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Exploring the Urban Form and Compactness: A Case Study of Multan, Pakistan

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Abstract: Sustainable development has become an immense challenge, one further complicated by rapid population growth in developing countries. Therefore, analyzing the existing compactness of urban areas is essential for guiding future urban development. Most of the previous research on urban compactness has been conducted in developed countries, whereas limited research has been conducted on urban compactness in developing countries. This study fills this research gap and contributes to the current body of knowledge by offering empirical evidence of compactness measurement based on the existing urban form using Multan city as its context. Multan is a metropolitan city in the growing phase, so measuring its compactness for the promotion of sustainable development is crucial. For this research study, various indicators are adopted from the literature, such as land cover changes, density, land use, road network, congestion index, walkability index, and shape performance index, in order to evaluate compactness. The above-mentioned indicators were analyzed using ArcMap and ERDAS IMAGINE software. This study concludes that Multan city presently lies between compactness and dispersion. To achieve full compactness, highly dense vertical development with a better public transport network should be encouraged. In addition, the prevailing building regulations should be revised to increase the floor area ratio, and incentives should be devised for developers to promote vertical infill development. Moreover, there is an emerging need to formulate and implement compact city policies. By retaining the compact character of Multan city, sustainable development will be promoted. Ultimately, this research study would be a valuable resource for urban planners, decision-makers, and relevant authorities in proposing future compactness policies for sustainable development. This research can be applied to other cities with similar demographic characteristics, population, area, geographical conditions, and structure to that of Multan.

Keywords: compactness; urban form; sustainable development; compact city development; Multan

1. Introduction

Our planet has suffered unrecoverable losses in the recent decade and has become more vulnerable to natural disasters. Unfortunately, the rate of exposure is growing fast. Further, cities are the major drivers for emitting greenhouse gases into the environment [1,2]. Due to the rapid growth of the world's urban population, it is estimated that urban space needs to be doubled in developed nations and increased by 326% in developing economies between 2000 and 2050 [3]. The increased number of people residing in urban areas can contribute to ongoing change in built-up areas, and cities can also be expanded in size [4]. The rapid expansion of the urban regions leads to the evolution of urban forms [5]. Moreover, social influence plays a considerable role in ameliorating some of the challenges related to the spatial development of the communities [6]. It shows the importance of cities which embody compact and sustainable development practices. Therefore, the evolution of urban form is crucial and can offer a decision-making basis for rapidly expanding cities [7]. In developing countries, sustainable development is considered an immense challenge. Owing to rapid population growth, achieving sustainable development has become complicated. In the case of developing countries like Pakistan, urbanization is the worst hinderance to achieving sustainability. Urbanization results from the up-gradation of human civilization with the verified advantages of economic growth and development [8]. The rapid increase in urbanization will take up the outskirts of agricultural land; due to urbanization, cities are getting overcrowded, and this phenomenon is resulting in the loss of agricultural land. In China, it is estimated that 1.5 million farmers lose their agricultural land every year due to urban expansion [9]. Cities are becoming congested, and pollution is increasing at an alarming rate due to substandard housing, poor infrastructure, and increased poverty. Around 3.3 billion individuals of the world population live in urban areas, and these figures are estimated to reach 5 billion by 2030. More than 90% of urban growth occurs in developing countries; Asia will host 63% of the global urban population, or 3.3 billion people, by 2050 [10]. Urban density management is one of the biggest challenges faced by many cities [11,12]. If current trends in population density continue, and all areas with high probabilities of urban growth undergo change, then by 2030, the world's built-up urban areas will increase by 1.2 million square kilometers, nearly tripling the global urban land area in 2000 [13]. This terrifying situation provoked researchers to ponder the essentials of sustainable urban development.

In South Asia, Pakistan is among the most urbanized countries, and its urbanization rate is quite fast, from 17% in 1951 to 32.5% in 1998 [14]. In comparison to 40% in its neighboring country, India, Pakistan is supposed to have 50% of the urban population by 2030 [15]. From 1998 to 2017, the urban population in Pakistan increased from 43.04 to 75.67 million, and the total population was recorded as 207.68 million in 2017 (Pakistan Bureau of Statistics, 2017). Cities are expected to be densely urbanized with vertical and horizontal developments by 2025. Currently, more than 50% of the urban population lives in ten major cities, including Multan. These cities have a population of more than 1 million [16].

In 1970, the first Master Plan of Greater Multan was prepared based on the British concept of a structural and local planning system. The second Master Plan of Multan was prepared in 1987. Unfortunately, these plans remain unapproved. Limited capacity and resources, unproductive and/or lack of planning tools, e.g., policy and legislation, zoning, and land suitability mapping for land use development are among the root causes prohibiting the implementation of these master plans. A lack of periodic updating is also observed for these plans. In 2008, the Integrated Master Plan of Multan was prepared to promote controlled land use development with efficient and proper urban planning techniques and tools. Unfortunately, instead of learning from past experiences, this master plan is not being implemented efficiently. Since 1987, the city has been expanding in all directions, mainly towards the north and northeast because of the availability of land and an accessible road network. Towards the west, growth is constrained due to the presence of the river Chenab. The growth pattern of Multan city is radial.

Most of the research on compactness measurement based on existing urban form has been conducted in developed nations, whereas research on compactness measurement is in developing economies, which are considerably different with regard to city form elements and socio–economic characteristics, is in its infancy. Moreover, analyzing the existing compactness of urban areas is essential for guiding future urban development. Our research fills these research gaps and contributes to the body of knowledge by offering empirical evidence on compactness measurement in a developing country context, i.e., Multan city. This study aims to quantify the compactness based on existing urban form to encourage possible practices towards sustainable development. The results of this research can be used to formulate compact city policies in order to restore urban compactness and promote urban sustainability in Multan city. In addition, this research will be helpful for local government departments of cities in other developing countries that have the same socio–economic characteristics, geography, area, population, and structure as Multan city, and motivate them to improve their urban compactness policies so as to encourage sustainable development.

The remainder of this paper is as follows: Section 2 describes compact development; Section 3 consists of the literature review regarding urban form and compactness; Section 4 presents the materials and methods; Section 5 presents the results and discussion of this study, and is followed by our conclusion.

2. Why Compact Development

In one way or another, urban form defines urban sustainability. Jabareen (2006) identified that the urban form is linked with various indicators essential for sustainable urban development. A compact urban form strategy is accepted worldwide as necessary to achieve sustainable urban development [17]. To intervene in sustainable urban development accordingly, the quantification of the compact urban form of the city is essential [18]. In addition, regulating policies also play a central role in attaining compact and sustainable development [19]. Sustainable development is one of the essential goals of several countries. The United Nations provides the 17 Sustainable Development Goals (SDGs) to achieve a better and more sustainable future for all. Goal 11 of the SDGs concerns sustainable cities and communities, making them safe, inclusive, resilient, and sustainable [20].

Hassan & Lee (2015) covered the ten most significant topics that are related to sustainable urban development (SUD), such as a balanced approach to SUD, socio–cultural awareness, urban sprawl, urban economic development, transportation, urban renewal, mitigating greenhouse gases (GHG), urban vegetation, assessment systems, and city structure and land use [21]. The Master Plan is a policy guide directed toward achieving a compact urban form and planned urban growth of a city in accordance with sustainable development. However, the cities in developing countries such as Pakistan face many barriers to implementing Master Plan policies. On the other hand, progressive cities of the world set an example for growing cities, revealing that it is possible to uplift a city, even from the slums, to a compact, sustainable, and prosperous city [22].

The compact city is distinguished by high-density development, mixed-use development, and a well-managed transportation system. It is observed that the residents of the compact city are more satisfied than those living in the sprawled area. Meanwhile, it is also noted that short distances to service facilities make the central region more livable than the low-density urban fringe [23]. The compact city has diverse effects and directly offers a schematic structure to urban form. It carries urban development vertically, and high densities promote sustainable development [24].

