

Analysing Spatial Growth in Peri-Urban Areas Using Spatial Metrics: Case Study of Indore

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ABSTRACT

Rate of urbanisation is rising in developing countries and the new trajectory of India's urbanisation states the growth of areas outside the administrative boundaries. With increasing urban population growth and its increasing demand for space, a wide range of land is required for habitation. Due to the limited and high valued land available within the city limits is leading to the extension of urban spatial growth outside the formal urban jurisdiction. This space is termed by scholars and researchers as 'peri-urban areas'. In this growing urbanisation for effective planning and management of land resources, the city's spatial growth patterns need to be quantified. Spatial metrics is a tool to study and analyse the pattern and structure of landscapes. The research is based on the application of the spatial metrics index for understanding the qualitative and quantitative nature of the built-up growth taking place in peri-urban areas. The research tries to evaluate the type and dynamics of the spatial growth pattern in the Indore peri-urban areas using spatial metrics over the built environment. It also explores the importance of the regional road network and the economic geography in the development of this zone and its related characteristics. The study of spatial growth of the city using spatial metrics enables the planners and policymakers to undertake the decision for sustainable development of the city.

Keywords: *Peri-urban areas, landscape expansion index, built-up intensity index, spatial metrics, built up analysis*

INTRODUCTION

The term peri-urban areas was first defined by T.L. Smith in 1992 as 'the built-up areas just outside the corporate limits of the city'.¹ Despite

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several attempts to define this space, there is no universally accepted definition. The definitions can be conceptualised under three heads – place, concept and process-based. These are majorly formed when developments such as a highway or a land-use change takes place in the rural areas. When a particularly rural area transforms into an urban area, it passes through a stage of ‘peri urbanisation’ and it is seen as a relative to what constitutes as an urban.^{2&3} The development of peri-urban areas is due to the pressure exerted by the inner city’s growth push. This pressure is major because of urban population growth and its increasing demand for space.

In the new trajectory of India’s urbanisation process, census towns show the higher increase in comparison to the statutory towns from 2001 to 2011⁴, indicating growth of areas outside administrative boundary. This economic development led to the increase of population density and built-up density outside formal urban jurisdiction.⁵ In the Indian context, the growth of peri-urban areas increased after the economic reforms of 1991.⁶ Under these reforms huge foreign direct investments were made for setting up technology-driven industries in urban areas. But, due to scarcity of land within the urban limits and speculative high land prices for the available land parcels, the areas just outside the city limits became favourable for such investment. Economic sectors like manufacturing, transport, storage and communication started growing at higher percentages in the sub-urban villages rather than the metropolitan core and sub-urban towns.⁷ This has led to comparative higher growth in peri-urban areas than their parent urban areas. Some other factors which act as a catalyst for the development of peri-urban areas include multiple local and state-level bodies and new authorities⁸, higher cost of living in the city and movement of people through gentrification process.⁹ The peri-urban areas are growing in the importance of urban and regional planning as they are the enablers of urban extension through the availability of land and water.

The spatial development of peri-urban areas is characterised as the expansion of an urban area in its surrounding environment. This process of urbanisation not only transforms rural areas to urban areas but also the landscape and associated socio-economic character of the region.¹⁰ The spatial expansion of the cities horizontally and vertically as well as the transformation of agricultural land to urban areas will be an important issue for urban and regional planners in India.¹¹ In this growing urbanisation for effective planning and management of land resources, the city’s spatial growth patterns need to be quantified. With this background, the research tries to analyse the spatial growth type and related dynamics in peri-urban areas around Indore Municipal

Corporation through the application of spatial metrics. This research is of importance to the planners and development policymakers to make informed decisions for planning and management of this zone.

Methodology

The research was conducted through image processing of the Landsat satellite imagery of the city acquired from the US Geological Survey for a different set of years. The years – 1991, 2001 and 2011 were chosen for the study in connotation to the statutory development plans of Indore in 1991 and 2021. Various bands of the acquired data were superimposed to create composite imagery for analysis. These were further processed to classify the image into land cover classes in built-up areas and non-built-up areas using supervised classification on GIS. Non-built-up areas include vegetation, shrubs, bushes, grasslands, open landscapes, agricultural lands, riverine vegetation, rivers and water bodies. To ensure the accuracy of the processed image kappa coefficients were calculated which were 0.86, 0.89, and 0.87 for the respective years. The minimum accuracy for a reliable land cover classification should be 80 per cent.¹² Then the processed Land Use and Land Cover (LULC) maps were used to extract the built-up areas and further spatial metrics were computed through geo-processing tools.

