Chapter 17
Geo-spatial Assessment of Inherent Smart Urban Attributes of Traditional Neighborhood-Level Communities in India

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Abstract City-making is a process in which several endogenous and exogenous variables associated with socio-economic, environmental, historical, and physical parameters play a significant role. The neoliberal and market-led notion of smart cities is highly criticized by many scholars for its polarized and inequitable approach to development. The traditional communities have continued for generations and inherit a unique living and residential culture bestowing them with an inherent smartness quotient. This concept of smartness for city planning is even more critical during the present times to understand the impact of the spatial structure of existing cities to deal with the COVID-19 outbreak. Authors identify a strong need to merge the two concepts of traditional communities and urban smartness for a holistic approach to building smart communities. This study aims to assess the smart spatial attributes of the traditional neighborhood-level urban communities such as compactness, walkability, and diversity. Primary household surveys were conducted in the walled city of Alwar, Rajasthan, India. The case study reveals compactly designed residential enclaves known as mohallas with mixed land use. The indigenous spatial elements such as squares (chowks), markets (bazaars), and streets (gali) proved to be crucial community gathering places for these settlements. Such zero-level assessment of existing socio-cultural and spatial attributes may enable the appropriate integration of intelligent technologies into our urban systems. Authors recommend harnessing the untapped potential of traditional communities in culturally rich countries like India to achieve the goals of a smart community.

17.1 Introduction

Cities are the centers of excellence and act as focal points for human interaction and commercial activities [1]. However, they are prone to undesirable consequences of inevitable urbanization phenomenon. On the one hand, urbanization contributes

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to the higher productivity of cities and on the other hand, it comes with challenges of urban sprawl, unemployment, high crime rate, slums, lack of adequate housing and infrastructure, urban inequality, environmental degradation, and weak financial capacities of urban local bodies [2]. The United Nations Department of Economic and Social Affairs [3] estimates that India alone can witness an increase of 416 million urban dwellers by 2050. It is a major developing economy and to tackle the critical urban challenges, an ambitious Smart Cities Mission (SCM) was launched in 2015 impacting a total urban population of more than 99,000,000 [4].

Usually digital and ICT-oriented interventions are awkwardly integrated into an existing physical setting for building smart cities. However, there is only 50% global access to the internet with an acute gender gap in connectivity [5]. Inappropriate digital interventions can widen these social gaps instead of bridging them. Also, this fuzzy concept is under constant scrutiny due to its top-down, market-oriented, and technocentric approach [6–9]. The top priorities of international communities under the aegis of Sustainable Development Goals are to reduce the digital divide, build digital capacities, and ensure the use of new technologies as a common good that favors a sustainable, inclusive, and resilient urban future. City-making is a process in which varied urban experiences and cultural patterns result in urban components unique to human settlement systems [10]. However, a high-tech variant may ignore the needs of its traditional communities and poorer residents by applying some short-term spatial fixes [11].

This ongoing tendency to overlook the "city" component from the concept of "smart city" and easily getting allured by the grandiose visions of modernization underpins a dire need to realize the existing potential of traditional settlements in terms of their built environment, non-technical attributes, urban planning practices, urban fabric, socio-cultural aspects, environmental and economic aspects. The physical and socio-cultural geography should perhaps be the common denominator to define the scope of smart city initiatives for different scales [12]. This study aims to analyze the spatial attributes of existing communities in the Indian context which can contribute to the objectives of smart urban development. Based on text computational analysis, a conceptual smart city model is proposed to assist in formulating a relevant set of indicators for the study. A case study approach is utilized to give an in-depth and multi-faceted insight into a traditional urban setting in India.

17.2 Literature Review

17.2.1 Concept of Smart Cities

A better-performing city balances all domains of urban life and achieves the goals of inclusive, safe, resilient, and sustainable development [13]. Accordingly, they are associated with many labels in the global policy discourse, such as sustainable cities, livable cities, digital cities, and smart cities, which have overlapping objectives in practice and are used interchangeably. Jong et al.'s [14] analysis of the 12 most frequently used city categories concludes sustainable city category is an umbrella node having greater resonance with urban policies worldwide. While some of these city categories such as intelligent city, ubiquitous city, and resilient city form a distant relationship with the central node, the smart city category forms one of the major axes with sustainable city category [9]. The very first definition of sustainability emerged in 1987 in the Brundtland report, emphasizing a development process that meets the needs of the present generation without compromising the needs of the future generation [15]. The 2030 agenda for sustainable development was put forth in 2015, covering themes such as poverty, education, climate change, socio-economic inequality, and safety, which are fundamentally relevant to urban areas [16].

The overall narrative of the smart city literature depicts a constant confusion between the digital and the sustainability agenda [17, 18]. In the 1990s, the smart city concept progressed through the Kyoto protocol with an explicit focus on environmental sustainability. However, post-2000, this concept observed a shift in its discourse from sustainable planning interventions to the fixing of urban spaces with digital technologies. Considering technology plays an important role in transforming urban life, the United Nations for Smart Sustainable Cities was launched in 2016 as a distinctive global smart city platform to act as a facilitator for building partnerships on smart cities and formulate implementation schemes with allied urban programs such as the new urban agenda, the Paris agreement, the connect 2020 agenda and 2030 agenda for sustainable development [19]. The Indian SCM is a centrally sponsored flagship program that has come a long way from focusing on technology as the only solution to adopting it as a means to achieve certain goals. The mission urges us to keep communities at the core, making the best use of the city's existing resources through cooperative and competitive federalism and integration of appropriate urban innovations. The various features of the smart cities mission can be graphically represented in Fig. 17.1 [20].

17.2.2 Research Gaps

Despite an exponential increase in smart cities research over the last decade, the term is vague and ambiguous which is mostly used as an instrumental concept instead of a normative concept. The issue with conflating and the self-congratulatory smart city is its market-led urban agenda rooted in a great misunderstanding about this concept [11, 21–23] The definitions and practical applications are unclear and multifaceted [9]. Audirac [24] mentions that inefficient incorporation of ICT with the existing spatial setting can result in a loose, fragmented, polycentric, and complex urban form with fast dispersing and de-concentrating land uses, and social and spatial segregation, congested streets, and disappearing open spaces. Angelidou [21] concluded that strategic planning is a missing component from the present smart city framework and urges to adopt human-centered approaches for solving urban problems. The authors conducted a comparative analysis of popular smart city interventions between their

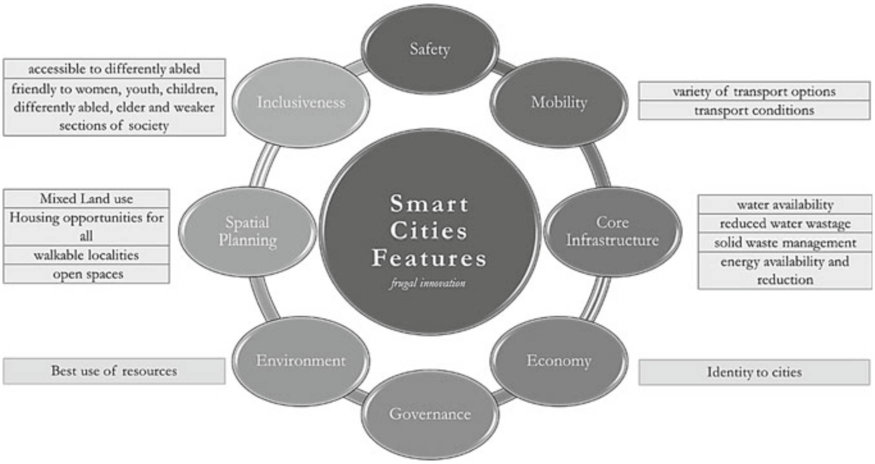

Fig. 17.1 Features of smart cities identified by smart cities mission

rhetoric targets and the real outcomes. Table. 17.1 indicates an uncritical, ahistorical, and aspatial understanding of data in most of these case studies, emphasizing the role of the overall socio-cultural context in which these initiatives are proposed.

Besides the critical literature review, an expert survey was conducted from a diverse professional background ranging from architects and urban professionals to engineers in energy and civil industries on www.questionpro.com in 2016. The experts rated the identified 15 broad urban aspects on a scale of 1 to 5 according to their importance in the smart cities development framework. Figure 17.2 shows that the experts' highest average rating is 4.45 out of 5 for mobility, closely followed by living, economic, spatial, and environmental. Also, experts gave very high importance to spatial, cultural, and physical dimensions than the already existing governance and social dimensions. This raises further necessity to pay heed to the concepts of the smart cultural urban landscape.

17.2.3 Conceptual Smart City Model

People interpret the term smart in different ways- for some, it is just the environmental goals, while it is an ICT-driven urban solution for others. Incorporating a digital vision and technological fixes may skew results to critical urban issues [37]. This study acknowledges that the strategy for smart urban development should perhaps begin with an assessment of the existing situation and aspirations of its communities. India's long history, diverse cultural setting, and domineering informal sector demand an indigenous tailor-made framework, instead of an imported scheme of actions from its western counterparts [38, 39]. The study identifies the following research questions-

Table 17.1 Global smart cities initiatives

	City	Smart interventions	Rhetoric targets	Real outcomes
1	Philadelphia, USA	• IBM's digital on-ramps initiative—provides a mobile, internet-based application for training marginalized low literacy workforce	• Bridge socio-economic present within the city	• The divides persist. residents targeted belong to de-industrialized inner-city neighborhoods but emerging information economy clustered in well-off areas
2	Rio de Janeiro [25–27]	• Integrated center of command and control, equipped with the latest technology in disaster management and response; control traffic flow and public transit systems	• Strengthening of security operations in public spaces • Urban mapping projects for informed decision-making • High-tech marketing rhetoric	• The concentration of CCTV cameras in the wealthier sections of town • Spotty public transit video feeds • No data for longer-term planning • The crime rate, social inequality, digital divide, and environmental issues have increased • Lack of transparency
3	Korea's ueco-cities [28]	• 64 cities with high tech ubiquitous computing embedded in city-scale cloud infrastructure	• Unique and innovative city type with high quality of life • Sustainable urban planning practices and civic empowerment	• Supply-side technology at the core • Socio-cultural aspects are neglected with no option for retrofitting existing communities • Local economies and traditional spaces are not considered
4	Singapore's IT revolution [11, 29]	• Intelligent island with inter-connected computers • Singapore ONE (One network for everyone)	• Advanced nationwide information infrastructure will change the lifestyle of citizens	• High-end wealthy customers inhabited fortified high-tech enclaves • The role of ICT in the long term is yet to be seen