The compact city is a suitable model of sustainable development, and this well-ordered model addresses the occurrence of urban dispersion [25]. Compactness, diversity, density, and mixed land use are the compact city's vital strategies for achieving sustainable development goals [26]. A compact city model can encourage sustainable transportation, sustainable use of land, social sustainability, and economic viability [27]. There are close associations between the compact city model and sustainability, such as the reduction in automobile dependence, the efficient social infrastructure and supply of public services, high densities, and the revitalization of the central city area [28]. In the present decade, the concept of a compact city has become one of the crucial strategies to achieve sustainability [29]. Compactness can usually be seen in developed countries. However, quantification of the compact urban form in developing countries can give us an idea of how far a city is from sustainability. Sustainability is a prevalent motivation to encourage compactness, to reduce private transportation, and promote the compact urban form [30]. The level of sustainability of the compact urban form was evaluated using five variables: compactness, diversity, accessibility, identity, and environment [31]. Moreover, the compact city suggests an essential strategy for building sustainable cities [32]. Compactness is widely recognized as a vital factor in a city's sustainable development. [33]. Further, urban sprawl is always a big challenge, so compact development is one of the best solutions to urban sprawl [34]. The extent of how existing cities like Multan with many planning concerns can benefit after adopting a compact urban form is still unrevealed.

This study explores the various indicators and dimensions of urban form that are useful for measuring compactness by reviewing past literature from different databases such as the web of science, Scopus, and google scholar. After that, this study quantifies the compactness level of Multan city based on the existing urban form, and indicators from the available data.

3. Literature Review: Urban Form and Compactness

Before quantifying urban form aspects, it is mandatory to clarify what urban form is by definition. In a broader view, the urban form can be defined as a spatial arrangement of non-moveable urban components on a specific interval of time [35]. Physical characteristics broadly explain a city's urban form [36]. It also comprises the following characteristics: shape, size, land uses, density, etc. These elements of urban form can be identified simply by considering their usefulness towards sustainability. Additionally, these elements can certainly be varied for developed and developing countries, and the reason for study can also change. The scale of consideration regarding urban form varies from massive regional or country-level to the small neighborhood unit [37].

Although compactness is always directed towards sustainable urban form [38], compactness doesn't have any well-acknowledged definition [39]. Conflict exists between authors, and everyone defines compactness according to the scope of the study or variable considered. Apart from the variation in definition, one core concept focuses on the concentration of development [39]. Generally, compact cities are designed to promote comparatively high residential density along with mixed land uses, efficient and sustainable modes of transportation, pollution reduction, and encouraging low energy consumption practices.

Quantifying the compactness carries some benefits. Firstly, it helps the policymakers know how far an area is to achieving sustainability. Secondly, it focuses on the impacts of compactness. Thirdly, it helps to develop policy guidance and can be efficiently used as an urban planning tool [40]. Compact development can be "distinguished by measuring the distance from the house to the business area in the city center and represented in a virtual city cylindrical with equal distribution of development in all parts. Meaning the less the distance is the degree of compactness above and vice versa" [41]. Burton (2002) suggested the various levels of urban compactness by types, such as density, a mix of uses, intensification, and built form [40].

In literature, some studies show the relationship between compactness and urban form. For example, a study was conducted to evaluate the compactness of urban form in eight neighborhoods of Dhaka, Bangladesh. They used six urban form indicators, including population density, evenness of development, clustering nature of development, diversity, floor use mix, and road network connectivity. They concluded that four neighborhoods were classified as low compact, three as moderately compact, and one as highly compact [42]. Another study was conducted to evaluate the urban form focused on the compactness dimension based on the built-up area density in the United States, Europe, and China. They divided the urban forms into four categories: central-compact, central-sprawl, decentralized-compact, and decentralized-sprawl. They concluded that urban forms were dominated by decentralized sprawl in the United States. At the same time, the urban form was a central compact in Europe and China. Moreover, they found that land consumption per capita increased in all cities from 1990 to 2014 [43]. Sustainability has become a solemn topic with respect to its long-lasting impacts. This is one reason decision-makers are promoting policies focusing on urban form and sustainability. This practice is very easy for new projects, but sometimes it is challenging to achieve such practices for existing dense and old cities. Multan is among one of the oldest cities in Pakistan. It has a master plan, but unfortunately, it has not been appropriately practiced. There are many reasons behind this, such as less political will, limited resources, less awareness, and particularly the behavior of the private profit-makers. The private profit-makers usually build private housing schemes without explicitly considering the directives of the Master Plan. To bring Multan into the mainstream of sustainability, it is essential to discourage these profit-makers who have influenced the departments. Table 1 shows some approaches to quantifying the urban form and compactness, which have been used in previous studies.

Table 1. Approaches to quantifying the urban form and compactness.

Sr. No.	Source	Study Focus	Indicators/Study Variables
1	[17]	Design concepts and principles of urban forms	Compactness Sustainable transport Density Mixed land uses Diversity Passive solar design Greening
2	[44]	Elements of urban form	Density Land use Accessibility and transport infrastructure Urban layout Housing and building characteristics
3	[45]	Quantitative analysis of urban form	Landscape ecology Economic structure Transportation planning Community design Urban design
4	[18]	Measuring compact urban form	Density Density distribution Transportation network Accessibility Shape Mixed-use land consumption
5	[46]	Measuring urban growth, urban form, and accessibility	Growth rates Density Spatial geometry Accessibility Aesthetics
6	[47]	Measuring sprawl across the urban-rural continuum using an amalgamated sprawl index	All development Low-intensity development All development clumpy Low-intensity development clumpy Impervious per capita Density change Population change
7	[48]	Measuring sprawl	Development density Land use mix Activity centering Street accessibility

Table 1. *Cont.*

Sr. No.	Source	Study Focus	Indicators/Study Variables
8	[49]	Measuring urban sprawl and compactness	Size Density Continuity Scattering Shape Loss of green space
9	[50]	Urban sprawl indicators and spatial planning	Spatial and temporal analysis Landscape metrics indices Urban fragmentation Land resource impact
10	[51]	Monitoring urban sprawl	Urban density Change in urban density Greenfield development rate Effective share of open space Patch density Mean shape index Openness index The share of urbanized land New consumption
11	[8]	A new strategy of sustainable neighborhood planning	Adequate space for street and efficient street network High density Mixed land use Social mix Limited land use specialization
12	[22]	Measuring urban sprawl and its drivers	Urban expansion classification Density analysis Spatial matrices Geospatial analysis
13	[52]	Measuring urban sprawl	Built a multi-dimensional index of combining city expansion, urban compactness, and urban form to measure the urban sprawl. Developed a multi-dimensional index to measure the spatio–temporal characteristics of urban sprawl

Various researchers have measured the urban form and compactness by adopting different indicators (see Table 1). Several past studies include density [2,10,11,15,36,38–41], mixed land use [2,10,11,36], accessibility and transport [10,11,36,38,40], land ecology/spatial and temporal analysis [37,42,44] and shape [11,41,43]. Most research studies were conducted based on the quantitative method, but limited use of ArcMap was seen in these studies. In addition, most of the research has been conducted in developed nations to measure the existing urban form, but limited studies has ben conducted in dveloping economies. Our research fills these research gaps and aims to analyze compactness based on urban form indicators. The nature of the present study is quantitative with widespread utilization of ArcMap. Moreover, in our study, the primary survey was conducted to collect the essential data for the adopted indicators in the study area. In addition, this research will add a new case study to the existing literature, which will be equally helpful for policymakers, urban planners, and government institutions at local, national, and global levels for devising compact city policies and promoting sustainable development. This research study will also be resourceful for other developing countries with similar demographic characteristics, population, area, geographical conditions, and structure to that of Multan city.