Spatial metrics is a tool to study and analyse the pattern and structure of landscapes. These were specifically used by landscape ecologists for quantifying the shapes and pattern of vegetation, however, in the modern times, it is used to study the land-use patterns to interpolate various urban growth models.¹³ These are further subdivided into three categories landscape, geospatial and spatial statistical metrics.

Urban Expansion Speed Index: The status of urban expansion is analysed using urban expansion speed. It can be mathematically defined as the average area developed per year.^{14&15} In the research, the positive value of the index means peri-urban areas are spatially expanding in the given period. Also, if the index value is negative, the spatial growth in peri-urban areas is shrinking. The equation to calculate the urban expansion speed index is as follows:

$$\text{Urban Expansion Speed Index [UES]} = \frac{\text{BUAn} + i - \text{BUAn}}{i}$$

Where BUAn and BUAn+i is the total area of urban built-up areas in n years and n+ i years respectively, the unit is km² and i is the total number of years.

Urban Expansion Intensity Index: As discussed in Section I, the

growth of peri-urban areas is majorly due to the impacts of growth inducing factors such as road network, economic development, major land uses or the terrain. As a result of these, certain directions around the city become favourable to the growth of peri-urban areas and are referred to as preference of urban development.¹⁵ This index is used to understand the spatial growth preference direction in peri-urban areas at a given period. In mathematical terms, it is defined¹⁶ as the percentage of urban expansion area occupied out of the total land area in a specific zone in the given time context.

$$\text{Urban Expansion Intensity Index [UEI]} = \frac{(\text{BUAn} + i - \text{BUAn})}{i} \times \frac{1}{\text{TLA}} \times 100$$

Where, UEI represents the annual average expansion intensity index of the *i*th spatial zone during the time quantum *t*, BUAn+*i* and BUAn represent the beginning and ending built-up area of *i*th spatial zone in km² and TLA represents the Total Land Area of spatial zone in the unit km². This index can be used for identifying the future potential direction of urban expansion in peri-urban areas as well as compares the intensity of growth in different time periods. The division standard of UEI¹⁷ is >1.92 – high-speed development; 1.05-1.92 – fast development; 0.59-1.05 – medium-speed development; 0.28-0.59 – low-speed development and 0-0.28 – slow development.

The overall peri-urban areas were divided into eight zones along the cardinal axis. These zones were intersected with the individual built-up areas extracted from LULC analysis to calculate the urban expansion intensity index for the corresponding years.

Landscape Expansion Index: It was proposed by Prof. Liu Xiaoping and is defined using buffer analysis of the feature. Buffer is defined as a zone of the specified distance around the feature. The index examines the feature by determining the entities occurring within or outside this buffer.¹⁸ The comparative advantage of this index is that apart from quantifying the spatial growth pattern of built-up areas it can examine its evolution process and its relationship with the spatial distribution of the built-up landscape. Landscape expansion index is calculated using the formula below:

$$\text{Landscape Expansion Index (LEI)} = \frac{A_o}{(A_o + A_v)} \times 100$$

Wherein *A_o* is the intersection between the buffer zone and the occupied feature and *A_v* is the intersection between the buffer zone and vacant category. The value of LEI varies from 0 to 100. Based on these values the entity class can be categorised into three types: (a) Infill development – new built-up area emerging up inside the hole

of already existing built-up area, (b) Edge Expansion – new built-up area spreads unidirectional in parallel strips from an edge and (c) Outlying development – the newly built-up area is isolated from the old patch.¹⁹ The value of LEI is 0 for outlying development, $0 < LEI \leq 50$ for edge expansion and $50 < LEI \leq 100$ for infill development. Outlying development or leapfrog development is the expansion of an urban area that requires the extension of supporting public facilities.²⁰ The landscape expansion index besides identifying the expansion types also describes the temporal process of pattern changes within the time periods. In the spatial planning domain, this index and its variants are an important tool for understanding the nexus and dynamics of urban growth. The buffers of 1 m were created around the new built-up patch developed in peri-urban areas and its area was calculated. The intersection of this buffer with the old built-up area patch was carried out to calculate the occupied area within the buffer. Using the formula of LEI, new built-up patches were classified into three classes of spatial growth.

