ANALYSING PATTERNS AND TRENDS OF URBAN GROWTH IN KOCHI: A GEO-STATISTICAL MODELING APPROACH

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DECLARATION

I, Varghese. K, hereby declare that the thesis entitled "**ANALYSING PATTERNS AND TRENDS OF URBAN GROWTH IN KOCHI: A GEO-STATISTICAL MODELING APPROACH**" submitted by me for the award of the degree of **DOCTOR OF PHILOSOPHY** is my bonafide work and that it has not been submitted so far in part or in full, for any degree or diploma of this university or any other university.

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CERTIFICATE

It is hereby recommended that the thesis may be placed before the examiners for evaluation.

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Dedicated to my Family, Relatives, and Friends

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VARGHESE. K

Table of Contents

List of Tables

List of Figures

List of Maps

Acronyms

ABM	Agent Based Modeling
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
ANERT	Agency for Nonconventional Energy and Rural Technology
ANN	Artificial Neural Network
ASEAN	Association of Southeast Asian Nations
ASI	Annual Survey of Industries
BII	Built-up Intensity Index
BP	Back Propagation
BSUP	Basic Services for Urban Poor
CA	Cellular Automata
CBD	Central Business District
CCTV	Closed Circuit Television
CDP	City Development Plan
CEPI	Comprehensive Environmental Pollution Index
CHTS	Cochin Harbour Terminus
CI	Compactness Index
CIAL	Cochin International Airport Ltd
CPA	Critically Polluted Areas
CPCB	Central Pollution Control Board
CPCB	Central Pollution Control Board
CRZ	Coastal Regulation Zone
CSEZ	Cochin Special Economic Zone
CT	Census Town
DAY	Deendayal Antyodaya Yojana
KWM	Kochi Water Metro
LCM	Land Change Modeler
LIG	Lower Income Group
LPG	Liquid Petrolium Gas
LULC	Land Use Land Cover
MC	Municipal Corporation
MLD	Million Liters per Day
MLP	Multi Layer Perceptron
MLP NN	Multi Layer Perceptron Neural Network
NBO	National Buildings Organisation
NCU	National Commission on Urbanisation
NCU	National Commission on Urbanization
NDBI	Natural Difference Built-up Index
NDVI	Natural Difference Vegetation Index
NGO	Non Governmental Organisation
NH	National Highway
NHAI	National Highway Authority of India
NHP	National Housing Policy
NIR	Near Infra Red
NITI	National Institution for Transforming India
NRK	Non Resident Keralites
NRY	Nehru Rozgar Yojna
NSDP	National Slum Development Programme
NSSO	National Sample Survey Organisation

DDA	Delhi Development Authority
DDP	District Domestic Product
DEM	Digital Elevation Model
DEM	Digital Elevation Model
EMC	Electrical Inspectorate and Energy Management Centre
EWS	Economically Weaker Section
FCA	Fuzzy Cellular Automata
FDI	Foreign Direct Investment
FYP	Five Year Plan
GBS	Gross Budgetary Support
GCDA	Greater Cochin Development Authority
GDDP	Gross District Domestic Product
GDP	Gross Domestic Product
GDVA	Gross District Value Added
GIS	Geographical Information System
GLCF	Global Land Cover Facility
GOI	Government of India
GPS	Geographical Positioning System
GSDP	Gross State Domestic Product
GSVA	Gross State Value Added
GUI	Graphical User Interface
GVA	Gross Value Added
HC	Health Centres
HDI	Human Development Index
HDIL	Housing Development and Infrastructure Ltd
HH	Household
HS	Higher Secondary
HUDCO	Housing and Urban Development Corporation
ICD	International Container Depot
ICT	Information and Communication Technology
ICTT	International Container Transshipment Terminal
IDW	Inverse Distance Weighted
NULM	National Urban Livelihoods Mission
OBC	Other Backward Caste
OG	Out Growth
OLI	Operational Land Imagers
OSM	Open Street Map
PCA	Principal Component Analysis
PM	Particulate Matter
PNG	Piped Natural Gas
PPP	Public Private Participation
PSU	Public Sector Unit
PWD	Public Work Department
RAY	Rajiv Awas Yojana
RGI	Registrar General of India
RGPSA	Rajiv Gandhi Panchayat Shashaktikaran Abhiyan
RMS	Root Mean Square
RRY	Rajiv Rinn Yojana
RS	Remote Sensing
SCST	Scheduled Caste Scheduled Tribe
SDP	State Domestic Product
SEPZ	Software Export Promotion Zone
SEZ	Special Economic Zone
SH	State Highway
SHG	Self Help Group
SIDCO	Small Industries Development Corporation
SISI	Small Industries Service Institute
SJSRY	Swarna Jayanti Shahari Rozgar Yojana
SOI	Survey of India
SRA	States Re-organization Act
SRTM	Shuttle Radar Topography Mission
ST	Statutory Town
STA	Spatial Trend Analysis
SWIR	Short Wave Infra Red

IHSDP	Integrated Housing and Slum Development Programme
IHSUP	Interest Subsidy Scheme for Housing Urban Poor
IT	Information Technology
IUDP	Integrated Urban Development Programme
IWAI	Inland Waterways Authority of India
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
JRY	Jawahar Rozgar Yojana
KCR	Kochi City Region
KFC	Kerala Financial Corporation
KIIFB	Kerala Infrastructure Investment Fund Board
KINFRA	Kerala Industrial Infrastructure Development Corporation
KITCO	Kerala Industrial & Technical Agency Organization Limited
KMC	Kochi Municipal Corporation
KMRC	Kochi Metro Rail Corporation
KSEBL	Kerala State Electricity Board Limited
KSHDC	Kerala State Handloom Development Corporation
KSIDC	Kerala State Industrial Development Corporation Ltd
KSPCB	Kerala State Pollution Control Board
KUA	Kochi Urban Agglomeration
TCPO	Town and Country Planning Organisation
TFR	Total Fertility Rate
TOI	Times of India
TPM	Transition Potential Modeling
UA	Urban Agglomeration
ULB	Urban Local Bodies
ULCRA	Urban Land (Ceiling and Regulation) Act
ULCRA	Integrated Development of Small and Medium Towns
ULG	Urban Local Governance
UNSD	United Nations Statistical Division
USEP	Urban Self-Employment Programme
USGS	United States Geological Survey
USHA	Urban Statics for Human Resources and Assistance
UWEP	Urban Wage Employment Programme
VAMBAY	Valmiki Ambedkar Awas Yojana
WTC	World Trade Center
WTO	World Trade Organisation
WUP	World Urbanisation Prospects

Chapter-1: Introduction

1.1 Background

The urbanization process is associated with the concentration of population in an area characterized by several benefits and drawbacks. People's tendency to aggregate in urban centers is linked to higher “quality of life” as a result of greater employment opportunities, a superior resource delivery system, better schools, basic services, enhanced health facilities, better infrastructure, and other such amenities (N. Banerjee, 1969). Although the concentration or absorption of the population in an urban area leads to the economic development of the area as well as contribute to the nation-building, it may also lead to scarcity of resources, issues related to the management of existing resources such as traffic, public distribution system, sanitation, water supply, pollution control, and other service deliveries (Brenner, 2013). Therefore, the planners and administrators often need to take many decisions frequently to meet the current requirements and balance the use of resources to meet the needs in the future (Roy, 2009).

The transformation of an area to urban takes place due to the change in economic activities of people from traditional agriculture to industrial and service-based economy along with the increase in population size and density of population in an area (Andersson et al., 2002). The “natural growth” of people in an urban region, migration, and areal expansion are the primary causes of urbanisation in India (Das & Bhusan, 2014). People tend to migrate to an urban area due to the pull factors in the destination associated with better quality of living, employment opportunities, and access to various services also push factors in the origin because of natural, political, or economic stresses and compulsions (Mu & Hu, 2016). The expansion of urban areas also takes place when nearby villages and small towns attain urban characteristics due to the interaction and proximity of these places with a city area (Dupont, 2007).

Historically urban areas are originated in places having core functions of temples, administration, commerce, crafts, and ports (Avari, 2007). These places were relatively small towns having different markets selling agricultural and plantation products, clothes, crafts, and jewelry (Avari, 2007). In the context of the Indian sub-continent, port towns and temple towns characterized an important role in urbanization (A. Banerjee &

Gupta, 2017; Josna Raphael & Kasthurba, 2015). Temple towns acted as a catalyst force to the development of the economy and also the society (Josna Raphael & Kasthurba, 2015). The administrators used to build temples mainly to demonstrate their devotion to various deities. They granted land and money to temples for carrying out rituals, foods for priests and pilgrims, and also to celebrate festivals. The donations received from pilgrims in cash and kind are used to finance trade and banking. This has made a large number of workers, traders, and artisans settle down near temples to cater to their needs, and slowly the places around it start developing into townships (Stein, 1960).

From the eighth century onwards, the subcontinent had several small towns emerge from large villages (Kadi & Nelavigi, 2015). People come to these towns from far-off and nearby places to buy local articles and sell cattle and plantation products. With the growth of trade in different articles, the traders also started to have a hierarchy of small, medium, and big traders (Kadi & Nelavigi, 2015). They sold spices and textile products through various ports such as Kochi and other ports in the country in exchange for costly articles from Southeast Asia and China (Subbarayalu, 2014). In the seventeenth century the Portuguese, Dutch, and English had their factories and warehouses in many port towns (Newitt, 1986; Thakur, 1981). The Mughal towns of the sixteenth and seventeenth centuries were known for their richness, population density, enormous architecture, and magnificent appearance (Bernier, 1826). The decline of Mughal power resulted in the abolition of towns linked with their control (Ali, 1975). Old towns declined as a result of political and commercial realignments, while new towns grew (Ali, 1975). In the mid-eighteenth century, the British started to acquire political control of India and the trade of the English East India Company expanded. This contributed to the emergence of port towns like “Madras, Calcutta, and Bombay” as new economic capitals, as well as a drop in trade in smaller port cities like Kochi (Rodriguez, 2002). Kochi has grown into a thriving cosmopolitan and commercial center of Kerala throughout the years. The city is also well-known for its great heritage, different ethnic groups, and ancient charm. In terms of lifestyle, clothing, plurality, economy, and prospects, Kochi has a distinct style statement that sets it apart from the rest of the province (Kuriakose & Philip, 2021). By 2031, the city region's population is forecasted to reach 2.27 million people (Kuriakose & Philip, 2021). This dramatic increase necessitates a thorough assessment of several major areas of urban growth trends and patterns, as well as civic infrastructure. Therefore, a study is required to understand the patterns of urbanization in Kochi. Using

a geostatistical modeling approach, the current study tried to draw inferences on Kochi's urban growth trends and patterns.

1.2 Varied Global Definitions of 'Urban'

A uniform definition of 'urban' in a global perspective has not been found any solution in urban studies. There are several basic definitions such as "an administrative unit with a minimum specified population" (McIntyre et al., 2001), "criteria of population density", "built-up area or urban morphology", "commuting density", "traveling distance" (Nilsson et al., 2013), "legal declaration", and "economic activities". In most Asian countries, "population density" and "economic activities" are prominent criteria used to define 'urban' (Aijaz, 2012).

As per the Demographic Yearbook-2018 published by United Nations Statistical Division (UNSD), 2018, about 105 countries in the world uses administrative boundaries including capital cities, municipal area, or other types of local jurisdiction as one of the criteria for defining an urban area among them 83 countries use it as the sole standard for distinguishing the urban from the rural areas (UNSD, 2018). In addition to other standards, 100 countries use population size or density as one of the criteria, out of which 56 countries use it as the sole criteria for the definition of the urban area (UNSD, 2018). Around 25 countries use economic characteristics such as non-agricultural employable population and 18 countries use urban infrastructure as one of the additional criteria for the definition of an urban area (UNSD, 2018).

Many Countries in Asia define urban areas based on demographic and economic factors (Aijaz, 2012). According to China's government policy on the classification of urban/rural habitation for statistical reasons, an area is designated as urban (Qin & Zhang, 2014). The department of "town planning and the interior ministry" defines Cyprus' urban area (Oktay, 2002). An area in Indonesia that meets particular criteria for "population density", "percentage of agricultural households", "access to urban facilities", the "presence of extra facilities", and "percentage of the built-up area" not used for housing (Mertens & Alatas, 1978). Malaysian urban areas are defined as gazetted areas and adjacent built-up areas with a total population of 10,000 or more people (Eng, 1995). Built-up areas are defined as areas that are adjacent to a gazetted area and have at least 60% of their inhabitants engaged in non-agricultural activities (Eng, 1995). Wards are treated as urban regions in Myanmar, according to the "General

Administration Department" (Roberts, 2018). These locations normally feature a higher density of building structures, a larger population, and more developed infrastructure. Nepal's urban area has been designated as a municipality by the government (Bakrania, 2015). Pakistan employs the legislative definition of places in conjunction with the "metropolitan corporation", "municipal corporation", "municipal committee", "town committee", or "cantonment" that exists at the time of the census (Javed & Riaz, 2020). According to the operational definition of an urban area in the Philippines, an area with more than 5000 residents and at least one establishment with a minimum of 100 employees, or five or more small-scale establishments with 10 to 99 employees, is considered an urban area (Xenos & Kabamalan, 2007).

1.2.1 Definitions of 'Urban' in India

According to the Census of India, Statutory Towns (ST), its outgrowths (OG)[1], and the Census Towns (CT) are known as 'Urban' (Ghosh & Khatun, 2021; Pradhan, 2017). Statutory Towns constitutes all places governed either by the "municipal corporation", "municipality", "cantonment board", or "notified area committee" (Ghosh & Khatun, 2021). "Outgrowths" are either a "village or a part of the village" which is "contiguous to a statutory town" having visible city infrastructure and amenities features (Chatterjee & Roy, 2021).

Villages can also be defined as 'urban', namely Census Town (CT) if they satisfy the three criteria set by the Census of India. These are "(1) a minimum of 5,000 people living in an administrative area, (2) density of population 400 persons or above per square kilometer, and (3) workforce of at least 75 percent of male main workers in the non-agricultural sector". It is noteworthy that the CTs are areas identified as urban but essentially it is under the rural governance system (Guin & Das, 2015; Pradhan, 2017). Towns in India are also defined based on their functions as industrial, commercial, defense, educational, religious, cultural, and tourist importance (Singh, 1977).

1.3 Global Urban Population

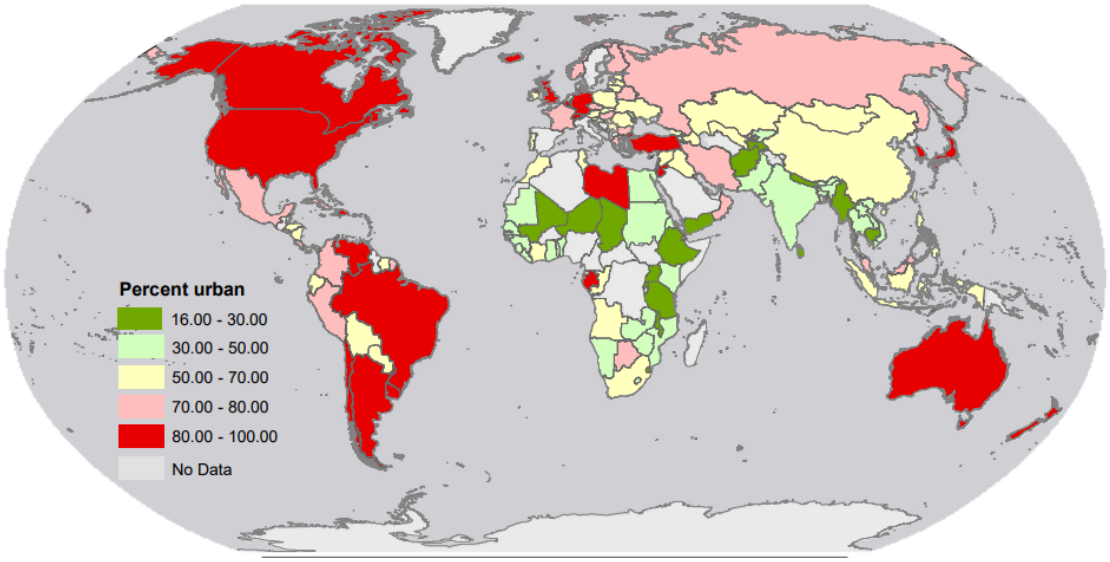
As per World Urbanisation Prospects (WUP) 2018 revision, 55.3 percent of the total world population lives in the urban area and it is expected that by 2050 it will reach 70 percent (United Nations, 2018). The majority of this growth is expected to be happening

[1] Area which are outside the statutory area and acquire urban characteristics over time

in India, China, and African countries due to the rapid urbanization process in recent years (United Nations, 2018). A spatial comparison of the urban population reveals that Africa has the least percentage of 42.5 percent people living in the urban area followed by Asian countries with an average of 49.5 percent as per the WUP 2018 revision (United Nations, 2018). The highest percentage of the urban population is in North America followed by South America, Europe, and Australia with 80.7, 74.5, and 68.2 percent respectively (United Nations, 2018).

A regional comparison within the continents reveals that within the African continent southern part of Africa is more urbanized with 63.6 percent people living in urban areas followed by Northern Africa with 52 percent and central Africa with 50 percent urbanization. Eastern Africa recorded the lowest percentage with an average of 28 percent people living in the urban area (United Nations, 2018).

Map 1.1: Percentage of Urban Population: 2009 to 2018



Note: Map is based on the latest available data for each country between 2009 and 2018.
Source: Adapted from United Nations Demographic Year Book-2018.

Similarly, Western Asia countries have the highest percentage of the urban population in Asia with a combined average of 72 percent followed by Eastern Asia that including China, Korea, and Japan reports 63 percent population living in urban areas (Ritchie & Roser, 2018). The Southeast Asian countries that include fully urbanized Singapore, Malaysia, Indonesia, Philippines, Thailand, Cambodia, and Myanmar have a collective figure of 49 percent living in urban areas (D. Kundu & Pandey, 2020). The Central Asian countries of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan together

have 48 percent of people living in the urban area (United Nations, 2018). The nine South Asian countries including India have an overall 35.8 percent urban population with the highest being Iran with 75 percent of its population living in the urban area. The lowest are Nepal and Sri Lanka with 19 percent of each urban population. It is expected that the urban percent of some countries in these two continents including India is expected to pick up at a faster rate (United Nations, 2018). A map of the world (Map 1.1), representing the percent of the urban population using the latest available data shows that many countries in these two continents have less than 50 percent of people living in the urban area (UNSD, 2018).

1.4 Urbanisation in India

With the recent trends in urbanization especially in developing countries, it can be expected that in the next few decades the urbanization is likely to increase in less urbanized and less developed countries (Myers, 2021). Similarly, relatively more urbanized countries and fully urbanized countries may like to limit the migrant population to have orderly urbanization and balanced governance (OECD/European Commission, 2020). The rapid process of urbanization in the developing world has considerably resulted in altering the pattern and intensification of land use in terms of natural resources, socio-demographic, health, and environmental changes (Seto & Reenberg, 2014). The pace of economic growth, especially in the developing countries leads to a greater urban expansion with structural changes on a large scale (Seto & Reenberg, 2014).

The first two decades of the post-independence period in India have not witnessed a major urban transformation (Mookherjee, 2003). This is evident from the fact that India’s urban population with little over 17 percent in 1951 had added only 3 more percent by 1971 (Table 2.4). Urbanization in India has started getting momentum after the liberalization of its economy in the early 1990s (Table 2.4). By 2001 the percent urban population rose to 27.8 percent (Table 2.4). As per the 2011 census, 31.2 percent of people are living in urban areas (Table 2.4). By 2020, India's urban population is expected to reach roughly 35 percent, or 48.2 million people, in absolute terms (United Nations, 2018). This means there are currently more people living in Indian cities than there are people in the world's third-largest country. The magnitude of the urban population in

India can also be understood from the fact that India's share in the global urban population was 11.3 percent in 2018 (United Nations, 2018).

Similarly, since independence, the large cities in India have been witnessing a significant change in their "land-use pattern" due to the increasing trend of population growth, rise in industrial and commercial activities, and considerable jump of the migrant population in these cities (Taubenböck et al., 2008). This process in large cities has necessitated adding newer land to the existing urban area resulting in areal expansion. The concentrated nature of urban growth also resulted in many adverse impacts such as increased pollution (Mage et al., 1996), scarcity of natural resources (Mohan et al., 2011), and compromise on biodiversity (Narayanan & Bindumadhav, 2019), and others.

1.4.1 Urbanization in Kerala

The urbanization in most of the Indian states is largely designated to cities and towns, whereas in Kerala except for some "Gram Panchayats" in the hilly regions and a few odd isolated areas, the entire state depicts the picture of an "urban-rural continuum" (Mohammed Firoz et al., 2014). According to the 2011 census, the percentage of the urban population of Kerala was 47.7 percent, much higher than the national average of 31.2 percent. The urban sector in Kerala as per the 2011 census comprises 5 municipal corporations, 53 municipalities, 16 out-growths, 1 cantonment board, and 461 census towns. Out of these, the corporations and municipalities house only 32.9 percent population while 64.6 percent of the population lives in census towns. Compared to other states in India, Kerala's "local self-government system" has been distinct in ensuring financial decentralization, involvement of local bodies in formulating and implementing plans, and also ensuring people's participation in development planning (Sivaramakrishnan, 2015). Currently, there are 1200 local governments in Kerala, which includes 941 "Gram Panchayats", 152 "Block Panchayats", 14 "District Panchayats", 77 "Taluks", 87 "Municipalities", and 6 "Municipal Corporations"[2].Among the 93 Urban Local Bodies (ULB) one corporation (Kannur) and 34 municipalities are formed post-2011. Among these, 23 of the new municipalities are in five districts of Malappuram, Ernakulam, Kozhikkode, Palakkad, and Kannur only.

As compared to the rest of the country, Kerala has a unique pattern of urbanisation. Development in the transport sector lead to a large number of scattered commercial and

[2] https://kerala.gov.in/local-self-governance

trading centers that later became towns (Kuruvilla, 2014). The state does not have any primate city and the problems connected with it (Mohammed Firoz et al., 2014). The rural to urban migration that increases the urban population and problems associated with it is negligible in the state. The urban growth in Kerala has tremendous possibilities as the labor stock in Kerala is rich with large-scale skilled labor, making it an ideal location for knowledge-based service sectors (Kumar, 2007).

1.5 Urban Policies in India

The "Government of India (GoI)" to uplift the economy and development of the nation devised "Five-Year Plans (FYPs)" soon after the Independence. The plans, which are prepared, executed, and monitored by the "Planning Commission of India" and in the last few years by the "NITI Ayog (National Institution for Transforming India)" undertook various policy measures to tackle the issues related to urban development in India. Though urban planning is a state subject in India's constitution, but just a few states have taken the lead in this area, and much of what exists as policy has originated from the central government (Shaw, 1996). Therefore, the urban policies as laid down in the five years plans carry greater importance as these are common policies followed by both the Centre and States.

During the First FYP (1951-56), the "Town and Country Planning Organisation (TCPO)", the "National Buildings Organisation (NBO)", and "Delhi Development Authority (DDA)" were set up (Bhagat, 2014). This has aided in improving the quality and efficiency of existing buildings while also promoting environmental sensitivity, housing technology research and development, and the training of qualified city planners (Rao & Kumar, 2019). During this period, the "Delhi Master Plan" was prepared as a model plan, which provided a framework for the preparation of master plans of other cities (Shaw, 1996).

During the "Second Five Year Plan" (1956-1961) there was an atmosphere of economic stability, as the actual economic growth of the country during the first FYP was higher at 3.6 percent than the targeted growth of 2.1 percent due to the focus on agriculture and allied services (MoSPI, 1968). The focus during this period shifted from agriculture to light and heavy industries. The industrial policy of 1956 gave priority to setting up industrial towns as the potential centers of urban development (MoSPI, 1968). It also necessitated the preparation of Master Plans for these cities for urban planning.

The “Third Five Year Plan (1961-1966)” though witnessed many unforeseen events such as the Indo-Sino war, Indo-Pak war, and droughts have turned out to be the turning point in the urban development and planning of India (Bhagat, 2014). During the same period, the town planning responsibility has shifted from Centre to States. It provided financial assistance for the development of master plans for cities and towns in several states. As a result, multiple master plans for various cities and towns were devised (Bhagat, 2014). The third FYP was the critical point in the urban development and planning process in India as for the first time a policy to formulate urban planning and land policy is created as it recognized the importance of balanced development (Bhagat, 2014). The urban land policy asked for "certain minimal directions" to be followed during the plan era in order to correct the urban growth pattern. Controlling urban property values, land use planning, master planning, and minimum acceptable standards for housing and other services, as well as strengthening municipal administration to take on new tasks, were among them (Shaw, 1996).

The Third Plan's regional and urban development goals were continued in the "Fourth Five Year Plan (1969-74)," and development plans for 72 urban areas were also launched (Bhagat, 2014). During this time, the "Housing and Urban Development Corporation (HUDCO)" gave financing to metropolitan authorities, “state housing boards”, and other urban institutions for urban development projects. Most of these housing projects were in large cities to house industrial working-class families (Bhagat, 2014). It also encouraged state governments to establish “metropolitan planning areas” to deal with the expanding areas outside the administrative city limits (Bhagat, 2014; Shaw, 1996).

The "Fifth Five Year Plan (1974-79)" included steps to manage land prices in cities, improve basic services in metropolitan area, solve metropolitan city challenges, and support national-scale development projects in metropolises (Rao & Kumar, 2019). Promoting the development of small and medium towns to ease the pressure of increasing urbanization in a few cities and for the betterment of rural areas was one of the objectives of this plan. The plan accentuated the need for infrastructural development of cities with a population of over three lakhs and a special scheme called the “Integrated Urban Development Programme (IUDP)” was launched to achieve this goal. During the fifth FYP a law called “Urban Land (Ceiling and Regulation) Act (ULCRA), 1976” was announced aimed at checking the land prices, preventing the concentration of land in the hands of a few people that promote speculation. The Act also establishes a cap on the

holding and ownership of unoccupied property in metropolitan areas, as well as the acquisition of excess land for the purpose of developing housing stock for the poor. To control the increase in land prices in cities, the Plan suggested several measures, including, “differential taxes on land-based on its use, higher taxes on vacant lands to discourage speculation, conversion tax on the change of land use and enhanced stamp duty on transfer of lands**”** (Rao & Kumar, 2019).

The "Sixth Five Year Plan (1980-85)" emphasized the necessity for decentralisation, stating that a national urbanisation policy should include regional issues and that more investment should be made in small and medium towns' growth. Thus after 15 years since the country started talking about the necessity of decentralized urban growth, it launched a project called the “Integrated Development of Small and Medium Towns (IDSMT)” in this plan (Shaw, 1996). The financial commitments for regenerating smaller urban centers are made in this plan. The scheme started with 231 towns selected based on the proportion of the urban population has later included more towns in the subsequent years. The major goal of this project was to provide infrastructure and basic services to communities with populations under 100,000 people in order to encourage growth. “Land acquisition and services, construction of new markets, provision of industrial estates, provision of other services and processing facilities for the benefit of agricultural and rural development in the hinterland, and low-cost sanitation” were among the state components eligible for central assistance under the IDSMT (Rao & Kumar, 2019).

The “Seventh Five Year Plan (1985-1990)” continued to emphasize the improvement of “small and medium towns” through the IDSMT project. It also stressed the need to involve the private sector in urban development since the delivery of public service is not feasible by involving only the government sector. The revitalization of civic bodies and greater autonomy to urban local bodies to ensure community participation in urban development has found greater importance. A bill referred to as the “65th (Constitution Amendment) Bill, 1989” introduced in the “Lok Sabha” to strengthen urban municipal bodies adopting the recomendations made by the “National Commission on Urbanisation (NCU)”. However, the bill aimed at having a third tier of governance after center and state in urban development failed to get the nod of Rajya Sabha largely due to the concerns of many states and union territories over the interference of the center in their area of control (Shaw, 1996). Apart from the decentralized administrative structures, the seventh plan also emphasized the need to preserve local diversity and a bottom-up

approach in planning. Towards the end of the seventh FYP, a new Programme called "Nehru Rozgar Yojna (NRY)" was launched with an emphasis on the creation of urban employment mainly targeted at the urban poor. Towards the end of the seventh FYP, a "National Housing Policy (NHP)" was announced in which the government facilitated for providing housing for the poorest and vulnerable sections.

The relevance and importance of the urban market for the country's economy were highlighted in the "Eighth Five Year Plan (1992-1997)." During the plan period, the average annual increase of employment in urban regions was around 3.8 percent, while it was around 1.6 percent in rural areas. The Plan highlighted key issues in the emerging urban scenario, including the growing gap between demand and supply of infrastructure facilities, "access to basic services such as drinking water, sanitation, education, and basic healthcare, and the backlog of housing shortages", which has resulted in the spread of slums and squatter settlements, as well as the deterioration of city environments. The eighth FYP also strengthened civic bodies and ensured greater autonomy to urban local bodies. The earlier bill (65^{th}) which could not get the nod of the Rajya Sabha has reintroduced the bill with some modification as the 74th (Constitution Amendment) Bill, 1992 and it was passed and became the 74th (Constitution Amendment) Act, 1992. The eighth FYP also continued the emphasis on the creation of urban employment targeting the urban poor (Shaw, 1996).

The "Ninth Five Year Plan (1997-2002)" stressed decentralisation and financial autonomy of urban municipal governments, with the goal of increasing efficiency and competitiveness through market-based initiatives (Bhagat, 2014). It stresses a state urbanization strategy that would establish greater coordination among various urban development programs. During the Ninth FYP, a new program called the "Swarna Jayanti Shahari Rozgar Yojana (SJSRY)" was launched by merging some of the earlier programs like NRY. It had two sub-schemes (i) "Urban Self-Employment Programme" and (ii) "Urban Wage Employment Programme". The ninth FYP has seen a new economic environment of liberation and structural reforms in the urban sector. To tackle the problem of housing, the "public and private participation (PPP)" model was encouraged. "Multi-National Companies (MNCs)" are also set up in this plan period. The private sector also played a key role in developing infrastructure in the urban areas. The major aim of the plan was "a) Development of urban areas as economically efficient, socially equitable, and environmentally sustainable entities; b) Accelerated development of housing, particularly for the low-income groups and other disadvantaged groups; c)

Development and up-gradation of urban infrastructure services to meet the needs of the growing population; d) Alleviation of urban poverty and unemployment; e) Promoting accessibility and affordability of the poor to housing and basic services; f) Improvement of the urban environment" (Rao & Kumar, 2019).

"Tenth Five Year Plan" (2002-2007) recognized the fact that urbanization played a key role in stepping up the economic growth in the 1980s and 1990s due to the economic liberalization (Bhagat, 2014). The Tenth FYP was developed against the background of the Union Budget of 2002-03, which proposed bold steps to encourage cities to implement substantial urban reforms. Through market-oriented urban reforms and the development of public-private partnerships in urban infrastructure and services, the reforms aimed to modernise cities' existing legislative, governance, and administrative structures. The Plan recommended property tax reform, user fee levying, boosting non-tax income, limiting establishment expenses, improved usage of municipal assets, and restructuring municipal accounting processes to make urban local governments financially robust (Rao & Kumar, 2019). The Tenth FYP acknowledged that urban development could not be achieved without enhancing the democratic framework and institutional establishment of the ULBs. The union government launched the "Jawaharlal Nehru National Urban Renewal Mission (JNNURM)" toward the end of the Tenth FYP for the "integrated development of urban infrastructure and services with a focus on providing basic services to the urban poor", such as housing, water supply, sanitation, road network, urban transport, and the development of inner/old city areas, among other things.

The "Eleventh Five Year Plan" (2007-2012) aimed to boost city efficiency and productivity by deregulating and developing land, eliminating the public sector's monopoly on urban infrastructure, and establishing a favourable environment for private investment (Planning Commission of India, 2007). The "National Urban Housing and Habitat Policy" recognizes that there is a need for the government to emphasize affordable housing to the "economically weaker section (EWS)" and "lower income group (LIG)" population as they lack affordability of the rising housing prices. In the eleventh FYP also JNNURM continued to be the main instrument for raising the level of infrastructure and utilities in the existing cities. The mission aimed to create economically productive cities by improving and expanding the economic and social infrastructure. It also emphasized basic services to the urban poor and initiated a wide range of reforms in the urban sector. Apart from it. The "Rajiv Awas Yojana (RAY)"

launched in 2011 aimed to support the states and ULBs to upgrade slums to accommodate the future urban growth and to ensure new slums are not surfaced. The scheme applied to all slums within a city, whether notified or non-notified, urban homeless, and pavement dwellers. It was also applicable to urban villages inside the planning area of cities (Bhagat, 2014).

The "Gross Budgetary Support (GBS)" of "the Centre for Urban Development" in the **"**Twelfth Five Year Plan (2012-2017)" increased substantially from 3.99 percent in the Eleventh Plan to 4.60 percent in the Twelfth Plan (Planning Commission of India, 2013). The 12th FYP learned from the experience of JNNURM that there are many weaknesses in the governing system at the city, state, and central levels. The Twelfth Plan includes a new JNNURM-II that incorporates the knowledge gained from JNNURM-I. It prioritised human and institutional capacities, local planning, and governance changes, all of which are necessary for a more fiscally and environmentally sustainable and inclusive governance process (Planning Commission of India, 2013). The 12th FYP also promotes private sector involvement in urban infrastructure sectors such as "water supply, sewerage, and waste management". The private sector can improve urban transportation by building and maintaining contemporary bus terminals with commercial complexes, over bridges, and city roadways, among other things. PPP projects are also being pursued in India to create metro rail lines (Planning Commission of India, 2013). The Twelfth Plan provided a portion of the funds in many ongoing programs to be used to build implementation capacity. In this direction, a new scheme for strengthening the capacity of the Panchayats, the "Rajiv Gandhi Panchayat Shashaktikaran Abhiyan (RGPSA)" has been introduced (Planning Commission of India, 2013). The 12th Plan also gives stress on cleaner energy and pollution control as it underlines the importance of environmental sustainability as it impacts the lives of communities in several dimensions. Therefore, the need to develop new energy-efficient practices in urban housing and transport to contain the growth in the energy demand is being given importance. The plan identifies many focus areas in this direction including "Advanced Coal Technologies", "National Wind Energy Mission", "National Solar Mission", "Technology Improvements in Iron and Steel Industry", "Technology Improvement in Cement Industry", "Energy Efficiency Programmes in the Industry", "Vehicle Fuel Efficiency Programme", "Improving the Efficiency of Freight Transport", "Better Urban Public and Non-motorized Transport", "Lighting, Labelling and Super-efficient Equipment Programme", "Faster Adoption of Green Building Codes and Improving the Stock of Forest and Tree Cover".

1.5.1 Impact of 73rd and 74th Constitution Amendment on the Urban Planning in Kerala

In its recommendations, the "National Commission on Urbanization (NCU)" created by the "Government of India" identified urban areas as drivers of economic momentum, and the "Government of Kerala" agreed that the economy and urban growth are intertwined. The economic possibilities of all urban places may not be the same. A city's productive capacity is determined by a number of factors, including its location, infrastructure availability, regional connections, and willingness to accept further investments (Govt. of Kerala, 2002).

Kerala has been practicing the national framework for municipal governance as formulated through the "73rd and 74th Constitution amendment Act", the "Kerala Panchayath Raj Act, 1994", and the "Kerala Municipalities Act, 1994". This has made a higher impact on the role, powers, and functions of all "Urban Local Bodies (ULB)". The provisions of public participation, transparency, and public disclosure under the act made a complete change in the functioning of ULBs. The governance, functions, and services of all municipal corporations, municipalities, and town panchayats of the state are based on these acts. This has been done to strengthen the role of urban local bodies to help in contributing to the social and economic development of the state. About 35 percent of the state's plan funds became the share of local governments (Govt. of Kerala, 2002).

With the full support of political parties, non-governmental groups, professionals, and elected members, the "State Planning Board" spearheaded the decentralisation plan in collaboration with the department of local administration. The beginning of the de-centralized planning campaign and the formation of a committee on power decentralisation are significant milestones. It was successful in harnessing public activity for participatory planning at the local level, resulting in not only a favourable atmosphere for true decentralisation, but also a strong demand for radical transformation in the legislative, administrative, and developmental institutions. It aided in the formalisation and institutionalisation of the paradigm shift toward a people-centered, bottom-up approach to planning and development that gives people a direct and ongoing participation.

The "Panchayath Raj Act" and the "Municipalities Act" were amended to integrate the committee's recommendations on decentralisation of powers, laying the legal groundwork for healthy and responsible institutions in local government. These, together with the committee's other recommendations, have greatly aided in the

institutionalization of the decentralized campaign as a firm foundation for "local self-government".

1.5.2 Criteria for Statutory Urban Local Bodies in Kerala

Kerala Municipalities Act does not prescribe any criteria for the constitution of Municipalities. The municipalities are elevated to the status of Municipal Corporation depending upon the importance of the city, urban growth, need for the development of the urban core and its periphery, density of population, income, and demand for more progressive civic administration. However, "Government as per G.O MS 108/67/HLD dt.2nd March 1967 had laid down the following standards for the constitution of new Municipalities".

i) "The locality should predominantly be urban i.e. at least 75 percent adult population of the area should be engaged in pursuits other than agriculture".

ii) "The population of the locality should not be less than 20,000 and the density of population should not be less than 4000 per 2.59 sq. km (1 square mile) except hilly areas".

iii) "Per capita revenue resources of the locality should not be less than Rs. 5 Lakhs".

1.5.3 State and Centre assisted Programs initiated for Urban Development in Kerala

The "Kerala State Poverty Eradication Mission" launched a Programme called "*Kudumbasree* (Prosperity of family)" which was initially conceived as an employment generation Programme through active involvement and empowerment of women for the eradication of poverty in rural and urban areas of Kerala. Later the "Kudumbasree Missions" role has expanded and it played an important role in coordinating various "urban poverty alleviation schemes of the Central and State governments". These include SJSRY and the two employment programs under it namely "Urban Self-Employment Programme (USEP)" and "Urban Wage Employment Programme (UWEP)". The SJSRY Programme was later re-launched as "Deendayal Antyodaya Yojana" – "National Urban Livelihoods Mission (DAY-NULM)", a family residing in an urban area with an annual income less than Rs 50,000 is considered an urban poor in Kerala and is eligible for all benefits under DAY-NULM. The other centrally sponsored schemes for which Kudumbasree is the nodal agency are "National Slum Development Programme (NSDP)", "Valmiki Ambedkar Awas Yojana (VAMBAY)", "Jawaharlal Nehru Urban Renewal Mission (JNNURM)", "Basic Services for Urban Poor (BSUP)" for

"Thiruvananthapuram and Kochi Urban conglomerations", "Integrated Housing and Slum Development Programme (IHSDP)" for smaller towns, "Rajiv Awas Yojana (RAY)" aiming at slum-free cities, "Urban Statics for Human Resources and Assistance (USHA)", "Rajiv Rinn Yojana (RRY)" and "Interest Subsidy Scheme for Housing Urban Poor (IHSUP)" (https://thekudumbashreestory.info/index.php/programmes/urban-programmes).

In 2015, a new Programme is known as "Atal Mission for Rejuvenation and Urban Transformation (AMRUT)" is launched replacing the JNNURM. While JNURRM had a top-down approach with maximum interference from central government focused mainly in cities, the AMRUT was a less restricted decentralized form with minimum interference of the central government targeting all towns and cities with a population of over 1 lakh. At the household level, it was to ensure that every urban household has access to tap water and a sewerage connection while at the city level it aims to develop greenery, well-maintained open spaces, and reduce pollution by switching to public transport or constructing facilities for non-motorized transport. The objective is to create infrastructure to provide basic services to households to improve the quality of life of all, especially the poor and the disadvantaged. There are nine cities in Kerala, which are covered under AMRUT programs projects on water supply, sewerage, storm water drainage, urban transport, open space, and parks. The projects in Guruvayur have already spent 43 percent of the funds whereas Alappuzha and Kochi have utilized 30 percent and 29 percent respectively (https://www.unnathi.kerala.gov.in /amrut/amrutreports).

1.6 Significance of studying urban growth patterns and trends

Urban growth is a process of physical and functional changes that occur due to the transition of non-urban landforms to urban landforms (Thapa & Murayama, 2010). The changes that occur in a city are mainly due to the expansion of population, change in land-use, industrial and commercial expansions, and also other societal changes such as social, political, and economic activities. The changes in urban pattern and growth are dynamic processes involving the relationship between space and time. It consists of a change in several components such as topography, land use, transportation, economy, demography, and government policies. As indicated earlier the urban area in the majority of the country is defined by different criteria, some countries use the number of inhabitants alone, some countries combine population density and economic criteria,

some other countries use infrastructure availability and built-up density of the area. In the absence of a uniform definition for 'urban' many scholars across the world uses classified satellite data to analyze the patterns and trends of urban growth. Many studies have identified the importance of "Remote Sensing and GIS technologies" to analyze "land use land cover (LULC)" changes (Bhatta et al., 2010; Harris & Ventura, 1995; X. Li & Yeh, 2002; Seto et al., 2011) along with the temporal growth trends at the city level. Urban growth is a complex spatial phenomenon in which several components (like land use, transportation, culture, population, policies, and economic) interact non-linearly with each other (Jurlina Alibegović & Kordej De Villa, 2008; Sandeep Maithani et al., 2007). It is important to understand these dynamic and complex inter-linkages through established growth models. The planners and decisions need precise and detailed information on the urban growth of the cities to measure the amount of development, location, pattern, trends, characteristics, various driving forces, existing and future consequences (Jiang & Yao, 2010).

There are demographical and spatial perspectives in understanding the urban pattern as a phenomenon. Although there are a lot of recent studies that focus on the spatial patterns of urban areas, there is very little theoretical explanation for such spatial patterns across countries (Lynch, 1964). However, several studies in the past few years analyzed the pattern of built-up and how it carried over the last few decades. Nevertheless, urban land is not equally distributed across the world due to geographic, climatic, and resource-related opportunities and constraints. Urban expansion over the last 30 years has been greatest along coastlines and low-lying coastal zones (Seto et al., 2011).

1.6.1 Importance of urban growth prediction

Urbanization is one of the most irreversible and human-induced activities that result in changes in land-cover, hydrological systems, climate, and biodiversity (Grimm et al., 2008). Fragmented and uncontrolled rapid urban expansion of cities poses a menace to urban development and therefore it is imperative to identify the forces behind it (Mondal, Das, et al., 2017). For a sustainable urban growth scenario, it is essential to identify the causes and consequences of urban growth (Bhatta et al., 2010). The forces behind the urban growth may vary from country to country and it may be different for developing and developed countries as well. Most of the megacities in China showed an urban expansion that is largely driven by demographic change, economic growth, and land-use policy-driven (Deng et al., 2005). According to him, rapid urban expansion has produced

tremendous social, economic, and environmental consequences such as reduction in arable land, migration, and a polarized economy. Before exploring the causes and consequences, it is also essential to understand the pattern, process, and trends of urban growth that has been occurring in the past few decades (Bhatta et al., 2010).

Some of the existing studies on urban growth clearly outline the importance of Spatio-temporal analysis of urban expansion and identify major reasons why the studies on land-use change receive the attention of the stakeholders. Firstly, decision-makers and urban planners need quantified information on urban growth and land-use changes (Jiang & Yao, 2010). Secondly, it helps the urban investigators to develop and modify theories of urban morphology (Heppenstall et al., 2011; Maria de Almeida et al., 2003). Thirdly, urban development and land-use changes are important inputs for some environmental models like urban climate models (Hu & Lo, 2007). Finally, urbanization is seen as a primary consequence of globalization as more than half of the world's population is living in urban areas (Jiang & Yao, 2010).

Urban growth predictions are extensively carried out in different cities around the world with the main goal of assisting in planning the future for sustainable management of various resources in the cities. Land-use change models help us to understand the causes and consequences of the land-use dynamics and also help in various scenario analyses for supporting planning and policy initiation (Valbuena et al., 2010; Verburg et al., 2004). According to him, land-use models should be able to address multi-scale characteristics of land use and evolve new techniques that can quantify neighborhood effects. It should also be useful in identifying the forces that influence the speed and spatial pattern of land-use changes, for estimating the impact of land-use changes, and supporting future land-use alterations under different scenarios.

Understanding the urban growth dynamics of a city especially the pattern and the trends of urban growth over a period of time helps us to understand the direction and magnitude of city expansion. It also assists us in planning the future requirements and also envisages a systematically sustainable urban growth model. Several works of literature agreed on the fact that static information on land use and other factors is inadequate to quantify the extent of land use expansion and study the urban growth of a city. Jay Forrester (1964) was the first to claim that the city dynamics cannot be studied within a static framework (Benenson & Torrens, 2004). Remote Sensing and GIS-based measurements enable us to visualize and understand the pattern and trends through various geo-statistical analyses

and validation. Based on various inputs and appropriate methods, it can also be used for simulating urban growth for a future time.

1.6.2 Driving factors of urban growth

Driving forces of urban growth can be classified into three broad categories namely socio-economic, biophysical and proximate causes. At different scales of analysis different driving forces have a dominant influence on the land use system. Forces at the local levels are factors like local policy and the ecological sensitivity of an area. At the city level, the distance to the markets, hospitals, metro, airport, and access to other infrastructure are the determinant of land use patterns. Proximate causes of land-use changes are land management variables like land-use policy. Selection and quantification of the relation between driving forces and land-use changes are important aspects of the model implementation (Verburg et al., 2004).

On a global scale annual growth in GDP is a major driving force behind the urban land expansion in China, whereas, in India and African countries, urban population growth is the dominant force (Seto et al., 2011). He also suggested that the urban expansion in recent times cannot be comprehended globally alone as many localized variables drive urban growth. "*Factors influencing land development"*" by Chapin and Weiss (1962) details many factors including the location of major highways, location of the workplace, various service areas such as location of city's water distribution, sewer, fire protection, police station, schools, zoning jurisdiction, sub-division jurisdiction, areas of mixed land use, old and destroyed residential areas for studying the dynamics of urban growth (Chapin & Weiss, 1962). Land value, tax rate, highway access, access to some provinces and routes, distance from school, and education expenditures are also extensively used in modeling residential allocation in cities. Almeida et al (2003) have used several variables for modeling the land-use change like area served by water supply, occupational density, social housing, distance to commercial centers, industrial zones, residential zones, sub-city settlements, and infrastructure and roads (Maria de Almeida et al., 2003). Conway T.M (2005) in her study on urban development located in the coastal zone of New Jersey has used several variables like distance to the nearest highway, road, settlement, open space, and water body (Conway, 2005). In addition, indicators like percentage of urban land within 100-meter and1-kilometer neighborhood, percentage of water body within 100 meters and 1-km neighborhood, the population density of the municipality, presence of sewer service, etc. The exploratory variables

were identified based on a stepwise regression model. The author observed that only six out of these variables are best accounted for the location of new urban development and these are distance to the nearest highway, nearest road, percentage of urban land within one km neighborhood, percentage of protected open space within 1 km neighborhood, the state of cells in 1986 as barren and the state of the cell as forest.

Table 1.1: Variables that are used as driving forces of urban growth in some studies

Sl. No	Variables	References
1	Built-up/residential zones	B. Mondal et al. (2016), Wenli Huang et.al (2008), J. Tang et. al (2007) Conway T.M (2005), Almeida et al (2003), Jose I. B and Luca D (2003)
2	Population Growth	Wenli Huang et.al (2008), K.S. Rajan and Ryosuke Shibasaki (2000)
3	Population density	Chia-An Ku (2016), B. Mondal et al. (2016), Arsanjani et. al. (2013), Al-Ahmadi et al (2009), Conway T.M (2005)
4	Housing density	B. Mondal et al. (2016)
5	Real GDP	Wenli Huang et.al (2008)
6	Land price/ housing price	B. Mondal et al. (2016), Arsanjani et. al. (2013)
7	Employment/Occupational density	B. Mondal et al. (2016), Almeida et al (2003)
8	Employment location	Almeida et al (2003)
9	Transportation/Road network	Chia-An Ku (2016), B. Mondal et al. (2016), Arsanjani et. al. (2013), Al-Ahmadi et al (2009), S. Maithani, 2009, Conway T.M (2005), Almeida et al (2003)
10	DEM/Slope/Altitude	Arsanjani et. al. (2013), Al-Ahmadi et al (2009)
11	Availability of Parks	Arsanjani et. al. (2013), Jose I. B and Luca D (2003)
12	Availability of sewer services	Conway T.M (2005)
13	River and Streams, presence of water body, area served by the water supply	Arsanjani et. al. (2013), Conway T.M (2005), Almeida et al (2003)
14	Distance to city center/accessibility to CBD	B. Mondal et al. (2016), Arsanjani et. al. (2013), Al-Ahmadi et al (2009), S. Maithani, 2009, Almeida et al (2003)
15	Distance to settlements	Chia-An Ku (2016), Conway T.M (2005)
16	Distance to industrial zones	Almeida et al (2003)
17	Distance to schools	Chia-An Ku (2016)

Source: Review of the literature.

Al-Ahmadi et al (2009) in their "Fuzzy Cellular Automata (FCA)" based urban growth model for the city of Riyadh, Saudi Arabia used slope, altitude, accessibility to the road, urban density, accessibility to the urban center, employment opportunity, accessibility to socio-economic centers and planning policies in terms of planned and unplanned area as the factors that drive the urban growth (Al-Ahmadi et al., 2009).

Environmental, economic, and governance-related indicators play an important role in formulating urban policies that would lead cities in the path of sustainability and management of resources. Though the environmental problems such as poor air quality,

water contamination, inadequate green surfaces, excess noise, traffic congestion, and poor housing quality have different reasons, the causes of urban degradation are happening due to the lack of sufficient environmental consideration in land-use planning and urban management (Jurlina Alibegović & Kordej De Villa, 2008). The "State of the World Cities", 2004/05 (UN-Habitat) underlines the need for strengthening small enterprises and promoting public-private sector partnerships thereby stimulating employment. The income indicators and unemployment rate at the local level are two important economic indicators considered to be influential factors for the growth of a city (UN-Habitat, 2004).

B. Bhatta (2010) in his analysis of urban growth and sprawl from remote sensing data has discussed in detail some of the causes of urban growth that results in compact as well as sprawled growth. Several common factors cause compact and sprawled urban growth including population growth, economic and industrial growth, the demand for larger houses, transportation, and the nuclear family. The increase in population in an urban area in countries like India is associated with four different components viz. (a) natural increase (b) rural to urban net migration, (b) definitional fulfillment of villages acquiring an urban status, and (c) areal expansion of existing cities and towns. As the economic capacity of people increases, the demand for living space also increases forcing the developers to construct more houses and other infrastructure causing areal expansion. Similarly, the establishment of new industrial units necessitates newer houses resulting in more impervious surfaces. Highways and expressways are essential in the context of urban economy and job opportunities, at the same time it leads to congestion and rapid growth along the linear stretches. The transition from a joint family to a nuclear family also results in more demand for new houses.

A study on the urban growth of Saharanpur, Uttar Pradesh has identified accessibility to roads, accessibility to the city center, and accessibility to infrastructure facilities as the factors for urban growth (S. Maithani, 2009). Wenli Huang et. al, 2008 in his study on Beijing used linear regression analysis of socio-economic data with the urban area as dependent taking population and real GDP as explanatory variables for predicting the urban land area for 2020 (Huang et al., 2008). Through his prediction model, he finds that the pressure on land would further grow and the agricultural land areas and other types of land nearby major roads are likely to become prime targets for urban expansion.

1.6.3 Settlement Pattern in Kerala

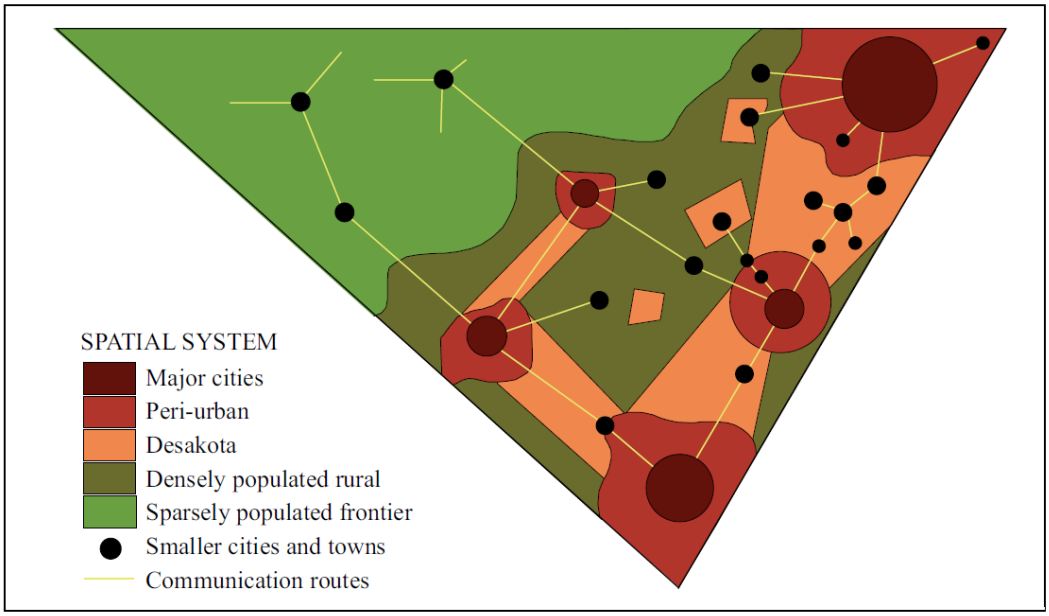
There is a higher rate of urbanization in Kerala reported in the previous census year. A major reason for such a higher urban population share is attributed to the reclassification of villages to census towns because of the sharp shift of its economic activities from the primary to the tertiary sector. Since these towns do not come under the municipal administration there are several challenges in terms of all-around planning and governance.

Kuruvilla Yacoub Z (2012) in his study underlines the key challenges of governance in these towns in terms of land use planning, waste management, public health, and transport facilities. He emphasizes the need for land use planning for providing infrastructure and civic amenities that will improve the quality of life for the people of these towns.

Many countries including India classify their lands as rural and urban-based on various characteristics such as settlement patterns, population density, occupational structure, infrastructure facility, etc. However, the settlement patterns of Kerala are unique in terms of its rural-urban continuum. Similar types of urbanization and patterns of settlement systems are also found in some of the South Asian countries (McGee, 2009) like Indonesia, and termed this phenomenon as “Desakota”. Pauchet and Oliveau (2016) argue that the rural-urban configuration of Kerala is also an extended version of the Desakota and it is found along with some distance from the coastal regions to the interior regions. His analysis is based on the study of some regions in Kerala that satisfies the McGee features that a large population is still engaged in agricultural activities, an increase in non-agricultural activities where agriculture was predominant, increase in female work participation in secondary and tertiary activities, and mobility of population between rural and urban areas. In other words, it refers to closely interlinked rural/urban livelihoods, communication, transport, and economic systems (Moench & Gyawali, 2008).

The settlements are linear, evenly distributed, and interconnected between rural and urban areas of Kerala especially in the central south belt. It is difficult to identify or distinguish the boundaries between the two except the fact that the urban centers will have little more commercial activities compared to their rural counterpart. This kind of pattern makes the settlement unique from the rest of the country.

Figure 1.1: Spatial Configuration of a Hypothetical Asian City



Source: Adapted from McGee (1991).

Many scholars believe that this type of pattern has resulted in managing and sharing its resources and also resulted in ensuring a better quality of life among the people living in both rural and urban areas (Mohammed Firoz et al., 2014; Qadeer, 2000) used a term "Ruralopolis" to describe this type of urban-rural linkages. They argued that Kerala is a ruralopolitan region with features of a Desakota. Thomas Isaac T. M. and Michael Tharakan P. K. (1995) used the nomenclature *"gragara"* by combining *'gra'* from the word *'gramam'* (means Rural) and the *'gara'* from *'nagaram'* (means Urban) to emphasize the mixed rural-urban settlement pattern and the mix of agricultural and non-agricultural activities in Kerala's spatial transformations.

1.6.4 Various Urban Growth Modeling Approaches

Modeling is a simplified representation of an existing simple or complex system. Through modeling, a large phenomenon can be summarized in a set of equations or computational diagrams. For example, in statistical or mathematical modeling, the models are equations like that of a regression model, which explains the linear or non-linear functional relationship of an indicator with a set of exploratory indicators. Similarly, computational models are built based on multiple types of data sets. The inputs for such a model in a GIS remote sensing environment can be geographical vector data, raster data, and a set of rules that modify the objects based on the criteria and weights. There are several computational methods like a neural network, cellular automata (CA),

agent-based modeling, etc. developed through computer programs that are used for simulation, scenario assessment, and prediction of urban growth. The models reveal the trends and patterns of the data in a future time based on the available data and help as an instrument for planning and decision-making.

Understanding the past, present, and future urban growth has an important role in the decision-making process (Shafizadeh Moghadam & Helbich, 2013). Several urban models are developed in the last two decades for understanding the urban growth dynamics of cities. In all these models the core requirement is a transition rule that has been obtained either using weight matrices (White & Engelen, 1993), multi-criterion evaluation (Wu & Webster, 1998) logistic regression (Wu, 2002), neural networks (X. Li & Gar-On Yeh, 2004), and decision catalog trees (X. Li & Gar-On Yeh, 2004; X. Li & Yeh, 2002). In all these methods, several variables are used for defining transition rules. Every variable is linked with a criterion that indicates its importance in the urban growth process. These criteria significantly affect the outcomes of urban simulation.

Through modeling and simulation, we can understand the past, present, and future visualization of the urban system and help in enhancing the problem-solving and decision-making capabilities more rationally and scientifically. In recent years computer simulation become the mainstream of urban modeling. For the development of an urban area, the local bodies require techniques and tools to evaluate how the land is currently used, to understand future demand, and to take steps to assure better planning of future urban development. It is a fact that the changes of land use in cities are conversion of non-urban land forms to urban land forms. The conventional survey and mapping techniques are expensive and time-consuming for the estimation of these changes and in most of the cities of India, this information is not readily available in the form of a master plan or city development plans. Therefore, researchers increasingly use remote sensing and associated techniques for the detection and analysis of urban expansion since it is cost-effective and technologically efficient.

Several geo-statistical and spatial models are used to study how highly decentralized decision-making processes can be employed in simulating and designing suitable urban structures. Though the common goals of the urban growth model are to assist in planning, decision making, adaptation, and mitigation of urban infrastructure, different models have different theoretical assumptions, methodologies, Spatio-temporal resolutions, and extent. Logistic regression models are one of the most commonly used approaches in the last two decades for predictive land-use modeling (Hu & Lo, 2007). To overcome the

limitations of each modeling, Arsanjani, et. al. (2013) in their study on Tehran city used the integration of Cellular Automata, Logistic Regression, and Markov Chain models to improve the explanatory power and performance of the standard logistic regression model.

"Agent-Based Modeling (ABM)" is another modelling approach that is frequently recommended for urban growth modelling. Many researchers have begun to focus on bottom-up approaches such as agent-based modelling, which allows one to simulate the individual actions of diverse agents and measure the resulting system behavior and outcomes on a temporal scale to better understand urban issues such as sprawl, congestion, and segregation. It allows us to construct, analyze, and test models made up of agents interacting in a given environment. Agents are discrete components of a Programme that represent social agents such as people and organisations. Over the last decade, there has been a significant surge in the use of ABM to simulate dynamics inside geographical systems. ABM provides for the decomposition of systems into distinct components, each with their own set of characteristics and rules (Heppenstall et al., 2011). “Agent-based models (ABMs)”, which are the most recent in the field of urban modelling, consider agents as entities capable of responding to and interacting with one another. The agents are categorised into homogeneous groups with similar attributes and actions. In general, agents' decision-making criteria necessitate a substantial volume of survey data. The presence of a large number of agents in a vast research region limits such comprehensive data collection (Valbuena et al., 2010). To address data limitations, numerous research used empirical data to depict agents' decision-making for which we have no behavioral data, such as distance to roads, trains, slope, and so on (Mustafa et al., 2017).

“Cellular Automata (CA)” is also widely used in urban growth prediction. It is an artificial process of locating urban activities based on the repetitive application of simple rules that give rise to identifying complex global patterns showing the spatial organization of cities (Michael Batty, 1997). Wolfram (1984) has demonstrated that CA can capture complex spatial processes and understand local behaviors and global patterns. CAs are the preferred modeling choice for simulating various spatial phenomena of land-use changes (Al-Ahmadi et al., 2009). The use of CA in modeling temporal and spatial complexities of urban land use and growth has significantly increased in the past one and a half-decade (Al-Ahmadi et al., 2009). Through this model, we can determine, how the ‘state’ of contiguous or adjacent ‘cells’ in a

rectangular array of cells changes their characteristics through the application of simple rules. The transition rules can be interpreted as the change from an undeveloped to a developed cell or a non-built-up to the built-up cell or vice versa and this change is a function of what is happening in the neighborhood of a cell.

Integration of “GIS, Remote Sensing, and Artificial Neural Network (ANN)” as a computational model is one of the most effective methods for urban growth modeling. S. Mohammady et. al, 2014 have simulated the urban growth of Sanandaj City, Iran, and predicted the complexities of growth. The structure and advantages of ANN enabled the author to perceive a complex and nonlinear pattern between data. ANN can be used for capturing associations within a set of patterns, where the amount of data and the number of variables are very large, the relationships between variables are vaguely understood and difficult to describe adequately with conventional approaches.

The “artificial neural network (ANN) models” how the human brain solves spatial data problems. It is often more efficient and takes less training data than classical classifiers when used in the context of “supervised classification”. One of its most significant advantages is that it is distribution-free, meaning that no underlying model for the multivariate distribution of class-specific data in feature space is assumed. “Nonlinear neural networks” can be thought of as a sophisticated mathematical function that converts input data (e.g., remotely sensed imagery) to the desired output (e.g., a land cover classification). One of the most extensively used neural network models is the “multi-layer perceptron”, which is utilized in the “back-propagation (BP) learning process”. One input layer, one output layer, and one or more hidden layers make up a standard BP network. Each layer has nodes (or neurons) that are connected by weights that are uneven. To use an analogy, the function of the hidden layer nodes is analogous to lines that can divide points in a feature space into numerous groups. According to research, a three-layer BP network may approximate any polynomial function. A neural network's entire operation runs like a “black box” (Ansari & Golabi, 2019). The “Land Change Modeler (LCM)” is another modeling module of Clark Labs which is used by several researchers to analyze the land-use changes for predicting the land uses based on “artificial neural network (ANN)” and “Markov Chain analysis” (Ansari & Golabi, 2019). Land change prediction in LCM is an empirically driven process that moves in a stepwise fashion from “1) Change Analysis, 2) Transition Potential Modeling, to 3) Change Prediction. It is based on the historical change from time 1 to time 2 land cover maps to project future scenarios”.

1.7 The Rationale for the Selection of Kochi City as Study Area

There are several reasons for selecting Kochi as the study area. Firstly, Kochi is known as the financial capital of Kerala. The economic importance of the city is clear from the fact that since the past many years Kochi contributing the highest percentage share of Kerala's "Gross State Domestic Product (GSDP)". World Bank (Subnational Doing Business in India 2009, Kochi) recognized Kochi as one of the seventeen major cities of India for ease of doing business. The city has many industrial units in diversified fields of information technology, electronics, shipbuilding, oil refining, petrochemicals, other chemicals, spices, and seafood. many adjoining towns and villages of the municipal corporation have become part of the planning division of the city. Mapping the pattern, trends and identifying development potential areas are extremely important for proper planning and management to utilize its resources. Secondly, Kochi has been included in the schemes of a smart city which has a greater emphasis on using digital and spatial technology for better planning, implementation, and delivery of services. Comprehensive spatial modeling has not been carried out so far for the city. Therefore, there is a larger scope of using geo-statistical modeling for predicting the growth and planning of the city. Thirdly, Kochi is an ecologically sensitive area. The resources that the population consumes are largely depending upon the land and water ecosystem. The dynamics of biodiversity degradation and its impact on the local communities are very crucial issues, especially for the development of a coastal zone. Therefore, modeling city growth patterns is very important for the creation of a more sustainable future for a coastal city like Kochi.

Kochi has rapidly grown beyond the city limits over the past decade. Expansion usually happens at the expense of agricultural land, destruction of natural and open spaces resulting in global environmental change (Huang et al., 2008). There is a need to quantify these changes to understand the land-use dynamics of the city. The recent infrastructural development initiatives in Kochi are expected to further increase the pace of urbanization and will necessitate the state government and the civic body to develop a more suitable plan to cater to its increasing residential and commercial requirements.

Kochi is one of the few cities in India that has multiple transportation facilities for public commuting and goods movements like shipyard, boat ferry, road transports, Mobility Hub (Vyttila) for intrastate and interstate commuting, "International Container Transshipment Terminal (ICTT, Vallarpadam)", the Metro Rail and an International

Airport. The city has attracted a large number of migrant populations because of better job opportunities, higher wage rates transportation networks, educational and health services, and a better standard of living. As a result, the city is expected to grow at a faster rate in the coming years. The present pattern of growth of the city is observed to be haphazard with problems of changing lifestyles, food habits, change in living standards, institutional weaknesses, improper choice of technology, and public apathy (Ravi & Subha, 2011). This necessitates the civic body to provide better services to the existing population and to develop a more suitable plan to cater to its increasing residential and commercial requirements. With the massive infrastructural and financial investment in the city, the economy of the city is expected to increase and will attract investors and other professionals both from the state and from outside Kerala. The Smart City project would further change the face of the city and necessitate a new approach in land use planning and urban growth modeling. Unlike other cities in India, Kochi requires a very diversified approach in terms of its urban development, because it is unique in terms of its tourism, aesthetic and ecological sensitivity.

"The town and country planning department" of the "Government of Kerala" is involved in preparing and executing structural plans for cities in Kerala. The existing structural plan of Kochi – 2001 was prepared in the year 1991. However, these are not strictly followed to ensure satisfactory development in the city and surrounding area. The fast-technological innovations in infrastructure, changing economic activities, changing environmental and climatic laws often create new urban scenarios and therefore necessitate changing the planning approach and thus the government agencies are often involved in revising the development plan to suit the changing needs. Compared to the census boundary of "Kochi Urban Agglomeration (KUA)", the "Kochi city planning area" is limited to a comparatively small geographical area that has close economic and transport linkages with the "Central Business District (CBD)". The Census of India has included as many as 45 census towns, 9 municipalities, and 2 outgrowths to the existing "Kochi Municipal Corporation" as part of the KUA making it roughly one-third of the total area of the Ernakulum district. Kochi city on the other hand has a corporation area along with the adjoining municipalities and census towns.

The city has witnessed a fast stride in terms of urban development in the last two decades. The IT infrastructure in Kakkanad, the International Airport at Nedumbassery, the newly built bridge connecting Vypin islands to the mainland, and residential and commercial real estate development in the city and the surrounding areas have caused various direct

and indirect development impacts in different sectors. It causes tremendous pressure on the existing infrastructure components. The most visible among them are increasing traffic congestion and the degradation of the urban environment.

According to a study conducted by the Labor Ministry in 2013, there is a 2.5 million migrant labor population in Kerala engaged in manual work in various sectors including construction. Kochi and the adjoining areas alone are estimated to have a two lakh migrant population. This along with the high level of population mobility from nearby towns largely for business and occupational purposes put pressure on existing land. This necessitates proper planning, land use development at the same time preserving the environment and heritage of the city. There are a substantial number of semi-skilled and skilled laborers in Kerala who out-migrate to Gulf countries and megacities of India. These "Non-Resident Keralites (NRK)" heavily invest in Kochi and the surrounding area as an investment option. This also contributes to land-use changes.

According to the report of the "Central Pollution Control Board (CPCB)" Kochi ranked 24th with a "Comprehensive Environmental Pollution Index (CEPI)" score of 75 in 2010 amongst the "critically polluted areas (CPA)" in the country. Based on the data on ambient air quality data of seven stations in the city shown that there is an excess of "particulate matter (PM)" and these are mainly attributed to the construction activities in the industrial, residential, and transportation sectors (KSPCB Report, 2010). The heavy traffic densities in the congested roads are also cited as a reason for the dust to get scattered and airborne. Since Kochi is a coastal city with a coastal line of approximately 48 kilometers, the urbanization in the city may lead to the disposal of wastes into these water bodies and get contaminated. It will be a threat to community health, the environment and to, the effective use of the canal system. The pollutants that are concentrated on urban surfaces degrade the biological, chemical, and physical characteristics of the water bodies posing threat to aquatic and terrestrial habitats (Triantakonstantis & Mountrakis, 2012). Quality of drinking water, the poor state of garbage collection, acute traffic congestion, higher pollution, affordable housing for the poor are some of the major urban developmental issues in the city at present.

1.8 Scope of the study

It is a known fact that rapid urbanization in developing countries has altered urban land use considerably in the last two decades. This trend is expected to take a further pace

since the level of urbanization has a low base than in the developed countries and also because the economic growth is higher than that of the developed economy. Thus, the increase in urbanization would necessitate continuous efforts from the government and other decision-makers to plan the development of its urban land that could meet the exponential demand for housing, transportation, industry, and other infrastructural development. In India, the existing urban development plan and growth potential are not largely supported by spatial techniques and growth models, and therefore most of the decision does not envisage future dynamics of its land use. In recent years digital technology has replaced many of the manual processes in every aspect of decision making. It is therefore very important to understand and suggest existing and future urban land use predictions with the help of information technology-based spatial information and land-use modeling. A scientific approach in forecasting the growth will help planners and decision-makers to take effective decisions in advance and also help to update and maintain the database regularly. Many of the Indian cities do not have plans backed by suitable geo spatial-statistical modeling techniques and still depend on manual planning to achieve its goal. This will result in the expansion of cities in a haphazard manner. Therefore, for a city to ensure a smart urban growth progression both in terms of the standard of quality of life and sustainable economic growth without doing much harm to the environment and natural resources it is imperative not only to invest in human, social and infrastructural capital heavily but also to plan the future with appropriate modeling techniques.

1.8.1 Research Questions

The review of literature, the importance of studying urban growth, and the other city-level issues discussed above have led to many questions which are required to be answered for understanding the dynamics of urban growth of Kochi.

1. How the macro-level development in the past few decades has influenced and shaped urban development processes in the Ernakulum district in which the study area is located?

2. What type of socio-economic, demographic infrastructure trends experienced in Kochi in the last few decades?

3. What are the various factors that influenced the urban growth of the city?

4. How can the complexity of urban growth be modeled and in what ways do these prediction models help in the future development of the city?

1.8.2 Objectives

Based on the above research questions the study focuses to achieve the following objectives

1. To examine and study the demographic and socio-economic characteristics of the urban development process of Ernakulam District for the last three decades in a comparative framework with that of Kerala and India.
2. To analyze the demographic transition, urban infrastructure, and housing amenities in Kochi and its comparison with major cities in Kerala and bordering states to understand the key drivers that influence the growth of Kochi.
3. To evaluate the existing socio-economic characteristics and housing amenities observed in different administrative areas and their relation to land-use dynamics of the city.
4. To estimate and predict the urban growth of the city in 2031.

1.9 Methodology

The analysis in chapter two is based on secondary data from the Census of India, the National Sample Survey, and data from various other government sources. Tables in all the sections have been prepared to show the development indicators of the district, state, along with those for the country in a comparable framework. For some indicators, graphs are also prepared to draw meaningful visual interpretations. In chapter three a micro-level analysis of city constituents is carried out based on the census of India data. In Chapter four, to bring out the disparities in economic activities within the city, the unit level data of economic census 2012-13 is used. Most of these tables are presented in terms of percent distributions and graphs.

For the analysis in chapters five and six, the Landsat imageries are used which have been obtained from the “Global Land Cover Facility” (GLCF-http://www.landcover.org/) three times 1992, 2001, and 2014. Several imageries of three decades at various intervals are obtained and compared to select the best three scenes of the same season. The selection of imageries has been kept to the nearest census years. However, the selection

of 2014 as the terminal year for the comparison is based on the appropriate time lag required for predicting the urban growth of the city for the future year of 2031 and also with the assumption that the socio-economic characteristics collected from census 2011 do not differ substantially within the three years. The LULC classification maps are prepared using supervised classification to identify the composition of land use for all these years. It is classified into various LULC of the "built-up, waterbody, wetland/paddy land, vegetation, and other lands". Linear features, such as the road and railway network are included in the built-up category since all the imageries used for the present study are of 30-meter resolution. The classified land use maps are then examined for the overall classification accuracy using "Kappa statistics" for further spatial analysis. The spatial pattern and temporal urban growth trends are analyzed with the help of RS-GIS software. The LULC zonal statistics and a built-up concentration index is estimated to understand the intensity of built-up in various parts of the city. The correlation between built-up areas and selected socio-economic indicators is worked out to understand how the socioeconomic indicators are associated with the change in the built-up area.

To predict urban growth in 2031, the "Land Change Modeler (LCM)" is used. It is an effective modeling tool developed by Clark Labs for analyzing the changes in LULC, modeling its relationship with different explanatory variables, and also used for projecting future changes. The major tasks that are performed through LCM are "change analysis", "modeling" the "land transition potential" and "predicting" the changes in the future. The future changes are projected based on the LULC map of two-point of time. Through the change analysis, the transition of LULC from 1992 to 2001 and 2001 to 2014 is carried out.