4. Materials and Methods

4.1. Research Setting

In the Asia subcontinent, Multan is one of the oldest cities, rich in history and culture, founded around 5000 BC as part of the Indus Valley Civilization, known as the city of Sufis and Saints. Multan City is located at latitude 30.18° N and longitude 71.48° E [53] in the southern part of the Punjab province in the core of Pakistan (see Figure 1). It is situated at the intersection of major roads connecting the north and south (Lahore and Karachi) and roads connecting the east and west of the country. The geographical location makes the city a pivotal and strategic site in Pakistan. Moreover, Multan city is the center of a significant hinterland of medium towns and large villages due to rapid urbanization [54].

Multan city is Pakistan's 7th most populous city and the 5th largest city in the Punjab province. Multan city consists of four administrative zones (Bosan Zone, Shah Rukn-e-Alam Zone, Musa Pak Shaheed Zone, and Sher Shah Zone) and 68 urban blocks, so-called union councils [55]. According to the population census of 2017, the total population of Multan city was 2.25 million (2,258,570 inhabitants) with an average annual growth rate of 2.23%. The entire household number was estimated at 293,402 in Multan city [55]. The city is spread over an area of 362 km^2. It is estimated that the gross population density is 6239 persons/km^2. Multan is the leading cultural and economic core of southern Punjab. It is the richest in agriculture in the Punjab province. It is famous for cotton crops and mango gardens, producing 40% of its total mango crop [56]. It is estimated that 63% of the total area was under agriculture and orchards in 2008, which was 78% in 1986 (Integrated Master Plan of Multan, 2008–2028). Before the British arrival, Multan was one of the famous handicraft centers [56].

Since 1987, the city has been expanding haphazardly in all directions, mainly towards the north and northeast, because of land availability and an accessible road network. The growth is primarily along corridors such as the Boson Road and LMQ road due to a high level of education, health, and other allied facilities. Towards the west, growth is constrained due to the presence of the river Chenab. The city's expansion towards the south and east direction is less intensive due to the lack of necessary facilities. The growth is less intense and scattered along major roads, including the Vehari Road, Bahawalpur Road, Duniyapur Road, Shujabad Road, and Multan Bypass Road. Such leapfrog development is causing urban sprawl. Therefore, the growth pattern of Multan city is radial rather than concentric.

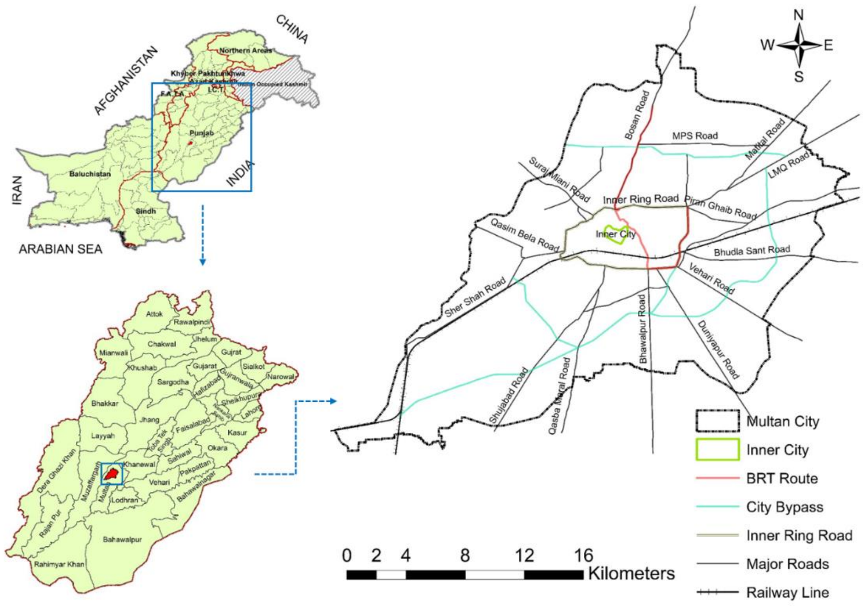

Figure 1. Geographical location of Multan city.

4.2. Research Methodology

This study is based on an extensive literature review, as well as primary and secondary data collection. Indicators for this study are adopted from the literature to measure the current compactness of Multan city. We choose the indicators that are vital for the local context, have data availability, and are easily measurable. Kohran's formula for calculating sample size is used as $n = N/1 + Ne^2$ where n represents the sample size, N is the number of households, and e is the desired margin of error.

According to the population census of 2017, the total number of households (N) was recorded 293,402 in Multan. The sample size was computed from the calculation to be 400 with a 5% margin of error. The convenience-based random sampling technique was used for data collection. For data collection, most respondents were standing in the street with their friends in the evening for talking purposes, or being available in the parks. This method was very convenient because some people avoided talking when they were in their houses. Primary data was collected by conducting field surveys using a questionnaire in Multan city. The data collected related to the mode of transport, the number of trips for shopping, education, work, and the availability of the pedestrian facility. In addition, data was collected related to the average speed of the vehicles on major roads during peak hours in the study area by taking 120 observations. An observation survey is also conducted to check footpath availability on the study area's major roads. The running length of the footpaths is measured using Google Earth. Secondary data is collected on historical growth patterns, land use break-up, population, population density, and the transportation network for Multan city. This data is obtained from Multan Master Plan (1987–2007), Integrated Master Plan of Multan (2008–2028), Punjab Development Statistics reports 2013–2018, Pakistan Bureau of Statistics reports, National Reference Manual on Planning and Infrastructure 1986, and UN-Habitat reports. Landsat images of the study area for 1987, 1997, 2007, and 2017 are acquired from USGS Earth Explorer to analyze land cover changes to measure the growth pattern. Table 2 shows the details of acquired images for land-use changes in Multan city.

Table 2. Details of acquired images for classification.

Year	Resolution (m)	Landsat	Row/Path	Date of Acquisition
1987	60	LANDSAT_5	039/150	25/10/1987
1997	30	LANDSAT_5	039/150	17/08/1997
2007	15/30	LANDSAT_7	039/150	06/09/2007
2017	15/30	LANDSAT_8	039/150	09/09/2017

Source: USGS Earth Explorer.

Moreover, mathematical equations are used to measure the urban form and compactness, such as Simpson's index, walkability index, congestion index, shape performance, average land consumption per person, and road network density (See Table 3). ArcMap software is used in this research study to prepare spatial maps. Moreover, ERDAS IMAGINE, an image processing software, is used to measure the land-use changes in the study area for the above-mentioned years. The findings and conclusions are based on the results of the data analysis for Multan city. Based on the results, some recommendations are given for the study area. Table 3 shows the adopted indicators for this research study and their description for evaluating the sub-indicators.

Table 3. Adopted indicators for this research study.

Sr. No.	Indicators	Sub-Indicators	Description
1	Land cover changes	-	Land-use changes for 1987, 1997, 2007, and 2017 were calculated from Landsat images by using ERDAS IMAGINE and ArcMap software.
2	Density	Gross population density (Persons/km^2)	A total population divided by the total area [57]
		Built-up area density (Persons/km^2)	The total population is divided by the built-up area of the city [57]
		Average land consumption per person (m^2)	A total population divided by land consumption area [58]
3	Landuse	Land use break-up	Land use data acquired from Integrated Master Plan of Multan 2008–2028
		Simpson's Index	Simpson's Index $= 1 - \sum\left(\frac{a}{A}\right)^2$ where a is the total area of a specific land use category and A is the total area of all land use categories
4	Transportation network	Mode share	Data were collected by conducting the primary survey
		Road network density (m/ha)	Road length divided by population [58]
		Congestion Index	Congestion Index = 1 − (A/M) where A is the average journey speed observed on the city's main roads during peak hours and M is a desire to average journey on main corridors during peak an hour, which is supposed to be 30 kmph [18]
		Walkability Index	Walkability Index = [(W1 × Availability) + (W2 × Facility rating)] where W1 and W2 are parametric weights, which assumed 50% for both, availability is expressed as the footpath length divided by the length of major roads in the city, and facility rating is a score estimated based on opinion on the available pedestrian facility [18]
5	Dispersion Index	-	$P = \frac{\Sigma \mathrm{diwi}}{\frac{2}{3}\left(\frac{A}{\pi}\right)^{1/2}}$ where di is the distance from the centroid of the zone to the city center, wi is the population of each zone, and A is the built-up area of the city [18]