(continued)

Table 17.1 (continued)

	City	Smart interventions	Rhetoric targets	Real outcomes
5	Digital Kyoto [30, 31]	• Academic-industry collaboration for future transportation planning, aesthetic corners, awareness campaign, and parking management	• Walkable Kyoto • Improve and diversify the public transportation systems and decrease the use of private automobiles	• Focus on social information infrastructure • Urban planning motivation to allow community members to participate • Initiated by academic researchers with a focus on non-technical research issues such as security and privacy
6	Barcelona [32]	• Smart city strategic plan in the 1990s	• Open data application in living labs for effective citizen collaboration • A sustainable and livable city with a competitive and innovative economy	• Considered a success story across Europe • A soft infrastructure-oriented strategy focusing on ubiquitous ICT, physical infrastructure, and human capital • Explicit focus on urban planning and urban renewal projects
7	Arab cities [33, 34]	• Post-1940s, several westernized housing projects in countries like Saudi Arabia, Egypt, and UAE	• Imported dwelling-units design and urban pattern- western thoughts of development • Modern architectural movement with a focus on the rational and efficient urban system	• Fragmented urban patterns led to fragmented community and missing neighborhood sense • Loss of local identity due to demolished and refurbished old towns • Impart functional improvements at the cost of losing many human and environmental qualities • From pedestrian scale to automobile-oriented highways

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Table 17.1 (continued)

	City	Smart interventions	Rhetoric targets	Real outcomes
8	Amsterdam—Dutch network society [35, 36]	• European pilot site for City-Zen energy-saving program	• Scale-up innovation efforts with data analytics to improve the way urban life of its citizens	• A shift from the traditional spatial planning model which focused on compactness, optimal land uses, and proximity to a networked society • Spatial segregation and complex logistics system with increased use of urban space

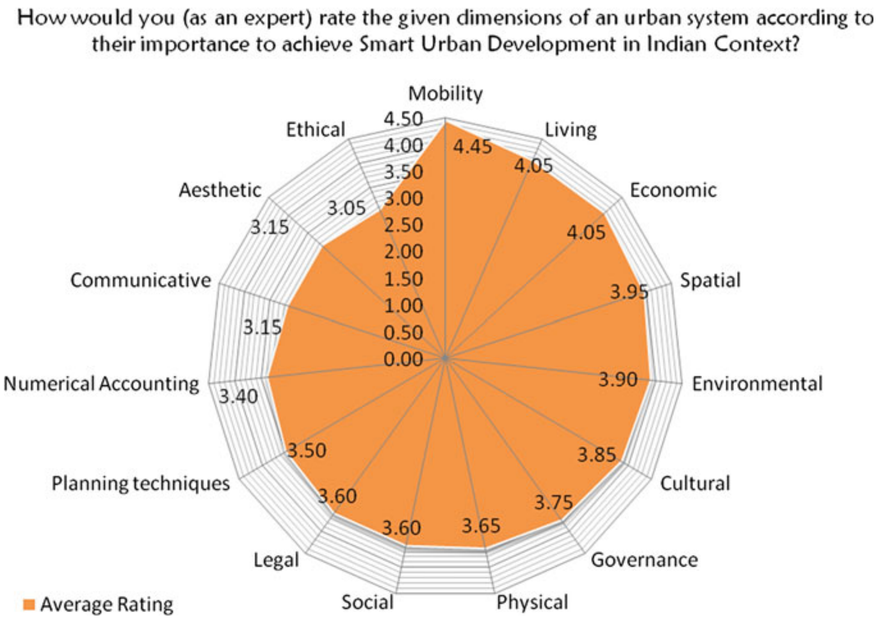


Fig. 17.2 Average rating of urban dimensions by experts

1. Can we have a conceptual smart city model which focuses on the overall vision of smart cities irrespective of the technological or planning instruments?
2. Do traditional settlements exhibit some level of indigenous smartness, which can be harnessed comprehensively instead of merely fixing with some popular and modern technology?

The null hypothesis assumes that the urban attributes of traditionally originated settlements exhibit some level of indigenous smartness. The study aims to develop

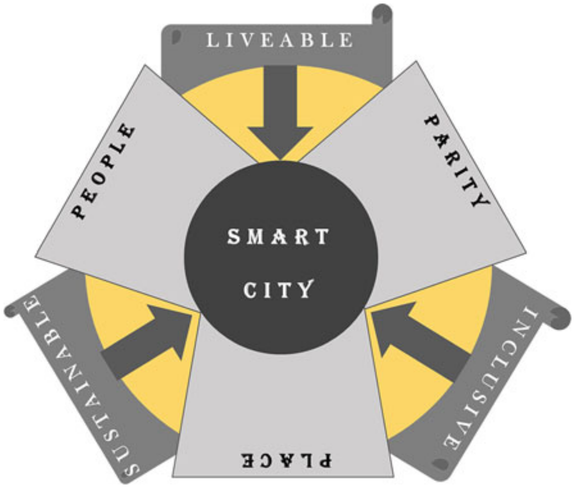


Fig. 17.3 A tripartite smart city model

a methodology for assessing traditionally originated settlements toward achieving objectives of urban smartness. The existing smart cities literature is mostly qualitative and diverse, and hence, systematic literature search and review coupled with aggregative and interpretative meta-synthesis is utilized to identify the key terms associated with objectives of smart urban development [40]. The study explicitly limits the focus of the study to their goals irrespective of the means of achieving these goals, whether it be employing urban design interventions or technological spatial fixes. The corpus of definitions of smart cities is prepared and analysis of recurrent terms, their clustering tendencies, and visualization algorithms reveal the key terms associated with the objectives of smart urban development. These terms include quality of life, sustainable economic growth, human capital, urban development, sustainable environment, socio-economic aspects, social inclusion, administrative efficiency, citizen services, and people's life-work integration [40].

Figure 17.3 represents the graphical representation of the tripartite vision of smart cities. Sustainability is mostly associated with the tangible aspects of a place, livability subsumes how people perceive their residential environment, and inclusivity is more about equality and parity experienced by all citizens. Therefore, the conceptual smart city model is assumed at the cross-section of 3Ps- people, place, and parity. This study defines a smart city as an urban community that strategically improves the quality of life and well-being of its citizens, adopts sustainable urban planning, promotes environmental protection, and focuses on the inclusive socio-economic growth of its community leveraging its hidden potential [41, 42]. This study explicitly focuses on the spatial attributes of a case of traditional Indian settlements which have continued for generations and undergone multiple transformations from an organic layout to a rationally planned development. A complementary research by Dhingra and Chattopadhyay [41, 42] analyses the socio-cultural attributes of a traditional Indian settlement and concludes fair performance in terms of cultural vitality, social cohesion, collective efficacy, sense of belongingness, degree of interpersonal trust, and perceived safety by residents.

17.3 Case Study

Indian historic cores are unique symbols of cities where old communities staying in residential quarters use socio-cultural practices to express their continuity for generations and thus, builds a relationship with the concept of Historic Urban Landscape (HUL) [43]. Kostof [44] deliberated about walled towns and temple towns-the former regards towns as defense and domination agents while the latter regards towns as holy places. The trend of walled cities fell apart in the 19th century due to population explosion and technological advancement, but in the mid-19th century, the older forms of the urban walls rose again with gated communities [45]. This phenomenon of walled cities is global in scope, with India having numerous such cities. Town walls of ancient India were modern in a military sense and depict a very high order of city planning representing an exemplary architectural heritage [46, 47]. Some of the prominent components of these settlements are colorful streets, carved facades, meandering streets, courtyard houses, and well-planned water structures.

17.3.1 Selection Criteria

The foremost criteria considered for the case selection are its local climatic conditions, which are also influenced by the region's physiographic and geographical conditions. A geographical region with semi-arid and sub-tropical climatic conditions, specifically prevailing in the Satluj–Yamuna water divide, is proposed. This includes Punjab, Haryana, eastern Rajasthan, and the union territories of Delhi and Chandigarh. Culturally, the region lies within the North cultural zone and administratively within the Northern zonal council. The second level of zoning shortlists the cities in the designated states that are neither too large nor too small urban areas. The designated zone also contains some regional priority towns declared under National Capital Region (NCR) Plan 2021 spanning the entire national capital territory of Delhi, one district of Rajasthan, nine districts of Haryana, and five districts of Uttar Pradesh [48]. It is also considered if the case study has the characteristics features of an HUL with living residential culture, traditional way of living, and an underlying socio-economic process of development. These traditional neighborhoods are locally known by different names, such as mohallas, katras, paras, and pol, depending on their region. Since India is a diverse country with different languages, local dialects, and social systems, the possibility of conducting primary surveys in local languages and logistics support is considered. Based on the above-mentioned selection criteria, the historic walled city of Alwar is shortlisted as the representative case study.

17.3.2 Macro-level Characteristics

Alwar is a land-locked district bounded by Gurgaon, Bharatpur, Mahendranagar, Jaipur, and Sawai Madhopur. It is 2.29% of the state's total area and 23.32% of NCR's total area [48]. It is the third most populous district in the state and covers an area of 8380 km^2. with 72% area under cultivation [49]. This has also been instrumental in promoting trade, commerce, and agro-based activities besides its strategic location. This region's advent goes back to about 200 years ago, implying rich architectural, archaeological, and cultural heritage [50]. The regional significance has further been enhanced after Alwar was declared a counter magnet and priority town for the southwest NCR zone. In 1973, the state Government of Rajasthan declared the urban area of Alwar district comprising 48 revenue villages and Alwar city under Rajasthan Urban Improvement Act, 1959 for a regulated and planned urban growth. Consequently, the first draft master plan for Alwar city was prepared in 1974 after conducting several physical and socio-economic surveys. The city enjoys serene scenic beauty, dense forests, seasonal streams, natural and human-made lakes, a national tiger reserve, religious and historical monuments, and a cultural legacy. It is an important weekend tourism destination and trading center for the surrounding region. The city has many educational institutions and industrial technical institutes and acts as the district administration seat through mini secretariat and district and sessions court. Figure 17.4 depicts the location of the case study. The city has a river in the northeast where the rainwater is drained toward the southeast. The west is bordered by Aravalli hills covered with lush greenery during monsoons, and the artificial Jaisamand lake flanks it in the south and the Siliserh lake and palace in the south-west.