The land surfaces in urban areas are often dominated by human intervention resulting in complex change patterns and finding it very difficult to interpret. Therefore, through LCM, a spatial trend analysis is performed which is a best fit polynomial trend surface to understand the pattern of change. For identifying the potential of land to transition a "Transition Potential Modeling (TPM)" is performed. Each sub-model for transition between the two maps is identified with a set of explanatory variables which includes the "density of population", "socio-economic index", "distance to major roads", "distance to the railway", "distance to metro", and "distance to shopping centers". These driver variables which are added in the model represent basic "suitability" for the transition. The transition potential modeling is done using a "multi-layer perceptron neural network (MLPNN)".

Figure 1.2: Methodological Framework

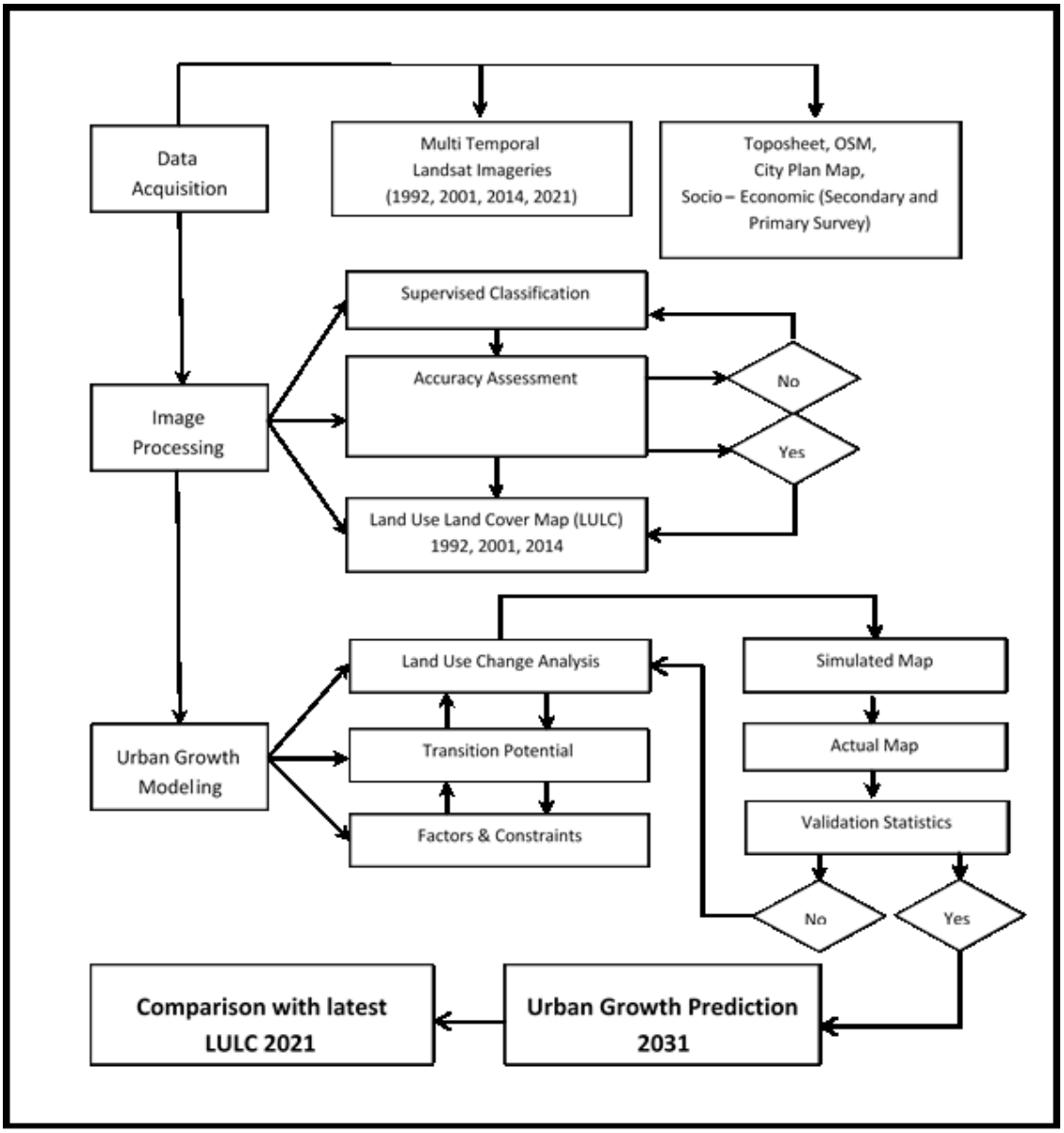


Table 1.2: Data Sources

Type of Data	Dataset	Source
Raster Data	LANDSAT-TM/ETM Satellite Imageries of four-time periods 1992, 2001, 2014 and 2021	Global Land Cover Facility (GLCF) and US Geological Survey (USGS)
Vector Data	Polygon feature (Land use, and municipal/census town boundaries.) Linear features (roads, railway, metro, and streams) Point features (Shopping center)	Toposheets, plan maps, OSM, Google Earth, and GPS
Secondary Data and Field survey	All variables, indicators, and indices discussed in different chapters	Census of India, State Government sources and through primary survey

Table 1.3: Software used in the present study

Type of Analysis	Software	Tasks
Data Analysis (Primary and Secondary)	Excel, STATA, and SPSS	Descriptive and Cross Tabulation, Statistical Tests
Raster Analysis	ERDAS IMAGINE and IDRISI	Classification and Spatial Analysis
Vector Analysis	ARC GIS and IDRISI	Feature Data creation and Spatial Analysis

This along with the "Markov Chain analysis" was performed to estimate the transition probability of LULC changes between the three-time periods. Finally, all these have been used to predict the urban growth of 2031.

1.10 Study Area

1.10.1 A short historical profile of Kochi City

Historically Kochi was a princely state under the Kingdom of Kochi that came into existence at the beginning of the 12th century. It was an important maritime countryside with its early rulers had their capital at Tiruvanchikulam located about 18 km north of Kochi. The nearby port of Muziris (now in Kodungalloor, the southern part of Thrissur district) was used as an international trade hub by the traders from China and Rome. This trade link attracted many settlers from other trade nations to Muziris. A heavy flood in 1341 destroyed the Muziris harbor completely and this led to the establishment of Cochin Port. The old merchants and settlers gradually shifted their base from Muziris to Cochin port that was recorded as the first instance of the growth of the town. As the harbor gained prominence the erstwhile rulers of Kochi also shifted their capital from Thrippunithura (presently a municipal town in Kochi Urban Agglomeration) to Kochi.

The early settlement of Kochi was based in Mattanchery. It was linked to the entire coastal stretch through the inland waters. Gradually it grew as a busy settlement. It has developed as a typical market town with a lot of commercial activities along the waterfronts. Nicolo Conti recorded that in 1440, Kochi was a city with only 5 miles of circumferences. The Chinese and Arabs carried out very intensive trade with the natives of the town. The majority of settlers were Jews and Muslims. Trading communities from Gujarat and the emigrants from Goa also established their trading centers in Mattanchery along with the native Hindus and other early settlers. Mattancherry grew into a market

town with a cosmopolitan character attracting foreign traders. However, developments in the adjoining Fort Kochi were also strengthened by the foreign traders.

In the 16th century, the arrival of the Portuguese witnessed rapid changes in the trading and colonization of Kochi. The territory was granted to the Portuguese in 1503 by the King of Kochi after the forces of Afonso de Albuquerque helped him fight the forces of Samoothiri of Kozhikode. They founded Fort Kochi for setting up factories, warehouses and also extended their domain on political and religious fronts. The arrival of the Portuguese witnessed rapid changes in the trading and colonization of Kochi. The King also permitted them to build Fort Emmanuel near the waterfront to protect commercial interest. The 'fort' in Fort Kochi comes from this fort. Portuguese built their settlement behind the fort, including a wooden church, known as St. Francis Church. Fort Kochi remained in Portuguese possession for about 160 years. The Portuguese dominance ended with the arrival of the Dutch in 1663. The Dutch East India Company tried to persuade the local rulers in monopolizing the pepper trade. In the process, they came across other forces like English, French, and Danish. Thus, almost for a century, Cochin became the center of political and commercial disturbances. The Dutch held Fort Kochi in their possession for 112 years until 1795, when the British took control by defeating the Dutch. Foreign control of Fort Kochi ended with the Indian independence.

Mattanchery had by then, developed into a typical market town with a lot of commercial activities distributed on the waterfronts. Agricultural products from the vast hinterland were sold and also exchanged for various other textiles, metal, and other products from the European market. Apart from many Jews and Muslim settlements, the trading communities from Gujarat and Goa were also established in Mattanchery along with the native Hindus and Christians. When Mattanchery started becoming overcrowded, in 1840, the rulers of Kochi shifted their capital to Ernakulam on the eastern side of the backwaters. New roads were laid down, market established and administrative and educational institutions were also set up. Ernakulam started developing as an administrative town. Mattanchery Fort Kochi and Ernakulam became municipalities in the early 20th century.

Though the three municipalities of Fort Kochi, Mattanchery, and Ernakulam were able to exercise power as in their respective jurisdiction, they were not in a position to solve the problems of urban growth as a whole or to have common planning in the area. Initially, in 1966 a joint town planning committee was constituted for coordinating the planning efforts in this area. Eventually, Cochin Corporation was formed in 1967 by

incorporating all three municipalities, Wellington Island, and a few other surrounding areas.

1.10.2 Historical growth of Kochi

Efforts were made from the beginning itself to provide necessary amenities and services to the people of the town. In early 1890 there have been two committees of merchants to look after the sanitation and conservation arrangements of Mattanchery and Ernakulam with grants from the "Cochin State Government". These committees were mainly responsible for maintaining roads and street lighting. For effective planning and administration of Ernakulam and Mattanchery, the rulers of Cochin enacted Municipal and Sanitary Improvement Regulation in early 1909 to make provision for the creation of Town Councils. Kochi was not included as part of it as it was already under the provisions of the Madras Town Planning Act. After the independence, the states of Cochin and Travancore got merged into Travancore-Cochin State and the Town Planning Regulations of Travancore is extended to Ernakulam and Mattanchery (Kuriakose & Philip, 2021).

The map of 1891 shows the location of early settlement concentration and planning efforts at Kochi. The settlement growth was mainly visible in Fort Kochi, Mattanchery, Thrippunithura, and Aluva. Once the work of Cochin Ports started in 1921 the settlements and infrastructure are expanded to the periphery of Fort Kochi, Mattanchery, the Wellington Island, Thrippunithura, and Aluva. The third map shows the settlement growth in 1951 during the time of the first census enumeration. The map shows the settlement started further increasing in Ernakulam and Thrippunithura area. The fourth map (1981) is showing how the settlements are spreading to the Ernakulam town areas, surroundings around the important road networks, and major transport junctions.

Thus, there are different forms of urban growth observed in Kochi. In early periods, the port city observed contiguous development followed by new transport junction-based growth is observed resulting in many satellite towns. The present type of growth is mostly contiguous towards the eastern part influenced by commercial and modern high-skilled economic activities (Kuriakose & Philip, 2021).

1.10.3 Location of Study Area

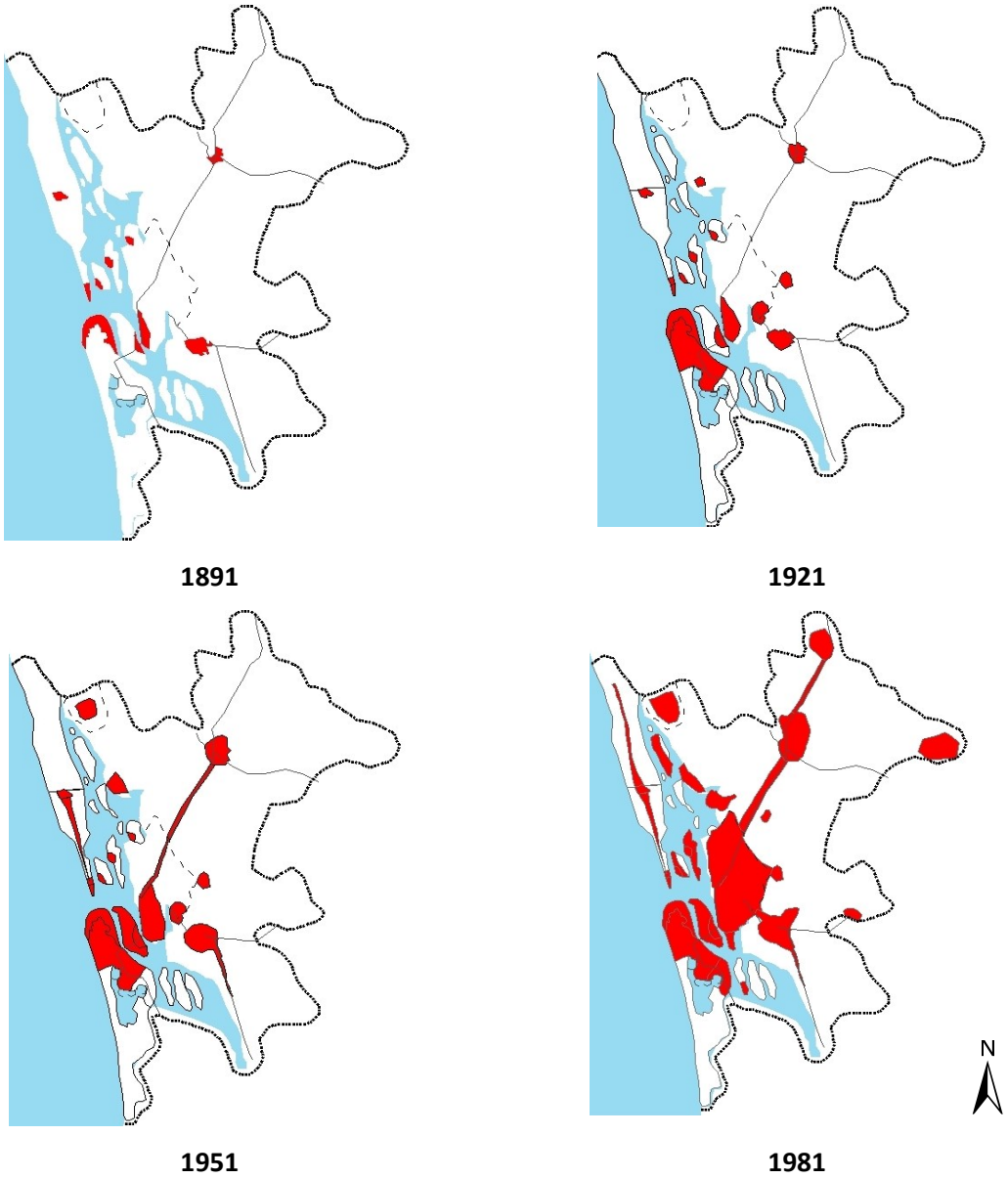
Kochi is located in Ernakulam District in Kerala State within a geographical extent of 9^0 53' 6" and 10^0 5' 0" North and 76^0 12' 7" and 76^0 23' 6" East. The district is bounded by Thrissur on the north and Alappuzha and Kottayam on the south, Idukki on the east,

and the Arabian Sea on the West. Kochi is a coastal city with a tropical climate. The temperature varies from 25^0C to 34^0C. Because of its proximity to the sea and a large area of inland water bodies the city remains humid almost the entire year. The city on average receives rainfall of 290 cm in a year. Kochi is also known as 'The Queen of Arabian Sea' because of its scenic ports with a lot of coconut trees and water bodies and also due to its importance for spice trading from the 14^{th} century.

1.11 Recent Infrastructural and Economic Activities in the City

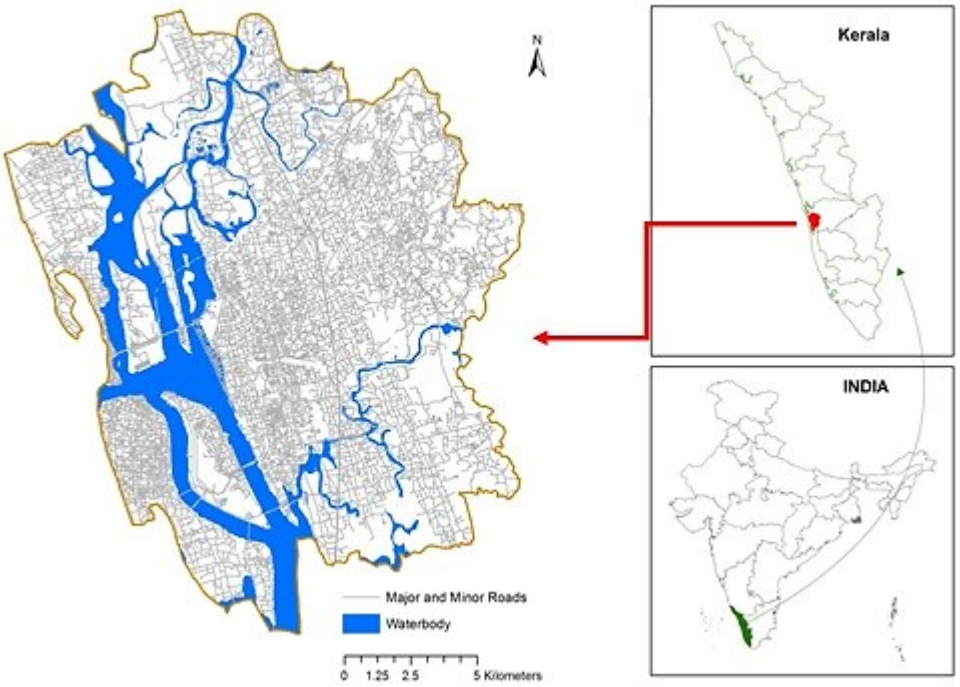
Kochi is widely recognized as the commercial and industrial capital of Kerala. The rise of Kochi as the financial capital city of Kerala is closely linked with the ancient trade, commerce and also, political and administrative history of Kochi. The city locates some of the key strategic, economic, and infrastructural facilities like the Naval Base, Cochin Shipyard, the "International Container Trans-shipment Terminal (ICTT)", The "Cochin Special Economic Zone (CSEZ)", Kochi Metro Rail, The Cochin International Airport, etc. The *"*Ministry of Urban Development, Government of India" recently identified Kochi (Rank 5) among the top 20 cities under the Smart City mission (Kuriakose & Philip, 2021). The core infrastructure development in the smart city includes E-Governance, water management, power supply, sanitation, solid waste management, efficient urban mobility and public transport, IT connectivity, affordable housing for poor, sustainable environment, safety and security of citizens, health and education, etc. (smart city guidelines, MuD, Govt. of India, 2015). The smart city tag is expected to boost the real estate prices in Kochi. Kochi Metro is another infrastructure initiative under the supervision of the Kerala Infrastructure Investment Fund Board, Govt. of Kerala. The first phase of 25.6 km of Kochi Metro from Aluva to Petta is already operational (https://kochimetro.org). The construction of phases 1A and 1B (1.9 km) from Petta to Thrippunithura is already in progress. The detailed report of the phase-II project from Kaloor to Kakkanad with an 11.2 km line is already submitted to the central government and the work is expected to start after the competition of the remaining work in Phase 1A and 1B. The third phase from Aluva to Angamali is also being planned. The metro rail in Kochi is expected to further escalate the land and the housing price, especially in areas close to this corridor.

Map 1.2: Early growth of settlements in Kochi city and surrounding areas



Source: Structural Plan of Kochi City Region, GCDA.

Map 1.3: Location map of the study area



Vyttila Mobility Hub is another infrastructure development plan under KIIFB, Kerala aimed at integrating various transportations such as Road, Metro Rail, and Water transport, to decongest Kochi city from traffic snarls. All kinds of passenger-friendly facilities such as cafeteria and refreshment kiosks, clean toilets, safe drinking water, clean platforms, security guarded compound with surveillance cameras, parking area, etc. already exist here. This multi-mode transport facility intends to promote the public conveyance system over the excess use of private vehicles, which will eventually result in the easing of urban traffic congestion and reduction of environmental pollution (http://www.vyttilamobilityhub.com).

In addition to these developments, the Cochin International Airport Ltd. (CIAL) has introduced a new international terminal with a built-up area of 1.5 million sq. ft. The increased passenger base has a very positive economic impact and is expected to increase the urban growth in the whole airport region. The region may attract retail and commercial ventures along with residential and hospitality development to support the increased demand.

Kochi is among India's leading cities for port infrastructure and has the largest and India's first global hub terminal, the ICTT at Vallarpadam. Warehousing and other port-related industrial developments will see tremendous growth in these areas.

Kochi is known for its high heritage value and contributes significantly to Kerala's tourism industry. With increasing infrastructure, the tourism industry is expected to flourish and create demand for housing, hospitality, and its allied services.

1.12 Scheme of Chapterisation

The first chapter is the *Introduction* in which the first section gives a brief account of disparities in urban definition in different countries and a discussion on global urbanization. A short outline of historical and present urbanization and urban policies in Indian and Kerala is also discussed in the chapter. The next section in the chapter details the scope of the study, the rationale for selecting Kochi as the study area, a detailed account of the study area, key research questions, the objective of the research, and the methodology used in the research. The last section gives the literature survey on urban growth in India and Kerala, settlement patterns in Kerala, and urban growth modeling along with the scheme of Chapterisation.

Chapter 2 titled "*Dynamics of Socio-economic Development in Ernakulam District: The Macro Context of Urban Growth in Kochi"* tries to attempt a stocktaking of the demographic and socio-economic characteristics of Ernakulum district and Kerala State within a comparative framework that of India. The objective is to determine how the macro-level development at the national and state level in the past few decades has influenced and shaped urban development processes in Ernakulum district and the city of Kochi. It gives into account the detailed analysis of the demographic characteristics of the district, the dynamics of growth of census towns in Kerala in 2011. It also discusses the sectoral workforce distribution, the economy, the industrial and infrastructural development in Ernakulam and Kerala.

Chapter 3 deals with the demographic structure and key urban infrastructure in the Kochi City Region demarcated in the structural plan of Kochi. The chapter has a detailed analysis of each of the administrative constituents of the city area. It gives a detailed account of the demographic, socio-economic and urban infrastructure at a disaggregated level for various decades based on the census data. In addition, the chapter also gives an account of various developmental indicators of Kochi Municipal Corporation with that of other major cities in Kerala and bordering states.

Chapter 4 gives a detailed town constituent-wise account of housing amenities of the city as per the 2011 census to understand the key drivers that influence the growth of the city.

It also evaluates the field survey data collected from various locations of the city. In this chapter, the data on "socio-economic, land, housing, basic amenities, and neighborhood cleanliness" is analyzed across three town constituents of Municipal Corporation, Municipality, and Census Town and tried to identify the urban growth in a micro context. The chapter also analyzed the interpolated surface based on grid-based average measurements of economic, land, housing, and also the distance to different infrastructure.

Chapter 5 analyses the land-use dynamics of the city observed in the past three decades using Landsat imageries of 1992, 2001, and 2014. The land consumption based on the actual spatial data is compared and the changes observed at both macro and micro-level are detailed in this chapter with the help of zonal statistics, compactness, and built-up intensity analysis.

Chapter 6 deals with the estimation of transition probabilities and the transition potentials to predict the growth of the city in 2031. The predicted model is then compared with the actual LULC of 2021 to look at the areas which are likely to have urban growth in future

Chapter 7 presents the major conclusions from the thesis, limitations of the study, and the way forward.

Chapter 2: Dynamics of Socio-Economic Development in Ernakulam District (The Macro Context of Urban Growth in Kochi)

2.1 Introduction

The growths of cities are closely associated with the overall socio-economic development of the district and the State it belongs to. Kerala along with most of the other states in India have received substantial funds for urban development under the central government and centrally supported programs since the middle of the Tenth Plan (Planning Commission, Government of India, 10th, 11th, and 12th Five Year Plan Reports). However, the adoption of programs and missions, their implementation, allocation of funds, utilization, and the outcome varied depending on the geographic distribution, political economy, and state's management of programs. Keeping this in view, it is imperative to attempt a stocktaking of the demographic and socio-economic characteristics of Ernakulam district and Kerala State within a comparative framework that of India. The objective is to determine how the macro-level development at the national and state level in the past few decades has influenced and shaped urban development processes in Ernakulam district. This is important as Kochi city and adjoining municipal towns are the major urban centers of the district.

The analysis in this chapter is based on secondary data from the Census of India, the National Sample Survey, and data from other government sources. Tables in all the sections have been prepared to show the development indicators of the district, state, along with those for the country. The trends and changes in some key indicators observed over the past decade for the district and state are presented and compared to the overall Indian context. Although the study mainly focuses on the developmental transitions from 1991 to 2011, some of the sections also discuss developments based on historical data from the 1901 census year. Some analyses in this chapter are also based on the data published by the state government for recent years.

2.2 About the State of Kerala and Ernakulam District

At the time of independence, the present state of Kerala had three distinct administrative entities of Travancore, Cochin, and Malabar. Rulers of Travancore and Cochin were known for their

progressive administration, bringing about major social reforms and setting up institutions of modern education. This has resulted in higher socio-economic development in the area. The other entity which is in the northern part, known as Malabar, was a part of the Madras Presidency directly administered by the British government in India. It was comparatively less populated and has remained at a low level of social and economic development.

The state of Kerala was created on 1st November 1956 as per the "States Reorganization Act (SRA)" of India by merging Travancore and Cochin with the Malabar district of Madras State along with Kasaragod Taluk of South Canara District which was part of Mysore State. At the time of formation of the state, it had only five districts, the Malabar (of the erstwhile Madras State and a small part of Mysore State) and four districts Thiruvananthapuram, Kollam, Kottayam, and Thrissur of the erstwhile Travancore-Cochin State. As per the 2011 Census, Kerala has 14 districts. Based on geographical, historical, and cultural similarities, these districts can be grouped into North Kerala (Kasaragod, Kannur, Wayanad, Kozhikode, Malappuram), Central Kerala (Palakkad, Thrissur, Eranakulam, Idukki), and South Kerala (Thiruvananthapuram, Kollam, Alappuzha, Pathanamthitta, Kottayam). Just like many other districts of India, almost every districts of Kerala have the same name as the important town or city within the district, the only exception being the Wayanad district. Though geographically Kochi city and Ernakulam town area are the same the city is more known in Kerala as Ernakulam whereas outside the state it is largely known as Kochi.

Historically the state has interacted with the world through ocean-borne trade for two thousand years. There is a long history of harmonious coexistence between people belonging to different religious faith. This along with governments initiatives backed by strong public participation had a positive impact on the social and economic changes of Kerala visible in the post-Independence period. It is to be noted that the success in the population transition and social sector in the last five decades are despite the sluggish growth of the economy in the state (Kannan, 1990). Kerala has very high achievements in the social sectors with the highest human development index and quality of living index in India (Sanitha & Singla, 2016). Kerala's per-capita agricultural output or industrial workforce is below the national average yet its prolonged investment in health, education and social welfare have contributed to raising Kerala's HDI (Rani, 1999). These factors have been considered key to the success of the 'Kerala Model' discussed by Amartya Sen (Kurien, 1995).

Ernakulam district formed within two years of the state formation was formerly a part of the princely state of Cochin. The administrative center of the district is located in Kochi or Cochin as it was known earlier. It is an old seaport town on the Arabian Sea coast, flanked by the Lakshadweep Islands on the west-south and the Periyar River on the north. It has been a trading hub from ancient times with trading contacts with Arabs, Chinese, Portuguese, Dutch, and British. The district is rich in water resources with Periyar and Muvattupuzha rivers as the major water resources of the district. Besides, various other tributaries are flowing towards the northern and eastern sides of the city. The district has 7 taluks, 124 villages, 9 statutory towns, and 47 census towns as per the 2011 census (Census of India, 2011).

2.3 Changing Demographic Profile

2.3.1 Population Share and Density

Kerala with an area of 38.9 thousand square kilometers and a 33.4 million population (Table 2.1) is one of the smaller states of India particularly in terms of geographical area. Lying on the south-western tip of India it accounts for just 1.2 percent of the land area and 2.7 percent of the population of India as per Census 2011. The Ernakulam district with an area of 3063 square kilometers and 3.3 million populations is located towards the south-central part of Kerala occupies 7.9 percent of its area and 9.8 percent of the population (Table 2.2). In terms of area, Ernakulam is the fourth largest district after Palakkad, Idukki, and Malappuram. The share in the population of Ernakulam has remained almost constant at 10 percent of the state's population. The share in population in many of the northern districts also has remained more or less the same, except Malappuram where the population share has increased from 10.6 percent in 1991 to 12.3 percent in 2011 (Table 2.2).

Table 2.1: Area and population

State/District	Area (in 000' Square Kilometers)	Population (in Million)		
		1991	**2001**	**2011**
Ernakulam	3.1	2.8	3.1	3.3
Kerala	38.9	29.1	31.8	33.4
India	3287.3	891.3	1028.7	1210.9

Source: Primary Census Abstracts, Census of India 1991, 2001, and 2011.

Ernakulam is a densely populated district, accommodating 1072 persons in a square kilometer as against the figure of 860 for Kerala (Table 2.2). and 382 at the national level (Census of India, 2011). Thiruvananthapuram, Alappuzha, Kozhikode, and Malappuram are the other districts that

are ahead of Ernakulam in terms of density of population. Unlike these districts, topographically, the eastern half of the district is a hilly area with less population density and the overall higher density of population in Ernakulam is due to the western part of the district which consists of Kochi and other urban areas with a very high density of population. The least density of population is observed in the hilly and rural districts of Idukki, Wayanad, and Pathanamthitta.

Table 2.2: District wise distribution of area, and population in Kerala

State/District	Area Share	Population Share			Population Density (Per km^2)		
		1991	**2001**	**2011**	**1991**	**2001**	**2011**
Kerala	**100.00**	**100.0**	**100.0**	**100.0**	**749**	**819**	**860**
Kasaragod	5.1	3.7	3.8	3.9	538	604	657
Kannur	7.6	7.7	7.6	7.6	759	812	852
Wayanad	5.5	2.3	2.5	2.4	315	366	384
Kozhikode	6.0	9.0	9.0	9.3	1118	1228	1316
Malappuram	9.1	10.6	11.4	12.3	872	1021	1157
Palakkad	11.5	8.2	8.2	8.4	532	584	627
Thrissur	7.8	9.4	9.3	9.3	903	981	1031
Ernakulam	**7.9**	**9.7**	**9.8**	**9.8**	**1170**	**1012**	**1072**
Idukki	11.2	3.7	3.5	3.3	215	259	255
Kottayam	5.7	6.3	6.1	5.9	830	885	895
Alappuzha	3.6	6.9	6.6	6.4	1415	1492	1504
Pathanamthitta	6.8	4.1	3.9	3.6	450	468	452
Kollam	6.4	8.3	8.1	7.9	967	1038	1061
Thiruvananthapuram	5.6	10.1	10.2	9.9	1344	1476	1508

Source: Primary Census Abstracts, Census of India 1991, 2001, and 2011.

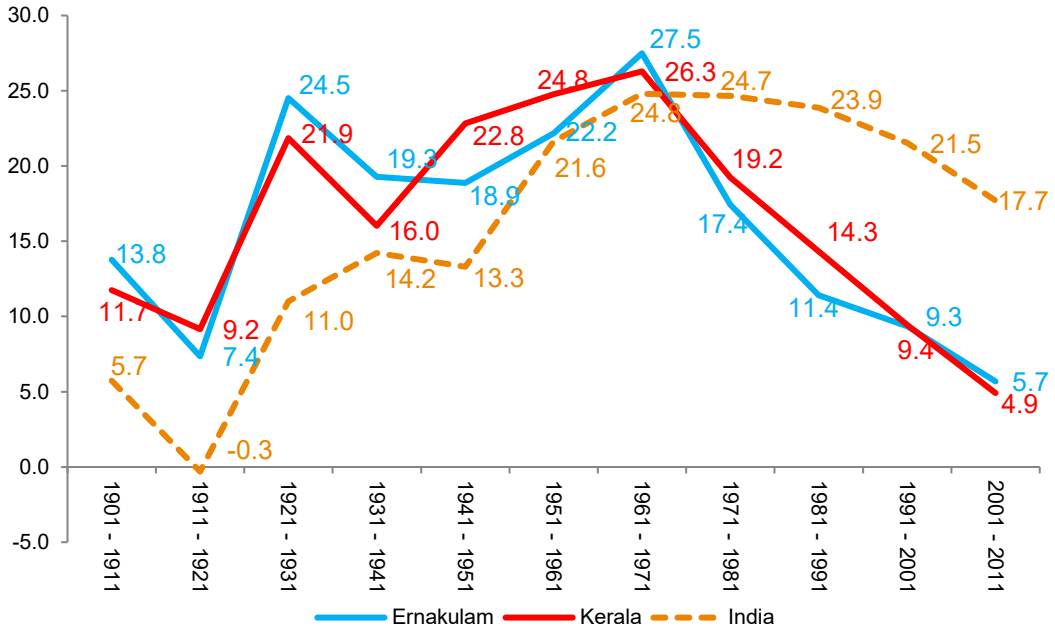
2.3.2 Population Growth

The trends in population growth of the Ernakulam district were similar to that of the state throughout the last 11 decades. Population growth trends of the state reveal that from 1901 to 1971, the growth was at a much faster rate than the rest of the country as a whole (Fig 2.1). The major factor contributing to this increase in population in the state was very high fertility and low mortality rate (Guilmoto & Rajan, 2002). However, the state's growth rate declined rapidly in comparison to other states from the 1970s, so much so that between 2001 and 2011 the decadal rate came down to below 5 percent for Kerala (5.7 percent for Ernakulam) against the national growth rate of 17.7 percent (Fig 2.1). One of the major reasons for such a sharp decline throughout the state is the significant decline in "total fertility rate (TFR)" post-1970, reaching replacement level by 1993 in all districts except Malappuram (Guilmoto & Rajan, 2002).

The high growth in population in the early decades of the century and its subsequent fall can be attributed to the low infant mortality rate in Kerala in the pre-Independence period and the fall in

its fertility rate in the subsequent years (Panikar, 1975). This has impacted the age structure of the state's population. As per the latest census, people aged 60 years and above account for 12.6 percent of the total population in Kerala as against 8.6 percent for all India. Similarly, the 0-14 age group population in the state also has declined from 43 percent in 1961 to 23 percent in 2011 (State Planning Board, 2018). The declining trend of the 0-14 age group population and the increasing trend of 60 plus population would eventually result in decreasing the 15-59 working-class population. Ernakulam district also has a similar trend as that of the state figure which may result in a decline in economically productive population. All northern districts especially Malappuram has a better advantage in terms of gaining a working-class age group population with 30 percent of its population being between the age group of 0-14 and only 9 percent people are in the 60 plus age group (Census 2011).

Figure 2.1: Growth rates of population in Ernakulam, Kerala and India over the decades



Source: Computed from Census of India data.

A comparison of census data (Table 2.3) reveals that the population growth of southern districts declined sharply as compared to northern districts and central districts of Kerala except for the Idukki district. Idukki and Pathanamthitta showed negative growth during 2001-2011. One thing which keeps apart Ernakulam from other districts is its growth consistent with the overall population growth of the state. In comparison to Ernakulam, the population growth of Malappuram in the north is

alarmingly high at 13.4 percent compared to the rest of the state with the second-highest being Kasaragod, again in the north with 8.2 percent growth over the previous decade (Table 2.3). Although the population growth rate in the northern and central districts also declined over time, the sharp decline in growth rate in the southern part of the state can be attributed to factors related to comparatively low fertility rate (Krishnan, 1976) owing to better educational and socio-economic status than the northern and central districts.

Table 2.3: District wise population growth rate in Kerala during 1951-2011

District/State/India	1951-61	1961-71	1971-81	1981-91	1991-01	2001-11
Kerala	**24.8**	**26.3**	**19.2**	**14.3**	**9.4**	**4.9**
Kasaragod	24.6	33.4	27.8	22.8	12.4	8.2
Kannur	30.2	31.8	24.3	16.6	7.0	4.8
Wayanad	62.6	50.4	33.9	21.3	16.1	4.6
Kozhikode	25.7	29.8	23.3	16.7	9.9	7.3
Malappuram	20.7	33.8	29.4	28.9	17.1	13.4
Palakkad	12.8	23.1	21.3	16.5	9.9	7.4
Thrissur	20.3	26.1	14.6	12.2	8.7	4.6
Ernakulam	**21.9**	**27.5**	**17.4**	**11.4**	**9.4**	**5.7**
Idukki	74.9	31.9	26.0	10.5	7.0	-1.9
Kottayam	16.0	17.1	10.3	7.7	6.9	1.3
Alappuzha	20.5	19.0	11.6	7.3	5.4	0.6
Pathanamthitta	23.5	15.8	9.4	5.6	3.8	-3.1
Kollam	31.6	25.9	18.3	10.7	7.4	1.7
Thiruvananthapuram	31.4	26.0	18.1	13.5	9.8	2.3

Source: Census of India, Population Tables, 2011.

2.3.3 Patterns of Urbanization

It may be noted that since the time of independence the urbanization in India is concentrated in higher-income states. The levels of urbanization in the states with high per capita income are generally high compared to the low-income states (A. Kundu et al., 2005). Kerala also reported a lower level of urbanization until 1981 compared to India probably linked with its low per capita income and other indicators of economic development at the beginning (Kannan, 2005). Kerala's urban population growth rate was higher than the national averages during the beginning three decades and fluctuated subsequently resulting in the state reporting a proportionately far larger urban population than the country in 1991 and 2011. Unlike other states in India, the settlement in Kerala is continuously spread rather than those separated with open lands or fields (State Planning Board, 2016). The statutory urban areas mostly came up along the major transport nodes and networks are the one that shows a distinct visual pattern compared to the urban areas classified as

census towns. As per census 2011, Ernakulam district has 68.1 percent urban population which is the highest among all the districts in Kerala (Table 2.4).

Table 2.4: Share of urban population and decadal growth rate (1901 to 2011)

Year	Percent Urban Population			Percent Increase		
	Ernakulam	Kerala	India	Ernakulam	Kerala	India
1901	11.5	7.0	10.8	-	-	-
1911	11.9	7.4	10.3	17.7	17.8	0.4
1921	12.2	8.7	11.2	10.5	28.3	8.2
1931	15.3	9.7	12.0	56.1	35.3	19.1
1941	16.2	10.9	13.9	26.1	30.4	32.0
1951	18.8	13.5	17.3	38.0	52.5	41.4
1961	23.3	15.1	18.0	50.9	39.3	26.4
1971	26.7	16.3	19.9	60.9	36.1	38.2
1981	39.6	18.7	23.3	57.7	37.5	46.1
1991	48.7	26.4	25.7	36.9	61.0	36.4
2001	47.6	26.0	27.8	7.6	7.7	31.5
2011	68.1	47.7	31.2	51.3	92.6	31.8

Source: Census of India, Population Table, 2011.

The level of urbanization of Ernakulam was always higher than the state as a whole from the beginning. The percent urban population of the district was 11.5 percent in 1901 compared to 7 percent for Kerala and 10.8 percent for India (Table 2.4). The share has slowly and steadily increased to 18.8 percent in 1951 but the relatively higher gap of about 8 to 10 percent is maintained in the next couple of decades (Table 2.4). However, the significant difference with that of the state and the nation is found from 1981 onwards. While the low percentage of the urban population in Ernakulam and the state during the initial period can be explained in terms of its agrarian economy, unique spatial structure, and settlement patterns (Sreekumar, 1990), the significant surge in the urban population of the district in the later decades can be mainly viewed in terms of shift of workforce from agriculture sector to tertiary sector and jurisdictional changes (Arya Lekshmi & Lancelet, 2019). Though many scholars observe that there is spread of habitation in Kerala especially in the coastal and midland regions and also less differential infrastructural access notwithstanding the area is rural or urban make the whole of Kerala as a rural-urban continuum, it is extremely important to analyze the role of the expansion of cities to the peripheral

areas especially in nearby medium size class towns and villages in the wake of decreasing population growth and increasing trend of urbanization.

Kerala's modest urban share in 1991 and 2001 is understandable in the context of its higher level of social development and a modest level of economic growth. In 1991 Kerala's urbanization with 26.4 percent for the first time crossed the national share of 25.7 percent (Table 2.4). In 2001 also, the urban share has remained close to the previous decade with 26 percent of people living in an urban area while the national figure has shown a moderate increase with 27.8 percent (Table 2.4). The share of the urban population reported an unprecedented surge in 2011 with 47.7 percent of the population becoming part of urban living (Table 2.4). A state-wise comparison of towns in 2001 and 2011 shows that the number of towns in Kerala has increased over three times in the last decade. Thus, the significant increase in the share of the urban population can be mainly attributed to the addition of new towns that fulfills the census criteria of the census definition of towns.

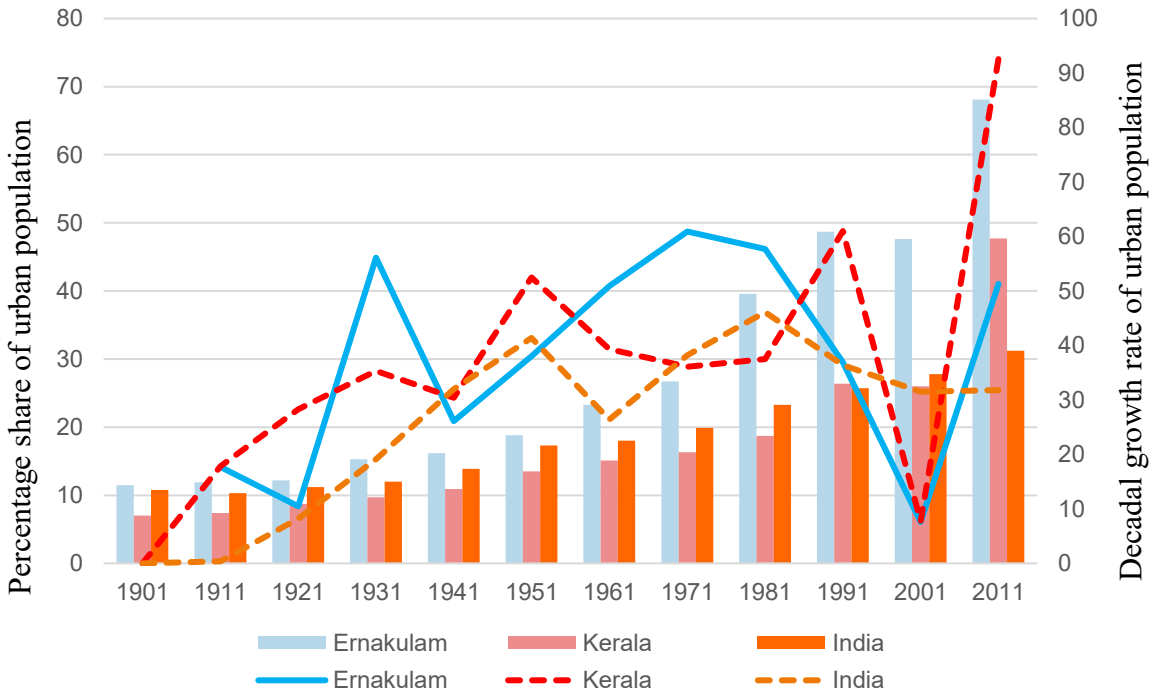
The urbanization in Ernakulam district however shows a much higher percent of 48.7 and 47.6 respectively for 1991 and 2001 compared to Kerala and the nation (Table 2.4). However, the quantum jumps from 47.6 percent to 68.1 percent for Ernakulam and 26 percent to 47.7 percent for Kerala in 2011 makes it clear that if the definitions of towns were applied properly the district and the state would have a much higher urban population in 1991 and 2001 also (Pradhan, 2017). Though the increase in nonagricultural activities, jurisdictional changes and, definitional criteria in the district as noted above through the literature, there is a necessity to explore the role of Kochi city and its expansion towards the peripheral areas in the increased share of the urban population of Ernakulam district. In the light of the surge in the urban population of the district, especially after 1971, it is important to understand the dynamics of demographic and infrastructural changes within Kochi city, the largest city and the financial capital of Kerala.

2.3.4 Growth Rate in Urban Population

Likewise, the growth rate in the overall population of the state, the growth of the urban population has also fluctuated over the decades (see Table 2.4 and Fig 2.2). Though the urban growth rate of the district has increased over time lower than the state and all India figures during 1941-51, the higher values can be partly explained as due to lack of rigorous definition of urban centers in the 1951 Census, the first conducted after the independence and partly due to the increased industrial activities post-partition (Crook & Dyson, 1982). During 1951-61, though the urban growth rate started decreasing both at national and state levels probably due to the declassification of towns

and due to standardization of the definition of urban centers (Bhagat & Mohanty, 2009). However, this trend is not observed at the district level as it continued to increase substantially compared to previous decades.

Figure 2.2: Shares of urban population and decadal growth rate



Source: Census of India, Population Table, 2011.

This shows that there were other reasons such as industrialization and socio-economic development associated with the district and the Kochi city that would have impacted the increased share in urban population. A very high urban growth was recorded for the district once again during 1961-71 and followed by a moderate fall in 1971-81, however, the scenario for Kerala was found to be different for which the decadal growth rate for 1961-71 and 1971-81 was 36.1 and 37.5 respectively followed by a substantial increase of 61 percent in the following decade (Fig 2.2). In the case of the district, however, there was a dramatic fall in the urban growth rate from 1981 to 1991 (Fig 2.2). This shows that the dynamics of urban change at the district and state level has other reason than declassification and standardization of definition. However, the growth rate of the urban population in Ernakulam and Kerala has dramatically fallen to less than 8 percent in 1991-2001, which can again be attributed to the large level of de-classification of towns in the

state (Fig 2.2). It also has marginally contributed to the decline of all India growth rates during this period. During 2001-11, due to the steep rise in the percentage of the urban population from 26 percent to 48 percent, the state saw a record-breaking growth rate of 92.6 percent (Fig 2.2). Ernakulam with a growth rate of 51.3 percent had a higher base compared to other districts in Kerala (Fig 2.2). This along with the identification of a large number of new areas as census towns has resulted in the steep rise in population growth in many other districts like Malappuram, Thrissur, Kasaragod, and Kollam. Thus, the major contribution to the rise in urban population was due to the increase in the number of Census towns from 99 to 461 in the same period. As a result of this, Kerala's rank which stood at 19th position in terms of the level of urbanization among the states in India, climbed to 10 positions in 2011 (Census 2001 & 2011).

2.3.5 District Wise Level of Urbanization and Urban Growth in Kerala 1991-2011

As noted in the previous section the percentage of the urban population in Kerala remained at the same level both in 1991 and 2001 and increased to 47.7 percent in 2011 (Table 2.5). Ernakulam district with the second-highest percentage in urban population with 48.7 and 47.6 correspondingly in 1991 and 2001 increased its figure to 68.1 percent in 2011, the highest among all the districts of Kerala (Table 2.5). The highest percentage of urban population across all districts in Kerala was recorded in Kannur with over 50 percent of its population already in urban areas both in 1991 and 2001, the figure has further increased to 65 percent in 2011 (Table 2.5).

Table 2.5: District wise percentage of urban population

State/District	Percent Urban Population			Percent Increase	
	1991	**2001**	**2011**	**1991-2001**	**2001-2011**
Kerala	**26.4**	**26.0**	**47.7**	**7.6**	**92.8**
Kasaragod	16.4	19.4	38.9	32.6	117.8
Kannur	50.9	50.3	65.0	5.9	35.3
Wayanad	3.4	3.8	3.9	29.0	6.6
Kozhikode	38.3	38.2	67.2	9.6	88.2
Malappuram	9.1	9.8	44.2	26.1	410.2
Palakkad	15.7	13.6	24.1	-4.8	89.8
Thrissur	26.3	28.2	67.2	16.6	149.7
Ernakulam	**48.7**	**47.6**	**68.1**	**7.6**	**51.3**
Idukki	4.7	5.1	4.7	13.2	-9.6
Kottayam	17.6	15.3	28.6	-6.6	88.6
Alappuzha	30.5	29.5	54.0	1.9	84.8
Pathanamthitta	13.0	10.0	11.0	-20.1	6.3
Kollam	18.5	18.0	45.0	4.5	154.8
Thiruvananthapuram	33.9	33.8	53.7	9.4	62.3

Source: Compiled from Primary Census Abstract, 1991, 2001 and 2011

Kozhikode with 38 percent and Thiruvananthapuram with 34 percent were the other two districts in Kerala which had a substantially higher percentage of the urban population than the state share (Table 2.5). The relatively new districts of Wayanad and Idukki followed by Malappuram and Pathanamthitta recorded a low level of urbanization during 1991 and 2001 (Table 2.5). Out of these districts, except Malappuram the other three districts also maintained a low percent in 2011, being the hilly area still dominated with agricultural activities. However, Malappuram has shown a dramatic increase in its urban population in 2011 with an increase from 9.8 percent to 44.2 percent (Table 2.5). The major reason for such increase is due to the change in status of many villages to census towns in 2011. The percentage of the urban population in nine districts out of the total 14 districts in Kerala exceeds the latest national level of 31.2 percent with four of them namely Ernakulam, Thrissur, Kozhikode, and Kannur have already crossed more than 65 percent of its population living in urban areas (Table 2.5). The increase in the urban population in Palakkad and Kottayam districts however has remained at a slow pace compared to other districts of Kerala. The figures of these districts are even less than the corresponding national figure of 31.2 percent (Table 2.5). The urban growth in Ernakulam district was similar to the overall urban growth rate of Kerala during 1991-2001. However, the growth rate of Ernakulam in the subsequent period has substantially increased. The district-wise urban growth for 1991-2001 and 2001-2011 in Table 2.5 reveals that the growth rate of Ernakulam has increased to 51.3 percent in 2001-2011, the figure being 7.6 percent during 1991-2001 similar to that of Kerala for the same period. Most of the districts in Kerala show a steep growth in urban population. Idukki district with an urban growth rate of 13.2 in 1991-2001 has experienced a negative growth rate of -9.6 in 2001-2011 (Table 2.5). This is largely attributed to the de-classification of Idukki town. The other districts which were predominantly rural like Wayanad and Pathanamthitta also experienced a decline in urban growth compared to the previous period.

It may be noted that the directorate of census operation expanded the area limits of "Urban Agglomeration (UA)" and thereby by recognizing many UAs in Kerala as million-plus cities in 2011 by changing the status of a large number of villages to census towns in and around the existing Municipalities and Corporations. The only city in Kerala that was categorized as a million-plus city in 2001 also was Kochi UA. All other newly categorized million-plus cities of Kannur, Kozhikode, Malappuram, Thrissur, and Thiruvananthapuram were the results of such large-scale definitional change mainly arising out of the shift in economic activities.

2.3.6 Statutory Towns and Census Towns in Ernakulam, Kerala, and India

Unlike other parts of the country, the number of statutory towns in the district, as well as the state, is much less than the census towns. Kerala's unique dispersed pattern of settlements is spread in such a way that there is continuity in urban and rural areas.

Table 2.6: Statutory and census towns in Ernakulam

Category	Ernakulam			Kerala			India		
	1991	2001	2011	1991	2001	2011	1991	2001	2011
Statutory towns	12	9	9	66	60	59	2987	3799	4041
Census towns	16	16	47	131	99	461	1702	1362	3894

Source: Census of India, District Census Handbooks, 1991, 2001, 2011

The rural-urban continuum of the district and Kerala is clear from the fact that as per the 2011 census Ernakulam has only 9 statutory towns but there are 47 census towns, a similar pattern is seen for the entire state with 59 statutory towns and 461 census towns (Table 2.6). This is because most of the villages in Kerala are having a very high population and density of population and only the criteria of more than 75 percent of the male main workers in non-agricultural activities elevated its status to census town.

2.3.7 Contribution of New Census Towns in Urban Growth in Ernakulam vis-a-vis other Districts

When analyzing urban growth in Kochi, it is important to understand the growth in census towns in the district in terms of increase in numbers and population. Table 2.7 presents the growth in the census towns in Kerala between 2001 and 2011. In comparison to 75.1 percent of new census towns in Kerala, Ernakulam has a 61.7 percent increase in 2011. About 93 percent of these towns of the district are in the KUA (Table 2.7). The Population Census of 2011 identified 362 new Census towns in Kerala. Of these, 346 were villages, and 16 were outgrowths of the statutory towns in 2001 (Table 2.7). The increase is unprecedented, and the second-highest among India's states, next only to West Bengal which recorded an increase of 537 new Census towns (Appendix 2.1).

These settlements had a total population of 6.8 million in 2001, which was about 89 percent of the incremental urban population in the state, the corresponding national figure being 26 percent (Appendix 2.2). Arguably, the spectacular pace of urbanization noted in 2001-11 is almost due to the rural-urban conversion based on the census definition. There is, however, no doubt that it also reflects a certain kind of dynamism in large villages in the state which has enabled them to attract different types of nonagricultural activities, giving them a distinctly urban character.

Table 2.7: Dynamics of growth in census towns in Kerala (2001-2011)

State	Change in 2001 CT			New CT in 2011		Total CT in 2011	Proportion of new town
	Total CT in 2001	De-notified to village in 2011	Upgraded /Merged with Statutory	Other Urban Area to CT	From Village to CT		
All India	**1362**	**55**	**144**	**141**	**2553**	**3857***	66.2
Kerala	**99**	0	0	**16**	**346**	461	**75.1**
Kasaragod	5	0	0	1	19	25	76.0
Kannur	38	0	0	0	22	60	36.7
Wayanad	0	0	0	0	0	0	0.0
Kozhikode	10	0	0	2	36	48	75.0
Malappuram	0	0	0	0	39	39	100.0
Palakkad	1	0	0	3	13	17	76.5
Thrissur	21	0	0	1	106	128	82.8
Ernakulam	**16**	**0**	**0**	**2**	**29**	**47**	**61.7**
Idukki	0	0	0	0	0	0	0.0
Kottayam	2	0	0	2	9	13	69.2
Alappuzha	6	0	0	2	25	33	75.8
Pathanamthitta	0	0	0	0	1	1	100.0
Kollam	0	0	0	0	24	24	100.0
Thiruvananthapuram	0	0	0	3	23	26	88.5

Note i) As per the 2011 census, there are 3894 census towns of which change of 11 census towns in 2001 and 48 in 2011 are unknown and it has been removed from the calculation.

ii) The number of census towns in 2011 is obtained by considering the census towns of 2001 and adding the number of urban and rural settlements, declared urban in 2011 and subtracting the number of census towns de-classified or the census towns upgraded or merged to statutory towns. However, in Kerala, there were no such census towns de-notified to a village or merged with statutory towns in 2011.

Source: Compiled by author from Census of India Population Tables, 2001 and 2011.

Though the increase of census town for Ernakulam in 2011 was about 3 times that of the previous census year as can be seen in for India, nearly 5 times increase for Kerala is due to the significant increase in census towns in districts such as Thrissur, Malappuram, Kollam, and Thiruvananthapuram. As per the 2011 census, the total number of census towns in Ernakulam is

47 as compared to 16 in 2001 (Table 2.7). The higher increase in census towns in 2011 compared to 2001 is also noted for other districts such as Kasargod, Kozhikode, Palakkad, Kottayam, and Alappuzha. The rural districts of Wayanad and Idukki did not have any census town both in 2001 and 2011, while the other hilly district of Pathanamthitta with no census town in 2001 has one census town in 2011 (Table 2.8).

Table 2.8: Share of new CTs to the increase in total urban population (2001-2011)

State	New CTs re-classified from Villages		Absolute change in Urban Population 2001-2011 (In Lakhs)	Share of new CTs (Low)
	Number	Pop 2001 (In Lakhs)		
All India	**2553**	**236.8**	**909.9**	**26.0**
Kerala	**346**	**68.0**	**76.7**	**88.8**
Kasaragod	19	2.33	2.75	84.8
Kannur	22	3.49	4.28	81.5
Wayanad	0	0	0.02	0.00
Kozhikode	36	8.37	9.71	86.2
Malappuram	39	12.44	14.61	85.1
Palakkad	13	2.25	3.20	70.3
Thrissur	106	11.59	12.57	92.2
Ernakulam	**29**	**6.20**	**7.57**	**81.9**
Idukki	0	0.00	-0.06	0.0
Kottayam	9	2.63	2.66	99.0
Alappuzha	25	5.06	5.27	95.8
Pathanamthitta	1	0.13	0.08	160.5
Kollam	24	6.91	7.04	98.1
Thiruvananthapuram	*23*	*6.27*	*6.51*	*96.3*

Source: Calculated from Population Tables, Census of India, 2001 and 2011 data.

The shares of the population of new census towns in 2001 to the increase in urban population during 2001-11 in select states are given in the last column of Table 2.8. These figures are explaining the contribution of the population of new Census towns that were villages in 2001 to the absolute increase in urban population, assuming no increase in their population in this period. In other words, they represent the lower limit of urban population contribution, given that we

would expect these towns to have a reasonably high demographic growth over the decade. Thus the contribution of the new census town in terms of population in Ernakulam in the overall incremental urban population between 2001 and 2011 is 81.9 percent which is about 7 percent less than that of the state share indicating that the intensity of rural-urban transformation was more in other districts than in Ernakulam (Table 2.8). It would be interesting to note that almost all the newly formed census towns in the Ernakulam district are within the KUA, which one can be argued in terms of the importance of Kochi in transforming the economic activities of the people living in the neighborhood.

2.3.8 Size Class Wise Rural Population in Ernakulam and Kerala Compared to India

Urbanization trends in Kerala highlight a special feature of its development. The size classwise villages and their population in the whole of Kerala has a sharp contrast with that of all India. In 1991, 2001, as well as in 2011 more than 96 percent of the villages in Ernakulam district and over 90 percent of villages in entire Kerala, had populations of more than 5,000 (Table 2.9). Whereas, the corresponding national figures were 3 percent in 2001 and 4 percent in 2011.

Table 2.9: Percentage of villages in the different size classes of villages and their share in the total rural population in 1991, 2001, and 2011: India, Kerala, and Ernakulam

India/ State	Year	< 500		500-999		1,000-1,999		2,000-4,999		5,000-9,999		>= 10,000	
		V	P	V	P	V	P	V	P	V	P	V	P
India	1991	38.5	8.6	26.6	16.1	22.1	25.8	11.0	29.3	1.4	12.1	0.4	8.1
	2001	36.9	7.2	24.5	14.2	21.9	24.7	13.5	32.2	2.5	13.2	0.7	8.6
	2011	32.9	5.7	23.7	12.4	23.3	23.7	16.1	34.6	3.1	14.9	0.8	8.7
Kerala	1991	0.3	0.0	0.2	0.0	1.2	0.1	7.4	1.8	18.2	9.1	72.8	89.0
	2001	0.4	0.0	0.0	0.0	0.7	0.1	5.1	1.0	15.2	6.7	78.6	92.2
	2011	0.2	0.0	0.3	0.0	1.1	0.1	5.7	1.2	14.4	6.5	78.4	92.2
Ernakulam	1991	1.1	0.0	0.0	0.0	0.0	0.0	2.2	0.5	11.2	5.6	85.4	93.9
	2001	1.1	0	0.0	0.0	0.0	0.0	1.1	0.1	6.7	2.8	91.1	97.0
	2011	0.0	0.0	1.6	0.1	0.0	0.0	1.6	0.2	4.9	2.0	91.8	97.8

Note: V = Percent Villages, P=Percent Population.
Source: Calculated from Census of India, Village Directories, 1991, 2001, and 2011.

This shows that the patterns of habitation in the district, as well as the state, is completely different from the rest of the country and it revealed the existence rural-urban continuum that substantially

blurred rural-urban classifications. Conventional revenue villages in the district hold large human settlements - as Table 2.9 also shows, 91.8 percent of the villages in Ernakulam have a population of above 10,000 which is much higher than the corresponding state figure of 78.4 percent. In the case of India, this is just 0.8 percent and close to 80 percent of the villages with a population of less than 2000 (Table 2.9). In almost every village of Kerala, residential and agricultural areas are not segregated and the population is therefore geographically dispersed. The villages' continuous settlement pattern, high rural density, and proliferation of non-agricultural activities allowed ample scope for the state Directorate of Census Operations to use discretionary powers to categorize them as urban areas. It would, therefore, be unsurprising if many more settlements in Ernakulam, as well as the State of Kerala, be classified as towns in the subsequent census years. However, steep urban growth without infrastructural support and provision of basic amenities may create deficiencies that would hinder sustainable urbanization. Moreover, there is a low population density in urban areas, despite the high population density of the state. The number of persons per square kilometer in urban centers was as low as 2,543 in 2001, which further decreased to 2,097 in 2011, primarily due to the new Census towns which have large agricultural lands. A second contributory factor to low urban population density is the massive investment in housing from remittances, resulting in larger plot sizes for residential units.

2.4 Sectoral Distribution of the Workforce

The role of understanding the changing pattern of sectoral distribution of workforce in Ernakulam is important to identify the growth factors of Kochi, the largest urban agglomeration in the state. The primary sector workforce in the district both for rural and urban areas has decreased over time. As the urbanization in the district and the state is very high, the decrease in the share of the workforce in agriculture and allied activities over the last two decades is in the expected line (Table 2.10). Though the overall workers in the secondary sector have increased in the district, its share in manufacturing which is largely a city-based activity has also decreased from 21 percent in 1991 to 17.9 percent in 2011, the decrease was even sharper for the State with 20.7 to 15.9 during this period (Table 2.10). The same trend has also been observed for all of India, though the share was observed to be much higher than the district and the state. Looking at the higher percentage of workers in the manufacturing sector in India compared to the state, it can be partially inferred that, unlike other urban areas, the contribution of the manufacturing sector in the urban development in

Kerala is less as can be seen from the table 2.10. Even though the construction sector employed a smaller percentage of the district's workforce in 1991 than manufacturing, the figure increased to 16.8% in 2011, narrowing the gap between the two sectors. This sector's overall state figure was equally low, at 6.1 percent in 1991, until improving to 16.8 percent in 2011 (Table 2.10).

Table 2.10: Sectoral distribution of the workforce in Ernakulam, Kerala, and India

	1991		2001		2011	
Sector of activity	Rural	Urban	Rural	Urban	Rural	Urban
Ernakulam						
Agriculture and Allied Act.	48.8	13.4	34.0	7.3	31.6	7.4
Mining and Quarrying	1.4	0.5	1.4	0.4	1.2	0.4
Primary	**50.1**	**13.9**	**35.3**	**7.8**	**32.8**	**7.7**
Manufacturing	14.8	21.0	16.6	19.1	13.2	17.9
Construction	5.5	9.0	9.3	13.3	13.0	16.8
Secondary	**20.4**	**30.0**	**25.9**	**32.4**	**26.2**	**34.7**
Wholesale, Retail Trade	10.5	20.7	10.6	16.5	8.9	13.6
Transport & Storage	6.0	13.0	9.2	12.6	10.0	13.4
Other Services	13.0	22.3	19.0	30.7	22.0	30.6
Tertiary	**29.5**	**56.1**	**38.8**	**59.9**	**41.0**	**57.6**
Kerala						
Agriculture and Allied Act.	56.1	20.7	39.8	12.3	38.4	11.7
Mining and Quarrying	1.1	0.7	1.1	0.4	0.8	0.5
Primary	**57.2**	**21.4**	**40.9**	**12.8**	**39.2**	**12.2**
Manufacturing	11.9	20.7	14.3	18.9	11.5	15.9
Construction	3.3	6.1	8.6	11.2	12.3	16.5
Secondary	**15.2**	**26.8**	**22.9**	**30.1**	**23.9**	**32.4**
Wholesale, Retail Trade	10	20.2	10.6	17.6	8.9	15.1
Transport & Storage	4.6	10.1	8.3	11.5	8.8	12.1
Other Services	13	21.5	17.3	28	19.1	28.2
Tertiary	**27.6**	**51.8**	**36.2**	**57.1**	**36.9**	**55.4**
India						
Agriculture and Allied Act.	82.3	13.3	74.5	8.2	73.2	8.8
Mining and Quarrying	0.5	1.1	0.6	1.0	0.4	0.6
Primary	**82.7**	**14.5**	**75.1**	**9.2**	**73.6**	**9.4**
Manufacturing	5.7	25.1	8.3	23.6	6.6	20.7
Construction	1.0	5.1	2.5	7.5	3.6	9.5
Secondary	**6.8**	**30.1**	**10.7**	**31.1**	**10.2**	**30.1**
Wholesale, Retail Trade	3.3	22.0	4.3	19.9	3.5	17.0
Transport & Storage	1.2	8.3	2.1	8.7	2.4	9.4
Other Services	6.0	25.1	7.8	31.1	10.2	34.1
Tertiary	**10.5**	**55.4**	**14.2**	**59.7**	**16.1**	**60.5**

Source: Calculated from economic tables, Census of India 1991, 2001, and 2011.

In comparison, the percent workforce in construction for all India was 5.1 percent in 1991 and increased marginally in successive census years (Table 2.10). The workforce in the tertiary sector in Ernakulam and Kerala especially in rural areas is higher than all India figures. The better social and educational development of the state irrespective of rural or urban compared to other states in India can be viewed as one of the reasons for such a higher share in tertiary sector workers.

However, in urban areas both in Ernakulam district and Kerala the share in 2011 was slightly less than the national average. While the workforce in transport, storage, and communication showed a slight improvement across the census years, the wholesale and retail trade has shown a decreasing trend. The major contribution of the workforce in the tertiary sector was of other services which have workers in administrative, professional, and technical services. Another contrasting pattern that can be observed both for Ernakulam and Kerala in comparison to India is the huge difference in rural areas, especially in the secondary and tertiary sectors. The percent of workers in the rural areas of India in the tertiary sector was 10.5 percent in 1991, the corresponding figure for Ernakulam and Kerala was as high as 29.5 percent and 27.6 percent respectively for the same year (Table 2.10). Similarly, it was 14.2 percent in 2001 and 16.1 percent in 2011 for All India, the district figure for these years was as high as 38.8 percent and 41 percent respectively (Table 2.10). While the rural-urban divide in the sectoral distribution of workforce in India is very high, the rural and urban areas of Kerala have a converging character, making it a distinct pattern with the rest of the country.

2.5 Trends in the Economy of Ernakulam District in Relation to Kerala and India

2.5.1 Per Capita Income of Kerala

An overview of growth in Kerala since Independence shows that the “state domestic product (SDP)” grew at a slightly higher rate than that of the country in the early fifties, declined in 1955-65 and rose again in 1965-70(State Planning Board, 2016). However, from the seventies through to the mid-eighties, Kerala’s growth was far below the national averages. During 1975-80, the growth rate of SDP was 2.11 percent per annum, much below the all-India average and that of the three neighboring states (State Planning Board, 2016). Although the growth rate went up to 3.08 in the eighties, it remained below the national average. It picked up after the mid-eighties to 6 percent per annum till 2000, much above the national figure(State Planning Board, 2016).

As stated at the outset of this chapter, the state was divided into three regions, each with its own set of social and economic characteristics at the time of its formation. The problems of regional imbalance and developmental deficiencies in backward regions have been addressed to a large extent throughout the years. The Department of Economics and Statistics, Government of Kerala, has released the SDP and "district domestic product (DDP)" data, which depict the economic structure at the district level (State Planning Board, 2016). Though Kerala’s per-capita income is

only marginally above the national average, the state has made tremendous strides in human development, the state index recording a faster and sustained increase from 0.677 in 1999-2000 to 0.790 in 2007-08. By comparison, the HDI for the country as a whole moved from 0.387 to 0.467 in the same period (Planning Commission of India, 2011). More importantly, while the "National Human Development Report 2001" noted a widening of inter and intrastate disparities, Kerala was unique in having negligible rural-urban and inter-district disparities (State Planning Board & Kerala), 2005). Scholars attributed Kerala's success in human development to a set of wealth and resource redistribution programs that were adopted in the seventies. High levels of education and political participation are also noted as explanatory factors. Nevertheless, Kerala has to catch up with its neighboring states in terms of per capita SDP and other indicators of economic development.

The differences in the growth rates of per capita income of the state and the nation were higher since the state had far lower levels of population growth than the rest of the country (see appendix 2.3). Between 2000-01 and 2012-13, the state economy grew at a rate similar to the all-India rate. As a result, the state's share in national income has remained about the same at 4 percent, much higher than its population share. In other words, the rise in the relative gap between Kerala and all-India is essential because the state's population growth was lower than the country's and not because it grew faster economically.

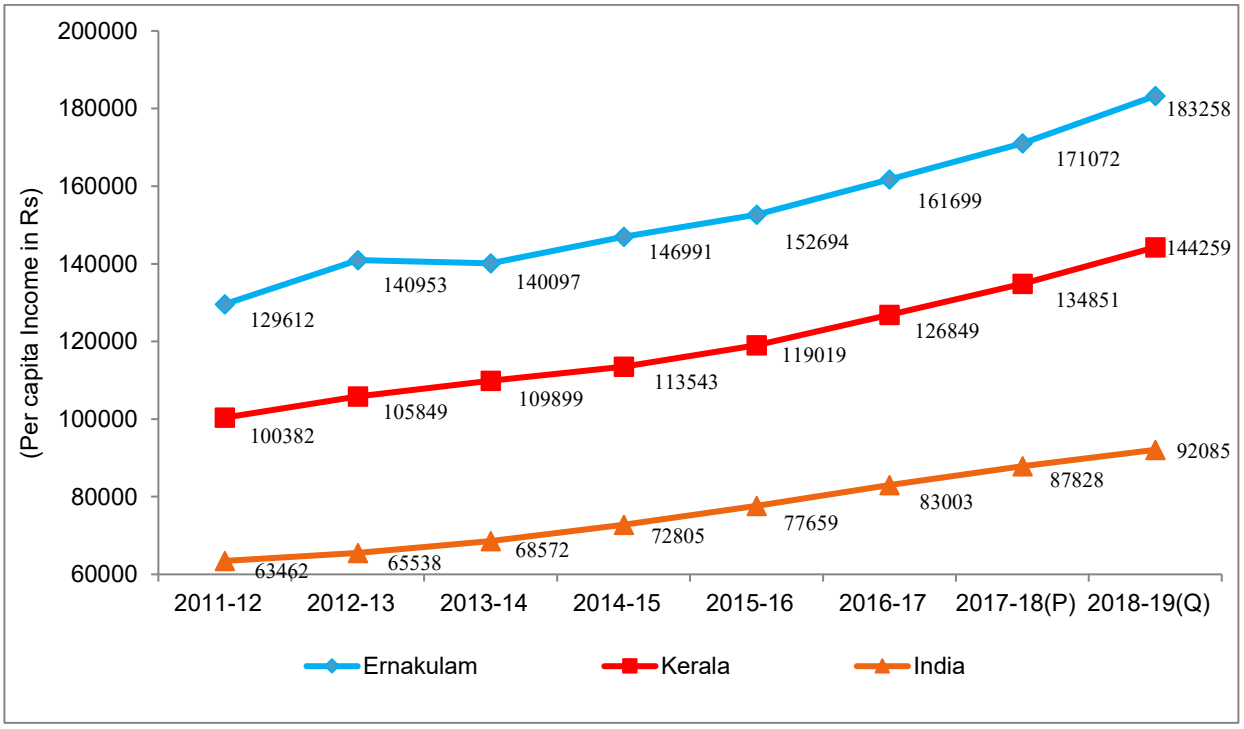
2.5.2 Per Capita Income of Ernakulam

Table 2.11 gives the income contribution of Ernakulam and Kerala and also the per Capita income of the district along with state and national figures from 2011-12 to 2018-19 for which relatively robust data are available from the government sources. The data presented in this section is in terms of the "Gross Value Added (GVA)" as the addition of product taxes and subtraction of subsidies required for the calculation of GDP figures are not available at the district level. Hence for Kerala and all India levels also GVA is taken as a proxy to the income to make it comparable with the district.

The per capita income of the district has remained higher than the overall Kerala figures during 2011-12 to 2018-19 (Fig 2.3). While Kerala reported a steady increase in the per capita income over the years, the district figures, in the beginning, were not as promising (Table 2.12). The per capita income of Ernakulam from 2015-16 onwards however has increased consistently. The increase in per capita income is important in the context of the development of the region (Table

2.11). The widening trend in the later years for Ernakulam shows the per capita income continues to be higher compared to the state and all of India.

Figure 2.3: Per capita income at constant prices of 2011-12 for Ernakulam, Kerala, and India



Source: Department of economics and statistics, Govt. of Kerala and National Accounts Statistics, Govt. of India

The share of Ernakulam in the overall economy of Kerala is highest among the district (Table 2.12). While the overall share of the state economy to India remained around 4 percent throughout the last 8 years, the share of the district to the state income for the same years is around 12.5 percent (Table 2.12). A detailed district-level analysis of the contribution of income to the state income illustrates the role of Ernakulam in generating more income as well as overall social development for the state. The income shares of each of the districts remained more or less the same throughout the years. Thiruvananthapuram, Thrissur, and Malappuram also contributed to the overall rise of income in Kerala. Over 40 percent of the total income of the state is coming from these four districts (Table 2.12). The relatively higher contribution of Ernakulam can partly attribute to the economic importance of Kochi as an income potential growth engine to the Kerala in coming years.

Table 2.11: Per capita income and its growth rates at constant prices of 2011-12 for Ernakulam, Kerala, and India

Year	Contribution of Overall Income		Per Capita Income (Rs)		
	Ernakulam To Kerala	Kerala To India	Ernakulam	Kerala	India
2011-12	12.7	4.1	129612	100382	63462
2012-13	13.1	4.2	140953	105849	65538
2013-14	12.5	4.1	140097	109899	68572
2014-15	12.7	4.0	146991	113543	72805
2015-16	12.6	3.9	152694	119019	77659
2016-17	12.6	3.8	161699	126849	83003
2017-18(P)	12.5	3.9	171072	134851	87828
2018-19(Q)	12.5	4.1	183258	144259	92085

Source: Based on the Gross Value Added (GVA) data from Central Statistical Organisation and Department of Economics and Statistics, Kerala.

