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THE URBAN MORPHOLOGY OF HYDERABAD, INDIA:
A HISTORICAL GEOGRAPHIC ANALYSIS

by

Kevin B. Haynes

A thesis submitted to the Graduate College
in partial fulfillment of the requirements
for the degree of Master of Science
Geography
Western Michigan University
June 2020

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Kevin B. Haynes, M.S.

Western Michigan University, 2020

Hyderabad, India has undergone tremendous change over the last three centuries. The study seeks to understand how and why Hyderabad transitioned from a north-south urban morphological directional pattern to east-west during from 1687 to 2019. Satellite-based remote sensing will be used to measure the extent and land classifications of the city throughout the twentieth and twenty-first century using a geographic information science and historical-geographic approach. This approach provides the basis for a structured archival historical-geographic analysis. Focusing on Hyderabad, India from 1687 to 2019, the objectives of this research are to: (1) delineate and quantify the geographic extent of built-up urban area using scanned historical maps and remotely sensed imagery; and (2) evaluate spatial patterns of change in urban area extent and form. Results indicate that historical factors such as the initial Qutb Shahi urban design, industrialization, the 1908 flood, early twentieth century pandemics, and globalization have shaped the extent and spatial patterns of Hyderabad urban form over time.

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Kevin B. Haynes

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1 Introduction

Cities are a microcosm of the complex relationship between humans and the environment. Humans adapt to and adopt the natural environment to meet specific needs. Attempts to shape the landscape have produced cities that undergo historical transformations. Humans adapt existing infrastructure and make alterations to meet contemporary needs. Many urban challenges revolve around how to deal with infrastructure designed for another time.

India has experienced unprecedented economic growth since economic liberalization took place in the 1990s (see Figure 1.1). At the same time, urban populations have consistently increased (see Figure 1.2). Spatial and temporal patterns can help us understand how best to plan cities for the future. Urban growth in many of India's largest cities has outpaced the ability of city planners to react. The history of India's built environment is dramatic. India, as with the greater South Asia and much of the Muslim world, urbanized much earlier than Europe. Thus colonial-era and later forms of municipal growth must be reconsidered in the light of this fact. The methods employed to study Indian urbanization are markedly different than the models used to analyze Western cities. From changing empires to colonialism under the East India Company, a company incorporated by British Royal charter as a monopolistic trading body, to the British Raj, when India was directly ruled by the British crown, to independent India and finally globalization has all influenced the development of urban areas. The oldest layers of Indian cities were designed to support regional kingdoms. The East India Company influenced the urban design to benefit its interests. Following independence, cities had to adapt to the infrastructure needs of a secular democracy. The history of layered, urban forms has created challenges to the city of today. The western world is now facing issues of urban population growth that colonized

realms experienced first. Population and economic pressures have stressed inadequate infrastructure.

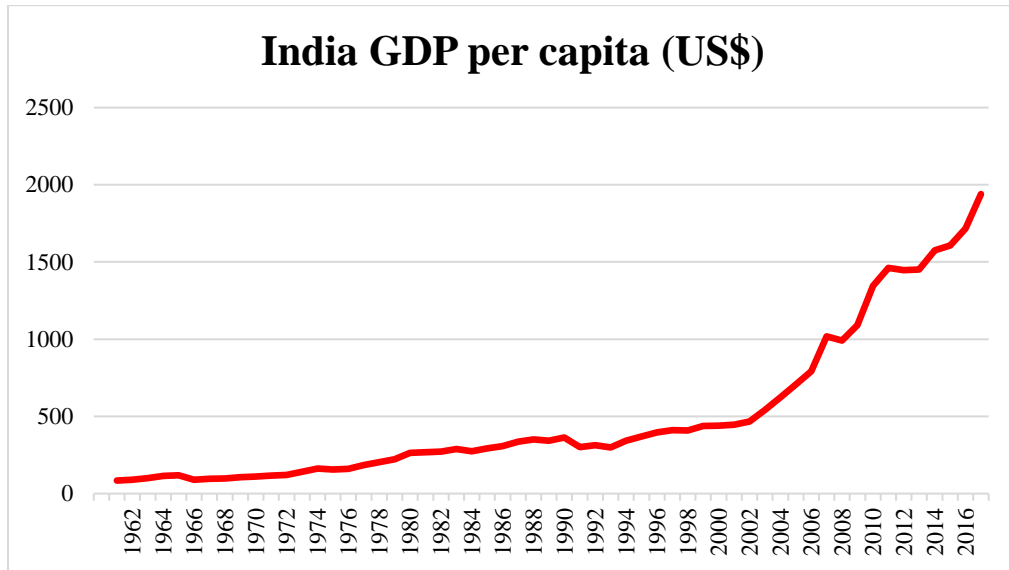


Figure 1.1 India GDP per capita (World Bank, 2018)

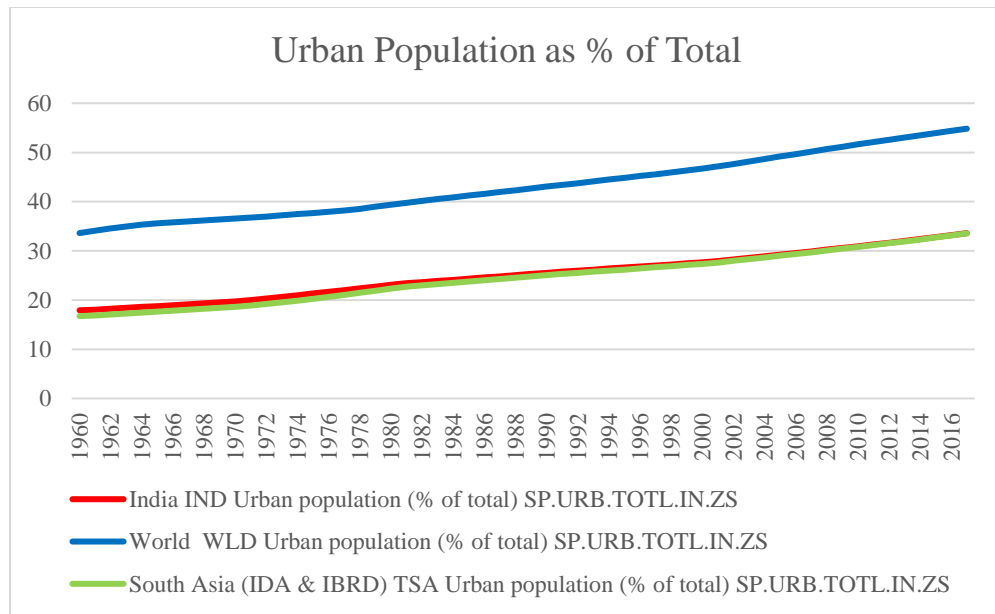


Figure 1.2 Urban population % of total (World Bank Data, 2017)

Urban growth has tended to outpace planning efforts by the various levels of government (Roy, 2009). Given current levels of capital investment, planners are facing challenges trying to keep up with the demands of the population and economic expansion. In its four centuries of

history, Hyderabad, the city this thesis research will focus on, has hosted kingdoms, colonization, and conquests. The results of human urban activity are etched onto the landscape. Gray (2008) projects Hyderabad to be the fourth fastest-growing city in the world from 2019-2035 (see Figure 1.3).

| Top 10 fastest-growing cities in the world, 2019-35 | | | | |
|---|-----------------------|-----------------|---|---|
| Rank | Growth (%/y, 2019-35) | City | GDP 2018 (\$ billion, constant 2018 prices) | GDP 2035 (\$ billion, constant 2018 prices) |
| 1 | 9.17 | Surat | 28.5 | 126.8 |
| 2 | 8.58 | Agra | 3.9 | 15.6 |
| 3 | 8.50 | Bengaluru | 70.8 | 283.3 |
| 4 | 8.47 | Hyderabad | 50.6 | 201.4 |
| 5 | 8.41 | Nagpur | 12.3 | 48.6 |
| 6 | 8.36 | Tiruppur | 4.3 | 17.0 |
| 7 | 8.33 | Rajkot | 6.8 | 26.7 |
| 8 | 8.29 | Tiruchirappalli | 4.9 | 19.0 |
| 9 | 8.17 | Chennai | 36.0 | 136.8 |
| 10 | 8.16 | Vijayawada | 5.6 | 21.3 |

Source: Oxford Economics

Figure 1.3 World's fastest-growing cities (Wood, 2018)

In the 1990s, the Andhra Pradesh government and Larsen & Toubro¹ formed a public-private partnership to build the Hyderabad Information Technology and Engineering Consultancy City or Hitech City, including infrastructure investment required to be a hub for the IT sector on the global stage. Larsen & Toubro are also building the Hyderabad Metro Rail, part of which began operation in 2019. Nara Chandrababu Naidu, the Chief Minister of Andhra Pradesh, lobbied Bill Gates to set up their office in Hyderabad. Naidu promised low taxes, land, continuous power, water, and high-speed internet. Hyderabad is now home to leading technology companies such as Microsoft, Google, Amazon, Facebook, Apple, Yahoo, IBM, Texas Instruments, Hewlett-Packard, and Intel to name a few. Though the infrastructure has been put in

¹ Larsen & Toubro is one of India's largest multi-national firms. It is a technology, engineering, construction, manufacturing, and financial services conglomerate, with global operations.

place to support Hitech, the city is still coming to terms with the new transportation and residential requirements. Hyderabad closed the Begumpet Airport in 2008 and built the Rajiv Gandhi International Airport close to Hitech City. In the late 2010s, Hyderabad built an eight-lane ring road that circles the city, with plans to construct an elevated inner-ring road and in 2019 began metro rail service.

Hyderabad was founded in 1501 after the nearby Golconda Fort settlement became obsolete. During this period urban settlement expended along an east-west axis. In 1806, the Secunderabad British military cantonment was founded, and urban settlement began expanding along a north-south axis. Since Hitech city was established, urban settlement has reverted to east-west urban settlement expansion. This thesis explores these metropolitan level shifts in the face of the importance of Hyderabad to the global economy.

This study will examine how the history of colonialism and globalization have shaped urban morphology in Hyderabad. Urban morphology theory presents a lens to filter history to determine how history has impacted the size and shape of a city. It focuses on the city plan as a starting point and follows how city plans changed and how the city developed in response to the plans, and the social and material realities of the time. While history from 1687-2015 can be a daunting undertaking. Urban morphology theory allows the vast amounts of history to be filtered to specifically focus on the objectives relevant to this study. Although there is a myriad number of interesting histories associated with South Asia and Hyderabad, it is impossible to explore all of them without getting lost. Scale is another confounding factor that complicates urban analysis. We could examine architecture, neighborhoods, or transportation systems. In this study, the scale of analysis will be the city, specifically, the urban extent. Of course, the urban morphology of architecture, neighborhoods, and transportation systems are related to the urban extent and each

other for that matter, the focus of this urban examination will be on the metropolitan level urban extent. From time to time, other scales of analysis will be brought into view for context, but the focus will be on the metropolitan scale. This study is designed to look at how the urban extent has increased and to evaluate the spatial patterns of change using satellite-based remote sensing and historical map analysis. This study continues research conducted by Alam (Alam, 1965; Alam & Khan, 1972), which is the only comprehensive metropolitan-level research focusing on Hyderabad. Alam's work on urban build-up in Hyderabad starts at the end of the sixteenth century and ends in the 1960s.

1.1 Objectives

From indigenous city to colonial city to information technology superpower, Hyderabad has experienced tremendous physical change over time. Shedding light on the histories of precolonial conditions, colonial, and post-independence, and their impact on urban morphology can help us understand the urban challenges that exist in India's largest cities. Specifically, this research will address the following objectives:

- 1) Delineate and quantify the **geographic extent** of built-up urban area in Hyderabad, India from 1687 to 2019 using a mix of scanned historical maps and remotely sensed imagery; and
- 2) Evaluate spatial **patterns and rate of change** in urban area extent and form over this study time-period, specifically focusing on the known change from north-south directional morphology to east-west, and, more importantly, determine the reason behind this directional change.

2 Introduction to Urban Morphology, Islamic Theory, Colonialism, and Globalization

Urban morphology is “the study of human settlements, their structure and the process of their formation and transformation” (Kropf, 2018, p. 9). Urban morphology is a common framework for the consistent and rigorous descriptive language of the built environment. This section will focus on urban morphology theory, Islamic cartography, the effect of colonialism on indigenous Indian urbanization, and the role of globalization in changing patterns of Indian urban morphology in the twenty-first century. This work will explore how cities have grown, change, and develop unique urban characteristics as a result of Islamic, colonial and post-independence histories.

The complex interconnectivity of urban morphology presents an analytical challenge. The oldest analytical approach is descriptive. The goal of all research tends to be descriptive at some level of analysis. This approach suffers from several weaknesses. The endless possibilities and subjective nature of the descriptive analysis is the most daunting challenge (Lynch & Rodwin, 1958). For example, how should the narrow winding labyrinths, full of dead ends and irregular streets of nonwestern cities be described? The author, often an outsider, attempts to make understand the city through the lens of their own experiences and conceptualizations (Falahat, 2014). This can result in superficially and poorly describing and evaluating the city based on their ideas of what a city ‘ought to be.’ Urban morphology theory has been developed to address the challenge of subjectivity.

More structured methods have been developed to address the challenge of subjective description. One such approach is the study of how the physical environment is transformed (Lynch & Rodwin, 1958). Historical-geographic analysis can help to focus the description on the nature of change and the conditions associated with changes. The limitations of this strategy are

the difficulties associated with disentangling which of the unlimited variables are most important and how they are related.

A more pragmatic approach taken by urban planners is to emphasize problem-solving or (re)shaping the physical environment to address problems. The pragmatic approach tends toward *realism*. The weakness of this approach is the assumption that ideas and theories are of no value as a guide for dealing with individual cases (Lynch & Rodwin, 1958). There is a static nature to this method. Each case is considered independent, and this method cannot easily learn from other cases. Urban morphology theory has become a powerful method for addressing the complex interconnection between humans and the urban environment.

One exceedingly complex interaction is the Indian colonial experience, which significantly altered Indian urban morphology. There are three phases associated with colonial urban morphology (Desai, 1995). Early colonial urban morphology focused on production and manufacturing stayed in enclaves separated from the indigenous town. While the Europeans themselves intermingled with Indian society, taking wives, and seeking courtly positions they had less impact on urban morphology than in later periods. The second stage or the suburban stage focused on the needs of Europeans who wanted a new architectural creations such as the bungalows. Finally, the grand phase focused on showing strength by building grand urban forms, such as the Victoria Memorial, the Gateway of India, and the Koti Residency.

The social order must be emphasized to understand urban design because it is the Indian social structure that is more important and a defining factor in the type of urban forms of pre-colonial India. British colonialism impacted both urban forms as well as social structures. In the post-independence period, Indian society is having to negotiate the complex impacts of British

colonialism on society. The colonial experience dramatically altered urban morphology, social structure, and religion.

Now globalization is placing new pressures on Indian society and the built environment. Since the 1980s and 1990s, globalization has significantly altered urban spatial relationships between humans and the environment. Historical processes place both internal and external urban pressures on the natural and built environment. The story of India is dramatic and long. Internal and external pressures placed on India, are equal to the socio-economic importance of India.

2.1 Urban Morphology

The use of history to study of urban morphology can be traced back to Conzen in the early 1960s. The Conzenian school of thought began with town-plan analysis. Three units of analysis—the town plan, patterns of building forms, and patterns of land use are essential to studying urban morphology. (Conzen, 1960). Departing from the prevailing British norm at the time, Conzen conducted microanalysis on the smallest units of urban form (Whitehand, 2001). Conzen's concepts and methods about the process of urban development and change helped to solidify this school of thought (Whitehand, 2001). The Conzenian school of thought became notable after Whitehand published several articles about Conzen's works (Whitehand, 1987, 2001, 2003) and produced several urban morphology students such as Larkham, Kropf, and Lilley.

The Italian school began independently starting with Saverio Muratori, an architect who focused on operational histories to teach architectural design studios but was scorned by his modernist architecture colleagues (Moudon 1997). Gianfranco Caniggia continued using historical approaches to *form* by exploring patterns of form. Finally, a third French school

developed when Philippe Panerai and Jean Castex founded a school of Architecture in Versailles that challenged modernism by placing importance on the historical development of cities with sociologists Jean-Charles DePaule (Moudon, 1997).

The three schools became aware of each other and began collaborating on theory and methodology. The International Seminar on Urban Form (ISUF) held a series of meetings in the 1990s that showed the emergence of an interdisciplinary field beyond the discipline of geography (Moudon, 1997). The three schools formed a consensus that, at the most basic level, there are three principles of morphological analysis; form, resolution, and time (Moudon, 1997). Form refers to the most basic physical elements buildings, open spaces, plots or lots, and streets. Four levels of resolution are commonly recognized; building/lot, the street/block, the city, and the region. Finally, historical analysis is the only way to understand urban forms because the elements of it are under continuous transformation.

2.1.1 Core Concepts

The study of urban morphology is not limited to concepts and methods mutually exclusive to geography, history, environmental or cultural studies. The built environment co-evolved with humans and the environment, but humans are the source of urbanization. Patterns, whether deliberate or the result of competing agendas produce relationships (Kropf, 2018). Spatial and temporal relationships linked to natural and cultural pressures create urban forms. Because urban morphology is not entirely deliberate, challenges arise from the distribution of resources caused by complex interactions between people and the environment.

The processes that create urban form are both deliberate and non-deliberate. Social and cultural processes evolve from interactions between individuals and groups and the physical environment. The *built environment* is the product of the transformation of the natural

environment through the application of human imagination. Political forces inhibit or alter how these imagined forms become a reality. Political reality forces individuals and interest groups to make compromises. Layered onto the social and political realities of urban development is the natural environment. The availability and cost of materials often constrain architecture. The natural environment influences the types of architecture of a given city.

The study of urban morphology is rooted in several core concepts (Kropf, 2018). *Pattern* makes up the most basic way of thinking about urban morphology. The patterns of relationships, deliberate or not, produce repeating physical patterns of urban forms such as streets, plots, and buildings. Again, these repeated patterns are known as form. Urban form is complex because the relationships between patterns are interconnected; streets frame plots and plots determine building size and shape, which in turn define neighborhoods, and neighborhoods define streets. We could examine the form of a subdivision, a neighborhood, the city as a whole. Each resolution is related to other units making the study of urban morphology challenging. Urban form extends to different hierarchies.

The term *urban tissue* refers to streets, plots, and buildings as a composite (Kropf, 2018), whereas, form refers to the features themselves, tissue refers to them as an intrinsic unit of analysis. Urban tissue is a necessary concept because each level is made up of the lower levels of analysis. *Urban sprawl* refers to urban tissue taking up more area over time. Urban tissue is the product of culture and the political environment of a city.

There are four main branches of urban morphology. Architects use the typomorphological or process typology and the configurational branches — these methods developed in the Italian and French schools. Geographers commonly use the historical-geography and spatial analysis approaches (Kropf, 2018). The historical-geographical approach stems from von

Humboldt's holistic approach to explaining diversity (Kropf, 2018). The historical-geographical method seeks to analyze how characteristics developed over time to explain the structure, patterns, and character of urbanization (Kropf, 2018). The spatial approach, on the other hand, stems from von Thünen's economic geography and models developed by Burgess and Hoyt (Kropf, 2018) making use of quantitative methods and GIS technology to understand relationships underlying the dynamics of urban systems.

The natural environment, human activities, and the physical products of transformation including built and planted features are aspects that are used to help identify the distinct urban tissues that make up a settlement. The fundamental aspects of urban morphology are the natural and built environments. The relationship between the natural and built environment runs parallel to the relationship people have to the environment. The type of use, ownership, social and economic, intention, construction, and perception (Kropf, 2018) shape the urban ecology. The right to access particular features of the built environment is a point of contention for many groups who lack socio-economic power. Natural and human activities interact to produce a quasi-natural built environment.

The material environment is a combination of natural physical features that make up a place and pattern of their relationships. Geology, landforms, water, climate, and ecology are features of the natural environment that we interact with and respond to by altering the natural environment to suit our needs. There is a *gradient of transformation* between the natural and built environment (Kropf, 2018). Therefore, the natural and built environment coexist but with varying degrees of density and intensity. The degree to which natural or built environments interact is the difference between urban and rural. Agriculture is undoubtedly part of the built

environment, but the density and intensity of the effects on the natural environment are less than in urban areas.

2.1.2 Islamic Cartography and Cosmology in Urban Design

To begin to understand the urban morphology of Hyderabad, it is essential to understand the history of Islamic geography, cartography and cosmology. Hyderabad was the Isfahan-I Nau or “New Isfahan” and its designer, Mir Momin Astarabadi (1585-1624/5) based this layout on Isfahan, Iran, also being built at the same time to mark the Islamic millennium. Hyderabad was founded in 1591 by the fifth sultan, Muhammad Quli Qutb Shahi. The city is named in honor of caliph Ali Ibn Ali Talib, the son-in-law and the fourth caliph of Islam, 656-661. Ali was known as Hyder, meaning lion in Arabic. The name literally means “Hydar’s city.” At the time the city was founded it was also known as Bhagyanagar, or city of Gardens. The city was designed by Mir Momin Astarabadi, a Persian intellectual who moved to the Qutb Shahi kingdom from Iran and became Prime Minister. Hyderabad, like Isfahan, follows Persian urban morphologies with intent to mirror the universe. The Islamic urban morphology that produced Isfahan and Hyderabad in the late sixteenth century was based on continuity and discontinuity from Greek philosophy being adopted and changed by Islamic cartography and cosmology. Neopythagorean was a school of Hellenistic philosophies which revived Pythagorean ideas in the first century BCE. Part of this philosophy deals with the desire for the soul to become one with the divine. Zoroastrianism or Mazdayasna is the oldest continually practiced religion originating in modern day Iran. These Islamic cities are the result of a fusion of Neopythagorean and Platonic knowledge with Islam and later Zoroastrian concepts. The urban forms that were produced took Islamic cosmology and ordered it in geometric ways that can be traced to Greek concepts. An

examination of Islamic cartographic and cosmological concepts is crucial to understanding the urban design of Hyderabad in the late sixteenth century.