Growth Density: Density, concerning planning means much the same as it does in ordinary languages, i.e. the number of objects such as people, dwelling units, economic activities, etc. per unit space. Information about density is of vital importance for planning purposes as most of the proposals are based upon its study. Density variations of a particular entity around a point help in revealing the growth patterns with reference to the point.²¹ It also helps in understanding the factors leading to such growth in the zones. It is defined as the ratio of the amount of urban land to the total land. The changes in this ratio temporally can help understand the growth of urban land uses in an area. Growth density as a means to understand the changes with increasing distance and its related intensity.^{22, 23} can be calculated as below:

$$\text{Growth Density [GD]} = \frac{AB}{n} \times \frac{100\%}{TB}$$

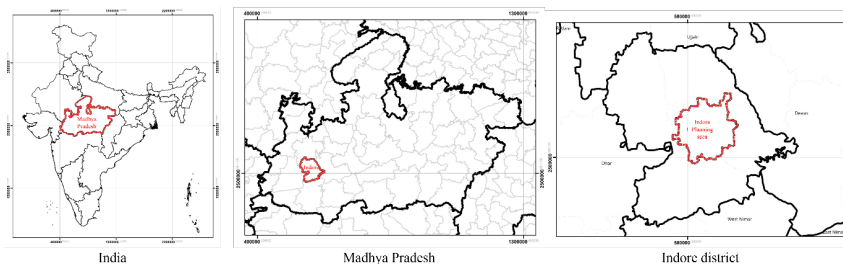
Where GD is the growth density of the urban growth type at the target buffer zone; TB is the total study area at the target buffer zone; AB is the newly developed urban area of the urban growth type at the target buffer zone; n is the year interval. This method is mostly applied in botanical science and micro organisms studies for analysing the impacts of growth and decline in species around the natural habitat present. In the same analogy, we have applied it around the city core for understanding the growth and decline of the particular spatial urban-type model and the reasons for its growth. All the three growth types' outlying, edge expansion and infill as identified in using the landscape

expansion index were analysed in this section in terms of their density from the municipal boundary with two km buffers zones. Therefore, for this, the zones of two km were created using the buffer tool from the municipal boundary. These buffer zones were then intersected with the individual built-up growth type in the two decades to calculate the growth density variations.