Table 2.12: District wise contribution of income in Kerala at constant prices of 2011-12

Districts	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18(P)**	**2018-19(Q)**
Kasaragod	3.6	3.1	3.4	3.3	3.4	3.3	3.4	3.4
Kannur	7.0	7.2	7.0	7.0	7.0	7.1	7.1	7.2
Wayanad	1.9	2.0	2.0	1.9	1.9	1.9	1.9	1.9
Kozhikode	8.1	8.7	8.4	8.7	8.6	8.4	8.6	8.7
Malappuram	9.8	9.4	9.6	9.6	9.4	9.2	9.8	9.8
Palakkad	7.3	6.9	7.4	7.2	7.3	6.9	7.0	7.0
Thrissur	9.6	9.9	10.0	10.1	10.0	9.8	9.8	9.9
Ernakulam	**12.7**	**13.1**	**12.5**	**12.7**	**12.6**	**12.6**	**12.5**	**12.5**
Idukki	3.8	3.9	3.7	3.7	3.5	3.3	3.3	3.1
Kottayam	7.0	6.6	6.5	6.3	6.5	6.5	6.4	6.4
Alappuzha	7.2	7.2	7.3	7.4	7.2	7.4	7.3	7.3
Pathanamthitta	3.2	3.0	3.1	2.9	2.9	3.0	2.9	2.8
Kollam	8.3	9.4	9.0	9.2	9.0	9.3	9.2	9.3
Thiruvananthapuram	10.5	9.5	10.1	10.0	10.5	11.5	10.9	10.7

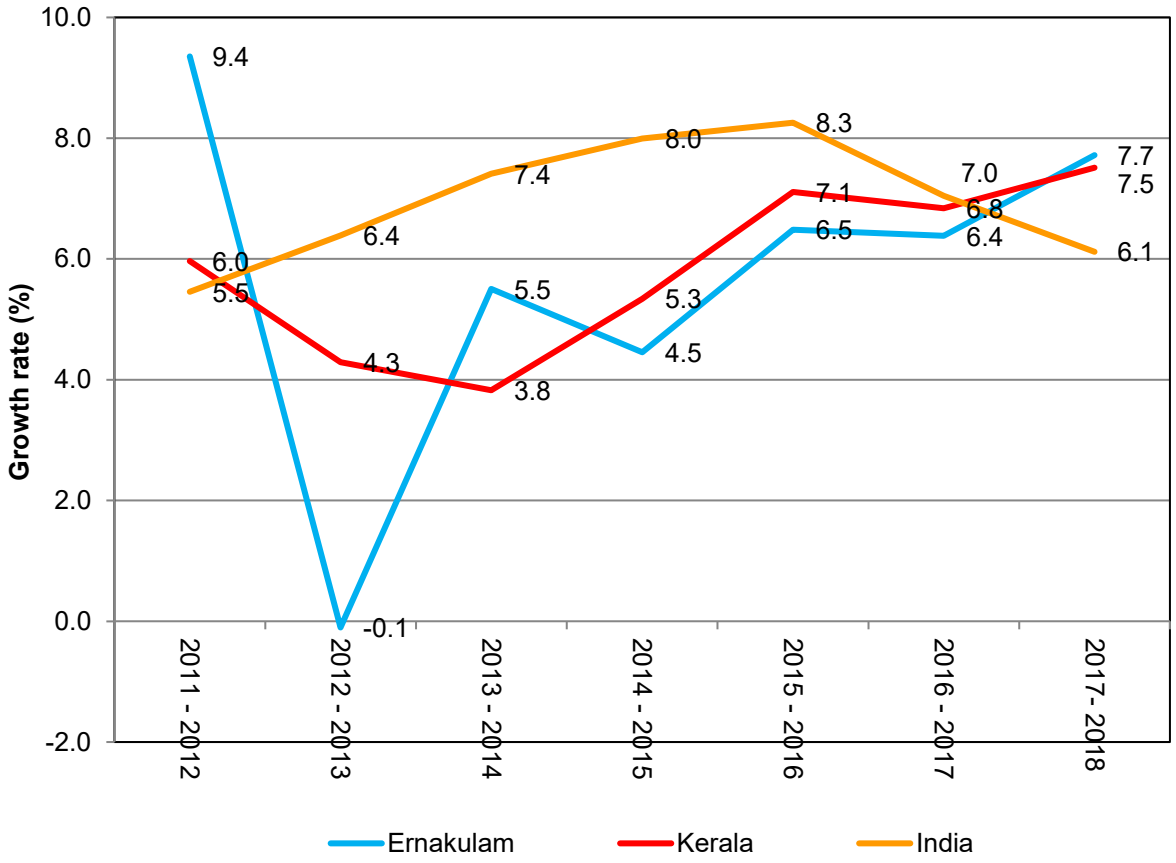
Source: Based on the data from the Department of Economics and Statistics, Kerala.

2.5.3 Growth Rate in Income of Ernakulam

The all India growth rate in income recorded a steady increase from 5.5 percent to 8.3 percent from 2011-12 to 2015-16, in the latter two years it showed a decline (Fig 2.4). However, in the case of Ernakulam, there were a lot of fluctuations in the initial periods (Fig 2.4). The growth in income of Ernakulam district during 2011-12 to 2012-13 (referred in fig 2.4 as 2011-12) was 9.4 percent, much higher than that of the state and all India figures. However, in the 2012-13 to 2013-14 periods, the growth rate of the district has drastically come down to -0.1 at a time when the state growth was 4.3 percent (Fig 2.4).

An analysis of sectoral income data for the district reveals that the negative growth is happened mainly due to the decline in income from the secondary sector, especially the manufacturing, electricity, gas, and water supply. The growth in income in the subsequent two years for the district was 5.5 percent and 4.5 percent respectively (Fig 2.4). During 2015-16 and 2016-17, the growth rate has remained almost equal. The quick estimate of 2017-18 shows the growth rate of the district at 7.7 percent higher than the state and national growth rates (Fig 2.4).

Figure 2.4: Growth rate in real GVA at constant prices of 2011-12



Source: Based on the data from the Department of Economics and Statistics, Kerala.

2.5.4 Sector-wise Gross Value Added (GVA) over time

The pattern of the workforce and the "gross value added (GVA)" distribution in disaggregated sectors of the economy represent a parallel narrative. The first part of this narrative has already been covered while discussing the structure of employment. Contributions from primary, secondary, and tertiary sectors to the GVA from 2011-12 to 2018-19 and its further disaggregation into sub-sectors for Ernakulam District and Kerala are presented in Table 2.13 and 2.14. Changes

in sectoral distribution can be witnessed in the continuing fall in the share of the primary sector in the state's GSDP as the data from 2004-05 to 2012-13 reveals that the decline was much sharper than the all-India level (See appendix 2.4 and 2.5). The new series data from 2011-12 to 2018-19 at 2011 constant prices also suggest that the primary sector in Ernakulam district has fallen from 13.5 percent in 2011-12 to 7.5 percent in 2018-19 while the state contribution during this period has declined from 15.2 to 9.3 percent.

Table 2.13: Contribution of different sectors and sub-sectors to GVA at constant prices of 2011-12, Ernakulam district

Sector of activity	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18(P)	2018-19(Q)
Agriculture & Allied	11.9	11.0	8.8	8.4	7.4	6.9	7.0	6.4
Mining & quarrying	1.7	1.2	1.2	2.0	0.6	1.2	1.3	1.1
A. Primary	**13.5**	**12.3**	**10.0**	**10.4**	**8.0**	**8.1**	**8.3**	**7.5**
Manufacturing	11.9	11.7	11.4	11.0	13.6	15.1	14.7	15.2
Construction	12.4	9.5	11.2	10.5	10.2	10.2	10.1	9.9
Electricity, Gas & Water	3.6	3.1	1.5	1.3	1.2	1.0	1.2	1.3
B. Secondary	**27.9**	**24.3**	**24.2**	**22.8**	**25.0**	**26.3**	**25.9**	**26.4**
Trade, Hotels & Restaurant	13.1	11.2	12.7	12.2	12.9	12.1	13.0	12.9
Transport, Storage & Com.	10.6	10.9	11.7	11.9	12.1	10.1	9.0	8.8
Financial Services	6.0	5.6	6.4	6.4	6.2	6.1	6.0	5.5
Real Estate & others	14.0	22.5	21.2	24.3	23.6	24.5	25.5	25.7
Public administration	6.6	5.4	5.7	4.6	4.5	4.6	4.8	5.1
Other services	8.2	7.9	8.2	7.5	7.7	8.2	7.4	8.1
C. Tertiary	**58.6**	**63.4**	**65.8**	**66.8**	**67.0**	**65.6**	**65.8**	**66.2**

Note: Transport, Storage & Com. stands for Transport, Storage & Communication, Agriculture & Allied includes crops, livestock, forest & logging and fishing, Real Estate & others includes Real Estate, Ownership of Dwelling & Professional services.
Source: Calculated by the author based on the data from Department of Economics and Statistics, Kerala.

Areas under agricultural cultivation have continuously shrunk in Kerala. Except for rice, pulses, banana, turmeric, tapioca, and rubber, all other crops recorded a declining trend in the area under cultivation (State Planning Board, 2018).

Table 2.14: Contribution of different sectors and sub-sectors to GSVA at constant prices of 2011-12, Kerala

Sector of activity	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18(P)	2018-19(Q)
Agriculture & Allied	14.4	13.8	12.4	11.9	10.7	10.0	9.5	8.8
Mining & quarrying	0.8	0.6	0.9	1.4	0.4	0.6	0.7	0.5
A. Primary	**15.2**	**14.4**	**13.3**	**13.3**	**11.2**	**10.6**	**10.1**	**9.3**
Manufacturing	10.2	10.8	9.9	9.8	11.9	13.2	12.8	13.2
Construction	15.8	14.4	15.1	14.9	14.1	14.2	13.8	13.7
Electricity, Gas & Water	1.4	1.3	1.3	1.2	1.2	0.9	1.1	1.2
B. Secondary	**27.3**	**26.5**	**26.3**	**25.9**	**27.2**	**28.3**	**27.7**	**28.1**
Trade, Hotels & Restaurant	15.8	17.0	16.7	17.0	17.4	16.5	17.5	17.4
Transport, Storage & Com.	8.3	8.3	8.8	8.8	8.7	8.4	7.7	7.1
Financial Services	4.3	4.3	4.6	4.8	5.1	5.0	4.7	4.4
Real Estate & others	12.6	13.5	14.7	15.5	15.7	15.8	16.4	16.6
Public administration	4.7	4.4	4.2	3.5	3.4	3.5	3.6	3.9
Other services	11.8	11.6	11.4	11.1	11.3	11.9	12.2	13.3
C. Tertiary	**57.5**	**59.1**	**60.4**	**60.8**	**61.6**	**61.1**	**62.1**	**62.6**

Note: Transport, Storage & Com. stands for Transport, Storage & Communication, Agriculture & Allied includes crops, livestock, forest & logging and fishing, Real Estate & others includes Real Estate, Ownership of Dwelling & Professional services.
Source: Calculated by the author based on the data from the Department of Economics and Statistics, Kerala.

Areas under agricultural cultivation have continuously shrunk in Kerala. Except for rice, pulses, banana, turmeric, tapioca, and rubber, all other crops recorded a declining trend in the area under cultivation (State Planning Board, 2018). The cropping pattern in Kerala suggests that there has been a shift away from labor-intensive food crops to less labor-intensive cash crops, even though their products are exposed to international competition and price fluctuations as is frequently seen with products such as natural rubber, coffee, or pepper. The data available in the economic review indicate that the food crops comprising rice, tapioca, and pulses accounted for just 10.12 percent of the total cropped area in 2017-18 at the same time the cash crops such as cashew, rubber, pepper, coconut, cardamom, tea, and coffee constituted 61.6 percent with the major share being coconut and rubber (Table 2.14). Farm prices have generally been unfavorable for farmers which is also reflected in the declining share of overall agriculture in the district and state income.

The secondary sector in the district, as well as the state, presents an entirely different picture. Its share in the district economy in 2011-12 was 27.9 percent while marginally reduced to 26.4 percent in 2018-19. The state also registered a similar figure with a marginal increase from 27.3 percent to 28.1 percent in the later year (Table 2.13 and 2.14). A comparison between the district and state suggests that the secondary sector in Ernakulam district has declined compared to the overall secondary sector in Kerala. The decline can be attributed to the slowdown in construction as also the production of electricity, gas, and water supply. The economic contribution from the construction sector was 12.4 percent in 2011-12, which was reduced to 9.9 percent in 2018-19 (Table 2.13). As noted for the district, it can also be seen that the state also reported a reduction in the construction sector through its percentage share was slightly higher than that of the district. The electricity, gas and, water supply though with a low base of 3.6 percent also reduced to 1.3 percent during this period; compared to the corresponding state figures of 1.4 to 1.2 percent, the decline for the district was sharper (Table 2.13). The share of manufacturing however has shown a marginal increase in the district and the performance of the district was better as compared to the state as a whole. This is contrary to the pattern we observe for Kerala where generally an erosion of the overall secondary sector is hidden due to an increase in the construction sector. The data reveals that there has been a recent improvement in the industrial sector due to emphasis on modern industries in the state. Most of the traditional industries such as handicrafts, textile, cashew, and coir are declining due to lack of technology, rising costs of production, non-availability of adequate land for industrial purposes, labor movements, and rise in competition from the national and international market.

The share of the tertiary sector in Ernakulam's economy, on the other hand, has increased over the years. The data for 2018-19 shows this share to be 66.2 percent, an increase of 7.6 points since 2011-12 (Table 2.14). As noticed above, the static contribution of the secondary sector, covering manufacturing, construction, and electricity which stood at around 26 percent in the district saw a rising services sector dominated economy in recent years (Table 2.14). The growth of the tertiary sector however for Kerala as a whole was comparatively slower than that of the district. The highest growth within the district in the tertiary sector has been in the real estate and related services where a sharp rise by more than 11.7 percentage points is observed as against an increase of 4 percent points for the state. An overview of the 2004-05 to 2012-13 data for Kerala (see

appendix 2.4) suggest that the transport sector as well as financial services which include the banking and insurance sector had higher growth in the tertiary sector.

Trade, hotels, and restaurants, which include tourism, are also, is important sectors in the context of the overall income of Kerala. Though this sector increased slightly from 15.8percent to 17.4percent at the state level, its share in Ernakulam district has not improved; it was much lower at 13.1 percent in 2011-12 and 12.9 percent in 2018-19, indicating that the district administration needs to take concrete steps to grow this sector because it is critical to the district's development (Table 2.14). Overall, it can be seen that there is a sharp decline in the primary sector, insignificant changes in secondary sectors, and very higher growth in service-based industrial activities in the district.

2.6 Industrial Development in Ernakulam and Kerala

The industrial sector of Kerala is clearly in a state of stagnation or decline. During 1980-90 the industrial growth in Kerala was fairly high. The economic liberalization policy in India in the early nineties adversely affected the growth in traditional industries and other small-scale industries promoted by the public sector. It could not withstand the stiff market competition and was also not able to attract investment from the private sector (Kerala Industrial and Commercial Policy, 2018). The industrial sector in Kerala is also lopsided in structure. There is a serious dearth of capital goods industries. Traditional industries comprising coir-making, cashew-processing, handloom-weaving, rubber-processing, tea, and coffee-processing and handicrafts are the main employers. Technological stagnation, rising costs of production, non-availability of land for industrial purposes, labor militancy, and competition from the national market have jointly ensured that few modern industries have arisen in the state recently (Kerala Industrial and Commercial Policy, 2018). Changes in the industrial environment following the establishment of the WTO regime in the mid-1990s have affected Kerala adversely. Subsequently, bilateral trade agreements and comprehensive economic cooperation agreements with ASEAN countries led to price fluctuations of cash crops such as tea, rubber, or coconut that are the mainstay of the state’s agricultural economy, even though their net impact on the national economy has been positive (Kerala Industrial and Commercial Policy, 2018).

A large number of small-scale industrial and handloom units in Kerala are in the cooperative sector. The major sources of support for cooperatives are the “KSIDC (Kerala State Industrial

Development Corporation Ltd)", "KFC (Kerala Financial Corporation)", "KINFRA (Kerala Industrial Infrastructure Development Corporation)", "Kerala State Handloom Development", "KITCO (Kerala Industrial & Technical Agency Organization Limited)", "SIDCO (Small Industries Development Corporation)", "SISI (Small Industries Service Institute)" and "Techno Park". The multiplicity of supporting agencies sometimes may lead to duplication of objectives and activities also.

Being a state with a high population density and acute scarcity of land, Kerala cannot go in for land-intensive industrialization. Understandably, attempts are being made to develop high-tech industries requiring greater skills and less land and/or natural resources. There have been several FDI commitments in Kerala in the IT sector (software and hardware products) and textiles, but these faced strong competition under the WTO regime. Changing consumer tastes and cheaper varieties of substitute production have also contributed to industrial decline along with power shortage and fluctuations. Kerala has thus become one of the least attractive destinations for national or global industries.

Table 2.15 depicts some key characteristics of the organized industrial sector in Ernakulam as a percentage share to Kerala and also the share of Kerala to that of India. The share of factories in Ernakulam district to the overall all factories in Kerala was 16.2 percent in 2011-12 while the share has increased to 19.3 in 2017-18 and it is the highest among all districts in Kerala (Table 2.15). During this period the share of factories in Kerala to the total factories in India remained the same at 3.2 percent (Table 2.15). In terms of the share of workers to the total organized sector workers in Kerala, Ernakulam showed a sharp increase from 13.6 percent to 23 percent in 2017-18 (Table 2.15). The share in total emolument which constitutes the wage and other incentives in the district have also gone up from 28.1 percent in 2011-12 to 35.9 percent in 2017-18 (Table 2.15). However, the share of workers of Kerala to All India has reduced to 2 percent in 2017-18 and that also resulted in the declining share of wages and incentives in the overall national figure (Table 2.15). The share of fixed capital in Ernakulam with 51.3 percent in 2011-12 has increased to 68.3 percent in 2017-18 (Table 2.15). Kerala's contribution though improved marginally but remained minuscule to the national figure indicating that the capital-intensive industries are less in Kerala as compared to many other major states. The figures of value of output and the gross value added for the district as a share of Kerala in both periods clearly show that Ernakulam is the dominant district within the state in terms of organized industrial growth. The value of the output of 62.7

percent in 2017-18 for the district suggests that all other 13 districts put together share only 37.3 percent of the total industrial output in the state (Table 2.15). The share of gross value added also increased but in terms of contribution to the national GVA marginally indicating that the contribution of organized manufacturing in Kerala to the national industrial outputs are negligible. While the overall contribution of Kerala to India is significantly less, the district-wise analysis reveals that Ernakulam contributes the lion's share in the industrial outputs of the state. Considering the topography of the district in which the eastern part of the city is a hilly area with rural set-up and the western part is the city of Kochi, one can easily assume that such a higher figure for Ernakulam district can be attributed to the growth of modern industries in and around the Kochi city since last few years.

Table 2.15: Key industrial characteristics of Ernakulam and Kerala as percent share

	Ernakulam to Kerala		**Kerala to India**	
Characteristics	**2011-12**	**2017-18**	**2011-12**	**2017-18**
Number of Factories	16.2	19.3	3.2	3.2
Number of Workers	13.6	23.0	3.2	2.0
Total Emoluments	28.1	35.9	2.0	1.7
Fixed Capital	51.3	68.3	0.8	1.3
Value of Output	62.3	62.7	1.9	2.0
Gross Value Added	44.6	51.3	1.1	1.5

Source: Calculated from Annual Survey of Industries (ASI) Data.

Table 2.16: Value of output by factory and worker

Year	Value of Output per factory (Lakh Rs)			Value of Output per Worker (Lakh Rs.)		
	Ernakulam	Kerala	India	Ernakulam	Kerala	India
2011-12	6013.32	1587.07	2654.98	161.7	33.8	55.3
2017-18	7078.0	2138.40	3396.18	176.5	67.6	66.0

Source: Calculated from various Annual Survey of Industries (ASI) Data.

When we compare Ernakulam district's per factory and per worker value of output (VO) with that of Kerala, it can be seen that the industrial productivity of the district is much higher than the state as a whole. The overall figures for the state are even much less than that of the nation as a whole (Table 2.16). The value of output per factory of Ernakulam in 2011-12 is found to be 6013.32 lakhs rupees while it has increased to 7078 lakhs rupees in 2017-18 which is much higher than the overall industrial productivity of Kerala and India (Table 2.16). The industrial productivity in terms of the value of output per worker in Ernakulam is also found to be the highest among the districts in Kerala with figures of 161.7 lakhs and 176.5 lakhs rupees in 2011-12 and 2017-18

respectively which is more than two and a half times higher than the figures of Kerala and India for the later period (Table 2.16). The above figures suggest that an increased emphasis on modern industries would certainly increase the overall industrial productivity of the district. As noted earlier, the contribution of Kochi city in this growth trajectory is extremely important not only to the district but to the state as a whole.

2.7 Education, Health, Transport, and Energy Infrastructure

This section attempts to bring forth the availability of district-level infrastructure in education, health, transportation, and communication. For the all-round development of an area, all these components play an important role.

2.7.1 School Infrastructure

The increased share of tertiary sector workers and income suggests that education is closely linked with the overall development of Kerala. Ernakulam and the adjoining Thrissur have about 8 percent of each share of schools in Kerala. Malappuram and Kannur had the highest share of schools in both periods (Table 2.17). The rural-dominated area such as Idukki Wayanad and Kasaragod are among the district with the least share of schools in Kerala (Table 2.17). It is understandable since the location of the schools is closely associated with the population size of an area and accessibility to the people. The schools per lakh population for 2012-13 and 2016-17 is calculated by computing the number of schools per one lakh projected midyear population based on the annual exponential growth rate of population between 2001 and 2011.

The schools in Ernakulam and Thiruvananthapuram are among the least and this can be explained in terms of higher population size and population density in these districts. However, Malappuram with the highest population in Kerala is found to be much ahead of Ernakulam in terms of the number of schools per lakh population (Table 2.17). The schools per lakh population in some rural dominated districts observed to be higher and it can be explained in terms of less population compared to all other districts in Kerala. In terms of government and aided schools as a percent to total schools, most of the districts were found to be decreasing while Ernakulam and Thiruvananthapuram have maintained the same level across the periods (Table 2.17).

Table 2.17: Share of total schools and percent of government and aided schools in Kerala

	Share of Schools		Schools per Lakh Population		Percent Govt. & Aided Schools	
District/State	**2012-13**	**2016-17**	**2012-13**	**2016-17**	**2012-13**	**2016-17**
Kerala	**12627***	**12981***	**37.5**	**37.8**	**93.2**	**91.8**
Kasaragod	4.4	4.6	41.9	43.2	92.1	87.6
Kannur	10.2	10.1	50.8	50.5	96.0	95.3
Wayanad	2.3	2.4	35.4	36.6	95.9	93.2
Kozhikode	9.8	9.9	39.7	40.0	96.3	93.6
Malappuram	11.7	12.0	35.1	35.3	90.1	87.3
Palakkad	7.7	7.7	34.2	34.4	93.1	91.3
Thrissur	8.0	7.9	32.1	32.1	93.2	92.1
Ernakulam	**8.0**	**7.8**	**30.4**	**30.0**	**90.0**	**90.2**
Idukki	3.8	3.8	43.0	45.2	95.0	92.9
Kottayam	7.2	7.1	45.9	46.5	94.2	94.1
Alappuzha	6.0	5.9	35.8	36.1	94.8	94.4
Pathanamthitta	5.8	5.7	61.6	62.8	93.9	93.5
Kollam	7.3	7.3	35.1	35.8	93.4	91.1
Thiruvananthapuram	7.8	7.7	29.9	29.9	90.2	90.2

*Note: * is the total number of schools in Kerala.*
Source: Calculated based on data from Statistical Handbook 2017, Department of Economics and Statistics, Kerala.

2.7.2 Health Infrastructure

Kerala's health care in terms of the majority of parameters is much ahead of other states in the country. The State is far ahead in maintaining low infant mortality, low maternal mortality, and also higher life expectancy. The better performance in the vital parameters is mainly due to the public health care facilities in Kerala. Though there is a substantial increase in the private health infrastructure, it is unaffected by the public healthcare delivery system in the state. A district-wise availability of government hospitals, health centers (HC), and bed availability is presented in table 2.18. Ernakulam district has the second-highest share of government hospitals in Kerala after Thiruvananthapuram, the state capital (Table 2.18).

Alappuzha, Thrissur, and Kozhikode also have an 8 to 10 percent share in the hospitals (Table 2.18). It can be read from the figures that the more urbanized districts have a higher share in hospitals than other districts which are less urbanized. In terms of primary health centers and other types of small health facilities, Ernakulam has an almost 9 percent share of the total primary health care center facilities of the state (Table 2.18). Malappuram district is highest with a share of 10.14

percent while here again the rural dominated districts such as Kasaragod, Wayanad, Idukki, and Pathanamthitta have less share in health centers (Table 2.18). In terms of availability of beds, Ernakulam has an 11.27 percent share for hospital beds and 14.09 percent share of public health centers making it the second-highest share of bed availability after the state capital (Table 2.18).

Table 2.18: District wise health care facility in Kerala (2013)

District	Share in Health Care Facility			Share in Bed Availability			Share of Hospitals to total health facilities	Share of Hospital Beds to total beds
	Hospitals	HC and others	Total	Hospitals	HC and others	Total		
Kasaragod	3.15	4.59	4.45	2.82	3.20	2.95	7.0	63.9
Kannur	7.87	8.41	8.35	7.05	9.18	7.76	9.3	60.6
Wayanad	3.15	3.38	3.36	2.86	3.47	3.06	9.3	62.2
Kozhikode	8.66	7.02	7.18	8.95	4.09	7.33	12.0	81.4
Malappuram	5.51	10.14	9.68	5.77	8.93	6.83	5.6	56.4
Palakkad	7.09	9.10	8.90	5.62	8.80	6.68	7.9	56.1
Thrissur	8.66	9.27	9.21	9.19	9.93	9.44	9.3	64.9
Ernakulam	11.02	8.84	9.06	11.27	14.09	12.21	12.1	61.5
Idukki	3.94	5.11	5.00	2.64	4.73	3.34	7.8	52.8
Kottayam	6.30	6.59	6.56	5.99	8.33	6.77	9.5	59.0
Alappuzha	9.45	6.76	7.03	10.03	6.18	8.75	13.3	76.5
Pathanamthitta	5.51	4.94	5.00	5.45	4.73	5.21	10.9	69.7
Kollam	7.87	6.85	6.95	7.03	5.14	6.40	11.2	73.2
Thiruvananthapuram	11.81	9.01	9.29	15.33	9.20	13.29	12.6	76.9
Total	100.00	100.00	100.00	100.00	100.00	100.00	9.9	66.7

Source: Calculated based on the data from Health at a Glance, 2013 published by the Directorate of Health Services, Government of Kerala.

As a percent to the total health care facilities, the number of hospitals in Ernakulam is 12.1 percent while the highest is in the adjoining Alappuzha with 13.3 percent, followed by Kozhikode and Thiruvananthapuram with 12.0 and 12.6 percent hospitals respectively (Table 2.18). In terms of hospitals beds to overall beds in the healthcare institutions, Ernakulam has 61.5 percent of hospital beds, while Kozhikode, Alappuzha, and Thiruvananthapuram have a higher percentage of hospital beds than Ernakulam (Table 2.18). The lower percentage of hospital beds also indicates that the public health centers and clinics contribute 39.5 percent of bed availability in the Ernakulam district (Table 2.18).

2.7.3 Transportation Infrastructure

The transport infrastructure in Kerala is superior to many other states in India especially in terms of connectivity and frequency of state-owned transports. It has an important role in the development of any area interlinking the urban and rural areas. Kerala is a unique state with all four forms of transportation is common especially in coastal districts. It has four airports, all of

them are international airports, the neighboring Tamil Nadu is the only other state in India having these many international Airports. The reason for such a large number of international airports is due to the relatively higher movement of expatriate working population to the Gulf and other countries. The railway network in Ernakulam is well connected with the rest of the country. The lines in Ernakulam is branching out to four directions, "North towards Chennai/Bangalore/Delhi (via Palakkad) and Mumbai/Delhi (via Kozhikode), South towards Thiruvananthapuram (via Alappuzha-Kayamkulam), South-west towards Willingdon Island and Cochin Harbour Terminus (CHTS), and southeast towards Thiruvananthapuram (via Kottayam-Kayamkulam)".

The Kochi Metro managed by "Kochi Metro Rail Corporation (KMRC)" is expanding as a major metro rail network in India which is beneficial for the tourists and the daily commuters of Kochi city and surrounding area. At present the Aluva Petta line is operational and the work from Petta to Trippunithara is progressing. The detailed project report for phase 2 from "Jawaharlal Nehru Stadium" to Info Park, Kakkanad is already been submitted to the "Government of India". A third phase in the form of extension of Aluva to Angamaly is also under planning.

The waterways in Kerala are also a popular mode of commuting for domestic, tourism as well as freight movements. Ernakulam with a sizeable backwater area has a good network of water transport systems. Kerala also has 18 ports of which the only major port, the Kochi Port is in Ernakulam district. It handles the export and import of container cargo at its terminal at Willingdon Island. The "International Container Transshipment Terminal (ICTT)", India's largest transshipment terminal operating from Vallarpadam is a part of Kochi Port managed by Cochin Port Trust.

A new modern water transport project under KMRC is the "Kochi Water Metro (KWM)" which is the first project in India of its kind. It envisages developing 15 water routes connecting 10 islands of Kochi covering a distance of 78 Kilometers. It is intended to be a project with a modern boat riding experience with energy-efficient, environment friendly with highest safety features at a frequent riding frequency to attract more commuters and eventually it will help in easing the road congestion and thereby pollution.

As in any other state, the road is the most commonly used mode of transport in the state. The contribution of the transport sector in Kerala's State Domestic Product (SDP) is 6.61 percent in 2015-16 calculated at 2011-12 constant prices as against 5 percent for India to its GDP (Govt. of Kerala, 2016). Out of this, road transport alone contributes 5.81 percent for the state as against

3.26 for India. The road network in Kerala includes National Highways maintained by the "National Highway Authority of India (NHAI)", "State Highways and District Roads" maintained by "Public Work Department (PWD)" of Kerala State, and other rural, urban, and project roads maintained by the local governments and projects like "Jawahar Rozgar Yojana (JRY)". All these roads have a significant contribution to the overall economy of the state.

Ernakulam has 7.5 percent of the total state highways in the state. The district roads share higher than the state road (Table 2.19). The share of total PWD road in Ernakulam is close to 10 percent, which is the second-highest share in the state (Table 2.19). The highest share of PWD roads in the state is in Kottayam while Kasaragod, Wayanad, and Alappuzha have the least share of roads (Table 2.19).

Table 2.19: District wise share of PWD roads and length of road (in Km) per lakh population in Kerala: 2015-16

	Percent Share of PWD Roads			Length of Road per Lakh Population		
District/State	State HW	District	Total	State HW	District	Total
Kasaragod	3.3	4.8	4.6	10.5	97.5	108.0
Kannur	5.6	7.4	7.1	9.5	78.6	88.1
Wayanad	3.0	3.3	3.2	15.5	108.1	123.5
Kozhikode	8.7	7.6	7.7	11.9	65.4	77.3
Malappuram	8.6	8.4	8.4	8.6	53.2	61.8
Palakkad	5.7	7.1	6.9	8.5	67.0	75.5
Thrissur	8.6	6.2	6.5	11.7	53.1	64.8
Ernakulam	7.5	10.0	9.7	9.7	82.2	91.9
Idukki	23.0	6.8	9.0	90.7	169.8	260.5
Kottayam	9.4	11.1	10.9	20.5	153.8	174.3
Alappuzha	5.7	4.7	4.9	11.7	60.9	72.6
Pathanamthitta	3.9	6.5	6.1	14.4	150.7	165.2
Kollam	2.9	7.6	6.9	4.7	78.3	82.9
Thiruvananthapuram	4.2	8.7	8.0	5.4	71.4	76.8
Kerala	100.0	100.0	100.0	80.6	93.3	93.3

Source: Calculated based on the data from Infrastructure Statistics, 2015-16, Department of Economics and Statistics, Government of Kerala.

Table 2.20: Vehicles per land (in Km) and population (per 1000 people)

	Vehicles per Kms.		Vehicles per 1000 Population	
	Kerala	India	Kerala	India
2011-12	177.4	49.0	206.4	131.7
2012-13	202.2	55.0	235.2	150.7
2013-14	225.8	58.0	262.7	157.5
2014-15	248.3	64.0	288.8	173.5
2015-16	261.8	70.0	304.5	190.0

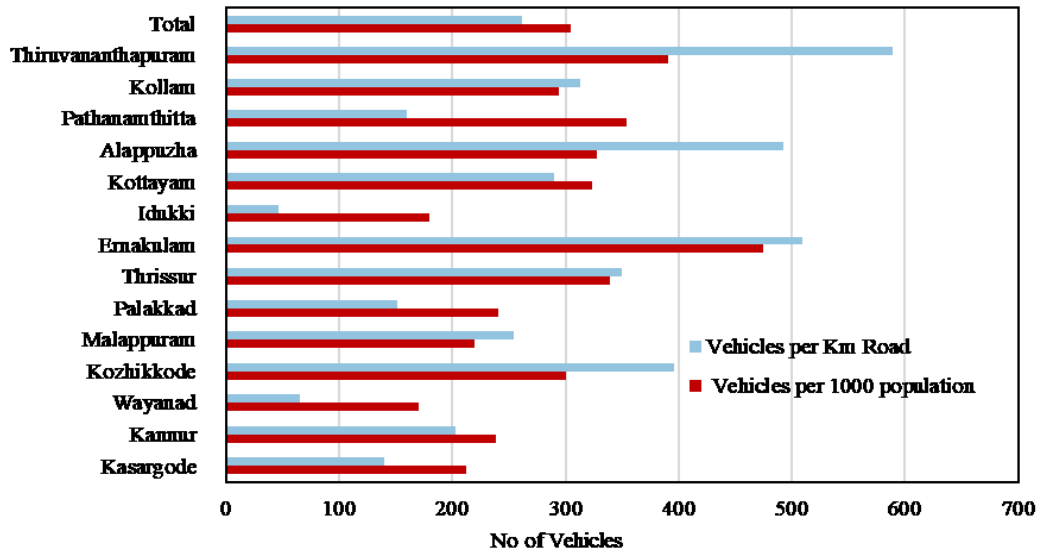
Source: Based on the data from Infrastructure Statistics, 2015-16, Department of Economics and Statistics, Kerala.

Though it appears, the share of state highways in Idukki is very high as compared to other districts of Kerala, in absolute terms, the length of districts road is much higher than that of the state highways making the overall share of PWD roads in Idukki less than that of Ernakulam and Kottayam (Table 2.19).

When the road length is calculated per lakh population, it can be seen that the places with the least population density have a higher length of roads. These are largely rural areas and topographically hilly areas and thus human settlements are comparatively at a higher distance than the plain areas. Therefore, the road length per lakh population is higher in these areas. In Ernakulam, the state highways as a ratio to the population are much less while the district road with 82.2 kilometers per lakh population is higher than many other urbanized districts in Kerala (Table 2.19).

Tables 2.20 illustrate that the vehicle density in Kerala is much higher than that of India. In Kerala, the vehicles per km have raised from 177 to 262 between 2011-12 to 2015-16 while the corresponding figures for All India were 49 percent in 2011-12 and 70 in 2015-16 (Table 2.20). This tells about the volume of vehicle penetration in Kerala. The vehicle density per 1000 population is also much higher in Kerala compared to all of India. In 2011-12 Kerala had a vehicle density of 206 while it is increased to 304 in 2015-16. During the same period, the vehicle density of India was as low as 132 and increased to 190 per 1000 population (Table 2.20).

Figure 2.5: Road length and population-wise number of vehicles in Kerala



Source: Based on the data from Infrastructure Statistics, 2015-16, Department of Economics and Statistics, Kerala.

A district-wise analysis of these indicators for 2015-16 reveals that the vehicles per kilometers and population in Ernakulam district were much higher than other districts of Kerala except for

Thiruvananthapuram for which the vehicles per km road was 590 as against 509 for Ernakulam district (Fig 2.5). The higher vehicle penetration in Thiruvananthapuram is understandable as it is the state capital and there is a considerable movement of public vehicles. It can also be noticed that the vehicle in terms of length of road and population is higher in more urbanized districts.

2.7.4 Energy Sector in Kerala

Energy is one of the major infrastructures that play a crucial role in socio-economic development, as it is an essential requirement for commercial, industrial, and residential purposes. A growing economy like Kerala needs to have stable and sustainable sources of energy supply as it plays important role in industrial production. The major source of power in Kerala is hydel and thermal power though a marginal production of solar and wind energy is also part of the sources of energy in Kerala. About 73 percent of the power generation in Kerala is from hydel power while 25 percent is from thermal power projects and the rest 2 percent is shared between wind and solar energy (Govt. of Kerala, 2016). The power generation activities are carried out mainly through "Kerala State Electricity Board Limited (KSEBL)", "Agency for Nonconventional Energy and Rural Technology (ANERT)", "Electrical Inspectorate", and "Energy Management Centre (EMC)".

2.8 Summary

The district of Ernakulam and the state of Kerala as a whole has a distinct urbanization pattern compared to the rest of the country characterized by its unique settlement pattern, communication, transport network, infrastructural amenities across rural and urban areas. Unlike other states in India, a balance in its resources and development can be seen throughout the state irrespective of rural or urban areas.

Variation in urban growth over time and across the district is very high in Kerala compared to other states in India. The analysis shows that it cannot be only explained in terms of dynamics of socio-economic development or its absence over time and space. A large part of such observance should be seen in terms of administrative decisions in classifying an area as urban especially for the state of Kerala where almost every rural areas have a large population size and also increased change in economic activities of the people in the last three decades due to better social and educational developmental characteristics of the state. The strongly decentralized system of

governance as per the mandate of the 74th constitution amendment also resulted in the overall improvement of the state irrespective of rural or urban areas.

The analysis brings out the importance of Ernakulam in the urban development process of Kerala. The percent urban population in Ernakulam was the highest among all districts in Kerala. However, the urban growth rate of the district during the last decade is observed to be much less than that of the overall urban growth rate of Kerala strengthening the argument that the contribution of new census towns to the incremental urban population in most of the other districts in Kerala was much higher than that of Ernakulam leading to believe that the urban growth of Kochi is not just dependant on increase in census towns. But, given the higher population-sized villages and changing nature of economic activities, it would be unsurprising if more settlements in Ernakulam and also the State be classified as towns in the subsequent census years. This will further lead to the expansion of Kochi city to the hinterlands. The steep urban growth without infrastructural support and provision of basic amenities may create deficiencies that would hinder sustainable urbanization.

Although the overall density of population is increasing over time, the number of persons per square kilometer in urban areas in Kerala has decreased between the last two decades, primarily due to the new Census towns which have large agricultural lands. A second contributory factor to low urban population density could be the massive investment in residential land and housing from overseas remittances, resulting in larger plot sizes for residential units.

The per capita income is important in the context of the development of a region. The analysis reveals that the per capita income continues to be highest in Ernakulam compared to the overall state and all India figures. The sectoral analysis of the income shows that the percent share of the tertiary sector has gone up for the district compared to the overall state while income from the primary sector has come down heavily and there is a marginal decline in the secondary sector. To revive the secondary sector attempts should be made to develop high-tech industries requiring greater skills and less land and/or natural resources as land-intensive industrialization is not suited for a state having a very high population density and acute scarcity of land. The higher per capita income for the district in recent times and the growth of tertiary sector especially in real estate, ownership of dwelling and professional services sector is important in the context of the economical and commercial importance of Kochi city as a potential growth engine to the state as a whole in coming years.

Similarly, the performance of other indicators such as the contribution of secondary and tertiary sector in terms of workforce, the industrial outputs in terms of the value of output was highest in Ernakulam compared to other districts in Kerala. The higher social development, rich cultural heritage, comparatively peaceful law, and order situation, and good transportation connectivity with other districts and neighboring states have made Ernakulam the best-ranked economies within the state. The overall effort of the district in comparison to the state in terms of industrial and infrastructural growth in recent years has been noteworthy. Much of these growths of Ernakulam district can be attributed due to the growth of Kochi as the major city in the region. A disaggregated analysis at the city level can further help in identifying and understanding the existing pattern within the Kochi city area and also will help in understanding and evaluating the future growth of the city.

Chapter 3: A Micro Assessment of Socio-Economic Structure of Kochi

3.1 Background

While the previous chapter gave a macro picture of the urban development process in Ernakulam district in a comparative framework that of Kerala and India, the present chapter is an attempt to analyze the key demographic, socio-economic, and infrastructural development that has shaped the urban development process in the planning areas of Kochi city comprising of the Municipal Corporation and the surrounding area. The chapter also presents a comparative picture of Kochi with other major Municipal Corporations in Kerala and neighboring states.

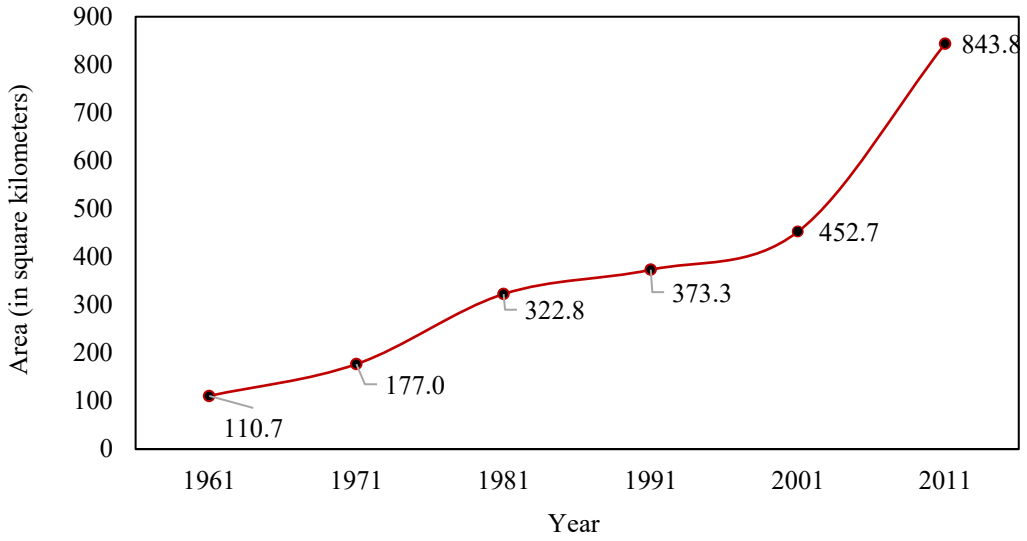
One thing, which emerged out from the previous chapter is the unique urbanization characteristics of the districts in Kerala that have a strong foundation built on health, educational, and transportation infrastructure along with effective decentralized governance compared to the rest of the country. As the settlement pattern and demographic characteristics in urban areas have a very distinct feature compared to the rest of the country (Sreekumar, 1990), it is imperative to evaluate the urban development process in Kochi from a micro perspective. Education coupled with low indigenous job opportunities has forced male outmigration to large cities of India and the Gulf countries in the seventies. This has not only changed the socio-economic character of Kerala but also had a tremendous impact on the land ownership, housing, health, and education of the people in the state in the later years (Zachariah et al., 2001). Education has also contributed to consistently shifting the workforce from the agriculture-oriented primary sector to the service-based tertiary sector especially in the last couple of decades. The manufacturing-based secondary sector had only a mediocre effect on the overall urbanization in Kerala.

3.2 The Areal Expansion of Kochi Urban Agglomeration (KUA)

Before attempting to the disaggregated urban characteristics of the Kochi city area that is included in the structural plan, it is important to understand the areal expansion of Kochi and surrounding area, which keeps on redefined in every decadal census. An analysis from agglomeration-wise data from the census reveals that in 1961 and 1971 the KUA had a total area of 110.7 sq. km and 177.0 sq. km respectively with the “Kochi Municipal Corporation” as the dominant unit in the area of

UA (Fig 3.1). Since then the area of agglomeration has expanded manifold. This increase is mainly due to the areal expansion by including more urban villages that satisfied the criteria of census definition from time to time.

Figure 3.1: Areal expansion of KUA



Source: Population tables, Census of India, 2011.

In 1981, the census has added a large number of villages that have attained the status of census towns due to the fulfillment of definitional criteria to the existing area taking the total area of KUA from 177.0 sq. km to 322.8 sq. km (Fig 3.1). It is, generally believed that the educational reforms contributed in a big way to shift the workforce from primary to the secondary and tertiary sector in areas around the cities. In 1991, the KUA has further expanded to 373.3 sq. km and in 2001 it increased to 452.7 sq. km (Fig 3.1). It is to be highlighted that as per the 2011 census, the KUA has an area of 843.8 sq. km, a steep increase of 391 sq. km (Fig 3.1). The almost two-fold rise in the area of the agglomeration from 2001 to 2011 may have left some confusion in the minds of researchers whether there are some flaws in the criteria used in defining the census towns in 2001. Nonetheless, the KUA with a total area of 843.8 sq. km and a population of 2.1 million is about 91 percent of the urban area and 95 percent of the urban population of the Ernakulam district (Fig 3.1 and Table 3.1).

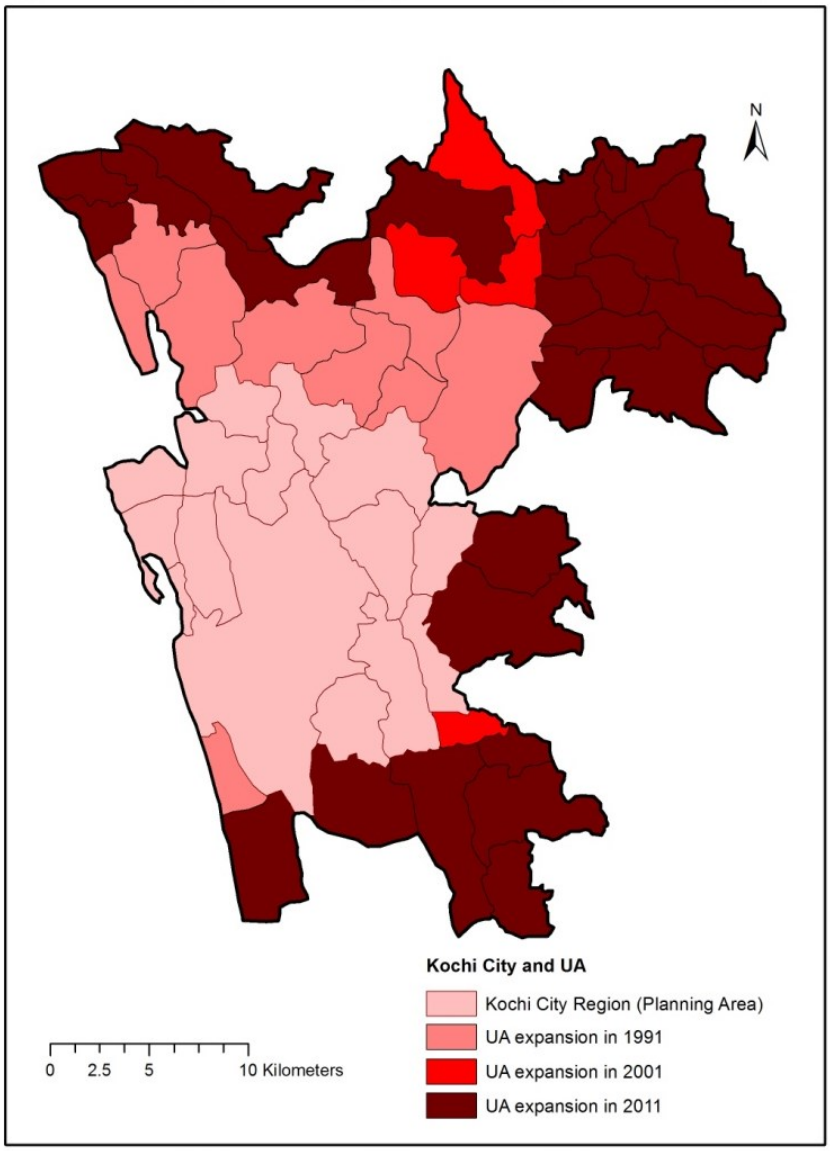
It is evident from the population density figure of 1991 (Table 3.1) that the KUA was more densely populated than the urban area of the district as a whole. This gap has reduced considerably in 2011 as more areas have become part of the agglomeration.

Table 3.1: Density of population and share of UA area

Year	Persons per Square Kilometer		Share of UA Area to Urban Area of Ernakulam
	Kochi UA	Ernakulam (Urban)	
1991	3056	2523	68.6
2001	2996	2785	85.3
2011	2512	2415	91.2

Source: Calculated from Town Directories, Census of India 1991, 2001, and 2011.

Map 3.1: Kochi City Region (KCR) and the Urban Agglomeration (UA) (1991 to 2011)

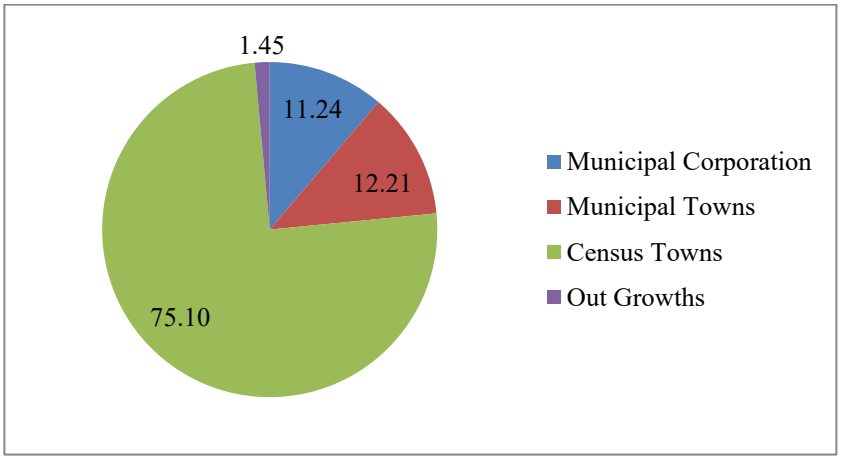


Source: Prepared based on the administrative map, census 2011

As per the 2011 census, the population density of urban Ernakulam was 2415 while that of the KUA is marginally higher with 2512 (Table 3.1). The areal expansion of the UA is contributing to

the decrease in population density in successive census years. The reason for such a decline in the population density can reasonably be argued in terms of the increase in census towns as noticed for many of the districts in Kerala explained in the previous chapter. It may also be highlighted that as per the 2011 Census, Ernakulam district has a total of 47 census towns of which 45 are within the UA. The maximum increase in the census town is in the areas surrounded by two municipalities of Angamali and Perumbavoor (both are close to the Kochi International Airport). Map 3.1 depicts the planning area of Kochi comprises the municipal corporation, adjoining municipalities, and census town, the expanded agglomeration area in 1991, 2001, and 2011. In terms of area, the KUA constitutes 91.2 percent of the total urban land in Ernakulam an increase of over 22 percent compared to the 1991 census (Table 3.1). Though the share of UA area in 2001 was 85.3 percent, the increase is partly attributed to the decrease in the overall urban area of the district because of the de-classification of some areas in the district. For example, *Koothattukulam and Piravom* in 1991 are classified as a municipality in 1991 but had a rural status in 2001. The census 2011 data reveals that more than 75 percent of the area in the UA is occupied by census towns while 25 percent is shared by the Kochi Municipal Corporation, Six municipalities, and 2 outgrowths (Fig 3.2).

Figure 3.2: Area-wise Share of Local Bodies in Kochi UA, 2011



Source: Town directory, Census of India, 2011.

A field visit in and around the study region also found that, aside from the four municipalities, the majority of these locations outside the planning area have urban village features with distinct settlement patterns. Most of the houses built in this area are cottages, bungalows, or farmhouses surrounded by a large parcel of land. As noted in the previous chapter the people in Kerala irrespective of rural or urban areas invest in lands and palatial houses. While some scholars argued

that the right to build houses is the individual's choice, it is a matter of social concern as more impervious surfaces add to more environmental problems (Zachariah et al., 2001). The classification of areas as 'urban' in such unique settlements is mainly characterized by the non-agricultural economic activity as noted earlier. The clustered built-up outside the structural plan area in Kochi are mostly found in areas around important transportation nodes and infrastructural locations as can be observed in other parts of Kerala.

The present study, therefore, focuses on the area included in the Structural Plan, 2001 prepared and monitored by the town and country planning department, Ernakulam, Kerala which is about 275 square kilometers with a population of 0.95 million as per the 1991 census. In subsequent census years, the population in the study area has increased 1.04 and 1.09 million respectively. The Kochi Corporation and the surrounding area that are part of "Kochi City Region (KCR)" together is 33 percent of the area of the "Kochi Urban Agglomeration (KUA)". Though it constitutes only one-third of the KUA area, in terms of the population more than 50 percent of people are living in Kochi city. The KCR in the subsequent section and also in the larger context of the theses is referred to as Kochi and it consists of "Kochi Municipal Corporation", the adjoining municipalities, census towns, and the intervening villages. The city-level census data for the 1991, 2001, and 2011 census years presented in the subsequent section is compared temporarily to understand the pattern and growth trends in different parts of Kochi.

3.2.1 Constituent Towns of Kochi City Region

The status of some of the constituent areas included in the present analysis has been changed in subsequent census years. The statutory status of Kochi corporation, Kalamassery, and Thrippunithura Municipality remained the same throughout the census years. Kakkanad was an outgrowth of Kochi corporation both in 1991 and 2001 and then elevated to the status of a census town in 2011. Vazhakkala, Eloor, Mulavukadu, Cheranallur, Maradu, and Thiruvankulam were census towns in all the last three census years. Kadamakkudy classified as a village in 1991 upgraded to the status of census town in 2001 and 2011. Njarackal and Elamkunnapuzha were classified as villages in 1991 and 2001 but elevated to census towns in the 2011 census. It is to be noted that in November 2010 Vazhakkala and Kakkanad census towns have merged to become Thrikkakkara Municipality. Similarly, Eloor and Maradu have also become independent statutory towns. This change in the classification of town may be reflected in the upcoming census of 2021. Although as per the 2011 census there are 15 town constituents in Kochi with "Kochi Municipal

Corporation (KMC)", two municipalities of Kalamassery and Thrippunithura, and 12 census towns, for temporal comparability of data across the census years from 1981 to 2011, data for 5 constituents are merged. Thus, the figure of Eloor includes Varappuzha, Thrikkakara includes Vazhakkala and Kakkanad census towns, similarly, Elamkunnapuzha includes Puthuvype census town. However, housing amenities data which were available only for the 2011 census is analyzed across all 15 town constituents.

3.2.2 Area and Population of Constituent Towns

As per the structural plan of Kochi 2001, the KCR has a total of 275.85 square kilometers (sq. km) of the area with the municipal corporation of Kochi constituting 94.88 sq. km area (Appendix 3.1). The total population of the region is increased from 0.85 million in 1981 to 1.09 million in 2011. The corresponding figures for the Kochi Municipal Corporation alone were 0.51 and 0.60 million. It can be observed from the population figures that the major contribution to the increase in population in the region as a whole is due to the increase in the population of satellite towns and some of the adjoining census towns (Appendix 3.1).

3.3 Demographic and Socio-Economic Characteristics of Kochi

3.3.1 Density of Population

It can be seen that the population density in the central region over the decades has increased consistently. The Population density in Kochi corporation area had substantially increased both in 1991 and 2001 with an addition of over 400 people per sq. km each respectively. However, the increase in 2011 over 2001 was only marginal (Table 3.2). It can be argued that the population has redistributed to other urban centers because of the presence of IT parks and other industries established outside the corporation area. In addition, many vertical residential expansions also have taken place outside the corporation area.

The figures of Thrippunithura, Kalamassery, Thrikkakara, and Maradu with a significant increase in population density in 2011 substantiate the claim (Table 3.2). Both Njarackal and Elamkunnapuzha over the years have reported a higher population density over the decades (Table 3.2). Though these come under the coastal belt with a low-lying area, the location of the international container terminal, major roads, and other transport linkages with the city center contributed to the area with a higher population density.

Table 3.2: Density of population in Kochi (1981-2011)

S. No	Constituent local body	Persons (per Sq. Km)			
		1981	1991	2001	2011
1	Kochi (M Corp.)	5409	5811	6277	6345
2	Eloor	2393	2595	2488	2652
3	Thrippunithura	2335	2733	3204	3713
4	Kalamassery	1621	2013	2338	2631
5	Thrikkakara	1395	1863	2388	2816
6	Mulavukadu	1110	1158	1185	1133
7	Maradu	2328	2834	3321	3620
8	Njarackal	2520	2672	2810	2763
9	Elamkunnapuzha	3766	4106	4336	4349
10	Cheranallur	1736	2021	2485	2889
11	Thiruvankulam	1479	1755	2070	2208
12	Kadamakkudy	1061	1136	1226	1262
	Kochi	**3099**	**3435**	**3775**	**3948**

Source: Calculated from district census handbooks of different census years.

However, the other low-lying areas like Mulavukadu and Kadamakkudy have not shown much improvement in terms of population density in any of the census years (Table 3.2). The population density of Mulavukadu which was 1158 persons per sq. km in 1991 increased marginally to 1185 in 2001 and then decreased to 1133 in 2011 (Table 3.2). The low base in the number of persons per unit area both in Mulavukadu and Kadamakkudy throughout the three census years when compared to other regions can be attributed to the fact that the majority of the area is uninhabited with wetland and mangroves. Another steady increase in population density is observed in Cheranallur with a population density of 1736 has consistently increased to 2889 in 2011 (Table 3.2).

3.3.2 Growth Rate of Population

The population growth of KMC and the surrounding area is depicted in Table 3.3. The rate of growth of population in the entire city area was sluggish in 1991-2001 when compared with 1981-91 except for two or three locations (Table 3.3). The percentage increase in population in the corporation area between 1981-91 and 1991-2001 was 7.4 and 8.0 percent respectively with a marginal increase over the previous decade (Table 3.3). However, the growth in the subsequent census year of 2001-2011 has gone down significantly (Table 3.3). The population growth in two

of the constituent area Mulavukadu and Njarackal has reduced in 1991-01 and has observed a negative growth in 2001-11 (Table 3.3). There can be several reasons for the decline in growth rate such as low fertility rate, distress migration from city to rural areas, or there may be reasons related to insufficient income to have permanent settlement in the region (Goswami et al., 2015).

Table 3.3: Percentage growth rate of population in Kochi (1981-91 to 2001-11)

S. No	Constituent local body	1981-1991	1991-2001	2001-2011
1	Kochi (M Corp.)	7.4	8.0	1.1
2	Eloor	8.5	-4.1	6.6
3	Thrippunithura	17.0	17.2	15.9
4	Kalamassery	24.2	16.1	12.6
5	Thrikkakara	33.5	28.1	17.9
6	Mulavukadu	4.3	2.3	-4.4
7	Maradu	21.7	17.2	9.0
8	Njarackal	6.0	5.2	-1.7
9	Elamkunnapuzha	9.0	5.6	0.3
10	Cheranallur	16.5	22.9	16.3
11	Thiruvankulam	18.7	18.0	6.6
12	Kadamakkudy	7.1	7.9	3.0
	Kochi	**10.8**	**9.9**	**4.6**

Source: Calculated from Primary Census Abstract, Census of India, 1981-2011.

The only major gain in population is recorded in Cheranallur where the population growth in 1981-91 was 16.5 percent and it is increased to 23 percent in 1991-01 (Table 3.3). Though the growth has shown a decline to 16.3 in the last census decade, it is still one of the areas with a higher population growth compared to many other regions of the city (Table 3.3). The reason for such higher growth in Cheranallur may be due to its proximity with the city center, the commercial and industrial towns of Edapally Eloor and Kalamassery (Table 3.3). Thiruvankulam rural area which is adjoining the Thrippunithura area also had shown a much higher growth in the initial periods before it slowed down to 6.6 percent in 2001-11 (Table 3.3). It can be analyzed from the data that the population growth in low-lying areas such as Njarackal, Elamkunnapuzha, and Kadamakkudy that have more wetlands, aquaculture, and agricultural lands the growth rate in population has considerably gone down. Since these areas cannot be developed into high-rise residential or commercial centers owing to environmental clearance due to their proximity with water bodies,

real estate growth in these areas are a distant possibility. This along with fertility decline and other reasons cited above will ensure that the growth of these areas will be slower than the rest of the place in the city area. Overall it can be said that the higher growth rate of population in the Kochi city area between 1981-91 and 1991-01 was due to the higher rate of growth in Thrippunithura, Thiruvankulam, Cheranallur, Kalamassery, Thrikkakara, and Maraud areas.

It can be therefore summed up that the low growth rate in the population of the city in recent decades to very low-level fertility rate pan Kerala compared to the rest of the country (P. S. Nair, 2010). There is a likely chance that the population growth of the city in the coming decades also be in a declining trend owing to many reasons. The transportation infrastructure of the city is much better than the many of the cities of India and therefore a large number of people stay back in their respective place of residence outside the city and prefer to commute daily. Such a decision is based on a couple of other social reasons. Some people who work in the city want to commute back to their place of residence to stay closer to their relatives or others may prefer the rural setup as it is less polluted and economically viable than the city life. There are kinds of literature that substantiate this claim since a large number of people staying outside the cities commute every day for work and work-related purposes (Mohanan, 2008)(Chandrasekhar, 2011). Some may argue that the preference for daily commutation is linked to insufficient income to have a permanent settlement in the city (George, 2016; Goswami et al., 2015). It is also important to note that all major cities in the state are in a linear path along the coastal line and all of them are conveniently distanced so that people can choose the nearest city for work or other purposes. Although the commuting population and other floating populations are not counted as part of the city population, it has a bearing on the existing urban infrastructure development of the city.

3.3.3 Sex Ratio

The sex ratio is a positive indicator that symbolizes gender equality. The continuous increase in the female sex ratio ensured that Kerala is women-dominated compared to most of the other states in the country. A close look at the city-level sex ratio indicates that the trend is similar to that of the state with a higher female population than its male counterparts in the city. While the increase in later years can be explained in terms of better health, high literacy rate, and a better standard of living among women, which is important for the generational progress of the people.

Table 3.4: Sex ratio in Kochi city

S. No	Constituent local body	1981	1991	2001	2011
1	Kochi (M Corp.)	987	992	1021	1028
2	Eloor	954	919	1002	1027
3	Thrippunithura	1016	1020	1032	1046
4	Kalamassery	920	956	977	1011
5	Thrikkakara	993	988	1019	1032
6	Mulavukadu	1009	1026	1050	1053
7	Maradu	1010	1001	1020	1016
8	Njarackal	1054	1054	1078	1058
9	Elamkunnapuzha	1021	1032	1057	1034
10	Cheranallur	1000	1018	1014	1018
11	Thiruvankulam	994	1004	1016	1035
12	Kadamakkudy	995	996	1021	991
	Kochi	**988**	**992**	**1021**	**1029**

Source: Calculated from Primary Census Abstract, Census of India, 1981-2011.

It may be noted that in 1981 the areas such as Mulavukadu, Njarackal, and Elamkunnapuzha had a better female sex ratio compared to the other urban regions in the city area (Table 3.4). Similarly, all the city constituent parts have increased their female ratio in the subsequent years (Table 3.4). The city has also benefited from the reforms in the education and health sector in Kerala which has contributed to higher female life expectancy resulting in a higher sex ratio. There is a high correlation between female literacy and sex ratio in the state indicates that education has played a crucial role in discouraging female feticide and also positively contributed to women empowerment which has a bearing on the generational progress of humanity.

3.3.4 Literacy Rate

The literacy rate reflects the level of basic education in an area and it is considered as a key indicator for the socio-economic progress of a region. The literacy rate of KMC and the surrounding area suggest that the improvement in literacy has taken momentum after the 1981 census.

The figures for all the city constituents taken together reported a literacy rate of about 80 percent in 1981 and has increased close to 95 percent in 1991 (Table 3.5). This has further increased in the subsequent census years making the city literacy rate 97.1 percent in 2011. The disaggregated figures of the 1981 census year suggest that the city had a comparatively lower level of literacy except for the industrial town of Eloor. Thrikkakkara in the eastern part of the city, again a rural area in 1981 had the lowest level of literacy with 69.6 percent. It may be noted that these places

were most agricultural areas before the 1991 census (Table 3.6). Subsequently, in the next ten years the literacy level of Thrikkakkara has increased to over 90 percent, i.e. an increase of about 21 percent (Table 3.5). An overview of the literacy rate in Kerala with that of India indicates that post-independence the gap between female literacy and overall literacy in Kerala has reduced considerably compared to the nation that eventually ensured higher literacy of the people in subsequent years.

Table 3.5: Literacy rate of Kochi City

S. No	Constituent local body	1981	1991	2001	2011
1	Kochi (M Corp.)	79.6	95.1	95.5	97.3
2	Eloor	91.6	93.6	94.7	96.7
3	Thrippunithura	80.5	94.3	96.0	97.7
4	Kalamassery	73.8	91.1	93.2	95.9
5	Thrikkakara	69.6	90.4	92.5	95.8
6	Mulavukadu	80.6	95.2	95.7	97.9
7	Maradu	77.1	95.1	95.2	97.2
8	Njarackal	79.7	95.2	94.8	97.5
9	Elamkunnapuzha	80.2	94.3	94.3	97.0
10	Cheranallur	79.4	95.1	95.4	97.5
11	Thiruvankulam	79.8	94.3	95.4	97.2
12	Kadamakkudy	80.6	95.8	94.3	97.2
	Kochi	**79.5**	**94.4**	**95.1**	**97.1**

Source: Calculated from Primary Census Abstract, Census of India, 1981-2011.

3.3.5 Workforce Transition

The workforce in the agriculture sector in Kerala has shown a decreasing trend in the past three decades. Among the crops, the sharpest decline was in paddy cultivation. The rice cultivation has been pushed to third position way behind rubber and coconut. The figures of the "Directorate of Economics and Statistics", Kerala suggest that area under rice cultivation has fallen in every district of Kerala during the period 1996-97 to 2012-13. Among all the districts Ernakulam reported the sharpest in paddy cultivation with a decline of 93 percent during this period (Table 3.6). In Kerala's context, the reduction in agriculture can be linked to the increased educational reforms in the last three decades and thereby people's participation in non-agricultural activities leading to a rural-urban transformation. To substantiate this trend in a micro setup, the census data of main cultivators and agricultural workers are combined and expressed as a percentage of total main workers for each of the constituents of the study area and presented in table 3.6.

Table 3.6: Percentage of agriculture laborers and cultivators

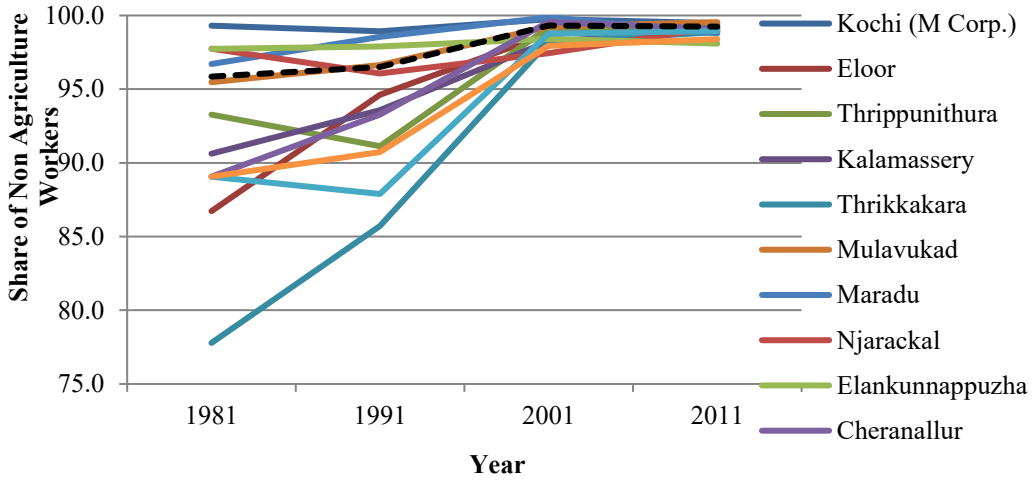
S. No	Constituent local body	1981	1991	2001	2011
1	Kochi (M Corp.)	0.7	1.1	0.2	0.5
2	Eloor	13.3	5.4	1.2	0.9
3	Thrippunithura	6.7	8.9	0.8	0.7
4	Kalamassery	9.4	6.4	1.8	1.1
5	Thrikkakara	22.2	14.3	1.8	1.1
6	Mulavukadu	4.5	3.4	0.7	0.5
7	Maradu	3.3	1.5	0.1	1.2
8	Njarackal	2.3	3.9	2.6	0.8
9	Elamkunnapuzha	2.3	2.1	1.6	1.9
10	Cheranallur	10.8	6.7	0.4	0.9
11	Thiruvankulam	10.9	12.1	1.2	1.1
12	Kadamakkudy	10.7	9.3	2.1	1.6
	Kochi Central City	**4.1**	**3.5**	**0.7**	**0.7**

Source: Primary Census Abstract, different census years.

The overall share of the agricultural sector in the study area has decreased from 4.1 percent in 1981 to as low as 0.7 percent in 2011 (Table 3.6). The areas where the share of the agriculture sector has considerably reduced are Eloor, Kalamassery, and Thrikkakara. This can also be understood in the context of the pace of urbanization in the area. The decline in percentage share in workers of the agriculture sector can be argued in the context of the increased pace of urban land transformation that took place during the 1991-2001 periods especially in Thrikkakara and other urban constituents in the eastern part of the central city. It can be seen that the share in the agriculture sector in 1981 and 1991 had ups and down in many constituents of the city. However, both in 2001 and 2011 the share has reduced more consistently (Table 3.6). Thrippunithura and the adjoining census town of Thiruvankulam recorded an increased share of agricultural workers in 1991 over the previous period but sharply declined its share in 2001 and 2011. The decline in the share of Cheranallur and Kadamakkudy which reported more than twice the share of the city region both in 1981 and 1991 also fell sharply in subsequent census years. The pattern of growth in Kochi clearly shows a transition from agriculture activities in 1981 and 1991 to a convergence in non-agriculture activity in 2001 and 2011 (Fig 3.3). As per the latest census, all constituent of the city shows over 98 percent of the total main workers involved in non-agricultural activities (Appendix 3.2). One of the reasons for the higher growth in non-agricultural activity in Thrikkakara can be attributed to the government policy intervention in the setting-up of Info Park, Cochin Special Economic Zone, the KINFRA, and other industrial and technology parks. As a

result of this, it can be argued that the land demand in the area has increased manifolds and the real estate developers are also cashing in on the high demand for the land here.

Figure 3.3: Convergence to non-agriculture economic activity



3.4 Financial Institutions

The banking sector plays an important role in the financial system and economy of a city. The major role of public and private commercial banks is to provide financial services to the general public, commercial establishments, and industrial units ensuring social stability and sustainable growth of the economy. The number of banks per ten thousand people in Table 3.7 shows that in 1991 and 2001 the banks were concentrated mainly in the corporation and municipal areas.

Table 3.7: Number of Banks (per 10,000 people)

S. No	Area	1991	2001	2011
1	Kochi (M Corp)	3.0	3.7	5.0
2	Eloor (M)	1.2	1.6	1.9
3	Thrippunithura (M)	2.2	1.7	3.0
4	Kalamassery (M)	1.3	1.4	2.0
5	Thrikkakkara (M)	0.2	0.3	3.5
6	Mulavukadu (CT)	0.4	0.9	1.8
7	Maradu (CT)	0.6	0.5	1.6
8	Njarackal	0.0	0.0	3.8
9	Elamkunnapuzha	0.0	0.0	1.4
10	Cheranallur (CT)	1.4	1.5	2.6
11	Thiruvankulam (CT)	1.6	1.4	3.0
12	Kadamakkudy	0.0	0.0	0.6
	Kochi City	**2.1**	**2.5**	**3.8**

Source: Calculated from District Census Handbook for various census years.

The increase of banks in other areas is an indication of more economic activities spreading to other areas. The number of banks per ten thousand populations in Kochi city has increased from 2.1 in 1991 to 3.8 in 2011. This increase can be mainly attributed to the increase in Kochi Municipal Corporation, Thrippunithura, Thrikkakkara, Njarackal, and Thiruvankulam. The least number of banks per ten thousand populations were found in Kadamakkudy, Elamkunnapuzha, Maradu, Mulavukadu, and Eloor area.

3.5 Transport Infrastructure

At the beginning of the 19th century, the British rulers developed Kochi as one of the most important ports with large volumes of external trade. They have introduced steamships between the East and West primarily for trade (Ibrahim, 1978). To exploit the rich commercial wealth of the area around Kochi, they have started a railway connecting the hinterland with the port. In the early nineties, the local rulers promoted cultivation and boosted agricultural production. This along with the growth of schools, hospitals, and also labor mobility necessitated new transportation facilities (Ibrahim, 1978).