Early arguments on the urban morphology of Islamic cities draw direct impact of either one factor or a collection of factors such as climate, or the absence of wheeled vehicles, lack of municipal organization, or lack of protection for streets against encroachment but there is a high level of disagreement about how these factors affect the city (Falahat, 2012). To better explain how Islamic philosophy has influenced urban design and architecture, Falahat (2012) offers a new approach. Each of the factors early twentieth-century authors identified are inter-related and woven into the life of people and affect the way they built their city (Falahat, 2012). For example, water plays an integral role in the shaping of a city but is not limited to an ecological physical presence, rather, water has associated meanings in religion, and religious philosophy (Falahat, 2012). Water is part of the Islamic daily prayer rituals and it represents the metaphysical space that Allah's throne sits upon. Water can be understood as part of the cosmic existence, represented as an element the Quran describes as part of paradise, and a material to cleanse the body to begin prayer to interact with the spiritual world. Water connects all parts of life in an Islamic city.

To better explain how this framework relates to urban design, the concepts of *nazm* and *nizam* can be employed (Falahat, 2012). Not to be confused with the Deccani Nizam rulers, though in concept they are related. A *nazm* is a regular geometric pattern, characterized by Islamic art and ornamentation (Falahat, 2012). While *nizam*, is a cognate word of *nazm* that means a hidden order or framework where all elements of a complex are connected to each other by a logic, but not a clearly defined regular order on the surface (Falahat, 2012). A *nazm* has a *nizam* but a *nizam* does not necessarily have a *nazm*. To Falahat, (2012), “*Nizam* is the direct

result of people's mental structures and presuppositions imposing their rules into the city – structural rules or formal ones – and the manifestation of the presence of the factor at all layers. Each layer imposes its order into the morphology of the city” (p. 95). For example, in the city of Isfahan, see Figure 2.1, the old city was built incrementally over time by people, where some principles and nazams did not have a hierarchy of importance, at different periods of time different nazams were more important, producing specific types of urban forms at that time producing a non-geometric form in this part of the city (Falahat, 2012). In the Safavid period, Isfahan was designed using a hierarchy of nizam that dominated, the ideas of the shah (Falahat, 2012). Hyderabad was also designed based on this nizam hierarchy. It was the Shah's view of order based on his interpretation of the Islamic philosophical/scientific school of cosmology that dominated the hierarchy of the nizam. From this hierarchy, other vital elements of the city such as water, society, and religion were inserted resulting in a geometric order derived from this hierarchy (Falahat, 2012).

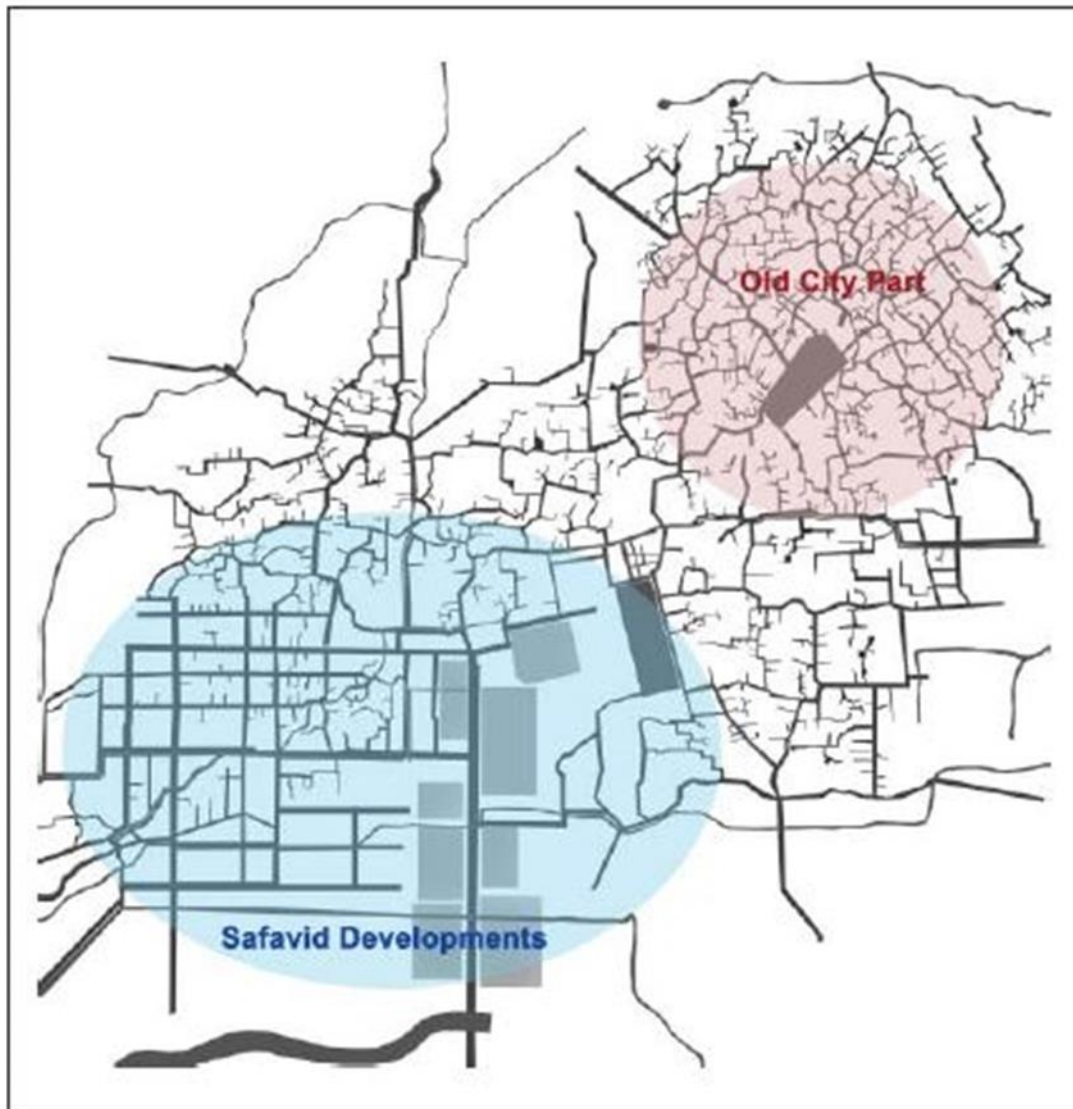


Figure 2.1 Isfahan, Iran transportation network morphology from (Falahat, 2012, p. 97)

Within Islamic geographic traditions, there are both continuity and discontinuity stemming from the Greek cartographic traditions, such as Ptolemy (Karamustafa, 1992a). These concepts tie into the concepts expounded on by Falahat (2012). The Savivid reordering principles can be directly linked to Hellenic science and philosophy. Ptolemy lived from 100-170 C.E. and his writings represent the culmination of Greek and Roman science and philosophy in many fields. Some, but certainly not all, of Ptolemy's writings on cartography were put into practice by

Islamic scholars. Ptolemy's writings, though, took on new meanings' centuries later in Europe (Karamustafa, 1992a). Continuity of pre-modern science, throughout time and across cultures caused discontinuities, yet among pre-Islamic Arabian, Persian, and Indian scholars there remains a keen understanding about the role that Greek cartography played in the heritage of Islamic cartography (Karamustafa, 1992a).

There is a clear role that Islamic cartography has in determining how the idea of a map is accepted as a basic form of communication with identifiable social functions (Karamustafa, 1992a). Although there is evidence of text-free maps from the pre-Islamic and early Islamic periods, maps were produced and consumed by elite groups (e.g., educated, literate, upper classes, and professionals such as astronomers, astrologers, sea captains, and political figures). Maps were not widely available in the pre-modern Islamic world. Although block printing techniques from China arrived in the early Islamic world, these techniques were not adopted in Islamic cartography until the late eighteenth century (Karamustafa, 1992a). A translation of *Geographie d'Edrisi* Muhammad al-Idrisi translated by Pierre Amedee in 1840 first focused scholarly attention on the study of Islamic geography (Karamustafa, 1992a).

Al-Idrisi is a prime example of how early Islamic thinkers continued pre-Islamic Greek philosophy while also diverging from it. Al-Idrisi became known as one of the foremost geographers and cartographers of medieval Europe (Ahmad, 1992). Two cartographic schools developed during the early period the Ptolemaic and the Balkhi schools with Al-Idrisi within the former (Ahmad, 1992). The Balkhi school was started in the tenth century by Abu Zayd al-Balkhi. Although the Balkhi school adopted some Ptolomic concepts the school focused on Islam and mapping Islamic regions. Al-Idrisi was aware of the Balkhi School but the Balkhi geographers only ever created regional maps of the Islamic empire while Al-Idrisi focused on

smaller scales of map production (Ahmad, 1992). Both schools of thought drew on Greek knowledge. Al-Muqaddasi of the Balkhi school uses Greek ideas of climates based on the length of the noonday shadow (Tibbetts, 1992). Al-Idrisi on the other hand made Ptolemaic sectional maps, while improving on ideas of Ptolemy. Climate regions were defined by latitude, which, Al-Idrisi expanded by dividing each region into ten groups (Ahmad, 1992). Al-Idrisi is the most widely known pre-modern Islamic scholar to adopt and diffuse Hellenic philosophy into Islamic scholarship. It is precisely this fusion of Greek and Islamic thought which later influenced the urban design of Isfahan and Hyderabad.

Cosmological diagrams or maps of reality are found as graphic aids to Arabic, Persian, and Turkish texts (Karamustafa, 1992b). Islamic cosmology, is characterized by continuity and discontinuity with pre-Islamic thought. There was no single, continuous tradition of cosmological speculation that produced a set of homogeneous diagrams to illustrate any universally accepted Islamic cosmology (Karamustafa, 1992b). Rather, there are several schools of thought. Three schools of premodern Islamic cosmology tradition have been identified: philosophical/scientific, gnostic, and mystic (Karamustafa, 1992b). The philosophical/scientific school of cosmology became an important part of Iranian philosophy and influenced the design of both Isfahan and Hyderabad based on the fusion of Greek form and Islamic cosmology. The Quran does not contain a systematic cosmology (Karamustafa, 1992b). The hadiths, the second major source of the Islamic religion are richer in cosmological content (Karamustafa, 1992b). These interpretations of the Quran offer details that complement the Quran but also elaborates on aspects of the Quran that are only mentioned in passing. The gnostic and mystic schools of cosmology discourages adopting inquisitive attitudes toward ambiguous sections of the Quran explaining them as being beyond human comprehension and viewed the philosophical/scientific

school with suspicion (Karamustafa, 1992b). The philosophical/scientific school of thought developed in the ninth and tenth centuries CE. were directly influenced by pre-Islamic theorizing, especially Greek (Karamustafa, 1992b). Islam spread through the Iranian and Indian regions in the second century of Islam and with it brought regional contributions to the philosophical/scientific school of cosmology. The adoption of Hellenistic philosophies such as neo-platonic ideas furthered speculation from the other schools. Both of these schools are esoteric in religion and assign priority to the hidden inner truth over outward manifestations and therefore went beyond the Quran and hadith to design their own cosmologies that had no parallel in literature (Karamustafa, 1992b). The philosophical/scientific school was markedly exoteric as it focused on how divine identity manifested in the material world. This exoteric cosmology is what produced modality of designing cities based on cosmology.

However, esoteric Islamic views also left a mark on the philosophical/scientific school of cosmology. Iranian influence on the philosophical/scientific school of Islamic cosmology has direct connections to Islamic urban design. Iranian influence on Islamic cosmology of the philosophical/scientific school fused Zoroastrian Mazdean philosophy and platonic ideas. Notably, Shahab al Din Yahya ibn Habash Suhrawardi in the twelfth century fused Islamic philosophy with Zoroastrian and Platonic ideas (Hodgson, 1974). Suhrawardi stated that his wisdom was nothing more than a restating of ancient knowledge, guided by mystical inspirations which had been misguided by *falsifah*, Arab philosophers since Aristotle (Hodgson, 1974). Suhrawardi revived Plato as against Aristotle and even traced Iranian tradition to Hermes long before Plato (Hodgson, 1974). The continuity from Hermes, Pythagoras, and Plato Islamic Iranian thought brought a focus on distinctive structures of society and of geometry. These

influences led to sixteenth century urban design of both Isfahan and Hyderabad using urban design to represent the cosmos, to create heaven on earth.

Shaykh Baha' al-Din al-'Amili was a Shia scholar, philosopher, architect, mathematician, astronomer, and poet who lived in during the Safavid period in Persia from 1547 to 1621. He mastered both the exoteric and esoteric sciences and defended both dimensions of Islam, arguing that esoteric comprehends the exoteric but the exoteric excludes the esoteric (Nasr, 1987).

Shaykh Baha' al-Din al-'Amili is known as one of the chief architects of the new city of Isfahan based on Islamic cosmology. During the Safavid period all aspects of society were related to a transcendent norm be it literature, architecture, city planning, or even sports (Nasr, 1987). The water that flowed in geometrically shaped gardens, the earth of the mud walls of structures had religious significance (Nasr, 1987). During this period, Persia rapidly became Shi'ite (Nasr, 1987). Shah Ismail claimed to be the reincarnation of his grandfather, Safi al-Din the progenitor of the Safivi order. The Safavid dynasty was originally a Sufi order but the Safavid order, which had become the ruling dynasty, tended toward exoteric and worldly things (Nasr, 1987).

The urban design of these Islamic cities follows both a continuity from ancient Greek philosophers, Zoroastrian philosophy as well as a discontinuity of cosmological concepts and ideas that have been fused with the ideas of Islamic philosophical/scientific school of thought. The outcome of this continuity and discontinuity from pre-Islamic to Islamic philosophy guided the design of urban forms that represented Islamic cosmological ideas but with the structure and geometry of pre-Islamic theorizing.

After 1000 CE, Islam spread gradually through most of the densely populated parts of the eastern hemisphere and by the thirteenth century, Islam had extended through the core area of the Sanskrit culture in India, Indochina, and Malaysia (Hodgson, 2009). By the fourteenth century

Islam had spread throughout the Hellenic peninsulas and by the fifteenth century had extended in all directions (Hodgson, 2009). Europe was subjected to Muslims but large parts of the Latin west and Russia remained relatively independent (Hodgson, 2009). In the case of India, the Sanskrit north was largely Islamized and the Dravidian south India came under Muslim domination (Hodgson, 2009).

The Delhi Sultanate was a Persianate kingdom that ruled most of India from 1206-1526 that came under the rule of five dynasties. Following a revolt against the Tughlaq sultan in 1347, the Delhi Sultanate stepped down and the Bahman Shah formed the Bahmani Sultanate. The Bahmani kingdom lasted from 1347-1527. In 1518, the Bahmani Sultanate broke into five states, Nizamshahi, Qutb Shahi, Barid Shahi, Imad Shahi, and Adil Shahi, known as the Deccan Sultanates. These Deccan Sultanates were the first major Shia Islam political influence in India (Jones, 2012). Beyond political influences, many Shia cultural forms began in South India, such as the *majlis* sermon and *marsiya* poetry (Jones, 2012), both of which commemorate the suffering of the Karbala martyrs deaths at the battle of Karbala. Likewise, Sufi practices share traditions with Shi'ism such as Sufi cults of devotion to Ali and his descendants. Shia culture was not imposed on the Deccan, rather Shia culture itself can trace its roots to the Deccan. Shia culture thrived in the Deccan throughout the late medieval India period.

To understand how and why Deccani rulers would have adopted an Islamic cosmology based in the philosophical/scientific school of cosmology which draws from pre-Islamic knowledge, it is essential to understand how non-religious traditions disseminate within regions of the Islamic world. The term Islamicate refers to “objects or cultural features that are not related directly to the religion but are often based on traditions taken over from other cultures and nurtured and developed by Muslims” (Savage-Smith, 1985, p. vi). The term is most

appropriate when used to refer to science and technology in the Islamic world, particularly to refer to how Hellenistic, Roman, and Byzantine have been adopted by the Muslim world (Savage-Smith, 1985). It refers to geographic regions where non-Islamic culture is shared. Different aspects of cultural, scientific and philosophical ideas developed during this period of time and were shared and adopted by each other. By the fifteenth century, exoteric Shia science and philosophy flourished among the dynasties in both Persia and the Deccan Sultanates. It could be said that because of exoteric Shia thought that became popular at the time, these kings were inspired to create Islamic society, including cities, into idyllic earthly Islamic representations. The scholars who expounded Islamic science and philosophy but had continued the lineage from Greeks offered the easiest way to create Islamic cities using the reordering principles Nazm and Nizam.

2.1.3 The Colonial City

The precolonial city architecture differs from that of the Mughal north (Alderman, 2010). In the north carved stone or marble was used to adorn buildings. Deccani architecture was influenced by south Indian Hindu traditions and relied on wooden columns and beams. Because these materials are less solid than Mughal construction, many of these buildings are either in poor condition or have collapsed (Alderman, 2010). Deccani buildings were adorned with stucco, painted, or used ceramic and wood for surface decorations. The Charminar in Hyderabad is an example of this late sixteenth century architecture. The Deccani sultans incorporated local Hindu elites into their power structures and brought in talented immigrants from throughout the Islamic world (Alderman, 2010). This resulted in a mix of cultural influences from the Persianate, Turkic, Arabic, and later European design. In Hyderabad, none of the Qutb Shai palaces have survived but Mecca masjid, the Charminar, aqueducts, mausoleums and bridges

have. Most of these Qutb Shahi era architecture has been hidden within twenty-first century urban sprawl.

Between 1750 and 1800, the urban population remained stable. There was a 8.7 % decline in urban population from 1872 until 1911 (Heitzman, 2008). The economic importance of India in the eighteenth and nineteenth centuries revolved around the lucrative textile industry made possible primarily through jute and cotton cultivation and processing. The importance of agricultural production kept the majority of the population in rural villages. At the time, wool dominated the European textile industry. The demand for Indian textiles started the process of colonialization that began as early as 1489. Language and values evolved in response to colonialism. Terms like the bungalow, cantonment, civil lines, and hill stations only exist in India (Desai, 1995).

The Mughal Empire, as well as smaller kingdoms, paid their armies with the rupee, which was backed by silver. British had a surplus of opium and silver from China from the opium trade in India making it easy for the British East India Company to pay more for their private militia. The British East India Company had a militia made up primarily of Indian soldiers. The battle of Plassey in 1757 between the British East India Company and the Nawab of Bengal, Siraj Ud-Daulah, solidified the power of British Colonialism on the subcontinent. After Siraj was deposed the British East India Company installed Mir Jafar as the new Nawab of Bengal. To repay the British East India Company, he allowed them to collect taxes on several administrative units. Before 1757, the British East India Company was a transnational corporation. After 1757, the permanent settlement of Bengal allowed the British East India Company became a political authority or *sarkar*, with the right to collect taxes. Though the Battle of Plassey was a turning point for British power on the subcontinent, it was the

exploitation of political dynamics already happening in eighteenth century India that led to a slow political takeover, such as political and administrative mismanagement in the Mughal Empire.

In the 1600s, colonialism in India was in its infancy and was not yet concerned with urban design. Colonial urban morphology developed in three phases (Desai, 1995). In the early days of colonialism, the institutions of colonialism did not seek to make urban design changes. While Europeans did mingle with Indian society, taking wives, and seeking courtly positions, these early forms of colonialism had less impact on urban design than later trends during the later British Raj. The next phase of colonial urbanization is the suburban phase. Europeans built bungalows and palaces outside of the trading posts. The Koti Residency in Hyderabad is one example of this. Life in the bungalow and the cantonment were kept carefully segregated from indigenous settlements, both in terms of official policy and cultural choice (Guha, 2008). However, as time progressed, it became essential for the Europeans to use Indians to help sustain themselves. They could not replicate the indigenous structures' power to create some center of dominance and subordination (Guha, 2008). Instead, what was created was essentially a tangling of British colonialism and Indian society that required each to resist as well as accommodate each other (Guha, 2008). After the British government took over control of India from the British East India company in 1858 following the Sepoy mutiny, the Nizam of Hyderabad had become one of the most vocal supporters of the British Raj and went so far as to become one of the largest supporters of the first and second world wars, sending vast amounts of money and soldiers to the war efforts in Europe. The Nizam used his palaces to project rank, independence and prestige in their relationship with the British (Alderman, 2010). The forms of power, privilege and subordination characteristic of British-Indian colonialism led to some new urban

forms that were in part influenced by Indians and in part by the British. The British built the Secunderabad Club, the Koti Residency, and the Basilica of Our Lady of the Assumption. While at the same time the Nizam began using European design in the courtly palaces. The resulting urban forms built under colonial conditions whether European or Indian became prominent near the end of the British Raj. As the colonial system developed, new urban forms were required to both assert dominance and maintain control on both sides as well as include Indians and Europeans in the process.

The bungalow is an architectural design that originated in the Bengal region of the subcontinent and adapted to meet the needs of Europeans. British women designed lavish gardens around the bungalows to attempt to reproduce the British countryside. Grand buildings like the British Residency in Hyderabad had extensive gardens. These urban forms were designed to distinguish the British from the indigenous people. In the British-only Hyderabad Club, a sign at the entrance stated, “No Indians or dogs allowed.” Segregation was indeed a part of the power structures present at the time.

Another colonial urban design development is cantonment. A military cantonment is a military enclave within the territory of princely kingdoms allied with the British Raj. Cantonments housed both European and Indian troops. Cantonments are racially segregated areas. The first significant demonstration of British military presence in India was in Lucknow and Hyderabad (Heitzman, 2008). The Hyderabad cantonment of Secunderabad was established in 1806. By 1863, 114 cantonments spread across India, mostly in the fertile northern plains. The purpose of the cantonments was to impose order. The colonial physical form is self-evident, but cultural order was also imposed. Rules about bathing and toilet practices, selling alcohol, creating bad smells, and playing music were designed to create separation (Desai, 1995). The

cantonments became essential parts of the urban histories of these cities. After independence, Secunderabad became the largest Indian Air Force base.

2.1.4 The Globalized City

The emergence of globalization as a hegemonic force in the latter part of the twentieth century has forever altered urbanization trends and urban form. Since WWII, processes by which capitalist institutions have freed themselves from national constraints have proceeded to organize global production and markets for their intrinsic purposes. This trend has greatly accelerated over the 1980s (Friedmann & Wolff, 1982). Transnational corporations are reorganizing economic maps around the world, India included, but also the urban forms of the cities within which they operate.