5. Results and Discussion

5.1. Land Cover Changes

Land use patterns and changes in developing countries are considered serious for stimulating sustainable urban development [59]. Land cover changes are an essential aspect of the city's urban growth. Changes in the land cover directly affect the environment due to the reduction in the agricultural area. In this research study, Landsat images of the study area were obtained from USGS Earth Explorer for 1987, 1997, 2007, and 2017. Landsat image preprocessing was accomplished using ArcMap and ERDAS IMAGINE for geo-referencing and sub-setting for the Area of Interest (AOI). These images were displayed in natural color composite using a band composition in ERDAS IMAGINE. Moreover, these images were classified by the maximum likelihood supervised classification technique in ERDAS IMAGINE. In supervised classification, a spectral signature is developed from a specific image location. Three land cover classes are identified: built-up area, vegetation, and water bodies. The built-up area includes the land covered by buildings and other man-made structures such as residential and commercial areas, industrial areas, roads, and mixed urban or built-up lands. The water body consists of rivers, streams, lakes, canals, and reservoirs [60]. Vegetation covers agricultural areas, open spaces, and forests. This classification provides the land cover changes images of the case study (see Figures 2–5). Change detection is made on these maps to quantify the differences in land cover change information based on the pixel at a different period. Accuracy classification assessment for 1987, 1997, 2007, and 2017 Landsat images were carried out to ascertain the quality of information from the data. In this research, accuracy assessment was determined by using the Kappa test. The resultant classification accuracies for 1987, 1997, 2007, and 2017 are 74.56%, 78.09%, 83.61%, and 80.37, respectively. The Kappa coefficient is rated substantially for 1987, 1997, and 2017, whereas it is most perfect for 2007.

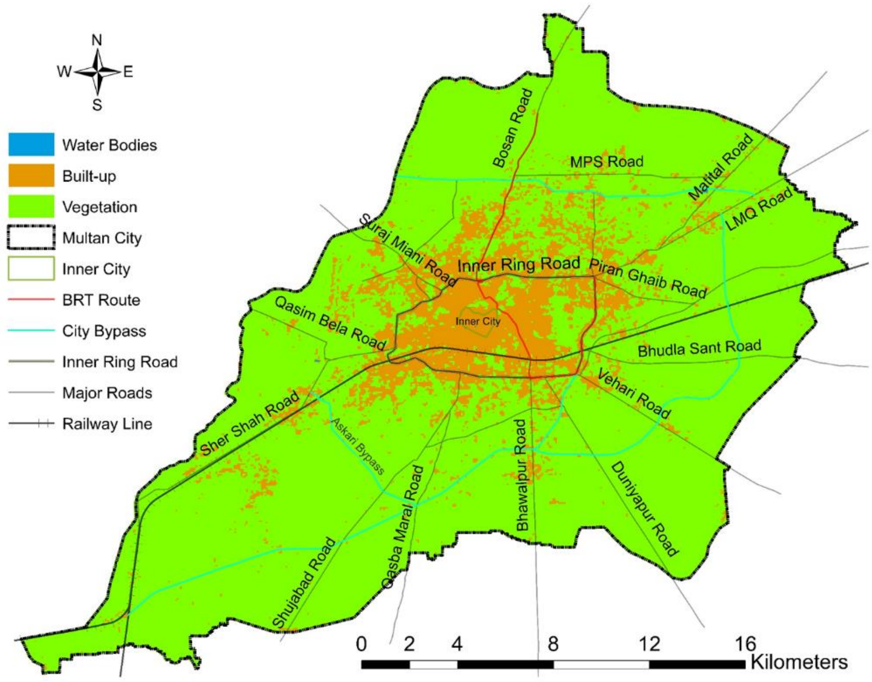

Figure 2. Land cover change classified image of 1987.

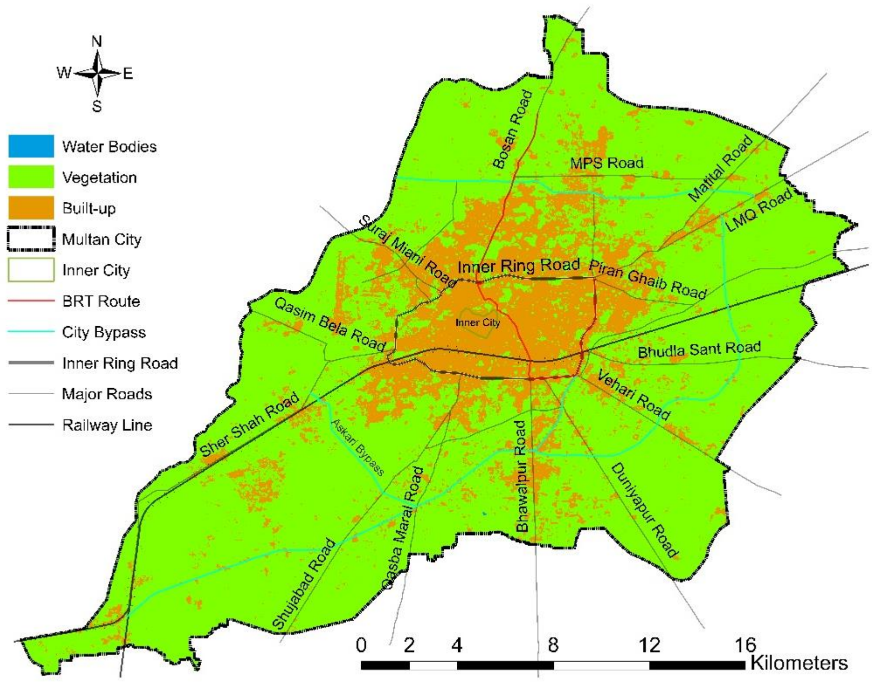

Figure 3. Land cover change classified image of 1997.

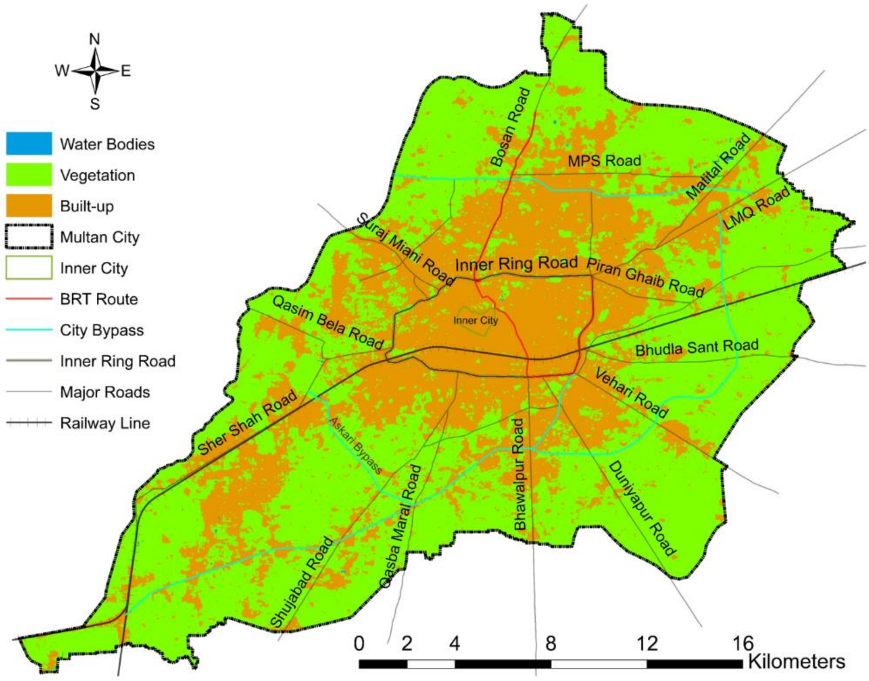

Figure 4. Land cover change classified image of 2007.