Kochi has a network of roads with three national highways connecting the city with other parts of the country. National Highway, NH-544 (*old number* NH 47) connects Kochi city with Salem in Tamil Nadu. NH-66 (erstwhile NH 17 and part of NH47) which connects Kochi with Mumbai and Kanyakumari passes through major towns in the Western Ghats. Similarly, NH 85 (erstwhile NH 49) connects Kochi with Rameswaram through various hill stations. "Cochin International Airport Limited (CIAL)" located at Nedumbassery in the northeast of Kochi is the largest international airport in Kerala in terms of both passengers traffic and flights. Kochi is well connected to major urban centers in the state as well as other places in the country through railway lines. The roads, waterways, railways, and the recently introduced intra-city Metro services are the prominent travel mode in Kochi city. It has a good network of inland waterway systems consisting of backwaters, canals, and lagoons. Waterways are mainly used by tourists and a section of people staying or working in areas close to natural water bodies where there is a weak adequate alternate transportation system. All these modes are considered to be the influential drivers of urban growth in the city since historically transportation nodes-based development is prominent in Kerala. Along with the city, the urbanization of nearby villages also accentuated the development of road transport that took place towards the end of the nineteen seventies. Almost every village in Kerala

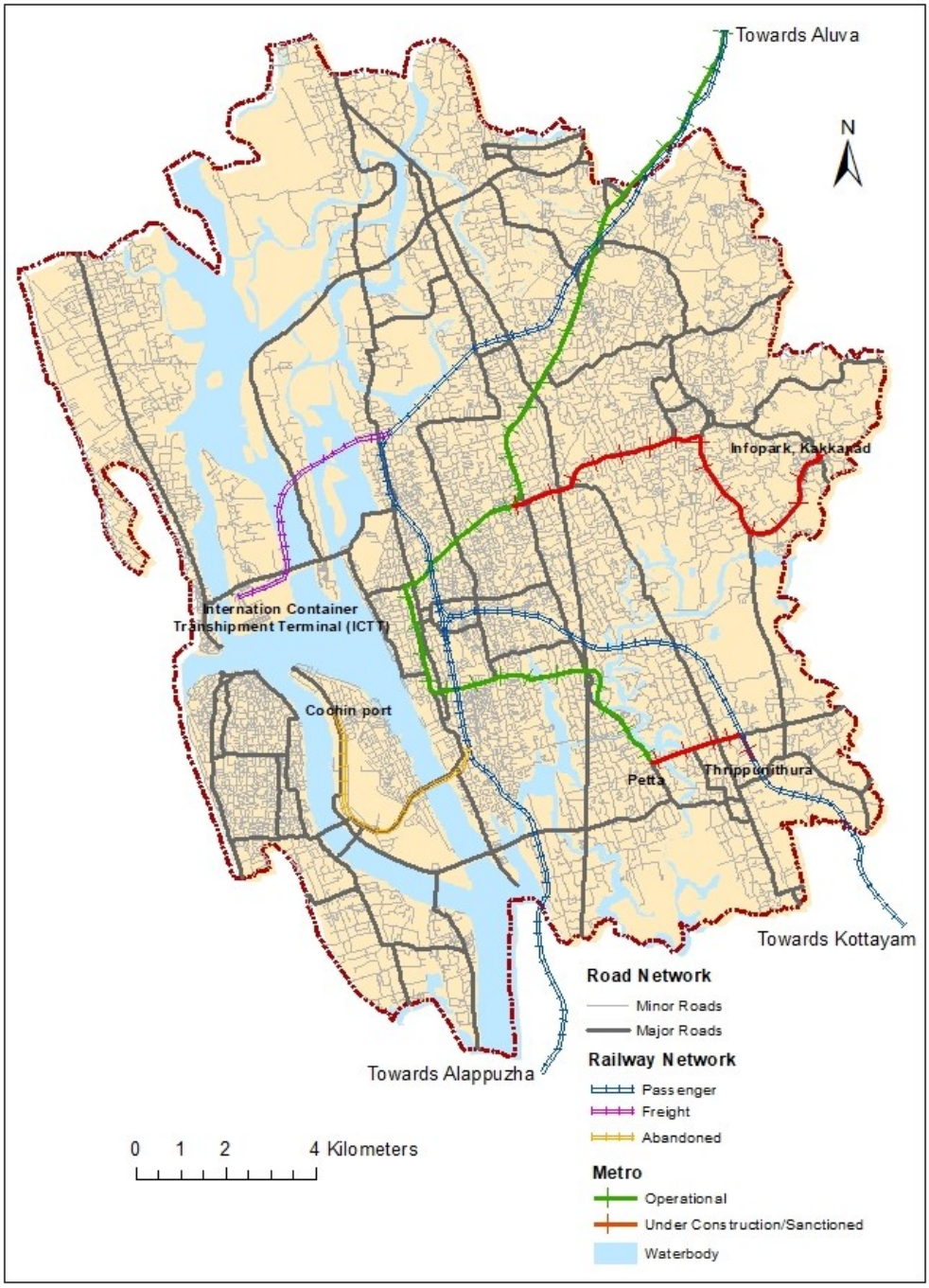
is linked by a motorable road. This has tremendously helped people with opportunities for commuting to work for non-agricultural activities from villages to towns (Ramachandran, 1997). It is estimated that over 86 percent of passengers and 65 percent of freight movements are through the roads (Appendix 3.3). The quantitative density of roads which is estimated as the road length per sq. km of area is highest in India with 1.7 kilometers per sq. km area which is substantially higher than other countries in the world and terms of population there are 4.63 km roads per 1000 people (Ministry of Road Transport and Highways (GOI), 2016). (Basic Road Statistics of India 2013-14 and 2014-15). Since the middle of the nineties, there is a cohesive effort on the part of the government to increase the road network in India keeping given the growth in the economy. As of 2009-10, the contribution of roads in the GDP is about 4.7 percent compared to the railway which is about 1 percent.

As per the 2011 census, the quantitative density of pucca roads in Kochi city is 6.45 sq. km. per sq. km land area (Table 3.8). As expected, the Kochi Corporation has the highest density of 11.46 km. per sq. km land among the constituent area (Table 3.8). The southern municipal town of Maradu also has a significant road density of 8.1 km per sq. km (Table 3.8). The more urbanized Thrippunithura and Thrikkakara have over 6 km. of road per unit land. Mulavukadu, Njarackal, and Kadamakkudy were at the bottom (Table 3.8).

The figures suggest that the eastern and southern part has a better road network in the city region (Table 3.8). In terms of density per 1000 population, the road network in Kochi is found to be significantly less compared with the national figure. The central city has 1.8 km of road per every 1000 people (Table 3.8). As pointed out earlier the eastern and southern part of the city has higher road density compared with the other parts of the city. The road density pattern shows that the urban growth potential in areas with a better road network is very high (Table 3.8).

Kochi Rail Metro is an intra-city rail transport system with innovative design encompassing people, nature, and sustainable development. At present the metro rail is operating from Aluva in the North to Petta in the South which will soon be extended to Thrippunithura as the construction work is in full swing. The initial work of phase II from Jawaharlal Nehru Stadium, Kaloor to Info Park, Kakkanad is already begun. Phase III connecting the satellite towns of Aluva and Angamali is also under planning. It is expected that the Metro transport system will considerably ease the existing vehicle pressure on the road and will eventually contribute to a better city commutation experience.

Map 3.2: Roads, Railway and Metro Network in Kochi City



Source: OSM and Google Earth

Table 3.8: Pucca roads in Kochi

S. No.	Area	Kms per Sq. Km			Kms per 1000 people
		1991	2001	2011	2011
1	**Kochi (M Corp.)**	12.8	11.3	11.46	1.8
2	Eloor (M)	1.37	1.87	3.10	1.2
3	Thrippunithura (M)	5.06	6.31	6.31	1.7
4	Kalamassery (M)	4.07	3.33	3.33	1.3
5	Thrikkakara (M)	1.46	1.77	6.01	2.1
6	Mulavukadu (CT)	0.21	0.31	1.09	1.0
7	Maradu (CT)	7.69	7.69	8.10	2.2
8	Njarackal*	-	-	1.86	0.7
9	Elamkunnapuzha*	-	-	3.34	0.8
10	Cheranallur (CT)	0.76	1.13	2.27	0.8
11	Thiruvankulam (CT)	1.14	1.53	2.86	1.3
12	Kadamakkudy*	-	1.16	1.55	1.2
	Kochi	**6.51**	**7.59**	**6.45**	**1.8**

Note: Figures are Njarackal and Elamkunnapuzha for 1991 and 2001 were not available as these were classified as villages in these census years. Similarly, Kadamakkudy in 1991 was classified as a village, hence figures are not available

Source: Calculated from District Census Handbook for various census years.

Inland water transport was a major freight and passenger transport system in Kochi. Because of the lack of timely technological up-gradation and investment, it has declined over time. To reduce the pollution and decongest the city the "Kochi Metro Rail Limited (KMRL)" has planned a Water Metro project with financial assistance from Germany. Though Kochi has a total length of over 1100 km. of waterways available, only 40 Km is navigable for motorable boats as the "Inland Waterways Authority of India (IWAI)" regulates a minimum depth of 2 meters as mandatory for the operation (https://kochimetro.org/water-transport).

3.6 A Micro Assessment of Commercial and Industrial Establishments in the city

Urban expansion of cities is closely linked with the pattern of the commercial and industrial sectors. The non-agricultural sector not only plays a pivotal role in the development of an area but also contributes to the economy of the state and nation as a whole. It is therefore important to have a holistic assessment of the status of existing commercial and industrial establishments in a micro perspective to understand the prospects for growth of Kochi. In this context, this chapter attempted to analyze the structure of major commercial and manufacturing establishments available in KMC and its surrounding areas using the sixth economic census (2013-14).

Unlike many other cities in India, the cities in Kerala do not have a strong industrial foundation. The GSDP data from 2011-12 to 2018-19 does not show any significant growth in the income from the secondary sector. This chapter aims to highlight some key economic characteristics in KMC and the adjoining constituent towns and their importance in the urban development of Kochi. Thus, the objective of this chapter is to highlight the existing status of commercial and industrial establishments at a disaggregated level and to identify key sectors and areas which can be economic growth-oriented.

The change in the demographic and socio-economic character of the city especially in the last few decades is believed to have changed the economic structure of the city. In this context, it is also interesting to analyze the pattern of establishments in the city to understand the economic prospects of the city core and periphery.

3.6.1 Structural characteristics of establishments in Kochi

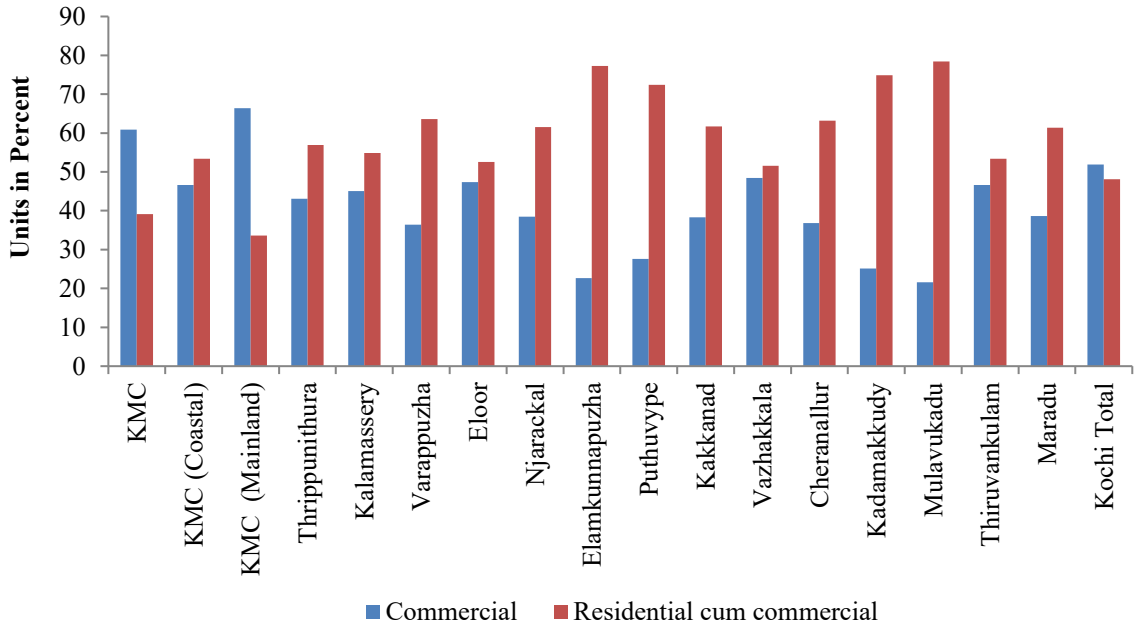
There are a total of 1,35,227 establishments in Kochi as per the economic census out of which 60.1 percent are located within the Municipal Corporation area and the remaining 39.9 percent are in the peripheral areas of the city (Table 3.9). Out of the 60.1 shares in the Corporation, 43.4 percent are located in the eastern side whereas 16.7 percent are in the coastal part (Table 3.9). This means that 72.2 percent of establishments within the Municipal Corporation are in the eastern part and only 27.8 percent are in the coastal area (Table 3.9). In other words, the eastern part of the corporation consisting of the mainland has a very high share in economic activities in terms of the number of establishments (Table 3.9). Similarly, out of the 39.9 percent establishments outside the corporation limit, the municipal towns of Thrippunithura and Kalamassery hold 6.3 and 5.3 percent share respectively (Table 3.9). Varappuzha, Elamkunnapuzha, Puthuvype, Kakkanad, Vazhakkala, and Maradu have between 2 to 4 percent share of units, while Eloor, Njarackal, Cheranallur, Kadamakkudy, Mulavukadu, and Thiruvankulam have less than 2 percent share in the total establishments in Kochi (Table 3.9). It is to be noted that as a proportion to the area the corporation has 858 establishments per square kilometer with the eastern side having a significant density of 1062 units per sq. kilometer, most of these establishments are located in a 4 km stretch on either side of the M.G. Road (Table 3.9).

Table 3.9: Commercial and industrial establishments in Kochi

S. No	Constituent Towns	Total Establishments	No. of Establishments per square kilometres
1	**Kochi MC**	**81388**	858
1.1	**Kochi MC (Coastal)**	**22635**	572
1.2	**Kochi MC (Mainland)**	**58753**	1062
2	Thrippunithura	8575	459
3	Kalamassery	7231	268
4	Varappuzha	3157	315
5	Eloor	2249	210
6	Njarackal	2132	247
7	Elamkunnapuzha	4928	565
8	Puthuvype	3274	464
9	Kakkanad	4208	240
10	Vazhakkala	4533	352
11	Cheranallur	2462	228
12	Kadamakkudy	1409	109
13	Mulavukadu	2170	113
14	Thiruvankulam	2473	236
15	Maradu	5038	408
	Kochi Total	**135227**	**480**

Note: (1) The area of each constituent town for the calculation of the number of establishments per square kilometres is as per Census of India, 2011 figures.
Source: Computed from the Sixth Economic Census (2013-14)

Figure 3.4: Establishments by use of the building/structure



Source: Based on data from Sixth Economic Census (2013-14).

Among the total establishments in Kochi, 51.9 percent are fully commercial and 48.1 are residential cum commercial structures (Fig 3.4). When we look at the corporation alone this gap is seen to be widened with 60.9 percent exclusive establishments and 39.1 percent structures are with mixed-use of residential cum commercial category (Fig 3.4). The higher overall percent in the exclusive commercial structure in the corporation is attributed to the higher percentage in the eastern part of the city with almost double the residential cum commercial structures in the area. A close look at the figures suggests that except for the mainland of Kochi MC in all other town constituents especially the census towns close to coastal and inland water bodies, the residential-cum-commercial units are much higher than exclusive commercial structures.

It can be visualized from figure 3.4 that the gap between the exclusive structure and mixed structure of residential cum commercial is very high in the island areas of Elamkunnapuzha, Puthuvype, Kadamakkudy, and Mulavukadu with over 70 percent houses/structures used for residential as well as economic activities. These areas have a relatively higher number of establishments in animal production, processing of meats, marine foods, production of wearing apparel, and retail stores that use their residential premises.

3.6.2 Ownership Status of Establishments

The ownership status of about 85 percent of the establishments in Kochi is proprietary (Table 3.10). This is followed by 7 percent partnership firms and around two percent each of Government/PSU, registered Companies, NGOs, and other types of establishments (Table 3.10). Kochi Corporation (Mainland), Kakkanad, and Vazhakkala have the least percent of proprietary firms with 78.6, 83.3, and 83 percent respectively. These areas have relatively more presence of partnership establishments compared to other areas. In places such as Elamkunnapuzha, Puthuvype, Kadamakkudy, and Mulavukadu the ownership status of more than 90 percent of units are proprietary with the majority being self-employed in the production and processing of meat, marine foods, and retail stores (Table 3.10).

The units registered as Company is only 2.2 percent in Kochi with the highest percent being 3.8 percent in the Kochi MC (mainland) (Table 3.10). Thrippunithura and Kakkanad are the only other areas having more than two percent units registered under “Company Act 1956”. Data suggest that establishments run by Government/PSU are also very less in Kochi, the highest being in Eloor and Vazhakkala with the former being an industrial town and the latter being an upcoming economic hub of Kochi. On average Kochi has 2.2 percent nonprofit organizations. The highest percent of

nonprofit units are in Kadamakkudy with 4.7 percent followed by Mulavukadu with 3.6 percent. All other areas except Kochi MC (mainland) have a share between 2 to 3.5 percent of non-profit institutions (Table 3.10). The *other* category which constitutes the units run by "self-help groups (SHG)", co-operatives and others are also very few in Kochi. The highest in these categories is found in Varappuzha, Eloor, and Vazhakkala with 4.1, 4.0, and 3.4 percent respectively (Table 3.10).

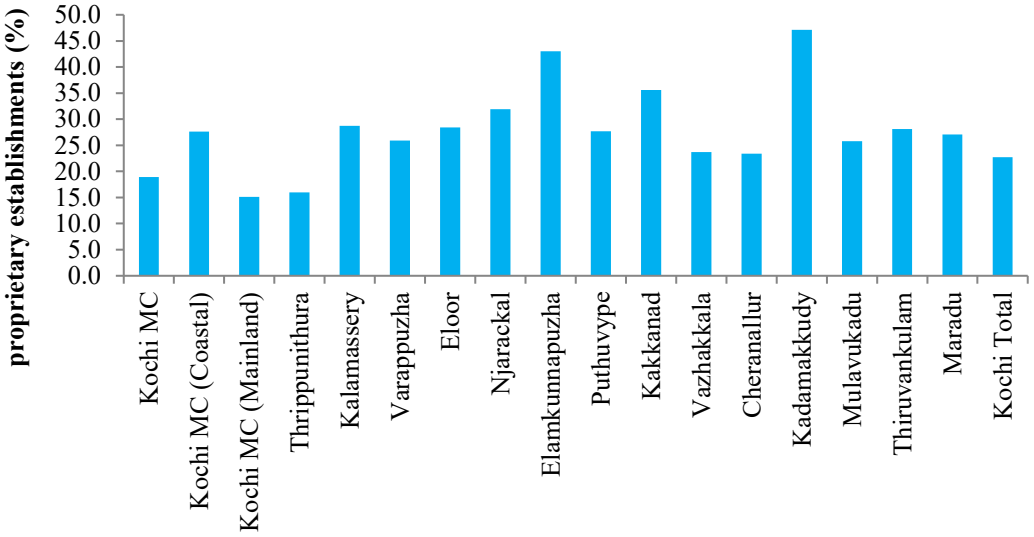
Among the proprietary establishments in Kochi, 22.7 percent are run by women entrepreneurs. This is twice the figures of overall Kerala, the second-highest among all states with 11.4 percent female ownership (Fig 3.5). The largest share in the number of establishments in India under women entrepreneurship is held by Tamil Nadu with 13.5 percent (All India Report of Sixth Economic Census, 2013-14). Data suggest that the percent of female-owned establishments is much higher in coastal and wetland areas of Kochi compared to the eastern part of the city (Fig 3.5).

Table 3.10: Ownership status of establishments in Kochi

Constituent Towns	Govt./ PSU	Proprietary	Partnership	Company	Non-Profit Institutions	Others
Kochi MC	**1.9**	**82.0**	**9.6**	**3.0**	**1.9**	**1.6**
Kochi MC (Coastal)	**1.7**	**90.8**	**2.3**	**0.9**	**2.9**	**1.3**
Kochi MC (Mainland)	**2.0**	**78.6**	**12.5**	**3.8**	**1.5**	**1.7**
Thrippunithura	2.2	87.4	4.1	2.1	2.5	1.6
Kalamassery	1.9	90.8	2.5	0.3	2.3	2.3
Varappuzha	1.8	89.0	2.1	0.1	3.0	4.1
Eloor	4.2	84.5	3.0	1.5	2.8	4.0
Njarackal	2.0	89.0	3.5	0.3	3.4	1.8
Elamkunnapuzha	1.1	95.3	0.3	0.0	2.2	1.1
Puthuvype	1.3	92.6	2.0	0.1	3.4	0.6
Kakkanad	1.9	83.3	8.6	2.4	2.0	1.8
Vazhakkala	3.4	83.0	5.3	1.5	3.4	3.4
Cheranallur	1.3	89.8	4.4	0.4	2.5	1.5
Kadamakkudy	1.6	90.7	0.8	1.3	4.7	0.9
Mulavukadu	2.6	92.4	0.4	0.0	3.6	1.0
Thiruvankulam	2.5	86.7	4.4	0.8	2.8	2.6
Maradu	1.6	88.9	3.3	1.4	2.5	2.3
Kochi Total	**2.0**	**84.7**	**7.1**	**2.2**	**2.2**	**1.8**

Source: Computed from Sixth Economic Census (2013-14).

Figure 3.5: Female owned proprietary establishments in Kochi



Source: Computed from Sixth Economic Census (2013-14).

Figure 3.5 clearly shows the traditional rural areas in the west and north-west side of the city which is elevated to the status of census towns in 2011 has more establishments with higher female-owned establishments (Fig 3.5). For example, Elamkunnapuzha and Kadamakkudy census towns have establishments with 43 and 47.1 percent female owners respectively. The workforce structure also shows that the female own account worker (non-hired) is also highest in Elamkunnapuzha and Kadamakkudy with 78 and 87 percent respectively (Fig 3.5). These areas have a comparatively higher number of establishments involved in the production of wearing apparel products which are a dominant area for women's work participation. The female-owned establishments are found to be low in the mainland of Kochi Corporation and the Thrippunithura Municipality mainly since these areas have more establishments in male-dominated wholesale and retail trade, real estate, transport, and storage sectors compared to other areas.

3.6.3 Major Source of Finance

More than 80 percent of establishments in Kochi are self-financed (Table 3.11). Kadamakkudy, Kochi MC (coastal), Varappuzha, and Kakkanad are among the areas with the highest self-finance establishments in Kochi. The least self-finance units among the city area were in Elamkunnapuzha and Mulavukadu with 45.5 and 62.2 percent respectively (Table 3.11).

Table 3.11: Major source of finance of the establishments

Constituent Towns	Self-Finance	Loan from banks	Financial Assistance from Govt. Source	Others
Kochi MC	**81.4**	**9.2**	**2.9**	**6.5**
Kochi MC (Coastal)	**87.0**	**3.8**	**2.7**	**6.5**
Kochi MC (Mainland)	**79.2**	**11.3**	**2.9**	**6.6**
Thrippunithura	81.8	7.0	6.3	4.9
Kalamassery	83.1	7.6	2.7	6.6
Varappuzha	85.8	2.9	2.4	8.9
Eloor	74.6	12.3	5.3	7.8
Njarackal	82.9	7.0	3.8	6.3
Elamkunnapuzha	62.2	27.7	1.2	8.9
Puthuvype	78.3	15.4	1.6	4.7
Kakkanad	86.5	6.3	2.4	4.8
Vazhakkala	79.0	9.6	4.1	7.3
Cheranallur	82.1	7.1	4.6	6.1
Kadamakkudy	90.3	0.6	2.2	7.0
Mulavukadu	45.5	38.7	2.8	13.0
Thiruvankulam	76.3	14.4	3.9	5.5
Maradu	79.7	8.9	2.7	8.7
Kochi Total	80.2	10.0	3.1	6.7

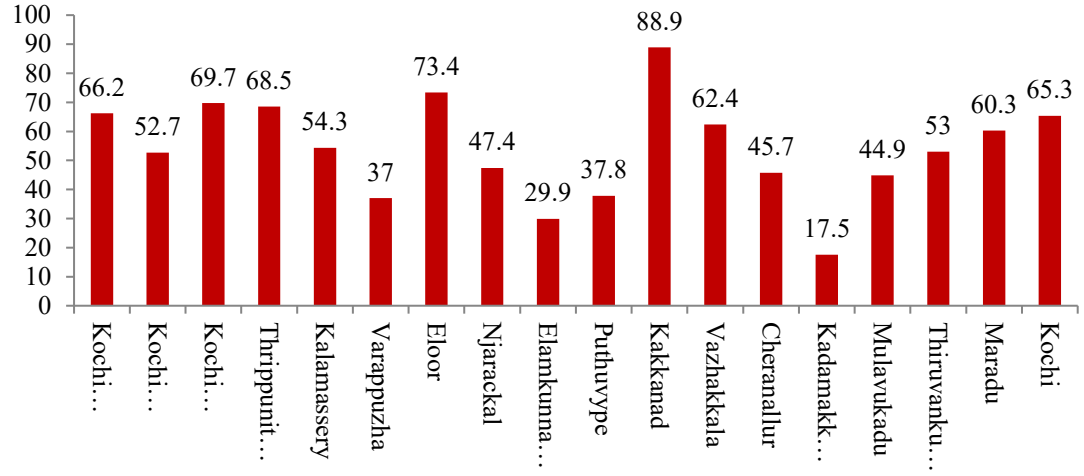
Source: Computed from Sixth Economic Census (2013-14).

These areas have a significant number of establishments set up by borrowing from financial institutions. There are 38.7 percent of establishments in Mulavukadu and 27.7 percent in Elamkunnapuzha that has taken loan from banks for setting up the establishment (Table 3.11). Puthuvype, Thiruvankulam, Eloor, and the eastern side of the corporation are the other areas having comparatively higher percent establishments run by taking loans from financial institutions. Kadamakkudy, Varappuzha, and Kochi MC (coastal) have the least percent of establishment set-up with bank loans. The city has an overall 3.1 percent establishment running with the help of financial assistance from Government sources. Establishments in Thrippunithura, Vazhakkala, and Cheranallur received comparatively higher financial assistance from Government while it is less in areas like Elamkunnapuzha, Puthuvype, Kakkanad, and Kadamakkudy with figures less than 2.5 percent (Table 3.11). The *other* category which includes borrowing from money lenders, loan from SHGs, and donations from other agencies put together are 6.7 percent (Table 3.11). Mulavukadu census town has 13 percent such establishments while Puthuvype, Kakkanad, and Thrippunithura have comparatively fewer establishments in *other* categories (Table 3.11).

3.6.4 Hired workers

Among all the workers employed in the establishments in the city, 65.3 percent are hired workers and the rest of the 34.7 percent are non-hired workers (Fig 3.6). Kakkanad and Eloor reported the highest percent of hired workers with figures of 88.9 and 73.4 respectively (Table 3.12).

Figure 3.6: Hired workers in Kochi



Source: Computed from Sixth Economic Census (2013-14).

Table 3.12: Gender wise proportion of hired workers in Kochi

Constituent Towns	Male	Female
Kochi MC	**63.4**	**73.9**
Kochi MC (Coastal)	**51.3**	**55.5**
Kochi MC (Mainland)	**66.2**	**79.9**
Thrippunithura	65.7	76.4
Kalamassery	50.9	59.9
Varappuzha	33.4	44.3
Eloor	75.6	66.9
Njarackal	42.7	55.4
Elamkunnapuzha	35.4	22.1
Puthuvype	39.8	33.2
Kakkanad	88.9	88.7
Vazhakkala	61.2	65.1
Cheranallur	44.4	48.7
Kadamakkudy	21.7	13.2
Mulavukadu	51.0	30.1
Thiruvankulam	53.2	52.3
Maradu	62.4	56.0
Kochi	**63.5**	**69.6**

Source: Computed from Sixth Economic Census (2013-14).

Understandably the former houses the "Special Economic Zone (SEZ)", Info park, Smart City, and "KINFRA Export Promotion Industrial Park" while the latter is an industrial town. The hired workers are found to be less in Kadamakkudy, Elamkunnapuzha, Varappuzha, Puthuvype, and Mulavukadu. These areas have a relatively higher percent of establishments in processing and preserving fish, prawns, and mollusks which are largely household-based own-account work. Out of the total male workers, 63.5 percent are hired workers while among female workers hired workers are found to be 69.6 percent (Table 3.12). Both the proportion of hired male and female workers is highest in Kakkanad followed by Kochi M. Corp. (Mainland) and Thrippunithura. In Kochi Municipal Corporation 63.4 percent of males and 73.9 percent of the female are hired, workers. The percent of male and female hired workers are found to be much less in coastal and other areas close to water bodies. As pointed out earlier these areas have quite a few establishments in the primary sector which is managed without hired workers.

3.7 Establishments by Broad Economic Category

Table 3.13 represents the percentage of establishments categorized by the broad economic activity. Establishments in the field of Agriculture and allied services in the city region are about 7.8 percent. Compared with cities outside Kerala these figures are higher because of its proximity to sea and back water as well as comparatively higher consumption of meat products which gives ample scope for fishing and livestock-related establishments. Though establishments in agricultural activities in the overall corporation area are only 3.4 percent, its share in the coastal area is much higher with 7.7 percent. The higher percent can be attributed to more animal production and fishing activities in coastal areas compared to mainland areas. Almost all places close to the western and north western part which are close to the sea and internal water bodies the figures are substantially high. For example, in Elamkunnapuzha almost 35 percent of establishments are involved in agriculture and allied activities. The adjoint Puthuvype and Mulavukadu along with Varappuzha and Kadamakkudy in the north which are surrounded by vast water bodies have also over 20 percent of establishments in agriculture and allied services (Table 3.13). The least agriculture-related establishments are found in the eastern side of the corporation along with Thrippunithura in the north and Vazhakkala in the east of the city. The percent establishments in the mining and quarrying category are negligible and therefore have not been shown as a separate category.

Among the total establishments in Kochi, the highest number of establishments are in the area of wholesale, retail trade which included repair and maintenance of motor vehicles and also food and accommodation services. As per the economic census, 30.8 percent of establishments is in trade-related activities including hotel and restaurants. Despite Kerala being a consumer state and also Kochi has a significant number of floating population as well as tourist inflow these figures are on the lower side compared to many other Indian cities. Still, it remains highest in Kochi having twice the share of the manufacturing sector. In the category of trade, about 75 percent are retail trade through specialized and non-specialized stores except motor vehicles and motorcycles together with food and beverage service activities (Table 3.13). Within the city, the Kochi Corporation has 34.7 percent of establishments in trade, food, and accommodation-related activities with an almost equal share in the coastal and mainland area of the corporation (Table 3.13). In other parts of Kochi also it is the dominant category and within this, the major portions are retail trades alone.

Table 3.13: Percent establishments by broad economic activity in Kochi

Constituent Towns	Agriculture and Allied	Manufacturing	Electricity, Gas, Water Supply etc.	Construction	Wholesale, Retail Trade, Hotel and Restaurants etc.	Transport and Storage	ICT	Financial Services, Insurance and real estate	education, health and social work	all others
Kochi MC	**3.4**	**13.1**	**0.5**	**2.3**	**34.7**	**11.4**	**1.9**	**11.9**	**5.5**	**15.3**
Kochi MC (Coastal)	**7.7**	**20.7**	**0.9**	**2.2**	**34.9**	**11.1**	**0.8**	**5.0**	**5.8**	**11.0**
Kochi MC (Mainland)	**1.8**	**10.2**	**0.3**	**2.3**	**34.6**	**11.4**	**2.3**	**14.6**	**5.4**	**17.0**
Thrippunithura	3.6	13.5	1.1	5.5	27.1	15.2	1.4	14.7	5.2	12.7
Kalamassery	9.8	17.1	0.3	2.4	27.3	9.7	1.4	10.8	8.2	13.0
Varappuzha	20.8	24.7	0.1	3.6	24.8	9.1	0.8	3.7	3.5	8.9
Eloor	8.4	18.9	1.1	3.6	24.2	16.4	1.2	5.4	7.4	13.3
Njarackal	19.5	19.3	0.3	2.1	28.3	8.8	0.6	5.1	5.9	10.1
Elamkunnapuzha	34.5	23.1	0.1	4.9	15.9	6.8	0.2	3.0	4.4	7.2
Puthuvype	25.8	20.3	0.2	8.8	20.2	7.6	0.3	6.6	2.7	7.5
Kakkanad	17.7	13.5	0.7	3.2	21.3	7.8	4.9	14.1	5.6	11.3
Vazhakkala	4.5	17.7	0.7	3.5	28.8	16.0	2.7	8.1	5.7	12.3
Cheranallur	12.8	19.9	0.4	4.8	26.0	11.4	0.7	5.6	4.5	13.9
Kadamakkudy	21.1	38.8	0.1	0.5	24.6	3.1	0.4	1.6	3.3	6.5
Mulavukadu	21.3	21.3	0.2	6.3	19.4	10.6	0.6	6.1	4.7	9.6
Thiruvankulam	9.3	16.7	0.3	3.3	26.4	7.4	1.8	13.3	7.6	13.8
Maradu	13.7	14.2	0.8	3.1	30.7	12.4	0.8	10.4	4.3	9.6
Kochi Total	**7.8**	**15.1**	**0.5**	**3.0**	**30.8**	**11.2**	**1.7**	**10.8**	**5.5**	**13.6**

Source: Computed from Sixth Economic Census (2013-14).

Wholesale, retail trade, hotel, and restaurants, etc. are found to be significantly less in Elamkunnapuzha, Puthuvype, Mulavukadu, and Kakkanad compared to other areas in the city. Construction firms constitute only 2.3 percent in the corporation areas while the percentage share in most of the surrounding areas is much higher indicating more commercial, infrastructural, and residential built-up activities outside the corporation area (Table 3.13). Puthuvype, Mulavukadu, Thrippunithura, and Cheranallur are the areas with a higher share of construction activities. The other two dominant economic activities in Kochi are transport and storage and financial services including the insurance sector and real estate. There are 11.2 percent establishments in transport and storage activity while 10.8 percent in financial and allied services (Table 3.13). About 13.6 percent of establishments in Kochi are in the 'all others' category which includes the legal activities, administrative services, and membership organizations that promote the interest of its members except business, employers, professionals, trade unions, and religious organizations. Such establishments are very few in Elamkunnapuzha, Puthuvype, and Kadamakkudy areas.

3.7.1 Major Manufacturing Establishments in Kochi

Industrial growth is vital for state and national growth. Agribusiness, science and technology development, entrepreneurship, self-sufficiency in military production, successful international trade, efficient use of natural resources, decrease in poverty and unemployment, and rise in per capita income and standard of living are all linked to this goal (Govt. of Kerala, 2017). About 15 percent of the total establishments in Kochi are in the manufacturing sector which is on the lower side when compared with most of the other cities in India. Out of these more than 52 percent of establishments are in the production of wearing apparel. Within the wearing apparel segment, the coastal and mainland corporation areas share 26 percent of each unit while all other areas have below 6 percent establishments involved in garments and related products. Another 11 percent of manufacturing unit deal with the production of different kinds of food products (Table 3.13). Elamkunnapuzha and Puthuvype in the coastal area have the highest share of such units compared to other areas in Kochi. Manufacture of fabricated metal products has a 6 percent share in the total manufacturing establishments in the region (Table 3.13). Similarly, the manufacturing of furniture and other wood products has a combined share of 9.7 percent (Table 3.13).

3.7.1.1 Garments and Other Wearing Apparels

There are 20473 establishments listed as manufacturing units in Kochi as per Economic Census 2013-14. About 55.3 percent i.e. more than half of the units are involved in manufacturing textile and wearing apparel (Table 3.14). The textile part which consists of the manufacture of raw materials required for making cloths, production of fabrics, etc. is only a minuscule component and more than 95 percent of units are in the production of readymade garments for the local market as well as exports (Table 3.14). While 63.3 percent of such units are located in the western part of the corporation, the eastern part of the corporation has 50 percent units of garments manufacturing (Table 3.14). Kadamakkudy has a total of 38.8 percent establishment in the manufacturing sector of which 75.3 percent is in wearing apparel production (Table 3.14). Kakkanad and Vazhakkala are the other city constituents having a relatively higher percentage of wearing apparel production in the entire city region with figures of 71 and 64.8 percent respectively though the share of establishments in manufacturing is about 14 to 18 percent only (Table 3.14). Elamkunnapuzha has 23.1 percent manufacturing firms of which 58 percent are in the apparel industry (Table 3.14). The adjacent Njarackal has 60.4 percent of establishments are engaged in wearing apparel with an overall manufacturing base of about 19.3 percent (Table 3.14).

3.7.1.2 Food and beverage production

About 12 percent of establishments in the entire Kochi region are in food and beverage production (Table 3.14). Out of this, the share of beverage production is negligible. Within the city constituents, the Municipal Corporation constitutes 11.6 percent with the major contribution coming from the western part of the corporation with 13.6 percent units while the eastern part of the corporation has a 10.2 percent share in the production and processing of food and beverages (Table 3.14). The majority of these units are involved in the processing and preserving of meat, manufacture of various grain mill products as well as starches and starch products. Again, most of the other coastal areas such as Njarackal, Elamkunnapuzha, and Puthuvype have a significantly higher percentage of food and beverage industry compared to the figures of overall Kochi. This is because due to its proximity with sea and inland waterbody these areas have more aqua farming activities and therefore a relatively higher number of establishments operating in the processing and preserving of fish, crustaceans, and mollusks, etc.

3.7.1.3 Other manufacturing establishments

The manufacturing of fabricated metal products has a share of 6 percent among the manufacturing establishments in Kochi. Within this Cheranallur, Mulavukadu, Thiruvankulam, and Maradu are the only dominant areas having 10 to 12.5 percent units of fabricated metal products (Table 3.14). Among the manufacturing establishments in the overall city areas, about 5 percent of units are in the manufacturing of wood products, straw, cork, etc. other than furniture. Mulavukadu has significantly higher units with 17.9 percent producing wood products while Thrippunithura, Varappuzha, Kakkanad, Cheranallur, and Kadamakkudy have very fewer units (less than 1.6 percent) in this sector (Table 3.14).

Table 3.14: Major Manufacturing establishments in Kochi

Constituent Towns	Food and Beverages	Textiles and garments	Wood products straw etc.	Printing and reproduction of recorded media	Fabricated metal products	Furniture	Others
Kochi MC	**11.6**	**56.2**	**5.1**	**5.1**	**5.4**	**3.8**	**12.9**
Kochi MC (Coastal)	**13.3**	**63.3**	**5.2**	**2.4**	**4.6**	**4.0**	**7.2**
Kochi MC (Mainland)	**10.2**	**50.6**	**5.0**	**7.1**	**6.0**	**3.7**	**17.4**
Thrippunithura	8.9	53.9	1.6	2.6	7.3	6.4	19.3
Kalamassery	13.6	52.8	5.6	1.9	7.0	3.5	15.6
Varappuzha	10.8	26.7	0.9	2.7	4.9	11.4	42.7
Eloor	12.4	55.2	5.2	1.4	5.2	3.5	17.1
Njarackal	17.0	60.4	5.8	1.7	5.1	2.4	7.5
Elamkunnapuzha	25.4	58.1	6.0	0.4	3.0	3.9	3.2
Puthuvype	23.3	54.2	8.1	0.3	6.8	3.6	3.8
Kakkanad	5.3	71.0	1.1	1.1	6.3	3.3	12.0
Vazhakkala	4.4	64.8	5.2	2.9	7.5	2.5	12.7
Cheranallur	9.4	45.5	0.4	2.9	10.6	10.4	20.8
Kadamakkudy	5.9	75.3	0.2	0.2	0.9	4.0	13.5
Mulavukadu	10.6	48.6	17.9	0.4	12.5	4.8	5.2
Thiruvankulam	13.1	47.5	6.8	2.4	11.9	4.6	13.8
Maradu	8.7	49.4	5.5	1.7	10.2	15.5	9.0
Kochi Total	**12.0**	**55.3**	**4.9**	**3.4**	**6.0**	**4.7**	**13.6**

Source: Computed from Sixth Economic Census (2013-14).

There is 4.7 percent of manufacturing establishments in the city region that make different kinds of furniture made of wood and metal (Table 3.14). The contribution of Maradu, Varappuzha, and Cheranallur in this is significantly high with 15.5, 11.4, and 10.4 respectively compared to other areas. The manufacturing establishments in the area of printing and reproduction of recorded media in Kochi are found to be 3.4 percent, the highest being in the eastern side of the corporation (mainland) with 7.1 percent of manufacturing units are in printing and related work which has

helped in increasing the overall tally to 3.4 percent, rest all places have a very low percent point (Table 3.14).

The *Others* category forms 13.6 percent in which the major percent contribution is the production of jewelry, decorative articles, musical instruments, sports goods, games and toys, medical and dental instruments, and other manufacturing establishments (Table 3.14). The figures for Varappuzha in this sector are exceptionally high with 42.7 percent followed by Cheranallur and Thrippunithura with 20.8 and 19.3 respectively (Table 3.14).

3.8 An Assessment of Developmental Characteristics of Kochi and Neighboring Cities

While comparing at a micro-level it is also important to look at the similarities and disparities of developmental indicators with that of similar cities in the neighborhood. In this context, an analysis of demographic, socio-economic, migration, and infrastructural characteristics of major municipal corporations from Kerala and the bordering states of Tamil Nadu and Karnataka having a population of 0.5 million to 1 million as per the 2011 census is required. Chennai and Bangalore which are large cities with a population of over 5 million are not considered in this analysis since being megacities may hamper the comparability. The objective of this analysis is to understand the relative performance of Kochi in different dimensions with that of similarly populated other cities in South India. Along with Kochi, the other cities included in this analysis from Kerala are Thiruvananthapuram and Kozhikode. There are four cities of Coimbatore, Madurai, Salem, and Tiruchirappalli from Tamil Nadu and two cities of Hubli-Dharwad and Mysore included in the analysis that satisfies the population criteria.

3.8.1 Demographic and Social Characteristics

The density of population in Kochi is 6057 persons per square kilometers as per the 2011 census (Table 3.15). Four cities have higher population densities than Kochi, three of these cities Coimbatore, Madurai, and Salem are industrial cities in Tamil Nadu and the other one is Mysore in Karnataka. The population density of Madurai is found to be exceptionally high compared to other cities. There are four cities with fewer population densities than Kochi, namely Kozhikode and Thiruvananthapuram, Tiruchirappalli, and Hubli-Dharwad.

As can be seen in other parts of the state, all the cities in Kerala have a higher female sex ratio than other cities. Kochi reported a sex ratio of 1027 females per thousand males (Table 3.15).

Tiruchirappalli in Tamil Nadu also reported a female ratio of 1025 (Table 3.15). Salem and Hubli-Dharwad were the two cities with a comparatively low sex ratio of 987 and 989 respectively (Table 3.15).

Table 3.15: Demographic Characteristics of Kochi and neighborhood cities (2011)

Cities	Population Density	Sex Ratio	Literacy Rate	Percent SC-ST Population
Kochi	**6057**	**1027**	**97.4**	**3.7**
Kozhikode	4419	1093	96.5	4.0
Thiruvananthapuram	4392	1054	95.1	9.6
Coimbatore	9950	997	91.3	10.3
Madurai	19589	999	90.9	6.6
Salem	9079	987	84.4	13.0
Tiruchirappalli	5768	1025	91.4	10.8
Hubli-Dharwad	4422	989	86.8	13.5
Mysore	8160	999	87.7	16.2

Source: Calculated from the Town Directory, Census of India 2011.

In terms of Literacy rate, cities in Kerala are far ahead of other neighboring cities with Kochi being the highest with a 97.4 percent literate population (Table 3.15). Salem, Hubli-Dharwad, and Mysore reported less than 90 percent literacy rate, which in the regional terms can be considered as a low literacy rate (Table 3.15). The SC/ST population in Kochi is 3.7 percentage, the lowest among all cities (Table 3.15). Kozhikode has a 4.0 percent SC/ST population which is also much less compared to many of the other cities in the neighborhood (Table 3.15). One of the reasons for such low SC/ST population in Kochi and Kozhikode can be attributed to the relatively higher percentage of upper-caste Christian and Muslim Population in these cities. Madurai also has a low percent of SC/ST Population (Table 3.15). All other cities have a very high percentage of the Hindu population, which includes a relatively higher denomination of the SC/ST population.

3.8.2 Employment Characteristics

Total workers as a percentage of the total population, workers in the age group of 15-59 years, and also the unemployment rate is presented in Table 3.16. In terms of workers as a percent of the total population, Kochi was among the highest after Coimbatore, Salem, and Madurai with 38 percent people in the workforce (Table 3.16). Kozhikode city with 32.2 percent workers was the least among the nine cities (Table 3.16). Among the active population in the 15-59 age group, five cities had more than half of the population in the workforce with Kochi having 53.2 percent (Table 3.16). In terms of the unemployment rate, it can be seen from Table 3.16 that all cities in Kerala have a

higher unemployment rate than the rest of the cities. Data indicates that the number of people who seek or are available for work is generally much higher in Kerala than other states in India basically because of the availability of more educated and skilled manpower in the state and low level of industrialization compared to other cities in comparison.

Table 3.16: Economic characteristics of Kochi and neighboring cities (2011)

Cities	Percent Workers in All Population	Percent Workers in 15-59 Age Groups Population	Unemployment Rate in 15-59 Age Group
Kochi	**38.0**	**53.2**	**18.8**
Kozhikode	32.2	45.4	27.0
Thiruvananthapuram	36.3	50.4	27.2
Coimbatore	40.5	54.5	8.9
Madurai	38.4	52.2	12.4
Salem	40.1	53.9	8.5
Tiruchirappalli	35.7	48.5	12.4
Hubli-Dharwad	35.4	49.9	8.9
Mysore	37.9	50.5	10.2

Source: Calculated from B-1 City Level Data, Census 2011.

The unemployment rate of Kochi is 18.8 percent with Kozhikode and Thiruvananthapuram being the highest with 27 percent (Table 3.16). In comparison, the situation of other neighboring cities in this regard is comparatively better.

3.8.3 Employment Status in Secondary Sector

The secondary sector workers in the 15–59 age group in Kochi is about 31.1 percent, which is higher than the other cities in Kerala (Table 3.17). Salem and Coimbatore have the highest percent (45.1 and 40.3 percent) of workers in the secondary sector (Table 3.17).

Table 3.17: Percent workers in the secondary sector (15-59 age groups) in Kochi and neighboring cities (2011)

Cities	Manufacturing	Electricity, Gas and Water Supply	Construction	Secondary Sector
Kochi	**16.6**	**0.6**	**13.9**	**31.1**
Kozhikode	12.7	0.7	15.8	29.2
Thiruvananthapuram	10.0	1.1	11.8	22.9
Coimbatore	29.6	0.4	10.3	40.3
Madurai	21.0	0.6	9.7	31.3
Salem	34.6	0.5	10.0	45.1
Tiruchirappalli	17.3	0.5	10.1	27.9
Hubli-Dharwad	17.4	0.8	11.2	29.4
Mysore	20.0	0.8	9.6	30.4

Source: Calculated from B-4 City Level Data, Census 2011.

One thing which keeps the cities in Kerala different from other South Indian cities is that the construction sector is the dominant constituent of the secondary sector except for Kochi. The cities in Kerala are far behind other cities in terms of the manufacturing workforce. The reason for such low figures of 16.6, 12.7, and 10 percent respectively for Kochi, Kozhikode, and Thiruvananthapuram may be because of political and labor-related issues (Table 3.17).

While in the cities in Tamil Nadu and Karnataka manufacturing sector is the prominent component. About 34.6 percent active working age group population is involved in manufacturing activities followed by Coimbatore with 29.6 percent (Table 3.17). The construction sector on the other hand in Kerala is much better as the figure for Kochi is 13.9 percent, while for Kozhikode is even high at 15.8 percent (Table 3.17). This is an indication that people invest more in the housing and real estate business in Kerala than other cities in the neighboring states.

3.8.4 Employment Status in Tertiary Sector

The overall tertiary sector in Kerala looks to be better than some of the other cities in the neighboring state. The tertiary sector workers in the 15-59 age group in Kochi are found to be 65.7 percent, while for Thiruvananthapuram the figure is even higher at 69.4 percent (Table 3.18). Coimbatore and Salem being the largest industrial towns in the region had figures 58 percent and 52.6 percent respectively.

Table 3.18: Percentage share of workers in tertiary sector (15-59 age groups) in Kochi and neighboring cities (2011)

Cities	X1	X2	X3	X4	X5	X6	X7	X8	X9
Kochi	15.2	10.5	4.4	8.3	7.3	12.1	2.1	5.7	65.7
Kozhikode	20.5	9.4	2.7	10.5	5.9	6.2	2.3	4.6	62.2
Thiruvananthapuram	12.5	9.7	6.4	11.7	7.7	12.8	2.0	6.6	69.4
Coimbatore	17.0	5.6	4.1	7.1	4.9	8.3	2.3	8.7	58.0
Madurai	22.3	8.2	2.8	7.1	4.4	5.1	3.8	13.6	67.1
Salem	17.5	6.5	2.5	6.4	3.9	5.6	2.9	7.4	52.6
Tiruchirappalli	19.7	10.5	3.7	8.3	5.0	8.6	4.1	8.7	68.5
Hubli-Dharwad	19.6	11.5	2.0	8.7	4.8	6.2	2.3	7.8	62.7
Mysore	18.5	9.5	3.7	9.9	5.5	7.7	2.8	9.2	66.8

Note: X1 - Wholesale and Retail Trade, X2 - Transportation and Storage, X3 - Information and Communication Technology (ICT), X4 – Education, Health and Social Work, X5 - Financial Services, Real Estate, and Professional, Activities X6 - Administrative Services, X7- Accommodation and foodservice, X8 – Recreational and other services, X9- Tertiary Sector.
Source: Calculated from B-4 City Level Data, Census 2011.

A close look at the sectoral distribution of workers in Kochi reveals that the wholesale and retail trade was the major component with 15.2 percent followed by the workforce in the administrative and defense service with 12.1 percent and transport and storage with 10.5 percent. However, the share of the wholesale and retail sector when compared to other cities is lower in Kochi, the lowest being in Thiruvananthapuram with 12.5 percent (Table 3.18). One thing which comes out from the table is that the wholesale and retail is the highest employed area in all the cities. As the figure suggests the transport and storage sector employs close to 10 percent of people in the cities in Kerala. ICT is another important area which started growing in recent years. Although the figure does not capture the recent trends, the percent figures as per the 2011 census show that Kochi and Thiruvananthapuram are ahead of other cities in the IT sector. One of the positive factors for the huge potential for growth of the IT sector in Kerala is the enormous skilled manpower availability. The percent of workers in the active age group in education, health, and social work in Kochi remains on the lower side compared to other cities in Kerala. The figures for financial services which include banking and insurances, real estate and other professionals, scientific and technical activities are comparatively higher in cities in Kerala (Table 3.18). The workers in accommodation and food service and also recreational services are found to be less in Kochi and other cities in Kerala compared to cities in the neighboring states (Table 3.18). Overall, the dominance of the tertiary sector in the cities of Kerala is expected to attain further momentum in the coming years with an emphasis on tourism, ICT, and health care services in the state.

3.8.5 Infrastructure and basic amenities

An analysis of some of the indicators related to infrastructure and basic amenities is presented in Table 3.19 to understand the relative importance of Kochi city in this dimension. The presence of an adequate pucca road tells about the existing transportation facility available in a city. Kochi with 18.1 km of Pucca road for every 10000 population is significantly higher than the other cities in these three states (Table 3.19). The state capital also had a relatively higher road length per 10000 populations. Mysore in Karnataka is also among the city with the highest pucca road length (Table 3.19). The least road density in terms of population is found to be in Hubli-Dharwad (Table 3.19). In terms of the percentage of households with electricity connections for industrial and commercial use, the Kochi has 17.8 percent which is the second-highest after Coimbatore (Table 3.19). Thiruvananthapuram and Tiruchirappalli were among the least percent of industrial and commercial electric connections in the cities of the southernmost part of India (Table 3.19). In

terms of the percent of waterborne latrine facilities calculated per 10000 households, it can be seen that Thiruvananthapuram is far ahead of other cities followed by Kochi and Madurai (Table 3.19).

Table 3.19: Select infrastructural indicators of Kochi and other neighboring cities (2011)

Cities	Pucca Road (in Kms) per 10000 Population	Electricity for Industrial and Commercial Use	Waterborne Latrine Facility per 10000 households	Hospitals per Million Population	Banks per 10000 Population
Kochi	**18.1**	**17.8**	**10587**	**11.5**	**4.9**
Kozhikode	9.1	13.8	9900	16.4	2.4
Thiruvananthapuram	11.0	4.8	14713	16.5	5.9
Coimbatore	8.9	21.8	8781	4.8	1.7
Madurai	7.5	14.4	10000	4.9	1.6
Salem	9.0	8.9	8438	2.4	1.0
Tiruchirappalli	9.8	5.6	8127	5.9	0.4
Hubli-Dharwad	4.2	15.1	8235	3.2	1.2
Mysore	11.8	15.3	9550	13.0	2.4

Source: Calculated from the Town Directory, Census of India 2011.

It may be noted that the number of latrine facilities in Kochi and Thiruvananthapuram exceeded the number of households as certain households may have more than one latrine facility in their house. Tiruchirappalli, Hubli-Dharwad, Salem, and Coimbatore were among the cities with the least access to waterborne latrine facilities (Table 3.19). The number of hospitals calculated per million population is found to be highest in the cities in Kerala with Thiruvananthapuram and Kozhikode being at the top than Kochi city which has a figure of 11.5 hospitals for every one million population (Table 3.19). The health infrastructure of Salem and Hubli-Dharwad is found to be very low among all the cities. Another indicator i.e. presence of "number of banks per 10000 population" is taken as a proxy to estimate how much strong a city is in terms of financial institutions. Thiruvananthapuram and Kochi with values of 5.9 and 4.9 percent were the topmost cities having better banking facilities among the nine cities considered in this analysis (Table 3.19). All other cities had the number of banks per 10000 populations less than half of the values of these two cities. The analysis here also pointed out that compared to the cities in the neighboring state of Kerala, Kochi city is ahead in infrastructural and other basic amenities and has the potential for future urban expansion.

3.8.6 Migration

Apart from the rise in a "natural increase in population", "net in-migration" in cities is seen as one of the major components of rapid urban growth in developing countries (Rogers & Williamson,

1982). Table 3.20 depicted the percent of migrants to the total population classified by "last residence" and the number of migrants with employment and business as a reason for migration. The percent migrants to the total population (2011) in Kochi was 40.2 percent with Coimbatore and Tiruchirappalli being the highest with 50.1 and 47.1 percent respectively (Table 3.20). A significant part of this may be due to the factor of marriage and people moving after birth. Among the migrant population in Kochi, the intra-district migrants are highest with 50.4 percent, followed by inter-district migrants with 33.4 percent (Table 3.20).

Table 3.20: Migrant Population of Kochi and neighboring cities (2011)

Cities	Percent Migrants to Total Population	Migrants by Last Residence				Employment and Business Migrants
		Intra-district	Inter-District	Inter-State	Others	
Kochi	40.2	50.4	33.4	14.3	1.9	17.0
Kozhikode	36.4	68.0	24.1	6.5	1.4	9.9
Thiruvananthapuram	41.3	69.2	19.3	9.9	1.7	13.3
Coimbatore	50.1	44.7	40.4	14.3	0.6	23.3
Madurai	34.9	54.7	41.6	3.1	0.6	16.2
Salem	25.7	50.8	40.6	7.7	0.9	18.3
Tiruchirappalli	47.1	50.5	44.3	3.5	1.8	15.5
Hubli-Dharwad	39.7	30.9	59.0	9.9	0.2	18.2
Mysore	48.6	48.7	40.9	10.0	0.5	16.8

Source: Calculated from D-3 City Level Data, Census 2011.

The interstate migrants in Kochi were 14.3 percent, the highest among the cities in Kerala and the bordering states (Table 3.20). The interstate migrants in Coimbatore also reported identical figures. The migration for employment and business reason in Kochi is found to be 17 percent much higher than other cities in Kerala; however, the percentage number was even higher in Coimbatore, Salem, and Hubli-Dharwad (Table 3.20).

3.9 Housing Amenities in Kochi and Neighboring Cities

An analysis of housing space in Kochi in comparison with other selected cities in Kerala and bordering states of Tamil Nadu and Karnataka as per the 2001 and 2011 census is presented in Table 3.21. It can be seen that the households with no exclusive room are found to be very less in Kochi and other cities in Kerala compared to cities in the bordering states (Table 3.21). The households with no exclusive room are the ones with all people living in the household sharing the same room for cooking and sleeping.

Table 3.21: Housing condition and living space in Kochi and neighboring cities

	Percent households with no exclusive room		Percent households with 3 plus rooms	
Cities	2001	2011	2001	2011
Kochi	0.7	0.8	72.4	72.8
Kozhikode	1.4	1.0	59.8	64.5
Thiruvananthapuram	1.2	1.1	62.1	67.7
Coimbatore	1.2	2.3	41.1	36.0
Madurai	3.8	3.7	22.6	21.7
Salem	7.4	6.9	26.9	25.4
Tiruchirappalli	6.9	7.1	21.9	22.4
Hubli-Dharwad	2.0	4.4	45.4	37.8
Mysore	6.4	6.4	27.0	28.9

Source: Calculated from Housing Amenities Data, Census of India 2001 & 2011.

These households generally belong to a very low-income category population. Data from the 2001 and 2011 census shows that such households are the least in Kochi with only 0.8 percent of households compared to other similarly populated cities in the southern part of India (Table 3.21). Salem, Tiruchirappalli, and Mysore are among the cities having the highest number of households with no independent room (Table 3.21). Similarly, in terms of living space, the houses in Kerala are much larger like Kochi having as many as 72.8 percent of households possessing houses with 3 or more rooms followed by Thiruvananthapuram with 67.7 percent and Kozhikode with 64.5 percent respectively (Table 3.21). With a relatively low household size compared to the cities in other states, Kochi has also portrayed the general aspiration of people like Kerala to have bigger houses. In comparison, the cities in the other adjoining states have significantly fewer percent houses with spacious living spaces.

Table 3.22 depicted the percent households with electricity and clean cooking gas. It is noticed that the percentage share of households with electricity connection was highest in Kochi compared to other cities. Though there was not much variation among the cities as most of the cities have improved substantially over the decade (2001-2011) (Table 3.22). Kochi tops the list with 99.1 percent of households having electricity as the main source of lighting with an increase of about 7 percent over the previous census year (2001) (Table 3.22). As per census 2011 data, this is higher than the average figure of 97 percent in the urban area of Kerala and 92.7 percent in urban India (Table 3.22). In terms of access to cleaner fuel for cooking, Kochi outperformed other cities with 91.7 percent of households having LPG/PNG connections (Table 3.22). Though there was a considerable transition from the traditional firewood-based cooking to cleaner energy between the two census period in Kochi.

Table 3.22: Housing amenities of Kochi and neighboring cities (2001 and 2011)

	Percent households with electricity as a source of lighting		Percent households with LPG/PNG for cooking	
Cities	2001	2011	2001	2011
Kochi	92.3	99.1	64.1	91.7
Kozhikode	83.2	97.8	27.6	53.9
Thiruvananthapuram	88.1	98.2	45.1	74.0
Coimbatore	95.1	98.3	51.7	82.3
Madurai	93.6	98.8	32.7	65.8
Salem	91.7	96.7	44.1	74.5
Tiruchirappalli	90.9	97.4	41.1	71.5
Hubli-Dharwad	86.0	96.3	56.7	65.9
Mysore	94.1	98.7	52.8	76.0

Source: Calculated from Housing Amenities Data, Census of India 2011.

The other cities in Kerala and neighboring states are lagging with Kozhikode having only 53.9 percent of households with gas connections as per the 2011 census data (Table 3.22).

Census figures suggested that the water connection in Kochi is better with 96.1 percent of households were connected to treated tap water access followed by Coimbatore and Mysore with 95 percent in 2011 (Table 3.23). Kozhikode in Kerala was reported as the last in the queue with only 38.1 percent of households having access to treated tap water connections (Table 3.23). Though census reported very high percent access of treated water to households in urban areas of Kochi, researchers pointed out that many of the areas especially the areas close to the northwestern part of the city do not receive tap water and has to rely on other sources such as bottled water, water tanks (Giri, 2019), well, and bore wells for their daily needs (Kuncheria, 2017). Being proximity to water bodies and the availability of substantial rain in Kerala, drawing groundwater through wells is seen as a common practice. Almost every household away from the major city centers uses a manual or motorized well for drawing water for their daily needs. This can be sighted as a reason for such a low percent use of treated water supply in many towns in Kerala. Since the water in the coastal area has more salinity, therefore, the untreated groundwater drawn through the well is not fir for dinking. The government should give more emphasis on installing more treatment plants, especially in the coastal areas to provide access to safe drinking water to the households. The households with drainage facility in Kochi city in 2011 showed a considerable improvement over 2001 with 71.1 percent of household's wastewater outlets being connected to a closed drainage system. This again requires drastic improvement as the presence of a large water body in the city and open drainage often result in mosquito breeding and environmental degradation.

Table 3.23: Water supply and drainage facilities in Kochi and neighboring cities (2001 and 2011)

	Percent households with treated tap water facility		Percent households with closed drainage facility	
Cities	2001	2011	2001	2011
Kochi	89.2	96.1	26.7	71.1
Kozhikode	31.3	38.1	15.7	51.2
Thiruvananthapuram	67.6	76.1	27.3	46.6
Coimbatore	92.5	95.8	44.0	59.7
Madurai	74.2	86.7	54.0	88.5
Salem	75.4	83.5	33.0	38.4
Tiruchirappalli	81.3	82.6	35.9	55.1
Hubli-Dharwad	89.2	84.6	56.4	69.8
Mysore	90.8	94.8	80.7	94.0

Source: Calculated from Housing Amenities Data, Census of India 2011.

Table 3.24: Household assets of Kochi and neighboring cities (2001 and 2011)

	Percent households availing banking facility		Percent households owning four wheelers	
Cities	2001	2011	2001	2011
Kochi	62.6	82.7	12.8	23.9
Kozhikode	53.8	76.8	7.0	16.3
Thiruvananthapuram	48.0	74.9	11.5	24.4
Coimbatore	36.5	69.5	8.2	13.4
Madurai	26.8	60.7	3.2	5.6
Salem	20.8	52.1	4.0	6.8
Tiruchirappalli	38.7	68.8	4.1	7.2
Hubli-Dharwad	52.8	65.9	5.4	8.8
Mysore	51.4	64.8	7.0	14.3

Source: Calculated from Housing Amenities Data, Census of India 2011

Kozhikode and Thiruvananthapuram also have a much lower figure of 51.2 and 46.6 percent respectively (Table 3.23). The data shows that Mysore and Madurai have a better drainage network compared to the rest of the cities under comparison. This is again another area where the local government needs to put a lot of attention to keeping the city clean and safe for people.

Another set of indicators compared among the households of cities in South India are the percent households with access to banking facilities and households owning four-wheelers. Households with access to banking facilities were highest in Kochi with 82.7 percent of households having the same followed by the other two cities of Kozhikode and Thiruvananthapuram in Kerala with 76.8 and 74.9 percent respectively (Table 3.24). This was comparatively lower in the cities in Tamil Nadu and Karnataka.

Households owning a car, jeep, or van is considered to be a proxy to understand the level of asset possession of households. It can be seen that both Kochi and Thiruvananthapuram with figures of 23.9 and 24.4 percent were among the highest in terms of possession of the same, while cities of Tamil Nadu and Karnataka have the least percent households owning four-wheelers (Table 3.24). It can be seen that in the cities of Kerala especially Kochi and Thiruvananthapuram the percentage of four-wheeler ownership have substantially increased compared to other cities.

3.10 Summary

Kochi has been aerially expanded almost eight times in the last 50 years and has been possessing the status of a million-plus population city from the last two census years, however, a close look at the data suggested that only one-third of the designated million-plus cities are having the official statutory status in terms of corporation and municipalities and the rest of the areas are assigned as census towns due to change in the economic status of the people from agricultural to non-agricultural economic activities. From the field observation, it can be clearly distinguished the areas outside the city master plan other than the municipal towns have a unique settlement pattern with most of the houses built in this area are cottages, bungalows, or farmhouses surrounded by a large parcel of residential lands.

The higher rate of increase in density of households in areas outside the corporation especially in Cheranallur, Thrikkakara, Kalamassery, Thrippunithura, and Maradu from 2001 to 2011 showed a residential growth which may be continued because of the major shift in economy directed towards east and south of the city. It can be argued that the higher density of population in these areas is partly due to the redistribution of the population to other urban centers because of IT parks and other industries established outside the corporation area.

Like other cities of Kerala, the population growth of Kochi also continues to decline. Many studies cited a low-level fertility rate in Kerala much below the all-India rate is the major reason for such decline. Due to this, there is a likely chance that the population growth of the city in the coming decades will follow a declining trend. The less chance of population growth is also linked to better transportation linkages with the neighborhood forcing a large number of people to stay back in their respective place of residence outside the city and commute daily for work and other reasons. In Kerala's context, the reduction in agriculture in Kochi can be linked to the increased educational reforms in the last three decades and thereby people's participation in non-agricultural activities

leading to a rural-urban transformation. One of the reasons for the recent higher growth in non-agricultural activity in Thrikkakara in the eastern part can be attributed to the government policy intervention in the setting-up of high-tech commercial establishments. As a result of this, it can be argued that the land demand in the area has increased manifolds and the real estate developers are also cashing in on the high demand for the land here.

Commercial banks are concentrated mainly in the corporation and municipal areas, but it can be seen that in the latter year it is increasing in many other areas which is an indication of the increase in economic activities and urban growth. Transportation junction-based townships are common in Kerala. Kochi is the only city in Kerala with a road, railway, metro, waterways, and an international airport. The transport infrastructure is best among the cities in the state. The linkages with adjoining rural areas are considered to be one of the reasons for the expansion of the city.

The finding reveals that spatially there are sharp differences in the structure of establishments between the western and eastern parts of the city. Among the total establishments in Kochi, only fifteen per cent are in the manufacturing sector, out of which more than half of the establishments are engaged in the production of wearing apparel and as many as twelve per cent in the food products sector especially in processing and preserving of fish and meats. In the tertiary sector also, the economic activities in the city are heavily dependent on sub-sectors such as trades, transport, storage and financial services including real estate business. The information and communication technology (ICT) which is a highly-skilled sector constitutes only a minuscule per cent of the total establishments in the city, with Kakkanad in the eastern part of the city being an exception having close to five per cent establishments in the ICT sector. Kochi is the largest commercial centre in Kerala, should aim for more environment friendly, technologically advanced and capital-intensive manufacturing diversification, so that the city can expand further and immensely contribute to the overall development of the state. The availability of highly skilled manpower, transportation connectivity and infrastructure development in the city needs to be used effectively for achieving this target to make Kochi one of the world-class cities in the World. Though there are many new economic and infrastructure developmental initiatives are happening in Kochi in recent years, the analysis of temporal changes in the structure of commercial and industrial establishments in the last eight years can reveal the economic prospects of the city, for which one has to wait for the release of unit-level data of the seventh economic census which is currently under process.

Chapter 4: An Assessment of Housing Amenities and Field-Based Evaluation of Select Characteristics

4.1 Background

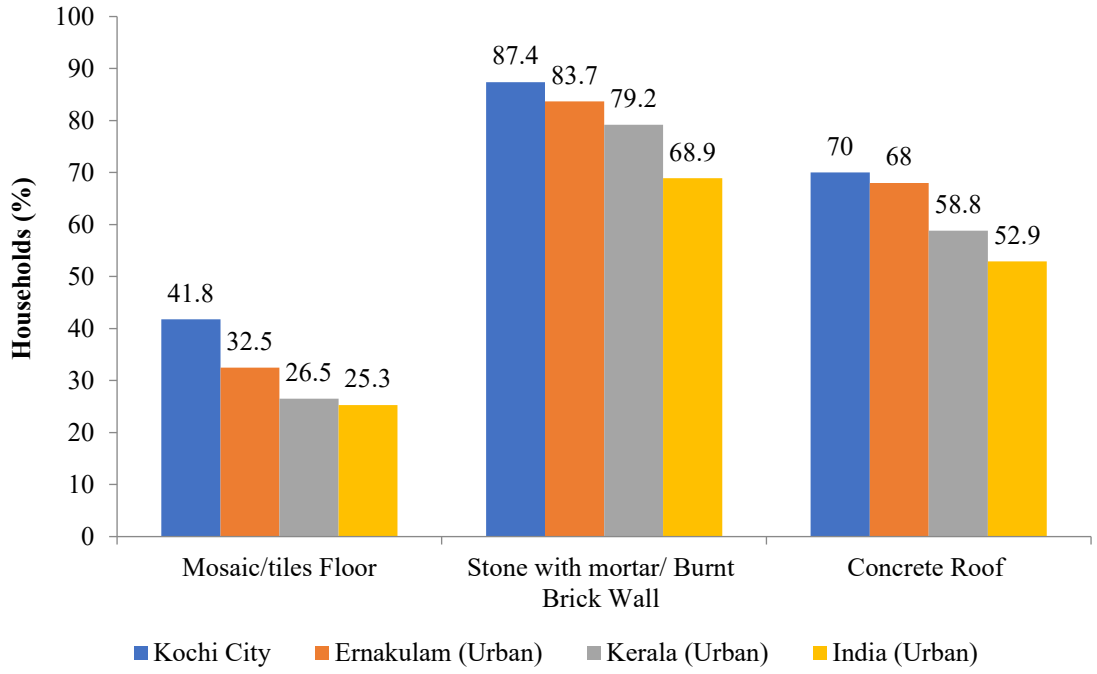
The present chapter is attempted to evaluate different housing amenities in Kochi and compare them with the overall urban areas of Ernakulam, Kerala, and India. For assessing the physical quality of housing, three indicators namely “mosaic/tiled flooring”, “stone with mortar/burnt brick wall”, and the “concrete roof” are taken. Another set of three indicators which explain the condition of houses, space, and socio-economic pressure on households namely percent households with the “condition of houses reported as good for living”, “households having three or more dwelling rooms”, and “the average family size of less than or equal to four members” are discussed in this chapter. Three indicators that explain the hygiene of the household premises, as well as the surrounding area namely “the percentage of households with flush latrine connected to the piped sewer system”, “households with flush latrine connected to the septic tank”, and “households with wastewater outlet connected to closed drainage”, are also analyzed both at a broader and a disintegrated level for the city. Similarly, three indicators of “access to treated tap water”, “electricity for lighting”, and “LPG/PNG for cooking” are prepared for different town constituents to understand the overall access and the pattern of the distribution network of these amenities. The economic conditions of the households are analyzed using three indicators namely “percentage of households availing banking service”, “households having computer or laptop with internet”, and “households owning a car, jeep, or van”. Each of these is grouped into indices of “physical structural quality”, ‘living conditions”, “cleaner housing environment”, “access to basic services”, and economic condition at a disaggregated level for Kochi to understand the pattern of availability of basic amenities in different parts of the city. These indices are calculated as the sum average of the standardized score (“z score”) obtained by subtracting the mean from each observation and dividing by the standard deviation.

4.2 The Structural Quality of Houses

Figure 4.1 depicted that in terms of material used for house construction, the houses in Kochi are better as compared to the urban areas of the district, state, and all of India. Throughout Kerala, the

residential buildings are not congregated as we see elsewhere in India and people live in independent houses surrounded by a compound wall (Kurian & Thampuran, 2011). The higher figure for the urban areas of the district indicates that the physical quality of the structure of the houses in Ernakulum district is superior to the urban areas of the state as a whole. It can be seen that the percentage of houses having 'mosaic/tile flooring' in urban Kerala and India do not differ significantly. The narrow gap can also be attributed to the fact that in Kerala granite flooring is a preferred type of flooring compared to mosaic/tiled flooring. However, the urban area of Ernakulum reported about 6 percent higher usage of marble/tiled flooring than that of Kerala as a whole, which also indicates a better physical quality of houses in the district.

Figure 4.1: Physical structural quality of houses in Kochi in comparison to the urban areas of Ernakulam, Kerala, and India



Source: Calculated from HH series data, Census 2011.

The figures also revealed that in all these three aspects, the overall physical quality of houses in Kochi city is better when compared to the figures of the urban areas of the district. However, there are sharp differences in the quality of housing based on the location within the city areas. Table 4.1 depicted that though Kochi Corporation's figure for mosaic/tile flooring is 41.8 percent, the

coastal and the western part of the corporation has reported it as around 19 to 22 percent only, indicating that the quality of the flooring in the coastal belt is significantly inferior to the mainland (Table 4.1).

Table 4.1: Physical structural quality of houses (2011)

	Percent Households			Physical structural quality index
Area Name	Mosaic / Tiled Floor	Stone with mortar/ Burnt Brick Wall	Concrete Roof	
Vazhakkala	46.5	85.5	80.5	3.14
Kochi (M Corp)	41.8	87.4	70.4	2.12
Kalamassery	40.8	85.0	76.5	1.98
Thiruvankulam	37.1	86.6	71.8	1.54
Maradu	37.6	82.6	71.5	0.47
Kakkanad	41.0	78.0	75.4	-0.01
Varappuzha	25.4	86.6	68.5	-0.07
Thrippunithura	42.7	77.2	74.5	-0.13
Eloor	25.5	86.5	66.4	-0.30
Cheranallur	33.6	79.5	72.9	-0.66
Kadamakkudy	22.0	88.6	60.6	-0.70
Elamkunnapuzha	21.5	88.1	55.2	-1.44
Njarackal	23.3	87.0	55.1	-1.56
Mulavukadu	21.7	87.4	50.3	-2.11
Puthuvype	19.0	88.5	48.5	-2.29

Source: Calculated from HH series data, Census 2011.