Case Study – Indore City Region

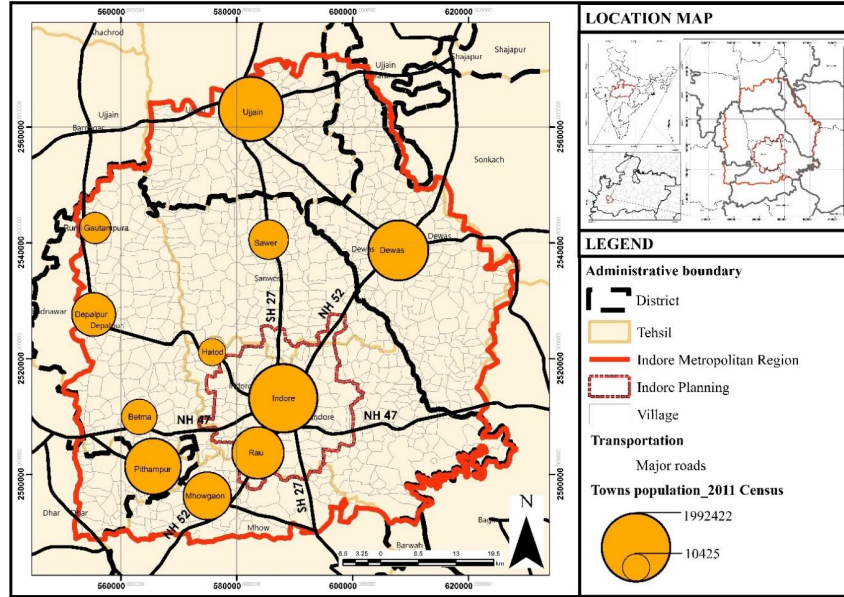
Indore – a tier II metropolitan city termed as the commercial capital of the state of Madhya Pradesh, is selected based on its population size, less geographical constraints to limit the city expansion and availability of secondary data (Fig. 1). The factors that lead to peri-urban area growth of Indore is its setting in the regional context. Indore and its immediate influence area have been defined as Indore Metropolitan region (refer Fig. 2) as per Indore Development Plan – 2021. It has seven major urban centres – Indore, Ujjain, Dewas, Depalpur, Sanwer, Pithampur and Mhow.²⁴ Industrial suburbs such as Pithampur, Mhow and Dhar are present in the south and south-western direction. Dewas and Ujjain, the religious hubs of the state are located in the north. Various economic activities such as transport Nagar and super corridor are also proposed just outside the municipal boundary. From a regional perspective, the city influences the urban fringe with economic activities. The productivity of the region strengthens the economy of the developing urban area. Indore is a commercial and industrial city, has a rapid pace of economic development and at the same time promotes increasing urbanisation in and around it.²⁵ It also serves as an educational, medical, industrial and trade hub in the western Madhya Pradesh. Another important factor for the growth of a peri-urban area of Indore is the network of roads connecting the city to nearby towns. The national and state highways passing through the Indore city (refer Fig. 2) like NH-52 connecting Delhi in the north to Mumbai in the south, NH-47 connecting to Ahmedabad in west and SH-27 connecting to the

Fig. 1: Indore Location Map



Source: Author.

**Fig. 2: Population Distribution in Urban Areas -
 Indore Metropolitan Region, 2011**



Compiled from Census of India, 2011

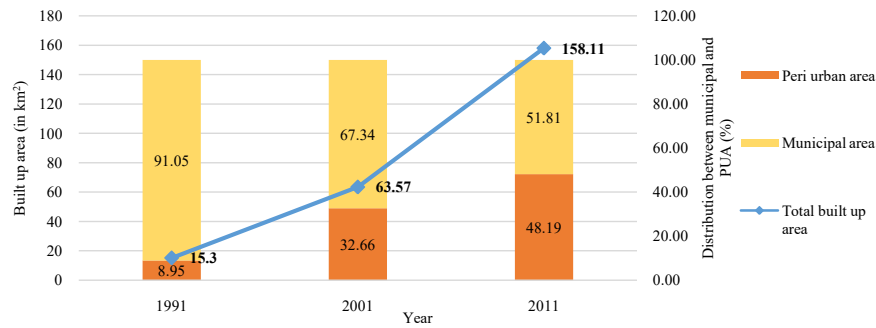
administrative capital of MP Bhopal in the east, has made the city a fast emerging transport and logistics hub of the country. For this research the peri-urban area considered is as per²⁶ i.e., an area lying between the municipal boundaries and planning boundary of the city.

RESULTS AND DISCUSSION

Spatial changes as the land cover change of built-up represent the growth pattern of the region. Land use land cover analysis reveals that the built-up area in Indore increased from 15.3 km² in 1991 to 158.11 km² in 2011. It was observed that the percentage distribution of this built up in the peri-urban area has increased from 8.95 per cent to 48.19 per cent (refer Graph 1). This spatial growth is linear and compact (refer Fig. 3) which is due to the transport network of radial and ring road respectively. The urban expansion speed in the peri-urban areas over the two decades reveals that peri-urban areas have spatially grown annually at a rate of 1.94 km² from 1991 to 2011 and increased to 5.54 km² from 2001 to 2011. Thus, it can be inferred that the growth of peri-urban areas around Indore Municipal Corporation has taken place at a rapid pace from 2001 to 2011.