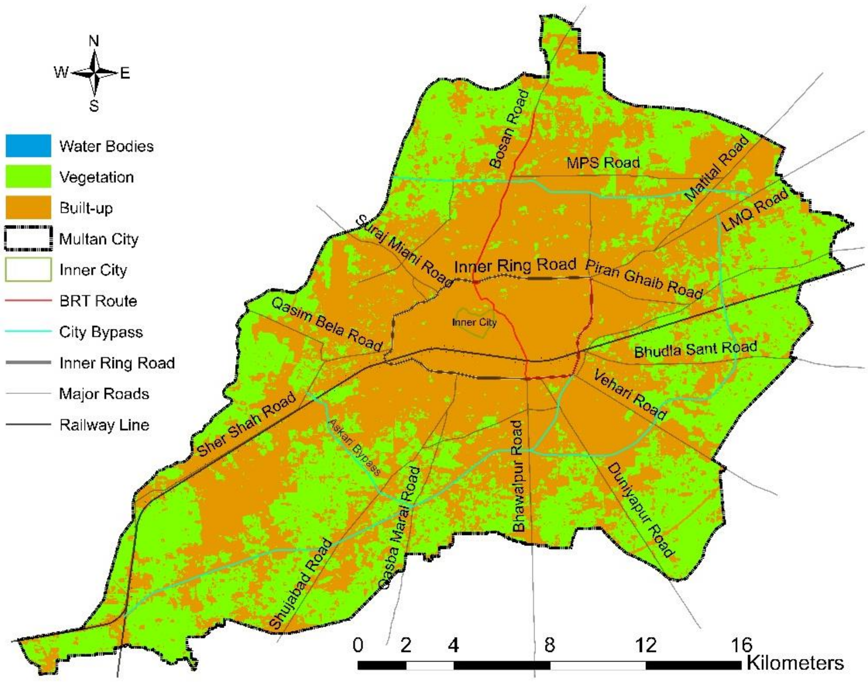

Figure 5. Land cover change classified image of 2017.

Figures 2–5 shows that the built-up area and vegetation have changed drastically. The magnitude and percentage of land cover changes for 1987, 1997, 2007, and 2017 are summarized in Table 4. The result indicates that the built-up area of Multan city has increased significantly from 5795.64 ha (16.01%) in 1987 to 22,790.20 ha (62.96%) in 2017. As a result, the vegetation was lost to the built-up area during the same period. Vegetation has significantly reduced from 30,388.65 ha (83.95%) to 13,398.61 ha (37.01%) between this duration. This shows that there was a great urban sprawl between 1987 and 2017. In addition, water bodies were slightly reduced. On the other hand, the decrease in vegetation is due to increased population and urban expansion in the study area from 1987 to 2017. It is concluded that the built-up area is significantly increased; consequently, vegetation is decreasing, which means that urban sprawl is growing gradually in Multan. It is concluded that there is a significant expansion of the built-up area noticed in the study area.

Table 4. Land use changes matrix of Multan city (1987–2017).

LULC Type	Area (Hectare)				Percentage			
	1987	1997	2007	2017	1987	1997	2007	2017
Built-up	5795.64	8113.86	14,813.80	22,790.20	16.01	22.41	40.93	62.96
Vegetation	30,388.65	28,072.77	21,374.16	13,398.61	83.95	77.55	59.04	37.01
Water Bodies	15.71	13.37	12.04	11.19	0.04	0.04	0.03	0.03
Total	36,200.00	36,200.00	36,200.00	36,200.00	100.00	100.00	100.00	100.00

5.2. Density

Density is one of the vital and fundamental elements among various other aspects of urban form. It helps evaluate the current urban functionality level related to specific land-use characteristics. Density is broadly used to assess urban sprawl and it is the essential component of the urban form [61]. Moreover, density is used to perform different analyses in order to understand the relationship between population and urban areas [58]; if the density of an urban area is decreasing gradually, it indicates the urban area is moving towards urban sprawl [18]. Three indicators are adopted to better understand the overall density distribution pattern in Multan city. These indicators include gross population density, built-up area density, and average land consumption per person.

5.2.1. Gross Population Density

Table 5 shows the gross population density of Multan city, which was 4146 persons per km^2 in 1998. It increased in 2017 and reached 6239 persons per km^2.

Table 5. Gross population density with population and area (1998–2017).

Year	Population	Area (km^2)	Density (Person/km^2)
1998	1,501,000	362	4146
2017	2,258,570	362	6239

UN-HABITAT suggests that to refrain from urban sprawl and encourage sustainable development, it is compulsory to acquire high density [8]. However, the population density of Multan city is relatively low for the UN-HABITAT recommendation. For sustainable neighborhood development, it is recommended to have 15,000 persons per km^2. However, the density of Multan city is increasing comparatively from 4146 persons to 6239 persons per km^2 from 1998 to 2017. Nonetheless, the figures are pretty low by the recommended sustainable development standards. Comparisons of Multan city with world cities having a similar population, area, and density are given in Table 6. It shows the population density of Multan city is higher than Salt Lake City, Harare, Haikou, and Goiania, which have the same population as Multan city.

Table 6. Comparison of Multan city with world cities.

Similar Population								
Cities (Countries)	**Salt Lake City, (USA)**	**Gujranwala (Pakistan)**	**Harare (Zimbabwe)**	**Haikou, (China)**	**Savar (Bangladesh)**	**Goiania (Brazil)**	**Bhopal (India)**	**Multan (Pakistan)**
Population	2,280,000	2,275,000	2,255,000	2,250,000	2,240,000	2,240,000	2,230,000	2,258,570
Urban Area (km^2)	1720	207	829	427	181	816	181	362
Gross Population Density (km^2)	1200	11,000	2700	5300	12,400	2700	12,300	6239
Similar Urban Area								
Cities (Countries)	**Cuiaba (Brazil)**	**Shantou (China)**	**Thrissur (India)**	**Leon (Mexico)**	**Odesa (Ukraine)**	**Valencia (Venezuela)**	**Bakersfield (USA)**	**Multan (Pakistan)**
Urban Area (km^2)	363	363	363	363	363	363	357	362
Population	795,000	2,515,000	2,575,000	1,660,000	1,100,000	1,540,000	575,000	2,258,570
Gross Population Density (km^2)	2200	6900	7100	4600	3000	4200	1500	6239
Similar Density								
Cities (Countries)	**Ria de Janeiro (Brazil)**	**Benin City (Nigeria)**	**Sekondi Takoradi (Ghana)**	**Taizz (Yemen)**	**Shenzhen (China)**	**Semarang (Indone-sia)**	**Zahedan (Iran)**	**Multan (Pakistan)**
Gross Population Density (km^2)	6300	6300	6300	6300	6200	6200	6200	6239
Urban Area (km^2)	1917	228	91	119	145	272	91	362
Population	11,990,000	1,445,000	570,000	750,000	905,000	1,690,000	565,000	2,258,570

Source: Demographia, World Urban Areas, 2018.

5.2.2. Built-Up Area Density

According to UN-HABITAT, high density is a smart choice in this era of rapid urbanization, and it is an essential element for sustainable urban planning. High-density urban areas carry many benefits, such as reductions in travel costs, shorter time emergency response, less travel time to facilities, greater energy efficiency, saving fuel costs, and a significant reduction in CO_2 emissions. To achieve a high populace density and minimize the downward development trend, it is recommended to have 15,000 people per km^2 [8]. For the analysis purpose, the built-up area of 1997 was considered to calculate the built-up density of 1998. Table 7 inferred that the built-up area density was 18,499 persons per km^2. This figure was more significant than the recommended density of UN-HABITAT. On the other hand, the built-up density significantly decreased and was very low in 2017 compared to 1998. This figure is less than the recommended standards of neighboring areas. It is concluded that a significant decline in built-up density shows that Multan city is moving towards urban sprawl.