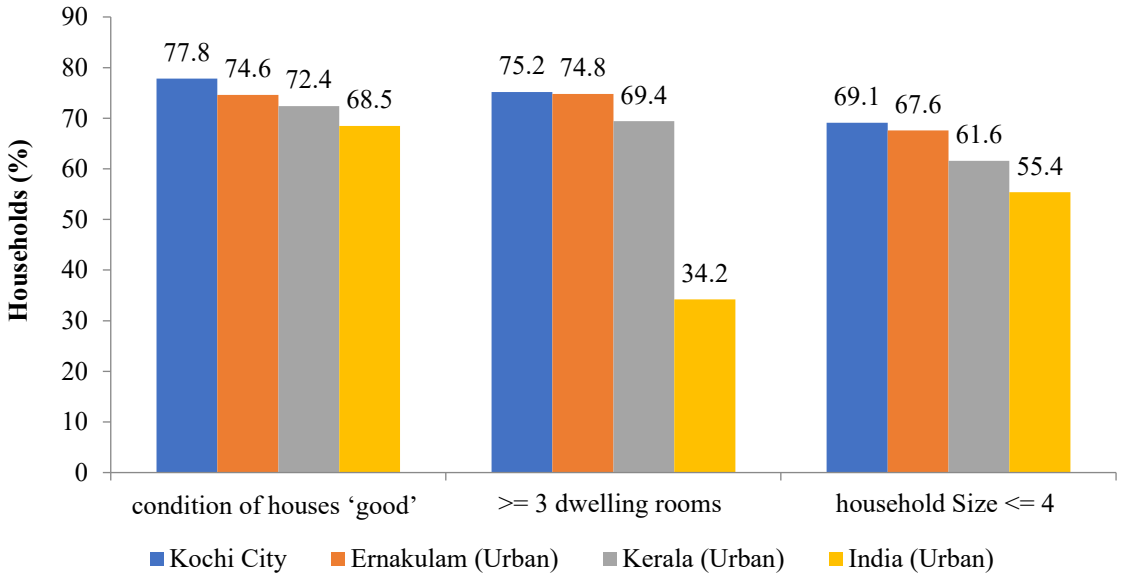
Njarackal, Elamkunnapuzha, Puthuvype along with the islands of Mulavukadu and Kadamakkudy have low flooring and roof materials compared with the rest of the city (Table 4.1). About 50.2 percent of houses with mosaic and tile flooring are in the mainland of Ernakulam. In terms of the material used for the wall, most of the constituents of the city have a consistent figure close to the city average indicating that most of the houses in the city are made of wall material with stone with mortar/ burnt brick (Table 4.1).

A micro-level analysis of the 'physical structural quality index' suggested that the overall higher figure of the city is due to the superior structural quality of houses in Vazhakkala census town (as per 2011 status) which have now become part of Thrikkakara municipality and also in the statutory towns of Kochi Corporation and Kalamassery (Table 4.1). Thiruvankulam and Maradu in the south also have better housing structures compared to other parts of the city. Alternatively, Elamkunnapuzha, Mulavukadu, Njarackal, and Puthuvype located in coastal areas have a poor physical structural quality of houses (Table 4.1).

4.3 Better living conditions

In terms of households that are reported as houses with good conditions for living, the overall scenario of Kochi is marginally better compared to all urban areas of the district. The Kochi city with 77.8 percent of households reported that the houses they live in are of 'good' condition with 3 percent higher than the overall urban areas of Ernakulam (Fig 4.2).

Figure 4.2: Households with better living conditions in Kochi in comparison to the urban areas of Ernakulam, Kerala, and India



Source: Calculated from HH series data, Census 2011

This higher percent status is mainly attributed to a higher percentage score in some pockets of the city especially in areas like Kalamassery, Kakkanad, and Vazhakkala in the eastern part of the city with a much better percent livable housing condition than many other parts of the city. Thrippunithura Thiruvankulam and Maradu municipal regions in the south also have a higher percentage than the city average. Understandably, the low-lying and waterlogged area in the villages situated in the coastal area namely Kadamakkudy, Mulavukadu, and Puthuvype has below average housing conditions in terms of livable houses. The households having 3 or more dwelling rooms explain the adequacy of living space and also the independence of the household members. Traditionally, most of the households in Kerala have given the primary emphasis on constructing beautiful houses with adequate living space. The three or more dwelling rooms are therefore

highest in Kerala compared to the all-India figure both in rural and urban areas. The percentage of households with three or more houses is about 75 percent in the city (Fig 4.2). The low gap with that of the district figure indicates that there is consistency in every level of aggregation.

Table 4.2: Households with better living conditions, 2011

Area Name	Percent Households			Living condition Index
	Condition of houses as 'good'	>= 3 dwelling rooms	Household Size <= 4	
Thiruvankulam	80.6	82.1	72.0	3.50
Vazhakkala	83.1	81.1	70.4	3.06
Thrippunithura	81.9	76.8	73.5	2.86
Kalamassery	84.2	78.0	68.4	1.65
Maradu	78.7	80.0	68.9	1.39
Kakkanad	82.4	73.9	70.7	1.09
Cheranallur	75.2	80.1	69.2	0.91
Eloor	76.6	76.8	70.1	0.60
Varappuzha	74.3	76.8	68.5	-0.42
Kochi (M Corp)	77.6	73.2	69.3	-0.50
Kadamakkudy	67.1	80.1	67.4	-1.24
Njarackal	74.4	75.1	65.7	-1.94
Mulavukadu	71.2	75.8	65.9	-2.25
Elamkunnapuzha	70.0	77.9	64.7	-2.36
Puthuvype	66.3	67.0	63.8	-6.34

Source: Calculated from HH series data, Census 2011.

Among the constituents of the city area the highest figures in terms of three-plus number of dwelling rooms are reported in Thiruvankulam in the south and Vazhakkala in the east (Table 4.2). Cheranallur, Kadamakkudy towards the north, and Maradu in the southern part of the city are the other areas where there is a significantly higher number of households with three-plus dwelling rooms (Table 4.2). Puthuvype in the coastal part of the city has the lowest percentage with only 67 percent of households having three or more dwelling rooms (Table 4.2). The corporation area of the city also falls below the average figure. Though the 73.2 percent figure is close to the city average of 75.2 percent the two percent difference is significant as the number of households is very high in the corporation compared to the rest of the areas of the city. The low figure in the city can also be attributed to the fact that there are a large number of households residing in houses with two or fewer dwelling rooms as a cheaper option for accommodation. In terms of households with 4 or fewer members, the average figure for the city is 69.1 percent (Table 4.2). This is again higher compared to the urban areas of the district as a whole. Households with small family sizes have less pressure of occupancy and lead to having a better living environment.

An overall 'housing condition index' based on the sum average of the standardized score (z score) of the percentage of households with the condition of houses as 'good', three or more dwelling rooms and percentage of households with four or less members revealed that Thiruvankulam, Vazhakkala, Thrippunithura, Kalamassery, Maradu, and Kakkanad are the areas having a better living condition than the municipal corporation area. From this dimension also, the island areas and coastal areas have remained far behind the rest of the areas in Kochi.

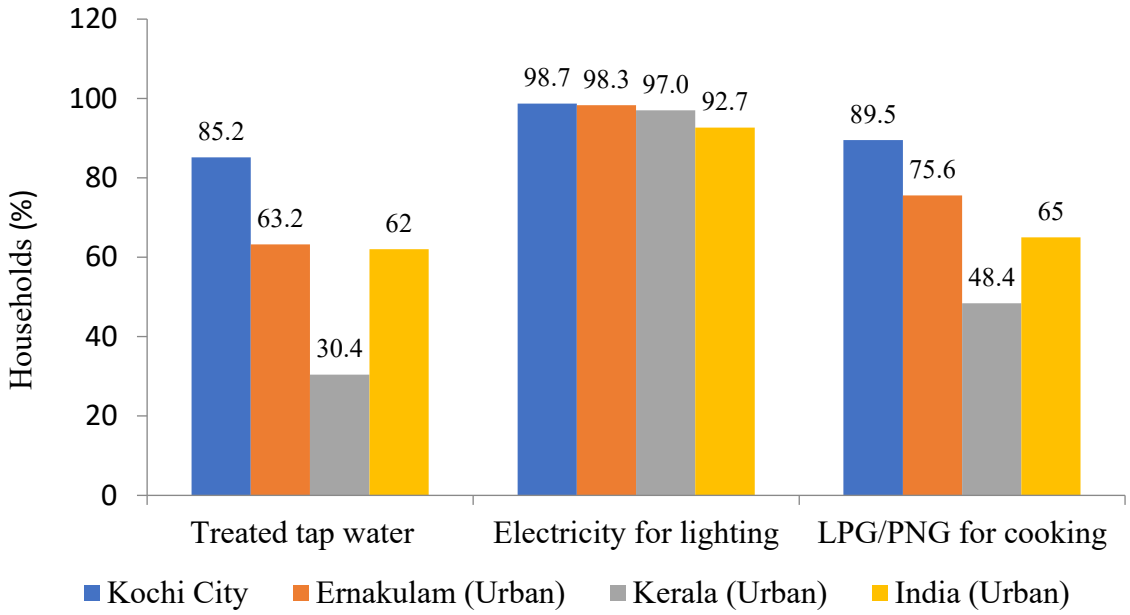
4.4 Access to Water, Electricity, and Gas

Households having access to safe drinking water, electricity for lighting, and access to cooking gas are analyzed to understand the wellbeing of households in terms of health and pollution-free environment. Treated water supply is essential for households to prevent the occurrence of water-borne diseases. Similarly, access to electricity and LPG gas is an indicator of access to cleaner energy. In terms of households with electricity for lighting, Kerala has the highest percentage among all the states in India. About 97 percent of the city households have electricity access (Fig 4.3).

4.4.1 Water Supply in the City

The primary source of water in Kochi city is the Periyar river located in the northern part of the city. The water treatment plant located in Aluva is the main source of treated water supply to the city with an installed capacity of 225 MLD and it serves the municipal corporation, four municipalities, and 27 adjoining panchayaths (Kochi Municipal Corporation, 2011). Though Kerala is known to have better performance in many socio-economic sectors compared to the rest of the country, the data indicates that it is lacking in ensuring treated or quality water supply to its city households. Only 30.4 percent of households residing in urban Kerala have access to the treated water supply (Fig 4.3). The urban area of Ernakulam has the highest percent of 63.2 among all districts followed by Palakkad and Thiruvananthapuram (Appendix 4.1). As per census figures, the Municipal Corporation area along with the coastal and other island areas in the city has the highest percentage of access to treated water supply with more than 95 percent of households having access to treated water supply in these areas (Table 4.3).

Figure 4.3: Households with safe drinking water, electricity, and cooking gas in Kochi in comparison to the urban areas of Ernakulam, Kerala, and India



Source: HH series data, Census 2011.

Though the piped connections in these areas are high in numbers, these places do not receive adequate water supply in reality, many households are dependent on other sources of water (Kuncheria, 2017; Vaidyanathan & Nathan, 2020). About 40 percent population was observed to use open wells and bore wells for their daily needs of water (Kuncheria, 2017). While some residents may have the option of wells in their premises to cater to their needs, others who are at the far end of the water distribution networks sourced in Aluva and Muvattuppuzha have to face frequent water shortages. Table 4.3 depicted Kalamassery in the northeast, Thrippunithura in the south, Kakkanad, and Vazhakkala in the eastern part of the city are having about 60 percent of the households with the supply of treated water, which is much below the average figures for Kochi City Region. Thiruvankulam, a census town adjacent to Thrippunithura municipality, has the lowest percent of 21.6 percent of households with access to the treated water supply (Table 4.3). The adjoining municipal town of Thrippunithura also shows only 58 percent of households with access to the treated tap water supply (Table 4.3). The scarcity of water in the city can be assessed from the fact that bottled water and water tanks are sourced from far of places and even from other adjoining districts of the state (Giri, 2019). The water crisis in the city is mainly driven by greater

demand due to population increase, fluctuations in rainfall patterns, weak supply infrastructure, pollution of water bodies, depleting groundwater, and salination (Vaidyanathan & Nathan, 2020).

Table 4.3: Households with safe drinking water, electricity, and cooking gas within the city of Kochi (2011)

Area Name	Percent Households			Overall Index for Water, Electricity and Cooking Gas
	Treated tap water	Electricity for lighting	LPG/PNG for cooking	
Kochi (M Corp)	96.1	99.2	92.6	3.37
Maradu	91.1	99.0	88.8	2.22
Cheranallur	83.8	98.8	88.3	1.61
Mulavukadu	98.8	97.6	87.8	1.19
Eloor	68.2	99.0	88.2	1.04
Vazhakkala	59.3	99.3	88.8	1.00
Kalamassery (M)	58.7	99.2	86.4	0.42
Thrippunithura (M)	58.0	98.2	90.6	0.35
Elamkunnapuzha	97.5	97.0	84.6	0.00
Puthuvype	98.8	95.5	85.7	-1.00
Kadamakkudy	96.0	97.5	75.9	-1.35
Kakkanad	62.4	98.3	79.2	-1.58
Njarackal	90.7	95.7	83.4	-1.66
Varappuzha	83.4	97.4	75.8	-2.04
Thiruvankulam	21.6	98.3	78.7	-3.58

Source: Calculated from HH series data, Census 2011.

4.4.2 Electricity for lighting

Households in Kochi Corporation, Eloor, Kalamassery, Vazhakkala, and Maradu have a near cent percent while Njarackal and Puthuvype in the coastal region are the least privileged areas in terms of access to electricity. The low gap in the urban area of the district and the city region show that there is a consistency in access to electricity throughout the state (Table 4.3).

4.4.3 LPG for cooking

However, in terms of access to LPG, the data revealed that the figures considerably vary across the city, district, and state. In overall urban Kerala, only 48.4 percent of households have LPG connections. Compared to this, figures for the district and the city are substantially high with 75.6 and 89.5 respectively (Table 4.3). Within the city, Kochi Corporation and Thrippunithura Municipality have the highest number of LPG connections with 92.6 and 90.6 percent of households with LPG connections (Table 4.3). Varappuzha and Kadamakkudy in north Kochi have the least LPG connections with 75.8 and 75.9 percent respectively (Table 4.3). The Kakkanad in the east which is a part of Thrikkakara Municipality and Thiruvankulam in the southern part of the

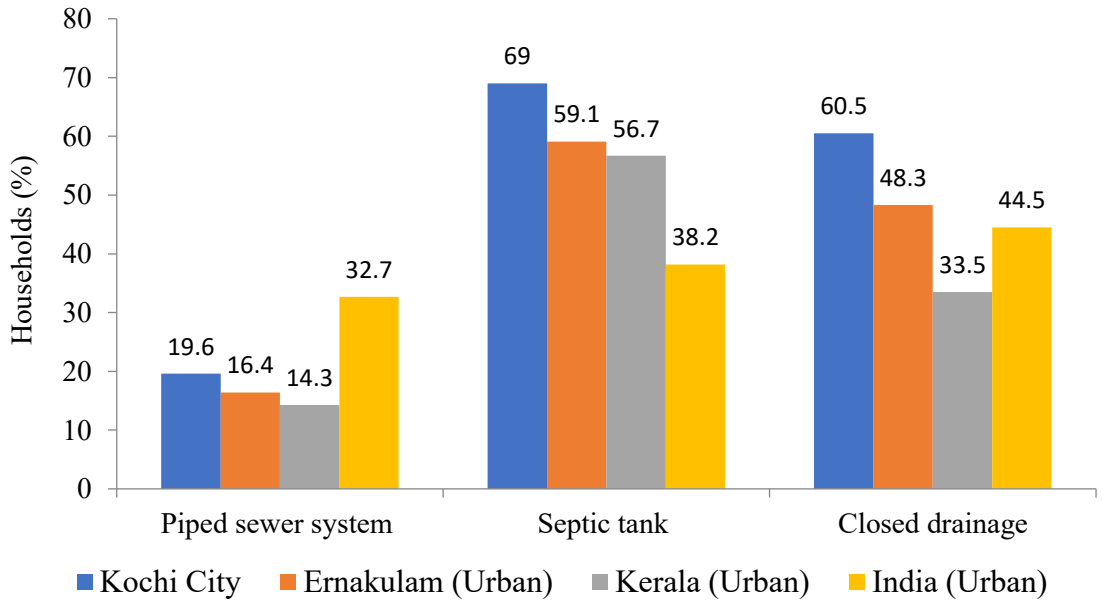
city was also lagging with 79.2 and 78.7 percent households with LPG connections compared to the overall city figures (Table 4.3).

The overall index for access to treated tap water, electricity, and LPG indicates that corporations and Maradu are having better access as compared to other areas. Based on the combined index, Varappuzha in the north and Thiruvankulam in the southeast of the city has the poorest access to these amenities.

4.5 Sewer System and Drainage

One of the major concerns of the towns in Kerala is that the local bodies do not give adequate priority in providing sanitation through the 'piped sewer systems' and 'drainage facility'. The state has not given enough priorities in scientific sanitation practices and effectively handling the dumping of waste. This has resulted in major health and environmental challenges especially in urban areas of the state. Improving sanitation has a significant role in leading a healthy life both for the households and the society.

Figure 4.4: Households with latrine facility and drainage in Kochi in comparison to the urban areas of Ernakulam, Kerala, and India (2011)



Source: HH series data, Census 2011.

As per the 2011 census data, Kochi city has 19.6 percent households having piped sewerage system as against only 16.4 percent of the households living in urban areas of the district (Fig 4.4). Most

of the households in the urban areas of the district practiced using the septic tank-based sewerage system (Fig 4.4). Health and environment wise the ideal system in cities and their suburbs are to have piped sewer systems maintained by the public work departments. This is because the houses are close to each other in cities and the use of septic tanks or pit latrines may lead to water contamination and also foul odors caused by poor maintenance. However, maintaining piped sewerage system in areas outside the city is not economically viable because of the dispersed settlement pattern. In such areas, the households generally use a septic tank-based latrine system. This needs to be maintained at proper intervals to avoid contamination of surface water sources and the environment.

A city constituent-wise comparison of the availability of piped sewerage systems shows that Vazhakkala and Maradu are better than other areas in the city. The western part of the city, especially Puthuvype and Kadamakkudy has an astonishingly low figure of 1.5 and 4.9 percent respectively (Table 4.4). It can be noted that almost all rural part of the city which are included in the structural plan has a substantially low percentage of household having piped sewerage system.

Table 4.4: Percentage of households with latrine facility and drainage (2011)

	Percent Households			
Area Name	**Flush Latrine connected to Piped sewer system**	**Flush Latrine connected to Septic tank**	**Closed drainage**	**Cleaner housing environment Index**
Cheranallur	14.6	76.0	44.8	1.22
Elamkunnapuzha	11.4	42.7	17.6	-4.05
Eloor	15.7	70.1	50.3	1.12
Kadamakkudy	4.9	68.0	17.4	-2.53
Kakkanad	20.7	62.2	53.8	1.27
Kalamassery (M)	13.1	76.4	58.9	1.88
Kochi (M Corp)	22.9	71.7	73.9	3.68
Maradu	25.1	64.4	48.3	1.77
Mulavukadu	15.9	62.0	29.3	-0.87
Njarackal	10.5	55.4	31.9	-2.10
Puthuvype	1.5	42.0	20.1	-5.34
Thiruvankulam	9.3	76.7	49.8	0.84
Thrippunithura (M)	17.8	67.5	47.1	0.98
Varappuzha	8.9	67.6	29.4	-1.30
Vazhakkala	28.3	66.5	65.6	3.44

Source: Calculated from HH series data, Census 2011.

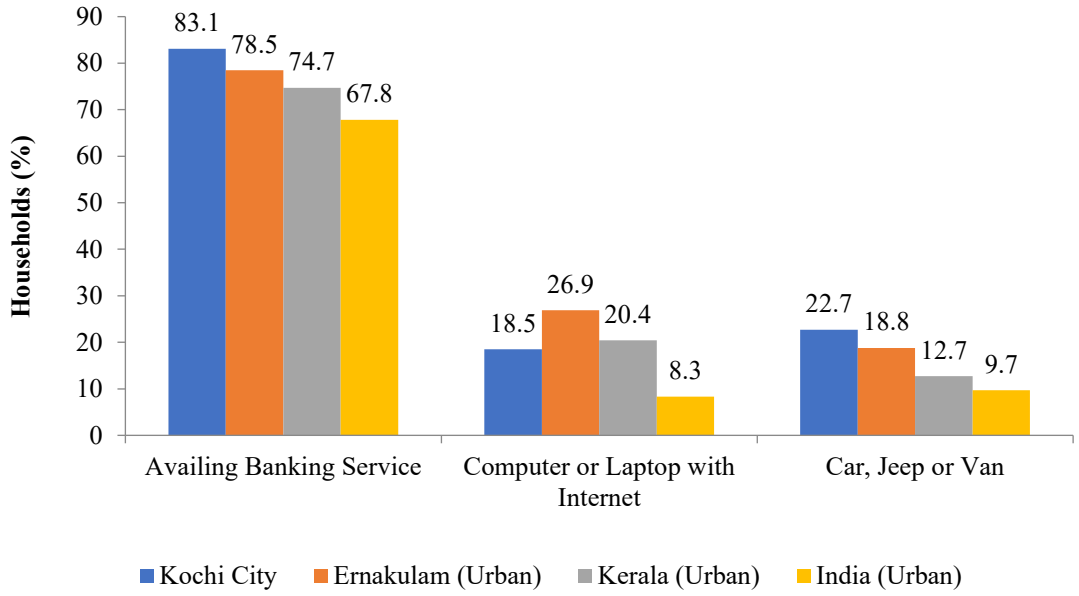
Adequate attention to improving the sanitation facilities in this area is very important as these areas have large water bodies which can be contaminated resulting in a serious health hazard. A city like Kochi needs to put a lot of emphasis on providing the best sanitation facilities. One of the reasons

for the ever-increasing mosquito breeding in Kochi can be attributed to the poor sanitation facility. The percentage of households with wastewater outlets connected to a closed drainage system also is not adequate for a city like Kochi which is ever-expanding. The overall figure for the households having closed drainage facilities in the city stood at 60.5 percent (Table 4.4). In comparison with the urban areas of the district as a whole, this figure is about 12 percent more, which is mainly due to the significantly higher figures of the corporation area. All other parts of the city have much less percentage on this account. Again, it can be seen that the traditional rural belt that became part of the city is lacking significantly in this aspect. The waste water outlet connected to the closed drainage is significantly lower in Elamkunnapuzha, Kadamakkudy, and Puthuvype compared to the rest of the city area with figures as low as 17.6, 17.4, and 20.1 respectively (Table 4.4). As pointed out earlier, these are the regions, which are in coastal and island areas with low-lying land. Undiscerning the conversion of such low-lying lands has resulted in surface drainage problems (S. Nair, 2010). It is important to impose strict laws in zoning and land developments to overcome such drainage problems in the future. As the urban drainage issues are specialized technical subjects, adequate expertise has to be developed and required institutional assistance for urban drainage management (S. Nair, 2010).

4.6 Banking Facilities and Assets

Another three sets of indicators that have been analyzed in the context of assessing the quality of urban living in the cities of Kerala are the “households availing banking facility”, “access to computers or laptops with internet facility”, and the “households having four-wheelers”. The spatial location-wise figures depicted the presence of affluent classes within the city region. In the urban area of Kerala, about 75 percent of households’ avail banking facilities (Fig 4.5). Urban areas in Ernakulam district are even better with 78.5 percent of households availing banking facilities with the city region alone having 83 percent households with banking facilities (Table 4.5). Njarackal, Elamkunnapuzha, and Varappuzha all of them being in the coastal and water-locked area have the highest number of households with access to banking facilities. Although in these regions commercial establishments and offices are less in comparison with other regions, the higher figures compared to other regions can be viewed as for receiving benefits of various welfare schemes of the government programs.

Figure 4.5: Households with Banking facility and selected assets in Kochi in comparison to the urban areas of Ernakulam, Kerala, and India



Source: HH series data, Census 2011.

Table 4.5: Households with Banking facility and selected assets within the city of Kochi (2011)

Area Name	Percent Households Availing Banking Service	Computer or Laptop with Internet	Car, Jeep, or Van	Index of banking Access and Assets
Cheranallur	82.9	10.3	16.6	-0.32
Elamkunnapuzha	91.6	4.6	7.0	-0.57
Eloor	82.9	9.5	13.7	-0.71
Kadamakkudy	75.0	3.7	5.9	-3.50
Kakkanad	77.4	20.1	29.2	1.28
Kalamassery (M)	80.0	19.1	28.1	1.47
Kochi (M Corp)	83.9	21.8	24.8	2.12
Maradu	85.2	13.0	17.7	0.51
Mulavukadu	67.8	5.1	6.4	-4.45
Njarackal	89.8	6.6	8.6	-0.45
Puthuvype	74.0	4.0	5.3	-3.69
Thiruvankulam	82.6	21.9	29.8	2.42
Thrippunithura (M)	87.3	23.6	27.4	3.16
Varappuzha	86.3	5.3	10.1	-1.04
Vazhakkala	85.0	25.1	35.4	3.77

Source: Calculated from HH series data, Census 2011.

Interestingly Mulavukadu, Puthuvype, and Kadamakkudy being in this region and also with fewer commercial establishments contradict this argument with figures as low as about 67.8, 74.0, and

75 percent respectively, much less than the city average of 83.1 percent. Households having computer or laptop with internet facility is also analyzed to see its variation across different locations. Though the data suggests that in the entire urban area of Kerala 20.4 percent of households have computers or laptops with the internet (Table 4.5). The figures for the district with about 27 percent households are better on this ground compared to the state as a whole. However, when the city region is compared with the overall urban area of the district figures the city has performed poorly. The overall low figures in the city are due to the substantially low figures in a certain area of the city, especially in the coastal and other island water-locked regions. Vazhakkala and Kakkanad being the IT hub and the center of other commercial zones have fared better than the overall city figures. Thrippunithura and Thiruvankulam in the south also have a better percentage of households having computers with internet facilities (Table 4.5).

In terms of households owning a car, jeep or Van urban are of Kerala has only 12.7 percent share while the urban area of Ernakulam district has about 19 percent households owning a four-wheeler. Within the urban area of the district, the city-region share is 22.7 percent (Table 4.5). Here again, as pointed out in the case of internet access, the households having four-wheeler ownership is also shown a similar pattern within the city. The eastern parts of the city being the center of more affluent residential societies and commercial centers have the highest percentage of households with four-wheelers (Table 4.5). The Kakkanad and Vazhakkala area has 29.2 and 35.4 percent of households with four-wheelers (Table 4.5). Kalamassery in the northeast and the southern region of Thrippunithura and Thiruvankulam also reported 28.1, 27.4, and 29.8 percent respectively in terms of four-wheeler access (Table 4.5). The area with relatively poorer households like Njarackal (8.6), Elamkunnapuzha (7.0), Puthuvype (5.3), Kadamakkudy (5.9), and Mulavukadu (6.4) are the areas where the households owning a car, van or jeep was the least among the city constituents (Table 4.5).

4.7 A Field-Based Evaluation of Socio-Economic and Housing Characteristics of Kochi

A household-level field survey is conducted to analyze some of the key socio-economic, household amenities, and other neighborhood factors of urban expansions. The data is collected from different parts of the city using a grid-based random sampling (Fig 4.6) keeping in mind the spatial coverage of the study area. The selection of the grid for the survey was based on the built-up density of the

area. The basic purpose of the survey was to identify the local driving factors that could influence the urban change and identify some of the striking variables and include it in the model as an input. An attempt is also made to analyze this data at an aggregated level by the administrative unit to capture the spatial disparities in the select indicators. The municipal corporation, adjoining municipalities, and census towns symbolize the "central business district (CBD)", the satellite towns, and the urban villages that are coming under the planning area. It is to be noted that the status of many existing census towns in the city planning area has changed to independent municipalities as per the decision of the government of Kerala in 2010. For example, Eloor which was classified as a census town in 2011 is now a municipality. The census towns of Vazhakkala and Kakkanad are now part of the Thrikkakkara Municipality. Similarly, Maradu was a *Grama Panchayath* and it is upgraded to the level of a municipality in November 2010. Thus the Kochi city at the time of the primary survey consists of the Kochi municipal corporation, five municipalities of Eloor, Kalamassery, Thrikkakkara, Thrippunithura, and Maradu, and eight census towns of Varappuzha, Elamkunnapuzha, Njarackal, Puthuvype, Cheranallur, Kadamakkudy, Mulavukadu, and Thiruvankulam.

4.7.1 Sample Selection

For spatial analysis of a city using field survey data, the sample coverage of the city is important. Therefore, the study region is first broken into a set of strata or grids. Thereafter a grid-based random sampling is used for the collection of the data from different parts of the city. The criteria for the best sampling location are based on the spatial characteristics of variability in the data. Since values of variables in one location tend to have a strong relationship with the values of nearby points, samples collected only from one location can provide redundant information and will not capture the geographical variation (Rogerson, 2015). The criteria used to select the number of grid and the households in this study are as below

(i) The total area of the study area is divided into square grids of 2000m by 2000m in size

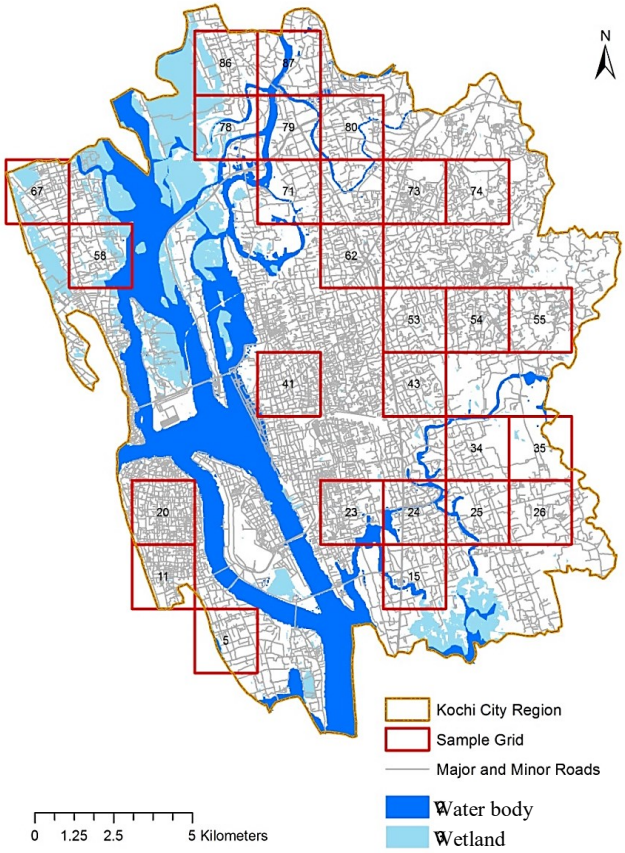
(ii) A total of 26 grids are selected based on the built-up in each administrative unit and geographical location of grids keeping the coverage of the entire city in mind.

(iii) No samples are collected from the peripheral grid if less than 50 percent area does not come under the study area.

(iv) A total of 312 households from 26 grids (each grid 12 households) are collected at random.

Of the total 312 sample households, six of them are dropped after data cleaning due to mismatching of the geographical coordinates. The sample location map is given below and the table showing the number of samples, administrative units along with the grid number are as per Appendix 5.1.

Figure 4.6: Sample location in Kochi City Region (KCR)



A comparison of selected indicators for three different administrative units has been carried out to examine the disparities of characteristics across the cross-sections. Of the total 306 households surveyed 83 households (27.1 percent) are from the grids that are part of Kochi Corporation, 129 households (42.2 percent) are from the municipality area and the rest of the 96 households (30.7 percent) belongs to census towns as per the administrative status of the towns at the time of the field survey (April/May 2018) (Table 4.6).

Table 4.6: Administrative unit wise sample households

Constituents	Sample Households	Percent
Corporation	83	27.1
Municipality	129	42.2
Census Towns	94	30.7
Total	306	100.0

Source: Field survey data (2018).

4.7.2 Socio-Religious Composition of Households

The religious and social group composition among the sample households is presented in Table 4.7. Among the households surveyed in the corporation area, 42.2 percent of households were Hindu, 34.9 percent Muslim, and 22.9 percent Christian (Table 4.7). The pattern of religious composition in the Municipal area was also similar to that of the corporation with 55.0 percent surveyed households being Hindu followed by Muslims and Christians with 26.4 percent and 18.6 percent respectively (Table 4.7). The religious composition of the households in the Municipalities is found to be similar to the composition of the religion of Kerala.

Table 4.7: Distribution of religion and social groups

Socio-religious categories	Corporation	Municipality	Census Town	Total
		Religion		
Hindu	35 (42.2)	71 (55.0)	49 (52.1)	155 (50.7)
Muslim	29 (34.9)	34 (26.4)	8 (8.5)	71 (23.2)
Christian	19 (22.9)	24 (18.6)	37 (39.4)	80 (26.1)
Total	83 (100)	129 (100)	94 (100)	306 (100)
		Social Group		
General	29 (34.9)	58 (45)	30 (31.9)	117 (38.2)
OBC	52 (62.7)	63 (48.8)	56 (59.6)	171 (55.9)
Others	2 (2.4)	8 (6.2)	8 (8.5)	18 (5.9)
Total	83 (100.0)	129 (100.0)	94 (100.0)	306 (100.0)

Note: Figures in parentheses are percentages
Source: Field survey data (2018).

In the case of census towns, the Muslim households are found to be significantly less in comparison to Hindus and Christians with only 8.5 percent of households belonging to that category (Table 4.7). Close to 40 percent of the households surveyed in the census towns were Christians. Geographically as verified from the census, 2011 the peripheral areas in the western and north western areas have a larger percent of the Christian population, in some areas higher than the Hindu Population. Muslim households in these areas are very low. Though Hindus are comparatively higher in the northeast and eastern parts like Kalamassery and Kakkanad, Muslim

households are also significantly high. Similarly, the Hindu population is highest in areas towards the south and south-east of Kochi in places such as Thrippunithura and Thiruvankulam. Among the surveyed households when calculated by social groups, it is found that 38.2 percent were from the general category, 55.9 percent OBC, and 5.9 percent households were 'Others' which is SC/ST combined (Table 4.7). The OBC was dominant in all the three town categories with a municipal corporation having 63 percent OBC's followed by 60 percent in census towns and 48.8 percent in other municipal towns. Though the OBC census is not available for general use, as per National Sample Survey Organisation (NSSO), Kerala has about 63 percent OBC population (Table 4.7).

4.7.3 Education

The education level of the head of the family is compared among the administrative constituents of the city. The pattern of education in both core and peripheral areas is similar to that of the district and the states. Less than two percent are reported to be illiterate in the Kochi city region. In the corporation area, only one head of household reported being illiterate while 15.7 percent said they are primary and middle educated (Table 4.8). About 64 percent possessed secondary and higher secondary education while 6 percent were graduates or above and 13.3 percent heads of households in the corporation area reported diplomas and other professional courses as their level of education (Table 4.8). The pattern of education in the municipality and the census town area is observed to be identical with a significant change in the graduation or above category compared to the corporation area. Two heads of households in each of these town constituents reported they are illiterate while about 21 percent said they are primary and middle educated (Table 4.8). In the Municipality area close to 60 percent are secondary or higher secondary educated. The percent of graduates and above in census town appear to be higher than its corporation and municipality counterparts.

In terms of all members of the households, less than 1 percent reported being illiterate in the city core area and the census towns, while 1.6 percent members were illiterate in satellite towns of the city. The primary educated in the city remained 17 to 23 percent people (Table 4.8). Though the secondary and higher secondary educated people remained dominant in all the town constituents of the city with 43 to 49 percent, the graduate and above category was also found to be higher with 21 to 24 percent in all the city area (Table 4.8). Those who are professionally qualified people range from 9 to 13 percent in the city area. It is to be noted that the percent in educated level includes people who are currently enrolled as well (Table 4.8).

Table 4.8: Educational attainment of the head of households and household members

Level of Education	Corporation	Municipality	Census Town	Total
Head of Households				
Illiterate	1 (1.2)	2 (1.6)	2 (2.1)	5 (1.6)
Primary and Middle	13 (15.7)	27 (20.9)	20 (21.3)	60 (19.6)
Secondary and HS	53 (63.9)	77 (59.7)	48 (51.1)	178 (58.2)
Graduation and Above	5 (6.0)	15 (11.6)	17 (18.1)	37 (12.1)
Professional Courses	11 (13.3)	8 (6.2)	7 (7.4)	26 (8.5)
Total	83 (100.1)	129 (100.0)	94 (100.0)	306 (100.0)
Household Members				
Illiterate	3 (0.9)	5 (1.6)	2 (0.8)	10 (1.1)
Primary and Middle	61 (17.7)	73 (22.9)	41 (17.2)	175 (19.4)
Secondary and HS	167 (48.5)	139 (43.6)	109 (45.8)	415 (46.1)
Graduation and Above	82 (23.8)	68 (21.3)	55 (23.1)	205 (22.8)
Professional Courses	31 (9)	34 (10.7)	31 (13)	96 (10.7)
Total	344 (100)	319 (100)	238 (100)	901 (100)

Note: Figures in parentheses are percentages
Source: Based on field survey data (2018).

4.7.4 Economic Characteristics

Among the households surveyed 22.2 percent declared self-employment or business as their major source of income while 45.8 percent reported their main income is from wage/salaried jobs (Table 4.9). Similarly, 25.2 percent of households mainly earned from casual works while 6.9 percent reported remittance from family members and pension constituted their major source of income (Table 4.9).

Table 4.9: Major Sources of Income classified by the type of administrative unit of the city

Source of Income	Corporation	Municipality	Census Town	Total
Self-Employment / Business	16 (19.3)	35 (27.1)	17 (18.1)	68.0 (22.2)
Wage / Salaried Job	44 (53.0)	59.0 (45.7)	37 (39.4)	140 (45.8)
Casual Work	17 (20.5)	27 (20.9)	33 (35.1)	77 (25.2)
Others (Pension/Remittance)	6 (7.2)	8 (6.2)	7 (7.4)	21 (6.9)
Total	83.0 (100)	129 (100)	94.0 (100)	306.0 (100)

Note: Figures in parentheses are percentages
Source: Based on field survey data (2018).

In the corporation area, 53 percent of households declared that their main earning is from jobs while somewhat identical percentages of 19.3 and 20.5 percent were reported in self-employed and casual work categories (Table 4.9). In the satellite town areas, the percent of self-employed/business categories were higher than the casual work category, the former being 27.1 percent and the latter with 20.9 percent Table 4.9). However, in the case of census towns, the

salaried source of income was only marginally higher than the casual work category with figures of 39.4 percent and 35.1 percent respectively Table 4.9). The source of income from the self-employed category was substantially less in comparison to the other two major categories of salaried and casual work Table 4.9).

Table 4.10: Monthly household income and expenditure

	Monthly Income (In Rupees 000)			Monthly expenditure (In Rupees 000)		
Type of Town	**Mean**	**Standard Deviation**	**C.V (%)**	**Mean**	**Standard Deviation**	**C.V (%)**
Corporation	36.0	19.1	53.1	27.8	24.2	87.0
Municipality	33.3	30.3	91.0	20.9	9.3	44.7
Census Town	30.8	12.8	41.6	23.7	12.1	50.9
Total	33.3	23.2	69.7	23.6	15.7	66.5

Note: C.V means Coefficient of Variation
Source: Based on field survey data (2018).

Households who reported pension or remittance from family members were close to each other between all the administrative categories ranging from 6.2 percent in municipal areas to 7.2 and 7.4 percent in the city core and the census towns Table 4.9). The average monthly household income in Kochi city is found to be around 33.3 thousand rupees and the expenditure as reported is 23.6 thousand rupees (Table 4.10). The average income, as well as the expenditure in the Corporation area, is observed to be higher among all town categories with 36 thousand and 27.8 thousand rupees respectively (Table 4.10). In the case of satellite town areas, the average income of households where reported little over 33 thousand while the expenditure was close to 21 thousand rupees (Table 4.10). The average income as reported by the household is less in census town areas however the expenditure is relatively higher compared to the satellite town areas. This is understandable as there are large numbers of commercial and other tertiary activities in the corporation area compared to the places outside the corporation limits except for some commercial centers in the eastern side of the city region. While the reason for such trends may also be attributed to more formal jobs with a relatively higher salary in statutory towns compared to census towns. The higher expenditure in corporation area may be associated with living costs both in terms of food and non-food expenditure. Similarly, the relatively higher expenditure in census towns may be attributed to commuting costs as the place of jobs are usually away from the residences. The higher coefficient of variation in the income of municipal towns indicates that there are more

income disparities among the households in the municipality than in the corporation and census town areas. The expenditure is relatively consistent in municipalities and census towns whereas the dispersion in expenditure is found to be higher in corporation areas. The average income of households in census towns is found to be less than that of the city core and satellite towns with figures close to 31 thousand rupees and also it was more consistent compared to other categories. The average expenditure among the surveyed households in census towns is found to be rupees 23.7 thousand higher than the municipality area (Table 4.10).

4.7.5 Mode of Traveling by HH Members for Work

Among the working members of families, the preferred mode of transport for work in the corporation area is the bus, two-wheelers, cycle, and pedestrian mode. 39.1 percent of people used either cycle or by walk to reach their work place, while 22.2 percent used two-wheelers and 21.4 percent used bus to reach their work place (Table 4.11). In municipality towns, 39.1 percent and 33 percent respectively used walk\cycle and motorized two-wheelers as the mode for reaching to the work place (Table 4.11). The higher number of workers commuting by walk or bicycle is perhaps due to the higher number of retail trades and low-skilled establishments which are located generally close to residences. Public transport bus was the third option with 12.2 percent (Table 4.11). About 8.7 percent of people used cars for commuting and 7 percent of people used other modes of transport such as metro, train, and ferry (Table 4.11).

Table 4.11: Mode of travel for work

Mode of transport	Corporation	Municipality	Census Town	Total
Bus	25 (21.4)	14 (12.2)	19 (21.6)	58 (18.1)
Car	9 (7.7)	10 (8.7)	9 (10.2)	28 (8.8)
Two-Wheeler	26 (22.2)	38 (33.0)	40 (45.5)	104 (32.5)
Walk/Cycle	45 (38.5)	45 (39.1)	13 (14.8)	103 (32.2)
Others (Ferry/Metro/Train)	12 (10.3)	8 (7.0)	7 (8.0)	27 (8.4)
Total	117 (100)	115 (100)	88 (100)	320 (100)

Source: Based on field survey data (2018).

Table 4.12: Average time and cost of travel for work

Urban Body	Travel Time (minutes)	Cost of Travel (Rs)
Corporation	**39.2**	**38.8**
Municipality	**34.4**	**60.1**
Census Town	**37.0**	**68.0**

Source: Based on field survey data (2018).

In census towns, as many as 45.5 percent use motorized two-wheelers for commuting to work, while 21.6 percent of people use the bus for reaching the workplace (Table 4.11). In almost every town in Kerala public transport system is better compared to other cities in India. In Kochi also, the public transport service is one of the preferred modes for commuting. However, for the work-related journey, the majority of the people used bikes and people living nearby either uses pedestrian mode or cycles to reach their work destination.

The average travel time in the city core is found to be relatively higher with 39.2 minutes compared to municipality and census town areas whereas the cost of travel is found to be close to 39 rupees (Table 4.12). The higher time can partly be attributed to the traffic problems rather than the distance of the travel. Similarly, the cost of travel is less since about 43.6 percent of people use public transport systems or two-wheelers for commuting to their work destination (Table 4.11). The average time for commuting for workers in the municipality areas is found to be a little less than 35 minutes, whereas for census town it was found to be 37 minutes. In terms of cost of travel, census town reported 68 rupees per day while in municipal town the cost of travel was about 60 rupees (Table 4.11).

4.7.6 Housing Characteristics

The people in Kerala usually prefer living in independent houses irrespective of rural or urban areas. Though in the recent past there are several vertical living spaces created in various parts of the cities especially in places such as Kakkanad and Maradu, the majority of households still prefer having houses built in small and medium plot sizes (Table 4.13). To understand the price differentials between different town types, information on the price of houses and lands are collected. It can be seen that the size of the plots increases as we move away from the city center. The houses built in census towns have an average land area of about 14 percent, while in the corporation and municipality area, the plot size is substantially less as expected with a size of 4.2 and 6.7 cents respectively (Table 4.13). It is to be noted that the usual measurement unit of land in Kerala is in *cents* and it is approximately equal to 48.6 square yards. The higher coefficient of variation indicates that in the outskirts of the city, people have highly dispersed sizes of plots. The coefficient of variation in Table 4.13 indicates that dispersion in size of the plot is less observed in the case of the corporation area compared to other areas.

Table 4.13: Average land owned by type of town

Type of Town	Area of Land Owned (in Cents)			95 % Confidence Interval	
	Mean	*Standard Deviation*	*C.V (%)*	*Lower Bound*	*Upper Bound*
Corporation	4.2	2.7	63.7	3.6	4.8
Municipality	6.7	5.6	84	5.7	7.7
Census Town	13.8	16.2	117.4	10.5	17.2
Kochi	8.2	10.5	128.3	7.0	9.4

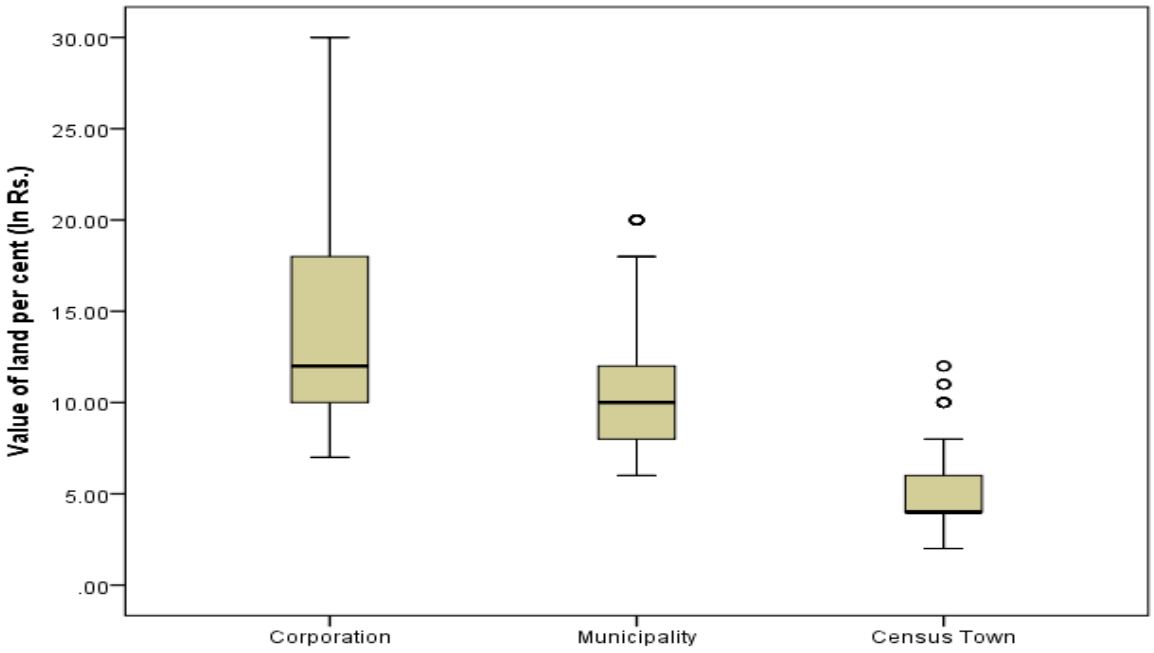
Source: Based on field survey data (2018).

Table 4.14: Average value of land by type of town

Type of Town	Land Value (percent in Lakhs rupees)			95 % Confidence Interval	
	Mean	*Standard Deviation*	*C.V (%)*	*Lower Bound*	*Upper Bound*
Corporation	13.8	4.6	33.4	12.8	14.8
Municipality	10.3	3.0	28.6	9.8	10.8
Census Town	5.1	2.0	40.0	4.7	5.5
Kochi	9.7	4.7	48.6	9.1	10.2

Source: Based on field survey data (2018).

Figure 4.7: Average land value percent (in thousands rupees) by type of town



Source: Based on field survey data (2018).

Similarly, the average price of the land is 13.8 lakhs percent incorporation area which comes out to be around 28.4 lakhs per 100 sq. yards (Table 4.14). The price of land was also high in the

municipality area with 10.3 lakhs percent (Table 4.14). In Census towns the price is observed to be little over 5 lakhs rupees. The anticipated value of houses is also ascertained to see the price differentials in the city center and the surrounding areas. While the prices in the corporation and adjoining municipal areas almost remained close to each other, in census towns it is substantially low. The reason can be associated with fewer infrastructures, relatively higher unskilled economic activities in areas close to wetland/paddy land areas, lack of adequate road transportation, and fewer housing amenities and resources in these areas compared to the corporation areas and statutory towns.

It is clear from figure 4.7 that the average land value below the median in each of the urban constituents is more consistent than the upper area indicating that there are highly dispersed values towards the higher side in all the urban areas although the average land values percent in municipality and census town is much less than that of the corporation areas. This shows that the disparity is more on the higher side than the lower side. There are a few outliers in the statutory as well as census towns. In city areas prices are generally high in areas which are near to the administrative offices and other service facilities.

4.7.7 Residential Price

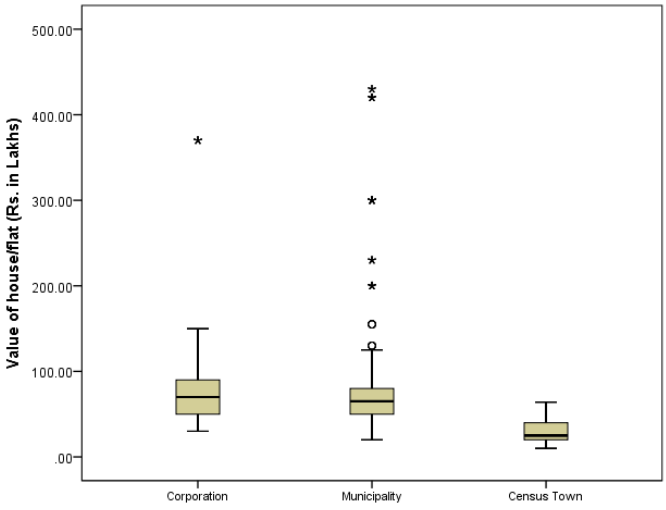
The value of houses is also ascertained to see the price differentials in the city center and the surrounding areas. While the prices in the corporation and adjoining municipal areas almost remained the same, the prices in census towns are found to be the least (Table 4.15). The reason can be associated with relatively less infrastructure and resources compared to the core areas of the city.

Table 4.15: Average housing price by type of town

Type of Town	Value of House (in Lakhs rupees)			95 % Confidence Interval	
	Mean	*Standard Deviation*	*C.V (%)*	*Lower Bound*	*Upper Bound*
Corporation	76.9	42.1	54.7	67.7	86.2
Municipality	75.7	56.8	75	65.7	85.7
Census Town	31.5	14.7	46.6	28.4	34.5
Kochi	62.5	48.2	77.1	57.0	67.9

Source: Based on field survey data (2018).

Figure 4.8: Average value of houses (in Lakh Rupees) by type of town



Source: Based on field survey data (2018).

From the box plot (Fig 4.8) it can be seen that the average value of houses in the corporation areas ranged from 25 lakhs to more than 1.5 crore rupees except for an outlier, however, it was between 50 to below 1 crore in most of the cases in municipality area and also the housing price has many outliers towards the upper side making the average housing price little over 75 lakhs rupees close to the average housing price in the corporation areas. The housing price distribution of census town was consistent with values concentrated around its average value of 31.5 lakh rupees (Table 4.15). The low housing value in these census towns is mainly because of the accessibility to the city core and also many of these areas are situated in low lands.

4.7.8 Physical Structure of Houses

About 95 to 96 percent of the building structure in Kochi city is permanent structures built with concrete materials while about 4 to 5 percent of houses were semi-permanent houses having a roof made with old traditional tiles laid on the wooden frame (Table 4.16). As evident from the rest of Kerala, an almost similar trend in physical housing structure is observed in all parts of the city area. No temporary structure was found in any of the surveyed households. Old traditional thatched roof houses are vanished not only from the corporation and other municipal towns but also from the census towns as people tend to remove the old structures and rebuild the houses with new permanent structures.

Table 4.16: Type of housing structure

Type of Town	Corporation	Municipality	Census Town	Total
Semi-Permanent	4 (4.8)	5 (3.9)	4 (4.3)	13 (4.2)
Permanent	79 (95.2)	124 (96.1)	90 (95.7)	293 (95.8)
Total	83 (100)	129 (100)	94 (100)	306 (100)

Note: Figures in parentheses are percentages
Source: Based on field survey data (2018).

4.8 Correlation Between Income and Housing Indicators

A correlation matrix between the selected set of variables of monthly income, land value, house value, age of the house, and houses with four or more rooms is obtained. The correlation is based on the aggregated value of grid-wise monthly average household income, average land value, average house value, percent houses with four or more bedrooms, and age of construction of houses. The correlation reveals that monthly household income is positively correlated with land value (0.643), house value (0.555), and the space of the houses (0.575) (Table 4.17). The monthly income and the structural age of the house are not significant and it is negatively correlated (-0.029) indicating that the households with new houses have relatively more income than the houses that are having old structures (Table 4.17). All these values are statistically significant at a 1 percent level of significance.

Table 4.17: Correlation among income and housing indicators

Variables	Monthly Income	Land Value	House Value	Age of House	Four plus bedrooms
Monthly Income	1	.643**	.555**	-.029	.575**
Land Value	.643**	1	.491*	.336	.491*
House Value	.555**	.491*	1	.298	.187
Age of House	-.029	.336	.298	1	.274
Four plus room	.575**	.491*	.187	.274	1

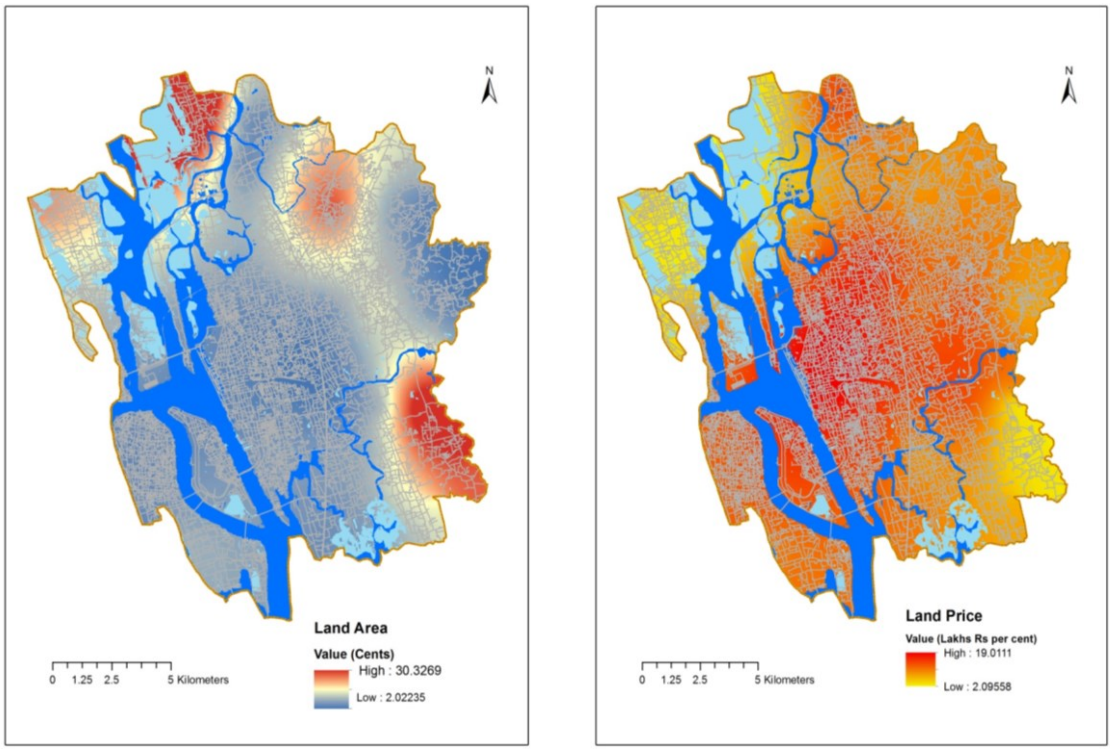
*Note: **. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).*
Source: Based on field survey data (2018).

4.9 Spatial Interpolation of Land Possession and Land Price

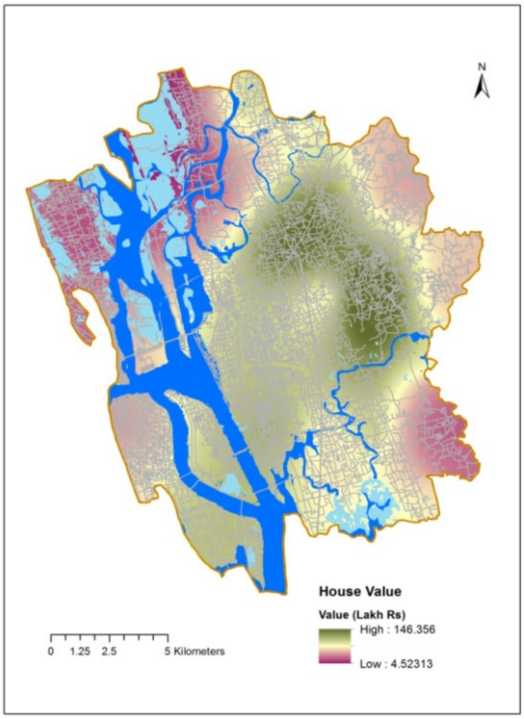
Spatial interpolation is used for creating a continuous surface based on the point/locational average value of various indicators. In other words, it predicts the values of raster cells based on limited sample data. Collecting data from each point within an area is very expensive and therefore the interpolated surface gives an understanding of the likely variation that occurs for a particular indicator or value in the neighborhood surface of a point based on all nearby points.

Map 4.1: Interpolated surface based on average land possession and land price in Kochi

Land Possession **Land Price**



Map 4.2: Interpolated surface of residential pricing



Source: Based on field survey data (2018).

"Inverse distance weighted (IDW)", spline and kriging are the most commonly used methods used for spatial interpolation in GIS analysis, and these types of interpolated surfaces are often called geo-statistical surfaces as it combines statistical interpolation techniques with spatial data. From the interpolated surface created for the land possession variable, it can be seen that the parcel of land towards the city core and the old city area is more compact than the coastal area (Map 4.1). Relatively larger land possession is found in peripheral areas like Thiruvankulam in the south, Elamkunnapuzha in the coastal area, and Varappuzha in the north (Map 4.1). Similarly, from the geo-statistical surface map of land price, it can be observed that the areas in the city core are highly-priced compared to the periphery areas (Map 4.2). The lands close to the coastal area in the west, wetland/paddy land area in the north, and also the census town of Thiruvankulam in the south have low land value compared to the city core (Map 4.2). This is closely connected to the type of economic activities and availability of land. The land cost in the central part of the city is highest followed by the eastern part of the city (Map 4.2). It can be seen from the above-interpolated surface map based on the residential pricing, the city core and majority of the areas towards the northeast direction have housing prices higher than most of the peripheral areas (Map 4.2).

As noted in the case of the land price, the coastal areas, the island areas of Kadamakkudy, and the adjoining areas have lower expected housing prices compared to the city core and other satellite towns of Kochi. Similarly, in the Thiruvankulam census town in the southeast of the city and also at the end of the eastern part of the city the housing price is interpolated to be relatively low compared to other city areas (Map 4.2).

4.10 Proximity to Basic Infrastructure

The average distance of the residences to the bus stops, workplace, hospital, and banks are interpolated and presented in map 4.3. The interpolated distance to bus stops in central areas is observed to be higher because samples were not collected from this area. It has less residential houses as these are exclusive commercial centers. Interestingly distance to the bus stops is found to be less in most of the peripheral areas (Map 4.3). This is largely due to better transport access in residential areas. Similarly, the majority of households in the north, northeast, and southeast reported that their workplace is having more distant from their place of residence (Map 4.3). This again can be viewed as most of the people in the peripheral areas travel to central areas and the eastern part of the city for work. Distance to health infrastructure in part of north and eastern side

is more than other parts of the city. Similarly, distance to banking was also found to be relatively high in the northeast part of the city (Map 4.3). In the case of hospitals and banks in sampled locations of Kochi, the distance was found to have less dispersion. The interpolated surface shows that some peripheral areas in the north and east have a higher distance to access hospitals and for banking, but this may not be significantly important. Access and availability of both hospitals and banks in Kochi are better compared to other cities in Kerala.

4.11 Access to Basic Amenities

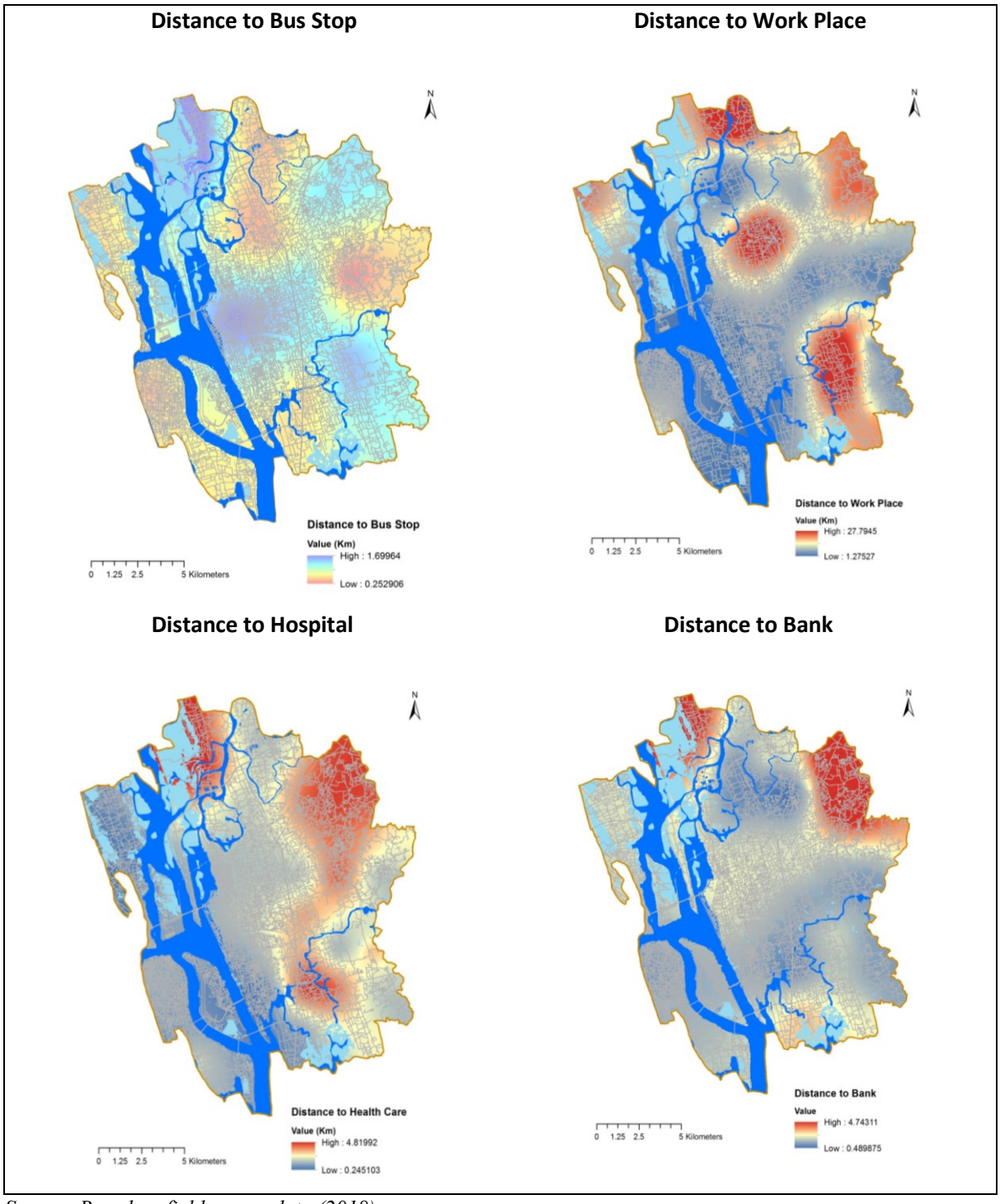
Among the surveyed households, all houses use LPG as their primary source of fuel for cooking. Among them, 47.6 percent of households also use firewood as a secondary source for cooking. This is because, like other parts of Kerala, many houses in Kochi have a dual kitchen set-up with one for LPG-based cooking and the other for cooking with firewood. As far as cooking fuel is concerned, no significant differences are found across the different town constituents. About 90.4 percent of the households in the corporation area use treated tap water as the source of drinking water, while tap water facility is found to be substantially less in the municipal towns of Eloor, Kalamassery, Thrikkakkara, and Thrippunithura except for Maradu municipality where all the 12 households surveyed have a tap water connection. About 30 percent of households in these municipal town areas use well for drawing water for drinking and their other daily needs. In early times the drawing of water from the well was done manually. Now since almost all the houses are having electricity connections, the water is drawn with the help of electric pumps and stored in overhead tanks, and then distributed through pipes within the dwelling units.

Although in the census towns 84.0 percent of households surveyed have a tap water connection, there is water scarcity in most of the areas close to the sea and the inland water bodies (Table 4.18). The pipeline, which carries water from Puthuvype, is the only source of drinking water in many of these households. The lack of a local secondary water system raises many concerns for the families across Elamkunnapuzha (Giri, 2019). The well water is not fit for any use as it is saline and contaminated with a yellowish color. About 12.8 percent of households in the peripheral areas especially in the coastal areas depended on other sources such as water tanks supply from the water authority.

Overall among the surveyed houses, 67 percent reported that the quality of water is very good, another 23.2 percent say it is good or satisfactory and 9.8 percent says the water has bad taste and

smell. About 31 percent of the households living in census towns have reported that the quality of the water is not good for drinking. So, water seems to be a major issue especially in the coastal area and also areas close to the industrial town of Eloor (Appendix 5.2).

Map 4.3: Proximity to basic infrastructure



Source: Based on field survey data (2018).

Table 4.18: Source of drinking water

Source	Corporation	Municipality	Census Town	Total
Tap water	75 (90.4)	87 (67.4)	79 (84.0)	241 (78.8)
Motorized well	8 (9.6)	39 (30.2)	3 (3.2)	50 (16.3)
Other Sources	0 (0)	3 (2.3)	12 (12.8)	15 (4.9)
Total	83 (100)	129 (100)	94 (100)	306 (100)

Note: Figures in parentheses are percentages
Source: Based on field survey data (2018).

Among the household, 79.5 percent of houses use a Septic tank-based latrine system while 20.5 percent uses piped sewer system in the corporation area. In the municipal area also the government-provided piped latrine facility was negligible as only 2.3 percent had the facility and this also was in those areas which are near the corporation areas, which means that almost 98 percent uses septic tank based latrine facilities. In the case of census towns, almost 99 percent of households said they use septic tank-based latrine facilities. In the case of drainage facility corporation area reported 99 percent drainage facilities while it was 52 percent in municipality areas and as low as 27.7 percent in census town areas. The figures suggest that the water and sanitation facility in the planning area of the city needs a lot of improvement and focused attention from the government is required to make the city more livable and economically viable.

4.12 Environmental and Neighborhood Cleanliness

When asked about the sources of pollution in the locality about 47 percent of households reported there is pollution from dumping of waste, traffic congestion-based smoke, and also noises. Some households also reported that the smoke from residual burning also contributed to the pollution of their surrounding (see Appendix 4.2). The cleanliness of the houses and neighborhood area is also an important aspect of a healthy neighborhood. Among the houses surveyed 11.4 percent responded that there is heavy water logging during monsoon season. The majority of these were in census towns that lie in the coastal areas of the city. When asked about garbage disposal 48.7 percent reported that they make their arrangement in disposing of the garbage while 50 percent say local authorities decide for the collection of garbage (see Appendix 4.3). In census towns, 74.5 percent of households make their arrangement for their garbage disposal. The figures suggest that the administrative intervention in disposing of household garbage was least in the peripheral census town areas. Out of the total sample households, 83.7 percent of households responded that they clean their courtyard on a day to day basis and 9.2 percent reported that they clean on alternate

days. Not much disparity is noted among the administrative unit in this dimension. It shows that people generally have a cleaning sense especially when it comes to their courtyard. However, in the case of the cleanliness of their neighborhood roads which is a local administrative initiative about 43.1 percent said nobody comes for cleaning the roads (see Appendix 5.2). Though in municipal corporation area this was below 5 percent, in municipality and census towns these were 48.8 percent and 69.1 percent respectively. When asked about the satisfaction level of the condition of roads 93.1 percent of households responded that they are satisfied.

4.13 Locality Surveillance and Safety

The locality surveillance system like the availability of "closed-circuit television (CCTV)" in the city was also shown a high disparity. When 13.3 percent of households in the corporation reported that there is a surveillance system, in the municipality area there was only 3.3 percent, while none of the households in the census town are reported any surveillance system in their area. When asked about any kind of eve-teasing is reported in their neighborhood only 1.3 percent of the household has said they faced such a situation. Similarly, when asked about safety for women especially at night, about 83.7 percent of households revealed that it is safe to move out at night. However, at the disaggregated level 18.1 percent in census towns said it is not safe for women at the night (see Appendix 4.3). Among the households surveyed about 86 percent households are aware of the helpline numbers of emergency services such as police, fire, and ambulance. However, this awareness was relatively less for the households who are in the census town area where the percent of awareness of emergency helpline numbers were 68.1 percent (Appendix 5.2).

4.14 Summary

The physical structure of houses in Kochi is better compared to the urban areas of the district, state, and all of India. A disaggregated analysis of different regions of Kochi reveals that the structure of houses in central areas and the eastern part of the city is better, but the coastal regions are very poor. In comparison to other cities in Kerala, Kochi has superior access and availability of hospitals and banks. Census town residents have lower average incomes than households in the city core and satellite towns. When compared to the results for the district's urban regions, the general physical quality of houses in Kochi city is superior. Most Keralan households have traditionally prioritized the construction of attractive homes with sufficient living space. Kerala has the greatest

proportion of three or more housing rooms in both rural and urban areas when compared to the rest of India. The fact that bottled water and water tanks are obtained from far away regions, including neighboring districts of the state, emphasizes the city's water scarcity. According to the data, it does not provide treated or high-quality water to its city residents. Only 30.4 percent of families in Kerala's metropolitan areas have access to purified drinking water. Sanitation is a major worry in Kochi City, on which the authorities must focus if the city's health and immune system are not to suffer further. To avoid future drainage issues, it is critical to enact tight zoning and land development regulations.

Chapter 5: A Spatio-Temporal Analysis of Built-Up Area, Its Relation with Socio-Economic and Housing Characteristics

5.1 Background

Remote Sensing data in the form of satellite imageries can be converted into useful information in the form of "Land Use Land Cover (LULC)" using various digital processing methods. Spatio-temporal analysis of urban land use in a city facilitates quantifying the extent of urbanization in a given area and how it affects a region's landscape (Jayalakshmy & Mereena, 2016). Quantifying the LULC of a city based on the classified map helps us in analyzing the patterns and trends in the study area and also it is important for urban growth prediction. Changes that occur in urban areas are the result of large-scale human modification of the terrestrial surface especially in developing countries (Issa & Al Shuwaihi, 2011). Land conversion and LULC change-related topics are considered to be important in the context of solving future challenges such as environmental sustainability, food security, and socio-economic stability in urban areas (Saifullah et al., 2017). The present analysis is based on the spatial data during the times period of 1992, 2001, and 2014. Apart from quantifying the landscape variations in the city, an attempt is also made to see the built-up concentration in the city and also the linear association of the built-up area with various socio-economic indicators to understand the indicators that have a significant contribution to the increase in the built-up area.

5.2 Source and Characteristics of Spatial Data Used in the Analysis

The Landsat imageries are obtained from the "Global Land Cover Facility (GLCF)" for three years 1992, 2001, and 2014. Several imageries of three decades at various intervals are obtained and compared to select the best three scenes of the same season.

Table 5.1: Specification of Landsat imageries

No.	Data/Sensor	Path	Column	Scale/ Resolution	Month/Year
1	Landsat5/TM	144	053	30 m	12/1992
2	Landsat5/TM	144	053	30 m	03/2001
3	Landsat8/OLI	144	053	30 m	01/2014

Source: https://landsat.gsfc.nasa.gov

The selection of 2014 as the terminal year for the comparison is based on the appropriate time lag required for predicting the urban growth of the city for the future year of 2031 and also with the assumption that the socio-economic characteristics collected from census 2011 do not differ substantially within three years. The specification of the imageries used in the study is given in Table 5.1.