Global cities have the financial infrastructure to maintain the complex services required to sustain transnational corporations to coordinate production, investment, and finance on a global scale despite local and regional needs (Sassen, 2002). There has been a consolidation of a small number of financial centers, at a time when it would be expected that importance would be decreased because of new information technology centers (Sassen, 2002). Dispersion and concentration are a key element of the organizational architecture of the global economic system. The specific forms assumed by globalization over the last decade have created particular organizational requirements. The corporate service complex collectively represents the networks of financial, legal, accounting and advertising firms that handle the complexities of operating in more than one national legal system, national accounting system and myriad advertising cultures (Sassen, 2002).

The *Desakota* model is a theory of urban growth in Asia that broadly argues that urban cores, peripheries, and areas along transportation routes between urban cores evolve as one

through a process of informal market-driven processes (Ginsburg, et al. 1991). This model aims at explaining how urban growth and economic development emerged simultaneously in Asia but via cities that are morphologically different from those in the west. The number of economic decisions that have to rapidly be made exceeds the ability for planners to manage growth directly; the population is too large for planning development and the cities are too vast.

Peri-urban environments are those areas emerging in the periphery around large urban cores, within a daily commuting distance to the city (Ginsburg, et al. 1991). The peri-urban environment is characterized by mixed land use and in the case of India is the result of informal planning processes. The *desakota* model is an urban, regional model specific to Asia, where urbanization preceded industrialization. The model consists of five types of spatial systems (McGee, 1991): (1) urban core; (2) The peri-urban region within a daily commute to the city; (3) the *desakota*, a region with an intense mixture of agricultural and nonagricultural activities, often stretching around the peri-urban region along transportation corridors to smaller nodal cities; (4) densely populated rural regions; and (5) sparsely populated frontier regions.

There are six main features of the *Desakota* (Ginsburg et al., 1991). First, before WWII, the regions around urban cores were used for small stakeholder agriculture production. Second, there is a trend toward nonagricultural production as an emerging 'pillow' for the economy. Three, the fluidity of transportation with inexpensive motorbikes and urban transportation systems. Four, an intense mixture of land use. Five, increased participation of females in nonagricultural activities. Finally, six, the *desakota* falls in a 'grey' zone of lesser administrative and economic controls than the urban core.

Informal planning processes of grey zones cause conflicts in the peri-urban environment. The Indian government uses informal development processes that produce mixed land uses but

create uncertainty in land tenure for the residents (Kadfak & Oskarsson, 2017), yet people continue to live in places with insecure land tenure because they have such limited options. In the wake of large-scale resettlement of slums before the Commonwealth Games in 2010, residents of many long-term informal settlements were relocated to the periphery before the forced relocation people self-identified with urban ideas of openness while after the relocation landscapes and residents sought to distance themselves from the city identity (Taubenböck et al., 2009).

Employment diversification should be viewed as a positive trend for peri-urban residents. There is a close relationship between industrial productivity and per capita income for rural communities (Veeck, 1991). The peri-urban environment allows for mixed land use with industrial land use coinciding spatially and economically alongside non-agricultural services and agricultural land uses. Mixed land use helps once agricultural households slowly transition away from agriculture. In the stock markets, the common appropriate phrase is 'do not put all your eggs in one basket.' Livelihood diversification is suitable for household stability. India cannot maintain economic growth with the majority of its population only working on small-scale farms in a traditional agricultural sector. The peri-urban environment is a decentralized catalyst for change in one sense but brings with it a new set complete and emerging of conflicts that force residence to renegotiate rights to local resources to support the urban core through livelihood diversification (Sreeja et al., 2017).

The economic and physical expansion of cities in India has surpassed the expectations of even the most forward-thinking planners. The government either cannot plan fast enough, or planners underestimate infrastructure needs, or there is a paradigm shift from centralized state-run infrastructure plans to infrastructure development planning managed by private developers

that are often given state monopolies to carry out this work, often with insufficient state oversight (Roy, 2009).

Indian planners cannot forecast and manage growth; urban planning has to be understood as the management of land resources through dynamic processes of informality (Roy, 2009). Regulations or laws cannot fix land use planning; this can only be accomplished in two ways. Firstly, by having vague laws where what is legal is based on what has a 'global' look or secondly, through a process where the state puts itself outside the law for development. Modern states in Asia do not plan with technology, counting, mapping, and enumerating. Rather, the planning process operates through what Roy (2009) calls the 'unmapping' of cities through the use of eminent domain and institutional flexibility in altering previous land-use decisions and regulations.

There are competing narratives in all Indian cities. Bangalore and Hyderabad are no exception. These cities provide world-class information technology (IT) services, and those companies demand world-class services. IT companies are provided 24-hour power and receive water from cleaner rural aquifers. In contrast, residents of most Indian cities do not have 24-hour water and electricity. Bangalore now has a \$100 helicopter taxi service but yet has a mean per capita monthly income of only \$420 in 2014 (Roy, 2009). Neoliberal development uses statist tools such as eminent domain for private development, the development of special economic zones that are easier to inundate via population displacement for development locations that *looks* world-class. This includes glass buildings that act as greenhouses that require more air conditioning in the Indian heat and contribute to excessive depletion of natural resources to support the global city. As all of these pan out, the majority of people are not able to take

advantage of the benefits of this development and continue to fear land insecurity and economic instability (Roy, 2009).

Given that conditions, conflicts, and cooperation simultaneously arise from peri-urban interactions. Land-use changes cause water conflicts. Peri-urban conflicts are rooted in the issue of land change, through systematic exploitation of the resources through the acquisition of land use and water to serve urban expansion (Vij et al., 2018). In Hyderabad, conflict arises from resources regularly and officially getting diverted from the periphery such as water and electricity to the IT sector business district and surrounding middle-class neighborhoods.

The process of urban expansion into peripheral areas also causes several environmental challenges. Northwest Delhi has had a 27% decrease in agricultural land from 1972 to 2003 (Rahman et al., 2012). Environmental impacts caused by structural changes in the peri-urban periphery of Hyderabad cause farmers to choose to use more water, machines, and chemicals to increase productivity contributing to environmental degradation (Hussain & Hanisch, 2014). Causes and effects of urbanization on agriculture include greater population pressures, high land prices, agricultural land consumption lost to other uses, insecure land tenure, in-migration, and decreasing farm incomes. The depletion of water, organic soil nitrogen, and increased chemical residue are all effects of the structural changes in the transformation of Hyderabad's peri-urban environment (Hussain & Hanisch, 2014).

Urban planners and architects in India are moving away from Western models of development to design urban environments that are more appropriate to Indian lifestyles and cultural values (Desai, 1995). The Desakota concept is helping researchers understand the patterns of urbanism in Asia. As India emerges as an economic powerhouse, urban systems are being evaluated, retrofitted, or built from scratch to effectively compete in the twenty-first-

century economy. The theoretical foundations of urban morphology and the impacts of colonialism and globalization lay the groundwork for GIS-based computer techniques for the monitoring of urban morphology and land-use changes. The next section will focus on how researchers use satellite imagery to monitor and measure changes in urban morphology.

3 Remote Sensing Techniques for Urban Observation

Urban build-up or urban extent is often considered as the central parameter for quantifying urban sprawl (Torrens Alberti, 2000; Barnes et al., 2001; Sudhira, 2004). Land cover and land-use change (LCLUC) analysis seeks to understand the dynamic land changes taking place. LCLUC is an interdisciplinary scientific theme that directly addresses the societal aspect of land processes (Justice et al., 2015). Understanding the dynamic phenomenon of urban sprawl requires land cover change analysis using remote sensing (Sudhira et al., 2004). Measurement of areal coverage and spatial distribution are needed to describe the morphology of an urban area adequately (Schweitzer & Steinbrink, 1998 as cited in Taubenbock et al., 2009).

Land classifications have been used to measure land use and land cover since the dawn of earth observation satellites in the 1970s. *Land use* refers to how land is used; land use is a cultural artifact while *land cover* refers to the biophysical material found on the land (Jensen, 2007). Land classification is used to measure urban sprawl (Rahman et al., 2012; Sudhira & Ramachandra, 2007; Garouani et al., 2017; Kumar et al., 2014; Sudhira et al., 2003; Kar et al., 2018). Land classification systems are altered depending on the objectives of the study, yet several standard systems have been adopted. Singh, (as cited in İlsever & Ünsalan, (2012) defines the basic premise of LCLUC; changes in LCLU result in changes in remotely sensed radiance values and that changes in radiance values due to LCLUC are much larger than other factors.

Satellite-based sensors such as the Landsat Multispectral Scanner System (MSS), Thematic Mapper (TM), Operational Land Imager (OLI), and Thermal InfraRed Sensor (TIRS) measure reflected or emitted electromagnetic radiation in different bands with specific

wavelength intervals. The principle of absorption and reflection of electromagnetic waves is used in remote sensing techniques to determine the type of land cover each pixel of data represents on the ground. Projecting multispectral bands in different ways in computerized geographic information systems can help delineate various LCLUC. False-color composites are created by placing various multispectral bands into the RGB color gun in GIS software. For instance, projecting the near-infrared (NIR) band as red can create a false-color composite where vegetation shows up as red. False-color composite techniques can help assist in the selection of training sites by visually showing areas of vegetation.

Several standardized systems for classifying LCLUC have developed. One of the most common methods of land cover classification was developed by the Multi-Resolution Land Characteristics consortium (MRLC) system that was adapted from the Anderson land level 2 classification system and created the national land cover database (Anderson et al., 1973). The Anderson land classification system differentiates levels of spatial resolution, which should not be confused with Landsat data processing levels. Level I differentiate urban land from other land-use classes such as agriculture, forests, and water. Level II delineates a detailed inventory of Level I classes. When measuring urban build-up, the specific use of an urban area is not necessary (Jain et al., 2016).

Sudhira et al. (2003) used digitized topographic maps from the 1971-1972 Survey of India to incorporate data from before satellites were operating. Using historical maps to support remote sensing proves to be a powerful technique for assessing urban land cover change over time. Historical maps have been produced for hundreds of years, making them a treasure trove of data about historical land use.

4 Data and Methods

This study conducts a spatiotemporal analysis using a time series of scanned maps and Landsat data to detect the Hyderabad urban footprint and its change using ESRI ArcGIS Pro

2.3.2. Landsat data has been continuously and freely available since 1972 with a spatial resolution of 60 m since 1972, and 30 m since 1982 (Bhatta, 2010). Table 4.1 shows the input datasets for this study. Specifically, scanned maps of Hyderabad from Alam (1965) provide snapshots from 1687 through 1961 followed maps generated using Landsat 1, 5, and 8 images spanning 1976 to 2015. Alam (1965) urban settlement maps are georeferenced, digitized, and compared to image classification results to determine urban change. Landsat images are available via the USGS EarthExplorer data clearinghouse.

Table 4.1 Data sources and characteristics

| Date | Data Source |
|--------------------------|--|
| 1687 | Alam (1965, p. 4); hand-drawn map (scanned and georeferenced) |
| 1750 | Alam (1965, p. 6); hand-drawn map (scanned and georeferenced) |
| 1865 | Alam (1965, p. 9); hand-drawn map (scanned and georeferenced) |
| 1900 | Alam (1965, p. 11); hand-drawn map (scanned and georeferenced) |
| 1930 | Alam (1965, p. 12); hand-drawn map (scanned and georeferenced) |
| 1944 | Alam (1965, p. 12); hand-drawn map (scanned and georeferenced) |
| 1961 | Alam (1965, p. 14); hand-drawn map (scanned and georeferenced) |
| 10/30/1976 10/31/1976 | Landsat 1 (MSS); 80 m spatial resolution; Level 1 |
| 04/11/1989 | Landsat 5 (TM); 30 m spatial resolution; Level 2 |
| 09/21/1996 | Landsat 5 (TM); 30 m spatial resolution; Level 2 |
| 10/27/2009 | Landsat 5 (TM); 30 m spatial resolution; Level 2 |
| 10/12/2015 | Landsat 8 (OLI); 30 m spatial resolution; Level 2 |

The preferable time for images to be taken is during vegetation green-up because arid, barren land and urban build-up have similar spectral signatures and are difficult to differentiate. Images taken after the monsoons have a wider range of spectral signatures that will make differentiation of land use more effective. The urban build-up has a very similar spectral response to the scrubland and barren land surrounding Hyderabad. The monsoon clouds cover the area during much of this time. Images near the end of the monsoon in August or September, when the monsoon has receded, but vegetation is still green is ideal. Images of this period are not always available. Imagery from the 1980s has many clouds during this time of year; for this reason, the 1989 image used to generate the map for that year is a different time of year than the rest of the images and result in a higher categorization of urban because barren earth and urban have extremely similar spectral signatures.

Landsat 1 images were downloaded radiometrically corrected. After mosaicking them together the study area was clipped from the full scene using an arbitrary boundary around the city. The study area fits within single Landsat 5 and 8 images and were also downloaded radiometrically corrected. The study area image were clipped to match the analysis extent. A supervised land cover classification will be applied by selecting training sites and using MLC. An accuracy analysis is conducted on the final classification due to the limitations of reference imagery. Final LCLUC maps were produced, and accuracy assessments conducted.

The Alam (1965) series of settlement maps were scanned and enhanced in Adobe Photoshop using a color correction tool. When maps have been scanned the ink on the backside of the page bleeds through the scan. The color correction tool corrects for this by turning the grey text bleed through to white. The images were georeferenced using the spatial adjustment toolset in ArcMap. The urban extent was then hand-digitized for each scanned image as a new polygon

(area) dataset. Vector polygons were rasterized and used as inputs for the change detection workflow (see Figure 4.1).

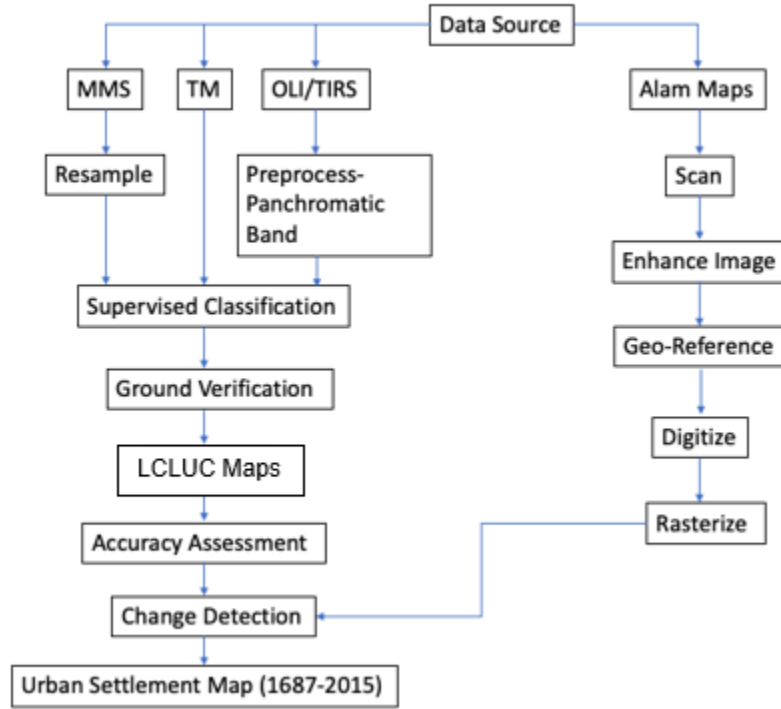


Figure 4.1 Methods workflow

4.1 Remote Sensing Techniques

Landsat 1 MSS data provides a spatial resolution of 80 m, while Landsat 5-8 was increased to 30 m. Landsat 1 imagery will be resampled to 30 m to make all images comparable using cubic convolution (Homer et al., 2004). The first step in the process of supervised classification is to locate training sites for each land cover type. Training sites were created by drawing polygons over areas that represent known/desired land cover types. Reflectance values inside these training sites are statistically summarized and applied to group pixels into classes with similar spectral characteristics. The initial classification system follows a modified National Land Classification Database (NLCD) classification system (see Table 4.2). Each of these land classifications were used to classify the images, and in the end low- and high-density urban were

merged together, and the rest of the categories were merged together to produce 2 categories, urban, and not urban. Hyderabad has a lot of barren/scrubland, but because the focus is to extract urban build-up, the NLCD categories barren and scrubland are being merged for the training sites. The three forest NLCD categories were merged into a single forest class. Rivers, lakes, ponds, and reservoirs (any open water surface) are classified as water. Finally, pasture and cultivated cropland are classified together as agricultural land. All categories except for water, and urban are excluded from the final analysis.

Table 4.2 Modified NLCD classification scheme

| Class/Value | Classification Description |
|--------------------|---|
| Low Density | Developed, Open Space-areas and low-density-areas with a mixture of some constructed but most vegetation. Impervious surface accounts for 20%-49% of total cover. |
| High Density | Developed, medium and high density with a mixture of constructed materials and vegetation. Impervious surfaces account for 50%-100% of total cover |
| Barren/Scrubland | Areas of bedrock, desert pavement, scarps, talus, slides, gravel pits, and other earthen material. Generally, vegetation accounts for less than 15% of the total cover. |
| Forest | Deciduous, Evergreen and Mixed forests |
| Agriculture | Pasture/Hay and cultivated crops are accounting for over 20% of total vegetation. |
| Water | Lakes, rivers, ponds, and reservoirs |

A maximum likelihood classification (MLC) assumes that the statistics for each class in each spectral band are normally distributed and calculates the probability that a given pixel belongs to a specific class. The MLC was applied to extrapolate the training sites to classify the rest of the pixels in the image. The class with the highest probability is assigned to each pixel (Harris Geospatial Solutions, n.d.). MLC was completed, the classes were merged together to create two groupings: urban and non-urban. The non-urban class was removed and the urban classification was overlaid on the ESRI base map.

An accuracy assessment was conducted to quantify how well the MLC assigned pixel classes. There is no consensus about which sampling unit is best (Stehman & Czaplewski, 1997). A pixel-based approach is commonly used (Conese & Maselli, 1992; Fiorella & Ripple, 1993; Fung & LeDrew, 1988; Knick et al., 1997; McGwire et al., 1993). Franklin et al. (1991) argue that remotely sensed data should be considered “point-sampled” data. Because accuracy assessment relies on reference imagery only the 2015 classification has been assessed. The reference imagery used is the 2015 Digital Globe imagery available via Google Earth. Accuracy assessment points were selected using ArcGIS by randomly placing 100 points. Each point was given a value of the classification that it intersected with. The accuracy assessment points were brought into Google Earth and each point was manually classified by the researcher as being urban or not. This produced a table with three columns, object ID of the point, classification intersection, and another with the accuracy assessment findings. This table was converted into a confusion matrix to determine the percent of points that were accurately classified producing the kappa statistic. A Cohen’s Kappa statistic measures the reliability for two raters that are rating the same thing, corrected for how often that the raters may agree simply by chance.

Finally, an analysis of the spatial patterns of change was conducted. The difference between each year was calculated using the raster calculator in ArcMap. Finally, a map was produced that includes the urban extent for each year on record, from 1687 until 2015 and beyond.

4.2 Research Objective 1: Geographic Extent

1) Delineate and quantify the **geographic extent** of built-up urban areas in Hyderabad, India from 1687 to 2015 using a mix of scanned historic maps and remotely sensed imagery.

To delineate and quantify the geographic extent of Hyderabad the series of urban settlement maps beginning in 1687 by Alam (1965; 1972) were scanned. The images were edited in Photoshop to improve the scan quality. The maps were georeferenced and urban extents hand-digitized in ArcMap. The LCLUC analysis was conducted on the selected Landsat images using the remote sensing techniques outlined in section 4.1.

4.3 Research Objective 2: Patterns of Change

2) Evaluate spatial **patterns of change** and **rate of change** in urban area extent and form over this study time, specifically focusing on the known change from north-south directional morphology to east-west, and, more importantly, determine the reason behind this directional change.

To assess the spatial patterns of change in Hyderabad, a GIS-based approach allows for a comparison of urban extent to determine the amount of spatial change over time. To determine why the spatial patterns identified have occurred, field surveys are a necessary part of remote sensing methodology and complement GIS analysis. Urban remote sensing remains a challenge due to the high number of mixed pixels. From experience, the researcher has discovered that Hyderabad has a particular type of problem associated with remote sensing. During the dry season, when satellite imagery is most available, the study area is dry making urban build-up and dry farm or barren land almost indistinguishable. The spatial resolution from the Landsat satellite program is 30 m, which means that if an object is smaller than 30 m, it will confuse GIS analysis. Perceptual aspects of the landscape and townscape can only be determined using qualitative non-participatory observation methods.

An archival analysis is also a necessary part of the historical-geographic analysis. This study is specific to Hyderabad, and many documents are only be available in Hyderabad. The

Telangana State Central Library, the Telangana State Archives, the Hyderabad City Library, the University of Hyderabad and the Osmania University provide access to archival data that is unavailable online or in the United States.

5 Results

This analysis uses historical map comparisons and remotely sensed image classification to delineate and quantify the **geographic extent** of built-up urban areas in Hyderabad, India, from 1687 to 2015. The analysis also draws from official Nizam documents as well as Hyderabad Municipal Development Authority (HMDA) master plans to evaluate the spatial **patterns of change** and **rate of change** in urban area extent and form over the study time period. This portion focuses on the shifting directional morphology of built-up urban areas from north-south to east-west over time to determine why such change occurred.

5.1 Geographic Extent of Urban Build-up

The Charminar and Mecca Masjid were the first buildings built at the site of the new city. The Charminar symbolized the thrown of Allah, while the fountain Gulzar Houz at the next intersection represented the cosmic water the thrown sat on. Back then, the fountain was used for drinking water, and had four troughs extending in each direction for animals to drink. The Qutb Shahi palace was located to the north of Mecca Masjid but it has been lost to time. The city continued to grow until 1687.

In 1687, Aurangzeb conquered the Qutb Shahi Empire in the Siege of Golconda. At the time, the urban built area amounted to approximately 11 sq. km. Following the annexation, Hyderabad, the capital of the Deccan, was relocated to Aurangabad.

The Nizams were appointed to manage the Deccan for the Mughals. Nizam means viceroy. In 1725, Mir Qamar-ud-din Khan Siddiqi Bayafandi or Nizam-ul-Mulk named himself Asaf Jah I and formed the Kingdom of the Nizam, also known as Hyderabad State. Asaf Jah I ruled from Aurangabad. During the first several decades of the Nizam's kingdom, Hyderabad's

growth remained stagnated. The economy could not function well without the wealthy noble landlord class.