Table 7. Built-up area density for Multan city (1998–2017).

Year	Population	Built-up Area (km^2)	Density (Person/km^2)
1998	1,501,000	81.14	18,499
2017	2,258,570	227.90	9910

5.2.3. Average Land Consumption per Person

Currently, there are no standards defined by which we can compare average land consumption per person (m^2) to determine how the relationship between our value and the ideal figure. However, by referring to other land uses, we can set a benchmark. In this study, the car is chosen as a reference point, the same as Kotharkar et al. (2014) and Liaqat et al. (2017) used for their Nagpur city (India) and Lahore city (Pakistan) research, respectively [18,58].

The total available area for Multan city is 362 km^2, and land consumption is 227.90 km^2, which equals 62.96% of the total land area in 2017. Moreover, it is determined that the average land consumption per person increased from 54.06 m^2 to 100.90 m^2 from 1998 to 2017 (see Table 8). Comparatively, the value is in an increasing trend from 1998 to 2017. However, this value is still relatively low as compared to average land consumption in Berlin and New York, which had much higher values of 279 and 249 square meters per person, respectively [58], and still higher in 2017 as compared to Nagpur, which was 56.57 square meters per person [18]. On the other hand, the car consumes an area equal to 40 square meters to maneuver, so it may be concluded that in Multan, a car consumed 73.99% space per person in 1998 and 39.64% in 2017. Individual car use as transport means will be more disruptive in cities with lesser consumption of land per capita. Restricting car use will retain and promote compact developments. Our findings are consistent with those of [43]. They found land consumption per capita increased in the United States, Europe, and China from 1990 to 2014.

Table 8. Average land consumption per person (m^2) for Multan city.

Year	Area (m^2)	Population	Average Land Consumption Per Person (m^2)
1998	81,138,600	1,501,000	54.06
2017	227,902,000	2,258,570	100.90

5.3. Landuse

5.3.1. Land use Break-Up

According to the Master Plan of Multan, the land use was divided into different categories, namely as residential, commercial, industry, educational institutions, public buildings, parks, graveyards, water bodies, and roads. The land use break-up of Multan city is vibrant, and it shows the precise comparison of land use distribution concerning the built-up area between the years 1986 and 2008 in Figure 6. The UN-HABITAT report on "A new strategy of sustainable neighborhood planning: Five Principles" suggests that the high-density area requires more area for high street coverage. High street coverage means that more land is allocated for roads and parking. To achieve sustainable development, adequate space for streets with an efficient network is needed. For this purpose, it is mandatory to provide at least 30 percent of the area for roads and parking [8]. However, in the case of Multan city, land use break-up for roads is less than half of that. It is recommended to allocate 15–20% of the area for open spaces and parks for compact city development, but it was pretty low in Multan city, from 1.5 percent in 1986 to 1.23 percent in 2008. More parks can also improve the residents' quality of life [62]. This land-use break-up also failed to comply with the National Reference Manual on Planning and Infrastructure standards, a policy document for land use development in Pakistan. The residential area is over the upper limit, which ultimately results from urban sprawl and haphazard growth in the study area.

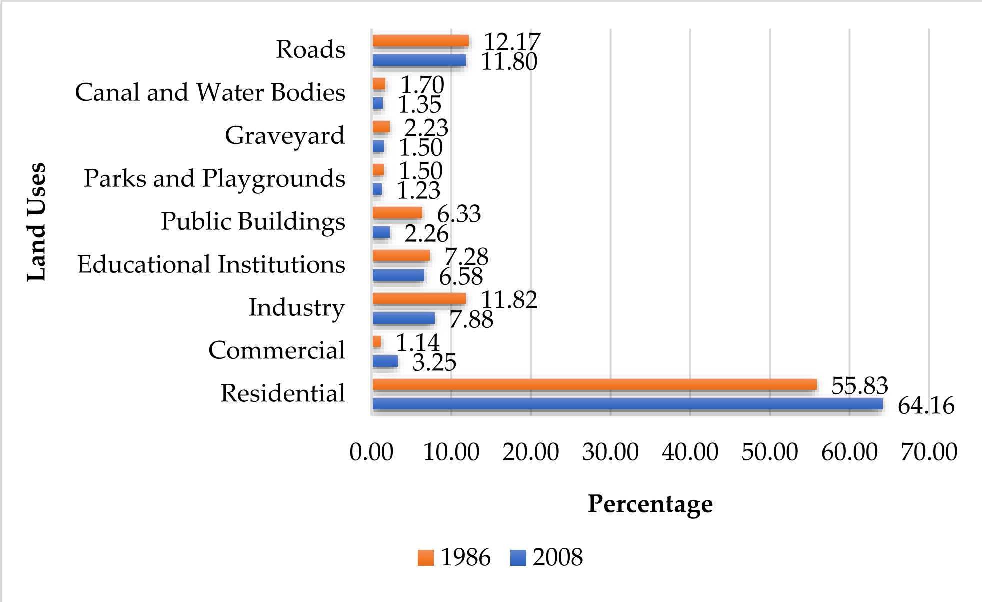

Figure 6. Land use break-up concerning the built-up area of Multan city. Source: Integrated Master Plan of Multan (2008–2028).

5.3.2. Simpson's Index

Simpson's Index is used to calculate the functions of an urban area [63]. In the case of Multan, the land use proportion is given in Figure 6. The value of the index falls from zero to 1. Where 0 indicates land uses as more homogeneous, and one represents the portion of land evenly distributed among all land uses [64]. This study considers nine different land uses to calculate this index. It includes residential, commercial, roads, industry, public buildings, education institutions, parks and playgrounds, graveyards, and water bodies.

In the case of Multan city, the Simpson's Index has been calculated: its value equals 0.6. According to Knaap et al. (2005), the higher the index value, the more evenly distributed the land uses [61]. Therefore, the computed value of the index for Multan is slightly higher than half of the value, which shows the even distribution of the land uses in the study area.

5.4. Transportation Network

For the last few years, the transportation sector in Multan has been getting worse and more congested every day. There is a lack of significant policies and master plan for the transportation sector. On the other hand, the Master Plan document provides an essential part of this sector, but this document is also not in priority. With rapid urbanization, the city has required an extensive transportation network that was not considered in the past. Currently, narrow roads with significantly less right of way result in chronic traffic congestion in some roads and pollution-related problems (Integrated Master Plan of Multan, 2008–2028). The transportation network is divided into four categories for this study: mode share, road network density, congestion index, and walkability index.

5.4.1. Mode Share

In Multan, the public transport system is neither efficient nor substantial enough to meet the current demand of the city. The inefficient public transport sector creates a terrible situation that pushes individual users to increase and engenders a disorganized network of private vans, three-wheelers Qingqi, and auto rickshaws. Bus Rapid Transit (BRT) is newly introduced in the city and is among the world's most reliable and efficient mass transit systems. However, it could only attract a limited area with limited users compared to its total urban area and the total urban population. Nadeem et al. (2021) conducted a study to evaluate the performance of the BRT system based on the passengers' perceptions and the

BRT standard scorecard in Multan, and concluded that BRT Multan is performing well in enhancing the public transport image of the developing county [65]. The total length of the roads in the urban area of Multan is 3018.60 km, taken from Open Street Map. Nevertheless, the metro route is limited to 21 km only, less than 1% (0.69%) of the total road length. Due to intense summer weather (on average 42° Celsius in June) in Multan, it is difficult to promote walking and cycling; however, special considerations towards this problem would conclude in ultimately worthwhile results. Provisions of tree-covered walkways will help reduce the atmospheric temperature and encourage walking and cycling in the city. Table 9 shows the mode share of Multan city. Aziz et al. (2018) suggested an integrated and hierarchical transit system to improve the transport sector [66].