5.2.1 Spectral characteristics of Imageries

The imageries used for the first two time period of 1992 and 2001 are "Landsat Thematic Mapper (TM)" and "Landsat 8 Operational Land Imagers (OLI)" for 2014. The Landsat 5 data has 7 bands while the Landsat 8 has a total of 11 bands. The band name, resolution, and wavelength of both sensor-based imageries are presented in Table 5.2.

Table 5.2: Spectral characteristics of imageries

Bands	Wavelength	Resolution
Landsat 5 (TM)		
Band 1 - Blue	0.45-0.52	30
Band 2 - Green	0.52 – 0.60	30
Band 3 - Red	0.63 - 0.69	30
Band 4 - Near Infrared	0.77-0.90	30
Band 5 – Shortwave Infrared	1.55-1.75	30
Band 6 – Thermal Infrared	10.40-12.50	120 (30)
Band 7 – Shortwave Infrared	2.08-2.35	30
Landsat 8 (OLI)		
Band 1 - Coastal aerosol	0.43 - 0.45	30
Band 2 - Blue	0.45 - 0.51	30
Band 3 - Green	0.53 - 0.59	30
Band 4 - Red	0.64 - 0.67	30
Band 5 - Near Infrared (NIR)	0.85 - 0.88	30
Band 6 - SWIR 1	1.57 - 1.65	30
Band 7 - SWIR 2	2.11 - 2.29	30
Band 8 - Panchromatic	0.50 - 0.68	15
Band 9 - Cirrus	1.36 - 1.38	30
Band 10 - Thermal Infrared 1	10.60 - 11.19	100 * (30)
Band 11 - Thermal Infrared 2	11.50 - 12.51	100 * (30)

Source: https://landsat.gsfc.nasa.gov

5.3 Normalized Indices of Vegetation and Built-up

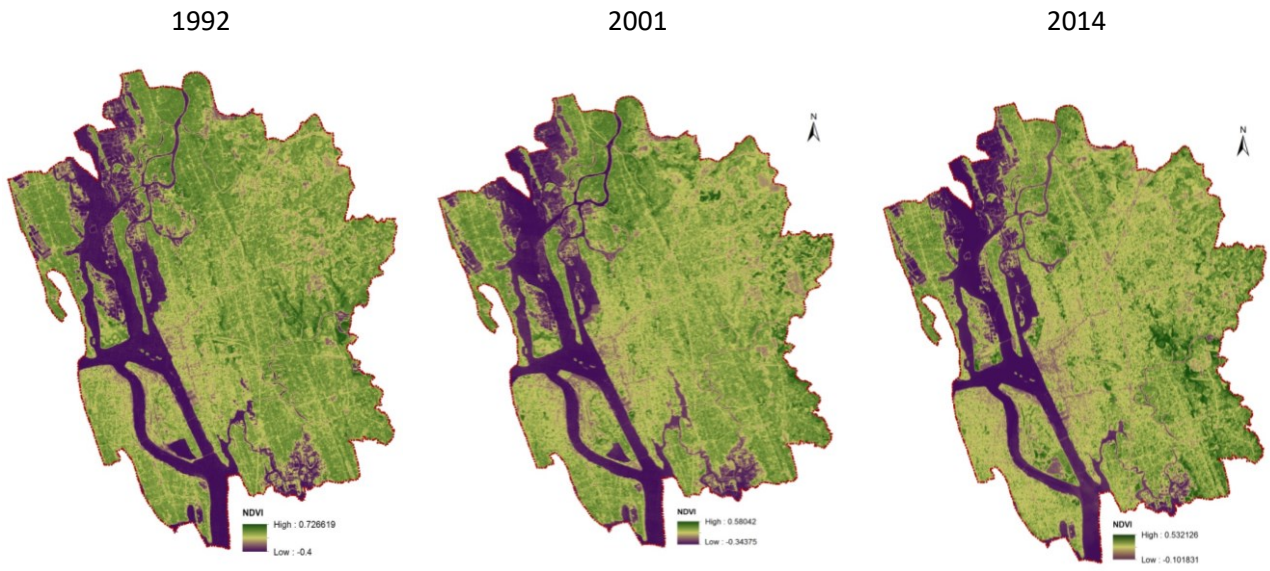
Before attempting the LULC analysis, a normalized index based on the bands that have high reflectance and absorption on vegetation and built-up is carried out. Both these indices are useful to have a macro picture of the spatial presence of the respective features. The normalized indices

are also been used for image classification (Zha et al., 2003) and enhancement of digital image quality (Jat et al., 2017).

5.3.1 Natural Difference Vegetation Index (NDVI)

NDVI is calculated using "Near Infra-Red (NIR)" and "Red bands" using the formula "(NIR-RED)/(NIR+RED)". NDVI is a widely used index in detecting the Spatio-temporal distribution of vegetation and it is also considered to be an important variable in urban planning (Chen et al., 2004). Though NDVI is useful in inferring the presence of vegetation cover it cannot be used to estimate the area of vegetation (Small, 2001). In terms of the band, for Landsat 5 data, NDVI is calculated as "(Band 4-Band 3)/(Band 4+Band 3)", while for Landsat 8, it is calculated as "(Band 5 – Band 4) / (Band 5 + Band 4)". The near-infrared band strongly reflects the vegetation and the red band absorbs the vegetation. The "normalized value of the index ranges from -1 to +1", a moderate positive value (0.1 to 0.3) represents low-density vegetation, a positive value (0.4 to 0.6) represents moderate vegetation while values ranging from 0.7 to 1 indicate dense vegetation.

Map 5.1: NDVI of Kochi (1992, 2001, and 2014)

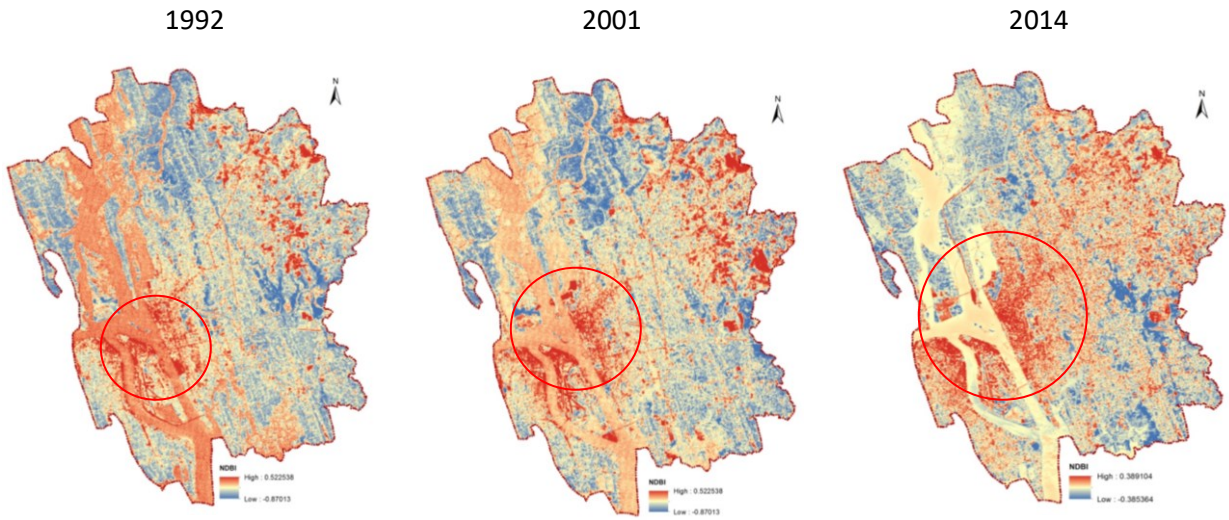


A close look at the NDVI revealed that the depth of the vegetation in the later years is gradually decreasing (Map 5.1). The overall vegetation in the city area is still comparatively higher due to the relatively higher presence of water body and the conducive weather as exist in the whole of Kerala. The maximum vegetation cover loss can be seen in the northeast direction of the city where the urban built-up is spreading as observed in the analysis from the previous chapter (Map 5.1).

5.3.2 Normalized Difference Built-up Index (NDBI)

"NDBI" is useful for an overall understanding of the pattern of the built-up area using satellite data. For "NDBI", "SWIR" and "NIR" bands are used as the built-up areas and bare soil reflects more in "SWIR" than "NIR". It is calculated as "NDBI = (SWIR – NIR) / (SWIR + NIR)". In the case of Landsat 5 imageries NDBI is calculated as "(Band 5 – Band 4) / (Band 5 + Band 4)", while for Landsat 8, NDBI is "(Band 6 – Band 5) / (Band 6 + Band 5)". Apart from the use of analyzing built-up patterns and temporal comparison of urban areas, it can also be used to automate the process of mapping built-up areas (Zha et al., 2003) as an alternative to conventional image classification techniques such as "supervised and unsupervised classification".

Map 5.2: NDBI of Kochi (1992, 2001, and 2014)



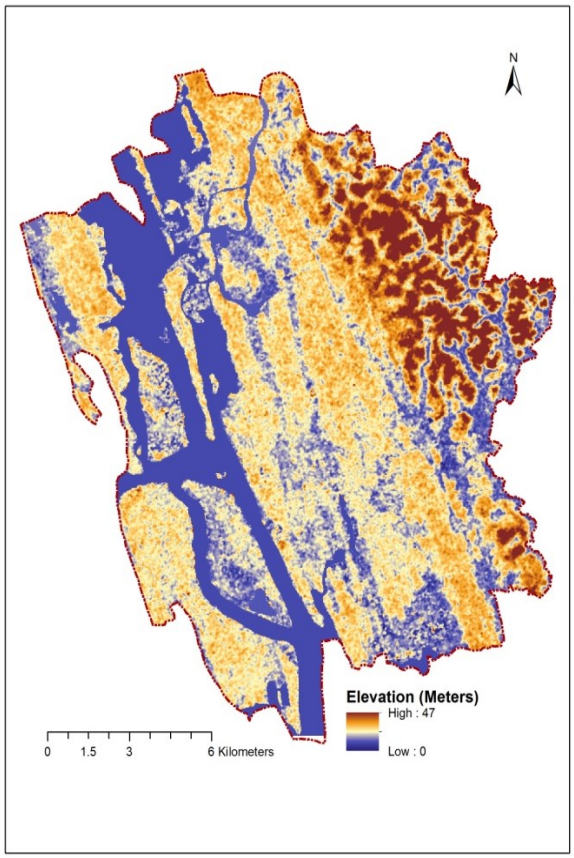
Between 1991 and 2001 Fort Kochi, Mattanchery, and Ernakulam town which forms the municipal corporation shows an increasing pattern in the built-up (Map 5.2). It can be noticed that in the latter year there is a shift in the intensity of built-up from the old city area and the central part of the corporation towards the northeastern direction. This area has a linear built-up expansion along with the metro, national highway, and rail network.

5.4 Surface Elevation of Kochi City

Coastal cities are usually characterized by a flat landscape, a tropical climate, flourishing economy, rich resources and access to marine trade and transport and these features are conducive for the urban expansion of cities (Yan et al., 2020). Most of the large cities in India and around the World

are situated close to coastal areas. Though on a global scale, the proximity of the city to coastal areas leads to urban expansion, at a local scale, the places close to the low-lying area may not be conducive for large-scale built-up expansion both in terms of built-up quality and also in terms of ecological reasons. Kochi city has an elevation ranging between 0 to 47 meters from the sea level from west to east (Map 5.3).

Map 5.3: Elevation of Kochi City



Source: DEM generated based on the SRTM data.

The places with water bodies, wetlands, canals, and agricultural fields in the west, south, and north have low elevation, whereas the places in the east and northeast have the highest elevation (Map 5.3). The low-level areas are ecologically sensitive and large-scale coastal regulation violations in the waterfront area are reported to be taking place in the city. It may be possible that the high demand for flats and villas facing natural lakes and riverfronts makes the real estate lobbies violate the norms in concurrence with the local authorities. The rampant construction within 200 meters

in the coastal region recently has led to the demolition of four newly built-up high-rise apartment complexes which were telecasted live in local news channels[3].

As per the "Supreme Court" directive, the apartments built by violating the "Coastal Regulation Zone (CRZ)" norms, at Maradu have been demolished emphasizing strict action against construction activities in these areas. Studies stated that sea level rises as a result of global climate change can affect the coastal low-lying areas of Kochi with permanent floods and coastal erosion. The high-raised residential and other commercial built-up in these areas also need to be supplemented with massive infrastructure and may worsen the situation. Therefore, such development may be more suitable in a relatively higher elevated area in the city.

5.5 Land Use Land Cover (LULC)

LULC based analysis is widely used in all spatial studies using satellite imageries. The term "land use" and "land cover" needs to be understood in the context of study related to change in landforms. Scholars described "land cover" as the biophysical state of the earth's surface and it describes the physical state of the land surfaces such as cropland, mountains, or forests (Mondal et al., 2019; Mondal, Dolui, et al., 2017). It originally referred to the vegetation types that covered the land surface and also other aspects of the environment such as soils, biodiversity, and groundwater. On the other hand, 'land use' can be termed as an outcome of manipulations influenced by humans on these biophysical states. Meyer, W.B stated that land use is how and why human beings employ the land and its resources. It is directly related to the purpose for which the land is used for human activities, making use of its resources or having an impact on them. The emphasis here is given more on the potential use of the land surfaces for the location of various activities. This connotation of the term 'land use' is implicit in the literature dealing with land use in the context of urban planning.

The magnitude of LULC change varies with the time period and the geographical area under study. Land-use change is driven by a variety of forces that relate differently to one another in different spatial and temporal settings. A subset of each of the three Landsat imageries of Kochi city for the period 1992, 2001, and 2014 are created and a "supervised classification" based on the "Maximum Likelihood method" is performed to extract the pixels in different classes. "Maximum Likelihood" calculates the probability that a given pixel belongs to a specific class based on the user trained

[3] (https:// specials.manoramaonline.com/Onmanorama/2020/maradu-flats-demolition/index.html).

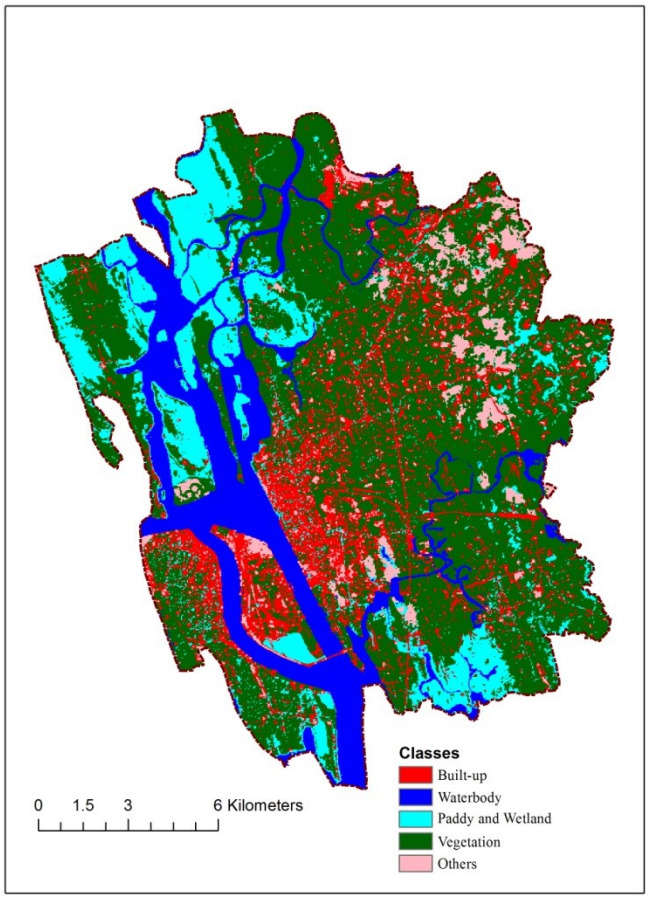
data patches. Each pixel is assigned to that class that has the "maximum likelihood" or the highest probability. Due to the unique land features of the coastal city of Kochi, the imagery is classified into five classes, namely, "Built-up", "Water body", "Paddy and Wetland", "Vegetation" which includes the thick vegetation as well as the pasture lands and "Others" which consists of dry soil and other open lands. An accuracy assessment of each of these classified imageries is carried out using the reference values taken with the help of high-resolution imageries from Google Earth and toposheets and "Kappa Statistics" for assessing the accuracy of the classification is subsequently generated (Pontius & Millones, 2011).

5.5.1 LULC: 1992

The LULC for 1992 is obtained with five broad classes of Built-up, Waterbody, Paddy and Wetland, Vegetation and Other which includes the dry fallow and open lands and is presented in Map 4.4. The accuracy assessment using Kappa Statistics for classification accuracy is presented in Appendix 5.1. The spatial pattern of built-up in 1992 suggests that the built-up is concentrated in the municipal corporation area. The detailed analysis of the pattern observed is discussed in the subsequent section.

Accuracy assessments of the classified maps are made using Kappa Statistics. With the help of geo-referenced toposheets and google earth timeline imageries for different periods a large number of the point feature classes is generated and assigned the LULC category it belongs to each of the points. The *extract values to point* option available in the spatial analyst tool in ArcGIS is used to extract the raster class in the classified map associated with each of these points by taking the inputs as point feature class and the classified map. It resulted in the merging of the raster class of the classified map to the attribute table of the ground-truthing points. A cross-tabulation of the class value based on the ground-truthing and a classified map is calculated. The row marginal totals and the total obtained for each of the categories are used for the calculation of producer's and user's accuracy. The producer's accuracy for a given LULC category is determined as the percentage of coincided points in the classified and reference points of a given land use category to the total reference class points observed for the same land use category.

Map 5.4: Land use land cover (LULC) map of Kochi (1992)



Source: LANDSAT-5 TM (1992)

Similarly, the users' accuracy is calculated as the percent of coincided points in the classified and reference points of a given land use category to the total of the classified values observed for the same land use category.

The overall agreement is the percent of total agreement between the classified and the reference points, i.e., the sum of the diagonal elements to the total points considered in the accuracy assessment. The Kappa statistics is a standard statistic to validate the overall accuracy and can be calculated as

$$K = \frac{p_a - p_e}{1 - p_e}$$

Where, p_a is the probability of overall observed agreement and p_e is the probability of random agreement or chance agreement.

Out of the total points classified as built-up, 122 points have matched with the ground-truthing or the reference data (see Appendix 5.1). The total number of built-up points selected from the reference map is 150. Therefore, the producer's accuracy for the built-up class is 81.3 percent i.e (122/150) x100. This would mean that 81 pixels are correctly classified in every 100 real built-up pixels. Similarly, the producer's accuracy for waterbody is found to be 95 percent, that of paddy and wetlands were 87 percent, for vegetation 82 percent, and for other land categories the accuracy was 80 percent. The same procedure is adopted for the calculation of the user's accuracy for each land use category, here the denominator is according to the user's hypothesis or the total cell value the user presumed it to be that particular category. Hence in the case of user's accuracy, the percent for the built-up category is 85.3 percent. This would mean that for every hundred pixels classified as built-up, 85 pixels are built-up in reality.

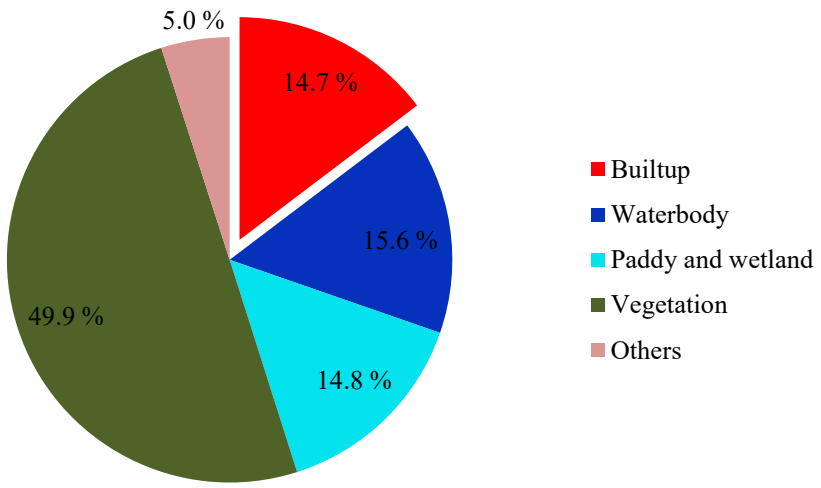
The overall agreement of the classification which is calculated as the sum of the diagonal elements or the perfect matching to the total points is 85 percent which is considered to be higher as per the available standards based on literature (Congalton, 1991, Abubaker et. Al, 2013). The overall Kappa statistics obtained for the classification is 0.81 which is statistically significant (Abubaker et. Al, 2013).

From the classified map, it can be seen that in the early nineties the built-up was concentrated in Fort Kochi, Mattanchery, Wellington Island, which is a part of the "Kochi Municipal Corporation (KMC)" and falls under the Kochi Taluk. The relatively higher concentration of built-up in this area is understandable since the population density in the western part of the corporation was the highest among the "Kochi City Region (KCR)" with an inhabitance of over 6500 persons per sq. km as per 1991 census data. The corporation area in the mainland of Ernakulam in Kanayannur Taluk also has a large patch of built-up area and here again the population density in 1991 was about 5500 persons per sq. km. In coastal areas of Njarackal and Elamkunnapuzha, the built-up patches were linear along the major roads and junctions. A large portion of this area is shared by paddy /wetlands along with vegetation. As per the 1991 census, over 20 percent of the people in these areas used fishing and other primary economic activities as their livelihood. Areas like Varappuzha, Kadamakkudy, Mulavukadu, and Kakkanad also had relatively sparse built-up compared to the rest of the city region. It is to be noted that during 1991 these areas had a large presence of wetland and paddy lands. Wetlands are the inbuilt landscape feature of Kochi. About 95 percent of the water sheet of Kochi comprises wetlands and canals. The pattern of built-up

found in other areas also suggests that built-up patches are larger in areas around the transport nodes and also in industrial pockets. The built-up area showed an increase in the southeast direction.

The comparatively low percentage of built-up in the city region indicates that at the beginning of the nineties the city observed a low level of urbanization as experienced in other similarly populated cities in the country. Vegetation was found to be the dominant class with almost 50 percent of its land covered with green surface followed by identical areas in the built-up, water body, and paddy/wetland, the difference is marginal with 14.7, 15.6, and 14.7 percent areas in these categories (Fig 5.1). Other lands, which consist of dry fallow and open land occupy about 5 percent of the total area of the city. Figure 5.1 clearly revealed that in 1992 agricultural activities remained a dominant category in most of the areas currently classified as census towns in Kochi city.

Figure 5.1: LULC wise Area of Kochi City Region (1992)



Source: Computed from LULC classification based on LANDSAT-5 TM (1992)

The low level of urbanization experienced especially in the second-tier cities in the country before the start of the globalization period is also seen in Kochi. The built area was mainly concentrated in the municipal corporation area along with the industrial locations in the northeastern part of the city. A zone-wise calculation of area is carried out which further reveals the built-up concentration in each of the town constituents.

5.5.2 Zone Wise Area Under Each LULC Category: 1992

The area of each of the classes is extracted according to the administrative boundaries of each of the local bodies within the city. This has been done to understand the pattern and trends of built-up at a local scale with the help of classified data. Table 5.3 represents the administrative unit-wise area in each of the LULC classes in 1992. As pointed out earlier the corporation area is shown in two parts to understand the distinct land use character within the corporation area. It can be noticed that in 1992, the Kochi corporation area has the highest built-up. The total area of the central part (Part 1, Kanayannur Taluk) and coastal (Part 2, Kochi Taluk) of the corporation is estimated to be 56.4 and 42.8 respectively (Table 5.3). The built-up in the central part of the corporation is found to be 26.6 percent of the total land area. Half of the area in this part was vegetation, while waterbody, wetland, paddy, and other land constituted 11.7, 6.9, and 4.3 percent respectively (Table 5.3). In the coastal part of the corporation, the total built-up percent stood close to 20 percent. Waterbody with 37.6 followed by vegetation with 29.2 percent was the most dominant class in this area. Wetland and paddy land in the coastal area of the corporation was estimated as 8.8 percent while the least percent was that of dry fallow and open land with 4.5 percent of the total area (Table 5.3).

Table 5.3: The Land Use Land Cover (LULC) area in sq. km of Kochi City (1992)

Town Name	Built-up	Water body	Paddy and Wetland	Vegetation	Others	Total Area
Kochi Corporation P1	15.0 (26.6)	6.6 (11.7)	3.9 (6.9)	28.5 (50.5)	2.4 (4.3)	56.4 (100)
Kochi Corporation P2	8.5 (19.9)	16.1 (37.6)	3.7 (8.8)	12.5 (29.2)	1.9 (4.5)	42.8 (100)
Eloor	1.7 (16.1)	0.4 (4.0)	0.1 (1.3)	7.6 (73.0)	0.6 (5.6)	10.4 (100)
Kalamassery	4.6 (19.3)	0.3 (1.3)	0.9 (3.7)	13.8 (58.6)	4.0 (17.1)	23.6 (100)
Thrippunithura	1.9 (10.2)	1.2 (6.3)	2.9 (15.7)	12.4 (66.6)	0.2 (1.2)	18.7 (100)
Maradu	1.5 (10.6)	1.4 (10.3)	3.3 (24.1)	7.2 (52.4)	0.4 (2.6)	13.8 (100)
Vazhakkala	2.6 (16.2)	0.2 (1.1)	0.5 (3)	10.0 (62.2)	2.8 (17.5)	16.1 (100)
Kakkanad	1.4 (12.1)	0.3 (2.2)	1.3 (11.2)	8.2 (72.0)	0.3 (2.6)	11.4 (100)
Varappuzha	0.2 (2.1)	0.8 (7.7)	3.1 (31.3)	5.9 (58.8)	0 (0.1)	10.0 (100)
Cheranallur	0.2 (2.4)	0.7 (7.5)	2.3 (24.1)	6.1 (65.1)	0.1 (0.9)	9.4 (100)
Kadamakkudy	0.1 (1.2)	3.5 (27.3)	6.5 (50.2)	2.7 (21.0)	0.0 (0.3)	13.0 (100)
Mulavukadu	0.2 (1.4)	6.4 (49.2)	3.9 (29.7)	2.5 (19.0)	0.1 (0.8)	13.0 (100)
Njarackal	0.3 (3.4)	1.6 (18.3)	3.3 (37.5)	3.6 (40.4)	0.0 (0.4)	8.8 (100)
Elamkunnapuzha	0.2 (2.0)	1.0 (10.0)	3.2 (33.2)	5.2 (54.6)	0 (0.2)	9.6 (100)
Puthuvype	0.2 (7.6)	1.3 (45.8)	0.3 (12.7)	0.9 (33.7)	0.0 (0.2)	2.7 (100)
Thiruvankulam	1.2 (10.7)	0.6 (5.7)	0.8 (7.1)	8.0 (72.4)	0.5 (4.1)	11.1 (100)
Kochi City	**39.8 (14.7)**	**42.3 (15.6)**	**40.0 (14.8)**	**135.2 (49.9)**	**13.4 (5)**	**270.7 (100)**

Note: The figure in parentheses is the percentages.
Source: Calculated from the classified imagery.

The other places in the cities with the significant built-up area were the industrial towns of Eloor and Kalamassery with 16.1 and 19.3 percent respectively (Table 5.3). Situated in the northeastern suburb of Kochi, both of these are the oldest and the largest industrial hubs in Kerala. Vazhakkala close to Kalamassery also had 16.2 percent built-up in 1991 (Table 5.3). The other parts, which have a sizeable built-up area in the city neighborhood, were Kakkanad, Thrippunithura, Thiruvankulam, and Maradu, all of them have over 10 percent built-up (Table 5.3). All the island and coastal areas outside the corporation had reported less built-up, it is understandable as the status of many of these constituents were villages as per the 1991 census. In almost all parts of the city, the vegetation cover was the dominant area except Kadamakkudy, Mulavukadu, and Puthuvype where the percent of water sheet was higher than the vegetation. These areas had the highest coverage of waterbody in the form of lakes, wetlands, and paddy lands.

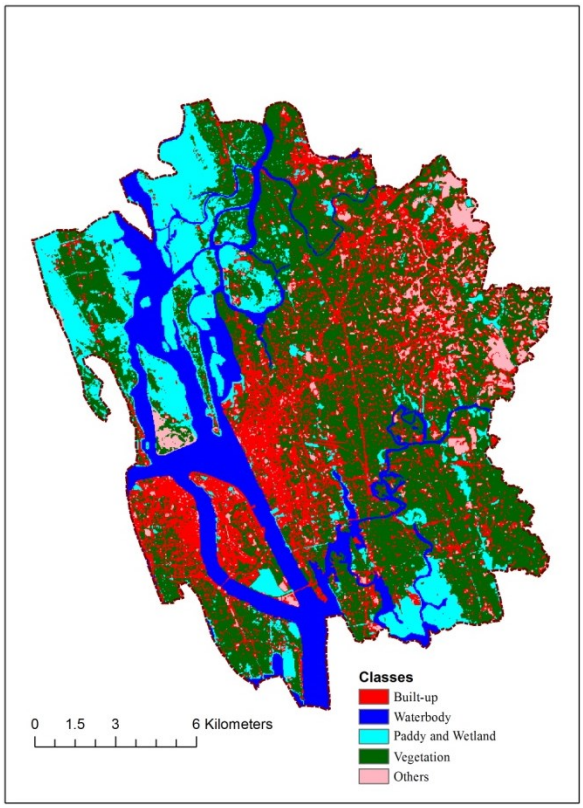
5.5.3 LULC: 2001

The LULC for 2001 was produced from Landsat TM/5 imagery with five broad classes of Built-up, Waterbody, Wetland/Paddy, Vegetation, and other types of lands which includes the dry fallow and open lands and is presented in Map 5.2. The accuracy assessment using Kappa Statistics for classification accuracy is presented in Appendix 5.2. The spatial pattern of built-up suggests that the built-up is expanding towards the northeastern direction on the outskirts of the corporation.

A total of 129 points classified as built-up matched with the ground-truthing or the reference data, which is obtained through toposheets and google earth timeline imagery. The producer's accuracy for the built-up class was found to be 86 percent (Appendix 5.2). This can be interpreted as 86 pixels correctly classified in every 100 real built-up pixels. Similarly, the producer's accuracy for waterbody was found to be 87 percent, that of paddy and wetlands were 81 percent, for vegetation 88 percent, and for other land categories, the producer's accuracy was 79 percent. In the case of user's accuracy, the percent for the built-up category is 88.4 percent i.e, (129/146) x 100. This would mean that for every hundred pixels classified as built-up, 88 pixels are built-up in reality.

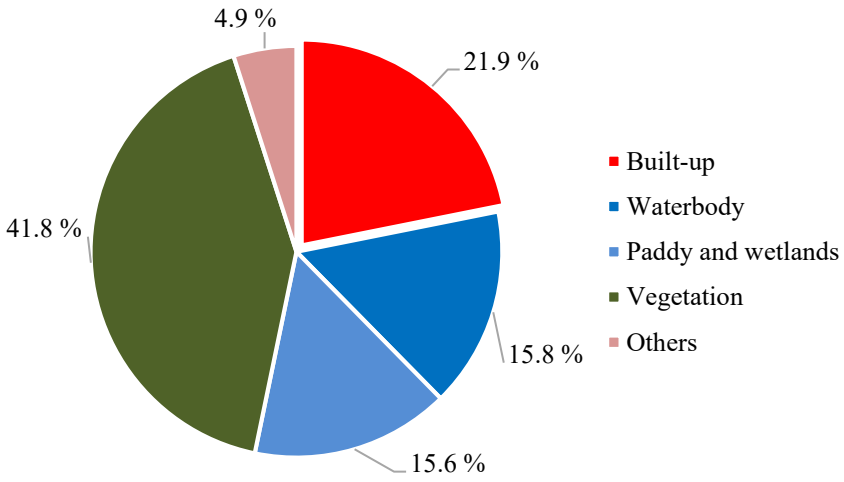
The overall agreement of the classification calculated as the sum of the diagonal elements or the perfect matching to the total points is 85 percent and considered acceptable as per the available standards based on literature. The corresponding overall Kappa statistics obtained for the classification is 0.81, which is also within the acceptable limit of accuracy requirement.

Map 5.5: Land use land cover (LULC) map of Kochi (2001)



Source: LANDSAT-5 TM (2001)

Figure 5.2: LULC wise area of Kochi City Region (2001)



Source: Computed from LULC classification based on LANDSAT-5 TM (2001)

Though the built-up has shown an increase in 2001, the direction of built-up growth was similar to that of 1992. There was a consistent increase in the total built-up area in 2001, which is estimated as 59.2 sq. km, amounting to 22 percent of the area of the city (Fig 5.2). In terms of absolute area, the increase in built-up over the previous period was close to 19 sq. km, that is, that makes an increase of about 7 percent over the previous time period (Fig 5.2).

The vegetation in 2001 was 42 percent while the other open land was 5 percent. This increase is built-up largely gained from the vegetation as it can be seen that the vegetation has reduced from 50 percent in 1992 to 41.8 percent in 2001 (Fig 5.2). The water body, wetland area, dry fallow land, and the open land category remained almost at the same level as that of the previous period (Fig 5.1 and 5.2). For further disaggregated analysis the zonal statistics are calculated based on the town constituent boundaries and it is presented in the next section.

5.5.4 Zone wise area under each LULC category: 2001

The built-up in the central portion of the corporation (Kochi Corporation P1) in 2001 is estimated as 34.1 percent of the total area of 56.4 sq. km while in the coastal part the built-up was 27.5 percent (Table 5.4). It can be seen that the vegetation cover in the central part of the corporation area has reduced by 6 percent point in 2001. In 1992 the total vegetation cover in the mainland of the corporation was about 50.5 percent compared to 44.4 percent in 2001. Similarly, in the coastal part of the corporation, the vegetation cover in 1992 was 29.2 percent of the total land while it has been reduced to 25 percent in 2001 (Table 5.4). It can be seen that the built-up area has considerably increased at the cost of the vegetation in these areas with an increase of 4.5 percent and 7.6 percent respectively over the previous decade (Table 5.4). In 2001, though the built-up area of all administrative divisions in the planning area has increased, the built-up in the northeastern part of the city such as Kalamassery, Vazhakkala, and Kakkanad has doubled. This unprecedented increase in the built-up in this area can be attributed to the start of large-scale economic activities such as special economic zone, Info Parks, etc. The other suburban towns of Eloor, Thrippunithura, and Maradu also have shown a significant increase in the built-up area. The gain in built-up in these areas is largely from the vegetation class.

As noted for 1992, the island areas situated in the coastal and northern part of the city had low built-up in 2001 also. These areas have a large area underwater body and wetland/paddy land with considerable vegetation.

Table 5.4: The LULC area in sq. km of Kochi City (2001)

Town Name	Built-up	Water body	Paddy and Wetland	Vegetation	Others	Total Area
Kochi Corporation P1	19.2 (34.1)	6.8 (12)	4 (7)	25.1 (44.4)	1.4 (2.5)	56.4 (100)
Kochi Corporation P2	11.8 (27.5)	16.1 (37.6)	2.6 (6.2)	10.7 (25)	1.6 (3.8)	42.8 (100)
Eloor	2.4 (22.6)	0.4 (4.3)	0.4 (3.6)	6.9 (66)	0.4 (3.5)	10.4 (100)
Kalamassery	8.1 (34.5)	0.2 (0.7)	0.6 (2.5)	11.2 (47.4)	3.6 (15)	23.6 (100)
Thrippunithura	2.5 (13.4)	1.4 (7.5)	3.3 (17.7)	11.2 (59.7)	0.3 (1.6)	18.7 (100)
Maradu	2.0 (14.6)	2.6 (18.7)	2.3 (16.5)	6.6 (47.9)	0.3 (2.3)	13.8 (100)
Vazhakkala	5.9 (36.8)	0.3 (1.7)	0.3 (1.7)	7.4 (46.1)	2.2 (13.5)	16.1 (100)
Kakkanad	2.8 (24.9)	0.1 (1.2)	0.6 (5)	5.6 (49)	2.3 (19.8)	11.4 (100)
Varappuzha	0.5 (5.2)	0.8 (7.9)	3.9 (39.3)	4.7 (47.4)	0 (0.2)	9.9 (100)
Cheranallur	0.7 (7.2)	1 (10.4)	2.2 (23.9)	5.4 (57.2)	0.1 (1.3)	9.4 (100)
Kadamakkudy	0.2 (1.2)	3.7 (28.6)	7.3 (56.6)	1.7 (13.5)	0 (0.1)	12.9 (100)
Mulavukadu	0.3 (2.6)	5.9 (45.3)	4.6 (35.5)	1.8 (13.9)	0.4 (2.8)	13 (100)
Njarackal	0.4 (4.7)	1.4 (15.8)	4.3 (48.5)	2.7 (30.6)	0 (0.4)	8.8 (100)
Elamkunnapuzha	0.3 (3.4)	0.8 (8.2)	4.5 (46.5)	3.9 (40.9)	0.1 (1)	9.6 (100)
Puthuvype	0.3 (12.5)	1.3 (47.8)	0.4 (16)	0.6 (21.1)	0.1 (2.6)	2.7 (100)
Thiruvankulam	1.7 (15.4)	0 (0)	1 (9.3)	7.7 (69.8)	0.6 (5.6)	11.1 (100)
Kochi City	59.2 (21.9)	42.7 (15.8)	42.3 (15.6)	113.2 (41.8)	13.4 (4.9)	270.8 (100)

Note: The figure in parentheses is the percentages
Source: Calculated from the classified imagery.

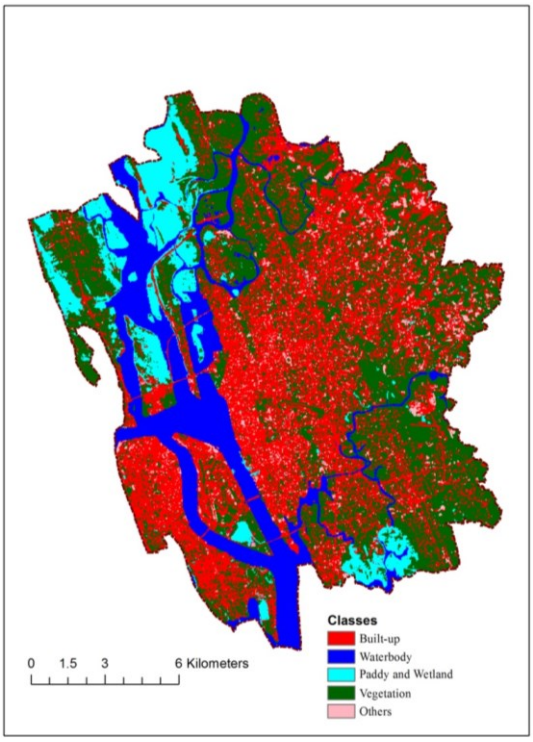
5.5.5 LULC: 2014

The LULC for 2014 based on the Landsat8/OLI imagery is presented in Map 4.6 and the accuracy assessment of the classification is presented in Appendix 5.3. The built-up pattern obtained for 2014 clearly shows the spread of built-up to the eastern side of the old city area. A significant built-up increase compared to 2001 can also be noticed in the southern part of the city.

In the classified map a total of 133 points classified as built-up matched with the reference data, obtained through ground-truthing and google earth timeline imagery. The producer's accuracy for the built-up class was found to be 88.7 percent, for waterbody it is 89 percent, paddy, and wetlands 75 percent, vegetation with 88 percent, and for other land categories, the producer's accuracy was 76.4 percent (Appendix 5.3). The overall agreement of the classification and the corresponding Kappa statistics obtained for the classification is 85 percent and 0.81, which is within the acceptable limit of accuracy requirement as the literature suggests.

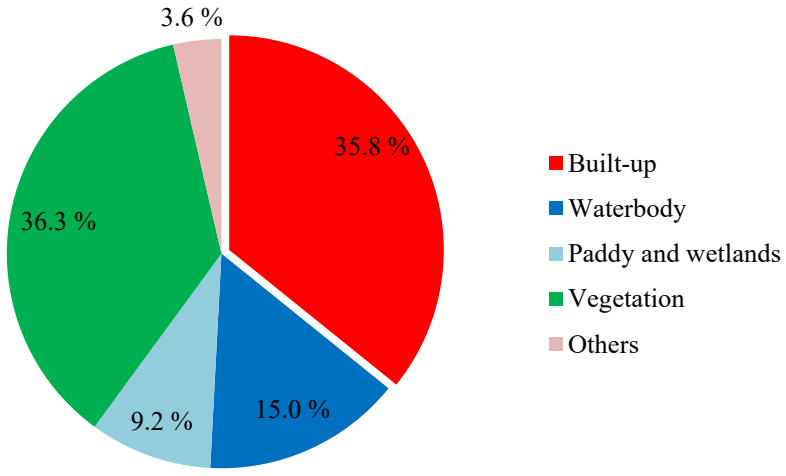
The pattern as observed from the classified map suggest that between 2001 and 2014 the city has expanded its built-up area in north-south and eastern direction (Map 5.6). The built-up has increased to 36 percent from 22 percent in 2001 (Fig 5.3). There is a decline in vegetation, paddy land, and open lands with the decline of vegetation being significant.

Map 5.6: LULC map of Kochi (2014):



Source: LANDSAT-8 OLI (2014)

Figure 5.3: LULC wise Area of KCR (2014)



Source: Computed from LULC classification based on LANDSAT-8 OLI (2014)

The overall vegetation of Kochi city in 2014 is estimated as 36 percent of the total area, while waterbody has 15 percent which is almost identical to the earlier two time periods. Similarly, there is a loss in the wetland and paddy lands category. As per the extracted area, the wetland and paddy land is 9 percent of the total area (Fig 5.3). Open land in 2014 is estimated to be 4 percent, a decline of about one percent to that of 2001 (Fig 5.2 and 5.3).

5.5.6 Zone wise area under each LULC category: 2014

As per 2014 classified data, almost half of the area in the Kochi Corporation has become a built-up area. The majority of this increase was observed in the central Kochi located in the Kanayannur Taluk. The Kanayannur part of the corporation had 19.2 sq. km of built-up area in 2001 and it rose to 31.2 sq. km in 2014 (Table 5.5). Similarly, the coastal areas of the corporation also showed an increased built-up with figures of 11.8 sq. km in 2001 increased to 16.9 sq. km in 2014 (Table 5.5). The major component among the land use categories in these two areas is built-up classes. As noted earlier during the period from 2001 to 2014 the built-up has increased in every administrative division of the city, the increase in the built-up was highest in Thrippunithura and Maradu. Maradu located at the Southern fringe of the Kochi city region shows a surge in residential development in recent years. The total built-up area of Maradu in 2001 was 2 sq. km and it has increased to 4.8 sq. km in 2014 (Table 5.5). Maradu is an ideal place to be developed for tourism development. It is the intersection of major highways and the national waterway and the coastal rail also passes through this area. It is also well connected to other parts of the city. A lot of private investment initiatives such as the “International Convention Centre (ICC)”, 5-star hotels, hospitals, and connectivity to road, water, and rail transports indicate that it is potential for tourism development (Govt. of Kerala, 2005). Similarly, the built-up area of Thrippunithura in 2001 was 2 sq. km and in thirteen years it has doubled to 5 sq. km of area. The major reason for the increase in built-up in these areas is due to the increase in real estate activities and these areas are also known for their residential preference as a result of the panoramic appearance with a lot of greeneries, natural lakes, and water bodies. The built-up has also consistently increased in the eastern part of the city. The Vazhakkala and Kakkanad census towns (Both are parts of Thrikkakara Municipality post-2011 census) have consistently increased the built area. As per 2001 classified data, the built-up in Vazhakkala is 37 percent of the total census town area while it is 25 percent in Kakkanad (Table 5.5). In 2014 both of these areas have become 47 and 35 percent respectively, an increase of 10 percent each over the previous time period (Table 5.5).

Table 5.5: LULC area in sq. km of Kochi City (2014)

Town Name	Built-up	Water body	Paddy and Wetland	Vegetation	Others	Total Area
Kochi Corporation P1	31.2 (55.3)	6.4 (11.4)	2.2 (3.9)	13.6 (24.1)	3 (5.3)	56.4 (100)
Kochi Corporation P2	16.9 (39.6)	16.1 (37.7)	1.2 (2.8)	7.4 (17.3)	1.1 (2.7)	42.8 (100)
Eloor	3.5 (34.1)	0.5 (4.6)	0 (0)	6.1 (58.7)	0.3 (2.7)	10.4 (100)
Kalamassery	12.3 (52.2)	0.1 (0.6)	0.1 (0.3)	9.2 (39.1)	1.8 (7.8)	23.6 (100)
Thrippunithura	5 (26.9)	0.8 (4.5)	1.5 (8)	10.9 (58.3)	0.4 (2.2)	18.7 (100)
Maradu	4.8 (34.8)	1.4 (9.8)	1.7 (12.5)	5.5 (40)	0.4 (2.9)	13.8 (100)
Vazhakkala	7.5 (47)	0.1 (0.9)	0.2 (1)	7.3 (45.7)	0.9 (5.4)	16.1 (100)
Kakkanad	4 (35.1)	0.2 (1.3)	0.2 (1.6)	6.2 (54.1)	0.9 (7.8)	11.4 (100)
Varappuzha	1.3 (13.6)	0.6 (6.5)	3.0 (30)	4.9 (49.4)	0.1 (0.6)	9.9 (100)
Cheranallur	2.3 (24.5)	0.9 (10)	0.3 (3.1)	5.6 (60.1)	0.2 (2.3)	9.4 (100)
Kadamakkudy	0.8 (6.1)	3.4 (26.4)	6 (46.2)	2.7 (21.2)	0 (0.1)	12.9 (100)
Mulavukadu	2 (15.7)	5.8 (44.9)	3.1 (23.8)	1.9 (14.9)	0.1 (0.8)	13 (100)
Njarackal	1 (11.1)	1.6 (18.6)	2.8 (32)	3.3 (37.4)	0.1 (0.8)	8.8 (100)
Elamkunnapuzha	0.9 (9.6)	1 (10.1)	2.6 (26.9)	5.1 (53.2)	0 (0.3)	9.6 (100)
Puthuvype	0.6 (22.4)	1.4 (52.4)	0.1 (3.3)	0.6 (21.7)	0 (0.2)	2.7 (100)
Thiruvankulam	2.5 (22.6)	0.2 (1.4)	0.1 (1)	7.8 (70.5)	0.5 (4.4)	11.1 (100)
Kochi City	**96.9 (35.8)**	**40.7 (15)**	**25.0 (9.2)**	**98.3 (36.3)**	**9.8 (3.6)**	**270.8 (100)**

Note: The figure in parentheses is the percentages.
Source: Calculated from the classified imagery.

It may be noted that Thrikkakara has emerged as a major residential region of Kochi with institutional developments, industrial establishments, and various "IT parks such as Smart City, Infopark, Kinfra HiTech Park, HDIL Cyber City, Electronics City, Kochi, World Trade Center (WTC)". About 25 percent of the IT-related exports of Kerala take place from this area. Kakkanad is also the administrative capital of Ernakulam District

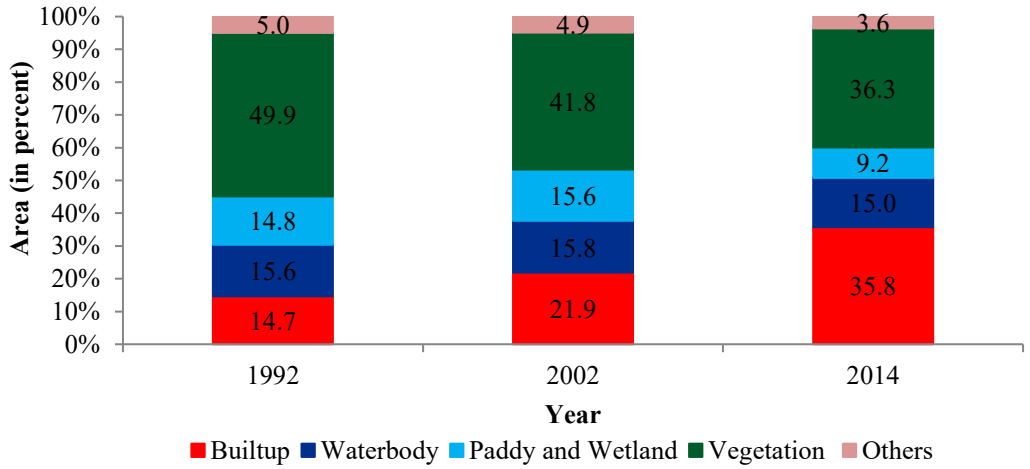
During 2014 the built-up in other coastal and low-lying areas also increased more than two times but with a low base. As indicated earlier majority of this area is covered with water bodies, wetlands, and agricultural areas. Among this Cheranallur bounded by Periyar River and its tributaries have comparatively higher built-up area than other constituent areas. It is located within proximity to industrial areas of Eloor and its linkage to the Cochin Port makes it suitable for industrial development activities. Being contiguous to the Eloor industrial area and Kochi Municipal Corporation, it has potential for wholesale trading and related storage facilities (Govt. of Kerala, 2005).

Overall in 2014, the Kochi city region has 36 percent built-up area compared to 22 percent in 2001, an increase of 14 percent (Table 5.5). The gain in built-up is largely from the vegetation land and other open drylands.

5.6 Temporal Comparison of Area under Different LULC Categories: 1992, 2001 and 2014

From figure 5.4 it can be observed that the percentage of the built-up area of the city during 1992 and 2001 has increased from 14.7 percent to 21.9 percent in 2001. The built-up has further increased to 35.8 percent in 2014. The graph also makes it clear that these built-up expansions have occurred at the cost of vegetation cover. The trend indicates that the built-up may continue to grow even after 2014, which will result in a considerable reduction in its green surface. With the reducing amount of open land and paddy land and also the need of protecting the existing green cover of the city the future expansion demands more land for the existing city planning area (Fig 5.4).

Figure 5.4: Percent distribution of the area under different LULC of Kochi City (1992, 2001, and 2014)



Source: Calculated from the classified imageries.

The area under paddy and wetlands in both 1992 and 2001 remains almost equal at 15 percent of the total land of the city, however, it has reduced to 9 percent in 2014 (Fig 5.4). Similarly, the percentage of area in the category of other lands has been around 5 percent in both 1992 and 2001 and then reduced to 3.6 percent in 2014. Overall it can be observed that the built-up growth of the city is increasing at a greater pace.

5.6.1 Growth in Built-up and Population

The growth rate in the built-up area during 1992-2001 was 49 percent while it was significantly increased in the later period with a growth rate of 63.6 percent (Table 5.6). It may be noted that the time gap between the first two time periods was 9 years and the later two time periods was 13 years. Therefore, an annual exponential growth rate for both time periods is worked out to estimate the average annual growth in the built-up area. It can be seen that the annual average growth from 1992 to 2001 with 4.4 percent was higher than that of the growth rate between the later two periods which was 3.8 percent (Table 5.6). So, the higher simple growth in the built-up is essentially due to the difference in the number of years. Nevertheless, the positive and significant annual growth of 3.8 percent can be attributed to the large-scale infrastructure build-up and real estate boom in recent years (Table 5.6). People working outside the state and abroad are increasingly investing in real estate as an investment option. The commercial growth of the city, especially in the tourism, hospitality industry, international trade, and IT industry due to lower cost of doing business compared to metro cities, has increased the demand for more office spaces, hotels, retail outlets, and residential apartments. The city's proximity to the sea and presence of backwater resulting in better climatic conditions and aesthetics has attracted a lot of investors to the city. This trend can be assumed to go up further as the city continues to expand its built-up area with several infrastructural initiatives such as multiple transportations, special economic zones, and the implementation of smart city projects. There is a surge in migrant workers in the city in the recent past especially in the construction and hotel industry which also demands more housing and amenities.

Table 5.6: Growth in Built-up and Population

Attributes	1991-2001	2001-2011
Built-up (Percent Increase) *	49.0	63.6
Annual Exponential Growth in Built-up*	**4.4**	**3.8**
Population Growth - Kochi M. Corporation	8.0	1.1
Population Growth - Kochi City Region	9.9	4.6
Population Growth - Kochi Urban Agglomeration	18.9	56.3

*Note: * Built-up growth is calculated based on the area generated from the classified imageries of 1992, 2001, and 2014, while population growth rates are calculated from Census of India population for various census years.*
Source: Calculated from the classified imageries.

The growth rate in the population of the Kochi corporation area during 1991-2001 was 8 percent which has further declined to 1.1 percent (Table 5.6). While a part of the population growth decline

can be argued in terms of the fertility decline existing throughout the state, it can also be viewed as the population redistribution process to the surrounding peripheral areas. The same kind of growth dynamics can be seen in the case of Kochi City Region where the population growth was 9.9 percent during 1991-01, which has come down to 4.6 percent in 2001-11 (Table 5.6). Despite the limited spatial expansion of urban agglomeration in 1991-2001 the growth rate of the population is found to be 18.9 percent, higher than the corporation and KCR growth (Table 5.6). This implies that large-scale population redistribution has taken place with people preferring quiet areas with comparatively low pollution, less traffic volume, and affordable housing. However, the reason for the higher growth rate of Kochi UA during 2001-11 can be attributed to the areal expansion of agglomerations over time as has been presented in the third chapter. In 2011 as many as 7 municipalities and 45 census towns were also added and made part of the agglomeration making it an agglomeration with over 2.1 million population.

5.7 Compactness Index (CI) and Built-up Intensity Index (BII)

Two indices of compactness and concentration of built-up are calculated to assess the independent built-up strength within a town constituent and also to understand the built-up concentration in an area concerning the whole city area.

5.7.1 Compactness Index (CI)

The area-based "compactness index" helps in determining the built-up compactness in a particular area. Compactness is normalized and ranges from 0 to 1 with a lower value indicating more compactness.

The index is calculated using the formula $CI = \frac{Total\ Area - Builtup\ Area}{Total\ Area}$.

More the built-up area in a region the compactness index tends to 0. The value close to one indicates a very low level of built-up and the dominance of other types of land-uses.

The derived compactness index shows that both parts of the municipal corporation area along with Kalamassery and adjoining Vazhakkala are denser in terms of built-up in 2014. The relatively higher figures of compactness index in 1991 in other parts of the city region indicate more fragmented and low-density built-ups. However, the compactness index figures in 2001 started to be lower in more areas of Kochi indicating the spread of urban built-up. In 2001 the western part of the city except the corporation part shows a higher compactness index value which indicates

the low level of urban development in that area (Table 5.7). By 2014 the built-up is expanded in all these areas as the value of the index has further reduced (Table 5.7). The built-up in the corporation area along with another nearby municipality started increasing further. The higher value of compactness index compared to the overall figure especially in areas of the city having more Island regions is indicating that fragmented and less dense built-up possibly due to the presence of more natural entities. Overall the figures of compactness index for Kochi for 1991, 2002, and 2014 have declined with figures of 0.85, 0.78, and 0.64 and show that the built-up is getting denser over time (Table 5.7).

Table 5.7: Year-wise compactness index

Compactness	Town Name	1991	2002	2014
High (< 0.64)	Kochi Corporation P1	0.73	0.66	0.45
	Kalamassery	0.81	0.66	0.48
	Vazhakkala	0.84	0.63	0.53
	Kochi Corporation P2	0.80	0.72	0.61
Medium (0.64 – 0.80)	Maradu	0.89	0.86	0.65
	Kakkanad	0.88	0.75	0.65
	Eloor	0.84	0.77	0.66
	Thrippunithura	0.90	0.87	0.73
	Cheranallur	0.98	0.93	0.76
	Thiruvankulam	0.89	0.85	0.77
	Puthuvype	0.93	0.89	0.78
Low (> 0.80)	Mulavukadu	0.98	0.98	0.85
	Varappuzha	0.98	0.95	0.87
	Njarackal	0.97	0.95	0.89
	Elamkunnapuzha	0.98	0.97	0.91
	Kadamakkudy	0.99	0.98	0.94
	Kochi City	0.85	0.78	0.64

Source: Calculated from the built-up and total area based on LULC.

5.7.2 Built-up Intensity Index (BII) of Kochi City

In order to further assess the intensity of built-up in each of the administrative divisions, a "built-up intensity index (BII)" for each of the time periods is calculated. This has been calculated by dividing the ratio of built-up to the total land area of a town constituent by the ratio of the built-up of the entire city to the total land of the Kochi city region and it makes the urban-land expansion speed of different regions of the city comparable (Yan et al., 2020).

Thus, $BII_i = \frac{BA_i/TA_i}{\sum BA_i/\sum TA_i}$, where BA_i and TA_i are the built-up area and total area of i^{th} town

A value of more than 1 for any local bodies indicates that the built-up intensity of that area is proportionately higher than the overall built-up pace of the city. Similarly, a value of less than 1 indicates the built-up intensity in the concerned constituent is less than that of the overall built-up pace of the city. The figures reveal that in 1992 the dominance of built-up intensity was in corporations and the industrial towns of Eloor and Kalamassery (Table 5.8).

Table 5.8: BII of Kochi City (1992-2014)

Intensity	Town Name	1992	2001	2014
High (> 1)	Kochi Corporation (Kanayannur)	1.81	1.56	1.54
	Kalamassery	1.31	1.58	1.46
	Vazhakkala	1.10	1.68	1.31
	Kochi Corporation (Kochi)	1.35	1.26	1.11
Medium (0.57 – 1.0)	Kakkanad	0.82	1.14	0.98
	Maradu	0.72	0.67	0.97
	Eloor	1.10	1.03	0.95
	Thrippunithura	0.69	0.61	0.75
	Cheranallur	0.16	0.33	0.68
	Thiruvankulam	0.73	0.70	0.63
	Puthuvype	0.51	0.57	0.62
Low (< 0.57)	Mulavukadu	0.09	0.12	0.44
	Varappuzha	0.14	0.24	0.38
	Njarackal	0.23	0.22	0.31
	Elamkunnapuzha	0.14	0.16	0.27
	Kadamakkudy	0.08	0.05	0.17
	Kochi City	1.00	1.00	1.00

Source: Calculated from the built-up and total area based on LULC.

In 2001 also, a similar built-up intensity is noted in the corporation area and the industrial town of Kalamassery (Table 5.8). A surge in built-up is noticed in Vazhakkala and Kakkanad region which is a part of the Thrikkakara Municipality which houses the district Collectorate and other major economic and infrastructural installations. This part of the city houses the "Cochin Special Economic Zone (CSEZ)", one of the largest IT Townships in India, the Kochi Info Park, one of the largest IT industrial parks of Kerala. The "software Export Promotion Zone (SEPZ)" is also located in Kakkanad. An estimated 55 percent of the total IT exports of Kerala are from Kakkanad. Apart from these the health, education, and real estate infrastructure is also booming up in the eastern part of the city. As per the 2014 built-up intensity index the corporation area and also the eastern part of the city show an increased pace of built-up compared to previous time periods (Table 5.8).

The economic transition from primary to tertiary activities to an extent has contributed to the enhancement of built-up between the time periods in the case of some town constituents. Kalamassery area shows a higher built-up intensity in the later periods than 1991. Though the built-up intensity is less in areas of Thrippunithura and Maradu, the built-up proportion has increased in 2014. Similarly, Vazhakkala and Kakkanad have higher built-up intensity in 2001 and 2011 compared to 1991 (Table 5.8). The growth in the later period in these areas can be attributed to the large-scale infrastructure build-up and real estate boom in the recent time in the city. It can be expected that the built-up will continue to grow, which will result in a considerable reduction in its green surface and also paddy/wetlands. The built-up increase in the coastal and island areas which earlier had a large vegetation cover substantiates this trend.

5.8 Correlation between built-up and select indicators of development

It is important to understand how various indicators of development are associated with built-up expansion. Some select indicators of the 2001 and 2011 census years about socio-economic and infrastructure development discussed in the previous chapter are correlated with the percent of built-up area in each town constituents in order to understand the relationship between them. The results are represented in tables 5.9 and 5.10.

5.8.1 Correlation Between Built-Up and Other Socio-Economic Indicators

It may be noted that built-up and population density for the year 2001 is positively correlated with a value of 0.372, which indicates that the increase in built-up is associated with an increase in population density and vice versa (Table 5.9). Kerala, irrespective of the rural or urban area has a high literacy rate, and its variation among the constituent areas in Kochi like other cities is also found to be very less because of a higher base throughout the state. However, the built-up and literacy rate has resulted in a negative correlation coefficient of -0.412, which suggests that the built-up is more in areas where literacy is comparatively low (Table 5.9). This can be interpreted as there may be clustering of built-up in areas with low literacy levels in comparison to areas having higher literacy attainment. The Built-up and percent of non-agricultural workers have a positive correlation but it is statistically insignificant (Table 5.9). The correlation between built-up and pucca roads is significant at a 5% level indicating that the increase in density of road is directly linked to an increase in built-up growth (Table 5.9). This is true in the case of urban areas

where the transport network is more as compared to rural areas. The banks per 10000 populations also show a significant positive correlation with the percent of built-up area.

Table 5.9: Correlation between built-up and other socio-economic Indicators (2001)

Variables	Built-up	Population Density	Literacy Rate	% Non Agr Workers	Pucca Road per Sq. Km	Banks per 10000 Population
Built-up	1	.372	-.412	.145	0.522*	0.462*
Population Density	.372	1	.256	.447*	.712**	.602*
Literacy Rate	-.412	.256	1	.642**	.370	0.482*
% Non Agr Workers	.145	.447*	.642**	1	.694**	.688**
Pucca Road per Sq. Km	.522*	.712**	.370	.694**	1	.798**
Banks per 10000 Population	0.462*	.602*	0.482*	.688**	.798**	1

*Note: * Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level*
Source: LULC (2001) and Census of India (2001).

Table 5.10: Correlation between built-up and other socio-economic Indicators (2011)

Variables	Built-up	Population Density	Literacy Rate	Non-Agricultural Workers	Pucca Road per Sq. Km	Banks per 10000 Population
Built-up	1	.469*	-.544*	.373	.677**	.552*
Population Density	.469*	1	-.069	.135	.804**	.477*
Literacy Rate	-.544*	-.069	1	.320	-.267	-.055
Non-Agricultural Workers	.373	.135	.320	1	.369	.699**
Pucca Road per Sq. Km	.677**	.804**	-.267	.369	1	.669**
Banks per 10000 Population	.552*	.477*	-.055	.699**	.669**	1

Source: LULC (2014) and Census of India (2011).

It shows that areas having more built-up areas have more financial institutions. The banks are normally located in areas where the population density is high as they can serve a large population. The other association which can be highlighted here is the relationship of non-agricultural workers which is used as a criterion for defining an area as urban with population and density of population. It can be seen that the correlation between non-agricultural workers and population density is significant at a 5 percent level which can be interpreted as the higher density of population is in areas where more non-agricultural workers are there. Similarly, it has a highly significant positive correlation with literacy rate, pucca road per sq. km, and banks per 1000 population indicating that

the increase in education, commuting network, and banking institutions are all important characteristics of increase in urban expansion.

The correlation between the built-up and the socio-economic and infrastructure indicators of the 2011 census also gave similar results (Table 5.10). The association between built-up and the density of population is positive with a correlation coefficient of 0.469 which is statistically significant at a 5 % level indicating that the density of population is higher in areas where more built-up areas are there (Table 5.10).

As noted in the case of 2001 result, the relation between built-up and literacy rate is found to be negative in 2011 also which can be seen as more built-up in areas with low literacy level. Similarly, the relation of built-up with pucca road per sq km is 0.677 which is highly significant at 1 percent level indicating the importance of road network in urban expansion. The built-up area and banks per 10000 populations are also positively correlated and it is statistically significant at a 5 percent level of significance (los). The result shows that the higher built-up increase leads to an increase in population density, road density, and financial institutions. The association of non-agricultural workers with other socio-economic indicators is also found to be positive, but it was highly significant in the case of banks per 10000 populations which is true in the case of urban areas.

5.8.2 Correlation between built-up and household amenities indicators

A correlation is also worked out to see the relationship of built-up area with that of the housing amenities indicators of Kochi based on the 2011 census data. The correlation coefficient of built-up with percent of households whose houses condition is reported as ‘good’ is 0.757 which is highly significant at 1 % los (Table 5.11). It can be interpreted that area with higher built-up has more households with good housing condition. However, there is no relation found between more living space (three-plus dwelling rooms) and built-up (Table 5.11). The latrine facility connected to the piped sewer system and the built-up area has a highly significant positive correlation (0.681) indicating that areas with more built-up have more latrine facilities connected to the piped water system (Table 5.11). Similarly, the households with access to the closed drainage system and the built-up area are highly positively correlated with a correlation coefficient of 0.905 which can be interpreted as the availability of drainage facility is more linked to higher built-up growth (Table 5.11).

Table 5.11: Correlation between built-up and select indicators of household amenities (2011)

Variables	Built-up (X1)	Good Houses (X2)	3 or more rooms (X3)	Piped Sewer (X4)	Drainage (X5)	Treated Water (X6)	LPG (X7)	Computer with internet (X8)	Four-wheel vehicles (X9)
X1	1	.757**	.006	.681**	.905**	-.373	.545*	.753**	.769**
X2	.757**	1	.380	.677**	.857**	-.746**	.257	.893**	.928**
X3	.006	.380	1	.268	.182	-.446	-.149	.252	.339
X4	.681**	.677**	.268	1	.762**	-.162	.578*	.647**	.636*
X5	.905**	.857**	.182	.762**	1	-.507	.483	.869**	.871**
X6	-.373	-.746**	-.446	-.162	-.507	1	.152	-.713**	-.769**
X7	.545*	.257	-.149	.578*	.483	.152	1	.347	.236
X8	.753**	.893**	.252	.647**	.869**	-.713**	.347	1	.974**
X9	.769**	.928**	.339	.636*	.871**	-.769**	.236	.974**	1

*Note: * Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level.*
Source: LULC (2014) and Census of India (2011).

The relation between built-up areas and households with access to the treated water supply is found to negative and insignificant with a value of -0.373 (Table 5.11). It is an indication that the city doesn't have an adequate piped water system. Most of the peripheral areas are still use alternate water sources such as wells and tanks for their daily needs as has been explained in the previous chapter. The association between built-up and use of LPG for cooking is positive at a 5 percent level of significance with a coefficient of 0.545 indicating that the increase in the availability of cooking gas is linked to a higher built-up area (Table 5.11). Households with computer or laptop with internet facility also shows a highly significant correlation with a coefficient of 0.753 (Table 5.11). It can be interpreted that the percent households with computers or laptops with internet facilities are more in areas having more built-up area. The households with cars, jeep or vans, and the built-up area also have a high correlation coefficient with a value of 0.769 indicating that the four-wheelers are more in areas with higher built-up expansion (Table 5.11).

5.9 Summary

The chapter tried to do a temporal comparison of built-up expansion in Kochi using satellite data at various points of time in the past three decades. Through the present study, it can be seen that during 1992, close to half of the total area of Kochi was under vegetation cover and the rest of the land is shared between built-up, water bodies, wetlands, and others. During the year, the built-up was less than one-third of the vegetation. By 2014 the built-up has increased by almost two and half times and it shared an identical percent with the vegetation category. This means that the built-

up growth mostly occurred at the expense of vegetation cover which is mostly pasture lands and trees that are part of the residential land use. The higher percent of built-up noticed in Eloor, Kalamassery, Kakkanad, and Maradu indicate that the city is expanding along the northeast, east, and southern part.

The built-up intensity in the Ernakulam part of the corporation is higher than its coastal part. The reason may be associated with a higher concentration of commercial and retail trade business in this area. Similarly, Kalamassery and Vazhakkala have shown a higher concentration of built-up in the later periods. Kakkanad in the east and Maradu in the south are the other potential areas that have a higher built-up intensity compared to the initial time period. These are relatively new areas that contributed to the urban growth in terms of commercial and residential expansion. This is also evident from the growth in population in these areas. Eloor in the north is the largest and oldest industrial area in the city though with a higher built-up intensity in the first two time periods shown a decline in the later period.

The linear correlation coefficients of built-up areas with socio-economic indicators show identical trends. It has a statistically significant correlation with population density. However, the increase in built-up and literacy rate is negatively correlated. As mentioned earlier the city has a higher literacy level like that of the state as a whole and it is consistent across the city area. However, areas having relatively less literacy has more built-up can be linked to retail trade being the prominent economic activity in the central part of the city. In both the years, the pucca roads per sq. km and banks per ten thousand populations have a significant correlation with the built-up area. The positive and significant coefficient for pucca roads is indicative of linear urban growth trends along the major roads in Kochi city. Since Kochi is known to be the financial capital of Kerala, banks play an important role for the people, industry, and infrastructure. The bank per ten thousand populations has a statistically highly significant correlation with the built-up area which explains the positive linkages of people and institutions with the banking sector. The correlation between built-up area and a select set of housing indicators shows that the physical quality of houses, households with access to piped sewerage, drainage, LPG for cooking, computers with internet, and households owning four-wheelers all have a positive impact on the built-up growth. Though houses with a spacious living environment are a key standard in Kerala, the correlation coefficient of the built area with households with three or more rooms does not show any significant correlation indicating that built-up increase in cities does not necessarily lead to spacious houses

owing to land pressure. The correlation coefficient of households with treated water supply is negative with the built-up area. It shows that compared to many other cities in India, the Kochi city still lacks piped water supply and heavily depends upon traditional well water like that of most of the rural areas of Kerala.

The recent economic and infrastructural surge in the city tends to attract a large migrant population. This along with the high level of population mobility from nearby towns largely for business and occupational purposes necessitates planners and decision-makers to evolve long-term strategies for Kochi city. Spatio-temporal analysis of land use patterns assists the policymakers and urban planners to have detailed information on existing landscape dynamics and also to assess the developmental characteristics, its consequences, and future urban planning prospects. Based on the observed pattern and trends of built-up growth, an attempt to model the future growth prediction is required for integrated planning and strategies to preserve the environment and heritage of the city. It assists us in planning the future requirements and also helps us to envisage a systematically sustainable city.

Chapter 6: A Geo-Statistical Modeling of Urban Growth in Kochi City

6.1 Background

Human activities in the recent past have tremendously altered Earth's surface especially in urban areas of developing countries. The increasing pace of urbanization in a haphazard manner especially in cities in India necessitates the requirement of a scientific method of planning and decision making. Understanding the patterns and trends of urban growth and the prediction of growth based on the LULC changes observed in the earlier time period with the integration of geo-statistical tools has gained tremendous importance in recent times due to the availability of various "graphical user interface (GUI)" based "remote sensing (RS)" and "Geographical Information System (GIS)". This chapter, therefore, tries to model the urban built-up of "Kochi City Region (KCR)" which comes under the structure plan 2001. For predicting urban growth, the "Land Change Modeler (LCM)" developed by Clarks Lab is used. The urban LULC change prediction in LCM is an empirically driven process that uses LULC and the explanatory variables to (a) analyze the change in LULC between two time periods, (b) modeling transition potentials, and also for (c) LULC prediction to a future date. The results obtained are highly important in urban planning, sustainable land use management, and land use policy decisions.

6.2 LULC Change Analysis

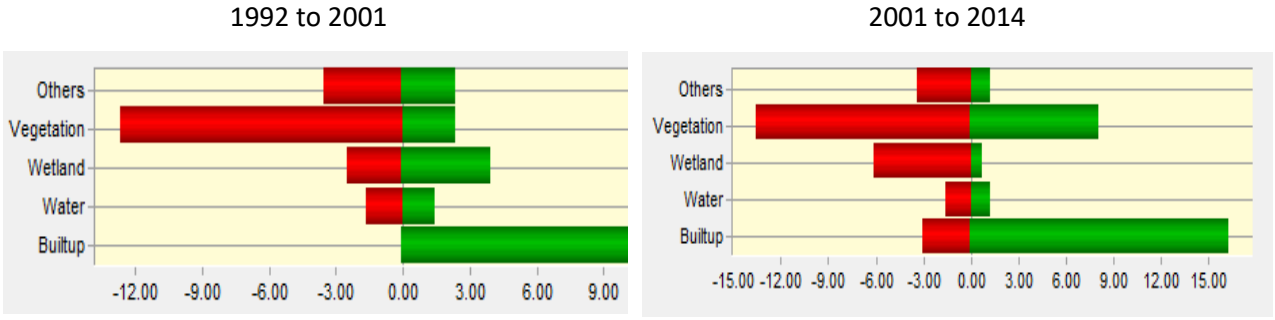
The LULC Change Analysis is carried out and assessed for the classified maps discussed in the previous chapter. The changes that are identified are called transitions from one LULC state to another. When there are many classes the combination of transitions will also be many and it is difficult and sometimes meaningless to model all the transitions. As a result, it is critical to identify the dominant transitions or changes that can be classified into sub-models for future investigation. Thus here, the gains and losses of five broad categories of "built-up, water, wetland, vegetation, and other lands (barren or open)" are discussed. The change analysis carried out through the LCM provides a graphical assessment of gains and losses in terms of area in each of the LULC categories between two time periods. Before starting the analysis through LCM, it is important to check the input parameters such as class sequence and categories of the two LULC maps thoroughly. It

should match, in other words, the pixel value of each class in both the maps should be the same. It is also very important that the spatial dimensions including resolution and projections have to be kept the same for both the LULC maps.

6.2.1 Gains and Losses between 1992 and 2001

It can be seen that the built-up gas gained the highest among the LULC categories with over 10 percent area gain from 1992 to 2001 (Fig 6.1). This is important since during this period the urban growth and changes started more visible due to the launch of economic reforms and liberalization in 1991.

Figure 6.1: Gains and losses in terms of percent area



Source: LULC 1992, 2001, and 2014.