Asaf Jah I died in 1748. In Mir Zizam Ali Khan the fifth Nizam moved back to Hyderabad, along with the noble class in 1763. In 1750, the urban built-up area measured approximately 13 sq. km. Hyderabad once again became a regional center of administration, trade, and culture (Alam, 1965). At the beginning of this period of urban settlement, the city had expanded to the east and northern settlement had not yet begun. The city extent remained much the same way it was during the Qutb Shahi dynasty.

By the mid-eighteenth century, the city had begun a period of reconstruction. Old buildings were demolished, and new ones built; many nobles built new homes to the south of the city. By the end of the eighteenth century, the city had three grand bazaars and a wholesale district.

In 1789, the Mir Akbar Ali Khan Asaf Jah III signed a subsidiary alliance with the British East India Company. The second twin city stage began with the founding of Secunderabad north of Hyderabad. The relationship between Hyderabad and Secunderabad and urban build-up remains a salient feature of urbanization until the present day. While urban growth was slow during the eighteenth and early-nineteenth centuries, by the mid-nineteenth century, urban growth expanded rapidly. There was no industrialization in Hyderabad until 1874 (Alam, 1965). By 1865, urban areas had expanded to 20 sq. km. The Secunderabad railway station was proposed in 1870 and finished in 1874 bringing industrialization to the city. By 1900, 7 sq. km. of urban area added totaling 27 sq. km. Industrialization profoundly changed the urban morphology of the city. New urban forms were created to satisfy the needs of industrialization.

The 1908 Musi River flood changed Hyderabad drastically by destroying the city's core and leveling buildings. Following this flood event, the city laid in ruins. The flood caused a mass movement of people from the city to new suburbs north and north-west of the city. The wealthy middle class moved from the city core to the suburbs, which resulted in an expansion of urban built-up area. In the post-flood decades, global influenza outbreaks and several plague outbreaks cause significant challenges for the city. The Nizam set up the City Improvement Board to address the city's sanitation and urban design flaws. Between 1908 and 1942, the City Improvement Board undertook massive public works across the city, demolishing slums, building model homes, laying new street patterns, and developing economic zones. By 1930, urban areas measured 27 sq. km. One major impact of the 1908 flood was the suburbanization of Hyderabad; people moved from the city core to the periphery. By 1944, the area of the city had grown to 32 sq. km.

From 1687 to 1944, the city grew by 23 sq. km., as shown in Figure 5.1. Growth was slow at first due to the political relocation of the Deccan to Aurangabad. Following the relocation of the Nizam back to Hyderabad, reconstruction and city improvement projects focused on the existing infrastructure. The arrival of the British East India Company, the formation of Secunderabad, industrialization, and the Musi River flood were all significant factors that drove an urban expansion.

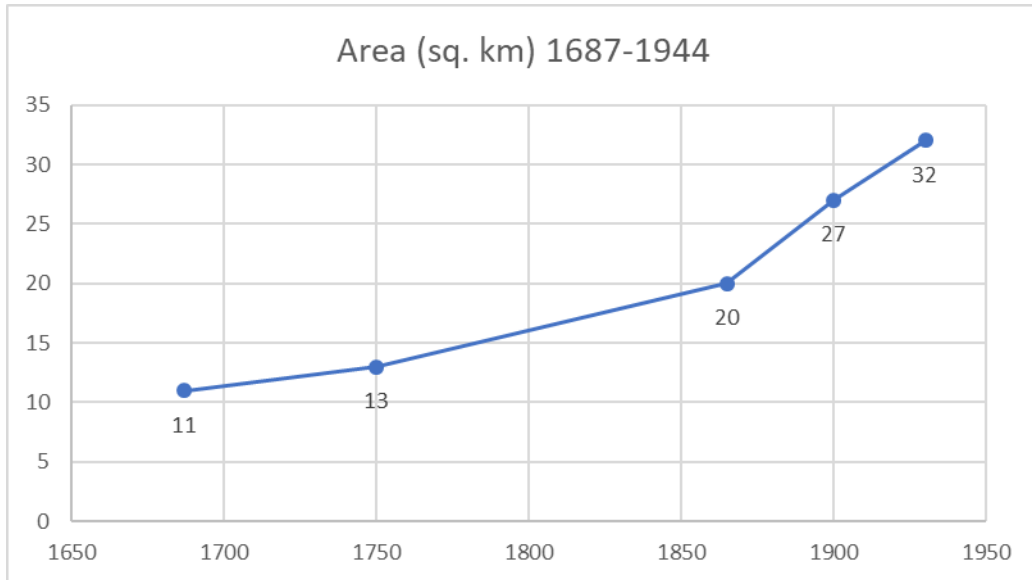


Figure 5.1 Hyderabad urban area from 1687-1944

Hyderabad State joined India in 1948 after a week of fighting between Hyderabad State and the Indian military. Hyderabad became the capital of the state of Andhra Pradesh, and government buildings located to the South East of Hussain Sager reservoir, between Secunderabad and the old city. Secunderabad became a center for the Indian National Army and the Indian Air Force Academy. Suburban growth increased throughout the second half of the twentieth century. Urban build-up is linked to population growth. The population of the city rapidly increased after Hyderabad was annexed by India in 1947, as shown in Figure 5.2.

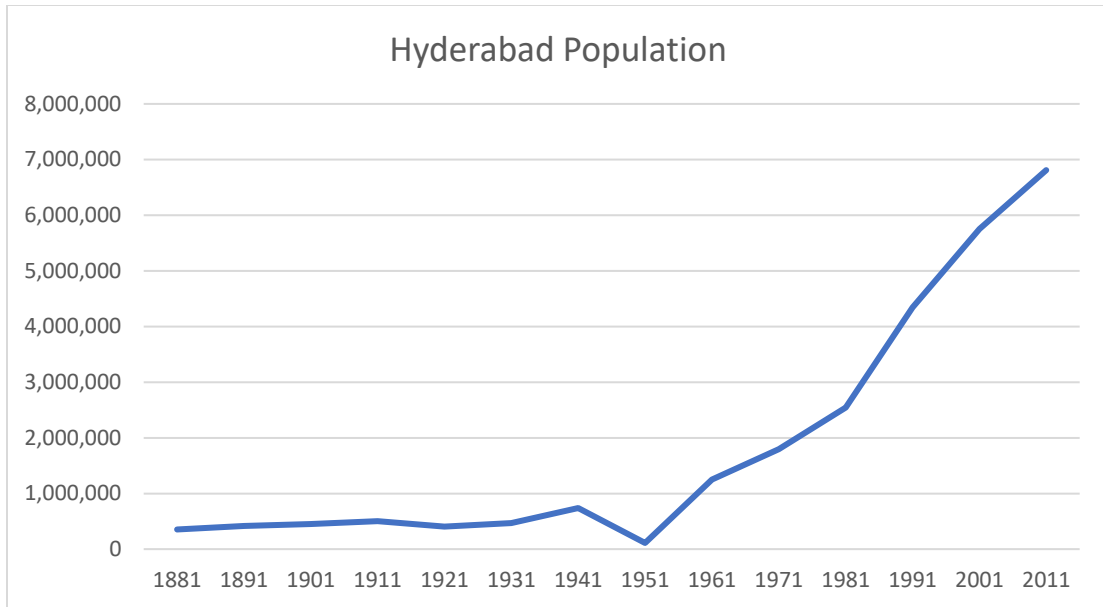


Figure 5.2 Hyderabad population (Source: Padmanabha & Venkatesh, 2011)

By 1975, the urban build-up had increased from 35 sq. km. in 1930 to 51 sq. km. The city was facing post-colonial urban growth typical of cities around the world. Population growth increased rapidly from this point forward. By 1989, urban build-up had reach 426 sq. km. Due to cloud cover, the selection of Landsat data was limited. Satellite data was selected from a different time of year, and as a result, data from 1996 is an outlier. By the end of the 1990s, the twenty-first-century global city was under construction. The data shows urban build-up decreasing, which, of course, is not a reasonable assertion. Overlooking this outlier, by 2009, urban build-up increased to 608 sq. km. By 2015, the city grew to 883 sq. km. From 1975 to 2015, the city grew by 832 sq. km. as shown in Figure 5.3.

Taken as a whole, the twentieth and early twenty-first century urban growth in Hyderabad is unprecedented in Indian history but follows global trends of other cities in the non-western world. Figure 5.4 shows urban growth from 1687-2015. Urban built-up area increased exponentially following economic liberalization in the early-1990s.

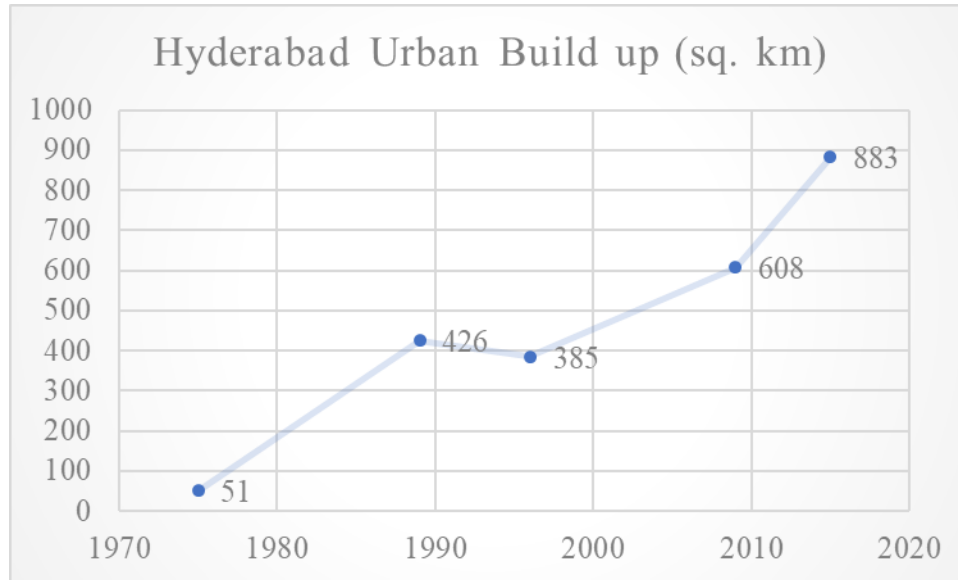


Figure 5.3 Hyderabad urban build-up from remotely sensed image classification

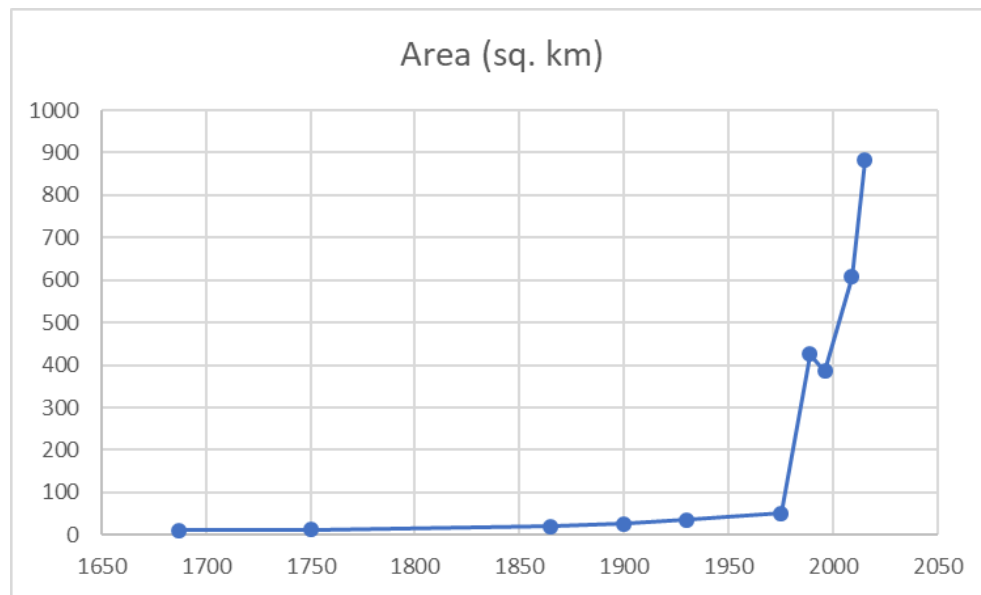


Figure 5.4 Hyderabad urban growth from 1687-2015

5.2 Spatial Patterns of Change

The settlement in the study area began with the construction of the Golconda fort. Initially, the location was a grazing area for shepherds; Golla Konda in Telugu means shepherds hill. Originally known as Mankal, the Kakatiya dynasty built the fort in 1143. Kakatiyas eventually ceded the fort to the Bahmani Sultanate in 1364 (Prasad, 1946). The Sultan Quli

Qutb-ul-Mulk founded the Qutb Shahi Dynasty at Golconda in the wake of a weakened Bahmani Kingdom in 1512. In 1563, Hussain Sagar Lake, a system of aqueducts, was built to provide more water to Golconda. The fort remained the urban center until the fifth Qutb Shahi ruler, Muhammad Quli Qutb Shah, founded Hyderabad in 1591. Golconda had become overcrowded and unsanitary, which shifted urban growth eastward.

As stated in Chapter 2, Hyderabad was the Isfahan-I Nau or “New Isfahan” and its designer, Mir Momin Astarabadi based this layout on the original new Isfahan, also being built at the same time to mark the Islamic millennium. Mir Momin Astarabadi (1553-1626) left his career in the Safavid court and came to the Qutb Shahi to serve as prime minister from 1581 to 1625 under two sultans, Muhammad Quli Qutb Shah and Muhammad Qutb Shah (Rajjak, 2015). The Insha-I Qasir-I Tabbasi, in the Salar Jung Museum (A.N. 31) provides evidence of the deep and historic relationship between the Qutb Shahi and Safavid Empires as a result of Mir Momin (Rajjak, 2015). The Iranian influence in medieval South Asia is profound. This influence can be seen as an example of how trade and politics were intertwined in the medieval period, as they are today.

In the late-sixteenth century, Safavid Shah, Shah Abbas I changed the image of Isfahan by applying a new ordering principle to the urban pattern of Isfahan in the south of the city (Ahmadi, 2016). The plan followed the ordering principles of early-Islamic town planning by mixing nuclear and linear patterns but with more emphasis on geometry and green spaces (Ahmadi, 2016). The two main focal points of the city was the Maidan-i-Shah, a large public square surrounded by mosques, palaces, and shops and second, the linear feature, Chahar Bagh, with a pavilions and gardens. It has been suggested that Isfahan and Hyderabad were designed based on Islamic cosmology (Ahmadi, 2016). Gardens are often viewed metaphorically in the

Islamic world as a re-creation of Eden, and is considered the highest level of Muslim paradise (Schwartzberg, 1992). The elements of the Persian Chahar Bagh are collectively symbolic of the universe (Alemi, 2013 as cited in Ahmadi, 2016). The terraces symbolize the cosmic mountains and the creation of the throne that represents Allah. The great pool placed in front of the Maidan-i-Shah represents the cosmic ocean that the throne sits upon (Ahmadi, 2016). The trees, flowers,

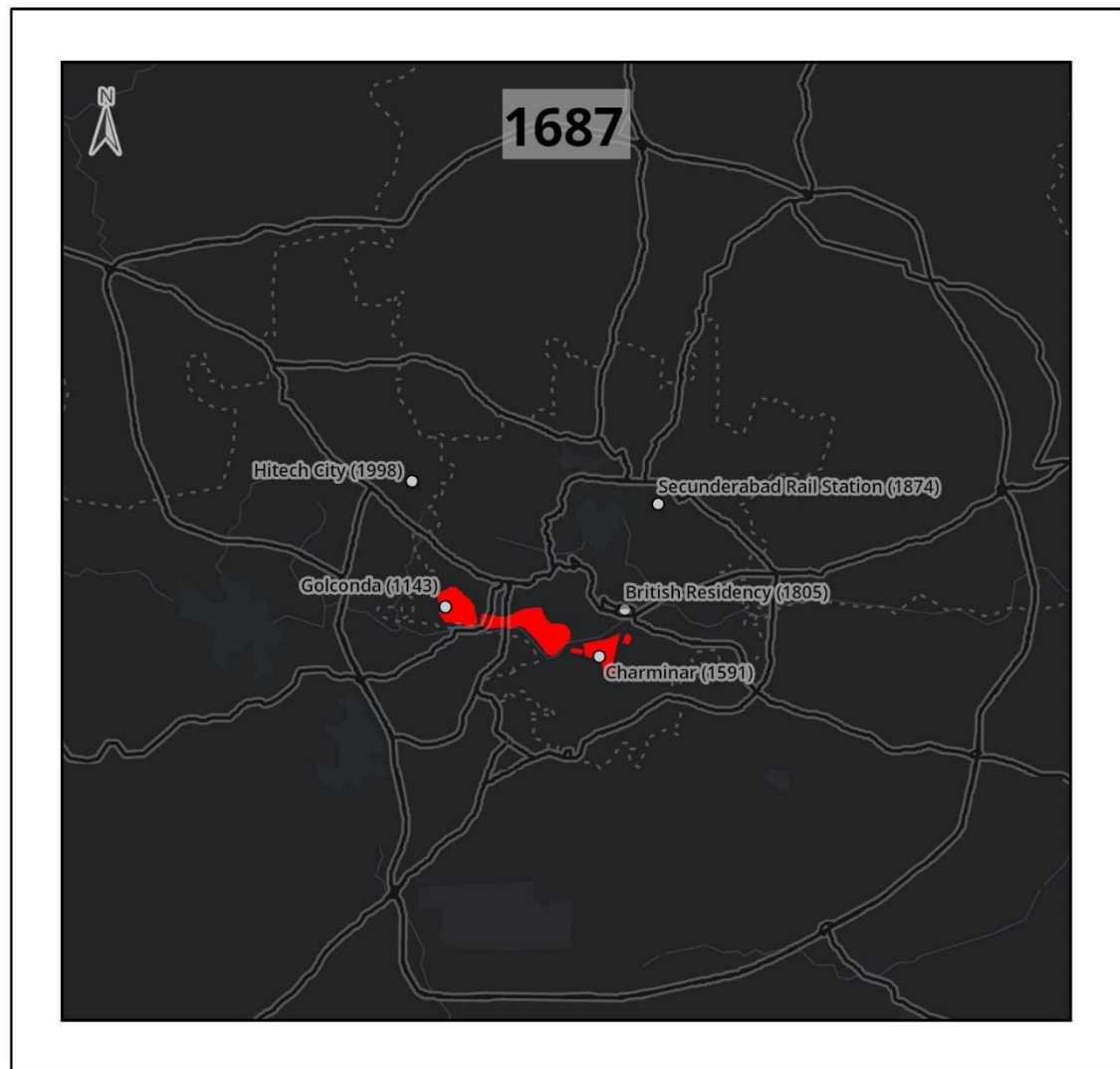


Figure 5.5 Hyderabad urban built-up extent in 1687

and animals complement the throne. In Isfahan, the throne is represented by the Maidan-i-Shah and Chahar Bagh Avenue along with the gardens represent this Islamic vision of paradise. In Hyderabad, the Charminar represents the throne of Allah, surrounded by Mecca Masjid and royal

palaces; Charminar Kaman road leads to the Gulzar Houz fountain representing the water the throne sits. The boulevard then leads to the river Musi. This early Islamic cosmological design set the stage for hundreds of years of urban growth. In the early days of Hyderabad, the locals called the city Bhagyanagar or the city of gardens (Rajjak, 2015).

The British East India Company established a factory in Masulipatnam, in what is now north-east Andhra Pradesh in 1611 but it was the Dutch East India Company who had been given permission to keep residency at Golconda in 1608 (Rajjak, 2015). Dutch records and letters give historical information about the Qutb Shahi and contain references to Mir Momin and the large numbers of Iranians holding official positions.

During the Qutb Shahi era of Hyderabad between 1591 and 1687, urban build-up grew on a west-east axis shown in Figure 5.5. Urban sprawl existed to connect Golconda to Hyderabad via the Puranapul Bridge, shown in Figure 5.6. The 10 km between Golconda and Charminar grew along the Musi River.



