.77

(f) ***Agriculture***: Analysis reveal decrease of agricultural area in Layer 3 and 4. Agricultural area should be separately reserved and earmarked for restricted use in the regional plan for Chandigarh.

(g) ***Forest***: Existing forest land is approx. 419.5 sq. km. A buffer of 200 m around the forest is proposed for enforcing no-construction activity

(h) ***Environment***: In order to cater to the concerns of environmental deterioration, afforestation should be proposed. Total afforestation can be proposed near seasonal rivers that shall not hinder the privately owned land in and out of the UT boundary.

(i) ***Growth***: A growth area of around 400 sq. km. can be proposed within the Chandigarh Periphery catering to the future growth requirement. Micro-level planning may need detailed planning and townships like New Chandigarh, Aero-city, education-knowledge health corridors, transportation zones, industrial townships and industrial belts as well as extension of Panchkula and Kalka-Pinjore area (refer Table 7.11).

(j) ***Traffic and Transportation***: Medium and long term traffic and transportation plans should be made for the Region. The recommendations on mass rapid transit system, bus rapid transit system, etc. can be made available for relieving the pressure of densification, in and around Chandigarh.

7.12 Conclusion

Chandigarh's development scenario is a realization of accommodating population that has seen a rise from designed limit of 5 lakhs to over 10 lakhs as per Census 2011 [22]. It is needless to mention that migration phenomenon cannot be avoided in any settlement especially in a city like Chandigarh offering good quality of life, green spaces, regularized legal framework and density control with a beautiful Shivalik backdrop and Sukhna Lake. It is regarded as one of the cleanest and greenest cites in India. However, statistics pertaining to demographics reveal that

the city is unsafe from the effect of population explosion unless roads are paved for accommodating the additional need. This is the sole reason where public and private developments have started eating up the peripheral lands in the form of unplanned settlements. This is the rising demand that is forcing to act against Le-Corbusier's vision of development scenario aimed for the City Beautiful.

Regional Plan evolution is a major agenda for any important growing urban centre like Chandigarh. The existing deficiencies within the Master Plans need to be understood and further fruitful deliberations are required for evolving a wholesome solution towards planning. Legal status and sanctity to Regional plans for Chandigarh region is lacking due to lack of legislative provisions under which regional plans may be forwarded. This is one of the major reason leading to haphazard and unplanned growth in sensitive areas around the Chandigarh UT. There is a grave need for enablement of legal provisions as a cohesive approach for a 'Region' unlike piecemeal sub-regional approaches. While these sub-regions help in shaping the growth direction ad magnitude, the entire area is not bound by legal document hindering a holistic planned development scenario. Thus, it can be stated that a comprehensive and balanced development is yet to be executed. There is a need felt for Chandigarh Regional Planning Act for Chandigarh and its Periphery for provision of a comprehensive Master Plan covering all major and minor sub-regions governed through a Planning Board, in general. Chandigarh requires a Regional Plan extending to the three states keeping in view to restore the visions of the initial city planners.

The development of a region focuses on understanding the fragments of a region and then realizing the region as a whole. Regional Development promotes the thinking of a bottom-up and top-down approach both. Chandigarh requires a legal framework backed by efficient tools and techniques of Smart Development scenarios for prosperous futuristic scenarios of growth. From a city perspective it shall focus on building up a Smart Growth, Smart Environment, Smart Infrastructure, Smart Energy and Smart People. From a Regional Perspective it shall focus on Building Smart Connectivity and Smart Governance. The need of Transit Oriented Development, Smart Grids, catering the needs of informal settlements through inclusive planning, building a good transport network and provision of expressways, setting of new townships like Aerocity, New Chandigarh and other new planned industrial and residential townships could be some of the regulatory measures at the planning level in transforming a region into a Smart Metropolitan Region. This chapter dealt with providing recommendations on strategies that can be adopted for translating an urban setup like Chandigarh into a Smart Metropolitan Regional Plan. The drivers of growth shall help us in understanding the growth phenomenon supported by online web information systems like Bhuvan-NUIS Thematic Mapping. The efficacy of Geospatial Technology suggests its usefulness in the analytical and decision making phase for better planning as a component of Smart City Planning.