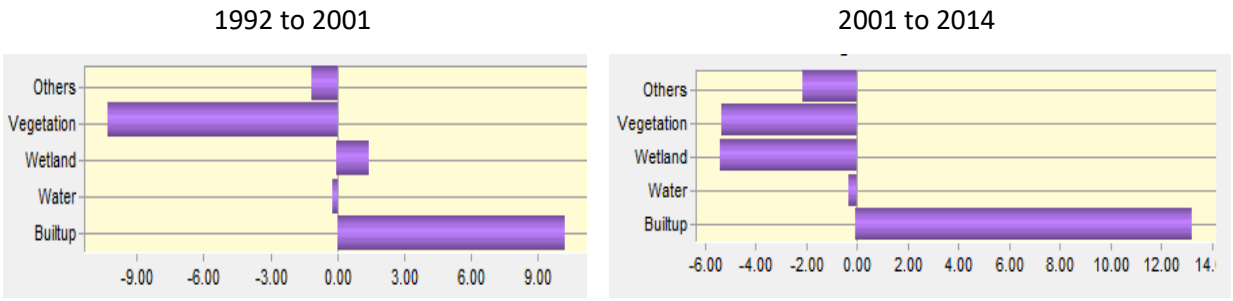
While waterbody and wetland lands showed a small margin of gain and loss, vegetation has a loss of over 12 percent area in 2001 and the gain is less than 3 percent (Fig 6.1). In the case of 'others' which constitutes open and dry fallow land shows over 3 percent loss in the area while the gain was less than 3 percent (Fig 6.1). The higher percent of loss for the vegetation and the gain in the built-up area clearly indicate that the maximum transformation is happening between these categories. Most of this vegetation is pasture lands and trees which are part of residential land use, as such, there is no restriction for construction activities (Kerala Preservation of Trees Act, 1986).

6.2.2 Net Change in LULC

The net change in LULC is the result obtained by taking the difference between the gains and the losses in each category. It can be seen that between 1992 and 2001 the net gain in built-up was highest followed by a marginal gain in wetland while vegetation and 'others' have a net loss in the area (Fig 6.2). A small net loss to the waterbody is also seen as a result of the construction of roads

and bridges over water bodies and also due to a small amount of miss-classification of pixels between the waterbody and wetland category.

Figure 6.2: Net change in each LULC class in terms of percent area



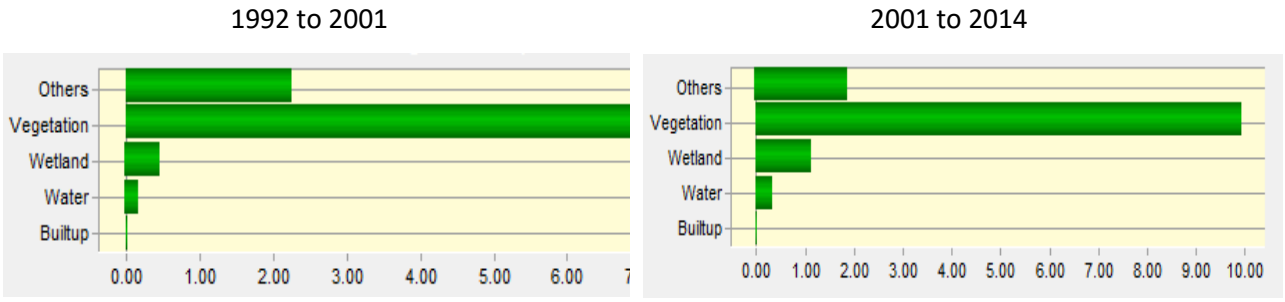
Source: LULC 1992, 2001, and 2014.

However, the net change in the area of each LULC category between 2001 and 2014 shows that only built-up has a net gain and all other classes had a net loss in areas, which shows that except built-up all other classes had a higher loss than the gain (Fig 6.2).

6.2.3 Contribution of All Other Classes to the Net Change in Built-Up

The net change in built-up is the contributions of each other LULC categories in the incremental built-up percent of the area. It shows that the vegetation to built-up followed by open to built-up was the major transitions taken place during 1992 to 2001 and 2001 to 2014 (Fig 6.3).

Figure 6.3: Net change in built-up between 1992 and 2001



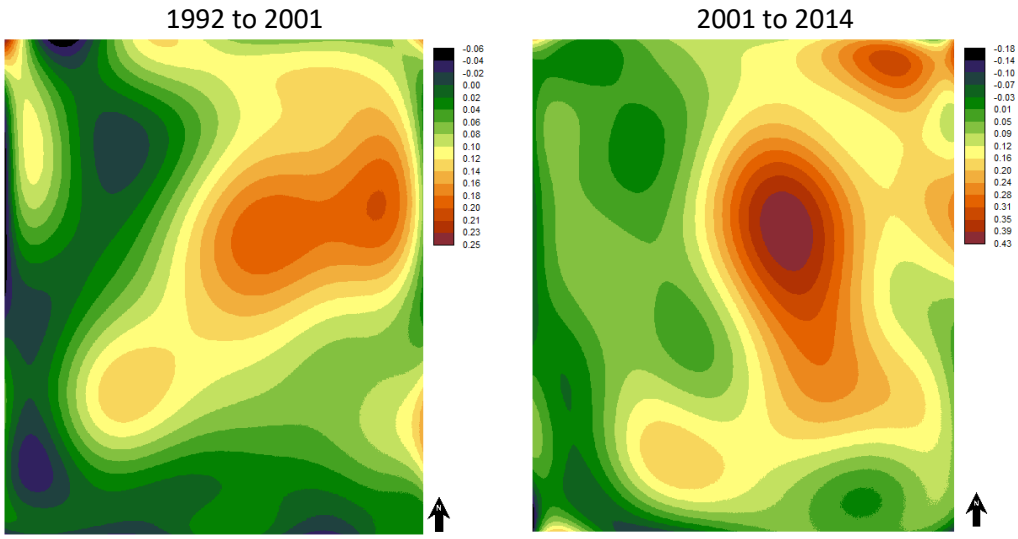
Source: LULC 1992, 2001, and 2014.

A small proportion of the area in wetland and waterbody is also converted to built-up, this can be possible through land reclamation, over the water/wetland construction such as roads or bridges as mentioned earlier.

6.3 Spatial Trend Analysis (STA)

While the graphs of the change in LULC quantify the gains and losses of built-up and other classes, the "Spatial Trend Analysis (STA)" result gives us more insight into the direction of changes during the two time periods. Unlike rural areas, the pattern of changes in urban areas is complex since human interventions dominate the changes and graphs alone are inadequate to interpret the changes (Fig 6.4). STA facilitates us to obtain a best fit polynomial trend surface to highlight the pattern of change in built-up. It has already been observed that the maximum changes to built-up in Kochi are gained from the vegetation followed by open land. The rapid and extensive growth of urban expansion converts the green and open space to built-up areas as an environment and development trade-off (Saifullah et al., 2017).

Figure 6.4: Spatial trend of built-up in Kochi



Source: LULC 1992, 2001, and 2014.

The STA calculates the polynomial equations for spatial data sets in multiple order from linear to 9th order polynomial and interpolates the surfaces based on the equations. The standard form of the equation for the polynomial fit is

$$z = \sum_{i=0}^{k} \sum_{j=0}^{i} b_{ij}\, x^{i-j} y^{j}$$

where k is the maximum order to be fitted, b_{ij} *is the coefficient of the equation, both i and j are iteration variables associated to k, in which i = 0,1,...k and j = 0,1...i.*

For example, to fit a cubic trend k = 3, the equation is:

$$z = b_{00} + b_{10}x + b_{11}y + b_{20}x^2 + b_{21}xy + b_{22}y^2 + b_{30}x^3 + b_{31}x^2y + b_{32}xy^2 + b_{33}y^3$$

The outputs of the raster surface maps are scale-free and do not have any special significance other than to indicate where the change was more intense (higher values) or less intense (lower values). The map is a generalization of the transition from any of the LULC in the previous time period to the later time period.

Figure 6.4 is a spatial trend of built-up for the 1992-2001 and 2001-2014 periods. The trend for the first period indicates that the change of different classes to the built-up occur in the north-eastern part of the city. It is understandable since in the earlier period the urban development was focused at the city core and directed towards the industrial towns of Eloor and Kalamassery. The major transportation network is also linked to these industrial towns. It may be noticed that the LULC transition to built-up for the 2001-2014 period has got a wider trend coverage directed towards the eastern part of the city (Fig 6.4). This is because apart from industries, due to new economic policy decisions of government such as setting up of SEZ and IT parks, the built-up trends started directed towards the eastern part. This area is fast transformed into a major commercial, residential and administrative region. It houses many educational institutions, industrial establishments, and also it is the administrative capital of Ernakulum district.

6.4 Driving forces of urban growth

In cities, the land-use changes are a continuous process involving various driver variables, and identifying them is essential for understanding the urbanization trends (Qu et al., 2014). The driving forces of urban land use mainly include the natural eco-environment, accessibility, socio-economic, neighborhood factors, relevant planning, and policies (Shu et al., 2014). But it may vary city by city depending upon the prevailing socio-economic conditions, neighborhood factors, accessibility of various resources, and government interventions that exist in a particular location. While the model remains constant, it is important to identify and choose the set of driving forces that determines the major reasons for the land-use conversions specific to the city under study for predicting the future growth trends. Different studies use different driving factors for urban expansion on a temporal as well as spatial scale. Socio-economic factors (Cao et al., 2019; Mahmoud & Divigalpitiya, 2019; Manu et al., 2015; Santé et al., 2010; Shafizadeh-Moghadam et al., 2017; Tian et al., 2005), slope (Liu et al., 2020; Poelmans & Van Rompaey, 2010; Yang et al., 2020), elevation (Liu et al., 2020), proximity to various facilities (Aguayo et al., 2007), neighborhood factors (G. Li et al., 2018), industrialization, economic development and GDP (Yan

et al., 2020), infrastructure, employment opportunity (Poelmans & Van Rompaey, 2010) and land use policies are among some of the factors identified by various studies that drive urban expansion. The majority of research studies suggested that urban expansion is associated with population growth, population density, proximity to various infrastructure, economic development, and policy initiatives.

The selection of driving forces that are to be integrated with the modeling process can be carried out by assessing the indicators that influence the change in the built-up of the city. After analyzing the relationship of built-up with population density and socio-economic composite indices derived from different indicators, the driving variable for urban growth prediction used in the present analysis is briefly discussed below.

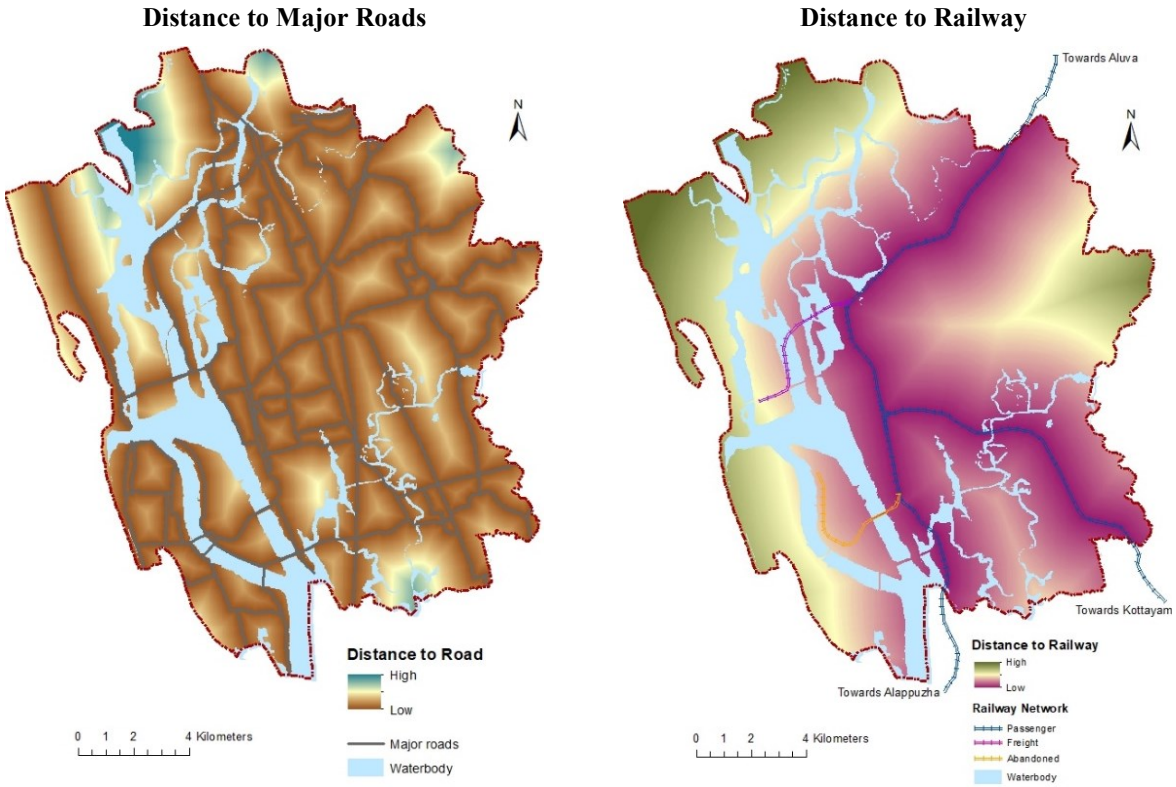
6.4.1 Proximity Indicators

6.4.1.1 Roads and Railway

In urban prediction modeling, the distance to roads and railways are extensively used as the potentiality of urban growth increases in areas close to it (G. Li et al., 2018). In the present model also these two variables are used for predicting the urban growth for 2014 and 2031.

The transport sector plays a crucial role in urban development both in terms of commuting and transporting goods. Transport infrastructure, travel behavior, and urbanization are closely interrelated and it increases the accessibility, making land more potential for further development, conversely also as built-up increases due to other factors the roads and other mediums of transportation also start to increase (Kasraian et al., 2016). As discussed in the previous chapter the major roads and railway in Kochi have been included as factors of urban expansion as it plays a crucial role in intra-city and inter-city linkages. Though Kochi has other modes of transport such as waterways and airport, these have limited impact to be included in modeling since these are specific to a part of the city and has to be treated separately. The role of roads in the urban built-up increase in Kochi can also be understood from the fact that roads like M.G. Road and Banerjee Road which are two of the busy roads have heavy built-up on either side (Map 6.1). The other state and national highways also have heavy built-up areas on either side of the roads. As the distance to roads increases the built-up also tends to decrease.

Map 6.1: Distance to major roads and railway:



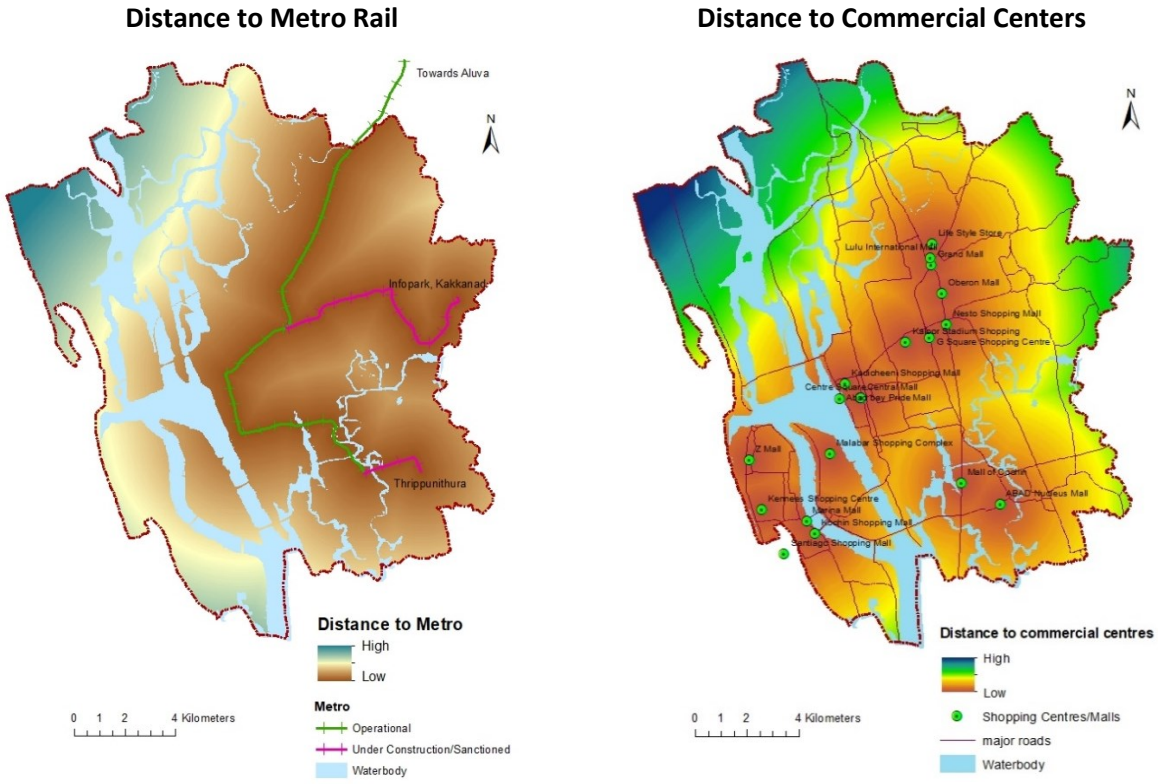
Source: SOI map 2010.

6.4.1.2 Metro Rail and Commercial Centres

In addition to roads and railways, the introduction of the metro and modern shopping methods has played a major role in attracting more people to the city and in turn contribute to the growth of the city (Wegener, 2013). Therefore, the distance to metro rail and major commercial centers as a proximity factor for urban growth is also included in the prediction model for 2031 (Map 6.2). Metro is one of the latest urban transportation systems for cities having heavy commuting density and a highly congested road network. It is free from traffic snarls and therefore one of the most convenient city transportation systems. The real estate developers and commercial establishments always try to be as close as possible to the metro network in order to increase the profitability and thus influence the urban built-up expansion (Map 6.2). In Kochi, the currently operational metro is from Aluva to Petta as shown by the green line on the map. The construction work of the section from Petta to Thrippunithura is already going on and the construction of the second phase towards Info park in Kakkanad will start any time now as the project has the nod of the state and the central

governments. The distance to the metro has not been included in the simulated map for the year 2014 as it was based on 1992 and 2001 spatial and non-spatial data and the metro was non-existent during that time period. However, the distance to the metro is included as an important driver variable in the prediction model for 2031 as the built-up tend to increase in the neighbourhood of the existing metro line and also in places around the sanctioned project, and as a result, the residential and commercial built-up tend to increase.

Map 6.2: Metro rail and commercial centers



Source: OSM and Google Earth.

In order to transform the city into a megacity, metro connectivity is essential for smooth commuting and the road-based transport systems alone are inadequate especially for those cities that has to cater to a large population. Also, with the introduction of the metro, we can expect that there will be hassle-free movement of people, reduced road traffic, and also helps in reduction in choking air pollution (Kumari et al., 2018). It can also be assumed that the introduction of the metro line change city's land use pattern and intensity of use, thereby altering the overall city structure (Sekar & Gangopadhyay, 2017).

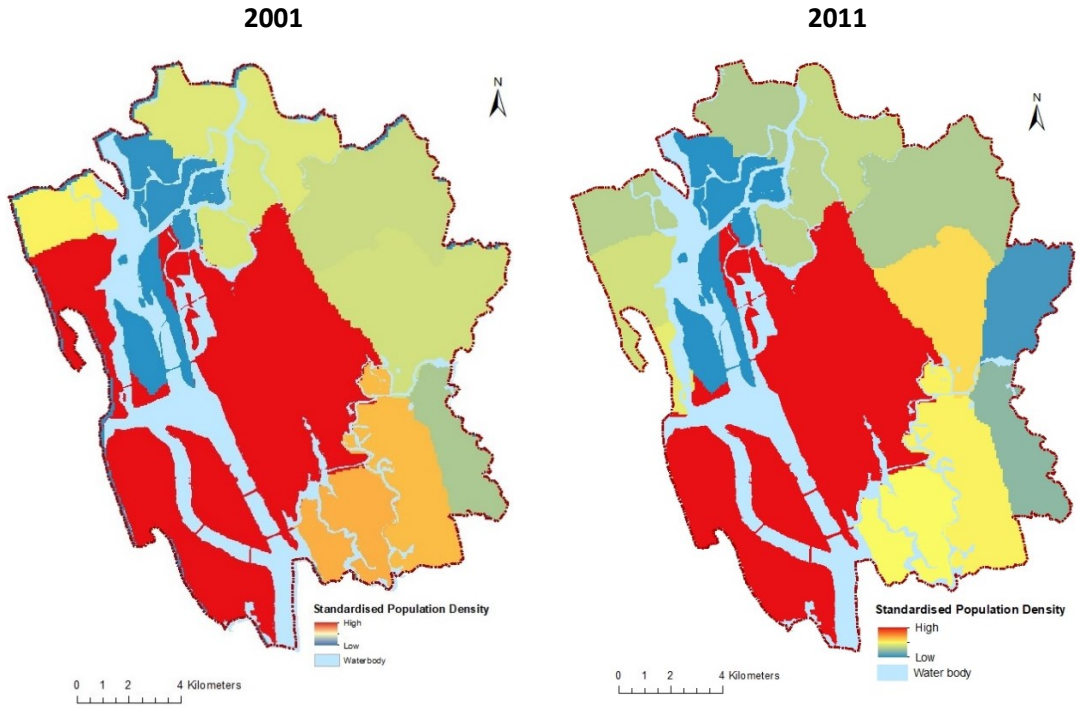
Some studies use marketplaces and commercial centers as driving forces of urban changes (Lambin et al., 2001). The built-up is tends to increase in an area close to commercial centers as people prefer to live close to their requirements of day-to-day life (Gharaibeh et al., 2020). Major commercial centers such as shopping malls are usually located in areas with better transportation network, as such, the residential and other shops in the area tends to increase. In Kochi majority of these commercial centers are located nearer to the transport corridors and nodes. It can be seen from the map that the areas with higher built-up like the municipal corporation and other satellite towns in the city have more commercial centers (Map 6.2).

6.4.1.3 The density of population and socio-economic index

Apart from the proximity indicators of roads, railway, metro, major shopping centers which are converted to the "Euclidian distance" maps for using it as inputs for modeling, another set of indicators from census 2001 and census 2011 are also included in the modeling which is identified based on correlation result discussed in the previous chapter. These are the population density, literacy rate, percent of non-agricultural workers, pucca road per sq. km area, and banks per 10000 people. Keeping in view of the direct relationship of density of population with the built-up, it has been included in the model separately as an input variable. Another indicator that is used as an input for predicting the built-up growth is a socio-economic index which is formed by reducing the dimension of literacy rate, percent non-agriculture workers, pucca roads (in Km) per square kilometer area and, the number of banks per ten thousand population. While population density has been kept as a separate explanatory variable as explained earlier, a "Principal Component Analysis (PCA)" based composite index is used to combine the other four indicators calculated from 2001 and 2011 census data (Table 6.1). This is done because including these variables separately in the model will reduce the performance of the prediction as it has to go through various iterations during the LCM model running. The index based on these variables is included in the modeling as it has shown a high correlation with the built-up area extracted and the result of the correlation is already discussed in the previous chapter. The model inputs in terms of a standardized raster map of the population density and socio-economic index of 2001 and 2011 are shown in Map 6.3.

The density of population in the municipal corporation area and Elamkunnapuzha in the west is found to be much higher than other areas of the city, whereas the area is covered by wetlands/paddy lands in the northwest and east of the city is relatively having less density of population (Map 6.3).

Map 6.3: Rasterized distance map of the density of population



Source: Computed from Census 2001 and 2011.

Table 6.1: PCA of Socio-economic indicators (2001)

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	2.855	71.369	71.369
2	.701	17.530	88.899
3	.268	6.699	95.598
4	.176	4.402	100.000

Source: Census of India (2001).

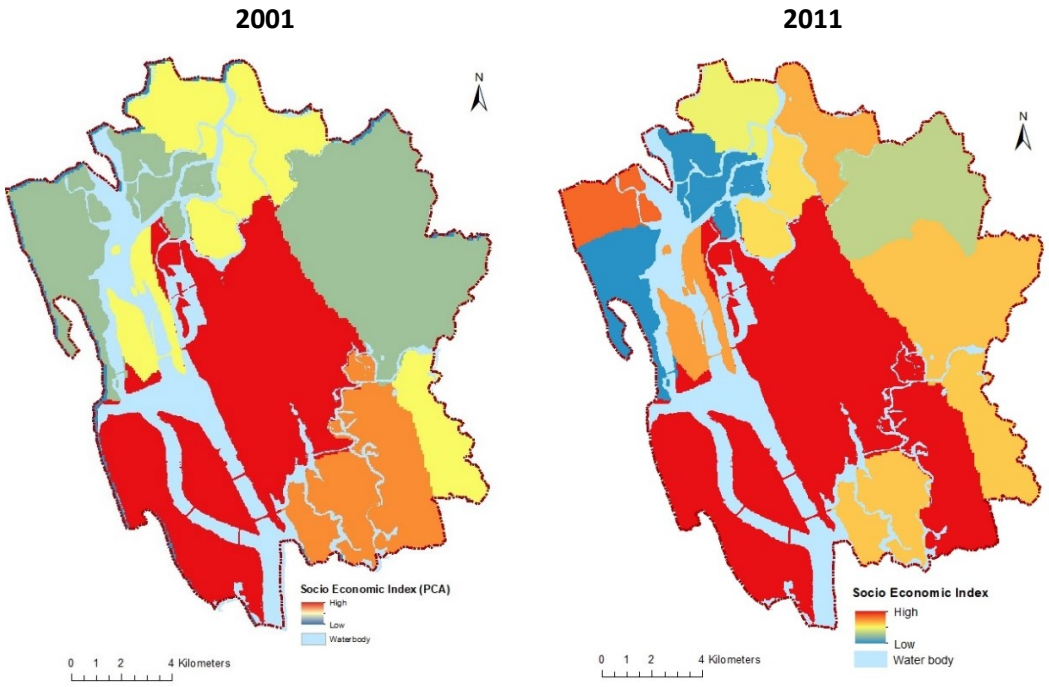
Table 6.2: Communalities and Component Matrix (2001)

Variables	Communalities	Component
Literacy rate	.510	0.714
Non-Agriculture Workers	.810	0.900
Pucca Roads (Kms) Per Sq. Km Area	.743	0.862
Banks per 10000 Population	.792	0.890

Source: Census of India (2001).

The first eigenvalue 2.855 represents the total amount of variance (71.369) that is explained by the first principal component and each of the commonalities is the square of the factor loadings and represents the amount of variance of the respective indicators in the first principal component (Table 6.1). The component values are the factor loadings of each indicator which represents the correlation between the first principal component and the corresponding indicators. In 2001 the percent variance explained by non-agriculture workers was highest with 81 percent followed by banks per ten thousand people with 79 percent, pucca roads per sq. km area with 74.3 percent, and literacy rate with 51 percent (Table 6.1).

Map 6.4: Rasterized distance map of Socio-economic Index



Source: Computed from Census 2001 and 2011.

Table 6.3: PCA of Socio-economic indicators (2011)

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	2.534	63.361	63.361
2	1.055	26.369	89.730
3	.308	7.693	97.423
4	.103	2.577	100.000

Source: Computed from Census (2011).

Table 6.4: Communalities and Component Matrix (2011)

Variables	Communalities	Component
Literacy rate	0.458	0.677
Non-Agriculture Workers	0.841	0.917
Pucca Roads (Kms) Per Sq. Km Area	0.531	0.729
Banks per 10000 Population	0.704	0.839

Source: Computed from Census (2011).

The comparatively lower variance by the literacy rate is largely due to the consistency and less spatial variation. As a model input requisite, the extracted principal score representing the socio-economic index is converted into a raster distance map and used as one indicator in the modeling. In the socio-economic index for 2011, the eigenvalue associated with the first principal component is 2.534 (Table 6.3). This in terms of the total amount of variance it works out to be 63.36 percent. Similar to the previous time period, in 2011 also the percent variance explained by non-agriculture workers was highest with 84 percent followed by banks per ten thousand people with little over 70 percent, pucca roads per sq. km area with 53 percent, and literacy rate with 46 percent (Table 6.3). The comparatively lower variance in literacy rate and the pucca road is largely due to the consistency and less spatial variation in the data compared to 2001. The extracted principal score is the socio-economic index which is converted into a distance map and used as an input in the modeling.

Thus, the variables which are included as explanatory variables in the modeling are population density, socio-economic index, distance to major roads, and distance to railway for predicting the built-up surface of 2014. Because of the scarcity of temporal vector data of roads and railway lines, and also with the assumption that highways, major roads, and railway lines are features that will not vary drastically over time, for both periods the same linear factors are included. The railway line that leads to the port in Wellington Island which is an abandoned line and also the line used exclusively for the freight movement to the "Vallarpadam International Container Depot (ICD)" is omitted since these lines are unlikely to explain the built-up growth in the surrounding area. Only the passenger railway line coming from Aluva side to Kottayam and Alappuzha which passes through large built-up patches is included in the modeling. For the later period 2001-2014 based on which the final prediction to urban growth in 2031 is made, two more factors of distance to metro and distance to major shopping centers are also used along with the variables considered in the previous time period. The location of the shopping centers is based on the field identification and also verified through google earth images. The inclusion of these parameters in the later period

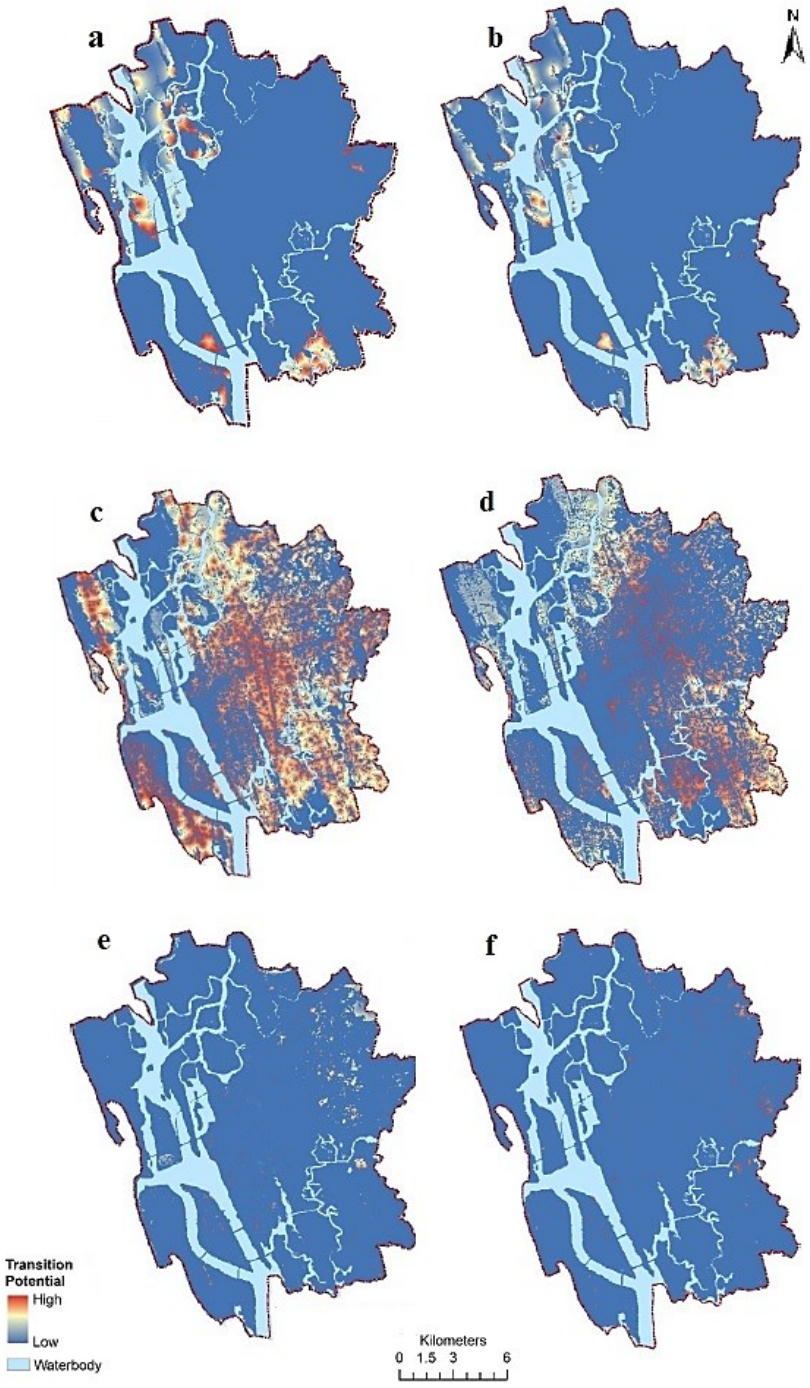
only is because these developments came much after the first time period of 1992-2001 and also due to the fact that it has a major contribution to the urban expansion of cities as evident through various literature discussed in the previous section.

6.5 Transition Sub-model using Multi-Layer Perceptron (MLP)

Identifying the potential for land transitions is an important step towards urban prediction. "Transition Potential Modeling (TPM)" allows us to group the major transitions into a set of sub-models. It essentially creates suitability maps for each transition that has the same underlying driving variables. The driving variables can be added to the model either as static or dynamic variables. The static variable expresses aspects of basic suitability for transition and it is unchanged over time while dynamic variables are time dependant variables that are recalculated overtime during the prediction process. Once the driver variables are selected, transition potential maps for each transition can be modeled using "Multi-Layer Perceptron (MLP)" "Artificial Neural Network (ANN)"

MLP procedure is a dynamic process based on a random sample of cells that experienced each of the two transitions being modeled and an additional set of random samples for each of the cases of pixels that could have, but did not go through the transition. Thus, the neural network in this modeling will consist of four classes, two transition classes, and two persistent classes. The persistent classes are the cases where each of the "from" classes remains the same. Our interest is the first two of these, i.e. the sample cells that experience transition from vegetation and other open lands to built-up, but the neural network will be able to train optimum if it has all the 4 classes. Based on the factors we entered to train, MLP develops a multivariate function that can predict the potential for transition based on the values at any location for the six explanatory variables. It does this by taking half the samples it was given to training on and it reserves the other half to test how well it is doing. The MLP constructs a network of neurons between the six input values from the explanatory variables and the four output classes (the transition and persistence classes) and a web of connections between the neurons that are applied as a set of random weights. These weights structure the multivariate function. With each cell it examines from the training data, it measures its error and adjusts the weights. As it gets better and better at performing this, the accuracy increases and the precision improves (i.e., the RMS error declines).

Map 6.5: Transition potential from different land-use classes to built-up



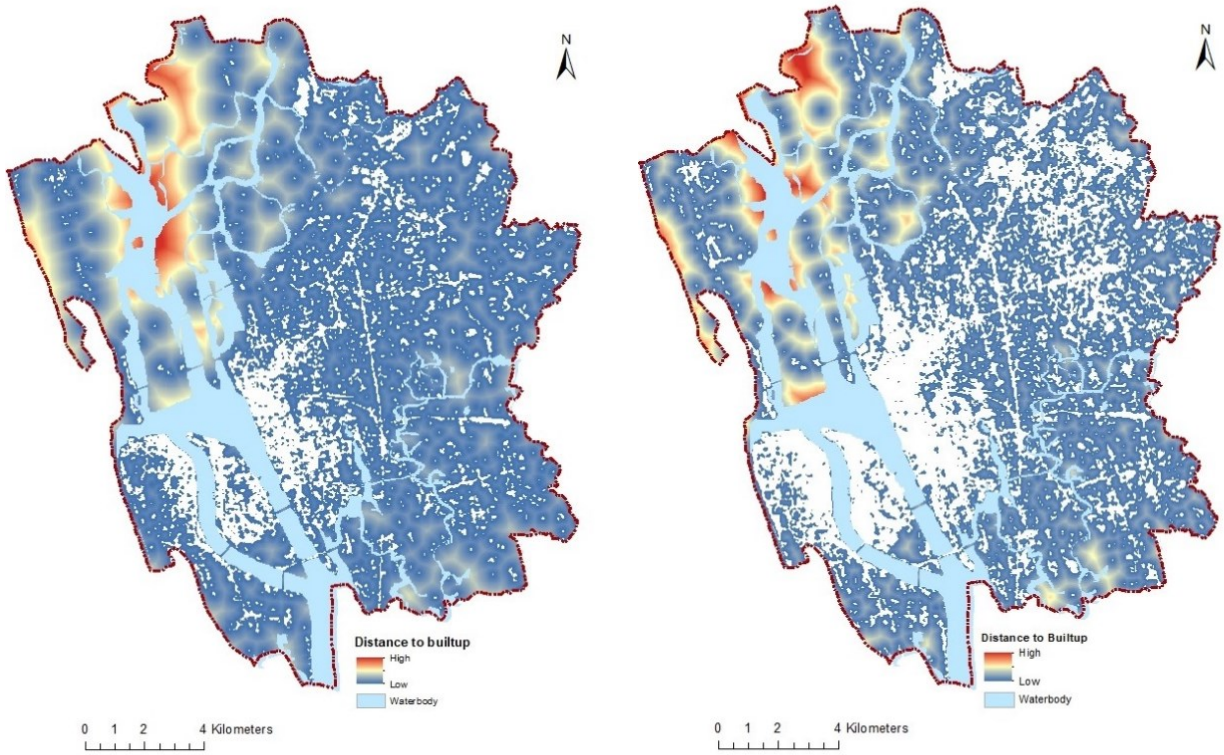
Note: 'a', Wetland/paddy to built-up (1992-2001), 'b' Wetland/paddy to built-up (2001-2014), 'c', Vegetation to built-up (1992-2001), 'd' Vegetation to built-up (2001-2014), 'e', Others to built-up (1992-2001), 'f' Others to built-up (2001-2014).
Source: Computed from LULC.

When the MLP completes its training, we need to decide if it has done well enough to model the transition otherwise we should re-train it with either the same parameters with a different set of random samples or by including new input parameters.

The transition potential shows that there are some areas within the wetland/paddy land areas that have a high potential to be converted to built-up in the future. Minor transitions like water to built-up which constitutes only a negligible area compared to the whole are not worth modeling. Therefore, transitions less than 0.5 sq. km are ignored in this analysis (Map 6.5). So, the dominant transitions that are taking place in the area such as the vegetation to built-up, wetland/paddy land to built-up and other lands to built-up are used to create the transition potential maps. The transition could have been done using a logistic regression also, but it requires these transitions to be modeled separately, and also in logistic regression a non-linear relationship need to be linearized by applying a log transformation. The MLP on the other hand allows us to model the two transitions at once and also it is best suited for modeling non-linear relationships.

Map 6.6: Distance to Built-up

1992 **2001**



Source: Computed from LULC.

It is logical to assume that the new urban growth will occur in places close to the existing urban areas because of its accessibility to infrastructure and amenities. It can be noted from the map that the northwest part of the city has a higher distance value which indicates that there will be less built-up growth in those areas. The white-colored regions are the existing built-up and the blue regions are the ones close to them which may have a higher probability of transition to built-up. The distance maps are obtained by extracting the built-up areas from the 1992 and 2001 LULC images and then filtering them with a 3x3 mode filter to remove any extraneous pixels (Map 6.6). It is logical to assume that during 1992 – 2001 and 2001 -2014, the new built-up is added to the near areas of existing built-up since city expansion is more contiguous in nature. Therefore, in order to see whether the nature of change in built-up as we move away from existing built-up is linear or non-linear, a histogram is computed by using the 1992 built-up distance map as the input file and the 1992-2001 change map as a mask, similarly using 2001 built-up distance map and 2001-2014 change map (Appendix 6.1 & 6.2). It can be seen that there is a very sharp decline in the frequency of change to urban as we move away from existing urban areas. This shows that the built-up has a non-linear relationship and hence MLP is a better modeling tool for predicting the urban change as compared to the logistic regression where we need to linearize it first by applying a logarithmic transformation (Map 6.6).

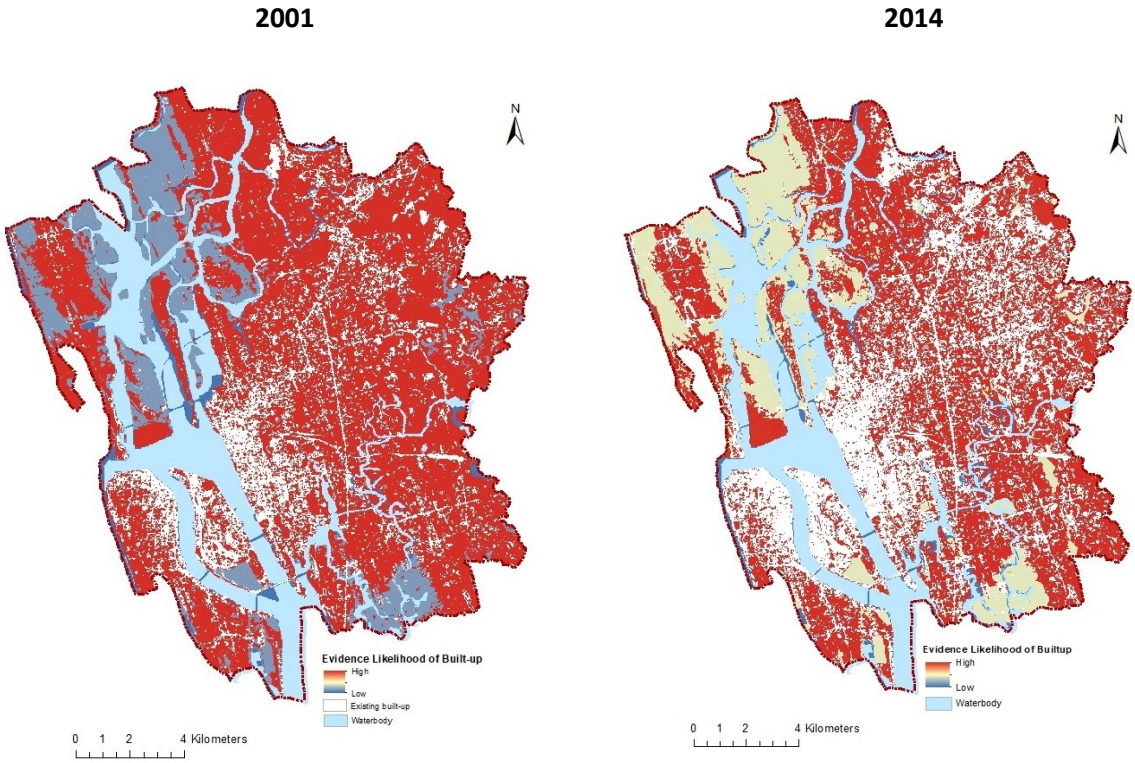
6.5.1 Evidence Likelihood Transformation of Built-up

When there are several qualitative variables such as LULC, it needs to be treated separately by creating dummy variables or Boolean layers for each class before they can be included in the model. The disadvantage of including many dummy variables in the model is it increases the number of variables in the model significantly and in turn, it may impact the model performance. One way of creating a quantitative variable from a categorical variable is the variable transformation using the evidence likelihood function which is available in the variable transformation utility module of the LCM in Idrisi Selva software.

The evidence likelihood function calculates the relative frequency with which different LULC categories occurred within the areas that transitioned from 1992 to 2001 as well as 2001 to 2014. In other words, it represents the likelihood of finding the LULC at the pixel in question if this were an area that would undergo transition. The white surface is the existing built-up and the red surface is the area that can change to built-up in the later time period (Map 6.7). In 2001, except for the

water body and most of the wetlands/paddy lands, the likelihood surface was more whereas for 2014 the likelihood surface of built-up is comparatively less since during 1992-2001 some of these areas has already become part of the built-up (Map 6.7).

Map 6.7: Evidence Likelihood of Built-up



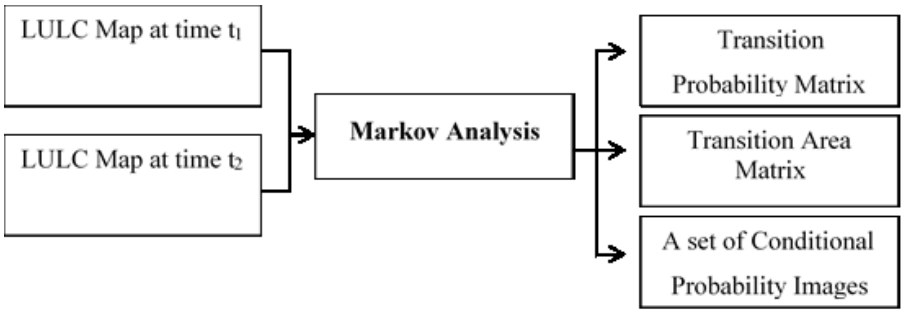
Source: Computed from LULC.

6.5.2 Markov Transition Probability

Markov chains were introduced in 1906 by Andrei Andreyevich Markov (1856–1922), a Russian mathematician known for his work on stochastic processes. It is named in his honor as Markov Chain. Urban change, especially in developing countries, can be termed as stochastic in nature as it involves random changes in its LULC over time. In urban studies, it is performed on a pair of LULC images for getting transition probability matrices, transition probability areas, and a set of conditional probability images (Takada et al., 2010). The transition probability matrix records the probability that a pixel of a given land use category will change to any other category in the next period of time. The transition probability matrix is the result of cross-tabulation of the two images adjusted by the proportional error. The transition areas matrix records the number of pixels that

are expected to change from each land use type to each other land type over the specified number of time units. In both of these files, the rows represent the older land cover categories and the columns represent the newer categories. The transition area matrix is produced by the multiplication of each column in the transition probability matrix by the number of cells of the corresponding land use in the later image. The conditional probability images report the probability that each land cover type would be found at each pixel after the specified number of time units. These images are calculated as projections from the latter of the two input land cover images (Fig 6.5) (Takada et al., 2010).

Figure 6.5: Inputs and outputs of a Markov analysis



Source: IDRISI manual

A discrete-time Markov Chain is defined as a sequence of discrete-time random variables expressed in terms of probabilities.

As done for any stochastic process the Markov technique is used for the prediction of change from one category to another category. A stochastic process X_t *(where t >= 0) can take a countable number of possible values. When the process is in state i at time t, then there is a fixed probability* p_{ij}*, that it will be in state j at time t+1 and it is given by*

$p(X_{t+1} = j/X_t = i, X_{t-1} = i_{t-1}, X_{t-2} = i_{t-2}, \dots\dots, X_1 = i_1, X_0 = i_0) = p_{ij}$

for all $i_0, i_1, i_2, \dots\dots, i_{t-1}, i, j$ *and t >= 0*

The Markov Chain Conditional Probability state that for any future state X_{t+1} *given that their paste states* X_0*,* X_1*,* X_2*,* $\dots\dots, X_{t-1}$*,* X_t*, the probability of the future state is depending only on the present type of state* X_t*. A Markov Chain conditional probability can be expressed as*

$p_{ij} = p(X_{t+1} = j/X_t = i)$ *and in matrix form as;*

$$P_{ij} = \begin{bmatrix} p_{00} & p_{01} & p_{02} & \cdots & p_{0j} \\ p_{10} & p_{11} & p_{12} & \cdots & p_{1j} \\ \vdots & \vdots & \vdots & \cdots & \cdots \\ p_{i0} & p_{i1} & p_{i2} & \cdots & p_{ij} \end{bmatrix}$$

Where i, j >= 0, 0 <= p_{ij} *<= 1 and* $\sum_{j=0}^{\infty} p_{ij} = 1$

6.5.3 Transition Probability of LULC

Transition probabilities in the context of LULC are the likelihood that a pixel of a given land use category will change to any other category in the next time period. The transition probability matrix records the probability that each land use category will change to every other category. It is the result of cross-tabulation of the two images adjusted by the proportional error. The transition areas matrix records the number of pixels that are expected to change from each land use type to each other land type over the specified number of time units. In both of these files, the rows represent the base year land cover categories and the columns represent the later year categories.

As discussed earlier, the transition probability matrix gives the probability that each land use category will change to every other category. The transition areas matrix, on the other hand, records the number of pixels that are expected to change from each land use to each other land use type over the specified number of years. The transition area matrix is produced by the multiplication of each column in the transition probability matrix by the number of cells of the corresponding land use in the later image. The conditional probability images report the probability that each land cover type would be found at each pixel after the specified number of time units. These images are calculated as projections from the latter of the two input land cover images (Takada et al., 2010). In both of these files, the rows represent the older land use and the columns represent the newer categories. The transition probability of built-up derived from 1992-2001 and 2001-2014 LULC is presented in Table 6.5. The diagonal elements represent the self-replacement probability of particular land use, while the off-diagonal elements are the transition probability from each land use to another land use. The sum of the transition probabilities of each row element will remain 1 as the total probability is always 1. From the transition probability for 2014 obtained based on 1992 and 2001 LULC categories the built-up to remain in the same class is as high as 0.993, which indicates that the conversion from built-up to other categories is minimal. Similarly, the probability of the water body remaining in the same category is found to be 0.911 (Table 6.5). This indicates that the transition of a natural water body to other categories is very low. A small probability of 0.046 from waterbody to wetland/paddy lands could be mainly because of cross-classification of a small number of pixels as both these are closely linked (Table 6.5). The persistence of wetland/paddy is found to be comparatively low with a probability of 0.72 (Table 6.5). The conversion of wetland/paddy to vegetation is 0.103, while to waterbody and built-up is 0.087 and 0.06 respectively (Table 6.5).

Table 6.5: Markov Transition Probability Matrices: 1992-2001 and 2001-2014

LULC	Built-up	Waterbody	Wetland/ Paddy	Vegetation	Others
		1992-2001			
Built-up	0.993	0.000	0.002	0.005	0.000
Waterbody	0.012	0.911	0.046	0.019	0.012
Wetland/Paddy	0.060	0.087	0.720	0.103	0.030
Vegetation	0.230	0.017	0.086	0.620	0.047
Others	0.543	0.035	0.046	0.219	0.157
		2001-2014			
Built-up	0.875	0.004	0.003	0.105	0.015
Waterbody	0.011	0.954	0.013	0.020	0.003
Wetland/Paddy	0.050	0.051	0.632	0.262	0.005
Vegetation	0.307	0.005	0.003	0.666	0.019
Others	0.522	0.015	0.030	0.227	0.207

Source: Computed from LULC

The higher transition probability to vegetation is because of the presence of mangroves and other pasture lands around the wetland. A small amount of wetland to built-up conversion is also happening mainly because of the residential infringements, road and bridge infrastructure in such areas. In the case of vegetation also the self-conversion rate is low at 0.62 (Table 6.5). The maximum gain from the vegetation is for the built-up with a probability of 0.23. It is to be noted that the major conversion of built-up in Kochi is from the vegetation land as these are urban residential land use and hence there is no major restriction in construction activities at the expense of vegetation. The other cross conversion is found from vegetation to wetland/paddy land mainly because of the likely conversion in low-lying areas. The others category which is dry fallow and open land to remain in the same category is very less with a probability of 0.157 (Table 6.5). It is because of the higher chance of vacant land conversion to the built-up area. The transition probability of other lands to built-up is estimated as 0.543 (Table 6.5). The chance of vacant land to be vegetation in the future is also more than the self-conversion rate with a probability of 0.219 (Table 6.5). Overall it can be seen that the transition probability of other land and vegetation to the built-up area is high followed by a small conversion rate from the wetland/paddy lands.

The Markov transition probability predicted for 2031 based on the 2001 and 2014 LULC indicate that the built-up to remain in the same category is 0.875 while the transition to the vegetation is 0.105 (Table 6.5). A part of the reason for such gain in transition to vegetation is the canopy that exists surrounding the built-up in Kochi as well as other parts of Kerala. The self-transition rate of waterbody is high at 0.954 and there is no significant conversion probability to other categories.

Wetland/Paddy on the other hand has only 0.632 probability to retain in the same class in the future. A major area of it may likely be converted into vegetation and a small portion to built-up and waterbody (Table 6.5). The wetlands in Kochi are continuously susceptible mainly because of the increasing urban infrastructure, residential and commercial developments. The proximity to the city core and availability of lands at cheap rates make developers easy targets. The matrix also indicates that there is a 0.666 chance that the vegetation will remain in the same class in the future. The most important transition of the vegetation is to built-up with a probability of 0.307 as noticed and reasoned for the previous period. It is evident from the transition matrix that the maximum conversion of built-up is taking place from the open land with a transition probability of 0.522. The open land to remain in the same land-use type is as low as 0.207 and an equal probability exists for its transition to vegetation area (Table 6.5).

6.6 Change Prediction

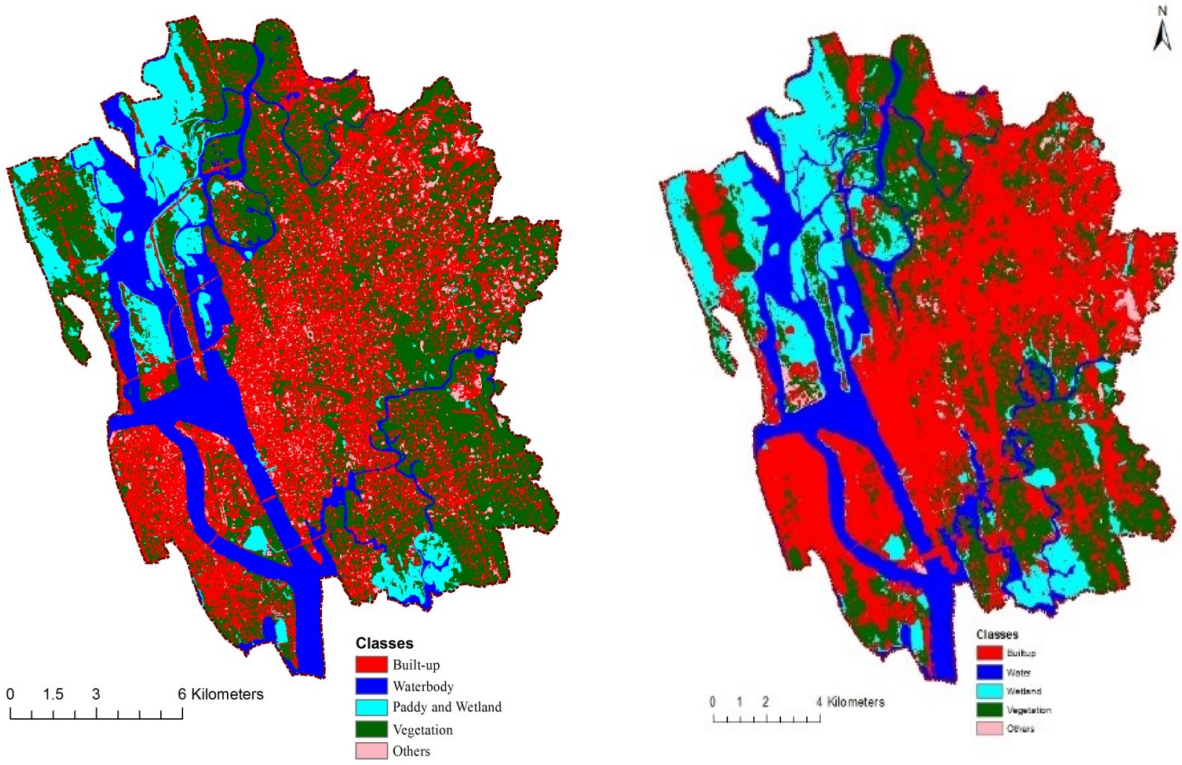
Urban growth prediction is the final stage of the change analysis. Using the LULC of later year, Markov Chain probability, and the output of the transition potential model, LCM predicts the LULC for a future date. It first determines the change that took place between 1992 and 2001, then calculates the relative amount of transition to 2014. This predicted LULC map for 2014 is then compared with the actual LULC of 2014 and validation statistics are calculated to check the accuracy of the prediction (Map 6.8). Once the desired accuracy is ensured, a similar model with the inclusion of new parameters for 2001-14 is used to calculate the relative amount of transition in the next 17 years i.e. 2031. The selection of the prediction year coincides with the draft City Development Plan (CDP) 2031. This is done in order to compare the CDP projection with the predicted built-up. The predicted LULC is also compared with the actual LULC 2021 to assess the pattern of growth.

6.6.1 Urban Growth Prediction for 2031

The change prediction for 2031 is based on the Markov transition probability and the transition potential maps created based on the land-use maps and the driving factors discussed in the previous section. To evaluate the prediction, a validation of the actual LULC map for 2014 and the simulated 2014 map is performed and it is presented in the diagram (Appendix 6.3).

Map 6.8: Actual and Predicted LULC of 2014

Actual: 2014 **Predicted: 2014**

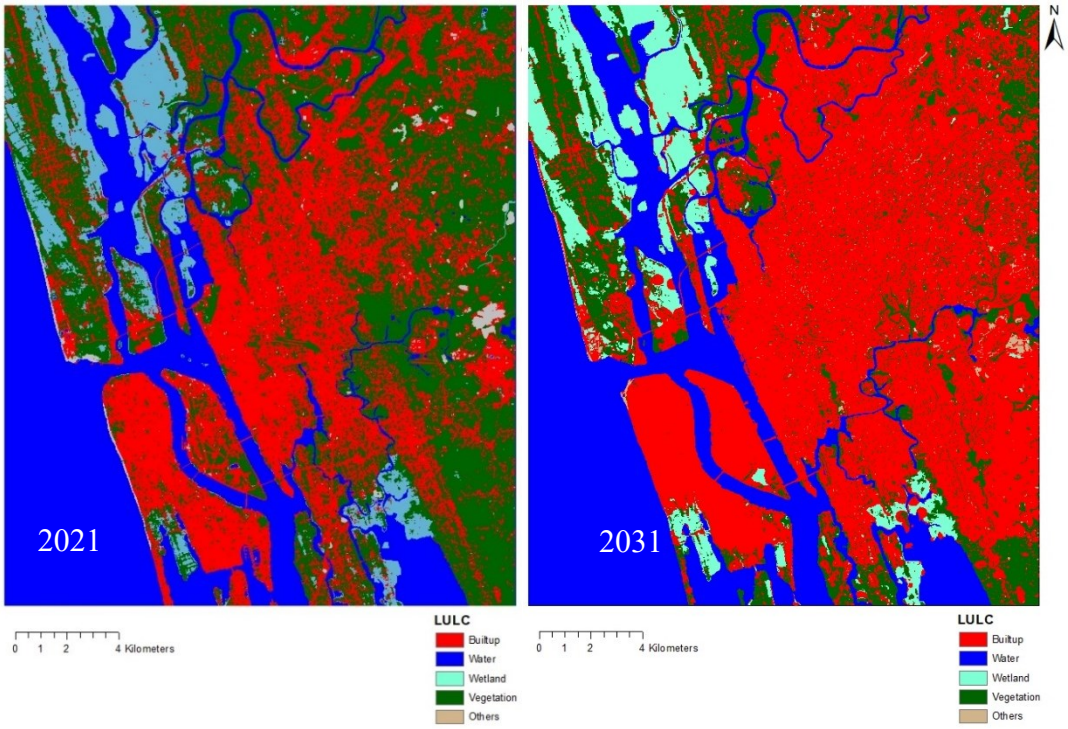


Source: Computed from LULC.

The prediction for 2014 is based on the Markov transition probability and the transition potential maps created based on the LULC and the driving factors.

A validation statistic is used to measure agreement between the comparison and reference LULC. Here the simulated LULC of 2014 is used as the comparison map and the actual classified LULC is used as the reference map. It is a comprehensive statistical measure used in comparing the classified maps of identical areas that answers how well a pair of maps agree in terms of the quantity and location of cells in each category. The predicted model has attained an accuracy level of 74 percent, which is acceptable as per various literature for predicting the LULC for a future date, accordingly the predicted model for 2031 is obtained keeping the same parameters (Map 6.9).

Map 6.9: Actual (2021) and Predicted (2031) LULC



Source: LANDSAT OLI 2021.

In order to further assess the predicted built-up in 2031, the latest Landsat imagery of 2021 is classified and compared. It can be seen that the direction and pattern of built-up growth observed in the predicted model relates to the pattern found in the actual LULC of 2021 (Map 6.9).

It can be seen that the majority of the planning area by 2031 will be converted to built-up (Map 6.9). Though the north-western part observed some increase in the built-up compared to the previous period, it is unlikely that these areas will undergo a major transition. Moreover, these areas are ecologically important and therefore it is important to protect the area from any large-scale development. Based on the predicted model, the chance of built-up expansion towards the peripheral areas of Kochi especially towards the northeast, east, and southeast area is very high (Map 6.9). The possible explanation for the expansion towards the southeast can be due to its linkage with Aluva municipality which is a fast-growing satellite town of Kochi and also its proximity to the International Airport at Nedumbassery. The eastern region as noticed from the literature and data is fast becoming well-sought areas of the city for residential, commercial, and technology enables industrial activities as these areas house educational institutions, Special

Economic Zone (SEZ), Information Technology (IT), and other IT-enabled services. Though Kumbalam, Kumbalanghi, and Chellanam in the southern periphery of the city and also Vadavucode-Puthenkurisu (CT) in the east of the city has been included in the City Development Plan, 2031, the predicted model emphasizes the need to include more areas in the planning agenda for the future development. The predicted surface also indicates that there is a likelihood for expansion towards more areas in the south and southeast of the city and that needs to be given more importance. From the observed prediction, it can be seen that the density of built-up in Maradu, Kumbalam, and Kumbalanghi in the south is likely to increase at a faster rate in the next 10 years. Similarly, apart from higher density in built-up in Thrippunithura and Thiruvankulam, the model suggests that the built-up may expand to areas towards the east of that region. It is important to protect the waterfront areas from large-scale built-up especially in places close to the coastal areas and natural lakes.

6.7 An Evaluation of CDP 2031 in the Context of the Predicted Built-up Growth 2031

Kochi and surrounding areas are identified as one of the fast-developing regions in the state, but it does not have a Master Plan after 2001. However, with the intervention of the Ministry of Urban Development, Government of India, Kochi Corporation has prepared a "City Development Plan (CDP)" 2031 aimed at using it as a basic document for urban reforms, infrastructure development, and also an input for the preparation of master plan like the structural plan 2001. The total area under the CDP is 369.72 sq. Km which is higher than the areas (about 95 sq. Km) under the structural plan 2001. One limitation is that while CDP is prepared in 2011, the latest data used in the report is of 2001 due to the non-availability of Census 2011 data at the time of finalizing the document as such there could be many changes that could not be comprehended due to various reasons such as technological changes due to innovations and investments. Therefore, it is imperative to review the document with new data and comprehend the required modifications.

Apart from the towns included in the structural plan 2001, the CDP has included 4 more census towns of Kumbalam, Kumbalanghi, Chellanam, and Vadavucode-Puthenkurisu. Since the former two are inland waterfront areas and Chellanam is a coastal area, these areas have higher potential for tourism and recreational development along with household industries. Similarly, Vadavucode-Puthenkurisu located in the east of the city has great potential for establishing modern industries

since it is in proximity to the economic zones in Kakkanad and surrounding areas. The urban growth prediction also shows a higher built-up projection in the eastern part of the city.

As discussed in previous chapters, Kochi is the most economically active city in Kerala having the highest commercial and industrial activities along with residential expansions to the peripheral areas. This put enormous pressure on existing land use, infrastructure, economy, and environment.

6.8 Summary

Urban growth analysis with the help of trends in data and satellite imageries over a period of time helps us to identify the pattern of change and help us in predicting the future land-use changes which is integral to managing the resources and planning process. Urban growth is dependent on several factors such as policy interventions, private and governmental funding, type of economic activities, and local factors. During the initial period, Kochi saw growth around the central areas and industrial locations, but due to drastic changes in economic activities and sectoral diversification especially in the eastern region, the urban growth is pointed towards the west to east. This trend will likely continue further towards the eastern side bringing more areas under the city planning area.

Chapter 7: Conclusion

A district-level analysis of socio-economic and infrastructural indicators in a macro context of urban growth in Kochi shows that urban growth cannot only be explained in terms of dynamics of socio-economic development or its absence over time and space. A large part of such observations should be seen in terms of administrative decisions in classifying an area as urban especially for the state of Kerala where almost every rural area have a large population size and also economic activities of the people changed from primary to secondary and tertiary sectors in the last three decades. The patterns of habitation and the population density in Kerala have produced a rural-urban continuum that substantially blurs rural-urban classifications.

There are several reasons which can be attributed to the unique urbanization trends and patterns in Kerala. The social and educational reforms of the state, the out-migration of people to large cities in India and also to gulf countries in the late seventies eventually enhanced the standard of living of the people back home. Another important administrative reason is the strict decentralized system of governance as per the mandate of the "74th Constitution Amendment Act" which has resulted in the overall improvement of the state irrespective of rural or urban areas. According to the latest census, the percent urban population in Ernakulam is the highest among all districts in Kerala. However, the urban population growth rate of the district during the past decade is found to be much less than that of the urban growth rate of Kerala. One of the reasons beyond doubt for such a difference in growth trend is the contribution of new census towns to the incremental urban population in many of the districts in the state. One can therefore argue that by seeing the highest percentage of urban population and relatively less contribution of census towns in the incremental urban population in Ernakulam as a reflection of the real urban expansion of Kochi, the financial capital of Kerala.

The increase in per capita income is important in the context of the growth and development of the region. Although Kerala's share in national income has remained higher than its population share, the relative gap in the economy between the state and nation has raised essentially because the state's population growth was much lower than the country's and not necessarily it grew faster economically. Though Kerala reported a steady increase in the per capita income over the years, the present study shows the Ernakulam district, in the beginning, was not as promising in terms of

per capita income. But the trend has widened in the later years for the district showing a higher per capita income compared to the state and all India figures. A detailed district-level analysis of the contribution of income to the state income illustrated the role of Ernakulam in generating more income as well as overall social development for the state. The income share of each of the districts to the state share remained nearly constant throughout the years. But the relatively higher contribution of Ernakulam can mainly be attributed to the importance of Kochi city as a potential economic growth engine to the state in the coming years. It is also evident from the fact that the most recent estimate of economic growth for the district is higher than the state and national growth rates. An analysis of sectoral income data for Ernakulam district shows negative growth in the period 2011-12 to 2012-13 mainly due to the decline in income from the secondary sector, especially the manufacturing, electricity, gas, and water supply. However, the share of manufacturing showed a marginal increase in Ernakulam and the performance was better as compared to the state as a whole. This is contrary to the pattern we observe for Kerala where generally an erosion of the overall secondary sector is hidden due to an increase in the construction sector.

It is evident by comparing Ernakulam district's per factory and per worker value of output (VO) with that of Kerala, that the industrial productivity of the district is much higher than the state as a whole. While the overall contribution of Kerala to India is significantly less, the district-wise analysis revealed that Ernakulam contributed the lion's share in the industrial outputs of the state. Considering the topography of the district in which the eastern part of the district is a hilly area with rural set-up and the western part is the city of Kochi, one can easily assume that the higher figure for Ernakulam district is due to the gradual growth of modern industries in and around the Kochi city since last few years.

Kerala's education and health care in terms of the majority of parameters is much ahead of other states in the country. The state is far ahead in maintaining high literacy, low infant mortality, low maternal mortality, and also higher life expectancy. The better performance in education and vital statistics is mainly due to the government-aided schools and public health care facilities in Kerala. Though there is a substantial increase in the private health infrastructure, it is unaffected by the public healthcare delivery system in the state. The overall figures of Ernakulam district in comparison to the state in terms of developmental indicators such as industrial infrastructure,

education, and health in recent years have been noteworthy as noted from the chapters. Much of these growths of Ernakulam district can be attributed to the growth of Kochi city.

A disaggregated analysis at the city level was therefore applied to understand the existing urban growth pattern of Kochi city and to evaluate the future growth of the city. Through in this thesis, an attempt is made to analyze the urban demographic, economical, and infrastructural trends using secondary data from different sources comparing the overall figures of Ernakulam district with that of the state to understand the urban development process from a macro perspective and then focussing on the micro-level analysis of Kochi city. The existing development dynamics of the city are also assessed before using any geo-statistical or spatial modeling to measure the growth trends. Thus, this study has focussed on identifying the patterns and extents of change in urban growth of Kochi city in the last three decades through spatial and non-spatial data, which is useful in terms of urban planning and policy formulation for Kochi. The analysis clearly indicated that over the years the city has grown extensively with huge prospects for the expansion of the city towards the eastern part of the city. In the absence of timely planning decisions, the urban sprawl can increase in the future. Because of more economic developmental activities in the eastern part of the city the land cost and the residential price can also have an upward trend in the near future. It is also evident from the empirical analysis that spatially there are sharp differences in the structure of establishments between the western and eastern parts of the city. Among the total establishments in Kochi, only fifteen percent are in the manufacturing sector, out of which more than half of the establishments are engaged in the production of wearing apparel and as many as twelve percent in the food products sector especially in processing and preserving of fish and meats. In the tertiary sector also, the economic activities in the city are heavily dependent on sub-sectors such as trades, transport, storage, and financial services including real estate business. The "information and communication technology (ICT)" which is a highly-skilled sector constitutes only a minuscule percent of the total establishments in the city, with Kakkanad in the eastern part of the city being an exception having close to five percent of establishments in the ICT sector. Being the largest commercial center in Kerala, Kochi should also look for more environment-friendly, technologically advanced, and capital-intensive manufacturing diversification, so that the city can expand further and immensely contribute to the overall development of the state. The availability of highly skilled manpower, transportation connectivity, and infrastructure

development in the city needs to be used effectively for achieving this target to make Kochi one of the world-class cities in the World.

Looking at the existing pattern of establishments in the secondary and tertiary sector in the city, especially in the eastern side of the municipal corporation, it is expected that the city will expand further towards the east, south-east and north-east side driving the town and country planning agency adding more adjoining towns in the planning area in near future. The pattern of establishments in the city shows clear disparities among the town constituents within the city especially between the western and eastern parts of the city. It is evident from the result of the economic census that the manufacturing base of Kochi is poor compared to most of the cities in India. Among the manufacturing establishments, more than half of them are engaged in the production of wearing apparel and as many as twelve percent of establishments are in the food products sector especially in processing and preserving fish and meats. The majority of such units are concentrated in the western and northwestern parts of the city close to coastal and other island town areas. Manufacturing of fabricated metal products, furniture, wood products, and printing and media are some of the other sectors which are dominant in other parts of the city. The city should focus on more diversified, economic, environment-friendly, and capital-intensive manufacturing which can drive the expansion of the city further and contribute to the overall development of the state and the nation. Though Kochi cannot go in for large-scale land-intensive industrialization having high population density and acute scarcity of land, attempts should be made to develop high-tech industries utilizing the skill surplus and less land and/or natural resources. In the tertiary sector also, the economic activities in the city are heavily dependent on sub-sectors such as retail trades, transport & storage, and financial, insurance, and real estate services. There have been a large number of FDI commitments in the information and communication technology (ICT) sector in Kerala (both software and hardware), but it faces strong competition under the WTO regime. The analysis based on the sixth economic census shows that the ICT sector which is a highly skilled and economically productive sector constitutes only a small percent of the total establishments in Kochi with Kakkanad in the eastern part of the city being an exception having close to five percent share. Due to the availability of highly skilled manpower and expected improvement in the investment environment, the city should focus on expanding its IT industry further. This along with the availability of better educational institutions, healthcare, hospitality industry, residential facilities, and also adequate recreational facilities can

make it one of the best knowledge cities of the country. The unit-level data of the 7th Economic Census which was supposed to be released in 2021 has been delayed possibly due to the Covid-19 pandemic. A comparison of the development in the last eight years will further give us a fair idea about how Kochi has progressed commercially and industrially in these years.

Apart from being one of the best cities under the Smart City project, the presence of multi-faceted transport infrastructure installations like international container trans-shipment terminal, railway junction, metro rail connectivity, international airport, surface transport connectivity with multiple national and state highways and a mobility hub inter-connecting railway, road and waterways, Kochi can be viewed as a future megacity. It is among the fastest-growing tier-2 cities on the western coast of India because of its logistics network, fast-growing IT hub, Special Economic Zone (SEZ) and also being one of the landing points of the longest undersea optical cable system linking South-East Asia, Middle East, and Western Europe making it the primary internet gateway to India. The real estate prospect of the city is also bright due to its excellent infrastructure, port-based development for the industry, increased foreign direct investment, and strong growth momentum in the IT and commercial sectors, creating an increased demand for housing in Kochi. However, lack of proper credit flow, trade union dictates, administrative and bureaucratic delays in setting up technology-infused industries can hinder the momentum of growth. The government should also promote policies and schemes to ensure a conducive entrepreneur-friendly atmosphere in the city and thereby accelerating the industrial growth and the economy of Kerala.

Over the years the urban planners have been faced difficulties in measuring urban growth patterns and estimating the requirements of the city for meeting future urban demands. In addition, the slow process in decision-making at the bureaucratic and political level further leads to uncontrolled urban expansion of the city. There is a decline in the growth of population in the city like other cities in Kerala which can be linked with a faster decline in fertility. But with the recent employment-related in-migration coupled with the increase in the secondary and tertiary sector workforce suggests the potentiality of Kochi as an important economic center in South India.

Though the secondary sector shows an increasing trend, there is a serious dearth of capital-intensive industries. There is a need for developing high-tech industries requiring greater skills and less land and/or natural resources

The rapid economic transition from primary to secondary and tertiary activities has contributed to a higher growth rate in built-up between the first two time periods. The built-up growth in the later

period was high and may be due to the shift in economic activities resulting in infrastructure and real estate increase in the city especially in the south and eastern part of the city.