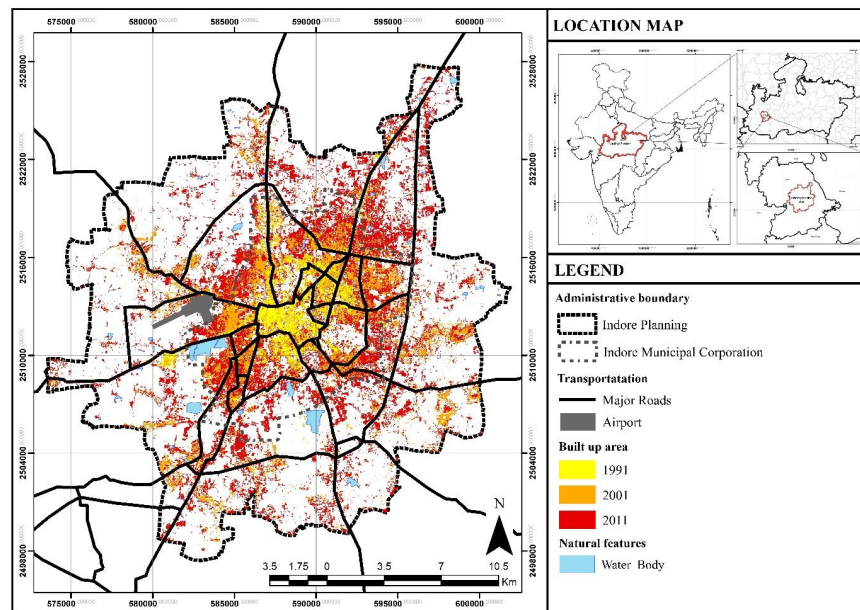
Urban Expansion Intensity Index: To further understand the

Graph 1: Built up area growth and its percentage distribution across municipal and peri-urban area, Indore, 1991 - 2011



Source: Author.

Fig. 3: Built-up Area Growth - Indore, 1991 - 2011



Source: Author.

growth factors for the development of peri-urban areas around Indore urban expansion intensity index was calculated by dividing the region into eight parts using the cardinal axis. The results reveal that from 2001-2011 the highest intensity growth is seen in the northeast direction, followed by north and south-east (refer Table 1). The least intensive development in the peri-urban areas is along the west direction followed by north-west. Comparatively, the urban expansion intensity in the peri-urban areas from 2001-2011 was more fast speed than 1991-2001

which was low and medium speed. This development in the southern direction is due to the extension of industrial activities to the periphery in the Mhow and Rau villages. Super corridor in the north and AB ring road connecting the north and south of NH - 3 plays a major role in the spatial development of the adjacent region (refer Fig. 4). The core areas of Indore are now getting depopulated and converting into commercial areas thus leading to the growth of urban areas at the outer core and periphery. The growth axes of the development pattern are south-west (towards Mhow) and North (towards Ujjain).²⁷ As per the study conducted by Kumar et al. (2007)²⁸ in Indore the development of the built-up land is sparse which is leading to haphazard urban growth in the city especially in the peripheral and rural-urban zones. The major constraint for spatial development in the west is the airport and environmentally sensitive zone in the south-east.

TABLE 1: URBAN EXPANSION INTENSITY INDEX - INDORE
 PERI URBAN REGION, 1991 - 2011

Directions	Urban Expansion Intensity Index				
	1991 - 2001	2001 - 2011			
SE	0.57	1.46			
SW	0.64	1.42			
NE	0.44	2.74			
N	0.33	1.48			
S	0.47	1.34			
NW	0.36	1.14			
W	0.55	1.01			
E	0.74	1.25			
Legend	High speed	Fast	Medium speed	Low speed	Slow

Source: Author.

Landscape Expansion Index: Landscape expansion index analysis was calculated to understand the urban growth type of the newly grown patches in peri-urban areas. From 1991-2001, the new built-up patches were 91.6 per cent outlying type. This covered an area of 15.65 km² which is 80.7 per cent of the total new built-up area in the peri-urban zone. From 2001-2011, nearly 55.8 per cent of the new built-up growth patches were outlying type but covered an area of 31.9 per cent of the total new built-up area. 36.59 km² which is 66 per cent of the newly developed area (refer Table 2). This is because the newly developed built-up area from 2001-2011 came in the proximity of the built-up area developed from