Figure 5.6 Puranapul Bridge

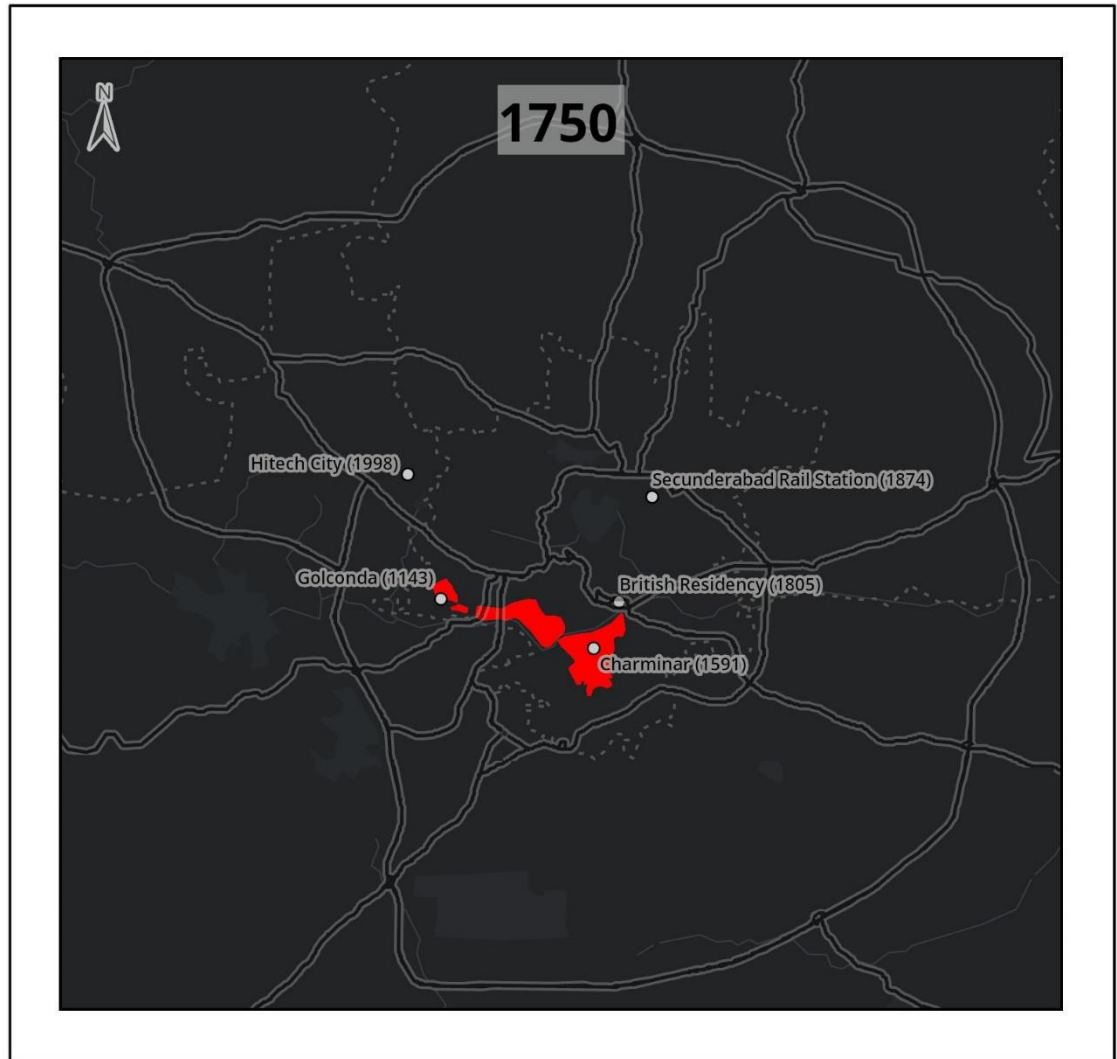


Figure 5.7 Hyderabad urban built-up extent in 1750

Hyderabad's growth and economy were stagnated because the capital was still in Aurangabad for 70 years after the Mughal annexation of the Qutb Shahi Kingdom. The first Nizam died in 1748, his successor Nizam Ali Khan moved back to Hyderabad, along with the noble class in 1763 and the city had begun a period of renewal. Old buildings were demolished, and new ones built; many nobles built new homes to the south of the city. By the end of the eighteenth century, the city had three grand bazaars and a wholesale district. Though there was still a strong west-east settlement axis, north-south economic activity during this period began to

emerge, and settlement trajectories started to change (Alam, 1965). Nobles began building homes to the south of the city (see Figure 5.70).

The shift of settlement patterns to a north-south axis occurred around 1789. The Nizam and the East India Company signed a subsidiary alliance. In colonial India, a subsidiary alliance



Figure 5.8 Hyderabad urban built-up extent in 1865

is a contract between rulers and colonists that allow the native rulers to remain independent, under the protection of the colonists, in exchange for a tribute to the colonists. The military cantonment of Secunderabad was created north east of Hussain Sagar Lake, and British palaces were built on the north bank of the river (see Figure 5.8). The boulevards initially symbolizing Islamic cosmology were extended north to link the city to the new Secunderabad. The Nizam

was a willing participant in the subsidiary alliance. The site of Secunderabad was jointly chosen by the Nizam and the British East India Company. It gave each other space, not too close to be a threat but not too far either so that they could keep an eye on each other. The colonial morphology road the coattails of the Qutb Shahi urban design. The main roads were already laid out on a north-south axis. After Secunderabad was founded, the boulevards were lengthened to connect the two settlements. It was also during this time that Golconda was completely abandoned. The twin cities of Golconda and Hyderabad shifted to the twin cities of Hyderabad and Secunderabad.

There was no industrialization in Hyderabad until 1874 (Alam, 1965). A few railway workshops opened in Secunderabad, which became the nuclei for future settlement (Alam, 1965). Growth south of the Musi River almost entirely stopped, and all new growth was to the north (see Figure 5.9). North of the river settlement centered on Begum Bazaar, Chaderghat, and the British Residency (Alam, 1965). Retail in Secunderabad expanded after the railway terminal was built in Secunderabad, and European residents increased the demand for luxury goods in the bazaars.



Figure 5.9 Hyderabad urban built-up extent in 1900

The railway had a major impact on urbanization in Hyderabad and Secunderabad. It led to increased importance of Secunderabad to the economics of the metropolitan area. The rail line from Mumbai to Hyderabad in 1874 was extended to Chennai via Warangal in 1898 (Alam, 1965). The railway accelerated the northward expansion of Hyderabad. Skilled trades, stockyards, and warehouses grew up around the rail station. These industrial areas became the core, from which residential areas and markets grew up around. Due to the railway, urbanization almost entirely ceased along the Musi River. From 1900, urban growth grew wholly on a north-

south axis (see Figure 5.9). Areas around Begum Bazaar, Chaderghat, and the Residency bazaar flourished (Alam, 1965). Before this era, the Chaddarghat area, north of the Musi, had only the Residency compound with bazaars surrounding it (Cohen, 2011). The expanded commercial activity led to suburban growth north of the Musi in the Chaddarghat area.

The most significant factors contributing to the twentieth-century growth of Hyderabad are plague epidemics between 1911 and 1945 and the Musi river flood of 1908. These factors contributed to the largest redevelopment in the history of Hyderabad and led to the creation of the City Improvement Board and the adoption of modern urban planning and public health interventions. The flooding and epidemics led to suburban growth and a more rapid urban growth to the periphery of the city.

The plague epidemics started in 1897 in Hyderabad State (Khatri, 1953). Hyderabad's first plague epidemic began in 1911. Between 1911 and 1912, 16,654 people died. At least 18 plague epidemics broke out between 1910 and 1945 (Rao, 2001). Anti-plague measures became more sophisticated over time leading to less severe epidemics after 1925 (Khatri, L.D., 1953). Early anti-plague measures included quarantine camps, segregation of patients and contacts, disinfection of houses, and disinfection of dead bodies. After 1930, systematic anti-plague campaigns included anti-rat trapping, baiting, and fumigation of nests. A flea and rat survey were started to monitor the anti-rat campaign progress.

On September 28, 1908, the Musi River flooded. Nearly 15,000 people died, and more than 19,000 homes were destroyed, a quarter of the city's population. The causes of the flood are attributed to heavy rains, an ineffective water tank system, and generally deforestation of the Musi River catchment basin (Cohen, 2011). Seventeen thousand water tanks provided drinking water and agricultural irrigation. These small tanks built along the river ranged from a few

meters to a hectare. These tanks served as flood prevention by capturing excess water. When a tank was breached, it would cause a domino effect downstream (Alam, 1965). In the two years prior, the city received a September rain of 4.29 inches (Cohen, 2011). In the 48 hours leading up to the flood, the city received 12 inches of rain, and the Esa basin received 33.19 inches, and the Musi basin received 28.91 inches (Cohen, 2011). Normally, the tanks were able to discharge excess water, but because the rains came in localized bursts, some tanks overflowed and were not able to discharge water fast enough. Because of the spatial distribution of rain in cloud bursts, some tanks overflowed the walls breached, causing a domino effect. On September 28, 1908, the river level in the city rose sixteen feet in less than four hours (Sheela, 1987 as cited in Cohen, 2011). The river reached a height of 45 feet, submerging the city center in as much as fifteen feet of water (Cohen, 2011).

Flood response can be viewed as being organized in two stages, the initial aftermath and rebuilding (Cohen, 2011). As in other princely states, the Nizam was viewed as being despotic, oriental, and ancient (Cohen, 2011). In the wake of the flood, several steps were taken to modernize. Under Nizam's control, the response was not purely modern or oriental but a hybrid (Cohen, 2011). Several steps were taken to rebuild the city and prevent future disasters. The Nizam brought in consultants to devise a plan (Cohen, 2011). The engineer Mokshagundam Visvesvaraya created a three-axis plan, rebuild, a plan to avoid future flooding, and a plan to build city drainage. Two tanks were built above Hyderabad, Osam Sagar was completed in 1920 and a larger tank Himayat Sagar Tank was constructed in 1927 to control the Esa and Musi rivers. The flood allowed the city to rethink how water flowed into and out of the city.

The flood prompted a fundamental northern shift in the urban population. Nobility and upper-middle classes moved north of the Musi River (Cohen, 2011). Most notably, suburbs to the northwest where people moved to new suburbs such as Red Hills and Masab Tank can be seen in Figure 5.10. Osmania University Arts College was constructed far north of the Musi in 1937. The flood created a permanent shift away from a Musi River-oriented urbanism.

Due to the flood and pandemics, “it was felt that the government should set to work to improve in every possible way the sanitation of the city and its suburbs by having a proper drainage system, by opening up the back streets and alleys, and letting in more light and air and

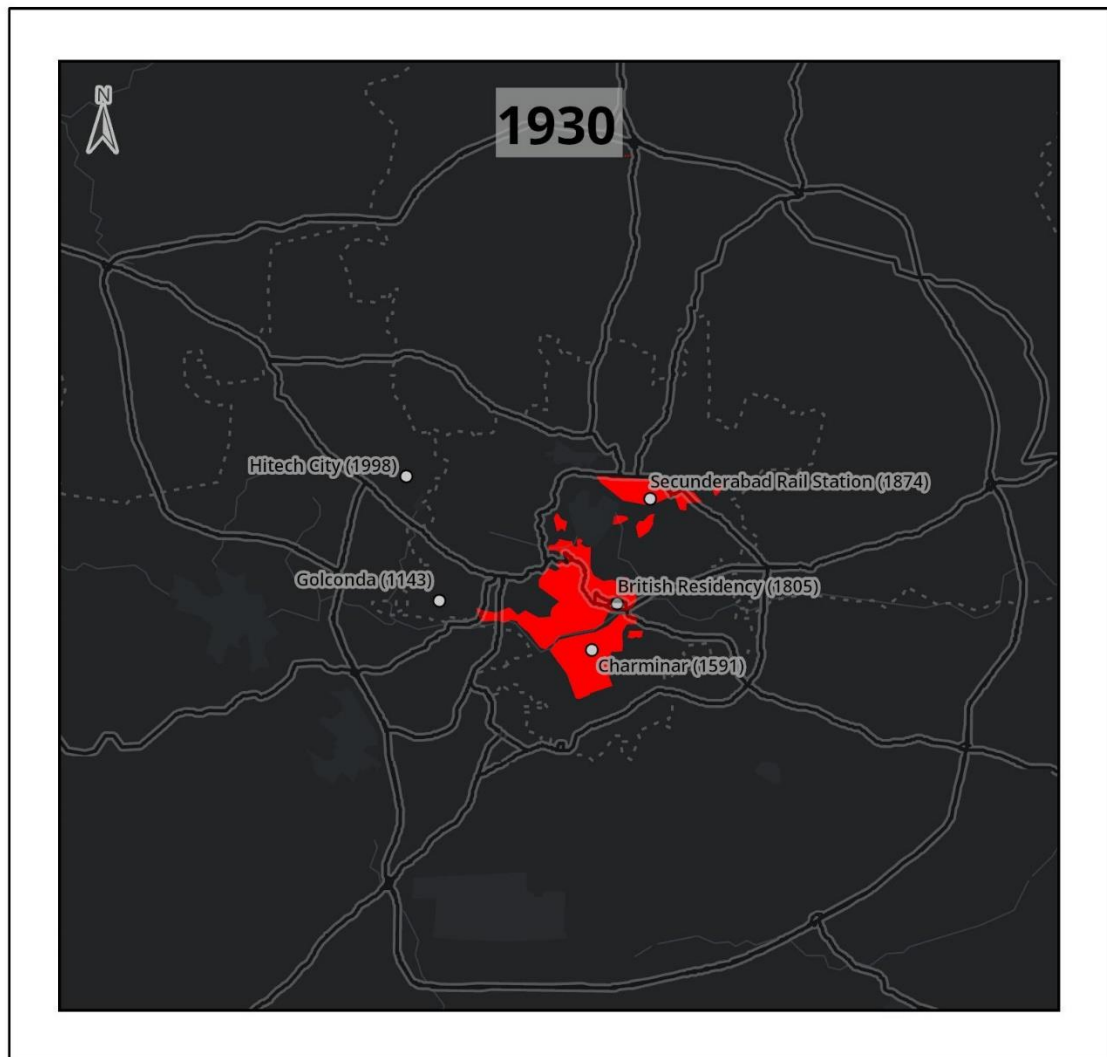


Figure 5.10 Hyderabad urban built-up extent in 1930

by dealing with the question of cemeteries and burial-grounds, etc.” (City Improvement Board, 1914, p. 1). The City Improvement Board was founded in 1914 to be a centralized body to redevelop the city. The Nizam approved the idea and referred the matter to the Ministers and Cabinet Council, who submitted their ideas on May 21, 1912. The first meeting of the City Improvement Board was held at Iram Manzil on June 29, 1912. The first practical work on the city began in 1914. The start of city improvement was slow due to the outbreak of WWI, which cost Hyderabad State materials and wages, and partly because of plague and influenza outbreaks (City Improvement Board, 1914). The City Improvement Board functioned from 1912 until 1941 and undertook a total of 45 major metropolitan level projects.

The City Improvement Board had a profound effect on the urban morphology of Hyderabad. Forty-five projects altered the architecture, street layout, street width, and neighborhoods of the city. The projects can be categorized as infrastructure, transportation, slum clearance, and economic. Infrastructure projects are related to water systems, bridges, and city beautification. Transportation projects focused on new road layouts and widening existing roads. Most projects are categorized as slum clearance, which involved demolishing residential neighborhoods, displacing residents, and building model homes. Economic projects focused on building markets and creating industrial areas.

The first sanctioned improvement scheme was the improvement of the Musi Riverfront and Afzulgunj Bridge. After the flood, the Nizam placed a moratorium on building in the flooded area because he planned to redevelop the whole area. The next important scheme was compensation for lands confiscated within the prohibited area. After the 1908 flood, people were not allowed to rebuild within a certain distance from the river, but the question of compensation for the land had not been settled (City Improvement Board, 1914). Three-fourths of the claims were resolved in 1914. Following the settlement of the land within the prohibited area, building laws and land acquisition rules were put in place. Land acquisition continued throughout the City

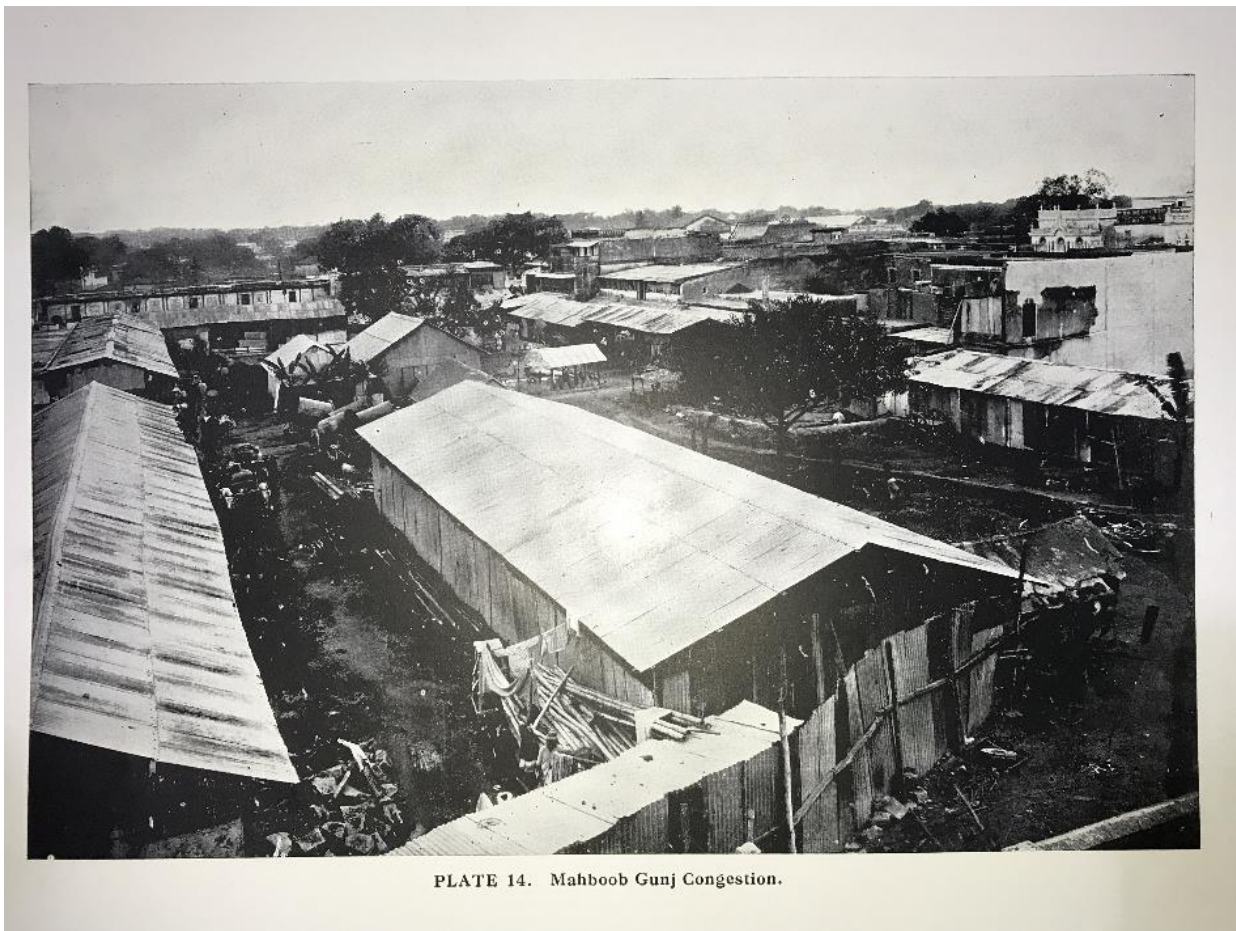


PLATE 14. Mahboob Gunj Congestion.

Figure 5.11 Mahboob Gunj congestion 1933 (City Improvement Board, 1933)

Improvement Board era. Improving public gardens was a low hanging development fruit because the land acquisition was not impeding progress.

The CIB began acquiring lands for housing the poor. The Sanitary Engineer proposed building model homes to address the massive homeless population caused by the 1908 flood. This project profoundly changed the architecture of Hyderabad. To house the poor removed from slums and congested areas, the government decided to build houses to accommodate them with sanitary requirements. Figure 5.11 shows an example of the type of residential conditions at the time. The goal of this project was two-fold, to resettle the displaced poor and to remove the plague and other epidemics from the city (City Improvement Board, 1928).

From the beginning, the scheme for housing the poor was to enhance the common good. The City Improvement Board decided that,

- a) The City Improvement Board would take a gross return of just 4%.
- b) The land has been assigned free, and no interest would be charged during the execution of the work would be passed onto the poor.
- c) For Municipal assessment and tax purposes, the above rates would be accepted.

Three types of buildings were proposed, and the design of these buildings changed slightly over time. Originally called poor man's quarters type A, B and C. Type A homes were rented from Rs. 6-8 per month and cost Rs. 1,800 to 2,000 to build. Type A homes were rented out for rent for 3-8 per month consisting of 3 rooms, one of 12' x 10' and two from 10' x 10' and a kitchen of 8' x 8, with an 8' x 20' veranda. Type B homes were rents were from Rs. 3-8 per month and cost Rs.900 to 1000 to build. Type B homes consist of two 12' x 9', one of 8' x 5-9', a kitchen of 8' x 5-9', and a kitchen of 10' x 7'. Type C homes were rented for Rs. 2 per month and

cost Rs. 600 to 650 to build. Type C homes have one 10' x 10' room with a verandah that is split into an outdoor kitchen.

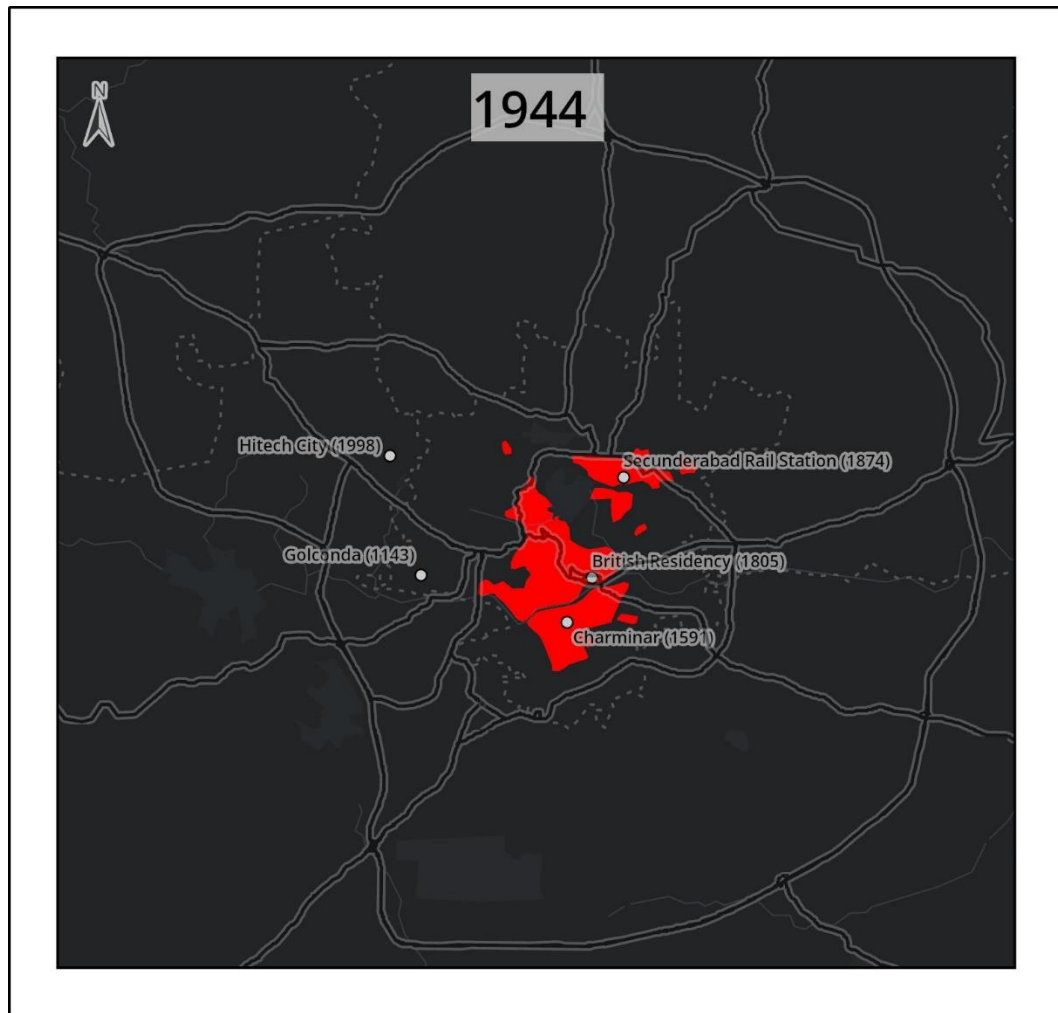


Figure 5.12 Hyderabad urban built-up extent in 1944

Between 1930 and 1944, the spatial impacts of the City Improvement Board project on urban sprawl. The urban build-up continues to extend northwest through this period; see Figure 5.12. The City Improvement Board accelerated suburbanization. Neighborhoods like Ameerpet, Masab Tank, Toli Chowki, and Banjara Hills took form.