Table 9. Mode share (%) of Multan city.

Mode of Transport	No. of User	Mode Share (% Age)
Non-Motorized	149	37.25
Private	119	29.75
Public	43	10.75
Rickshaws/Qingqi	89	22.25
Total	400	100

The mode share of transport and number of trips to the study area were extracted from primary data. Table 9 shows that the mode share of non-motorized transport is higher than the other modes of transportation. The mode share of non-motorized transport is 37.25%. Private transport contributes 29.75% of the total mode share in Multan city. The mode share of public transportation in Multan is 10.75%, less than the cities of the world listed in Figure 7. In Multan city, it is determined that most trips are work trips, contributing to 51% of the total trips, and the rest are education and shopping trips. Thus, enhancing the public transport system with an efficient road network is necessary.

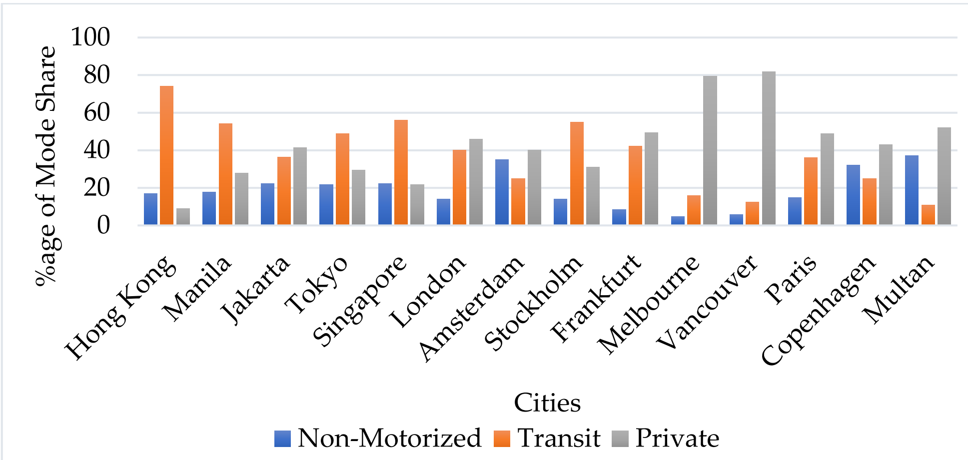

Figure 7. Comparison of mode share of Multan with the world's cities.

5.4.2. Road Network Density

Regarding transportation parameters for sustainable development, it is recommended to have a higher road network density value but less value of road length per capita [18]. Gross road network density (m/ha) is calculated by the total length of the roads divided by the total built-up area of the city. Road length per person is the total road length divided by the population. The total length of the roads is about 3,018,603.15 m, taken from Open Street Map and calculated in ArcMap. In the case of Multan city, the calculated road network density is 132 m/ha (see Table 10), which is higher than the value of the cities of the world listed in Figure 8. For Multan, the road length per person's computed value is 1.3 m per person (see Table 10), which is lower than Sydney and greater than the remaining cities of the world, which are listed in Figure 9. It shows that Multan is a compact city according to the value of road network density, and it is a sprawling city due to the higher value of road length per person. It means that Multan city is standing between compactness and dispersion. Table 10 shows the road network density and road length per person in Multan city.

Table 10. Road network density and road length per person in Multan city.

Total Road Length (m)	Built-Up Area (ha)	Road Density (m/ha)	Population	Road Length per Person (m/person)
3,018,603.15	22,790.20	132	2,258,570	1.3

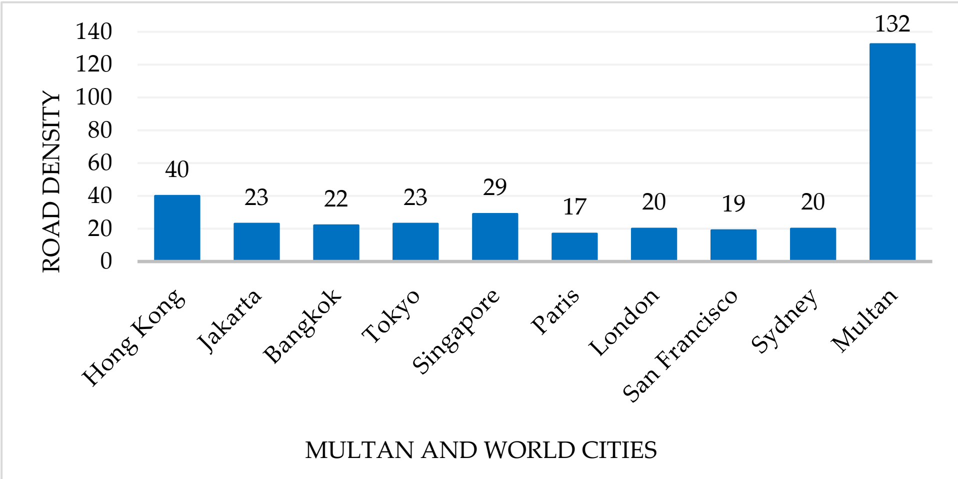

Figure 8. Comparison of road network density (m/ha) of Multan with world cities.

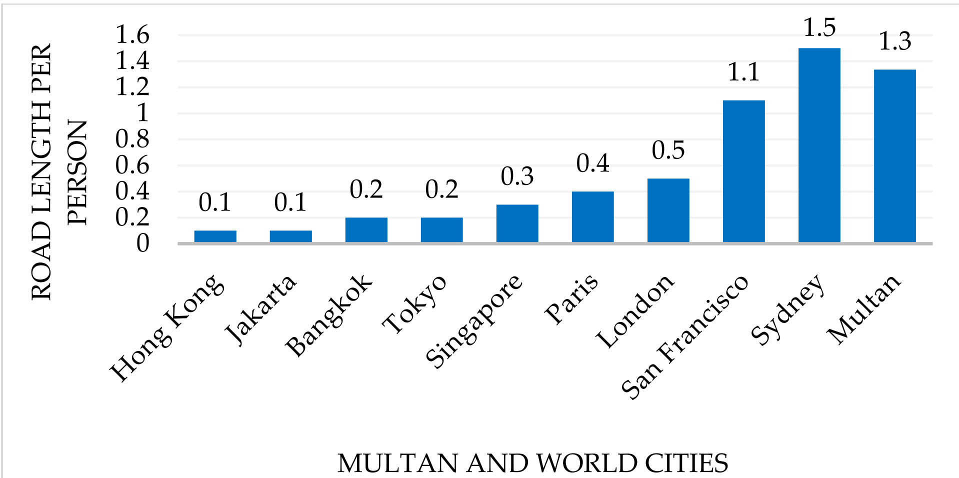

Figure 9. Comparison of road length per person (m/person) of Multan with world cities.

5.4.3. Congestion Index

One hundred and twenty (120) observations were taken during peak hours on the main roads of Multan, such as the Bosan, LMQ, and Vehari roads. The average speed of the vehicle was recorded 22.75 km/h. Therefore, the calculated value of the congestion index for Multan city is 0.2417. A higher congestion index reduces mobility, and lower congestion index values lead to higher mobility [18]. Therefore, the congestion index value for Multan city is somehow lower, which leads to less congestion and better mobility on the major roads.

5.4.4. Walkability Index

In the case of Multan city, availability is calculated by taking the length of the footpath through an observation survey on each road and then measuring the length using Google Earth. The total length of the roads is about 3018.60 km. It is calculated that the entire length of the footpath is 221.63 km (see Figure 10). The facility rating is 0.47 on a scale of 0 to 5 based on the opinion of 400 respondents from field surveys. The rating is low because most of the roads are encroached by hand carts, displaying items in front of shops and ramps. The computed value of the walkability index is 0.27. The walkability index range is zero to 1, where 0 represents poor walkability and 1, good [18]. For Multan, the walkability index's calculated value is below the index's average value, which shows that the city has a particular shortage of pedestrian facilities.