TABLE 2: URBAN SPATIAL GROWTH TYPE - INDORE
 PERI URBAN AREA, 1991 - 2011

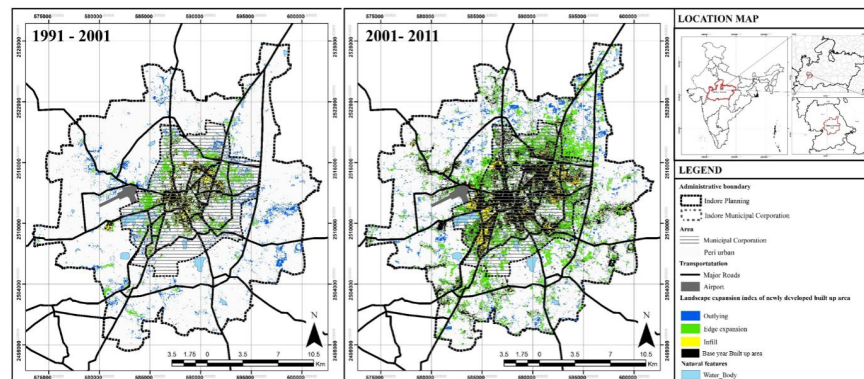
Growth type	1991 - 2001		2001 - 2011	
	Patch {in #} (%)	Area {in km ² } (%)	Patch {in #} (%)	Area {in km ² } (%)
Outlying	5082 (91.6)	15.65 (80.7)	5478 (55.8)	17.69 (31.9)
Edge expansion	413 (7.4)	3.49 (17.9)	3827 (38.9)	36.59 (66.0)
Infill	50 (0.9)	0.25 (1.2)	511 (5.2)	1.15 (2.0)
Total	5545	19.39	9816	55.44

Note: The values are calculated using the ArcGIS software and parenthesis represent the percentage.

Source: Author.

1991-2001. Based on the study of the distribution of population and built-up area, compact development took place within the Indore municipal corporation between 2000 and 2010 and there was an expansion of these settlements towards the municipal boundaries²⁹ (Kotharka and Bahadur, 2019). This indicates that the development was majorly edge expansion as they were the extension to the already existing built up. Majority of the edge extension is in the area between the municipal boundary and AB road (refer Fig. 4). Similarly Gupta et al. (2014)³⁰ analysed that the process of sub-urbanisation and ex-urbanization is prominent in Indore because of inner ring roads or commuter belt. This has led not only the people to occupy the land spaces outside but also categorically alter the land use pattern of the land encroached.³¹ This means that the AB road or ring road is inducing compact development in the region. Also, the overall urban growth development in Indore peri-urban areas is leapfrog.

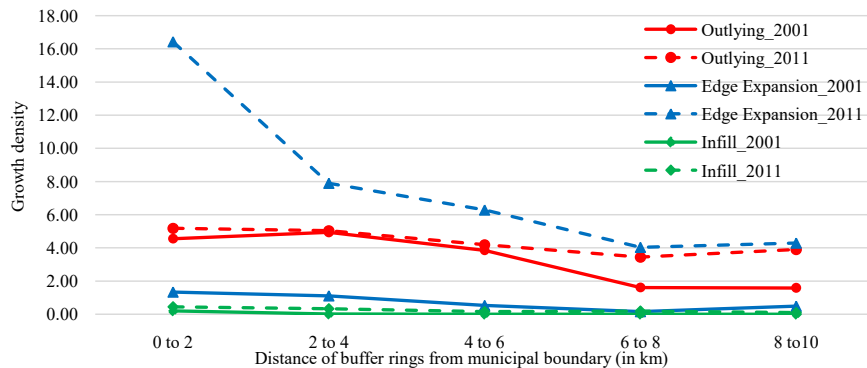
Fig. 4: Landscape Expansion Index - Indore,
 1991 - 2001 and 2001 - 2011



Source: Author.