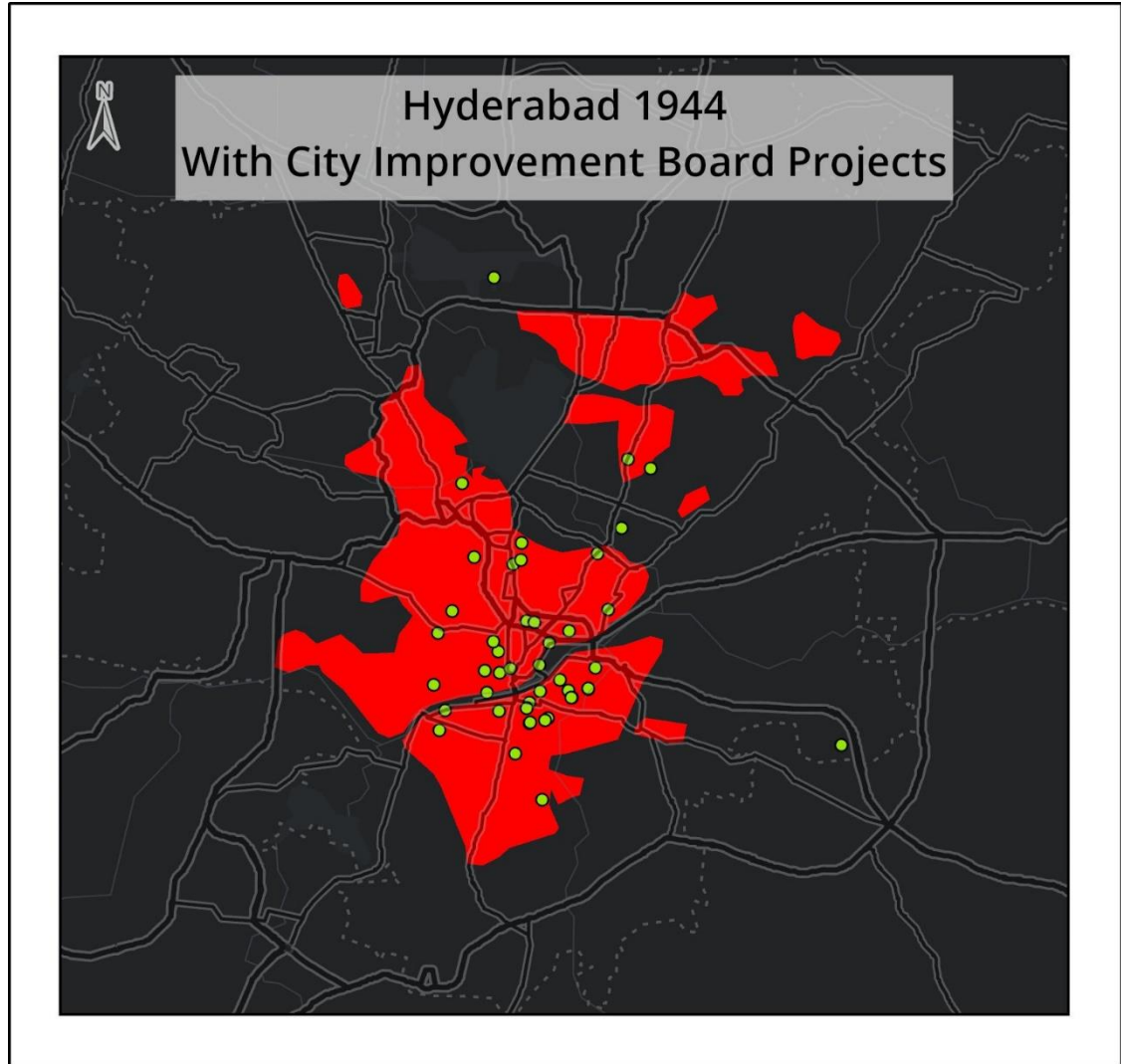


Figure 5.13 CIB projects until 1944

Between 1914 and 1930, the projects focused on addressing overcrowding and sanitation. After 1930, the City Improvement Board began focusing on commercial and economic development (Beverly, 2015). The first large-scale economic planning project started in 1932 with a scheme to lay out a 120-acre industrial area in Musheerabad east of Hussain Sagar.

Though not all suburban growth was a result of the City Improvement Board, the City Improvement Board can be viewed as a proto-masterplan spanning the metropolitan area as shown in Figure 5.13. The City Improvement Board, along with the Secunderabad Town

Improvement Board, were dissolved into the Andhra Pradesh Housing Board after Hyderabad joined India in 1948. This agency continued until it was bifurcation of Andhra Pradesh and Telangana in 2014. The City Improvement Board is the foundation for all metropolitan level planning in Hyderabad and continues to have a lasting impact on its urban morphology to this day. Private development was also significant throughout this period.

In the post-independence period, two major factors contributed to the metropolitan development of Hyderabad. First, the political events following the partition of India. Second, the migration of people, especially Muslims, to Gulf countries starting in the 1960s. The partition of India took place in 1947. The Nizam believed he could remain sovereign and maintain their political identity (Zyskowski, 2008). Following the breakdown of diplomatic negotiations between India and the Nizam, India forced the abdication of the Nizam. Hyderabad State joined India in 1948. The reorganization of the states in 1956 made Hyderabad the capital of a new state called Andhra Pradesh. These political events had significant impacts on Hyderabad and Secunderabad.

Post-independence political events impacted the demography of the city (Alam, 1962). Communal violence in north India caused many lower-class Muslims to relocate to Hyderabad while most wealthy Muslims relocated to Pakistan. Communist uprisings in the rural areas of Andhra Pradesh led wealthy landowners to relocate to the city. The reorganization of the states helped to strengthen the metropolitan development of Hyderabad (Alam, 1962).

Migration became a salient factor for Hyderabad after the 1960s. In the 1921 census, only 341 people had emigrated from Hyderabad State (Ali, 2007). A random sample survey of Muslim households in the old city between 1984 and 1986 found that 21% had at least one family member in the Gulf (Naidu 1990, 1996 as cited in Ali, 2007). A different survey found

that 60% of all male children were working in the Gulf (Ali, 2007). Migration is due to work, study, and travel opportunities. However, social and political changes in Hyderabad as a result of joining the Indian Republic had significant implications for migration.

Until 1948, the regional kingdom of the Nizam had a strict social stratification based on one's relationship to the Nizam (Ali, 2007). Social, political, and economic life revolved around the Nizam. After the abdication of the Nizam in 1948, the social and political system was undone. Later, the economic system was undone by the dispossession of the landholdings of the Nawabs. Since social and political status was defined by the relationship with the Nizam and the economic system was largely based on social and political status, Muslims were at the top of the Nizam hierarchy. The status stratification system for Muslims fell apart. During the time the seventh and last Nizam, there was little opportunity for economic mobility (Ali, 2007). Almost overnight, the social stratification system was overturned, and the Indian secular capitalist system was instituted. By the 1950s and 1960s, education and job opportunities increased the opportunity for social mobility where individual achievement was becoming more important than caste or nobility in defining status (Ali, 2007). However, the opportunity was unequal. Many non-elite Muslims and Hindus who became educated in the 1960s were finding it difficult to find opportunities because of discrimination against Muslims and discrimination against lower-caste Hindus. These socio-economic changes led to the migration of Muslims to the Gulf region, which continues to this day. Hyderabad has always been a cosmopolitan city, but normative migration since the 1960s, due to mid-twentieth century political events have

solidified the cosmopolitan identity of Hyderabadis. Although not directly related to metropolitan level urban sprawl. The political upheavals of the mid-twentieth century have

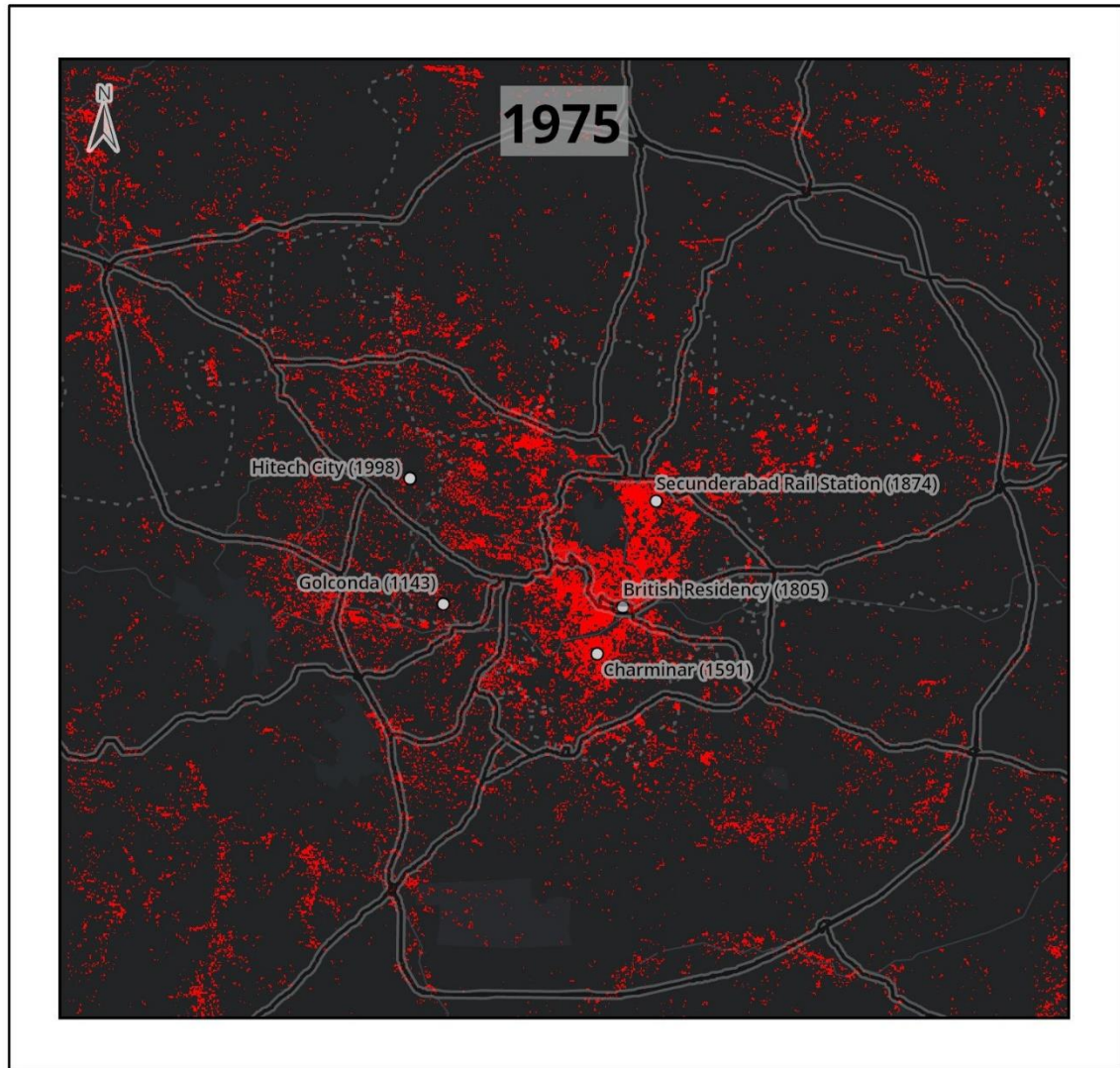


Figure 5.14 Hyderabad urban built-up extent in 1975

impacted the social and economic trajectory of the city, as we will see in the second half of the twentieth century.

Suburban growth increased throughout the second half of the twentieth century. Urban sprawl remained limited between the 1940s and 1970s due in part to the changes in social and economic systems. It takes time after major political upheaval and reorganization to create and

implement metropolitan level planning. Urban development was planned under the Nizam. After 1948, urban growth was unplanned.

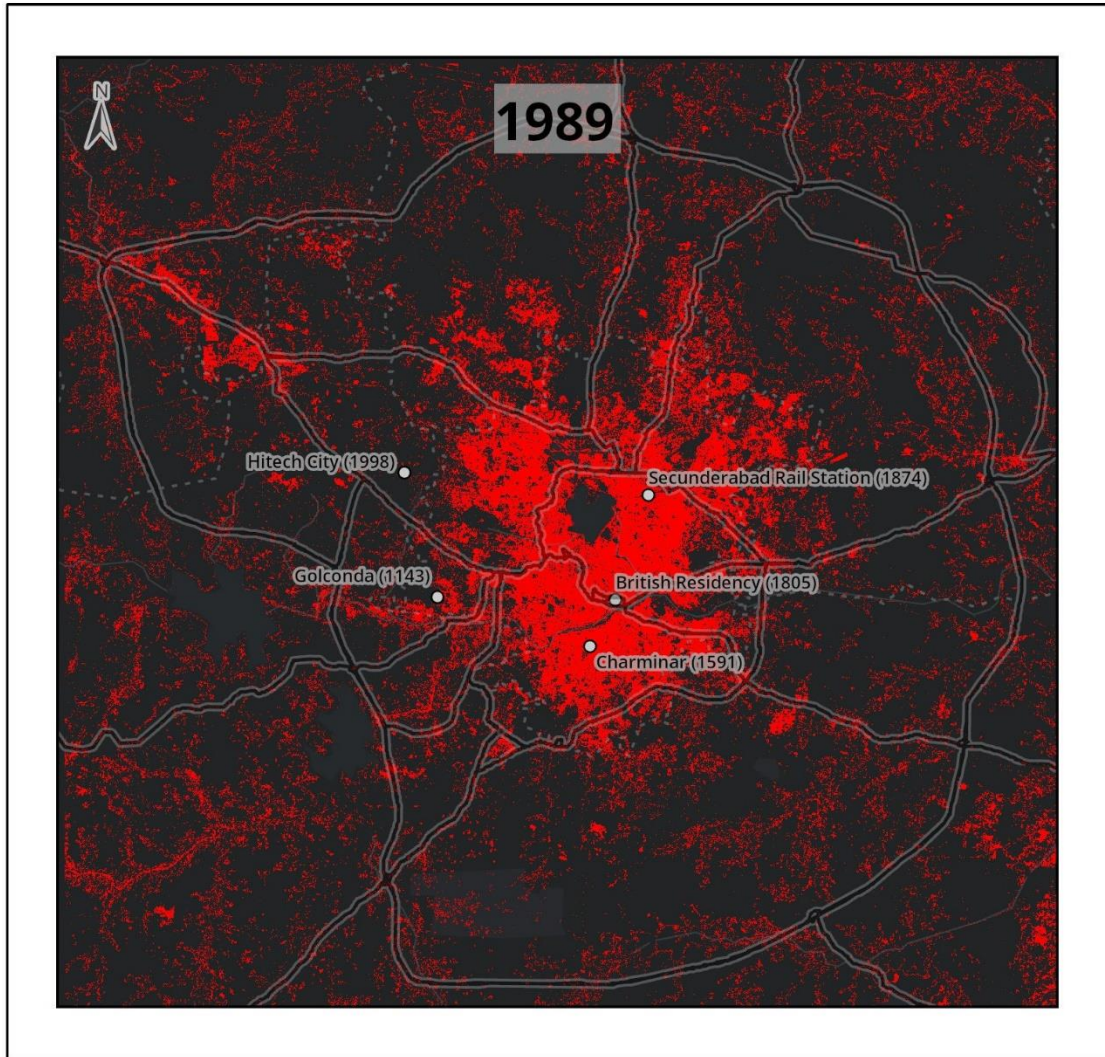


Figure 5.15 Hyderabad urban built-up extent in 1989

Between the 1940s and the 1970s, the population doubled in size from around 1 to 2 million. However, the city itself did not significantly increase in the built-up area (see Figure 5.14). Between the end of the City Improvement Board works in 1946 and 1975, the city footprint remained much the same size, on a north-south axis connecting Hyderabad to Secunderabad, with the suburbs situated in the northwest.

In just 14 years, the city's population ballooned to almost 4 million residents. The effects of population increase, and unplanned growth resulted in urban sprawl in the latter part of the twentieth century (see Figure 5.15). New urban build-up increased southward for the first time since 1865. The city also grew to the north-west, encompassing Hussain Sagar for the first time. Secunderabad's urban footprint also grew during this period.

Between 1989 and 1996, remotely sensed data shows a decrease in the urban build-up due over-classification of urban area. All the satellite images for this project were taken during the early fall, except for 1980, which was taken in the spring. This caused changes to the spectral characteristics of the image. Landsat was unable to capture a cloud-free image of Hyderabad between 1980 and 1989. For these reasons, a spring image was selected for this study. This allows for distinct spectral signatures between urban build-up and barren soil. In Hyderabad, concrete is the most used construction material. The similarity of spectral signatures between dry, barren soil and urban build-up constructed with concrete made by the same barren soil makes remote sensing classification challenging during dry times of the year. It can be reasoned that the 1989 classification overclassified urban build-up where perhaps there was none. This hypothesis is backed up by increased speckling in the 1989 classification and less defined urban edges. As Figure 5.16 shows, the 1996 classification has much more distinct edges and less speckling than the 1989 classification.

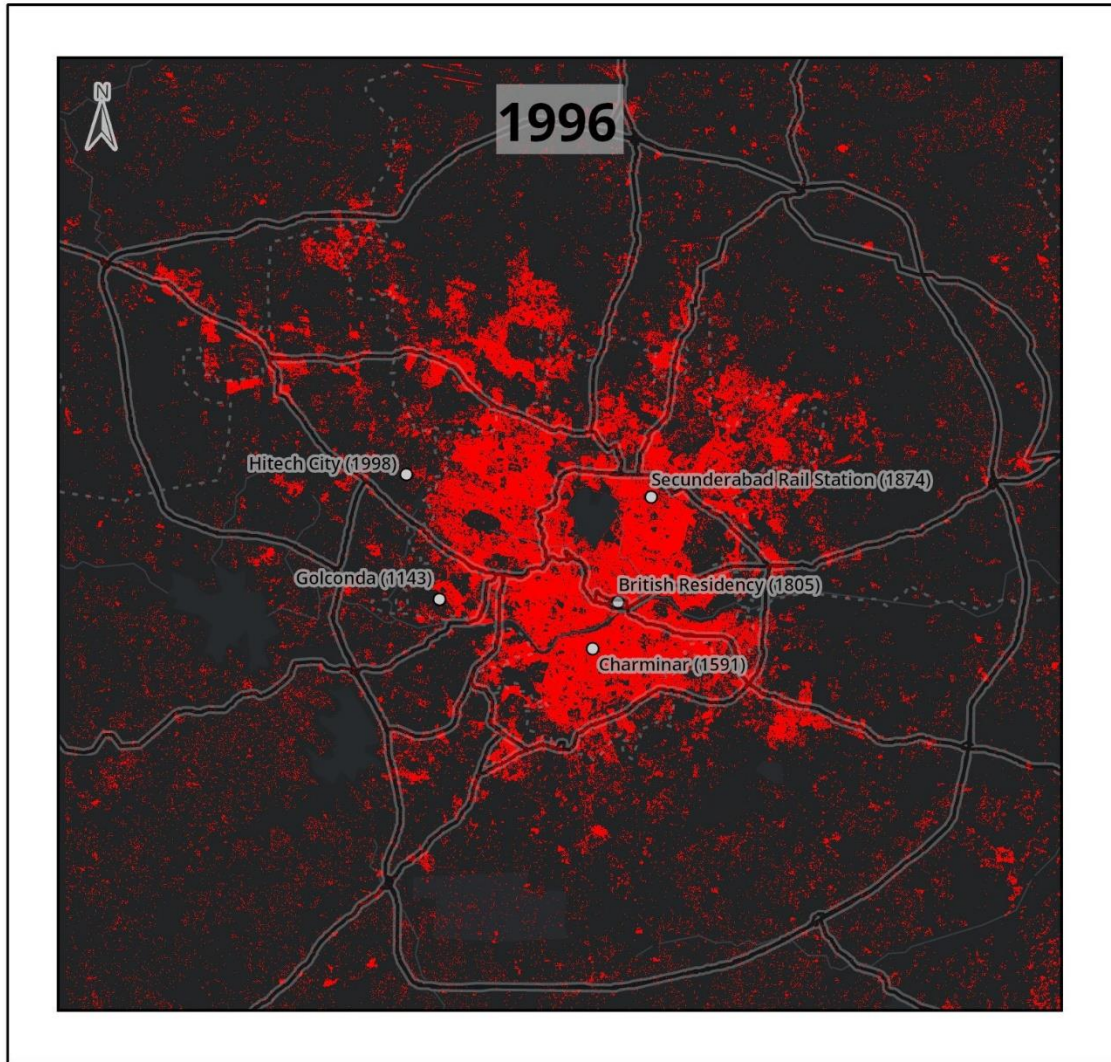


Figure 5.16 Hyderabad urban built-up extent in 1996

Suburban growth in the 1990s expanded in the western periphery of the city. It was a time of major changes to both Hyderabad and the world. Globalization sets new requirements for urban morphology. There was a sizable growth of nodal communities around the city, especially to the northwest but also south and southwest. Cyber tower, the first tower of Hitech City, was inaugurated on November 22, 1998. Hitech City became the core of a larger IT special economic zone known as Cyberabad. Between 1995 and 2001, major road-widening projects were carried out in different parts of the city. These plans were part of some of the provisions of the 1975 Development Plan for the Municipal Corporation of Hyderabad (Hyderabad, 2020). The 1994

master plan revised the master plan to target the expected population of 2011. The major challenge of this period was globalization. New forms of land use were necessary, which had never existed before. Hyderabad faced massive changes in less than 10 years, lands in Hyderabad that were allocated by the government for agriculture were transformed into the National Institute of Fashion Technology, Shilparamam cultural shopping center, and the Cyber Towers.