Almost half the areas of the Kochi City Region had higher vegetation in 1992 which includes agriculture and pasture land. It may be recalled that as per the 1991 census, there were five to six percent workers engaged in agriculture and allied activities in most of the places outside the corporation boundary except a few places like the industrial towns of Eloor and Kalamassery in the north and north-eastern part of the city. This indicates that at the beginning of the nineties other than the Kochi Municipal Corporation and the industrial towns the built-up density was comparatively low. Thus, the city observed a low level of urbanization as experienced in other parts of the country. Towards the beginning of 2000, the built-up area started increasing probably linked to the economic liberalization policies. However, during 2001 also vegetation was found to be the dominant class but lower than the previous time. The increase in built-up is found to be mainly at the cost of the vegetation area. A similar pattern is observed for 2014 also with growth in built-up largely gained from the vegetation and paddy/wetlands. The built-up intensity is found to be higher in the central and eastern parts and lower in the northwestern part of the city. The built-up area of the city is steadily increasing. It can be expected that the built-up will continue to grow, which will result in a considerable reduction in its green surface and also paddy/wetlands. The built-up growth is expected to be directed towards the east and southeast locations of the city. As data also suggested, the reasons for such growth trends can be attributed to several reasons.

The Eastern part of the city is comparatively at a higher elevation, which is important in the context of a place that receives more rains and is flood-prone. The road density is also comparatively higher in the eastern part. The presence of SEZ and IT parks, which can boost commercial and residential real estate. The extension of Metro (work already started) from the central city to Kakkanad in the east may increase further expansion directed towards the east. The South and southeastern part is also likely to witness increased built-up density within the existing administrative boundaries but peripheral expansion is unlikely to happen as the areas are surrounded by paddy fields and water bodies which are protected areas.

The North and northwest part of the city is unlikely to have built-up growth as these areas are low-lying areas, with agro-processing and aquaculture activities and it is unfit for high-rise construction, these areas are also ecologically sensitive which restrict the large scale built-up growth.

From the spatial polynomial trend of built-up in Kochi, it can be seen that during the 1992-2001 period, changes of different classes to the built-up occurred towards the north-eastern part of the city. It is understandable since during this period the urban development was focused at the city core and directed towards the industrial towns of Eloor and Kalamassery. However, the spatial trend of built-up for the 2001-2014 period has got a wider coverage directed towards the eastern part of the city. This is because apart from the industrial areas, Kakkanad in the eastern part of the city is being transformed into a major commercial, residential and administrative region. Similarly, in southern areas such as Maradu and Thrippunithura also there was a considerable gain in built-up from other classes.

The built-up concentration in the Ernakulam part of the corporation is higher than the coastal part of the corporation. Similarly, Kalamassery and Vazhakkala have shown a higher concentration of built-up in the later periods. Kakkanad in the east and Maradu in the south are the other potential areas that have a higher built-up intensity compared to the initial time period. Eloor in the north is the largest industrial area in the district though with a higher built-up intensity in the first two time periods reduced in the later period.

Although the Kochi Corporation area recorded a decline in population growth during the past two decades, the suburbs have a significant growth in the population. The built-up intensity index shows that Kalamassery, Maradu, Vazhakkala, and Kakkanad are the areas that have higher urban growth in 2014 compared to 1991. The recent economic and infrastructural surge in the city tends to attract a large migrant population. This along with the high level of population mobility from nearby towns largely for business and occupational purposes necessitates planners and decision-makers to evolve long-term strategies for Kochi city.

The linear correlation coefficients of built-up areas with socio-economic indicators show identical trends. It has a statistically significant correlation with population density. However, the increase in built-up and literacy rate is negatively correlated. As mentioned earlier the city has a higher literacy level like that of the state as a whole and it is consistent across the city area. However, areas having relatively less literacy has more built-up can be linked to retail trade being the prominent economic activity in the central part of the city. In both the years, the pucca roads per sq. km and banks per ten thousand populations have a significant correlation with the built-up area. The positive and significant coefficient for pucca roads is indicative of linear urban growth trends along the major roads in Kochi city. Since Kochi is known to be the financial capital of Kerala,

banks play an important role for the people, industry, and infrastructure. The bank per ten thousand populations has a statistically highly significant correlation with the built-up area which explains the positive linkages of people and institutions with the banking sector. The correlation between built-up area and a select set of housing indicators shows that the physical quality of houses, households with access to piped sewerage, drainage, LPG for cooking, computers with internet, and households owning four-wheelers all have a positive impact on the built-up growth. Though houses with a spacious living environment are a key standard in Kerala, the correlation coefficient of the built area with households with three or more rooms does not show any significant correlation indicating that built-up increase in cities does not necessarily lead to spacious houses owing to land pressure. The correlation coefficient of households with treated water supply is negative with the built-up area. It shows that compared to many other cities in India, the Kochi city still lacks piped water supply and heavily depends upon traditional well water like that of most of the rural areas of Kerala.

Spatio-temporal analysis of land use patterns also assists the policymakers and urban planners to have detailed information on existing landscape dynamics and also to assess the developmental characteristics, its consequences, and future urban planning.

Based on the observed pattern and trends of built-up growth, and application of geo-statistics-based modeling for future growth prediction suggested for the integrated planning to save the future of the Kochi city. The predicted urban growth model for the year 2031 suggested a concentrated built-up growth in all directions from the center of the city except the western part. The exception of the western part is mainly because of the presence of the sea in the same direction. The concentrated nature of growth by 2031 will happen by consuming mostly the fragmented vegetation/tree covers presently lying between the built-up patches. The extensive areas in the east, northeast, and southeast direction are presently covered by vegetation covers. As most of the land in Kochi is categorized as residential land, therefore, the restriction on the cutting of trees is automatically not applicable to restrict built-up growth through consuming the vegetation cover. Therefore, the reason for the concentrated nature of built-up growth by 2031 by filling the existing fragmented patches is inevitable. It is also noteworthy that the city development plan of the KMC also suggested a similar nature of unidirectional built-up growth in the future. The result of the present study is therefore having the similarity in predicting the trends and possibility of built-up growth by 2031.

The predicted models presented in this thesis can therefore be utilized to give directions and guidance in the planning process of the city. Though the surrounding areas of Kochi have a vast presence of census towns these areas are essentially residential plots and the city will have to depend upon vertical expansion in the panning area to cater to more economic activities. However, there is a chance for increasing the economic and commercial activities in these peripheral areas if more infrastructures like an extension of metros and expansion of existing transport networks.

The relationship of various demographic and economic indicators with built-up area expansion can be considered as important to measure the urban pattern and growth trends. However, the drivers of urban growth keep on changing with time and the recent developments in real-time dynamic data will help more time-intensive research in predictive urban growth models.

Bibliography

Aguayo, M. I., Wiegand, T., Azócar, G. D., Wiegand, K., & Vega, C. E. (2007). Revealing the driving forces of mid-cities urban growth patterns using spatial modeling: a case study of Los Ángeles, Chile. *Ecology and Society*, *12*(1).

Aijaz, R. (2012). *Democracy and Urban Governance in India*. Academic Foundation.

Al-Ahmadi, K., Heppenstall, A., Hogg, J., & See, L. (2009). A Fuzzy Cellular Automata Urban Growth Model (FCAUGM) for the City of Riyadh, Saudi Arabia. Part 1: Model Structure and Validation. *Applied Spatial Analysis and Policy*, *2*(1), 65–83. https://doi.org/10.1007/s12061-008-9020-6

Ali, M. A. (1975). The Passing of Empire: The Mughal Case. *Modern Asian Studies*, *9*(3), 385–396. https://doi.org/10.1017/S0026749X00005825

Andersson, C., Rasmussen, S., & White, R. (2002). Urban Settlement Transitions. *Environment and Planning B: Planning and Design*, *29*(6), 841–865. https://doi.org/10.1068/b12813

Ansari, A., & Golabi, M. H. (2019). Prediction of spatial land use changes based on LCM in a GIS environment for Desert Wetlands – A case study: Meighan Wetland, Iran. *International Soil and Water Conservation Research*, *7*(1), 64–70. https://doi.org/10.1016/j.iswcr.2018.10.001

Arya Lekshmi, P. T., & Lancelet, T. . (2019). Trends of urbanisation in Ernakulam with respect to Kerala. *Journal of Global Resources*, *5*(2), 41–48. https://www.isdesr.org/wp-content/uploads/2019/08/6.-Laxmi-Arya.pdf

Avari, B. (2007). *India: The Ancient Past: A History of the Indian Sub-continent from c. 7000 bc to ad 1200*. Routledge.

Bakrania, S. (2015). Urbanisation and urban growth in Nepal. *Governance. Social Development, Humanitarian Response and Conflict (GSDRC), Applied Knowledge Services of University of Birmingham, Birmingham, UK. Http://Www. Gsdrc. Org/Wp-Content/Uploads/2015/11/HDQ1294. Pdf.*

Banerjee, A., & Gupta, S. (2017). Industrial Development of Port Towns in India. *Journal of Rural and Industrial Development*, *5*(1), 1.

Banerjee, N. (1969). What Course for Urbanisation in India? *Economic and Political Weekly*, *4*(28), 1173–1176. http://www.jstor.org/stable/40739871

Benenson, I., & Torrens, P. (2004). *Geosimulation: Automata-based modeling of urban phenomena*. John Wiley & Sons.

Bernier, F. (1826). *Travels in the Mogul empire* (Vol. 1). W. Pickering.

Bhagat, R. B. (2014). Urban policies and programmes in India: Retrospect and prospect. *Yojana*, *58*, 4–8.

Bhagat, R. B., & Mohanty, S. (2009). Emerging pattern of urbanization and the contribution of migration in urban growth in India. *Asian Population Studies*, *5*(1), 5–20.

Bhatta, B., Saraswati, S., & Bandyopadhyay, D. (2010). Urban sprawl measurement from remote sensing data. *Applied Geography*, *30*(4), 731–740. https://doi.org/10.1016/j.apgeog.2010.02.002

Brenner, N. (2013). Theses on Urbanization. *Public Culture*, *25*(1 69), 85–114. https://doi.org/10.1215/08992363-1890477

Cao, X., Liu, Y., Li, T., & Liao, W. (2019). Analysis of Spatial Pattern Evolution and Influencing Factors of Regional Land Use Efficiency in China Based on ESDA-GWR. *Scientific Reports*, *9*(1), 520. https://doi.org/10.1038/s41598-018-36368-2

Census of India. (2011). *District Census Hand Book, Ernakulam*. https://censusindia.gov.in/2011census/dchb/3208_PART_B_ERNAKULAM.pdf

Chandrasekhar, S. (2011). Workers commuting between the rural and urban: Estimates from NSSO data. *Economic and Political Weekly*, 22–25.

Chapin, F. S., & Weiss, S. F. (1962). *Factors influencing land development: evaluation of inputs for a forecast model*. Institute for Research in Social Science, University of North Carolina.

Chatterjee, S., & Roy, S. (2021). Land use land cover dynamics with the outgrowth of Burdwan town (India): problems with sustainable solutions. In G. S. Bhunia, U. Chatterjee, A. Kashyap, & P. K. Shit (Eds.), *Land Reclamation and Restoration Strategies for Sustainable Development* (pp. 603–626). Elsevier. https://doi.org/10.1016/B978-0-12-823895-0.00032-4

Chen, J., Jönsson, P., Tamura, M., Gu, Z., Matsushita, B., & Eklundh, L. (2004). A simple method for reconstructing a high-quality NDVI time-series data set based on the Savitzky–Golay filter. *Remote Sensing of Environment*, *91*(3–4), 332–344.

Conway, T. M. (2005). Current and Future Patterns of Land-Use Change in the Coastal Zone of

New Jersey. *Environment and Planning B: Planning and Design*, *32*(6), 877–893. https://doi.org/10.1068/b31170

Crook, N., & Dyson, T. (1982). Urbanization in India: Results of the 1981 census. *Population and Development Review*, *8*(1), 145–155.

Das, D. N., & Bhusan, S. (2014). Magnetism in India's Metros: A Study on Migrants' Choice of Destination. *Social Change*, *44*(4), 519–540. https://doi.org/10.1177/0049085714548537

Deng, X., Zhan, J., & Chen, R. (2005). The patterns and driving forces of urban sprawl in China. *Proceedings. 2005 IEEE International Geoscience and Remote Sensing Symposium, 2005. IGARSS'05.*, *3*, 1511–1513.

Dupont, V. (2007). Conflicting stakes and governance in the peripheries of large Indian metropolises – An introduction. *Cities*, *24*(2), 89–94. https://doi.org/10.1016/j.cities.2006.11.002

Eng, C. K. (1995). The Dynamics of Urban Demographic Change in Malaysia: An Analysis of the 1991 Population Census. *Asian Geographer*, *14*(1), 58–70. https://doi.org/10.1080/10225706.1995.9684000

George, J. (2016). An Assessment of Inclusiveness in the Urban Agglomeration of Kochi City: The need for a change in approach of urban planning. *MPRA*, *90149*.

Gharaibeh, A. A., Shaamala, A. H., & Ali, M. H. (2020). Multi-Criteria Evaluation for Sustainable Urban Growth in An-Nuayyimah, Jordan; Post War Study. *Procedia Manufacturing*, *44*, 156–163. https://doi.org/10.1016/j.promfg.2020.02.217

Ghosh, P. K., & Khatun, S. (2021). Statutory vs census towns: modeling the differences of urban development using statistical approach in India: a micro level case analysis. *Modeling Earth Systems and Environment*. https://doi.org/10.1007/s40808-021-01089-5

Giri, G. G. (2019, March 28). Far-flung areas quench Kochi's thirst. *Times of India*. https://timesofindia.indiatimes.com/city/kochi/far-flung-areas-quench-citys-thirst/articleshow/68605158.cms

Goswami, B., Kumar, A. N., & George, K. K. (2015). *Patterns of commuting for work: A case study of Kochi City* (No. 5; RULSG OCCASIONAL PAPER 2015). Centre for Development Studies. http://14.139.171.199:8080/xmlui/handle/123456789/600

Govt. of Kerala. (2002). *Urban Policy and Action Plan for Kerala, 2002*. https://townplanning.kerala.gov.in/2018/12/06/urban-policy/

Govt. of Kerala. (2005). *Kerala Sustainable Urban Development Project Report*.

Govt. of Kerala. (2016). *Infrastructure Statistics Report, 2015-16*. http://www.ecostat.kerala.gov.in/index.php/general-publication

Govt. of Kerala. (2017). *Industrial Potential Survey Report of Ernakulam*. https://industry.kerala.gov.in/images/Potentialsurvey/PSRErnakulam.pdf

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., & Briggs, J. M. (2008). Global Change and the Ecology of Cities. *Science*, *319*(5864), 756–760. https://doi.org/10.1126/science.1150195

Guilmoto, C. Z., & Rajan, S. I. (2002). District level estimates of Fertility from India's 2001 Census. *Economic and Political Weekly*, 665–672.

Guin, D., & Das, D. N. (2015). New Census Towns in West Bengal:'Census Activism'or Sectoral Diversification? *Economic and Political Weekly*, *50*(14), 68–72.

Harris, P. M., & Ventura, S. J. (1995). The integration of geographic data with remotely sensed imagery to improve classification in an urban area. *Photogrammetric Engineering and Remote Sensing*, *61*(8), 993–998.

Heppenstall, A. J., Crooks, A. T., See, L. M., & Batty, M. (2011). *Agent-based models of geographical systems*. Springer Science & Business Media.

Hu, Z., & Lo, C. P. (2007). Modeling urban growth in Atlanta using logistic regression. *Computers, Environment and Urban Systems*, *31*(6), 667–688. https://doi.org/10.1016/j.compenvurbsys.2006.11.001

Huang, W., Liu, H., Luan, Q., Jiang, Q., Liu, J., & Liu, H. (2008). Detection and prediction of land use change in Beijing based on remote sensing and GIS. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci*, *37*, 75–82.

Ibrahim, P. (1978). The development of transport facilities in Kerala: a historical review. *Social Scientist*, *6*(8), 34–48.

Issa, S. M., & Al Shuwaihi, A. (2011). Analysis of LULC changes and urban expansion of the resort city of Al Ain using remote sensing and GIS. *2011 6th International Workshop on the Analysis of Multi-Temporal Remote Sensing Images (Multi-Temp)*, 245–248.

Jat, M. K., Choudhary, M., & Saxena, A. (2017). Urban growth assessment and prediction using RS, GIS and SLEUTH model for a heterogeneous urban fringe. *The Egyptian Journal of Remote Sensing and Space Science*, *10*(3), 1–19.

Javed, N., & Riaz, S. (2020). Issues in Urban Planning and Policy: The Case Study of Lahore, Pakistan. In *New Urban Agenda in Asia-Pacific* (pp. 117–162). https://doi.org/10.1007/978-981-13-6709-0_5

Jayalakshmy, S. S., & Mereena, C. S. (2016). Spatio-Temporal Dynamics of Urban Expansion of Cochin City Region in GIS based on Buffer Gradient Analysis. *International Journal of Science and Research*, 325–331.

Jiang, B., & Yao, X. (2010). *Geospatial Analysis and Modeling of Urban Structure and Dynamics: An Overview* (pp. 3–11). https://doi.org/10.1007/978-90-481-8572-6_1

Josna Raphael, P., & Kasthurba, A. K. (2015). Understanding the Cultural Influence through Space Syntax on the Spatial Configuration of Temple Towns of Kerala, India. *Journal of Civil Engineering and Environmental Technology*, *2*(5), 461–468.

Jurlina Alibegović, D., & Kordej De Villa, Ž. (2008). The role of urban indicators in city management: a proposal for Croatian cities. *Transition Studies Review*, *15*(1), 63–80. https://doi.org/10.1007/s11300-008-0171-6

Kadi, A. S., & Nelavigi, K. P. (2015). Growth of Urbanisation in India. *The International Journal of Science and Technoledge*, *3*(7), 30.

Kannan, K. P. (1990). Kerala economy at the crossroads? *Economic and Political Weekly*, 1951–1956.

Kannan, K. P. (2005). Kerala's turnaround in growth: Role of social development, remittances and reform. *Economic and Political Weekly*, 548–554.

Kasraian, D., Maat, K., & van Wee, B. (2016). Three Decades of Transport Infrastructure Development and Travel Behaviour Change in the Netherlands. *REAL CORP 2016–SMART ME UP! How to Become and How to Stay a Smart City, and Does This Improve Quality of Life? Proceedings of 21st International Conference on Urban Planning, Regional Development and Information Society*, 977–981.

Kochi Municipal Corporation. (2011). *City Sanitation Plan, Kochi, 2011*. https://www.mohua.gov.in/upload/uploadfiles/files/CSP_Brochure_Kochi.pdf

Krishnan, T. N. (1976). Demographic transition in Kerala: Facts and factors. *Economic and Political Weekly*, *11*(31/33), 1203–1224.

Kumar, R. (2007). *Rise of regions after reforms: late development strategies for the software industry in Tamil Nadu, Andhra Pradesh, and Kerala in India*. Massachusetts Institute of

Technology.

Kumari, B., Tayyab, M., Shahfahad, Salman, Mallick, J., Khan, M. F., & Rahman, A. (2018). Satellite-Driven Land Surface Temperature (LST) Using Landsat 5, 7 (TM/ETM+ SLC) and Landsat 8 (OLI/TIRS) Data and Its Association with Built-Up and Green Cover Over Urban Delhi, India. *Remote Sensing in Earth Systems Sciences*, *1*(3–4), 63–78. https://doi.org/10.1007/s41976-018-0004-2

Kuncheria, A. (2017, January 4). Kerala's Water Crisis. *The Kochi Post*. https://kochipost.com/2017/01/04/opinion-we-need-to-conserve-and-regulate-demand-to-tackle-keralas-looming-water-crisis/

Kundu, A., Sivaramakrishnan, K. C., & Singh, B. N. (2005). *Handbook of Urbansation in India*. Oxford University Press, New Delhi.

Kundu, D., & Pandey, A. K. (2020). World Urbanisation: Trends and Patterns. In *Developing National Urban Policies* (pp. 13–49). Springer Singapore. https://doi.org/10.1007/978-981-15-3738-7_2

Kuriakose, P. N., & Philip, S. (2021). City profile: Kochi, city region - Planning measures to make Kochi smart and creative. *Cities*, *118*, 103307. https://doi.org/10.1016/j.cities.2021.103307

Kurian, S. M., & Thampuran, A. (2011). Assessment of housing quality. *Institute of Town Planners, India Journal*, *8*(2), 74–85.

Kurien, J. (1995). The Kerala model: Its central tendency and the outlier. *Social Scientist*, 70–90.

Kuruvilla, K. (2014). Census towns in Kerala: Challenges of urban transformation. *Research Notebooks, School of Habitat Studies*, 1–12.

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., Coomes, O. T., Dirzo, R., Fischer, G., Folke, C., George, P. S., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E. F., Mortimore, M., Ramakrishnan, P. S., Richards, J. F., … Xu, J. (2001). The causes of land-use and land-cover change: moving beyond the myths. *Global Environmental Change*, *11*(4), 261–269. https://doi.org/10.1016/S0959-3780(01)00007-3

Li, G., Sun, S., & Fang, C. (2018). The varying driving forces of urban expansion in China: Insights from a spatial-temporal analysis. *Landscape and Urban Planning*, *174*, 63–77. https://doi.org/10.1016/j.landurbplan.2018.03.004

Li, X., & Gar-On Yeh, A. (2004). Data mining of cellular automata's transition rules.

International Journal of Geographical Information Science, *18*(8), 723–744. https://doi.org/10.1080/13658810410001705325

Li, X., & Yeh, A. G.-O. (2002). Neural-network-based cellular automata for simulating multiple land use changes using GIS. *International Journal of Geographical Information Science*, *16*(4), 323–343. https://doi.org/10.1080/13658810210137004

Liu, X., Huang, Y., Xu, X., Li, X., Li, X., Ciais, P., Lin, P., Gong, K., Ziegler, A. D., Chen, A., Gong, P., Chen, J., Hu, G., Chen, Y., Wang, S., Wu, Q., Huang, K., Estes, L., & Zeng, Z. (2020). High-spatiotemporal-resolution mapping of global urban change from 1985 to 2015. *Nature Sustainability*, *3*(7), 564–570. https://doi.org/10.1038/s41893-020-0521-x

Lynch, K. (1964). *The image of the city*. MIT press.

Mage, D., Ozolins, G., Peterson, P., Webster, A., Orthofer, R., Vandeweerd, V., & Gwynne, M. (1996). Urban air pollution in megacities of the world. *Atmospheric Environment*, *30*(5), 681–686. https://doi.org/10.1016/1352-2310(95)00219-7

Mahmoud, H., & Divigalpitiya, P. (2019). Spatiotemporal variation analysis of urban land expansion in the establishment of new communities in Upper Egypt: A case study of New Asyut city. *The Egyptian Journal of Remote Sensing and Space Science*, *22*(1), 59–66. https://doi.org/10.1016/j.ejrs.2018.03.006

Maithani, S. (2009). A neural network based urban growth model of an Indian city. *Journal of the Indian Society of Remote Sensing*, *37*(3), 363–376. https://doi.org/10.1007/s12524-009-0041-7

Maithani, Sandeep, Jain, R. K., & Arora, M. K. (2007). An artificial neural network based approach for modelling urban spatial growth. *ITPI Journal*, *4*(2), 43–51.

Manu, A., Twumasi, Y. A., Lu, K. S., & Coleman, T. L. (2015). Predicting urban growth of a developing country city using a statistical modeling approach. *International Journal of Geomatics and Geosciences*, *5*(4), 603–613.

Maria de Almeida, C., Batty, M., Vieira Monteiro, A. M., Câmara, G., Soares-Filho, B. S., Cerqueira, G. C., & Pennachin, C. L. (2003). Stochastic cellular automata modeling of urban land use dynamics: empirical development and estimation. *Computers, Environment and Urban Systems*, *27*(5), 481–509. https://doi.org/10.1016/S0198-9715(02)00042-X

McGee, T. (2009). *The spatiality of urbanization: the policy challenges of mega-urban and Desakota Regions of Southeast Asia*.

McIntyre, N. E., Knowles-Yánez, K., & Hope, D. (2001). Urban Ecology as an Interdisciplinary Field: Differences in the use of "Urban" Between the Social and Natural Sciences. In *Urban Ecology* (pp. 49–65). Springer US. https://doi.org/10.1007/978-0-387-73412-5_4

Mertens, W., & Alatas, S. (1978). Rural Urban Definition and Urban Agriculture in Indonesia. *Majalah Demografi Indonesia*, *5*(10), 40–70.

Ministry of Road Transport and Highways (GOI). (2016). *Basic Road Statistics of India 2013-14 and 2014-15*. Ministry of Road Transport and Highways Delhi, India.

Moench, M., & Gyawali, D. (2008). Desakota: reinterpreting the urban-rural continuum. *Final Report Desakota II A*. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.675.4381&rep=rep1&type=pdf

Mohammed Firoz, C., Banerji, H., & Sen, J. (2014). A Methodology to Define the Typology of Rural Urban Continuum Settelments in Kerala. *Journal of Regional Development and Planning*, *3*(1), 49–60.

Mohan, M., Pathan, S. K., Narendrareddy, K., Kandya, A., & Pandey, S. (2011). Dynamics of urbanization and its impact on land-use/land-cover: a case study of megacity Delhi. *Journal of Environmental Protection*, *2*(09), 1274.

Mohanan, P. C. (2008). Differentials in the rural-urban movement of workers. *The Journal of Income and Wealth*, *30*(1), 59–67.

Mondal, B., Chakraborti, S., Das, D. N., Joshi, P. K., Maity, S., Pramanik, M. K., & Chatterjee, S. (2019). Comparison of spatial modelling approaches to simulate urban growth: a case study on Udaipur city, India. *Geocarto International*, *35*(4), 1–23. https://doi.org/10.1080/10106049.2018.1520922

Mondal, B., Das, D. N., & Bhatta, B. (2017). Integrating cellular automata and Markov techniques to generate urban development potential surface: a study on Kolkata agglomeration. *Geocarto International*, *32*(4), 401–419. https://doi.org/10.1080/10106049.2016.1155656

Mondal, B., Dolui, G., Pramanik, M., Maity, S., Biswas, S. S., & Pal, R. (2017). Urban expansion and wetland shrinkage estimation using a GIS-based model in the East Kolkata Wetland, India. *Ecological Indicators*, *83*(November 2016), 62–73. https://doi.org/10.1016/j.ecolind.2017.07.037

Mookherjee, D. (2003). Differential urbanisation model: the case of a developing country, India

1961–91. *Tijdschrift Voor Economische En Sociale Geografie*, *94*(1), 38–48. https://doi.org/10.1111/1467-9663.00235

MoSPI. (1968). *Statistical Year Book*.

Mu, G. M., & Hu, Y. (2016). Urbanisation and Migration. In *Living with Vulnerabilities and Opportunities in a Migration Context* (pp. 1–23). Springer.

Mustafa, A., Cools, M., Saadi, I., & Teller, J. (2017). Coupling agent-based, cellular automata and logistic regression into a hybrid urban expansion model (HUEM). *Land Use Policy*, *69*, 529–540. https://doi.org/10.1016/j.landusepol.2017.10.009

Myers, G. (2021). Urbanisation in the Global South. *Urban Ecology in the Global South. Springer, Cham*, 27–49.

Nair, P. S. (2010). Understanding Below-replacement Fertility in Kerala, India. *Journal of Health, Population and Nutrition*, *28*(4). https://doi.org/10.3329/jhpn.v28i4.6048

Nair, S. (2010). Challenges in urban water management in a changing environment case study from a growing tropical city. *NOVATECH 2010*, 1–7. http://documents.irevues.inist.fr/bitstream/handle/2042/35646/11107-237NAI.pdf?sequence=1

Narayanan, Y., & Bindumadhav, S. (2019). 'Posthuman cosmopolitanism' for the Anthropocene in India: Urbanism and human-snake relations in the Kali Yuga. *Geoforum*, *106*, 402–410. https://doi.org/10.1016/j.geoforum.2018.04.020

Newitt, M. D. D. (1986). The East India Company in the Western Indian Ocean in the early seventeenth century. *The Journal of Imperial and Commonwealth History*, *14*(2), 5–33. https://doi.org/10.1080/03086538608582711

Nilsson, K., Pauleit, S., Bell, S., Aalbers, C., & Nielsen, T. A. S. (2013). *Peri-urban futures: Scenarios and models for land use change in Europe*. Springer Science & Business Media.

OECD/European Commission. (2020). *Cities in the World* (OECD Urban Studies). https://doi.org/https://doi.org/https://doi.org/10.1787/d0efcbda-en

Oktay, D. (2002). The quest for urban identity in the changing context of the city. *Cities*, *19*(4), 261–271. https://doi.org/10.1016/S0264-2751(02)00023-9

Panikar, P. G. K. (1975). Fall in mortality rates in Kerala: An explanatory hypothesis. *Economic and Political Weekly*, *10*(47), 1811–1818.

Planning Commission of India. (2007). *Eleventh Five Year Plan (2007-2012)*.

https://niti.gov.in/planningcommission.gov.in/docs/plans/planrel/fiveyr/11th/11_v1/11th_vol1.pdf

Planning Commission of India. (2011). *India Human Development Report 2011: Towards Social Inclusion*. http://www.im4change.org/docs/340IHDR_Summary.pdf

Planning Commission of India. (2013). *Twelfth Five Year Plan (2012-2017)* (Vol. 1). SAGE Publications Pvt. Limited.

Poelmans, L., & Van Rompaey, A. (2010). Complexity and performance of urban expansion models. *Computers, Environment and Urban Systems*, *34*(1), 17–27. https://doi.org/10.1016/j.compenvurbsys.2009.06.001

Pontius, R. G., & Millones, M. (2011). Death to Kappa: birth of quantity disagreement and allocation disagreement for accuracy assessment. *International Journal of Remote Sensing*, *32*(15), 4407–4429. https://doi.org/10.1080/01431161.2011.552923

Pradhan, K. C. (2017). Unacknowledged Urbanisation: The New Census Towns in India. In *Subaltern Urbanisation in India* (pp. 39–66). https://doi.org/10.1007/978-81-322-3616-0_2

Qadeer, M. A. (2000). Ruralopolises : The Spatial Organisation and Residential Land Economy of High-density Rural Regions in South Asia. *Urban Studies*, *37*(9), 1583–1603. https://doi.org/10.1080/00420980020080271

Qin, B., & Zhang, Y. (2014). Note on urbanization in China: Urban definitions and census data. *China Economic Review*, *30*, 495–502. https://doi.org/10.1016/j.chieco.2014.07.008

Qu, W., Zhao, S., & Sun, Y. (2014). Spatiotemporal patterns of urbanization over the past three decades: a comparison between two large cities in Southwest China. *Urban Ecosystems*, *17*(3), 723–739. https://doi.org/10.1007/s11252-014-0354-3

Ramachandran, V. . (1997). On Kerala's Development Achievements. In J. Drèze, A. Sen, A. Sen, & M. A. Sen (Eds.), *Indian development: Selected regional perspectives*. Oxford University Press.

Rani, P. G. (1999). Human development index in India: A district profile. *Journal of the Gokhale Institute of Politics and Economics*, *XLI*(I), 9–13.

Rao, K. A., & Kumar, K. P. (2019). Urban planning and policies in India, Urban poor in the sight of five year plans and programmes. *International Journal of Research in Social Sciences*, *8*(2), 678–689.

Ravi, F. Aa., & Subha, S. B. V. (2011). Ecological foot print analysis-a sustainable

environmental management tool for Kochi city. *International Journal on Transportation and Urban Development*, *1*(1), 5.

Ritchie, H., & Roser, M. (2018). *Urbanization*. Our World in Data. https://ourworldindata.org/urbanization

Roberts, J. L. (2018). Urban. In *Routledge handbook of contemporary Myanmar* (pp. 64–71). Routledge.

Rodriguez, D. M. (2002). *Paradigm in Thanjavur town: Understanding and furthering traditional urbanism in South India*. University of Notre Dame.

Rogers, A., & Williamson, J. G. (1982). Migration, urbanization, and third world development: an overview. *Economic Development and Cultural Change*, *30*(3), 463–482.

Rogerson, P. A. (2015). A New Method for Finding Geographic Centers, with Application to U.S. States. *The Professional Geographer*, *67*(4), 686–694. https://doi.org/10.1080/00330124.2015.1062707

Roy, A. (2009). Why India Cannot Plan Its Cities: Informality, Insurgence and the Idiom of Urbanization. *Planning Theory*, *8*(1), 76–87. https://doi.org/10.1177/1473095208099299

Saifullah, K., Barus, B., & Rustiadi, E. (2017). Spatial modelling of land use/cover change (LUCC) in South Tangerang City, Banten. *IOP Conference Series: Earth and Environmental Science*, *54*(1), 12018.

Sanitha, V. P., & Singla, N. (2016). Structural Transformation in Kerala's Economy: Is There any Role of Agriculture Sector. *Journal of Regional Development and Planning*, *5*(2), 45.

Santé, I., García, A. M., Miranda, D., & Crecente, R. (2010). Cellular automata models for the simulation of real-world urban processes: A review and analysis. *Landscape and Urban Planning*, *96*(2), 108–122. https://doi.org/10.1016/j.landurbplan.2010.03.001

Sekar, S. P., & Gangopadhyay, D. (2017). Impact of rail transit on land use and development: Case study of suburban rail in Chennai. *Journal of Urban Planning and Development*, *143*(2), 4016038.

Seto, K. C., Fragkias, M., Güneralp, B., & Reilly, M. K. (2011). A Meta-Analysis of Global Urban Land Expansion. *PLoS ONE*, *6*(8), e23777. https://doi.org/10.1371/journal.pone.0023777

Seto, K. C., & Reenberg, A. (2014). *Rethinking global land use in an urban era* (Vol. 14). MIT Press.

Shafizadeh-Moghadam, H., Asghari, A., Taleai, M., Helbich, M., & Tayyebi, A. (2017). Sensitivity analysis and accuracy assessment of the land transformation model using cellular automata. *GIScience & Remote Sensing*, *54*(5), 639–656. https://doi.org/10.1080/15481603.2017.1309125

Shafizadeh Moghadam, H., & Helbich, M. (2013). Spatiotemporal urbanization processes in the megacity of Mumbai, India: A Markov chains-cellular automata urban growth model. *Applied Geography*, *40*, 140–149. https://doi.org/10.1016/j.apgeog.2013.01.009

Shaw, A. (1996). Urban policy in post-independent India: An appraisal. *Economic and Political Weekly*, 224–228.

Shu, B., Zhang, H., Li, Y., Qu, Y., & Chen, L. (2014). Spatiotemporal variation analysis of driving forces of urban land spatial expansion using logistic regression: A case study of port towns in Taicang City, China. *Habitat International*, *43*, 181–190. https://doi.org/10.1016/j.habitatint.2014.02.004

Singh, O. P. (1977). Some Basic Principles for Functional Classification of Towns: A Critical Review. *National Geographical Journal of India*, *23*(3&4), 195–199.

Sivaramakrishnan, K. C. (2015). *Governance of Megacities Fractured thinking, Fragmented setup* (First). Oxford University Press.

Small, C. (2001). Estimation of urban vegetation abundance by spectral mixture analysis. *International Journal of Remote Sensing*, *22*(7), 1305–1334.

Sreekumar, T. T. (1990). Neither rural nor urban: Spatial formation and development process. *Economic and Political Weekly*, *25*(35/36), 1981–1990.

State Planning Board. (2016). *Economic Review (2016)*. https://spb.kerala.gov.in/economic-review/ER2016/

State Planning Board. (2018). *Economic Review (2018)*. https://spb.kerala.gov.in/economic-review/ER2018/

State Planning Board, & Kerala), K. (Govt. of. (2005). *Human Development Report Kerala (2005)*. https://www.niti.gov.in/planningcommission.gov.in/docs/plans/stateplan/sdr_pdf/shdr_kerala05.pdf

Stein, B. (1960). The economic function of a medieval South Indian temple. *The Journal of Asian Studies*, *19*(2), 163–176.

Subbarayalu, Y. (2014). Forms of labour in ancient and medieval South India (up to the thirteenth century). *Studies in People's History*, *1*(2), 153–162. https://doi.org/10.1177/2348448914549896

Takada, T., Miyamoto, A., & Hasegawa, S. F. (2010). Derivation of a yearly transition probability matrix for land-use dynamics and its applications. *Landscape Ecology*, *25*(4), 561–572. https://doi.org/10.1007/s10980-009-9433-x

Taubenböck, H., Wegmann, M., Berger, C., Breunig, M., Roth, A., & Mehl, H. (2008). Spatiotemporal analysis of Indian megacities. *Proceedings of the International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *10*(Part B), 75–82.

Thakur, V. K. (1981). Role of Iron in the Origin of Second Urbanisation in India: A Resurvey of Evidence. *Proceedings of the Indian History Congress*, *42*, 61–69.

Thapa, R. B., & Murayama, Y. (2010). Drivers of urban growth in the Kathmandu valley, Nepal: Examining the efficacy of the analytic hierarchy process. *Applied Geography*, *30*(1), 70–83. https://doi.org/10.1016/j.apgeog.2009.10.002

Tian, G., Liu, J., Xie, Y., Yang, Z., Zhuang, D., & Niu, Z. (2005). Analysis of spatio-temporal dynamic pattern and driving forces of urban land in China in 1990s using TM images and GIS. *Cities*, *22*(6), 400–410. https://doi.org/10.1016/j.cities.2005.05.009

Triantakonstantis, D., & Mountrakis, G. (2012). Urban Growth Prediction: A Review of Computational Models and Human Perceptions. *Journal of Geographic Information System*, *04*(06), 555–587. https://doi.org/10.4236/jgis.2012.46060

UN-Habitat. (2004). *The state of the world's cities 2004/2005: Globalization and urban culture* (Vol. 2). UN-HABITAT. http://mirror.unhabitat.org/pmss/getElectronicVersion.aspx?nr=1163&alt=1

United Nations. (2018). *World Urbanisation Prospects (WUP) 2018 Revision*. https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf

UNSD. (2018). *Demographic Yearbook*. https://unstats.un.org/unsd/demographic-social/products/dyb/dyb_2018/ on 05.05.2020

Vaidyanathan, J., & Nathan, H. S. K. (2020). Water management in a growing mega city in Kerala. *International Conference on Environment Challenges and Solutions. Manava Rachana University (Faridabad)*.

Valbuena, D., Verburg, P. H., Bregt, A. K., & Ligtenberg, A. (2010). An agent-based approach to model land-use change at a regional scale. *Landscape Ecology*, *25*(2), 185–199. https://doi.org/10.1007/s10980-009-9380-6

Verburg, P. H., Schot, P. P., Dijst, M. J., & Veldkamp, A. (2004). Land use change modelling: current practice and research priorities. *GeoJournal*, *61*(4), 309–324.

Wegener, M. (2013). The future of mobility in cities: Challenges for urban modelling. *Transport Policy*, *29*, 275–282. https://doi.org/10.1016/j.tranpol.2012.07.004

White, R., & Engelen, G. (1993). Cellular Automata and Fractal Urban Form: A Cellular Modelling Approach to the Evolution of Urban Land-Use Patterns. *Environment and Planning A: Economy and Space*, *25*(8), 1175–1199. https://doi.org/10.1068/a251175

Wu, F. (2002). Calibration of stochastic cellular automata: the application to rural-urban land conversions. *International Journal of Geographical Information Science*, *16*(8), 795–818. https://doi.org/10.1080/13658810210157769

Wu, F., & Webster, C. J. (1998). Simulation of natural land use zoning under free-market and incremental development control regimes. *Computers, Environment and Urban Systems*, *22*(3), 241–256. https://doi.org/10.1016/S0198-9715(98)00044-1

Xenos, P., & Kabamalan, M. M. M. (2007). Emerging Forms of Union Formation in the Philippines. *Asian Population Studies*, *3*(3), 263–286. https://doi.org/10.1080/17441730701746417

Yan, Y., Ju, H., Zhang, S., & Jiang, W. (2020). Spatiotemporal patterns and driving forces of urban expansion in coastal areas: A study on urban agglomeration in the pearl river delta, China. *Sustainability*, *12*(1), 191.

Yang, J., Wang, Y., Xiu, C., Xiao, X., Xia, J., & Jin, C. (2020). Optimizing local climate zones to mitigate urban heat island effect in human settlements. *Journal of Cleaner Production*, *275*, 123767. https://doi.org/10.1016/j.jclepro.2020.123767

Zachariah, K. C., Mathew, E. T., & Rajan, S. I. (2001). Impact of Migration on Kerala's Economy and Society. *International Migration*, *39*(1), 63–87. https://doi.org/10.1111/1468-2435.00135

Zha, Y., Gao, J., & Ni, S. (2003). Use of normalized difference built-up index in automatically mapping urban areas from TM imagery. *International Journal of Remote Sensing*, *24*(3), 583–594.

Appendices

Appendix 2.1: Dynamics of Growth in Census Towns in select States between 2001 and 2011

STATE	Change in 2001 CT			New CT in 2011		
	Total CT in 2001	De-notified to village in 2011	Upgraded /Merged with Statutory Towns in 2011	Other Urban Area to CT	From Village to CT	Total CT in 2011
All India	**1362**	**55**	**144**	**141**	**2553**	**3857**
Kerala	**99**	**-**	**-**	**16**	**346**	461
West Bengal	252	4	4	11	526	781
Assam	45	2	3	6	80	126
Jharkhand	108	4	23		107	188
Odisha	31	1			86	116
Andhra Pradesh	93	6	18	22	137	228
Tamil Nadu	111	6			227	332
Rajasthan	38	3	2	4	76	113
Uttar Pradesh	66	4		2	204	268
Maharashtra	127	11	8		171	279
Bihar	5		1	4	52	60
Karnataka	44		11	13	81	127
Gujarat	74	1	24	21	83	153
Madhya Pradesh	55	3	4	18	46	112

Source: Compiled by author from Census of India Population Tables, 2001 and 2011.
Note: The number of census towns in 2011 is obtained by considering the census towns of 2001 and adding the number of urban and rural settlements, declared urban in 2011 and subtracting the number of census towns de-classified or the census towns upgraded or merged to statutory towns.

Appendix 2.2 Share of New CTs to Total Urban Population Growth between 2001-11

State	New CTs re-classified from Villages		Absolute change in Urban Population 2001-2011 (million)	Share of new CTs (Low)
	Number	Pop 2001 (million)		
All India	**2553**	**23.68**	**90.99**	**26.0**
Kerala	**346**	**6.80**	**7.67**	**88.8**
West Bengal	526	3.89	6.71	57.9
Assam	80	0.46	0.95	48.5
Jharkhand	107	0.71	1.94	36.5
Odisha	86	0.50	1.48	33.6
Andhra Pradesh	137	1.75	7.54	23.2
Tamil Nadu	227	1.62	7.47	21.7
Rajasthan	76	0.64	3.87	16.6
Uttar Pradesh	204	1.42	9.93	14.3
Maharashtra	171	1.37	9.73	14.1
Bihar	52	0.34	3.05	11.1
Gujarat	83	0.66	6.78	9.7
Karnataka	81	0.56	5.62	10.0
Madhya Pradesh	46	0.30	4.09	7.2

Compiled by author from Census of India Population Tables, 2001 and 2011.

Appendix 2.3: Per Capita Income at constant prices of 2004-05 and related indicators for Kerala and India

	2004 -05	2005 -06	2006 -07	2007 -08	2008 -09	2009 -10	2010 -11	2011 -12	2012 -13
Contribution of Kerala to India	4.01	4.04	3.97	3.95	3.91	3.93	3.86	3.91	4.05
Growth rates of GSDP for Kerala	-	10.09	7.90	8.77	5.56	9.17	6.92	5.85	5.92
Growth rates of GDP for India		9.48	9.57	9.32	6.72	8.59	8.91	6.69	4.47
Per Capita GSDP for Kerala (Rs)	36278	39601	42382	45733	47900	51897	55082	59052	63491
Per Capita GDP – India	27286	29413	31768	34241	36037	38599	41472	43657	45046

Source: The Directorate of Economics and Statistics, Government of Kerala and National Accounts Statistics, Ministry of Statistics and Programme Implementation, Government of India

Appendix 2.4: Contribution of Different Sectors and Subsectors to GSDP at Constant Prices of 2004-05, Kerala

Sector	2004 -05	2005 -06	2006 -07	2007 -08	2008 -09	2009 -10	2010 -11	2011 -12	2012 -13
Agriculture & Allied	17.5	16.7	14.5	13.1	12.7	11.5	10.0	9.9	9.5
Mining & quarrying	0.4	0.5	0.4	0.4	0.4	0.5	0.4	0.5	0.4
A. Primary	17.9	17.1	14.9	13.5	13.1	11.9	10.4	10.4	9.9
Manufacturing	8.6	8.0	7.9	8.5	8.3	7.6	7.9	7.8	7.5
Construction	12.2	12.7	12.7	11.9	11.5	11.7	12.8	12.6	12.2
Electricity, Gas & Water	1.8	1.8	1.7	1.7	1.2	1.3	1.3	1.2	1.2
B. Secondary	**22.6**	**22.5**	**22.3**	**22.1**	**21.0**	**20.6**	**22.0**	**21.6**	**20.9**
Trade, Hotels & Restaurant	20.0	20.5	21.0	20.7	20.5	21.2	19.3	18.3	17.9
Transport, Storage & Com.	9.9	10.2	11.0	11.6	12.8	13.8	14.8	15.8	16.8
Financial Services	5.1	5.5	5.9	6.3	6.7	6.8	7.2	7.5	8.0
Real Estate & others	10.9	11.1	11.5	11.7	12.1	11.6	11.8	11.4	11.9
Public administration	4.2	4.1	4.3	4.5	4.4	3.9	3.6	4.4	5.8
Other services	9.5	9.1	9.2	9.7	9.5	10.2	11.0	10.6	8.9
C. Sub-Total of Tertiary	59.6	60.4	62.9	64.4	66.0	67.5	67.6	68.0	69.2

Source: Calculated based on the data from the Directorate of Economics and Statistics, Kerala

Appendix 2.5: Contribution of Different Sectors and Sub-sectors to GSDP at Constant Prices of 2004-05, India

Sector of activity	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13
Agriculture & Allied	19.0	18.3	17.4	16.8	15.8	14.6	14.6	14.4	13.9
Mining & quarrying	2.9	2.6	2.6	2.5	2.4	2.3	2.2	2.1	2.0
A. Primary	**21.9**	**20.9**	**20.0**	**19.3**	**18.2**	**16.9**	**16.8**	**16.5**	**15.9**
Manufacturing	15.3	15.3	16.0	16.1	15.8	16.2	16.2	16.3	15.8
Construction	7.7	7.9	8.0	8.1	8.0	7.8	7.6	7.9	7.7
Electricity, Gas & Water	2.1	2.1	2.1	2.0	2.0	2.0	1.9	1.9	1.9
B. Secondary	**25.0**	**25.4**	**26.1**	**26.2**	**25.8**	**26.0**	**25.7**	**26.1**	**25.3**
Trade, Hotels & Restaurant	16.1	16.5	16.7	16.8	16.6	16.5	17.0	16.1	16.1
Transport, Storage & Com.	8.4	8.6	8.8	9.1	9.4	10.0	10.3	10.6	10.7
Financial Services	5.8	6.1	6.7	7.2	7.6	7.8	8.3	8.7	9.4
Real Estate & others	9.0	9.0	9.0	9.0	9.3	9.3	9.0	9.3	9.8
Public administration	5.9	5.6	5.2	5.1	5.8	6.2	5.7	5.6	5.5
Other services	8.0	7.9	7.5	7.3	7.3	7.2	7.2	7.1	7.3
C. Sub-Total of Tertiary	**53.1**	**53.7**	**53.9**	**54.4**	**56.0**	**57.0**	**57.5**	**57.4**	**58.7**

Source: Calculated based on the data from Central Statistical Organization, Government of India)

Appendix 3.1: Area and Population of Kochi City Region: 1981 to 2011

S.No	Constituent local body	Area (in Sq. Kms)	Population			
			1981	1991	2001	2011
1	Kochi (M Corp.)	94.88	513249	551332	595575	602046
2	Eloor	21.95	52528	56969	54618	58218
3	Thrippunithura	18.69	43646	51078	59884	69390
4	Kalamassery	27.00	43767	54342	63116	71038
5	Thrikkakara	27.46	38318	51166	65564	77319
6	Mulavukadu	19.27	21397	22322	22842	21833
7	Maradu	12.35	28749	34995	41012	44704
8	Njarackal	8.60	21672	22978	24166	23760
9	Elamkunnapuzha	11.66	43911	47878	50563	50714
10	Cheranallur	10.59	18381	21407	26316	30594
11	Thiruvankulam	10.49	15517	18412	21717	23160
12	Kadamakkudy	12.91	13696	14668	15824	16295
	Kochi City Region	**275.85**	**854831**	**947547**	**1041197**	**1089071**

Note: (i) The figures of Eloor for census years 1991 to 2011 are the sum of Eloor and Varappuzha (ii) The figures for Thrikkakkara for census years 1991 to 2011 is the total of Vazhakkala and Kakkanad and (iii) the figures for Elamkunnapuzha for census years 1991 to 2011 is the total of Elamkunnapuzha and Puthuvype.
Source: Census of India

Appendix 3.2: Percentage of Non-Agricultural Workers (other than cultivators and agricultural laborers)

S. No	Constituent local body	1981	1991	2001	2011
1	Kochi (M Corp.)	99.3	98.9	99.8	99.5
2	Eloor	86.7	94.6	98.8	99.1
3	Thrippunithura	93.3	91.1	99.2	99.3
4	Kalamassery	90.6	93.6	98.2	98.9
5	Thrikkakara	77.8	85.7	98.2	98.9
6	Mulavukadu	95.5	96.6	99.3	99.5
7	Maradu	96.7	98.5	99.9	98.8
8	Njarackal	97.7	96.1	97.4	99.2
9	Elamkunnapuzha	97.7	97.9	98.4	98.1
10	Cheranallur	89.8	93.3	99.6	99.1
11	Thiruvankulam	89.2	87.9	98.8	98.9
12	Kadamakkudy	89.7	90.7	97.9	98.4
	Kochi Central City	95.9	96.5	99.3	99.3

Note: (i) The figures of Eloor for census years 1991 to 2011 are the sum of Eloor and Varappuzha (ii) The figures for Thrikkakkara for census years 1991 to 2011 is the total of Vazhakkala and Kakkanad and (iii) the figures for Elamkunnapuzha for census years 1991 to 2011 is the total of Elamkunnapuzha and Puthuvype.
Source: Census of India

Appendix 3.3: Freight and Passenger Movement by Road Transport and Railways in India during 1999-2000 to 2011-12

Year	Percent Road Freight Movement	Percent Railways-Freight Movement	Percent Road Passenger s	Percent Railway Passengers
1999-2000	60.5	39.5	81	19
2000-01	61.3	38.7	82	18
2001-02	60.7	39.3	83.1	16.9
2002-03	60.7	39.3	84.5	15.5
2003-04	61	39	85	15
2004-05	61.1	38.9	85.8	14.2
2005-06	59.9	40.1	87.4	12.6
2006-07	61.4	38.6	86.7	13.3
2007-08	62	38	86.3	13.7
2008-09	62.5	37.5	86.1	13.9
2009-10	62.8	37.2	86	14
2010-11	64.3	35.7	85.9	14.1
2011-12	64.5	35.5	85.9	14.1

Source: Ministry of Road Transport and Highways, Government of India

Appendix 5.1: Kappa Statistics for accuracy assessment of LULC Map 1992, Kochi City

		Reference Data					
	Class	Built-up	Water body	Paddy and Wetland	Vegetation	Others	Total
Classified Data	Built-up	122	0	1	6	14	143
	Water body	0	95	8	2	3	108
	Paddy and Wetland	1	4	87	7	0	99
	Vegetation	10	1	3	82	3	99
	Others	17	0	1	3	80	101
	Total	150	100	100	100	100	550

Class	**Producer's Accuracy**	**User's Accuracy**
Built-up	81.3 %	85.3 %
Water body	95.0 %	88.0 %
Paddy and Wetland	87.0 %	87.9 %
Vegetation	82.0 %	82.8 %
Others	80.0 %	79.2 %
Overall Agreement	**85.0 %**	
Error of Omission	**0.21**	
Overall Kappa Statistics	**0.81**	

Appendix 5.2: Kappa Statistics for accuracy assessment of LULC Map 2001, Kochi City

		Reference Data					
	Class	Built-up	Water body	Paddy and Wetland	Vegetation	Others	Col Total
Classified Data	Built-up	129	0	2	2	13	146
	Water body	1	87	12	2	1	103
	Paddy and Wetlands	2	10	81	7	2	102
	Vegetation	6	2	4	88	5	105
	Others	12	1	1	1	79	94
	Row Total	150	100	100	100	100	550

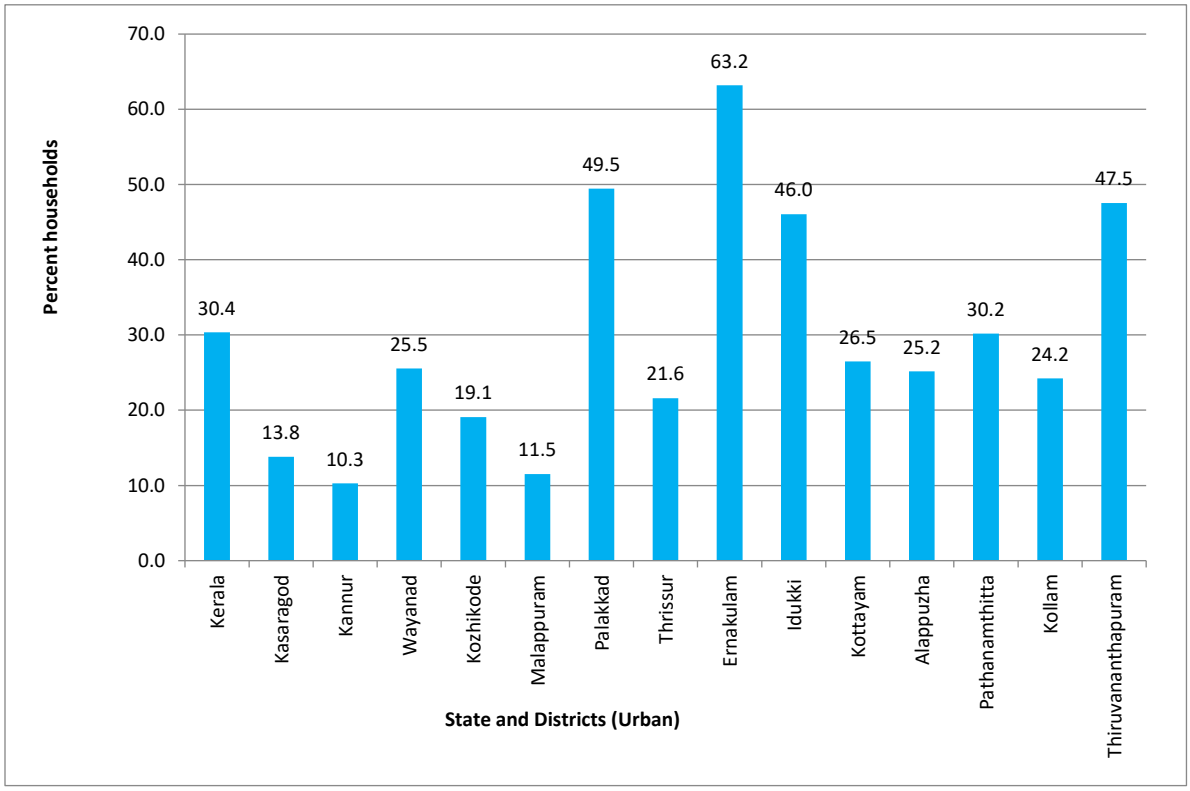
Class	**Producer's Accuracy**	**User's Accuracy**
Built-up	86 %	88.4 %
Water body	87 %	84.5 %
Paddy and Wetland	81 %	79.4 %
Vegetation	88 %	83.8 %
Others	79 %	84.0 %
Overall Agreement	**85.0 %**	
Error of Omission	**0.21**	
Overall Kappa Statistics	**0.81**	

Appendix 5.3: Kappa Statistics for accuracy assessment of LULC Map 2001, Kochi City

		Reference Data					
	Class	Built-up	Water body	Paddy and Wetland	Vegetation	Others	Col Total
Classified Data	Built-up	133	1	2	5	8	149
	Water body	1	89	16	1	0	107
	Paddy and Wetland	3	8	75	5	2	93
	Vegetation	4	1	6	88	3	102
	Dry/open land	9	1	1	1	42	54
	Row Total	150	100	100	100	55	505

Class	**Producer's Accuracy**	**User's Accuracy**
Built-up	88.7	89.3
Water body	89.0	83.2
Paddy and Wetland	75.0	80.7
Vegetation	88.0	86.3
Others	76.4	77.8
Overall Agreement	**85.0 %**	
Error of Omission	**0.18**	
Overall Kappa Statistics	**0.81**	

Appendix 4.1: Households with access to treated water supply in urban areas of the districts in Kerala



Source: Census of India, 2011

Appendix 5.1: Sample Locations and the Number of Samples

S. No	Grid No.	Administrative Unit of sample collection (as per current status)	No. of Samples
1	5	Corporation	12
2	11	Corporation	12
3	15	Municipality	12
4	20	Corporation	12
5	23	Corporation	12
6	24	Municipality	12
7	25	Municipality	12
8	26	Census Town	11
9	34	Municipality	12
10	35	Census Town	12
11	41	Corporation	12
12	43	Corporation	11
13	53	Municipality	11
14	54	Municipality	12
15	55	Municipality	12
16	58	Census Town	11
17	62	Corporation	12
18	67	Census Town	12
19	71	Census Town	12
20	73	Municipality	11
21	74	Municipality	12
22	78	Census Town	12
23	79	Census Town	12
24	80	Municipality	12
25	86	Census Town	12
26	87	Municipality	11
	Total		**306**

Source (Field Survey, 2018)

Appendix 4.2

Category	Corporation	Municipality	Census Town	Total
Sources of pollutants in your neighbourhood				
No pollution	44 (53)	72 (55.8)	49 (52.1)	165 (53.9)
Dumping of waste	11 (13.3)	8 (6.2)	22 (23.4)	41 (13.4)
Garbage disposal to water bodies	0 (0)	15 (11.6)	5 (5.3)	20 (6.5)
vehicular traffic	11 (13.3)	12 (9.3)	15 (16)	38 (12.4)
Noise	4 (4.8)	15 (11.6)	0 (0)	19 (6.2)
smoke from cooking or residual burning	2 (2.4)	6 (4.7)	3 (3.2)	11 (3.6)
Mosquito	11 (13.3)	1 (0.8)	0 (0)	12 (3.9)
Others	0 (0)	0 (0)	0 (0)	0 (0)
Cleaning of courtyard/surroundings in a week				
Never	0 (0)	1 (0.8)	1 (1.1)	2 (0.7)

Category	Corporation	Municipality	Census Town	Total
once in a week	3 (3.6)	3 (2.3)	2 (2.1)	8 (2.6)
twice in a week	1 (1.2)	2 (1.6)	1 (1.1)	4 (1.3)
Alternate days	9 (10.8)	9 (7)	10 (10.6)	28 (9.2)
Daily	65 (78.3)	113 (87.6)	78 (83)	256 (83.7)
Not applicable	5 (6)	1 (0.8)	2 (2.1)	8 (2.6)
Total	83 (100)	129 (100)	94 (100)	306 (100)
Cleaning of streets/roads by the local authority				
Never	4 (4.8)	63 (48.8)	65 (69.1)	132 (43.1)
occasionally	64 (77.1)	42 (32.6)	27 (28.7)	133 (43.5)
Regularly	15 (18.1)	24 (18.6)	2 (2.1)	41 (13.4)
Self-cleaning	0 (0)	0 (0)	0 (0)	0 (0)
Don't know	0 (0)	0 (0)	0 (0)	0 (0)
Total	83 (100)	129 (100)	94 (100)	306 (100)
Street light works in a week				
No street light/never	0 (0.0)	2 (1.6)	1 (1.1)	3 (1)
Once a week	0 (0.0)	0 (0.0)	2 (2.1)	2 (0.7)
twice a week	0 (0.0)	1 (0.8)	2 (2.1)	3 (1)
Alternate days	5 (6.0)	9 (7.0)	2 (2.1)	16 (5.2)
Daily	78 (94.0)	117 (90.7)	87 (92.6)	282 (92.2)
Total	83 (100)	129 (100)	94 (100)	306 (100)
satisfaction of the condition of street/road				
Yes	80 (96.4)	118 (91.5)	87 (92.6)	285 (93.1)
No	3 (3.6)	11 (8.5)	7 (7.4)	21 (6.9)
Total	83 (100)	129 (100)	94 (100)	306 (100)
Street/road maintenance by local authorities				
Never	0 (0)	53 (41.1)	3 (3.2)	56 (18.3)
Occasionally	50 (60.2)	58 (45)	80 (85.1)	188 (61.4)
Regularly	33 (39.8)	18 (14)	11 (11.7)	62 (20.3)
Total	83 (100)	129 (100)	94 (100)	306 (100)
locality have any surveillance				
Yes	11 (13.3)	4 (3.1)	0 (0)	15 (4.9)
No	72 (86.7)	125 (96.9)	94 (100)	291 (95.1)
Total	83 (100)	129 (100)	94 (100)	306 (100)
Emergency help line for calling Police, Fire and Ambulance				
Yes	75 (90.4)	125 (96.9)	64 (68.1)	263 (86.3)
No	8 (9.6)	4 (3.1)	30 (31.9)	42 (13.7)
Total	83 (100)	129 (100)	94 (100)	306 (100)

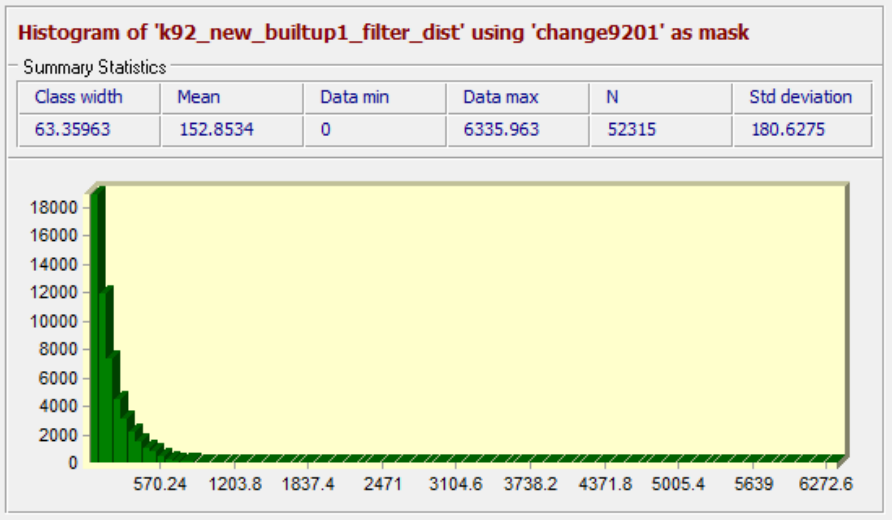
Source (Field Survey, 2018)

Appendix 4.3

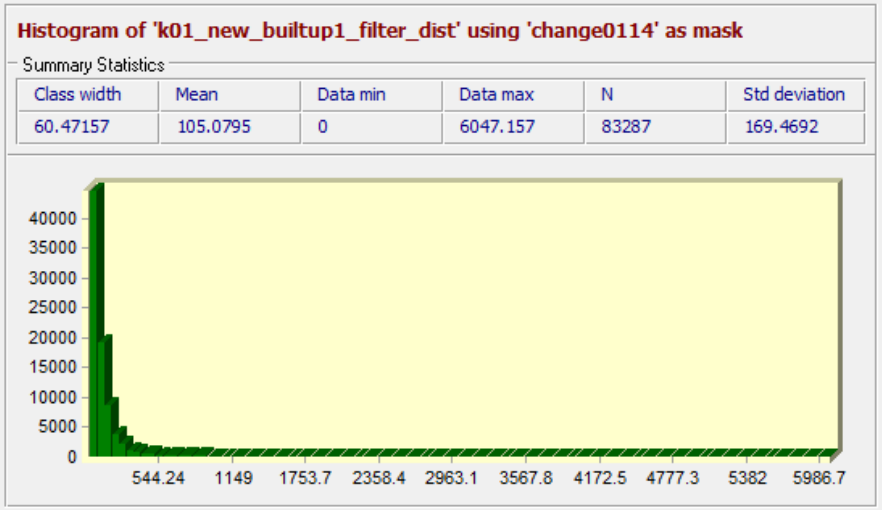
Category	Corporation	Municipality	Census Town	Total
Any kind of eve-teasing noticed in your locality				
Yes	3 (3.6)	1 (0.8)	0 (0)	4 (1.3)
No	80 (96.4)	128 (99.2)	94 (100)	302 (98.7)
Total	83 (100)	129 (100)	94 (100)	306 (100)
Safety for night movement especially for women				
Not Safe	4 (4.8)	9 (7)	17 (18.1)	30 (9.8)
Occasional Issues	12 (14.5)	7 (5.4)	1 (1.1)	20 (6.5)
Fully safe	67 (80.7)	113 (87.6)	76 (80.9)	256 (83.7)
Total	83 (100)	129 (100)	94 (100)	306 (100)
Any flooding/large scale waterlogging in your area during Monsoon				
Yes	4 (4.8)	6 (4.7)	25 (26.6)	35 (11.4)
No	79 (95.2)	123 (95.3)	69 (73.4)	271 (88.6)
Total	83 (100)	129 (100)	94 (100)	306 (100)
Mode of garbage disposal				
Local Authorities	73 (88)	56 (43.4)	24 (25.5)	153 (50)
Private Arrangement	3 (3.6)	0 (0)	0 (0)	3 (1)
Self-Disposal	6 (7.2)	73 (56.6)	70 (74.5)	149 (48.7)
Others	1 (1.2)	0 (0)	0 (0)	1 (0.3)
Total	83 (100)	129 (100)	94 (100)	306 (100)

Source (Field Survey, 2018)

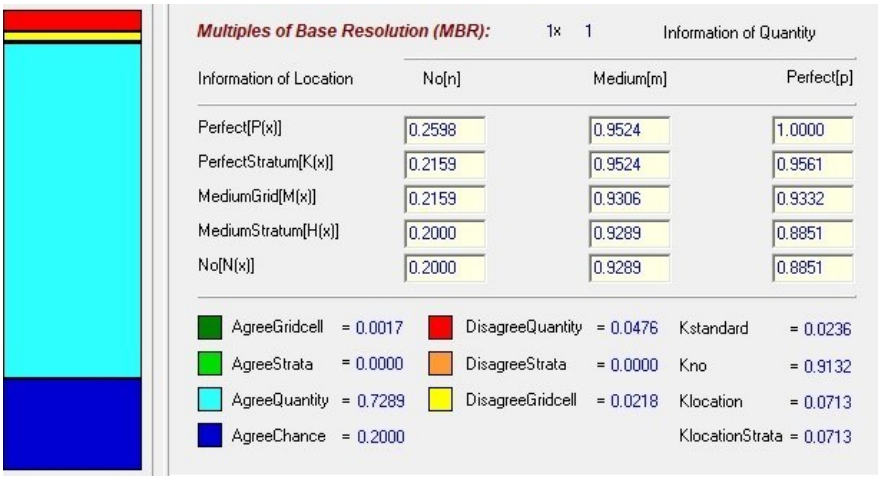
Appendix 6.1: Change in frequency of built-up with respect to existing built-up



Appendix 6.2: Change in frequency of built-up with respect to existing built-up



Appendix 6.3: Validation of the actual and simulated map of 2014



Field Survey Questionnaire

1. Identification of Sample Households

1.1 Taluk:	1.2 Corporation/Municipality/Census Town/Panchayat:
1.3 Ward No. (if Corporation/Municipality)	1.4 HH ID:
1.5 Name of Head of the Household:	1.6 Address:
1.7 Geographic Location	Grid. No. Latitude: Longitude:

2. Socio-economic, land and housing characteristics of the household

1	Religion: (Hindu – 1, Muslim – 2, Christian – 3, Others – 9)	
2	Social Group: (ST -1 , SC- 2 , OBC – 3, General – 9)	
3	Major Source of income of the household (Business-1, Private Job - 2, Government Job - 3, Remittance from family members – 4, Pension -5, Others - 6) (If multiple response, write all corresponding codes)	
4	Approximate total monthly income of the household (in Rs.)	
5	Approximate household monthly consumption expenditure (in Rs.)	
6	Total number of bed rooms in your house/flat?	
7	Approximate age of construction of house (in number of years)	
8	Type of structure of house: Temporary (Katcha) -1,Semi Permanent (Semi Pucca) -2, Permanent (Pucca) -3	
9	Approximate present value of the house/flat (in Rs.)	
10	Area of land owned (write in cents, if in acres multiply it by 100)	
11	Approximate value of land per cent (Rs.)	

3. Demographic Characteristics of household members (including those who are working outside the city)

No.	Name	Relation to HH (Code given below)	Age (in Years)	Sex (Male 1 Female-2)	Education	Occupation	If working, distance to work place (in Kms)	If student, distance to school/ Collage (in Kms)	Mode of transport for commuting (Code given below, if multiple mode mention all codes)	Approximate travel time per day (in hours)	Cost of travel per day (in Rs.)
1											
2											
3											
4											
5											
6											
7											
8											

Relation to HH: Self – 1, Spouse – 2, Son – 3, Daughter- 4, Father – 5, Mother – 6, Brother – 7, Sister – 8, Grand Son – 9, Grand Daughter- 10 Father-in-law – 11, Mother-in-law – 12, Others – 13 **Education**: Write the actual completed education, **Occupation**: Write the actual occupation **Mode of transport**: Public/Private Bus – 1, Metro – 2, Train-3, Ferry – 4, Own Car-Petrol – 5, Own Car-Diesel – 6, Uber/Taxi – 7, Scooter/Bike – 8, Cycle – 9, Walk – 10 (if multiple travel mode, please mention all corresponding codes)

4. Access to Basic Amenities

1	Primary source of energy for cooking: (LPG/PNG -1, Electricity – 2, Firewood – 3,Kerosene – 4, Others – 9) Cost incurred for cooking fuel (in Rs. per month):	
2	Main source of drinking water: (Tap water - 1, Tubewell/borewell - 2, Bottled water -3, Well- 4, Spring- 5, Others – 9). Cost incurred for water (in Rs. per month):	
3	Distance from main source of drinking water: (Within dwelling – 1, Outside dwelling but within the premises – 2, Outside the premises and within 200 meters – 3, More than 200 meters - 9)	
4	Perceptional quality of drinking water from the main source:(Very Good – 1, Good/satisfactory – 2, Bad taste with unknown causes – 3, Cloudy due to unknown causes – 4)	
5	Type of Latrine used (Flush/pour latrine connected to piped sewer system – 1, Flush/pour latrine connected to Septic tank - 2, Pit latrine - 3, Others – 4)	
6	Availability of Sewerage line? (Yes-1, No – 2)	
7	Availability of Drainage (Yes-1, No – 2)	
8	Type of Drainage (Open temporary (kutcha) - 1, Open permanent (pucca) - 2, Covered permanent (pucca) - 3, Under ground – 4)	

5. Environment and health related details

1	Do you experience any flooding/large scale waterlogging in your area during Monsoon? (Yes – 1, No - 2)	
2	According to you, what are the sources of pollutants in your area? (No pollution – 1, Dumping of waste – 2, Industrial/garbage waste disposal to water bodies - 3, Increased Vehicular Traffic - 4, Noise – 5, Smoke from cooking or residual burning – 6, Others (specify):	
3	Mode of garbage disposal: (Local authorities-1, Private arrangement-2, Self – 3, Others – 9)	
4	Distance to the nearest garbage dumping area: (Within 250 meters – 1, 250 to 500 meters - 2, 500 to 1 km – 3, More than 1 km – 4, Don't know - 9)	
5	How often you clean your courtyard/surroundings in a week? (Never – 0, Once in a week – 1, Twice in a week – 2, Alternate days – 3, Daily – 4, Not Applicable-5)	
6	How frequent your streets/roads are cleaned by the local authority? (Never – 0, Occassionally-1, Regularly – 2)	
7	How frequent your street light works in a week? (No streetlight/Never – 0, Once in a week – 1, Twice in a week – 2, Alternate days – 3, Daily – 4)	
8	Are you satisfied with the present condition of your street/road? (Yes-1, No-2) How frequent your street/road is maintained by local authorities? (Never – 0, Occassionally-1, Regularly – 2)	

9	Does your locality have any surveillance (CCTV) system? (Yes-1, No-2)	
10	Any kind of eve-teasing noticed in your locality? (Yes-1, No-2)	
11	How safe is your locality for mobility in night especially for women? (Not safe – 0, some occasional issues– 1, Fully safe - 2)	
12	Do you have any emergency help line for calling Police: (Yes-1, No-2) Fire: (Yes-1, No-2) Ambulance: (Yes-1? No-2)	

6. Access to neighborhood facilities

No	Facilities	Place/Name	Distance in (Kms)
1	Shopping Mall		
2	Bank and other commercial centers		
3	Metro Station		
4	Bus Stand/Station		
5	Health Facility/Hospital		

Undertaking

I hereby undertake that the information collected will be purely used for research/academic activities and confidentiality of the data will be strictly maintained.

Date Research Investigator