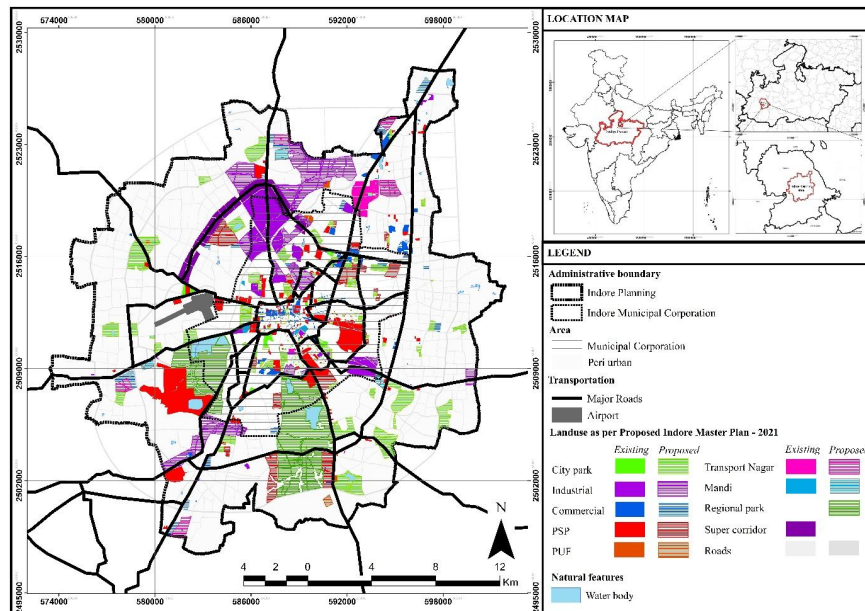
Growth Density: Furthermore, to understand the factors contributing to specific growth type in peri-urban areas the density parameter was applied. Growth type per unit area was calculated in the buffer zone of two km from the municipal area. The areal extent the outlying development is maximum from 1991-2001 and its density across the buffer in the given period is highest in the zone of 2-4 km. This is due to the inner ring road and the influence of Pithampur and Rau areas in the south. From 2001-2011, edge expansion development has the highest aerial extent, and its density is highest in the zone of 0-2 km (refer Graph 2). This is owing to the outlying development that took place between 1991-2001 in the next adjacent ring and also due to the development of outer ring road or AB road. From 1991-2001, it was observed that the infill type of development remained constant throughout the buffer zone and outlying development decreases with distance. The spatial development density variations from 2001-2011 reveal that the edge expansion is decreasing with increasing distance and outlying and infill development remains constant across the buffer. The residential development in 2006 exceeded by nearly 45 per cent to what was envisaged in Indore Development Plan-1991 due to lack of implementation mechanism and delay in the enforcement of Indore Development Plan 2021 (*ibid*). The growing population pressure and requirement of urban land for development led to unintended growth, development of slums, squatters and unauthorised colonies. This uneven expansion of the city is attributed to the ‘regulatory fractures’ and ‘rent-seeking interest’ by the private developers outside the municipal boundary.^{32 & 33} The institutional and legal process of development permissions is not clear in peri-urban areas due to the dynamic boundary changes.

Graph 2: Density Variations of Spatial Growth Types - Indore Peri-Urban Area, 1991 - 2011



Source: Author.

**Fig. 5: Proposed and Existing Major Land Uses –
 Indore Master Plan, 2021**



Developed from Indore Development Plan, 2021

CONCLUSION

India's growing urbanisation over the years and the pressure on the land resource within the urban administration, the growth of peri-urban areas is evident. For making the cities more liveable and fostering sustainable growth, an evidence-based planning and policy formulation approach needs to be adopted. On similar lines, the application of spatial metrics is used in the research for identifying the dynamics of spatial growth in the region, especially the peri-urban areas. Landscape expansion index has its importance in quantifying the urban built-up type to monitor the expansion of urban growth over different periods. This is helpful to planners and policymakers to monitor and understand the urban dynamics which are ever-changing due to technological advancement and development. From the research, it was evident that built-up area growth is much higher in the peri-urban areas as compared to the municipal area. This growth is haphazard and sparse. The spatial growth is prominent along the major regional roads connecting the city to major metropolitan centres and the economic geography of the city. The development of industrial land-uses is taking place outside the municipal limits which are acting as the catalyst of growth. Peri-urban areas are the future growth areas of any city. Thus, the identification of

patterns of spatial growth and its analysis in this region would help in effective land-use planning, ultimately focussing on sustainable urban landscape planning and management.

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