The Cyberabad Development Authority was set up in 2001 and took 52 sq. km. of the jurisdiction from the Hyderabad Urban Development Authority. The Master Plan for Cyberabad Development Authority Area came into effect on October 29, 2001. The plan envisioned “a model for other urban areas in the country by providing clean air and water, high quality of services such as sanitation and waste management, and the best standards of power, housing, and transport” (Cyberabad Development Authority, 2001, p. 1)” A salient feature of Cyberabad is the encouraging of “mixed land use allowing varying degrees of commercial use in Residential Zones when the plots are large and face wide roads” (Cyberabad Development Authority, 2001, p. 1). At the same time, the Hyderabad 2020 plan was finalized to replace the 1980s master plan, which had been revised to meet the needs through the 1990s. Hyderabad 2020 laid down space requirements for two decades of growth. The 2020 plan has no mechanism for enforcement and implementation. It states, “if the Master Plan proposes wide roads, footpaths, parks and gardens and improved standards of drainage and other services, then those things cost money. There is no way whatsoever to meet these costs unless the people living in the area themselves contribute through various taxes and user charges” (p. 3). This has played out in the development of lands zoned conservation in Gopanpalli, which transitioned from agricultural lands to high-rise apartment complexes over 20 years. Looking back, we can see the 2020 master plan failed to foreshadow the full extent of future urban growth needs. In 2003, construction began on the

Hyderabad Metro Rail, an elevated metro system that opened in 2018. Major transitions were taking place during this period. The 1980s and revised 1990s plans were agrarian focused. The 2020 plan served as a transitional plan while attempting to improve planning efforts with ongoing urban growth.

By 2009, urban growth expanded rapidly in the western periphery of Hyderabad, as shown in Figure 5.17, which exceeded the 2020 master plan. Unplanned growth around Hitech city can be seen north, west, and south of Hitech City. One obvious development was the construction of the outer ring road, this 158 km, 8-lane expressway connected urban nodes or periphery communities, becoming increasingly important to the economy of Hyderabad. This will be discussed in detail in Chapter 6. Another important development is urban growth along the Mumbai Highway, the major transportation route to the north-west of the city. The vision of Hyderabad as an IT center and global city conceived of in the 1990s was beginning to have visible and quantitative impacts on the urban morphology of metropolitan Hyderabad. By 2009, the global city urban morphology has a clear mark.

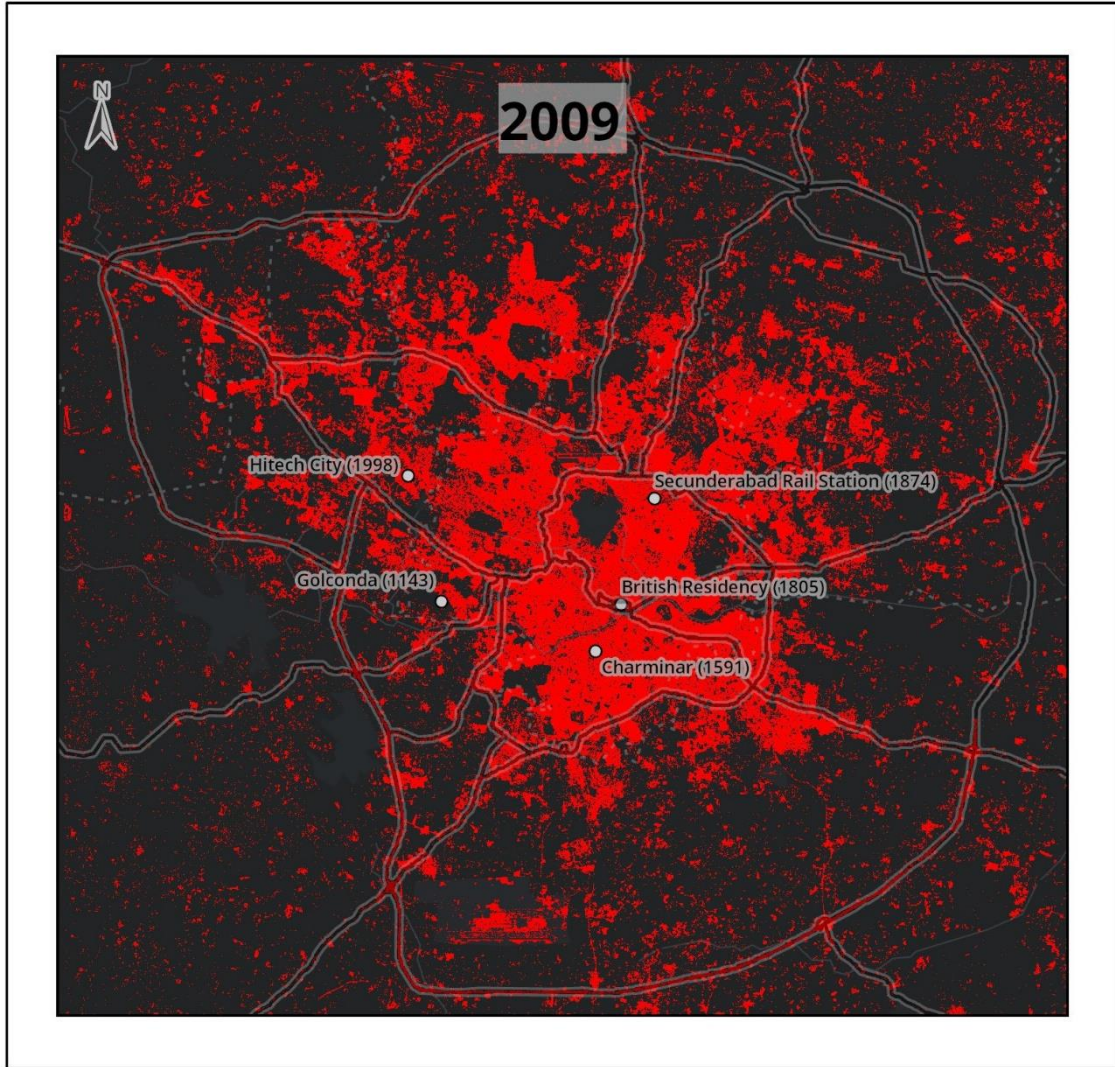


Figure 5.17 Hyderabad urban built-up extent in 2009

By 2015, Outer Ring Road was completed, and the global city footprint of metropolitan Hyderabad is identifiable. Northwest urban growth increased in intensity, as shown in Figure 5.18. Since

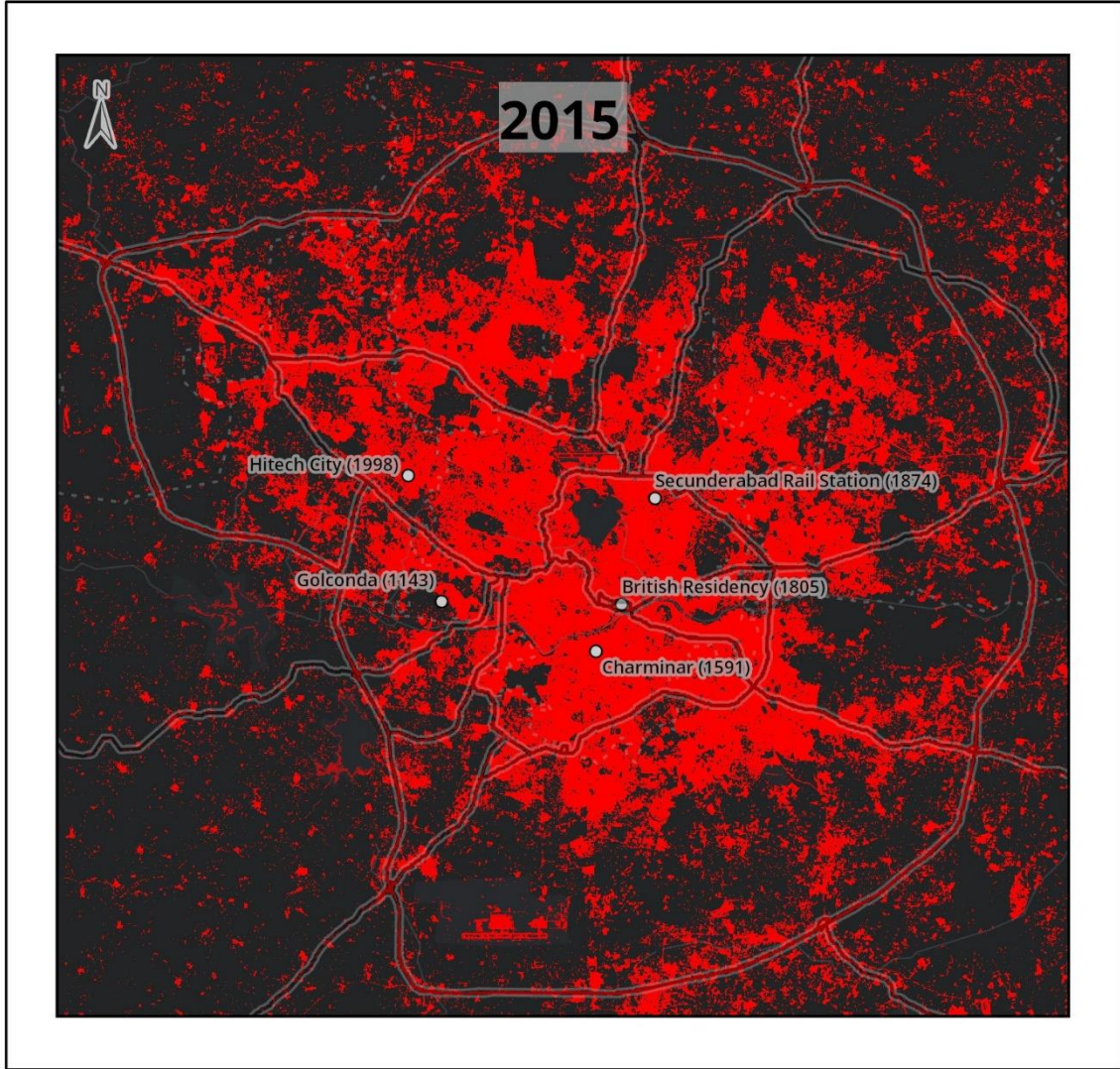


Figure 5. 18 Hyderabad urban built-up extent in 2015

Urban growth of Cyberabad, the northwest periphery continued to grow through this period. An accuracy assessment was conducted on the 2015 dataset. The accuracy assessment found a Cohen's Kappa Statistic of .83 and an overall accuracy of 93%. A kappa value of 1 implies perfect agreement while 0 means no agreement at all. A 0.82 kappa is a very good agreement.

Table 5.1 Accuracy assessment on 2015 classification

| | | Ground Truth | | |
|------------------|-----------|--------------|-----------|-------|
| | | Urban | Not Urban | Total |
| Classification | Urban | 30 | 3 | 33 |
| | Not Urban | 4 | 63 | 67 |
| | Total | 34 | 66 | 100 |
| Agreement | | 30 | 63 | 93 |
| By Chance | | 37.4 | 21.78 | 59.18 |
| Cohen's Kappa | | 0.83 | | |
| Overall Accuracy | | 0.93 | | |

5.3 Summary

In sum, from the year 1687 to 2015, Hyderabad has changed tremendously in terms of built-up area related to population growth and other factors (e.g., political changes, planning or lack thereof) discussed (see Figure 5.18). In Figure 5.18 the lighter red tone represents early urban extent, while the darker red represents more recent urban extent. Figure 5.18 illustrates the combined paper map and remote sensing analyses confirm both the increase in the geographic extent of Hyderabad over time, but also the spatial patterns of that change.

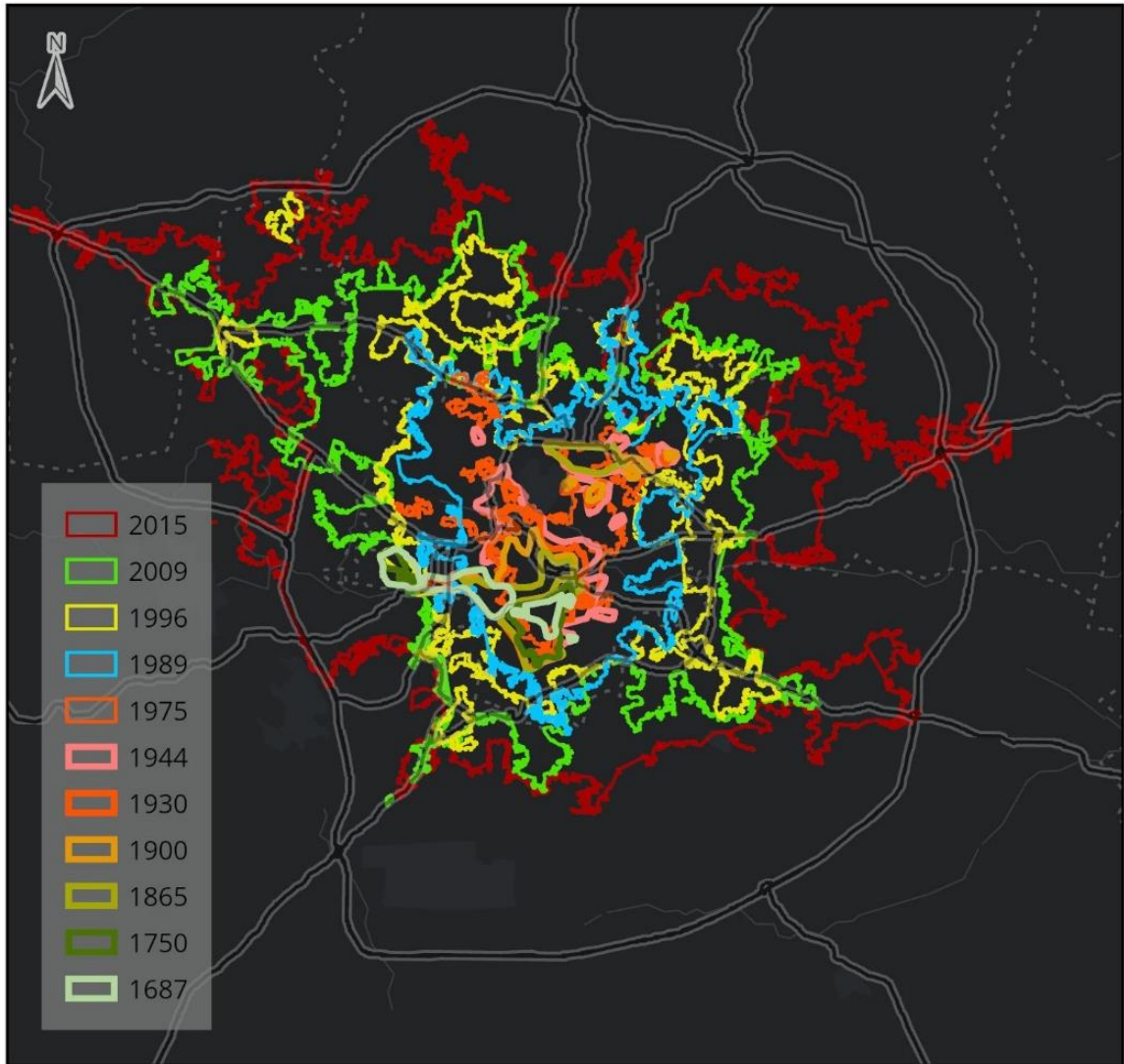


Figure 5.9 Hyderabad urban growth map from 1687-2015

6 Discussion

India, as with greater South Asia and much of the Muslim world, urbanized much earlier than Europe. Thus colonial-era and later forms of municipal growth must be reconsidered in the light of this fact. This study has determined that although the city was designed based on an Islamic cosmological representation of paradise, this initial design has been eroded by history. The methods employed to study Indian urbanization are markedly different than the models used to analyze Western cities. Urban morphology is a marketed different geographic approach from other Western urban theories. The basis of this analysis is that history has the biggest influence on urban extent, form, and topology than anything else.

Taking urban morphology as “the study of human settlements, their structure and the process of their formation and transformation” (Kropf, 2018, p. 9) allows for a structured analysis of urban change. Urban morphology provides a common framework for the consistent and rigorous descriptive language of the built environment. It allows a method for exploring how Hyderabad has grown, changed, and developed unique urban characteristics as a result of the historical transformation from early urbanization to globalization. Islamic cosmology forms the beginning of the long history of Hyderabad urban morphology. Contemporary urban morphology provides a way to contextualize these philosophical concepts and histories by placing an emphasis on urban planning and how these plans have played out over time.

The lens of urban morphology has allowed me to delineate and quantify the geographic extent of the built-up urban area in Hyderabad, India from 1687 to 2019 using a mix of scanned historical maps and remotely sensed imagery. While the technical application of remote sensing land classification should not be undermined, placing these geospatial products into the context

of historical processes, we can further explore how important events have helped shape the Hyderabad we know today.

Furthermore, urban morphology has helped to focus historical events through the lens of urban planning to filter the vast amount of history to specifically evaluate spatial patterns of change in urban area extent and form over the study time period. By using urban morphology theory this study has been able to focus on the reasons behind the known change from north-south directional morphology to east-west, and, more importantly, determine the reason behind this directional change. It is easy to get lost in all the interesting aspects of history. Urban morphology allows analysis to focus on specific aspects of history that account for urban morphological change by placing an emphasis on the urban plan as the basis for analysis.

Throughout this analysis, several important events and time periods have come to light that helps understand how the urban extent and patterns of spatial change have changed and come to be. The founding of Hyderabad based on Islamic cosmology that can be traced back to Greek philosophy, the return of Hyderabad as the regional center after being annexed by the Mughal Empire, industrialization, the 1908 flood and disease epidemics, and finally globalization have been found to be the most important factors shaping the urban extent of Hyderabad.

Hyderabad was designed as the new Isfahan, this initial design sets the stage for centuries of urban change. Originally designed by Mir Momin Astarabadi as an earthly representation of the universe, the street layout of north-south boulevards allowed for the city to expand northward during later periods. The early city and its ideal provided a starting point for the city to grow into a global center of IT and commerce.

The decline of the Mughal Empire and the emergence of the Kingdom of the Nizam was another significant step in the history of Hyderabad. While the regional capital had moved to Aurangabad, Hyderabad fell into a physical and economic state of disrepair. The noble classes had moved to Aurangabad and the economy could not maintain itself. After the city became the capital of the newly formed Deccan kingdom, a period of revitalization preceded the arrival of the British East India Company. Crumbling palaces were torn down, buildings were repaired, and the nobility built new palaces south of the old city.

The British East India Company helped to bring industrialization to Hyderabad starting with the railroad and the founding of Secunderabad. This twin-city state saw the emergence of northward urban expansion. The original road network was extended to connect the old city to new settlements north of the Musi River such as the Koti Residency and Secunderabad. As time progressed, the relationship between the Nizam and the British strengthened. The Nizam became one of India's most vocal supporters of the British Raj and became one of the largest British financial supporters during the first and second world wars.

The 1908 Musi River flood and influenza and plague epidemics that followed have been found to be the most significant time period impacting the size and shape of contemporary Hyderabad. The flood event caused a severe sanitation crisis in the city. The flood became a catalyst for urban change and the City Improvement Board emerged as the administrative leader of this change. The healthy relationship between the Nizam and the British led to a mixing of modern planning techniques with regional kingdom methods. Scientific methods were employed to redesign the city while using the political and economic apparatus of a regional kingdom. This mix provided decades of healthy redevelopment, suburbanization, and health. The city de-densified, roads were widened, new road networks were created which framed, new

neighborhoods that were designed to be more hygienic. The first half of the twentieth century saw the urban design catch up to the industrialization that had already taken place. The city was redesigned to be an important center of industry and commerce.

Indian independence was discovered to have a minor impact on the urban extent of Hyderabad. Post-independence saw periods of communal violence in Hyderabad as with the rest of India. It can be surmised, though outside the scope of this study, that the social and political instability of the post-independence period led to a stagnation of adoption of new urban design and development. Although the urban extent did not change much following independence, one significant change to the city was the ingress of migrants from rural areas. This movement of people led to architectural changes such as the upward growth of buildings and the re-densification of the city. Due to a lack of leadership in the planning process, the post-independence period saw disorganized and unregulated development. Urban planning and development were regulated and planned during the Nizam and the Qutb Shahi eras. After independence, the city had very little planning.

In the 1990s, globalization emerged as a significant factor in changing the size and shape of the urban extent. The urban plans of the 1980s for the 1990s could never have foreseen the impact that globalization and the emerging IT sector would have on the city. Unplanned western growth of urban extent fueled by the emerging IT sector is the first departure back to an east-west urban axis. By the end of the first decade of the new millennium, the Hyderabad 2020 master plan, and the Cyberabad Master plans emerged as the first plans to consider globalization. This author considers the Hyderabad 2020 plan the first master plan in the post-independence period to begin to re-regulate and control urban growth and development. There were masterplans throughout the post-independence period, but they were methodologically outdated

and there was little mechanism to enforce the adoption of these plans. The Hyderabad 2020 plan is the start of the plan for Hyderabad to become a global city.

If the Hyderabad 2020 plan was the start of global city planning, then the Hyderabad 2031 master plan is the full embodiment of a vision that Hyderabad is and will become a globally important city. The Hyderabad 2031 Master Plan is truly a globalized, technically designed, and realistic plan for Hyderabad. The plan includes future modeling and cutting-edge geospatial methods. The plan predicts the expansion of urban growth to the west of the city, as shown in Figure 5.18. Hyderabad 2031 has seven guiding principles that have been derived from planning theory and practice around the world. These seven guiding principles are the multiple nuclei concept, rural-urban continuum, transit-oriented development, urban growth boundary, peri-urban development, provision of social amenities, and environmentally suitable development. Understanding the guiding principles of the Hyderabad 2031 plan helps understand how the Hyderabad Metropolitan Development Authority is guiding the process of urban growth and sustainability.