During the Vedic era, Alwar was a part of Matsya kingdom, one of the 16 great kingdoms in India. In 1492 CE, the city originated with a grand city wall boundary around Bala fort situated on the Aravalli hills, and the princely state of Alwar emerged [43]. The originally planned walled city was surrounded by city walls interrupted by five gateways and surrounded by a moat filled with water. There was a strong influence of the Muslim league from 1555 to 1574 CE, which was later transferred as a small principality to the Ahirwal and Mewat region controlled by the Ahir community. The "Land of Ahirs" is described as a "folk region" and a "cultural geographical region" by historians J. E. Schwartzberg and Lucia Michelutti, respectively [52]. In 1948, four former princely states of Alwar, Bharatpur, Dholpur, and Karauli consolidated to form the United States of Matsya, which was later merged with the Greater Rajasthan to form the United State of Rajasthan in 1949. During the late 1950s and early 1960s, to extend the city limits further, the ramparts were leveled, and the moats were filled, thus removing the physical presence of the walled city from its historic landscape. Presently, only the Delhi gate in the north exists depicting great architectural skills.

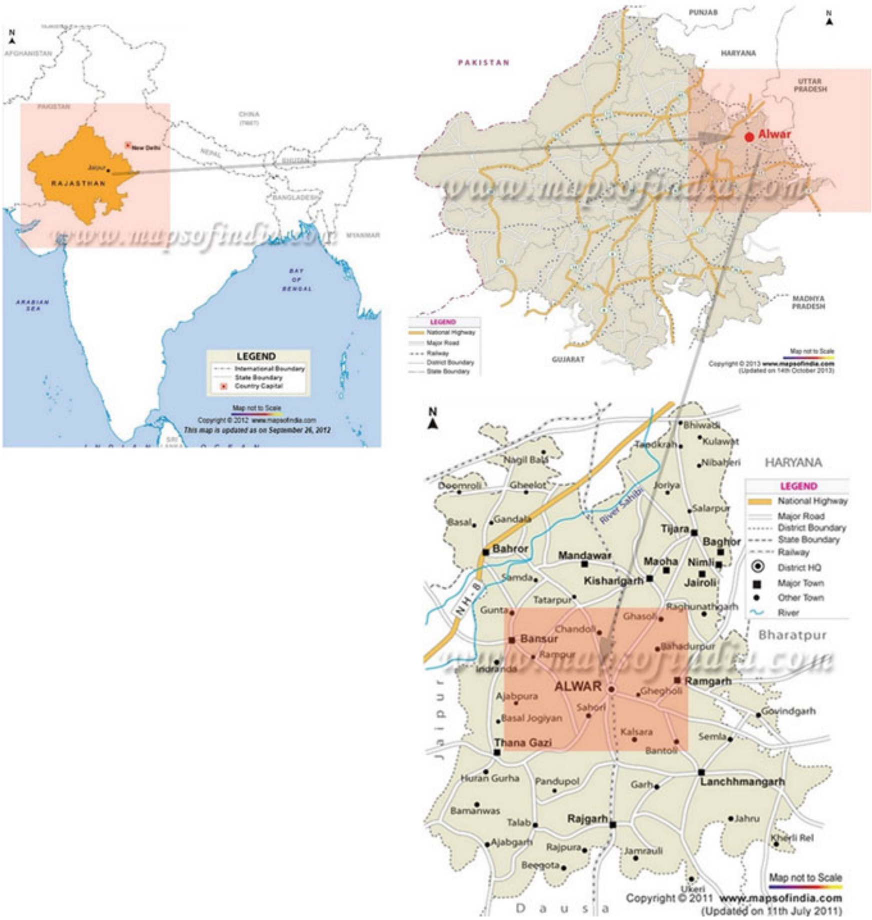


Fig. 17.4 Location of case study [51]

17.3.3 Micro-level Characteristics

The existing street network in the study area is majorly narrow and organic, but the arterial roads are planned with visual linkages to historic monuments and Aravalli hills, as shown in Fig. 17.5. The built-form is quite compact which is well suited to the semi-arid climatic conditions of the region. Historic neighborhoods locally known as mohallas portray rich architecture comprising of perforated walls (jalis), balconies (jharokhas), and overhangs (chajjas) to ensure passive cooling techniques. The openings in the traditional houses vary in size from as small as jalis to as large as courtyards, thus promoting cross ventilation, privacy, and less exposure to sun on their surfaces. It is further shaded by chajjas and Jharokhas. There are two kinds of buildings in these settlements- residences ranging from royal palaces to small havelis

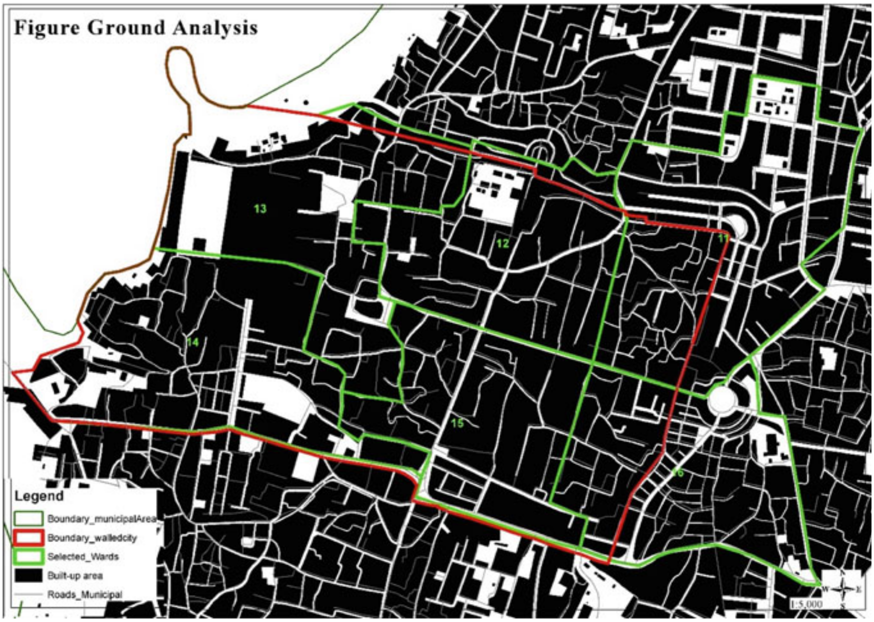


Fig. 17.5 Municipal wards for the pilot survey

and religious places which act as important community gathering places. The typical traditional dwelling units are mostly oriented and sited to avoid direct sun rays inside the habitable rooms and facilitate mutual shading with narrow streets. The materials used for construction include marble, sandstone, and lime mortar to ensure good insulation and bad conduction. The passive cooling mechanism portrayed by the traditional buildings shows the presence of smart cultural and spatial components in these settlements. The entire city is like a family in an Indian traditional urban setting with strong socially knit systems [47].

Structurally, a traditional mohalla maintains chowks at the junctions of internal streets, usually spotted with some tree or a well or a landmark at its node [43]. These chowks act as important community gathering places where the key idea was collective participation. Step wells and water tanks also form an important component of the overall urban morphology. Also, these areas acted as important public spaces in the social landscape of the city. The open spaces along with water bodies assist in maintaining the microclimate cooler as well as act as critical nodes for social and cultural activities. Multifunctional and introverted courtyard type planning is quite common with rooms surrounding it, which the family uses either for sleeping or grinding spices or making pickles or making pottery, or other craft-based activity. The functions of spaces are quite ambiguous changing during different times of a day, seasons, or events. The traditional markets (bazars) are another critically planned components of these settlements which are fused into the overall fabric of the city. The growth of these bazars is governed by the needs of the communities in a prominent

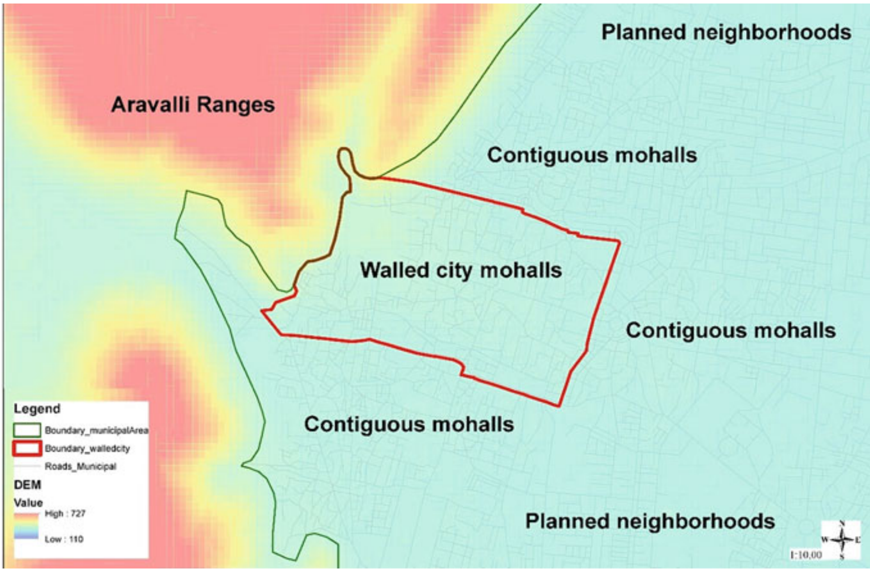


Fig. 17.6 Digital elevation model

linear pattern identified by the socio-economic profile of people and types of items it majorly sells. The topography in Fig. 17.6 shows elevated Aravalli hills flanking the city in the west, with urban development taking place on the plain land. However, the later filing of the moat to expand the city in its contiguous areas can be attributed to waterlogging during monsoons faced by these contiguous mohallas.