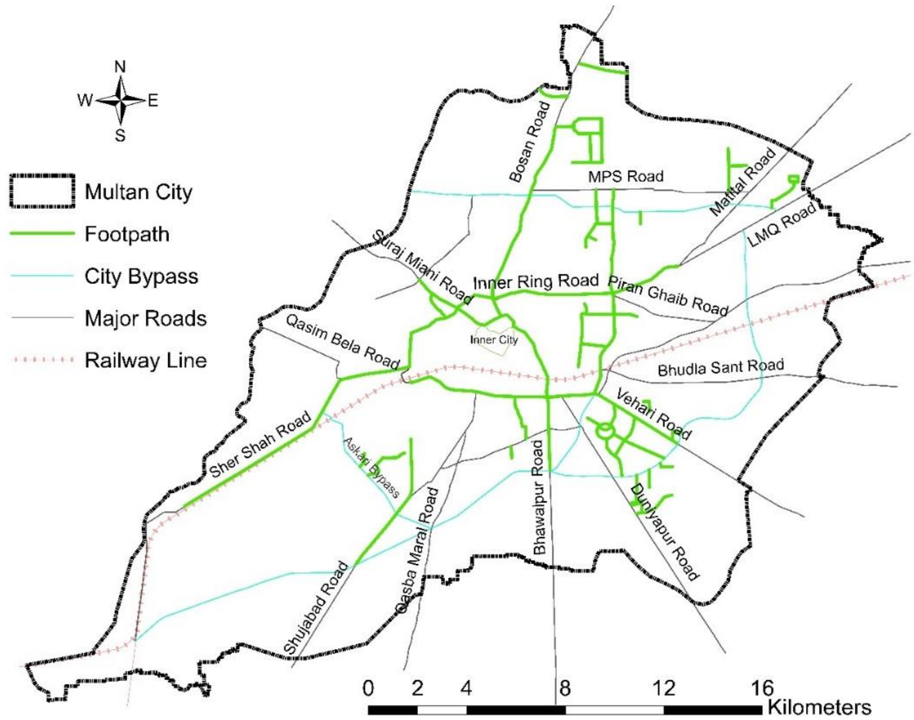

Figure 10. A map showing footpaths in Multan city.

5.5. Dispersion Index

The dispersion index is calculated to measure the shape performance of the city. It is "the ratio of the average distance per person to the center and the average distance per person to the center of a circle whose area would be equal to the built-up area with a uniform density" [18].

The value of distance from the centroid of the zones to the city center was computed using ArcMap. The population value was taken from the Punjab Development Statistics report. The value of the dispersion index at 1.0 is considered the threshold between dispersion and compactness. The larger the dispersion index value, the less compact the city [18]. It is determined that the value of the dispersion index for Multan city was 0.86 in 2017, estimated at 2.17 in 1998. For Multan city, it is concluded that the value of the dispersion index has been significantly reduced from 1998. It is also concluded that the value of the dispersion index for Multan is less than the ideal value in 2017, which means the city is heading towards urban compactness. Figure 11 compares the dispersion index of Multan city with the world's cities. It shows that the value of the dispersion index of Multan city is less than other cities, which means that Multan is more compact than those cities of the world.

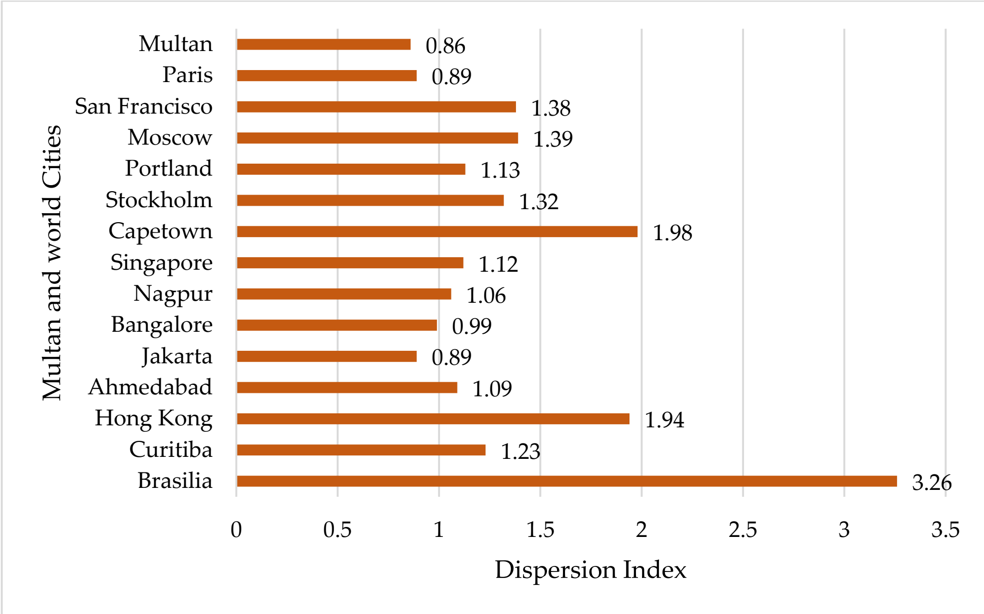

Figure 11. Comparison of the dispersion index of Multan city with world cities.

6. Conclusions

The main focus of this research is to measure the existing compactness based on urban form indicators in Multan city. This research contributes to the current body of knowledge by offering empirical evidence of compactness measures in the context of a developing country. It presents the current level of compactness derived from five urban form indicators, namely land cover changes, density, landuse, transportation network, and dispersion index. Based on the analysis performed in this research, it is concluded that Multan city is currently standing between compactness and dispersion. Further, the study represents that the city is moving towards urban sprawl due to informal development. The analysis found that Multan city is moving towards dispersion, that the relevancy of agricultural land is reducing, that built-up area density is declining, that land use is evenly distributed, that the share of public transport is lower than private transport, and that there is a greater road length per person. Nevertheless, some indicators comply with the concept of compact and sustainable development, such as increasing gross population density, dispersion being less than ideal and decreasing compared to 1998, and higher road network density. The city has an average walkability facility, and the congestion index leads to less congestion and better mobility on the major roads of Multan. This study concluded that implementing regulations and the Master Plan are feeble. Based on the findings of this research, spatial growth should be managed by encouraging vertical infill development, population density should be enhanced by promoting vertical development, building regulations should be revised to increase the floor area ratio, and regulations should be more relaxed for the public to promote compactness and sustainable development in the city. The government should increase the portion of green space in the newly developed areas.

Moreover, there is a need to take adequate measures independently and discourage current development practices on the urban fringe. The city's existing urban form and spatial structure favor the compact city model for Multan to achieve sustainable urban form. This study also concluded that the local government and other development-related departments should implement a strong enforcement mechanism for sustainable development in the future. Furthermore, Multan city must formulate policies on compact cities to promote compactness and sustainable development in the near future. Finally, this study will be helpful to urban planners, decision-makers, and relevant authorities in proposing future compactness policies and promoting sustainable development. This research would also be helpful to local government departments of cities in other developing countries that have the same socio–economic characteristics, geography, area, population, and structure as Multan city in comparing the existing compactness of their cities, and perhaps it will encourage them to improve their urban compactness policies that encourage sustainable development.

This study has some limitations; it quantifies compactness for the years 1998 and 2017. Future research can be conducted to compare the results of our research with the current year, which will assist in discovering the current compactness level of Multan city. Our study can be extended using more indicators of the urban forms to compute compactness.

In addition, the case study of compactness evaluation in developing nations will help compare developed nations' results in future research. The results of our study can be generalized to another context as the indicators of urban form and evaluation methods utilized in this study are transferable. Cities around the globe should be focused on diversified mixed-use development to promote compactness. However, research conducted in different geographical contexts should determine the threshold value of urban form indicators based on their local setting for better application.

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