The Hyderabad metropolitan area currently contains around 9.7 million residents, with a projected increase to 16.1 million by 2031. The multiple nuclei concept is proposed to help take the strain from the center or core nuclei and distribute it over a larger area. The city core cannot sustain further population density. Hyderabad 2031 defines how these nodes will function concerning the core, as shown in Figures 6.1 and 6.2. The goal is to specialize these nodes into certain economic activities to better serve the various populations within them and the city core

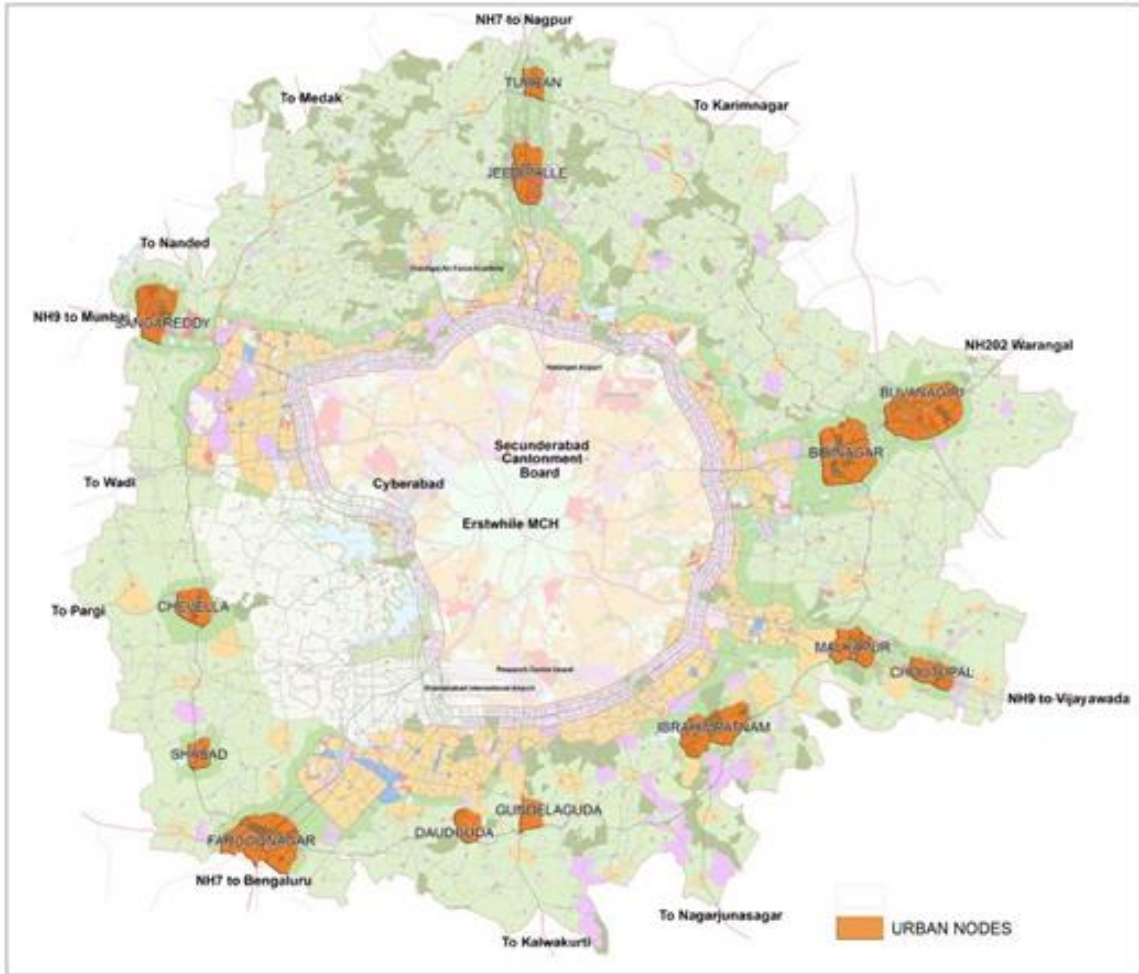


Figure 6.1 Hyderabad 2031 planned nodes (Hyderabad 2031, 2020)

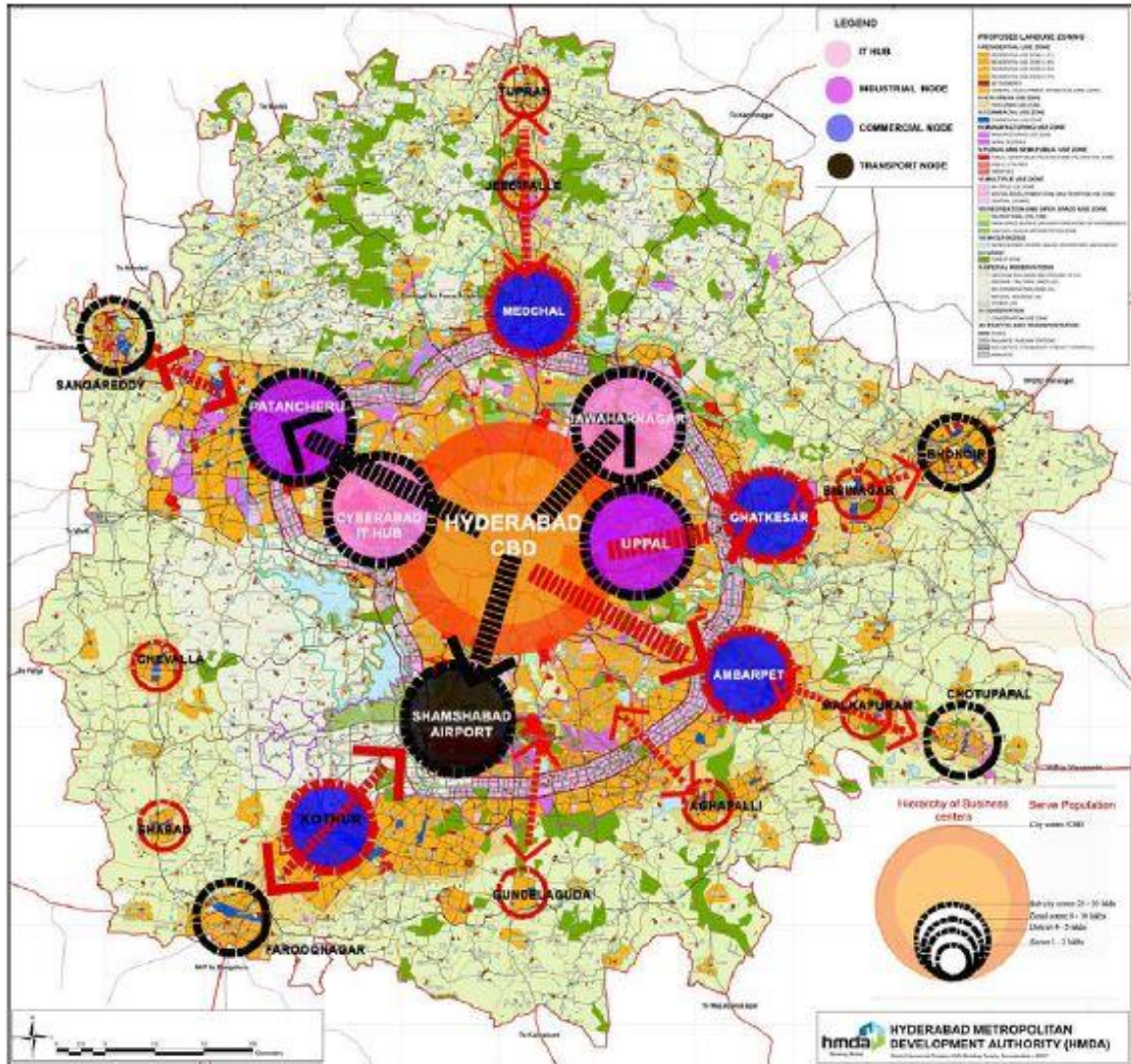


Figure 6.2 Hyderabad 2031 nodes by specialty (Hyderabad, 2031)

The urban-rural continuum is the gradual change in urban build-up intensity from the city core to the peripheral areas. The city cannot withstand an influx of residents living within the city core. Many new migrants, often poorer families moving to the city from remote areas for work, stay in nearby villages and commute to the city each day. The urban-rural continuum principle seeks to plan growth with the understanding that an urban-rural fringe is a place of transformation from rural villages to urban. Hyderabad 2031 envisions urban-rural fringe transformation taking place in three stages. First, the transformation of agricultural land use is taking place. The increase in population leads to more demand for products, improved

transportation facilities, and increased awareness of and direct contact with the city. Second, changes in occupational structure as the village responds to new employment opportunities. More private businesses and increased public transportation increase household income leading to better-furnished homes, but at this stage of development will not see an increase in basic amenities such as water, sewer, and drainage. The third stage of development will see urban land use growth. Real estate investors will develop the village into residential colonies or industrial sites, and land value will increase. Farming will progressively decline, and the way of life in the village will become increasingly urban.

The purpose of an urban boundary is to supply and synchronize urban growth by supporting utilities and development-friendly policies within the boundary while preserving open space, agricultural land, and environmentally sustainable development. Also known as a service boundary, should encompass current and future growth. The urban boundary has been defined to encompass all phase-wide development.

Peri-urban development seeks to include the periphery into urban development. Land and water resources of the surrounding metropolitan area are required to sustain the urban population. Agricultural development of the peri-urban areas is included in the context of the urban core by promoting rings of agricultural activity. Dairy and intensive farming have short shelf lives and must be closest to the city. Other goods, such as vegetables can be grown further away from the city. Hyderabad 2031 includes agricultural zones in the development plan to protect rural livelihoods and cater to the needs of both urban and rural populations.

Social amenities have been proposed according to the Ministry of Urban Development UDPFI guidelines. The UDPFI guidelines are a framework for renewed planning systems. Each type of village, city, and megapolis has central government regulations on the types of social

amenities that village/city, Mandal, district and state governments are required to plan for. Some of these amenities are planned for at the local level, while others such as education, health, and finance are identified at the Mandal and state levels.

Finally, environmental suitability development proposes the Hyderabad Metropolitan Development Authority plans should be in harmony with the environment. Zoning is the main instrument used to protect the environment. Segregation of residential, commercial, and industrial areas have been planned, and existing corridors must be designed with a green buffer to protect the residential areas from air and noise pollution. Industrial areas are planned so that specialized treatment plans can be installed in clusters to reduce infrastructure costs. Hyderabad 2031 incorporates the region see Figure 5.21. The city core, the periphery, and the extended rural region into the development plan. For the first time, Hyderabad has developed an urban master plan while being fully aware of the impact globalization will have in the next decade of growth. The city has planned for both global economic growth with IT hubs to facilitate economic development that taps into the global demand for IT services. The city has also planned for how to sustain a global IT hub with nodal development of specialized economic zones and rural agricultural requirements. Figure 5.22 shows the projected urbanization of Hyderabad until 2031. There is a noticeable northwestern trend in growth, with nodal growth to the north, east, and south of the city. Urban growth from the 1990s to 2010 was mostly unplanned. Urban planners at the time were unable to predict the impact of globalization on the city. Hyderabad 2031 was

designed with a full understanding of what the city needs to do to grow in the twenty-first-century.

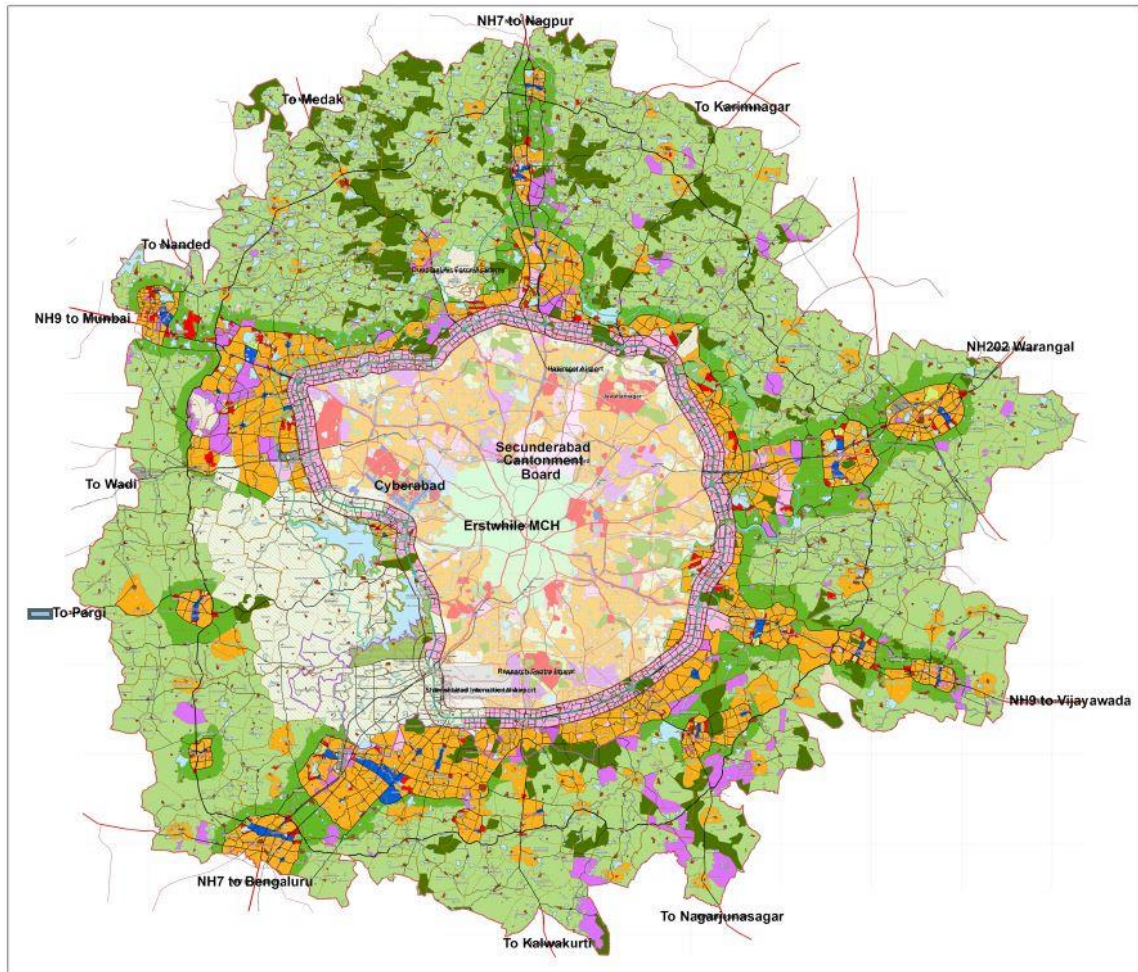


Figure 6.3 Hyderabad 2031 master plan zoning (Hyderabad 2031, 2020)

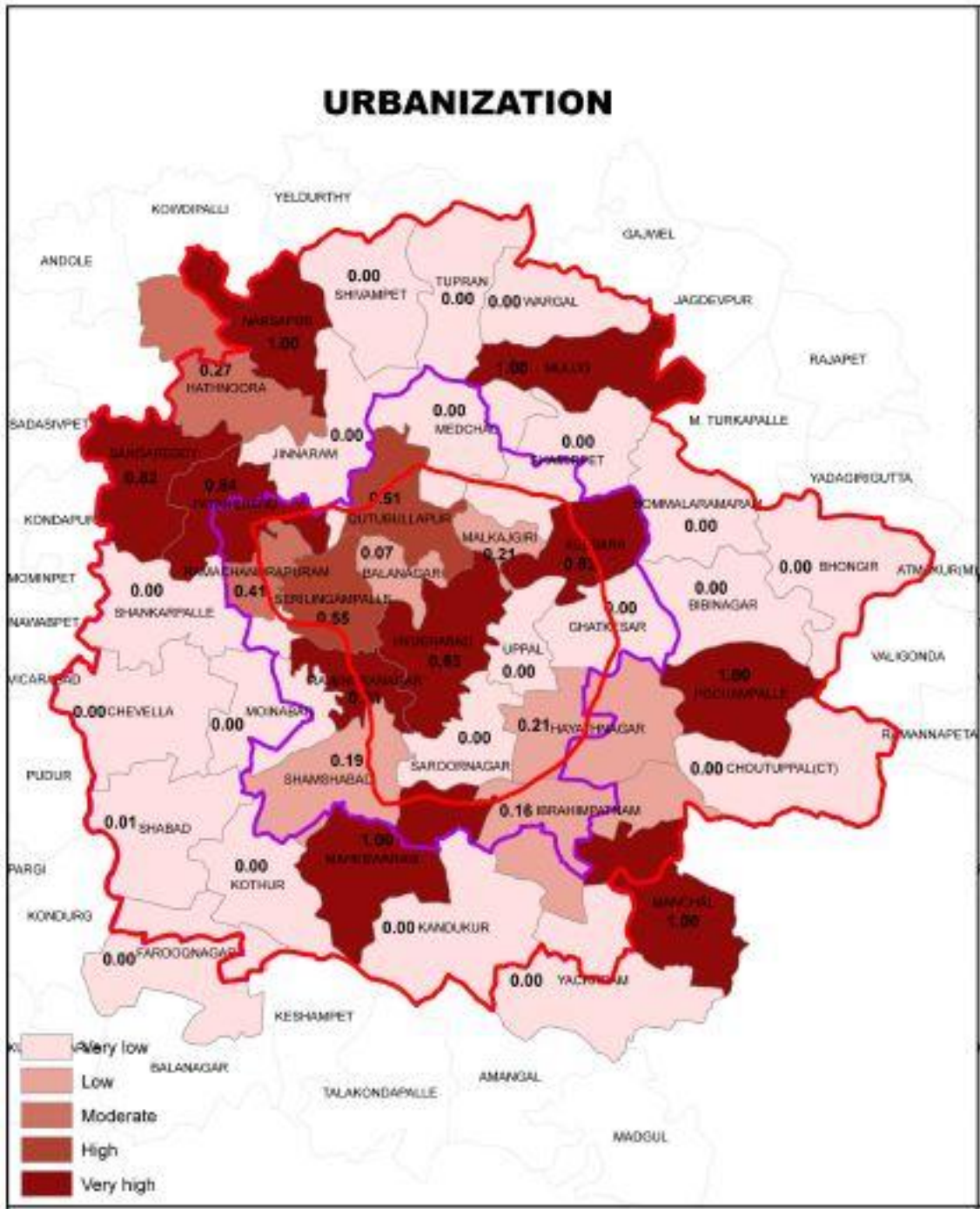


Figure 6.4 Hyderabad 2031 predicted Urbanization (Hyderabad 2031, 2020)

The Desakota model of urban growth in Asia is based on the concept that cities were not planned but instead grew using informal techniques. The *Desakota* model is a theory of urban growth in Asia that broadly argues that urban cores, peripheries, and areas along transportation routes between urban cores evolve as one through a process of informal market-driven processes (Ginsburg, et al. 1991). This analysis finds that although the Indian government may have accepted informal urban development processes that produce mixed land uses but created uncertainty in land tenure for the residents in the past, they are largely not doing this anymore. Post globalization urban planning indicates that unplanned informal urban growth is being reined in and planned. The Desakota model is an effective model for understanding how Hyderabad, Indian and other Asian cities grew in the post-war period. However, as nations come to grips with the urban needs required by globalization, effective planning processes have been and continue to be put in place to control urban growth in the face of globalization.

This study faces some limitations. The availability of historical satellite imagery is limited by cloud cover. There is also a limitation of being able to conduct accuracy assessments of earlier time periods because of a lack of reference datasets. Although the urban morphology method acts as a lens to filter the endless important histories of Hyderabad, South India, South Asia, and the greater Muslim world, it remains impossible to fully capture all of the significant histories that have helped to shape Hyderabad into the global city it is today. This analysis could be conducted at a different scale of analysis and produce different results. This analysis could also be conducted in a more limited time frame. The task of exploring the time period from 1687 to 2015 was a laborious task. More research is needed to examine the histories between the 1908 flood and independence. That time period is perhaps the most important part of the urban history of Hyderabad and much more research is needed to understand the causes and implications of what happened. Likewise, this analysis has brought to light the need for a new Indian specific globalization planning model that explains how planning is being conducted in face of globalization but also how we should model future urban change in the twenty-first-century.

Hyderabad is a microcosm of the complex relationship between humans and the environment. Hyderabadis have adapted to and adopted the material realities to meet specific needs at various periods of their history. Attempts to shape the landscape have produced a city that has undergone massive historical transformations. What Hyderabad needs the city to be like now is very different than what they needed hundreds of years ago. Hyderabad has adapted the current needs to the existing infrastructure and is making alterations as they are able. Many urban challenges revolve around how to deal with infrastructure designed for another time.

7 Conclusion

By delineating and quantifying the geographic extent of built-up urban area in Hyderabad, India from 1687 to 2019 using a mix of scanned historical maps and remotely sensed imagery major time periods have been identified as turning points in the development of the urban growth of the city. This analysis has emphasized time periods that have had a greater impact on changes in urban extent than others. The founding of Hyderabad, industrialization, the 1908 flood and pandemics, unplanned population growth throughout the twentieth century and finally globalization have all been identified as major factors in the growth of Hyderabad from 1591-2019.

Using the urban morphology method to evaluate spatial patterns of change in urban area extent and form from 1591-2019 while specifically focusing on the known change from north-south directional morphology to east-west; this study has determined that initially the design of Hyderabad based on a combination of pre-Islamic and Islamic exoteric cosmology was the most influential factor in the patterns of change in the late sixteenth and seventeenth centuries. After being annexed by the Mughal Empire, the patterns of change moved away from the hierarchies of Islamic cosmology and toward other types of urban morphologies. The process of new urban morphologies began when the capital of the region returned to Hyderabad from decades in Aurangabad. Colonization and industrialization played important roles in shifting urban change northward. The 1908 flood and the early twentieth century pandemics that followed were perhaps the most impactful era for urban morphological change since the city's inception in 1591. Although the city grew after India's independence, the city grew in more or less an unplanned fashion until the twenty-first century when post globalization urban planning have attempted to mediate urban growth.

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