17.4 Methodology

Every city has a unique spatial signature that develops over the years due to strong influences of cultural, geographical, social, economic, political, and religious factors. The compact city model is inseparable from the principles of sustainable development, smart urban growth, and green city, which is believed to impact the overall quality of life, accessibility, car dependency, walking and cycling behavior, use of existing facilities, neighborhood satisfaction, social cohesion, individual and community's well-being [53–66]. Most commonly used measures for compactness mostly cover economic and morphological density, transportation network, mixed-use and intensification [54, 56, 59–61, 63, 66–70]. The shape index is also widely used to measure the level of compactness and clustering, thus determining the length of infrastructure and commute distances within cities [57, 62, 68, 71].

The degree of land use mix is also an important strategy for creating a sustainable, diverse, and compact urban form [68, 72]. It refers to the presence of various urban functions within an area, thus stimulating walking for transport and offering opportunities at the physical and social level of interaction [70, 73]. The built environment can also be spatially characterized by a street network that shapes its residents' behavioral and mobility patterns [74]. It is a critical component of walkability related to urban form regarding the directness of routes between two locations in a street network [73]. Some online tools such as walk-score and walkshed quantify walkability based on proximity and importance of neighborhood amenities [75–77]. There are many frameworks developed worldwide to assess the walkability of urban areas taking into account both qualitative and quantitative variables such as public services, streetscapes, sense of safety, path quality, connectivity, land use mix, density, sense of enclosure, street design, comfortable civic squares, diversity, and open spaces.

Considering the proposed smart city model as a conceptual base, a pool of indicators using keyword search is prepared under social, economic, environmental, mobility, living, governance, physical, spatial and cultural dimensions. The variables of interest (VoI) are classified into cognitive variables, factual variables, and spatial variables based on their data type and possible collection instruments. A pool of indicators that may prove relevant to assess the characteristics of an urban system to achieve the goals of smart urban development is prepared. Since smartness and its associated objectives are abstract, it is imperative to convert them into measurable observations. Thus, the operationalization of variables is used to reduce subjectivity and increase the reliability of the assessment metrics. From the pool of indicators, a set of VoI is selected based on seven criteria for phase-wise screening viz. relevance, specificity, redundancy, measurability, data collection feasibility, the spatial scale of reference, and the number of times secondary sources cite it [78–83]. The flowchart for the selection of indicators is graphically represented in Fig. 17.7.

For the first level of screening, the pool of indicators is categorized into neighborhood level, city level, city and neighborhood level, building level, and at all three levels based on their relevance on the spatial scale. Since the study focuses on the mesoscale, only the neighborhood level indicators are retained. In second-level screening, redundant indicators and variables are merged to remove any duplicity. Next, their frequency of usage by other studies is assessed and those with at least two citations are retained and the rest are dropped off. The variables and indicators are assessed for their specificity and measurability, followed by suitable operationalization. Further, based on data type availability, the indicators can be either objective or subjective- cognitive variables, factual variables, and spatial variables. The next level of screening considers possible data collection instruments- household surveys, secondary data, field surveys, and cognitional mapping and only specific, measurable, and convenient to collect VoI are modified based on pilot-testing and reconnaissance surveys. Table 17.2 lists indicators and variables employed for the assessment of spatial attributes of the case study.

GIS is extensively used to derive the identified spatial metrics for these three geographical regions to assess the five territorial smart urban attributes of the study area. Analysis tools, conversion tools, data management tools, geostatistical analyst tools, network analyst tools, spatial analyst tools, spatial statistics tools, spatial design network analysis open-source extension tools [84], Axwoman 6.3,

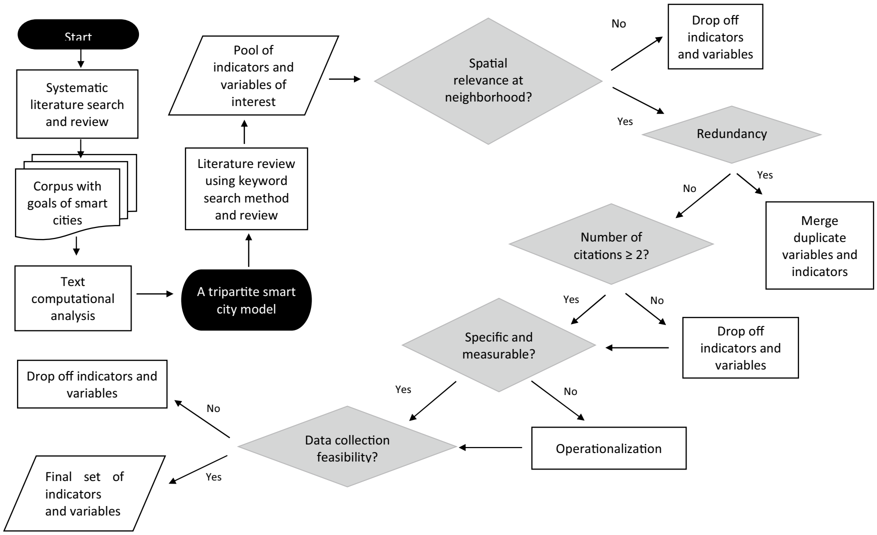


Fig. 17.7 Selection of indicators and variables

and AxialGen extensions [85] of ArcGIS 10.1, 10.4 and 10.5 versions are used for spatial mapping and analysis. Open-source software depthmapX v0.8.0 is used for estimating syntactic variables [86]. The validity of spatial data should reflect the extent to which it represents the real world, while the accuracy level can vary from one database to another [72].

All core urban elements relevant to the study are mapped on ArcMap 10.5 using google imagery as the base map for validation. Also, google earth and google maps were deployed to capture the real-time location of points of interest and survey locations during the field surveys, which were later exported from *.kml format to *.shp format in ArcMap. There are three sources for spatial data-AutoCad files in *.dwg format and Master Plan 2031, which was collected from UIT, Alwar in April 2017; OpenStreetMap data, which was retrieved from QGIS OSM plugin and www.geofabrik.de platform in September 2019 and participatory field surveys, which were conducted from January to April 2019. The road network of OpenStreetMap data provides detailed information on road attributes created by open crowd-sourced and editable mapping services [54, 87]. Following shapefiles and layers are used for further analysis.

1. Road centrelines
2. Administrative boundaries- wards and zones
3. Land use
4. Building footprints
5. Boundaries of perceived neighborhoods, walled cities, and contiguous settlements through cognitional mapping.

Table 17.2 Final set of SUAs, indicators, and VoI

	Smart urban attribute	Indicator	Variable
1	Accessibility	Road network density	Road length (in meters)/km^2
		Intersection density	Number of intersections/km^2
			The proportion of four-way intersections
			Segment/intersections ratio
		Connectivity	Gammaindex $= L/L\max = L/3(V-2)$ where L is the number of segments & V is the number of intersections
			Alphaindex $= (L-V)+1/(2V-5)$ where L is the number of segments & V is the number of intersections
			connectivity
		Centrality measures	Mean Euclidean distance
			the overall shape of the city-betweenness
		Network topology	Angular connectivity
			Syntactic connectivity
			Easy way-finding- choice
			Local choice—100 m
			Global integration
			Local integration
		Detour analysis	Mean crow flight
			diversion ratio
2	Shape compactness	Perimeter index	Ratio of the perimeter of equal area circle and perimeter of the shape
		Exchange index	Share of the total area of the shape that is inside the EAC about its centroid
3	Density	Morphological density	Density of the built environment
		Neighborhood density	No of mohallas per km^2
		Jobs density	Commercial floor area ratio
4	Green and open spaces	Porosity index	Ratio of open space to built-up area
		Greenness index	Ratio of green areas to built-up area
5	Diversity	Land use mix index	Entropy index

(continued)

Table 17.2 (continued)

	Smart urban attribute	Indicator	Variable
			Herfindahl Hirschman Index (HHI)
		Intensity of development	Residential area/non-residential area
			Built-up area/open area
		Clustering index	Average nearest neighbor (ANN) ratio
			global Moran"s I index
			Getis and Ord's G statistics

17.5 Assessment of Spatial Smart Urban Attributes

Spatially, the city has evolved from approximately 0.88 km^2. organic-walled city to approximately 41.95 km^2 planned municipal area. They both have contrasting attributes in terms of socio-economic compositions and their spatial features. Also, historical genesis shows an intermediate boundary of 1.24 km^2. with majorly organically developed contiguous mohallas. Thus, these boundaries have developed in different periods by different agents with different forces of development. This study classifies the spatial hierarchy into three categories- walled city boundary developed till the 1940s, contiguous settlements boundary that developed as organic development around the then existing walled city, and municipal area boundary, which is the present designated boundary per the Master plan 2031. The neighborhoods in the city can be further categorized into five classes based on their development phase. Walled city mohallas were the very first settlements laid out on ancient town planning principles, which were extended to its contiguous areas to accommodate an additional influx of population. These neighborhoods have a majorly organic street network and traditional mohalla structure with chowks. However, the central business district shifted from the Tripoliya in the walled city to Hope Circus in its contiguous area. Between 1940 and 1980, many planned neighborhoods emerged under Town development schemes (TDS) by Alwar Municipal Council (AMC), such as Manu Marg and Lajpat Nagar, to accommodate migrated refugees. Till 2005, Urban Improvement Trust (UIT) has planned several housing schemes as plotted development which was allotted through auction and lottery mechanisms. Post NCR phase has seen mostly a multi-story residential culture flourishing with apartments and housing societies as gated communities. Upadhyaya and Jakhanwal [47] recommends the growth of the city inwards instead of fragmentation between the historic core and isolated suburbs so that the city blends with the existing structure and its accompanying transformations.