References

1. Kalia R (1999) Chandigarh: the making of an Indian City. Oxford University Press, New York
2. Mayer A (1950) The new capital of the Punjab. J Am Inst Archit 14(4):166–175
3. Town and Country Planning Organization (2011) Concept note on Chandigarh and its region, M.o. Development, Editor, Town and Country Planning Organization, Chandigarh, p 1–30
4. Prakash V (2002) Chandigarh's Le Corbusier: the struggle for modernity in Postcolonial India. Studies in modernity and national identity. University of Washington Press, Seattle
5. Shaw A (2009) Town planning in Postcolonial India, 1947–1965: Chandigarh re-examined. Urban Geogr 30(8):857–878
6. Lang JT, Desai M, Desai M (1997) Architecture and independence: the search for identity—India, 1880–1980, Lang JT (ed), Oxford University Press, Delhi, New York, p 347
7. Nilsson S (1973) The New Capitals of India, Pakistan, and Bangladesh. Scandinavian Institute of Asian Studies. Monograph series, vol 12. Routledge/Curzon, New Delhi, London, p 230
8. Marg (1961) Special issue on Chandigarh. In: Corbusier L et al (eds) A new planned city. Marg, Bombay
9. Perera N (2006) Chandigarh: India's modernist experiment. In: Gordon D (ed) Planning twentieth century capital cities. Routledge, London and New York, pp 226–236
10. Scott JC (1998) Seeing like a state: how certain schemes to improve the human condition have failed. In: Scott JC (ed) The Yale ISPS series, vol 3. Yale University Press, New Haven and London, p 432
11. Kakkar K (2013) Evolving a regional perspective on 'Greater Chandigarh Region' (GCR) using RS & GIS, in Urban and Regional Studies Department. Indian Institute of Remote Sensing, Dehradun, p 57
12. Chalana M (2014) Chandigarh: city and periphery. J Plann Hist 14(1):62–84
13. Evenson N (1966) Chandigarh. Environmental design and development series, vol 1. University of California Press, New Delhi and Berkeley, p 116
14. Chandigarh Master Plan, Master Plan of Chandigarh 2031, C. Department of Urban Planning, Editor. 2031, Chandigarh Administration, Chandigarh
15. Administrative Atlas of India (1971) Census of India 1971 Administrative Atlas of India. M.o. H. Affairs (ed). Office of the Registrar General & Census Commissioner, India
16. Punjab Government Gazette (1952) The Punjab New Capital (Periphery) Control Act, 1952. P.G.G. Extraordinary (ed). Government of Punjab, Punjab, p 677
17. Corbusier L (1979) The three human establishments. Punjab Government, Department of Town & Country Planning, Chandigarh
18. Sarin M (1975) Planning and the urban poor: The Chandigarh experience (1955–1975), London
19. Census of India (2011) District census handbook Chandigarh: Village and Town Directory. In: District census handbook Chandigarh. Office of the Registrar General & Census Commissioner, Delhi, India
20. Census of India (2011) Primary census abstract report 2011, A-1: Series. In: Primary census abstract. Office of the Registrar General & Census Commissioner, Chandigarh, India
21. Census of India (2001) Primary census report 2001, H-H: Series. In: Primary census abstract. Office of the Registrar General & Census Commissioner, Chandigarh, India
22. Census of India (2011) Primary Census Report 2011, H-H: Series. In: Primary census abstract. Office of the Registrar General & Census Commissioner, Chandigarh, India
23. Corbusier L (1964) The periphery control plan of Chandigarh. Collection of Foundation Le Corbusier, Paris
24. Saini SS, Kaushik SP (2011) Land use changes in Haryana Sub-region of Chandigarh periphery controlled area: a spatio-temporal study. Inst Town Planners, India J 8(4):96–106

25. Inter-State Regional Plan (2001) Inter-State regional plan for Chandigarh Region. Town and Country Planning Organization, Chandigarh
26. CISMeR (1999) Chandigarh Interstate Metropolitan Region Plan (CISMeR), 2021. In: Riberio EFN (ed). Chandigarh UT Administration, Chandigarh
27. Ribeiro EFN, Ansari JH (2002) A proposed concept plan for the Chandigarh Inter-state Metropolitan Region-2021. In: Takhar J (ed) Celebrating Chandigarh. Grantha Corporation, Chandigarh, pp 431–435
28. Upadhyay R (2012) Centre to revive Ribeiro's development plan. Daily Post India, Chandigarh
29. Kumar V (2012) UT administration fails to finalise master plan yet again. In: Hindustan Times. Hindustan Times, Chandigarh
30. New Chandigarh Master Plan (2015) Detailing of Master Plan New Chandigarh, P. Department of Town & Country Planning (ed). Department of Town & Country Planning, Punjab, SAS Nagar, p 117
31. Economic Statistical Organisation Punjab (2017) Economic statistical Chandigarh. Central Statistical Organisation, New Delhi
32. Ministry of Women & Child Development (2009) Gendering human development indices: recasting the gender development index and gender empowerment measure for India. Ministry of Women & Child Development, New Delhi
33. Confederation of Indian Industry (2011) Annual Report 2010–11. In: Confederation of Indian Industry Annual Report, New Delhi
34. India, C.o. (2013) Sample registration system statistical report 2013. In: SRS statistical report, New Delhi
35. National University of Educational Planning and Administration (2006) Annual report 2005–06. In: National University of Educational Planning and Administration Annual Report, New Delhi
36. Yeh AG, Li X (1996) An integrated remote sensing and GIS approach in the monitoring and evaluation of rapid urban growth for sustainable development in the Pearl River Delta, China. Int Plann Stud 2(2):193–210
37. Nicholas M (2008) Remote sensing tutorial. National Aeronautics and Space Administration
38. Yesserie AG (2009) Spatio-temporal land use/land cover changes analysis and monitoring in the Valencia Municipality, Spain, March 2009. Masters Program in Geospatial Technologies, Dept. Lenguajes y Sistemas Informaticos Universitat Jaume I, Castellon, Spain
39. Ridd MK, Liu J (1998) A comparison of four algorithms for change detection in an urban environment. Remote Sens Environ 63(2):95–100
40. Singh A (1989) Review article digital change detection techniques using remotely-sensed data. Int J Remote Sens 10(6):989–1003
41. Yuan D, Elvidge CD, Lunetta RS (1998) Remote sensing change detection: environmental monitoring methods and applications. Chapter: Survey of multispectral methods for land cover change analysis. Ann Arbor Press
42. Hu Z, Lo CP (2007) Modeling urban growth in Atlanta using logistic regression. Comput Environ Urban Syst 31(6):667–688
43. Zeng YN et al (2008) Modeling spatial land use pattern using auto-logistic regression. Int Arch Photogrammetry Remote Sens Spatial Inf Sci 37(B2):115–118
44. Guiping W et al (2009) Simulation and analysis on the land-use patterns of Nanjing city based on AutoLogistic method, p 1–6
45. Cheng J, Masser I, Ottens H (2003) Understanding urban growth system: theories and methods. In: Conference proceedings