Table 17.3 shows that the walled city mohallas are highly dense with 290 persons per hectare (pph) and 60 households per hectare (HHph), followed by contiguous old mohallas with 154 pph and 30 HHph. The UIT schemes which were developed

Table 17.3 Neighborhoods' typology

Existing neighborhoods typology	Walled city mohallas	Contiguous old mohallas	Town development schemes post-1940s	Post-1980 planned colonies	Post-2005 planned colonies
Population density (pph)	290	154	94	79	93
Average HH size	4.84	5.16	5.14	5.08	4.93
HH per hectare	60	30	18	16	19
% SC population	4.04	27.73	17.24	10.69	8.54
% ST population	0.11	5.35	0.97	7.60	0.93
% literates	83.91	73.19	82.17	78.95	76.53
% female workers to total workers	17.44	21.62	21.21	19.38	24.50
% household industry workers	5.77	5.96	3.85	2.30	1.93
% main workers	92.66	86.32	91.62	94.08	93.00
% marginal workers	7.34	13.68	8.38	5.92	5.52
% non-workers	66.91	66.73	66.20	68.37	67.64
% employed	33.09	33.27	33.80	31.63	32.36

post-industrialization, have the lowest population density of 79 pph and merely 16 HHph. Average household size is minimum in walled city mohallas and maximum in contiguous old mohallas. The literacy rate is almost equivalent in all five types of settlements, which is above the state average of 66.11% in the 2011 census. There is a high proportion of scheduled caste in contiguous old city mohallas, which can be attributed to the extension of their historical social structure while there is a high proportion of scheduled tribes in the outskirts of the city. The small-scale household industries prevail in contiguous and walled city mohallas due to their economic activities for generations. All five neighborhoods perform well in terms of workforce distribution with maximum marginal workers in contiguous old city areas, indicating a predominant informal sector. The proportion of female workers is highest in newly planned residential areas followed by contiguous old mohallas.

17.5.1 Compactness

Compact city term is an umbrella term used for various urban characteristics such as density and walkability. While compact city refers to metropolitan level policy,

Table 17.4 Compactness metrics

Boundary	Shape perimeter (km)	Shape area (km^2)	Radius of EAC (km)	Perimeter of EAC (km)	Area intersected by EAC (km^2)	Perimeter index	Exchange index
Walled	4.44	0.88	0.53	3.32	0.69	0.75	0.79
Contiguous	6.68	1.24	0.63	3.95	0.96	0.59	0.77
Municipal	33.38	41.95	3.65	22.96	34.14	0.69	0.81

compact urban development is a more localized concept and usually indicates a neighborhood scale [69]. This study understands compactness in terms of the shape of the spatial boundary while its allied metrics are addressed separately. A measure of shape compactness is a numerical quantity that represents the degree to which a shape is mostly circular, which implies maximum accessibility [88–90]. An equal-area circle (EAC) is the most compact of shapes concerning cohesion, perimeter, and proximity, thus widely used for measuring compactness [56, 91]. Some commonly used reference shape techniques are the ratio of the perimeter of the shape to that of a corresponding EAC, the ratio of the areas of the shape and the minimum bounding circle, the ratio of an area moment of inertia of the shape to that of the EAC [59, 88, 89, 92].

Perimeter index is the ratio of the perimeter of EAC and perimeter of the shape, thus focusing on the compactness of outer boundaries and is one of the natural measures of compactness of a walled city [90, 91, 93]. Exchange index is the share of the total area of the shape that is inside the EAC about its centroid, thus focusing on the extent to which the urban footprint fills a circle of the same area centered at its centroid [90, 93]. Higher levels of exchange compactness ensure higher cohesion and proximity levels, thereby increasing the accessibility of a geographical region [90]. Table 17.4 shows the calculations for perimeter index and exchange index for which EAC is calculated around the centroid of each boundary. The highest perimeter index corresponds to the walled city at 0.75 while the exchange index of all three boundaries is doing equally well. Therefore, in terms of shape compactness, all three boundaries are performing considerably fairly. Figure 17.8 graphically compares the three spatial boundaries in terms of their shape compactness. In terms of perimeter index, the walled city was planned most compactly while in terms of exchange index municipal area performs best.

17.5.2 Density

Urban density is a widely used metric to indicate the carrying capacity of urban land in terms of people, activities, and buildings [71, 90]. Figure 17.9 and Table 17.5 show that the gross population density of the walled city and contiguous settlements are ~224 pph and ~234 pph, respectively, while it is very low for the municipal area (~56 pph). The household density of the walled city and contiguous settlements

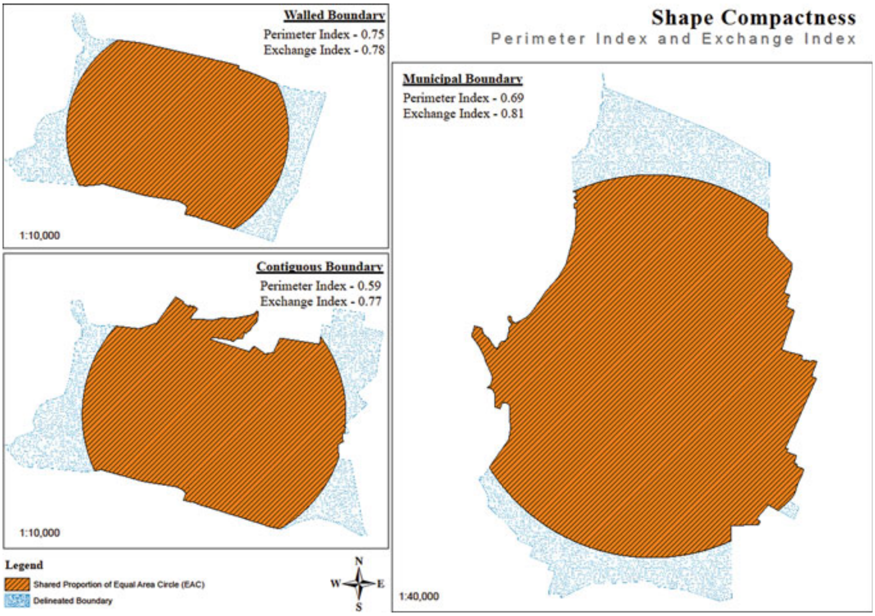


Fig. 17.8 Comparison of shape compactness

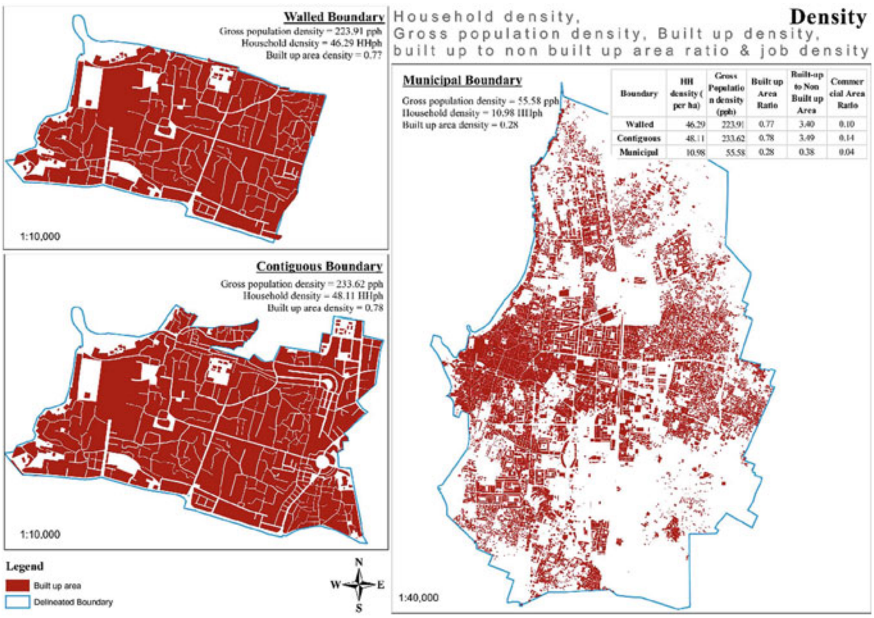


Fig. 17.9 Comparison of density

Table 17.5 Density metrics

Boundary	Total area (km^2)	Number of households	Total population	BUA (km^2)	BUA ratio	HH density (per km^2)	Gross population density (per km^2)
Walled	0.88	4,068	19,679	0.68	0.77	4,628.58	22,390.81
Contiguous	1.24	5,968	28,978	0.96	0.78	4,811.44	23,362.23
Municipal	41.95	46,063	233,179	11.59	0.28	1,098.01	5,558.32

Table 17.6 Green and open spaces metrics

Boundary	Total area (km^2)	BUA (km^2)	Open space (km^2)	Green space (km^2)	Porosity index	Green index
Walled	0.88	0.68	0.20	0.04	0.23	0.04
Contiguous	1.24	0.96	0.28	0.04	0.22	0.03
Municipal	41.95	11.59	30.36	0.92	0.72	0.02

are ~46HHph and ~48HHph, while the municipal area has ~11HHph. Built-up area (BUA) ratio of the municipal area is very low at ~0.28, while contiguous settlements have a BUA ratio at ~0.78. It also indicates an underdeveloped situation within the municipal area, with large pockets of open areas still lying underutilized.

17.5.3 Green and Open Spaces

Landscape ecologists widely use porosity to describe the land coverage condition in terms of the penetration of open spaces in urban form [57, 94]. Table 17.6 shows the calculations of two indices- porosity and greenness indices. The greenness index is the ratio of green spaces to the total area, indicating the extent of vegetation in the geographical area. The porosity index is very high for municipal area at 0.72, whereas the greenness index of all three boundaries is comparable with the walled city ranking highest at 0.04. This confirms the low built-up area ratio of the municipal area which is mostly left underdeveloped as shown in Fig. 17.10.

17.5.4 Diversity

The key diversity indicators include a balance of residential and non-residential land uses, entropy measures such as Theil's index, clustering measures such as G statistic and Moran's I dissimilarity index, the ratio of built-up to open area and mix of horizontal and vertical land use [56, 58, 60, 64, 68, 95]. Balance index is the simplest

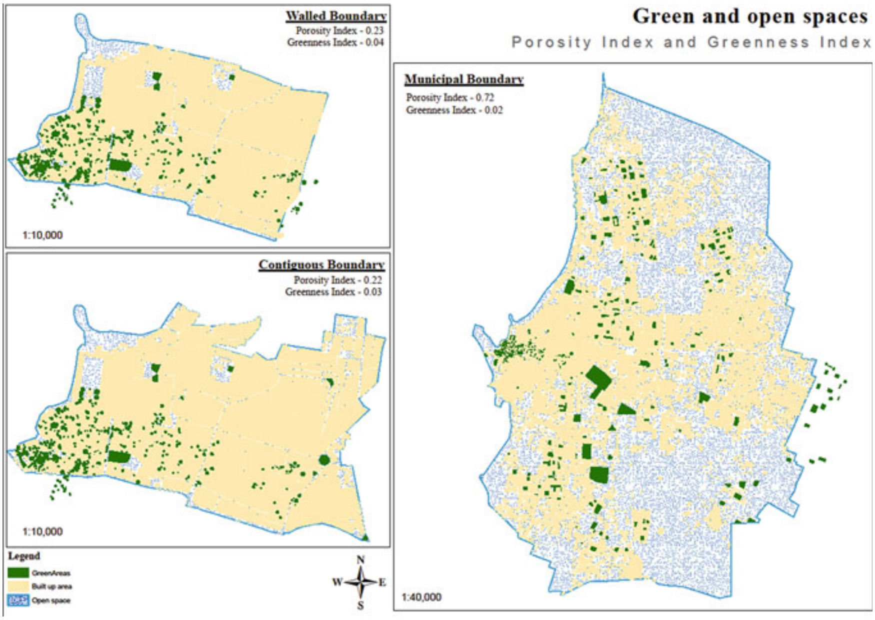


Fig. 17.10 Comparison of green and open spaces

measurement that takes into consideration the total amounts of land use for two categories, while entropy index takes into account the relative percentage of two or more land-use types within an area [96–99]. Theil entropy index can be given by $\mathrm{ENT} = -\frac{\sum_{i=1}^{n} P_i \ln(P_i)}{\ln(n)}$, where P_i is the proportion of each land-use type i in the area and $n \geq 2$ be the number of land-use types i. Another commonly used index to assess LUM is Herfindahl-Hirschman Index (HHI), given by $\mathrm{HHI} = \sum_{i=1}^{n} (100 * P_i)^2$, with a value equal to 1 in case of single land use [96, 97, 99]. The land-use measures indicate the overall distribution of land use within the study area irrespective of their arrangement [96].

Spatial metrics which are used for estimation of spatial distribution include clustering index, dissimilarity index, exposure, and Gini index. Global Moran's I index is a very commonly used indicator for quantifying the degree of clustering, with a value closer to $+1$ representing a perfectly compact development and a value closer to -1 representing a perfectly dispersed development [57, 62, 68, 71]. Other used clustering indices are Getis and Ord's G statistic and average nearest neighbor (ANN) ratio [68, 71]. ANN is given by $\frac{\overline{D}_o}{\overline{D}_E}$, where $\overline{D}_o$ is the observed mean distance between each feature and its nearest neighbor and $\overline{D}_E$ is the expected mean distance for the features given in a random pattern. Table 17.7 and Fig. 17.11 shows results of entropy index, residential to non-residential area ratio, HHI, global Moran's I, G statistic, and ANN. The entropy index of the municipal area is highest at 0.81 whereas HHI is highest for the walled city at 0.41. The ratio of residential to non-residential area

Table 17.7 Diversity metrics

Boundary	Land use mix		Intensity of development	Clustering index		
	Entropy index	HHI	Ratio of residential to non-residential area	ANN	Getis-Ord general G	Moran's I
Walled	0.73	0.41	1.50	1.17	5.06E−04	0.91
Contiguous	0.74	0.40	1.42	1.03	3.73E−04	0.99
Municipal	0.81	0.34	1.08	0.72	1.62E−04	0.88

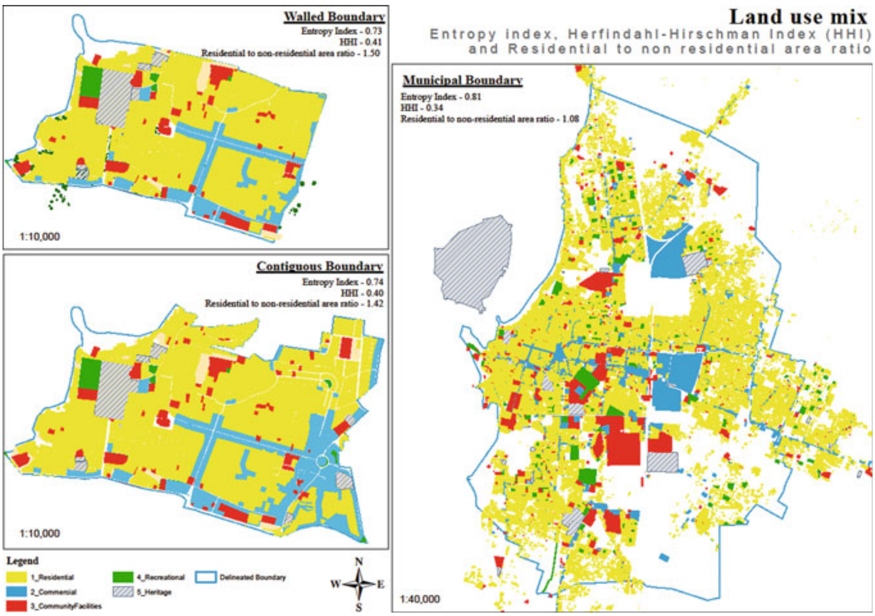


Fig. 17.11 Comparison of land use mix

is highest for the walled city and lowest for the municipal area at 1.50 and 1.08, respectively. The clustering analysis shows the highest index in terms of ANN and Getis Ord General G statistic while the contiguous area has the highest Moran's I value. The lowest clustering indices correspond to the municipal area which is also illustrated in Fig. 17.12. The morphology of walled and contiguous settlements is majorly organic for its residential areas with narrow and winding streets while its planned-on grid for relatively new housing areas. The analysis shows a comparable land use mix in all three spatial hierarchies; however, the clustering analysis shows compactly planned traditional settlements.

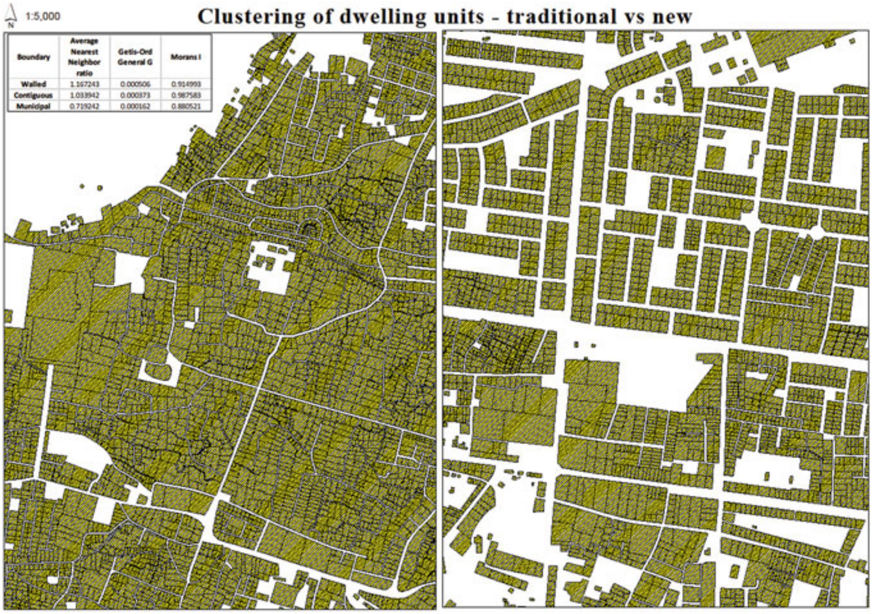


Fig. 17.12 Comparison of clustering indices

17.5.5 Accessibility

The spatial configuration and road network of cities can be analyzed using the graph-based approach, space syntax theory, spatial design network analysis, and urban network analysis. In morphic language, syntax is defined as a set of defined rules, that structures combinations of elementary objects, relations, and operations. Hillier et al. [100] generated space syntax theory (SST) to show the formal syntax of human space organization, space patterns made by human societies, and their relationship with social patterns. Networks can be characterized by measures such as depth, choice, closeness, centrality, and betweenness [101]. Axial maps are the most commonly used method for analyzing street networks [101, 102]. The key single syntactic variable, which can explain other relevant attributes of spatial configuration is depth, i.e., the count of intervening spaces between two spaces [103]. Other relevant syntactic variables include indices such as integration, connectivity, control, choice, and intelligibility [101]. Topologically, the entire spatial structure can be represented with respect to integration value which indicates a normalized measure of depth in an urban system. Global integration value is estimated for the whole urban system whereas local integration value is estimated for a partial system defined by vertices residing within a defined distance [101, 102]. The more integrated a spatial structure is, the shorter are its topological distance from the rest [102, 104]. Other syntactic variables which are of concern include connectivity which is defined by the number of connections a spatial unit has with other adjacent units and choice attribute which indicates the tendency to attract higher mobility irrespective of the network's geometrical properties [74, 103]. Together high values of syntactic variables can indicate another property of a spatial configuration known as intelligibility [103].

For network centrality, reciprocal of farness (mean euclidean distance (MED)), line connectivity, and betweenness are employed. The network detour analysis compares straight line distance to actual network distance. Mean crow flight (MCF) and diversion ratio (DR) is used to determine the deviation of the network from the most direct path. The multiplicity of routes generally supports several small commercial outlets in a neighborhood, thus permitting pedestrian choices and variations in their journey [64]. Thus, connectivity is directly proportional to the density of street intersections and blocks. Once the downloaded street network from OSM is validated using Google imagery, the topology of the road is checked for errors and repaired by removing the isolated and duplicate lines. sDNA provides tools for 2D and 3D spatial network design analysis in GIS and CAD while Depthmap allows topological measurements on the graph-based representation of the axial map to infer the behavioral characteristics of the spatial setting [102]. Table 17.8 shows the estimated measure of the original street network of three spatial hierarchies. The red indicates very high values, yellow indicates moderate and green indicates very low values in Figs. 17.13 and 17.14.

In terms of geometrical connectivity, all three spatial hierarchies have comparable performance whereas topologically the traditional settlements are highly connected in terms of their angular and syntactic connectivity. In terms of centrality measures, the walled city has high betweenness and closeness (inverse of farness) and in terms of detour measures, the lowest value of DR of the walled city suggests a less deviated network from the shortest path. Figure 17.13a shows that the syntactic connectivity is high in contiguous networks followed by walled city and municipal area networks. However, the local integration of old city areas is high, implying a conducive pedestrian network (Fig. 17.13d). Local integration within 100 m is around 30 for the walled city in comparison to around 44 for municipal area network. Figure 17.13b, c show that with the transition from the walled city to contiguous and municipal area network, the choice and global integration have reduced. The choice attribute of walled city network within 100 m is 71.26 whereas it is 297.67 for municipal area network, indicating less way-finding capacities for pedestrians as the network is transformed. Figure 17.14a, b shows that the walled city network ranks very high in term of centrality measures- closeness and betweenness. Detour analysis is represented by Fig. 17.14c, d shows that MCF and DR are highest for contiguous and walled city areas indicating a less deviation from the ideal shortest path.

17.6 Conclusions

The term "smart" is vague and is mostly explored with an overemphasis on technology-supported interventions at an urban scale. However, most scholars

Table 17.8 Accessibility metrics

Original network boundary	Centrality measures			Detour measures		Syntactic variables					
	Line connectivity	MED (m)	Betweenness (m)	MCF (m)	DR	Angular connectivity	Syntactic connectivity	Total choice	Control-choice value 100 m	Global integration	Local integration 100 m
Walled	3.58	7.56E+02	5.81E+03	5.50E+02	1.44	2.68	4.05	1.59E+04	71.26	2.30E+02	29.89
Contiguous	3.79	1.17E+03	4.42E+04	8.92E+02	1.34	2.96	4.44	1.22E+05	125.93	8.36E+02	40.84
Municipal	3.88	3.55E+03	6.84E+05	2.93E+03	1.26	1.06	2.68	5.61E+06	297.66	2.42E+03	44.21

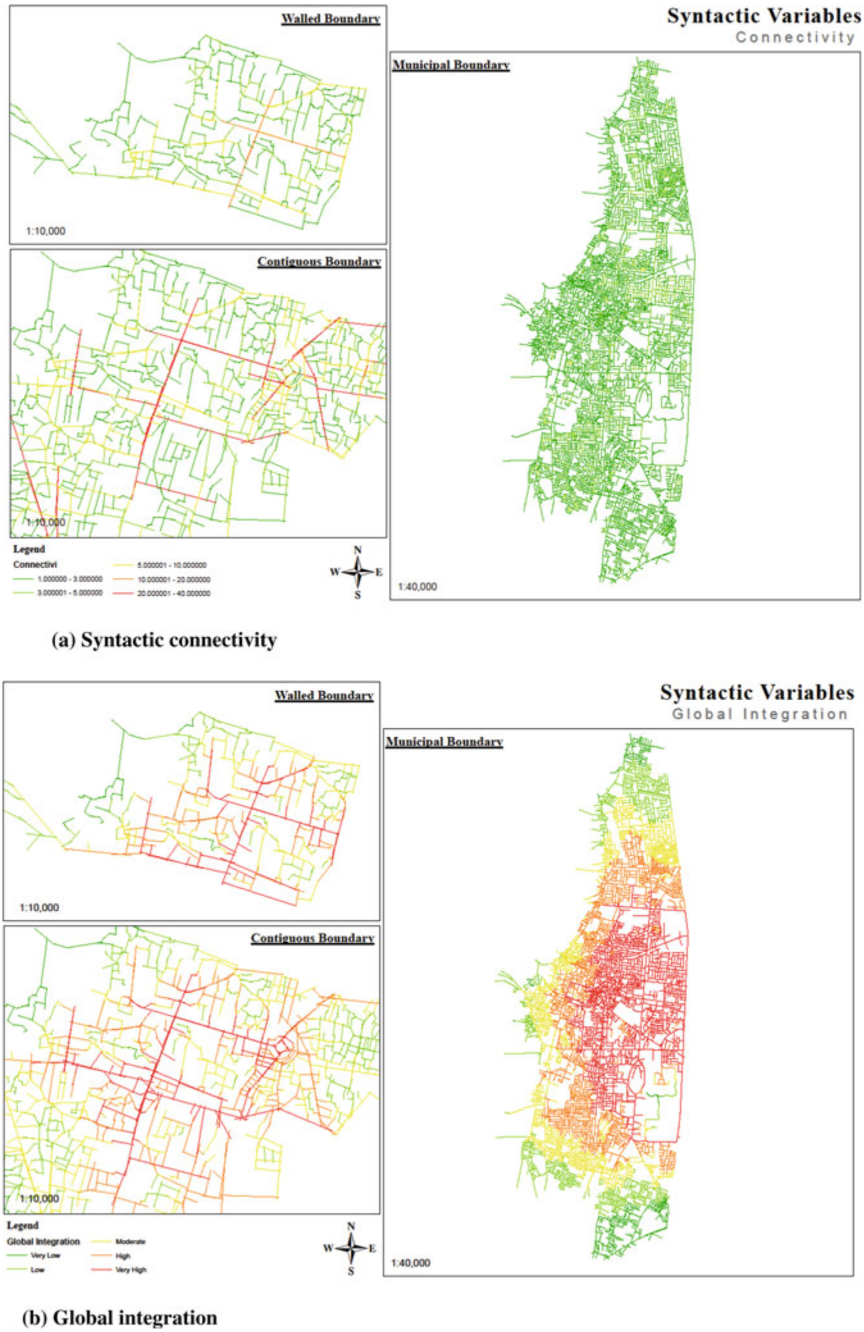
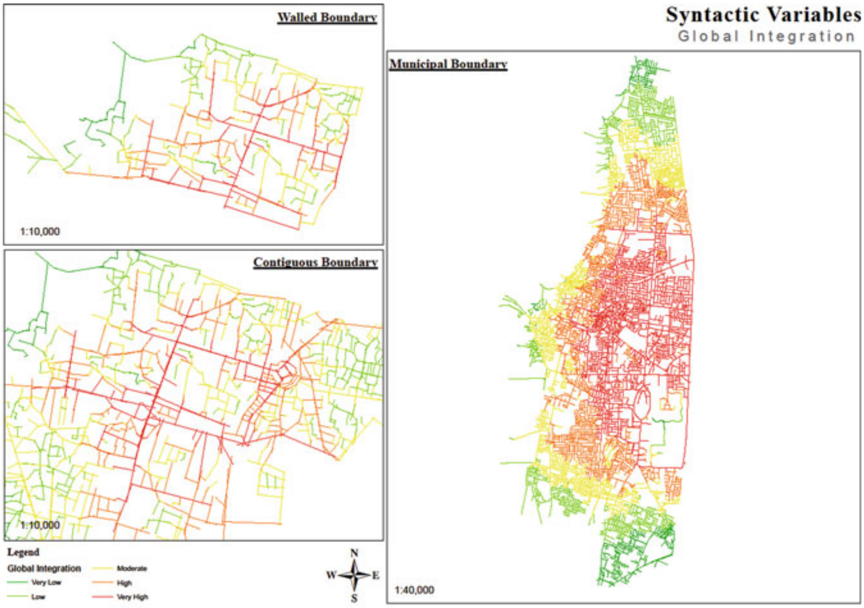
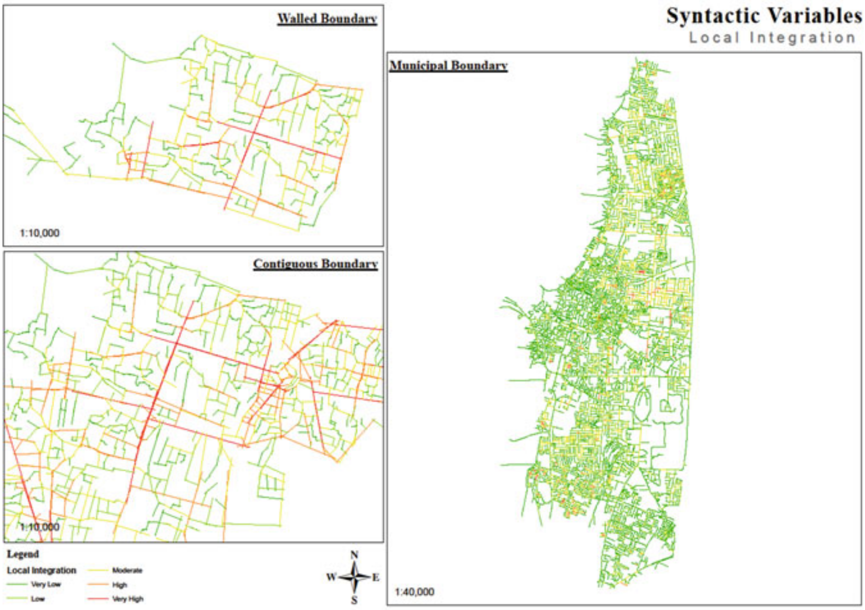


Fig. 17.13 Comparison of syntactic variables

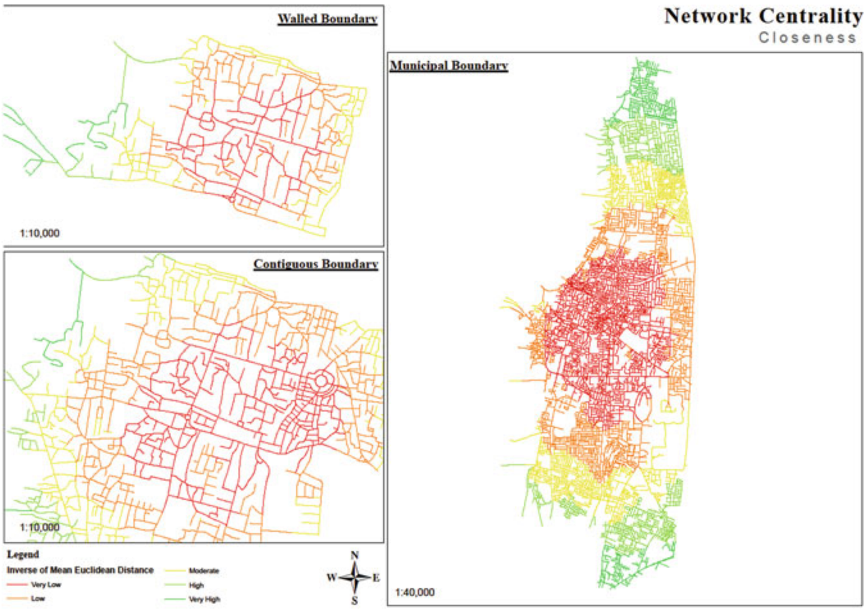


(c) Choice

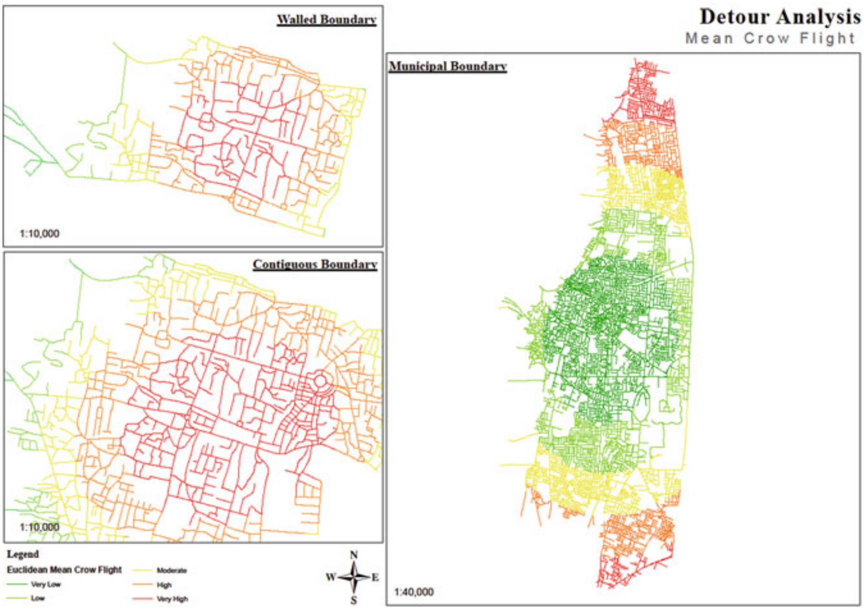


(d) Local integration

Fig. 17.13 (continued)

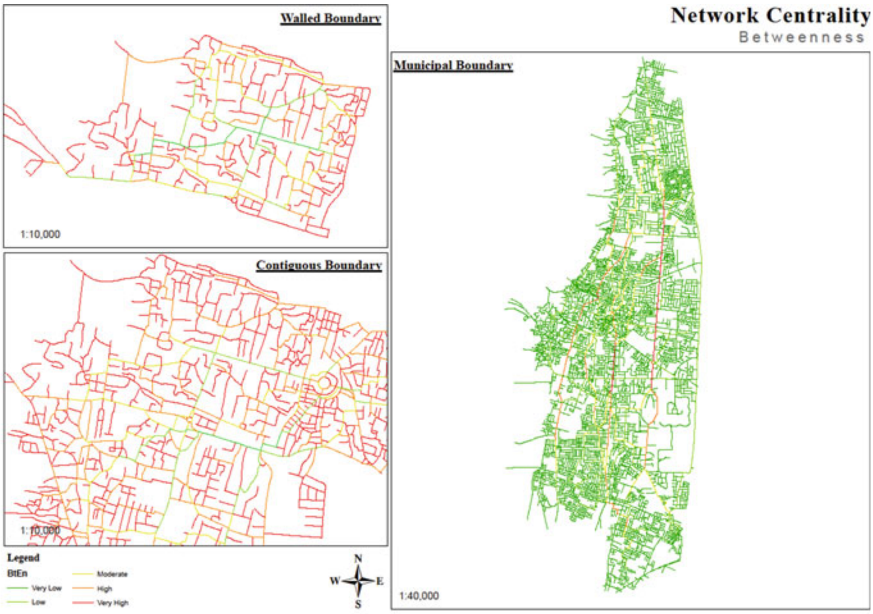


(a) Closeness

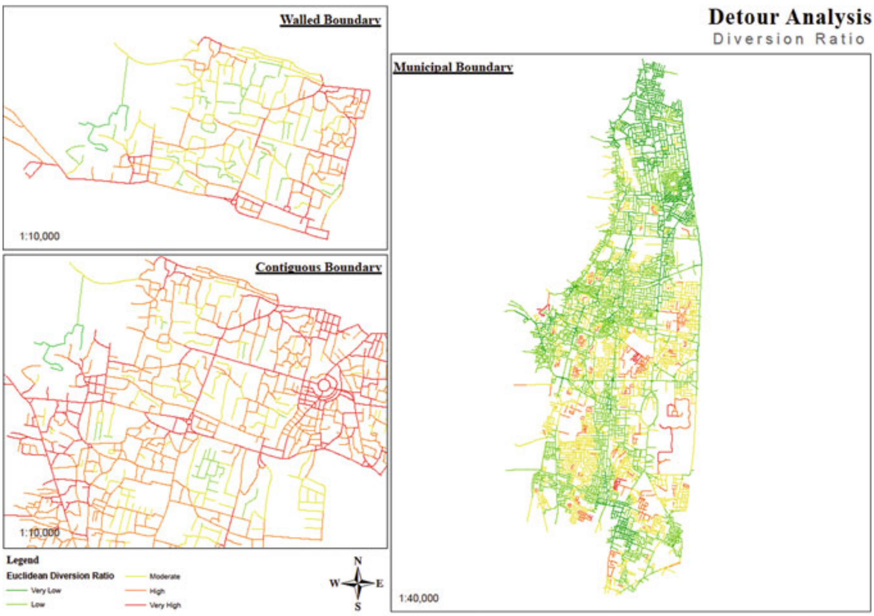


(b) Mean crow flight

Fig. 17.14 Comparison of network metrics



(c) Betweenness



(d) Diversion ratio

Fig. 17.14 (continued)

support the vision of a rationalist and balanced approach to smart urban development. Thus, it is crucial to understand the overall narrative and lacunae in the current smart city framework. There are three research gaps identified in the concept- ambiguity in the "smart" label; fragmented intervention strategies missing out critical urban aspects such as society, economy, history, culture, and geography; and underutilization of existing cities' hidden potential. Most of the cities have organically evolved over the decades suiting to the needs and aspirations of the existing communities and their cultural patterns. But critical analysis of global smart city interventions shows that the strengths of their socio-cultural landscape and built environment are neglected by introducing few out-of-context spatial repairs to the urban fabric.

The study undertook a spatial assessment approach to realize the strengths of walled cities in terms of their urban fabric, spatial accessibility, walkability, porosity, land use mix, density, and compactness. The study assesses spatial urban attributes of a case of traditional HUL in India to achieve the goals of urban smartness. Alwar in the north Indian state of Rajasthan is selected for this purpose, which was originally planned as a walled city and has most of its traditional roots intact with a rich residential culture of mohallas, a unique way of life, and prevailing cultural economic activities. The study understands and synthesizes a conceptual tripartite vision of smart cities which is objective-oriented and holistic. The three core objectives which are employed for the development of the final set of indicators for the study are sustainability, livability, and inclusivity at the cross-section of three urban components- people, place, and parity. An assessment of shortlisted spatial smart urban attributes is carried out for the case study based on the identified spatial hierarchy and development phase- the walled city, contiguous city, and municipal area. The overall urban morphology shows that walled and contiguous cities have mostly organic street networks whereas the majority municipal area is planned on a rectangular grid. Smart urban attributes which embrace spatial variables include compactness, density, green and open spaces, diversity, and accessibility.

The geospatial assessment is conducted using ArcGIS tools and depth map software for estimation of syntactic and network-related variables, clustering indices, and derived spatial metrics such as entropy and density. The spatiotemporal assessment of the case study shows a relatively better performance of traditional settlements in terms of perimeter index, density, clustering indices, green spaces, and network topology. The traditional settlements have an integrated street network conducive for pedestrian movements concerning their syntactic and geometrical properties, indicating overall high intelligibility. After the COVID-19 outbreak in 2019, there were debates about the possibility of high transmission rates in congested urban settings, bringing denser areas into the negative limelight. However, density cannot just be looked at as a physical quantity and has a social value attached to it. The socio-cultural attributes such as collective efficacy and social cohesion might perform much better in the traditional communities either due to the clustering of their dwelling units or a strong sense of belongingness. Also, the economic activities which are majorly home-based running through the courtyards of households are perhaps more resilient to handle the shocks of such unprecedented situations when all multinational companies chose the work-from-home model. Another interesting feature of traditional dwelling units is the multifunctional open spaces and courtyard planning that provides a segregated system of public, semi-public, and private spaces within the dwelling unit, thereby creating spatial necessities for home isolation and quarantine.

The devastating impacts of climate change and urban disasters urge us to revisit indicator sets and find out their linkages with spatial planning of cities. It is imperative that the new urban interventions focus on the smart culture of their societies and consequently integrate innovations into existing urban systems in a pragmatic manner. While incremental initiatives entail the technological dimension, radical initiatives can combine technological, organizational, and collaborative innovations comprehensively. Since the model is validated for a traditional medium-sized Indian city with moderate climatic conditions at a neighborhood scale, future research can explore other traditional settlements. Researchers can also explore the working of traditional and modern towns to understand each case's urban attributes, thus drawing comparisons between their inherent smartness.

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Statements and Declarations The authors declare that they have no conflict of interest.

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